NILE BASIN INITIATIVE

Nile Equatorial Lakes Subsidiary Action Program

Kagera River Basin Management Project

FEASIBILITY STUDY FOR *TABA-GAKOMEYE* WITHIN THE FEASIBILITY STUDIES FOR 4 SMALL MULTIPURPOSE DAMS IN THE KAGERA RIVER BASIN

FEASIBILITY STUDY REPORT - Final version

DECEMBER 2012

TRACTEBEL Engineering
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ISO 9001:2008 SGS

Our ref. : P.003214.RP28
Entity : HSP
Imputation: P.003214.0001

Client : NILE BASIN INITIATIVE

Project : **Feasibility studies for 4 small multipurpose dams in the Kagera River Basin**

Subject : **Feasibility Study Report – Final report for Taba-Gakomeye site in Rwanda**

Comments : **The following names will be used from now for the 4 dam sites: Taba-Gakomeye in Rwanda, Karazi in Tanzania, Buyongwe in Burundi, and Bigasha in Uganda**

This report includes the detailed findings of the various water use and water demand studies, the environmental and social examination and the detailed technical, financial and economic assessment of Taba-Gakomeye site in Rwanda.

This study was carried out by Tractebel Engineering with the following contributions:

- *CACG (compagnie d'aménagement des coteaux de Gascogne) for all the study about irrigation ;*
- *GEOGEOPHY for all the geophysical investigations ;*
- *Southern Mapping Company for all the aerial survey (LiDAR);*
- *Technical Resources Services for the studies about geotechnical investigations, socio-economic survey, water supply, aquaculture and livestock watering studies as well as economic and financial analysis.*

REV.	YY/MM/DD	SUBJECT OF THE REVISION	STAT.	WRITTEN	VERIFIED	APPROVED
04	12/12/14	Revised as per comments	Final	JMB/MMK/NTO	Jean-Luc Pigeon	Nathalie Tomczak
03	12/11/22	Economic and financial analysis included	Draft	ATA/MMK/NTO	Jean-Luc Pigeon	Nathalie Tomczak
02	12/10/26	Report by country	Draft	ATA/XMO/JMB/MMK/NDA/NTO	Jean-Luc Pigeon	Nathalie Tomczak
01	12/09/21		Draft	ATA/ELA/JMB/MMK/NDA/NTO/PYB	Nathalie Tomczak	Jean-Luc Pigeon

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INITIALS AND ACRONYMS

ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
CDC	Community Development Committee in Rwanda
CWR	Crop Water Requirement
DEA	Directorate of Environmental Affairs in Uganda
DEM	Digital Elevation Model
DRC	Democratic Republic of Congo
EAC	East African Community
EBCR	Economic Benefit to Cost Ratio
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
ENPV	Economic Net Present Value
ENSAP	Eastern Nile Subsidiary Action Program
ESIA	Environmental and Social Impact Assessment
ETo	Potential Evapotranspiration
FWL/FSL	Full Water Level/ Full Supply Level
GIS	Geographic Information System
GPS	Global Positioning System
GWh	Giga Watt hour
HH	Household
HV	High Voltage
ICOLD	International Commission on Large Dams
IESE	Initial Environmental and Social Examination
IMP	Irrigation Management Plan
IWR	Irrigation water requirement
IWRM	Integrated Water Resources Management
KRBMP	Kagera River Basin Management Project
kV	Kilo Volt
LiDAR	Light Detection And Ranging
LSU	LiveStock Unit
LVBC	Lake Victoria Basin Commission
LVEMP	Lake Victoria Lake Victoria Environmental Management Project
MAF	Mean Annual Flow
MAR	Mean Annual Runoff
MINAGRI	Ministry of Agriculture and Animal Resources of Rwanda
MININFRA	The Ministry of Infrastructures of Rwanda
MINIRENA or MINELA	The Ministry of Natural Resources of Rwanda
MOL	Minimum Operating Level
Mm3	Million Cubic Meters
MW	Mega Watt

MWL	Maximum Water Level
NBI	Nile Basin Initiative
NEA	National Environment Act in Uganda
NEL-COM	Nile Equatorial Lakes Council of Ministers
NEL-CU	NELSAP Coordination Unit
NELSAP	Nile Equatorial Lake Subsidiary Action Program
NEL-TAC	Nile Equatorial Lakes Technical Advisory Committee
NEMA	National Environmental Management Authority in Uganda
NEMC	National Environment Management Council of Tanzania
NGO	Non-Governmental Organization
NWL	Normal Water Level
OP	Operational Policies
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMU	Project Management Unit
REMA	The Rwanda Environment Management Agency
RGPH	*Recensement Général de la Population et de l'Habitat* General Census of Population and Habitat
RN	*Cote de Retenue Normale* Full Water Level
SAP	Subsidiary action program
SRTM	Shuttle Radar Topography Mission
SSR	Sequential Stream flow Routing
SVP	Shared Vision Program
ToR	Terms of Reference
TIWRMD	Trans-boundary Integrated Water Resources Management and Development
UICN	*Union Internationale pour la Conservation de la Nature* International Union for Nature Conservation

EXECUTIVE SUMMARY

The Project area site is included in the Southern Province of Rwanda, on an affluent of Mwogo River, between Huye District near “Taba” village and Nyamagabe District near “Gakoyeme” village.

The aim of the study was to undertake the feasibility study for a dam with emphasis on agricultural development (irrigation, livestock and fisheries production), water supply, energy and flood protection.

The investigations gave the following results:

- The 2008 aerial survey carried out to produce rectified colour images and a digital terrain model (DTM) was used in this study for the Project area. Digital colour images were also used to produce colour orthophotos of the project area.
- Geophysical investigations have checked the suitability of the selected site for the construction of the dams and appurtenant structures. The used methodology was the electrical resistivity techniques based on the response of the earth to the flow of electrical current. 2D geological profiles were generated with stratification and water table readily usable in the study. The investigation depth was about 25 meters.
- Complementing the geophysical investigations, the Consultant performed geotechnical investigations in the form of four test-pits dug to 2m depth in naturally consolidated soils in order to sample the composition and structure of the subsurface. The geophysical and geotechnical investigations show that the overlaying material is suitable for dam core.
- The hydrological study has included inflows assessment, determination of the flood hydrographs, sediment transport study and climate change features. The hydrological study shows that average annual rainfall is about 1 440 mm with the peak occurring in April.
    - The annual runoff within the period 1962-2009 is about 1,25 m^3/s. However the hydrological regime is rather smooth. The ratio of maximum monthly discharge to minimum monthly discharge is equal to 2,18. The guarantee discharge is variable from 0,78 to 1,2 m^3/s respectively for a Full supply Level from 7 to 28 meters.
    - With a storage capacity of about 3,1 Mm^3 (for 14 meters dam height), the ratio of storage capacity to mean annual inflows is very low (8%). As a consequence, the annual sedimentation rate is quite important and the site is rather exposed to siltation. According to the annual sedimentation rate at Taba-Gakomeye site (about 0,075 Mm^3 per year), the outlet threshold should be set 7m above the minimum ground elevation, giving a dead storage of 0,79 Mm^3 representing more than 10 years of sedimentation storage.
    - The net losses due to evaporation is about 0,5% of the annual inflow.
- The water demand for all the uses leads to a maximum of 14 Mm^3/year, meaning 0,44m^3/s. As the natural guaranteed discharge of the River is 1,80m^3/s, it would be therefore possible to provide all the water demands with the River without dam as the natural inflows is sufficient all the year (even during the dry season) to satisfy the maximum water demand.

- Furthermore, the analysis of the aerial survey lead to find 60 ha of cultivated land, flooded by the reservoir in case of the construction of a 14m high dam, which represents about 150 affected households according to the estimation of the plot size in the area.

Thus, it is recommended to carry out the project without dam construction. The components of the project without dam will be as follows:

- The designed perimeter for irrigation is covering a geographical area of 203 ha, out of which the net irrigated area could be estimated around 183 ha, due to the right of way of canals and drains. The perimeter is divided in 4 different areas as follows.

	Area 110	Area 1	Area 2	Area 3	**Total**
Expected net irrigable area (Ha)	45	74	15	49	**183**

  It should be noticed that the design of the irrigation scheme has taken into account the issue of flood in this area.
  It is proposed to grow an equal area of maize, potatoes, beans and soybeans during the rainy season, while introducing a crop rotation. During the rainy season, farmers will be able to shift with irrigation from their early maize varieties to later hybrid and more productive varieties. The dry season will be mostly dedicated to vegetables. Growing periods of the different crops may present certain flexibility in time. It is expected to reach a yield of 5 t/ha for maize, 1,6 t/ha for beans and soybeans, 15 t/ha for potatoes, and from 2 to 6 t/ha for vegetables, depending on the crop which will be grown.
- The proposed scheme for water supply covers districts and sectors of Nyamagabe District [Kamugeri, Gasaka, Tare Sectors], Nyaruguru District [Mata, Ruramba Sectors] and Huye District. 35 140 households could benefit from the project.
- Livestock watering will be provided by the water supply as Rwanda has a zero grazing policy.
- Aquaculture is already a known activity in the area. 27 fish ponds have been identified within the project area to be developed.

The summary of costs for all the components of the project is included in the following table.

Water Use Component	**Capital Investment Costs US $**
Irrigation	5 534 000
Potable water supply	21 930 000
Aquaculture	1 210 000
Sub-total	**28 674 000**

For the economic analysis, three economic indicators are calculated:

- Economic Internal Rate of Return (EIRR) that has to exceed 12% the economic cost of capital,
- Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

The irrigation component shows the following economic performances:

- EIRR: 31,9%
- ENPV: + 5 164 000 US$
- EBCR: 2,01

The water supply component shows the following economic performances:

- EIRR: 44,2%
- ENPV: + 36 734 000 US$
- EBCR: 1,88

The aquaculture component shows the following economic performances:

- EIRR: 1,69%
- ENPV: - 234 000 US$
- EBCR: 0,79

Irrigation and water supply show positive economic performances taking into consideration indirect revenues and collective increased incomes related to project nature and activities (such as appreciation of land, economic growth, employment). However, aquaculture shows negative economic performances.

At the request of the client, the components of the project with dam have been investigated as well as follows:

- Homogeneous 14m earthfill dam has been designed. The cost of the dam is about 10 million US$. Costs (estimated at about 1,5 million US$ by Newplan consultant) of environmental and social management plan as well as resettlement action plan should be added on this amount.
- The irrigation component will have an area reduced compared to the option without dam as the upstream areas will be flooded by the reservoir of the dam. The net irrigable area would be around 100Ha divided in three different areas. This component would not be economically viable due to the weight of all headwork compared to the available net irrigable area.

1. INTRODUCTION

1.1. Preamble remarks

Following the inception visit in October 2011, the names of the four dams have been renamed as follows:

- Taba-Gakomeye (Rwanda),
- Karazi (Tanzania),
- Buyongwe instead of Kiremba (Burundi),
- Bigasha instead of Omumukura (Uganda).

1.2. Background of the study

The Nile Basin Initiative (NBI) is a partnership of the riparian states[1] of the Nile, which endeavours to develop the River Nile in a cooperative way, to share socio-economic benefits, and to promote regional peace and security. The NBI's Strategic Action Program is composed of two complementary programs: the basin wide Shared Vision Program (SVP), which aims at building confidence and capacity all over the basin, and Subsidiary Action Programs (SAPs), which initiate concrete investments on the ground in the Eastern Nile and in the Nile Equatorial Lakes sub-basins.

The Nile Equatorial Lakes Subsidiary Action Program (NELSAP)[2] implements three river basin projects, among which the Kagera River Basin Management Project (KRBMP). Its objective is "to establish a sustainable framework for the joint management of the water resources of the Kagera river basin and prepare for sustainable development oriented investments, in order to improve the living conditions of the people and to protect the environment". The Kagera River Basin lies West and Southwest of Lake Victoria, and its total area of 59 800 km² is distributed among Burundi, Rwanda, Tanzania and Uganda. It has a population of nearly 15 million people.

The Kagera basin is characterized by a low productive peasant agriculture and water scarcity for grazing and household. In many places, the population pressure is increasing and triggers off land degradation, deforestation, loss of soil fertility and over exploitation of wetlands. Eventually, climate change and its various impacts are likely to make the situation even more stressful.

[1] Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda. Eritrea is as an observer.

[2] The countries of the NELSAP: Burundi, DR Congo (DRC), Egypt, Kenya, Rwanda, Sudan, Tanzania, and Uganda.

The link between poverty and water scarcity is nowadays acknowledged and well known. According to the International Water Management Institute, the whole area is going to suffer from economic water scarcity in 2025. These countries could have enough water resources to meet their needs, only by setting up infrastructures and regulation systems. Hence, improving water infrastructures and management will be of a crucial importance.

Furthermore, agriculture remains the economic mainstay: there is an increasing need to develop irrigation in the area. As for livestock and aquaculture, they remained relatively underdeveloped in most of the places. Eventually, in rural areas, the population has a very low access to electricity and safe water supply, which dramatically impedes the development of the Basin.

Thus, to tackle the abovementioned basin issues, the NELSAP and the KRBMP procured Tractebel Engineering - Coyne and Bellier to undertake a feasibility study of 4 small dams, that is to say below 15m according to World Bank classification criteria, one in each country:

- Taba-Gakomeye dam in Rwanda,
- Bigasha dam in Uganda,
- Karazi dam in Tanzania,
- Buyongwe dam in Burundi.

This study is carried out in parallel with an Environmental and Social Impact Assessment (ESIA).

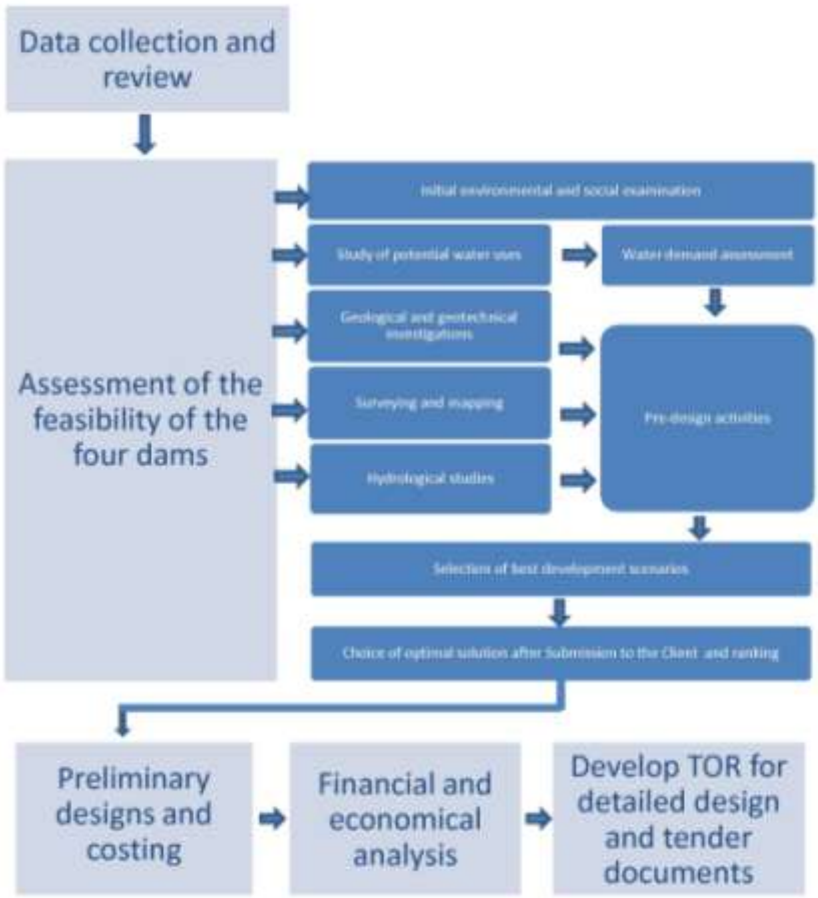
1.3. Study objective

According to the Terms of Reference (ToR), the following objectives for this study are as follows:

- To carry out detailed feasibility studies including preliminary designs and cost estimates for the four small dams, with emphasis on agricultural development (irrigation, livestock, aquaculture and fisheries production), water supply, energy and other uses, as found to be permitting;
- To undertake preliminary environmental and social examinations in order to comply with the international standards and environmental and social requirements of the national environmental management agencies and the World Bank’s safeguard policies;
- To develop Terms of Reference for the detailed designs and tender documents for implementation of the selected projects.

To fulfil these objectives, the following activity flow chart (see Figure 1) has been followed all along the study.

Figure 1: Activity flowchart of the feasibility studies for Kagera Project



1.4. Place of the feasibility study report within the Project cycle

This report comprises, as requested by the ToR,

- The technical studies, including:
  - Description of multipurpose storage reservoir projects;
  - Design of the selected dam' infrastructure and appurtenances;
  - Detailed technical, financial and economic assessment of the multipurpose dam sites; and
- The preliminary concept of a local water development program, including:
  - the detailed findings of the various water use studies regarding agriculture, fisheries, livestock, hydropower, water supply, etc;
  - the detailed findings of water demand assessment,
  - the recommended project implementation approach;
- The initial social & environmental examination of the projects;
- The terms of reference for the detailed designs and tender documents in case of dam construction.

1.5. Main constraint in the project cycle

The inception report mentioned that one of the main issues was the Light Detection And Ranging (LiDAR) topographical survey. The LiDAR survey was critical in the schedule of the Project in order not to delay the overall project activities.

It has not been possible to carry out the Rwanda LiDAR survey by the lack of authorization from the Rwanda National Lands Centre, which provided the LiDAR data (25cm resolution maps) carried out in 2008 by Swedesurvey mid-April as well as the Rwanda digital orthophoto images in May. It should be noticed that the interpretation of the data from aerial survey takes time. Thus, the uses of these data have delayed the overall study.

2. DESCRIPTION OF THE KAGERA PROJECT

2.1. Regional context

The countries of the NELSAP have identified a number of projects to promote poverty alleviation, economic growth, and reversal of environmental degradation in the sub-basin. The investments are grouped into two major programs: Natural Resources Management and development of projects, and the Power Trade and Development program. The two programs target investments in agricultural development, fisheries development, water resources management, water hyacinth control, hydropower development and transmission interconnection. The Natural Resources Management sub program consists of three Integrated River Basin Management projects, namely Kagera, Mara and Sio – Malaba - Malasiki River Basin Trans-boundary Integrated Water Resources Management and Development Projects. The Projects are aimed at poverty reduction and achieving socio-economic development through the rational and equitable use of the shared water resources of their respective River Basins.

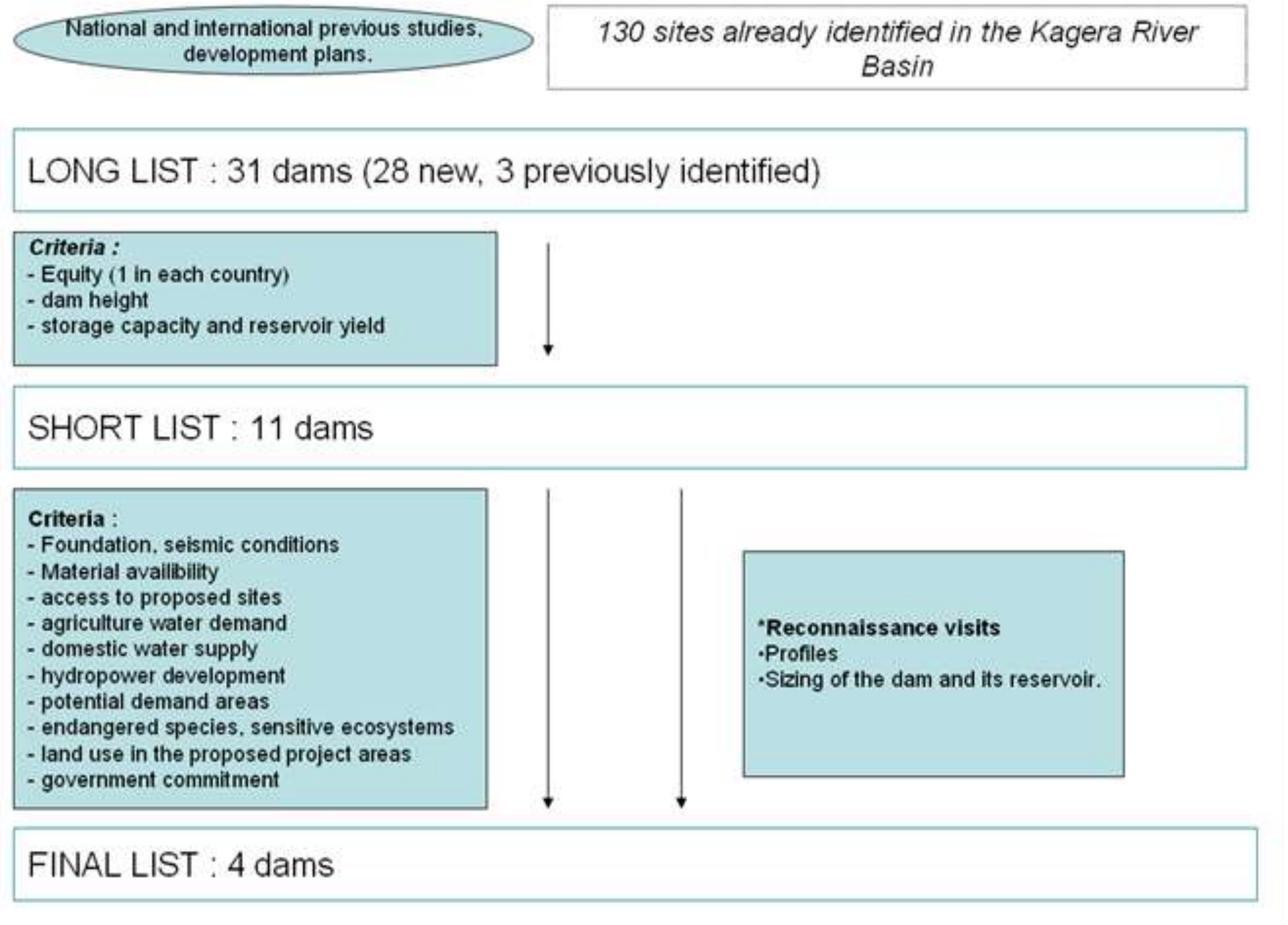
The project objective of the Kagera Trans-boundary Integrated Water Resources Management and Development Project is to establish a sustainable framework for management of water resources of Kagera River Basin, in order to prepare for sustainable development oriented investments that will improve the living conditions of people while protecting the environment.

The NBI/NELSAP has received grant financing from the World Bank Nile Basin Trust Fund towards preparation of a strategic portfolio of regional water resources investment projects in the Kagera River Basin and has applied part of the proceeds of this grant to undertake consultancy services for a feasibility study for development of four small multipurpose dams/reservoirs with emphasis on agricultural development (irrigation, livestock, aquaculture and fisheries production), energy, water supply and other uses, which is the purpose of this study.

2.2. Project history

The Kagera River Basin Management Project recently completed a study [a] for identification and rapid assessment of potential small dams for the multipurpose uses of agricultural development, hydropower generation, water supply, etc. The study identified 28 new dam sites and made preliminary assessment of 3 previously identified dams from the Rwanda Irrigation master plan. From this list of 31 sites, 11 sites were selected. From the shortlist of the 11 sites, after applying technical considerations, four sites, one for each country, have been finally selected. The scheme below highlights the identification process:

Figure 2: identification process for the four dam sites

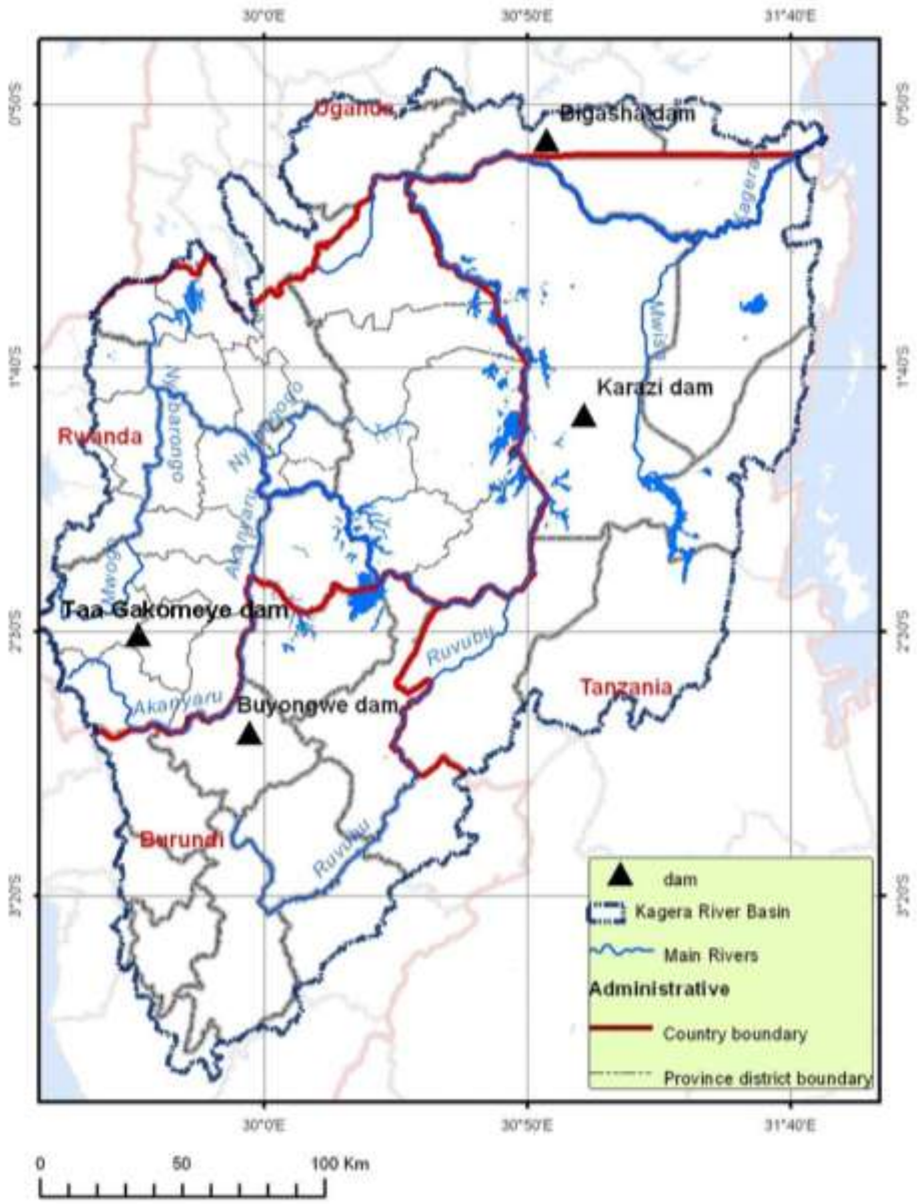


However, the study did not consider environmental and social economic considerations in the identification of the dam sub-projects. Thus, the aim of this present study is the feasibility studies for these four priority multipurpose dam sites, which study will assess the technical, social, economic & financial, and environmental viability of these multipurpose dam projects.

2.3. Location of the Project

The locations of the sites are shown on the following map within the Kagera River Basin.

Figure 3: location of the four sites within the Kagera Project



Source: terms of reference of this study (from USGS-SRTM-NVE-CGIS-NUR)

The coordinates for the axis of each dam based on the terms of reference have been recorded as follows:

Table 1: Coordinates of the four dam sites

(WGS84 system)

Country	Dam site	Y (DD)	X (DD)	Z (m)
Rwanda	Taba-Gakomeye	-2,50775	29,60169	1659
Burundi	Buyongwe	-2,81669	29,95647	1382
Tanzania	Karazi	-1,82336	31,01526	1324
Uganda	Bigasha	-0,94818	30,89745	1261

2.4. Location of Taba-Gakomeye site

Since 2006, Rwanda is divided into five provinces (See the following map). Each province is divided into district, sectors, cells and villages, with different roles:

- The Provincial administration checks whether District Development Plans correspond to national policies or not; promotes social and economic development at the provincial scale.
- The District is in charge of coordinating economic development, planning, financing and executing services to the Sector level.
- The Sector has some technical skills with social affair officers, forest officers and agronomists. The main organization is the Community Development Committee (CDC).
- The Cell is usually composed of 100 to 200 households and includes a CDC.

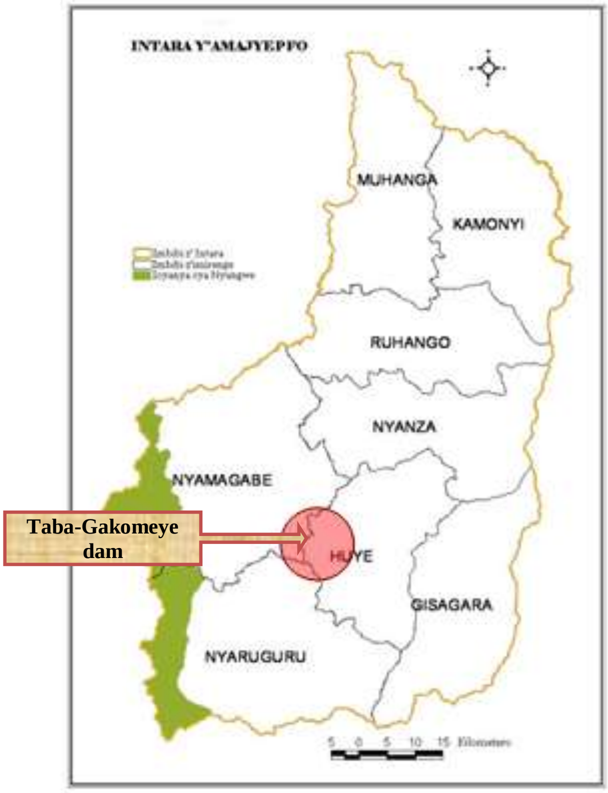
Figure 4 : Rwanda administrative map

Source: Nationsonline project

The Project area site is included in the Southern Province of Rwanda, which is one of Rwanda's five provinces created in 2006, on an affluent of Mwogo River. The dam site is between Huye District near “Taba” village and Nyamagabe District near “Gakoyeme” village (see the following map).

The capital city of Southern Province is Nyanza (also known as Nyabisindu).

Figure 5 : Southern Province administrative



Source: Southern Province's official website

Nyamagabe and Huye Districts include respectively 17 and 14 sectors.

Two dam sites have been investigated on the same River during the inception mission. The coordinates for the axis of each dam was recorded as follows:

Table 2: Taba-Gakomeye dam axis coordinates

DAM AXIS COORDINATES					
Site	WGS 84 (DD)		UTM / WGS 84 (m)		Bank
	Longitude	Latitude	X	Y	
			UTM 35S		
Taba Gakomeye - Rwanda					
Alternatif	29,58863	-2,51664	787871,98	9721548,18	Left
Alternatif	29,58991	-2,51817	788014,08	9721378,61	Right
TOR	29,60145	-2,5073	789300,68	9722578,77	Left
TOR	29,60286	-2,50993	789457,01	9722287,46	Right

3. METHODOLOGY

This chapter will present the methodology used all along this report for each specific investigations.

3.1. Methodology for the LiDAR surveying and mapping

3.1.1. Context

The existing maps mentioned in the ToR are 1/50 000 scale (probably 10/15m interval isohyets) and therefore not usable as reference for the tasks under consideration, in particular for dam and appurtenant workings as well as for irrigation design.

A Light Detection And Ranging (LiDAR) survey was planned to be undertaken covering reservoir footprint and working areas as specified in the Terms of Reference. LiDAR is an optical remote sensing technology that can measure the distance to, or other properties, of a target by illuminating the target with light, often using pulses from a laser. Another advantage of this technology was the possibility of getting high definition aerial pictures which are of high interest for the social and environmental as well as for the irrigation studies.

As a LiDAR survey was untaken in 2008 by Swedesurvey, this survey was used for this study.

3.1.2. Methodology

According to Swedesurvey in 2008, the aerial photography was taken using a digital camera system, Vexcel UltraCam-X, which records digital raw-data for the images simultaneously in the different bands panchromatic, red, green, blue and near infrared. The data was kept in a storage device onboard the aircraft.

After the photo flight, data was transferred, from the on-board storage system to easily transportable exchangeable hard discs, using a special copy computer. The raw-data on these discs was then transferred to the post processing stage to make the three different final products, panchromatic images (PAN), colour images (RGB) and colour infrared images (CIR). The CIR images consist of the red, green and near infrared band.

The post processing consisted of three steps: radiometric processing, geometric processing and image adjustments for each product. A high-quality central projection PAN image was created first during the initial two steps.

To produce the final RGB image, the first two steps created one single central projection digital pan-sharpened image using the higher resolution panchromatic image and the separate colour bands (R,G,B) of lower resolution. The same procedure follows for the CIR images including their colour bands. Lastly, the three image products were adjusted for tonal differences within the images and between the images, brightness and contrasts were corrected and the colours balanced.

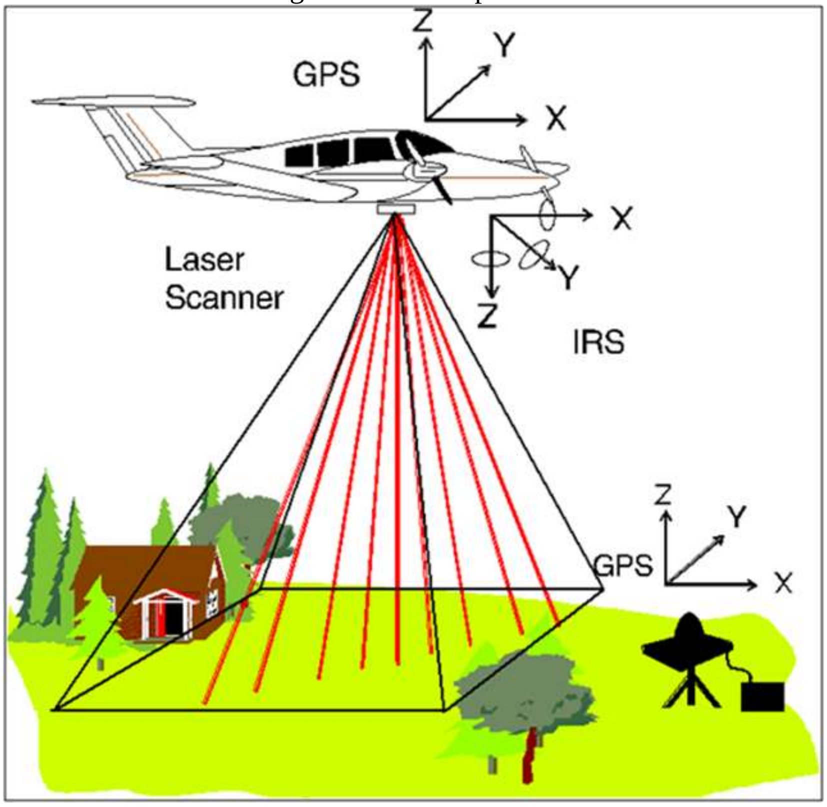
The strip navigation and the triggering of camera exposures at pre-selected points were done using GPS technology on board the aircraft. The co-ordinates for the pre-selected points were decided in the flight planning stage. At the same time as the photo was taken, GPS and INS data were also recorded in a computer onboard the aircraft and at the same time GPS data was recorded in a GPS receiver placed at a ground reference station that had known co-ordinates in a given geodetic reference system. INS data is recorded with an Inertial Measurement Unit (IMU), and GPS/INS data is used for the precise determination of position and attitude of an airborne sensor. This data was later used in orthophoto production. The use of GPS/INS technology minimizes the need for ground control points.

The images and GPS/INS data went through a quality check according to a quality control system. This includes controls such as, exposure and image quality, presence of cloud, cloud shadow or smoke in the images, overlap between images and runs, coverage and a check that a complete set of files exists. The digital aerial photography process produces a lot of data. A total of about 20 Tb (Terabyte) of image data has been produced during the 2008 aerial photography campaign.

3.1.3. Results

The 2008 aerial photography mission was covering the whole of Rwanda, about 26338km^2, with low altitude digital aerial photography. The objective was to produce digital orthophoto images with a resolution of 0,25 meters using the photographs. In addition, the images were used to produce a base map at 1:50 000, covering the entire country, which has been used for this study.

Figure 6: LiDAR process



The project extent was defined on the basis of existing map as well as inception field mission.

Topographical map based on the LiDAR data was produced for the dam site (see maps in Appendixes). The data could lead different type of topographical maps that has been used all along this report.

3.2. Methodology for the geophysical and geotechnical investigations

3.2.1. Introduction

Geophysical and geotechnical investigations have been performed geo-referencing the essential soil and rock features so as to establish the engineering properties of rocks and soils, check surfacial deposits and reveal tectonic-structural patterns.

Geophysical investigations have checked the suitability of the selected sites for the construction of the dams and appurtenant structures. The geotechnical investigation campaign gave a factual picture of each site and of their characteristics so that the setting out of the workings can be adapted.

3.2.2. Geophysical methodology

The geophysical investigations took place from the 21 to the 31 of January 2012. The methodology was the same one for the two dam sites: Electrical resistivity techniques are based on the response of the earth to the flow of electrical current. Measurements are made by placing four electrodes in contact with the soil or rock. A current is caused to flow in the earth between one pair of electrodes while the voltage across the other pair of electrodes is measured. The depth of measurements is related to the electrode spacing. Several types of electrode configuration and survey geometry exist in resistivity measurements.

Figure 7: Measurements at site

A 2D resistivity profiling consists in a succession of vertical electrical sounding, but interpreted by inversion, with a calculation of the lateral and the topographical effects. In this case, the distance between two electrodes is 5 m on the dam site. The number of electrodes varies from 24 to 48. The investigation depth is about 25 meters.

In these geological contexts, refraction seismic is not adapted. The fresh rock, which is outcropping, presents a very fast velocity. If weathered rocks underlay, it is invisible. On the other hand, the resistivity method is able to visualise this possible geology. More, it is able to locate faults which are difficult to determine with the seismic refraction method.

3.2.3. Geotechnical methodology

In addition to the geophysical investigations presented above, the Consultant performed geotechnical investigations in the form of 10 test-pits dug to 5m depth in naturally consolidated soils in order to sample the composition and structure of the subsurface. The test-pits aim at complementing the geophysical investigations and at checking the potential permeability of the reservoir so that the geological hazards are mitigated.

The location of the test-pits were properly selected with the Geophysical Engineer and the Civil Infrastructure Engineer and recorded by GPS. The procedures and methods used in the profiling of the test pits adhere to internationally accepted codes.

Test pitting was undertaken manually to the maximum depth (about 5m) or refusal, whichever occurs first.

After excavation all test pits were photographed and profiled by a qualified engineering geologist. Soil samples were taken where required, following which test pits were backfilled:

- Soil Classification (5 samples per test pit):
  - Specific gravity
  - Sieve analysis
  - Water absorption
  - Silt content
  - Moisture content
  - Atterberg Limits

- Strength and Deformation Test (2 per pits):
  - Direct Shear Test
  - Compaction MDD
  - California Bearing Ratio – 3 ptd 97% MDD
  - Consolidation Test - Œdometer
  - Permeability Test – constant Head

The Consultant identifies, geo-references possible source of construction materials and took samples for laboratory testing to assess their engineering properties. The aggregate tests (2 per quarry) will consist on:

- Los Angles Abrasion
- Aggregate Crushing Test
- Sodium Sulphate
- Specific gravity + Water Absorption
- Soluble salts
- Aggregate Impact Value
- Alkali reaction.

3.3. Methodology for the hydrological study

3.3.1. Context

The availability of hydrological records has conditioned the way of executing the studies: if no direct data is available, the determination of the classic parameters has been carried out by correlation to neighbouring known catchments or through internationally accepted methods.

The results included in this report are the main results for Rwanda site in order to understand the findings of the entire report. The hydrological report is annexed in the Appendix H.

3.3.2. Monthly discharge computation

For the proposed dam sites at Taba-Gakomeye (ToR and Alternative), the Consultant deduced the monthly discharges from the discharges of Mwogo River at Mwaka. Mean discharge (Qyr) values came from gauging stations as follows:

River	Gauging Station	Area	Mean Discharge	Avg. Rainfall	Runoff	Loss	Coef. Runoff	Loss/Rainfall	Loss/Runoff
		A	Qyr	Pyr	RO	EA	CRO	EA/Pyr	EA/RO
		(km²)	(m3/s)	(mm)	(mm)	(mm)			
Mwogo	Mwaka	2 800	31.79	1 340	358	982	0.267	0.733	2.74

and from dam sites as follows:

Dam Site	Area	Coefficient of Runoff	Avg. Rainfall	Runoff	Mean discharge
	A	CRO	Pyr	RO	Qyr
	(km²)	-	(mm)	(mm)	(m3/s)
Taba Gakomeye (ToR)	101	0.267	1440	384	1.231
Taba Gakomeye (Alternative)	93	0.267	1440	384	1.133

For Taba-Gakomeye (ToR):

$$Q\ Taba-Gakomeye\ ToR\ = \frac{Qyr\ (Taba-Gakomeye\ ToR)}{Qyr\ (Mwaka)} \times Q(Mwaka)$$

For Taba-Gakomeye (Alt.):

$$Q\ Taba-Gakomeye\ Alt\ = \frac{Qyr\ (Taba-Gakomeye\ Alt)}{Qyr\ (Mwaka)} \times Q\ \ Mwaka\ \ .$$

Results are discussed in the section dedicated to the inflows analysis in chapter 4.4.3.

3.3.3. Methodology for the sediment measurements

For the sedimentation issues, guidelines from World Meteorological Organization and Dr. Mkhandi S.H. report from Department of Water Resources Engineering recommended that the sampling points for suspended sediment have to be located at the hydrometric stations. Indeed, sediment measurements have to be coupled to discharge measurements to compute relationships between liquid and solid discharge measurements. Unfortunately, the catchment of Taba-Gakomeye dam site is ungauged. A sedimentological measurement campaign will not be relevant without gauging.

Thus, in order to assess the sedimentation rate, the Consultant has used existing sedimentation data within the catchment area. As mentioned in the hydrological study (see Appendix H), Taba-Gakomeye dam site is located in the upstream half part of the basin (zone I and II) as well as Upper Ruvubu, Ruvyironza, Kanyaru and Nyabarongo reservoir projects. Sediment data from Nyabarongo and Ruvubu Rivers have been considered representative of the sedimentation rate of Taba-Gakomeye dam site.

3.3.4. Methodology for the optimization of the reservoir capacity

3.3.4.1. OBJECTIVE OF THE OPTIMIZATION

Dams mainly serve to ensure an adequate supply of water by storing water in times of surplus and releasing it in times of scarcity, thus also preventing or mitigating floods. Dams that have small storage capacity in relation to the gross Mean Annual Runoff (MAR) are known as “annual dams”. They are likely to fill from empty every year except the very worst seasons or even single floods.

The adopted methodology is a Sequential Stream flow Routing (SSR) and according to this method a continuity equation of the water volumes is applied to calculate reservoir levels and therefore reservoir volumes, evaporation and outflows from spillway and outlet structure.

The erratic inflow of the river passes through the storage reservoir will be delayed and attenuated as it enters and spreads over the reservoir surface. Water is then released through a controlled outlet.

The optimization consists of determining the minimum reservoir capacity which allows an average constant water release with an acceptable deficiency.

3.3.4.2. METHODOLOGY

The aim of the reservoir operation simulation is to determine the total reservoir capacity which will meet the downstream demand. The methodology used to perform the reservoir operation studies was as follows:

- A series of monthly water inflows at each dam site, over a number of years sufficient to be representative of the long-term flow pattern was established;
- The downstream water demand with the aim of allocated all inflows available was established;
- The balance between the water flowing into the reservoirs and the water flowing out of the reservoirs (water demand, spillage, and evaporation) was determined on a monthly time-step basis. The results of the balance are the volume and the levels of the reservoir at the end of each month, and the water provided to meet the demand.
- The simulations were performed assuming that the reservoirs capacity is constant throughout the whole period of simulation (38 years). Allocation for sediment storage has been taken into account by setting the outlet structure threshold above the dead storage level.
- A criterion defining the ability of the reservoirs to meet the water demand has been established. This criterion quantifies the frequency and the volume of shortfalls that might occur and answers the question regarding the risk of not meeting the demand. The definition of water demand shortfall (deficiency) is the number of month when the water demand is not satisfied divided by the total number of month of the simulation.

Several reservoir capacities were tested for which the deficiency has been evaluated. For each of those reservoir capacities, the discharge guaranteed 10% of the time has been computed.

3.4. Methodology to define the water uses and water demand

3.4.1. Methodology for the water demand

The chapter about water uses and water demand aims to describe at first the existing water uses in the Project area (irrigation, water supply, livestock watering, aquaculture, hydropower), then to assess the potential demand and finally check the technical and economic constraints of the associated installations and finally state about a feasibility development level for each potential water use.

3.4.1.1. IRRIGATION WATER DEMAND METHODOLOGY

Irrigation water requirement:

Irrigation water requirement (IWR) depends on several factors, including cropping patterns, crop-growth periods, crop coefficients (Kc), potential evapotranspiration (ETo), effective rainfall and deep percolation for rice paddies.

Irrigation water requirement is calculated by multiplying crop area and crop water requirement (CWR) of respective crop. Crop water requirement is usually measured in terms of evapotranspiration and depends on climatic conditions and constraints in each area. The irrigation water requirement for each crop is estimated as follows:

$IWR = \Sigma Crop\ Area \times [CWR - Effective\ rainfall]$

CWR of the paddy crop is estimated as:

$CWRrice=[\Sigma(KcricexETo+ Deep\ percolation]$

Crop water requirement (CWR) for other crops is estimated as:

$CWRother\ crops=\Sigma(Kcother\ crops\ xETo$

Water demand forecasting for irrigation:

Agricultural water demands are primarily a function of the following:

- Meteorological conditions;
- Crop type;
- Cropped area for each type of crop;
- Type of irrigation method and irrigation efficiencies;
- Water charges (to be discussed with the local Authorities).

In estimating future agricultural demands the changes in one or more of the above factors must be predicted. Owing to the potential for changes in the future and the relatively few variables, component analysis is the forecasting methodology likely to yield the best results.

Component analysis is a forecasting method based upon the usage of water by individual components. The expected trends in water demand of each component (e.g. changes in irrigation technology, climatic changes, crop type and irrigation area) should be analysed separately and the overall result assessed.

Meteorological conditions are yet changing due to the effects of global warming. For agriculture, the basic factors are rainfall and evaporation rate. As rainfall decreases and/or evaporation rates increase, the irrigation needs increase or vice versa.

Changes in crop type may also have a significant impact on water demands, which may or may not be positive. High value crops such as bananas and garden vegetables generally have higher water requirements than, for example, grain crops.

Changes in cropped area may either be a difference in total surface, if new land is developed or cultivated land becomes fallow, or be the result of variations of crop type, if the surface of one crop type is changed to accommodate changes in another type.

Losses and inefficiencies usually account for a significant proportion of total irrigation requirements both for lack of proper drainage and for improper technologies. Their impact may be alleviated through various improvement programmes and the specialist will have to determine the chances and extent of these.

Creating water user associations can also affect water demand and use. The main purpose behind water user associations is to assure better access to water and unbiased equity in distribution. Hence, while water user associations are beneficial in many ways, their establishment may increase water demands. Water charges have a significant impact on water demands because of the incentive to reduce waste in water application, though consideration must be given to willingness to pay and ability to pay on the part of the water users (but this would not be applicable to the conditions prevailing in the sites concerned).

Changes in irrigation technology may also affect the water demand. Modern technologies that deliver water to the plant more efficiently reduce overall demand by diminishing field losses and non-beneficial evapotranspiration.

Improvements of water management and irrigation system operation at field level also reduce irrigation water use by improved efficiency and reduced losses.

Other means of limiting agricultural water uses is practising new techniques such as precision irrigation and deficit irrigation, though the aptitude of farmers to adopt such techniques must be assessed and assistance extension services supplied if too low.

3.4.1.2. WATER SUPPLY DEMAND METHODOLOGY

<u>Water supply requirement:</u>

In general estimating rural water demand and use is difficult because the majority of rural domestic water supply systems are manpowered or unmetered, data concerning domestic rural water demand and use is often expensive and time consuming to collect and the level of service provided by the water supply system is often unknown.

There are two key methods of assessing rural domestic demand and use. These are:

- Indirect methods, where the quantity of water consumed is calculated from population levels and estimated demand levels in terms of per capita consumption;
- Direct methods where socio-economic surveys and participatory techniques involving the relevant stakeholders are used to estimate the current and future water demand and use.

The Consultant has followed indirect approach which is considered as the most practical method. For such approach, the following information is required:

- Population data;
- Per capita water demand;
- Unaccounted for water levels i.e. the difference between the total quantity of water abstracted and the quantity of water consumed.

Rwanda's national water sector policies have a target per capita water demand of 20 litres/person/day for rural water supply.

Forecasting water supply demand:

Historical information for domestic water demand and use in rural zones is unlikely to be available. This means that it is impossible to directly assess the future rural domestic water demand and use through trend analyses. The two most important factors that affect future domestic water demand and use are:

- Population growth (the annual ratio of the area is very high);
- Change in the level of service due to an upgrading trend in the water supply needs.

Population growth can be estimated from national, regional or local trends. It should however be noted that improvements in infrastructure, such as multipurpose water schemes, may step up the population growth above the average.

Upgrading of water supply schemes and the consequential changes in the level of service are difficult to predict. It has been postulated that the upgrading of rural water supply schemes is related to Tariff levels where distribution metered network can be planned (in suburban zones).

For sake of simplicity and accounting for the inaccuracy of statistical data, the Consultant will make assumptions concerning the upgrading (e.g. from a reservoir connection to a communal borehole to house connection).

The increase in water demand may also be estimated from other areas where similar upgrading of the water and sanitation infrastructure has occurred.

Tanzanian Water Design Manual provides following data per capita demand based on levels of service. The following table has been finally adopted for this assignment.

Table 3: Water supply data per capita demand

Water Supply	Urban	Peri-urban	Rural
Communal Water Points / others	30%	60%	80%
Yard Taps	20%	20%	20%
Multiple Taps House Connection	50%	20%	0%

This document provides as well the levels of services, based on affordability, meaning income levels. The following table provide the level of services per capita demand.

Table 4: Level of services per capita

Levels of Services	Litres / person / day
Communal Water Points / others	25
Yard Taps	70
Multiple Taps House Connection	150 for high income 100 for middle income as a mean – 120 lpd

On these data, it is normal practice to add 30% to the domestic water demand for non-domestic demand.

This Manual in Section 4.7 reports as well system losses that have to be accommodated for in the production end. It states that the 25% is grossly underestimated. For piped system therefore, a 30% is added to total water demand for losses.

Table 4.21 of the Manual gives peak day factor for various users varying between 1.00 and 1.50 and the weighted one normally used is 1.15, as the climate variance is not significant in the tropical climate.

3.4.1.3. WATER DEMAND FOR LIVESTOCK

Water requirement for livestock:
The livestock water requirement is estimated by multiplying the number of livestock animals times the water use per head of livestock (Litre/day per animal).

Water demand forecasting for livestock:
The forecasting of the future water demand for livestock will be primarily based on the assumption that the water use per head is kept constant (according to the breed and purpose of the stock) and the livestock number is projected on the base of the growth trend in past years.

Section 4.6.4 of *Tanzanian Water Supply Design Manual* is dedicated for livestock water demand assessment. The livestock unit is defined as follows:

One Livestock Unit (LSU) is equivalent to:

- one head of cattle
- 2 donkeys
- 5 goats or sheep
- 30 heads of poultry (hens, ducks etc)
- 0.5 or 0.33 high grade dairy cow

Livestock growth depends on land carrying capacity and water availability. If both conditions suffice then 10 years growth can be up to 25% and 20 years growth up to 50% at an annual rate of 2,6% for cattle and 2% for goats / sheep.

The Manual recommends 25 litres/LSU/day and segregated as follows:

- Dairy Cow: 50 - 90 litres/day (50 adopted)
- Local Cattle: 25 litres/day
- Sheep and goat: 5 litres/day
- Donkey: 12,5 litres/day
- Pig: 10 litres/day
- Poultry: 30 litres/100 birds/day

3.4.1.4. WATER DEMAND FOR FISH FARMING

The section will deal with fish production using ponds (closed system) and neither cage nor continuous (open system) flow. In addition, the proposed ponds will not be mechanized for aeration or pelleted feeds.

According to the "Inland fisheries and aquaculture" report (Patrick Dugan et al., 2007), mechanically aerated and pelleted feeds can produce fish up to 10000 kg/Ha. The cage production can produce up to 100 kg/m3. On the other hand normal pond fish production is as follows:

- regularly stocked and fertilized Tilapia: 1 000 to 2 000 kg/Ha of pond/year
- as above but with brewery waste, oil seed cakes, brans and manure: 3000 to 5000 kg/Ha/year
- unfertilized ponds: 320 kg/Ha/year

In the "Guiding principles for promoting aquaculture in Africa" (FAO and Worldfish Paper No 28, 2006), full fish ponds design procedure has been provided. The tank size is normally L:W:D = 30:3:1 in order to maximize the flushing. Fish farming water demand is not significant after catering for evaporation and percolation into soils and will mainly depend on space available for ponds installation. Alternatively, the ponds size should be dependent on the demand for fish in the locality and the existing marketing system.

In the "Strategic assessment of warm water fish farming potential in Africa" (FAO by Kapetsky, Technical Paper 27), the relationship between population density and the occurrence of fish farming is studied: based on assumptions about farm-gate sales, population density is interpreted as local market potential.

Fish farms do occur at densities of <5 person/km^2 and a limited amount of data from Zambia and Tanzania indicates that even at these densities, there are commercial activities.

There is a tendency for the density of fish ponds per district to increase with increasing population density. However, because the population data are in rather broad ranges, attempting to develop a regression relationship was not possible. To examine the effect of local demand on fish farming potential, the following assumptions were made to estimate the number of *subsistence* and commercial farms that could be supported by farm-gate sales at given population densities.

The assumptions were:

- Pond area of 0,04 ha sizes and an output of 2 t/ha/year for a subsistence farm; respective area and output for a modest commercial farm at 0.4 ha pond sizes and 3 t/ha/year;
- Farm-gate sales confined to an easy walking distance: a 2 km radius of the farm for a subsistence farm; a 4 km radius for a commercial farm due to an implicit proximity to an all-weather road, making a commercial farm more easily accessible for walk in and drive in customers than for a subsistence farm.
- A potential market of 1 kg of fish/person/year for a population within a 2 km radius for a subsistence farm and the same for a population within a 4 km radius for a commercial farm. One kg of fish/per caput is about 10% of all Africa mean fish consumption per caput.
- 50% of the output sold at the farm-gate for a subsistence farm and 25% of the output for a commercial farm.

Population density has been used to establish demand for fish and by extension demand for fish ponds.

3.4.1.5. HYDROPOWER DEVELOPMENT

Simulation was carried out for power generation at the dam site. The methodology is the same as described in chapter 3.3.4 about optimization of the reservoir capacity, except that the water demand is now defined by the requirement of energy production.

Initially, the firm energy is determined, that is to say energy production that can be provided by the reservoir at a given failure rate (failure admitted here: 10% of the maximum time). This production is the average energy response, assumed constant throughout the year.

In the simulations, the firm energy is determined by iteration according to a monthly time step, changing the value of the demand to obtain the rate of deficit (or failure) desired. The calculation allows for variations in the height of the reservoir between the Full Supply Level (FSL), above which the excess water spilled, and the Minimum Operating Level (MOL) below which energy can be produced (deficit).

In a second step, the secondary energy produced is computed. Secondary energy is the energy obtained by turbine of excess water, once the energy product is guaranteed and the reservoir is full.

The total energy is then defined as the sum of firm energy and secondary energy. Every month, the energy produced is determined by the following formulae:

$$E = P \times Nb \times 24$$

$$P = Q \times g \times \Delta H \times \rho$$

Where:

P:	Power in kW
E:	Energy in kWh
Nb:	Number of days in the month
g:	9,81 m/s²
ΔH	net head
ρ	Turbine efficiency

It is to be noted that in this simulation, the power demand is constant and the water demand varies accordingly depending on the available net head (reservoir water level). The head losses has been assumed to be 10% of the total head and the turbine efficiency equal to 0,8.

3.4.1.6. ENVIRONMENTAL FLOW REQUIREMENT

The Hydrological Index Method is one of the various approaches used to estimate environmental flow requirements. This method is based on simple indices, as a percentage of average annual flow or a percentile from the flow duration curve, on monthly basis. The indices used for environmental flow assessment in various countries of the world are provided below:

• France: A hydrological index is used in France, where the freshwater fishing law (June, 1984) required that residual flows in by-passed sections of river must be a minimum of 1/40 of the mean annual flow (MAF) for existing schemes and 1/10 of the MAF for new schemes (Souchon and Keith, 2001).

• United Kingdom: In regulating abstractions in UK, an index of natural low flow has been employed to define environmental flow. Q95 (i.e. that flow exceeded 95% of the time) is often used. The figure of Q95 was chosen purely on hydrological patterns. However, the implementation of this approach often includes ecological information (Barker and Kirmond, 1998)

• USA (Tennant method): Tennant (1976) developed a method using calibration data from hundreds of sites on rivers in the mid-western states of the USA to specify minimum flows to protect healthy river environment. Using USGS data, this method is based on aquatic habitat being very similar when they are carrying the same proportion of the average flows. Ten percent of the average flow is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms (Poor or minimum habitat). Thirty percent is recommended as a base flow to sustain good survival conditions for most aquatic life forms and general recreation (fair and degrading habitat). Sixty percent provides excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. In a large river, it can be useful in developing a quick response, such as for evaluating water right application potential impacts.

Taking into account that Taba-Gakomeye dam sites are characterized with poor or minimum habitats, an environmental flow of 10% of the MAF have been retained for each site. Furthermore, such a criterion is also applied in France for new schemes.

3.4.2. Methodology for the evaluation of each potential water use

3.4.2.1. CONTEXT

SWECO has carried out the “Development of Kagera Integrated River Basin Management and Development Strategy” study for NELSAP in 2010. In the table 1.5 of the main report, a water use prioritization exercise has been carried for each district or province and has been expressed in the following summary table. This table shows that the water supply is always the main prioritization.

Figure 8: Water use prioritization

No.	Administration	Water Supply and Sanitation	Soil and Water Conservation	Irrigation and Drainage	Fisheries	Flood Mitigation	Drought Mitigation
1	2	3	4	5	6	7	8
	Burundi						
1	Kirundo	H	H	H	H	H	H
2	Ngozi	H	H	H	L	H	M
3	Kayanza	H	H	M	L	M	M
4	Muramvya	H	H	L	X	L	M
5	Bujumbra R.	H	H	X	X	X	L
6	Mwaro	H	H	L	X	L	M
7	Bururi	H	H	X	X	X	L
8	Rutana	H	H	X	X	X	M
9	Gitega	H	H	H	L	H	M
10	Ruyigi	H	H	L	L	L	M
11	Karuzi	H	H	M	L	M	H
12	Cankuzo	H	M	L	L	L	M
13	Muyinga	H	M	M	L	M	H
	Tanzania						
1	Ngara	H	M	L	L	L	H
2	Biharamulo	H	M	L	L	L	H
3	Karagwe	H	M	H	H	H	H
4	Muleba	H	L	L	H	L	H
5	Bukoba	H	L	H	H	H	M
	Uganda						
1	Rakai	H	M	L	X	L	H
2	Isingiro	H	H	M	L	M	H
3	Mbarara	H	H	L	X	L	H
4	Ntungamo	H	H	M	X	M	H
5	Kabale	H	H	L	X	L	M
6	Kisoro	H	H	X	X	X	H

H = *high* M = *medium* L = *low* X = *insignificant*

No.	Administration	Water Supply and Sanitation	Soil and Water Conservation	Irrigation and Drainage	Fisheries	Flood Mitigation	Drought Mitigation
1	2	3	4	5	6	7	8
	Rwanda						
1	Musanzi	H	H	M	H	M	L
2	Gakenke	H	H	M	L	M	L
3	Rulindo	H	H	L	X	L	L
4	Gikumbi	H	H	L	X	L	L
5	Nyabihu	H	H	M	X	M	L
6	Ngororero	H	H	L	L	L	L
7	Rutsiro	H	H	X	X	X	L
8	Karologi	H	H	L	L	L	L
9	Nyamagabwe	H	H	L	X	L	M
10	Nyaroguru	H	H	H	X	H	M
11	Gisagara	H	H	H	L	H	H
12	Huye	H	H	L	X	L	H
13	Nyanza	H	H	H	L	H	H
14	Ruhango	H	H	H	L	H	H
15	Muhanga	H	H	H	M	H	M
16	Kamonyi	H	H	H	L	H	H
17	Nyarugenge	H	H	H	L	H	H
18	Kicukiro	H	H	H	L	H	H
19	Gasabo	H	H	M	X	M	H
20	Bugesera	H	H	H	H	H	H
21	Rwamagana	H	H	H	H	H	H
22	Ngoma	H	H	H	H	H	H
23	Kirehe	H	L	H	H	H	H
24	Kayonza	H	L	M	H	M	H
25	Gatsibo	H	L	M	H	M	H
26	Nyagatare	H	L	M	H	M	H

H = *high* M = *medium* L = *low* X = *insignificant*

Source: "Development of Kagera Integrated River Basin Management and Development Strategy" by SWECO in 2010

3.4.2.2. ANALYSIS

This above study and the socio-economic survey reported in appendix J lead to prioritize the water demand. However it should be taken as well into consideration the technical feasibility of each use as well as the economic analysis.

3.5. Methodology for the Initial Environmental and Social Examination (IESE)

3.5.1. Position within the Study and goals

The environmental and socio-economic analysis has been carried out since the beginning and concurrently with the engineering studies. Consequently, the former will orientate the latter in order to develop the most needed water uses according to requirements and capacities of the riparian population, to minimize and mitigate the impacts of the dam and reservoir construction on physical, biological and human environment and to reduce such impacts.

Planned at the early stage of the project development, the IESE may also orientate and bring inputs (and reciprocally) to the regulatory ESIA studies (carried out independently by another consultant), if the time schedules of both allow for.

Regarding environmental issues, the present study is to be considered as preliminary since environmental feasibility, identify environmental challenges, main impacts and mitigation actions will be actually addressed by the ESIA consultant.

The overall output is the Initial Environmental and Social Examination Report concluding on the "environmental feasibility" of the scheme. Conclusions have been based on the impact assessment for the project and the justification of fatal flaws or critical impacts, if any, for the concerned project.

3.5.2. Regulatory context of projects financed by the World Bank

3.5.2.1. LARGE DAM DEFINITION CONTEXT

The World Bank distinguishes between small and large dams in the Operational Policy 4.37 as follows.

(a) Small dams are normally less than 15 meters in height. This category includes, for example, farm ponds, local silt retention dams, and low embankment tanks.

(b) Large dams are 15 meters or more in height. Dams that are between 10 and 15 meters in height are treated as large dams if they present special design complexities--for example, an unusually large flood-handling requirement, location in a zone of high seismicity, foundations that are complex and difficult to prepare, or retention of toxic materials. Dams under 10 meters in height are treated as large dams if they are expected to become large dams during the operation of the facility.

This definition of "large dams" is based on the criteria used to compile the list of large dams in the World Register of Dams, published by the International Commission on Large Dams (ICOLD).

3.5.2.2. WORLD BANK OPERATIONAL POLICIES

The World Bank group has served as a forerunner by defining Operational Policies (OP) that serve as guides as part of the assessments of the projects submitted to this body for financing. The Bank classifies each proposed project to determine the appropriate extent and type of Environmental Assessment. The World Bank classifies the proposed project into one of four categories, depending on the type, location, sensitivity, and scale of the project and the nature and magnitude of its potential environmental impacts.

The main directives and policies that apply here are the following:

- OP 4.01: "Environmental assessment";
- OP 4.04: "Natural habitats";
- OP 4.11: "Physical cultural resources"
- OP 4.12: "Involuntary resettlement": For Kagera Project, it is worth to mention that:

  - "Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project designs";
  - "Where impacts on the entire displaced population are minor, or fewer than 200 people are displaced, an abbreviated resettlement plan may be agreed with the borrower".
- OP 4.37: In this OP, the World Bank considers that "generic dam safety measures designed by qualified engineers are usually adequate" for small dams.
- OP 7.50: "Projects on international waterways".

3.5.3. Regulatory context within the NBI

The NBI has taken steps to put in place systems and mechanisms to ensure environmental and social safeguards in all its interventions at the following three key levels:

- Basin-wide level,
- Sub-basin (SAP) levels,
- Project level.

The NBI has issued an Environmental Assessment Framework for Regional Power Projects and a Preliminary Environmental and Social Management Framework for Project Preparation and Implementation.

It should be noticed that, as a rule, any project funded through development partner funding will be subject to internationally accepted environment screening, following Wold Bank guidelines and / or development partner requirements.

It is specified that some environment and socio-economic key issues should be taken into consideration for mitigation measures during the ESIA.

4. TECHNICAL STUDIES

4.1. Introduction

This report will take into consideration the findings of the previous reports, which has changed the design of the project. Thus, this chapter will present first the main findings of all investigations and surveys, meaning:

- Aerial survey;
- Geophysical and geotechnical investigations;
- Hydrological analysis;
- Water uses and water demand.

The preliminary design and costing could then be presented taking into account the previous results and the decision of the country following these findings.

Based on these design results, the initial environmental and social examination will then give the first results mainly based on the aerial survey.

4.2. Aerial survey for Taba-Gakomeye site area

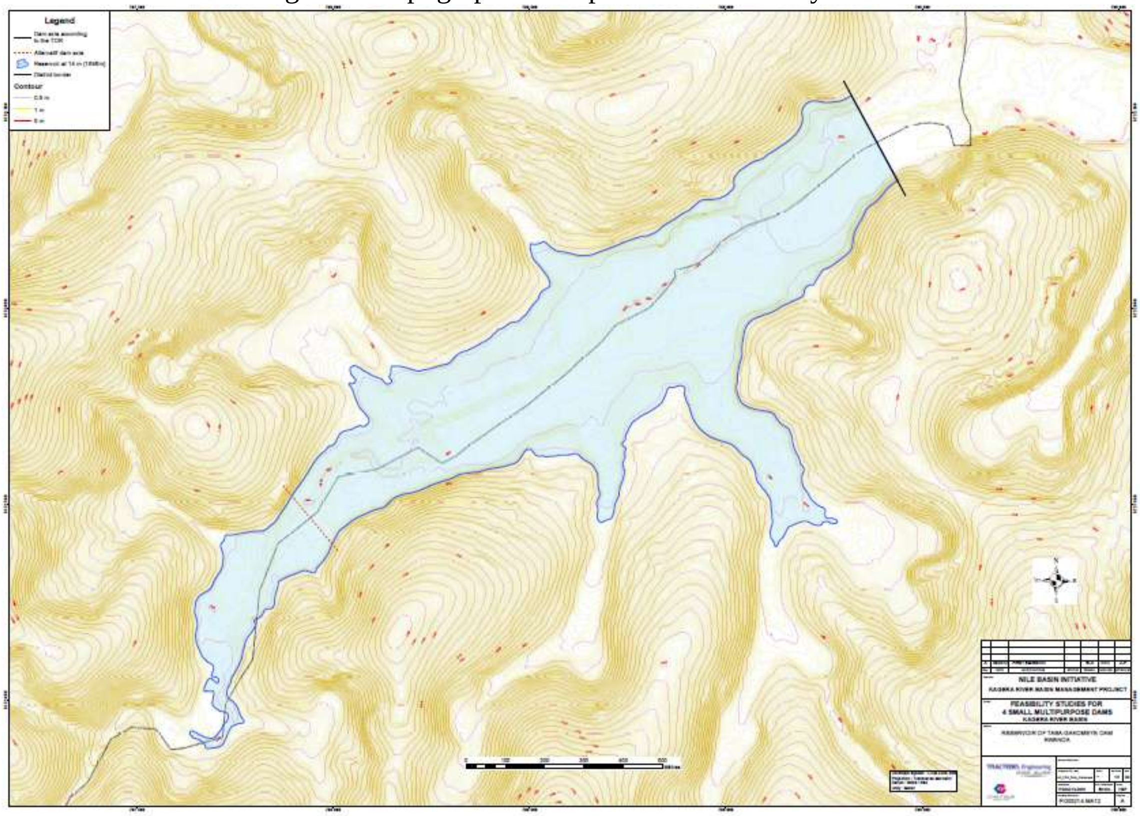
4.2.1. Context

The aerial survey in Rwanda was carried out in 2008 for the preparation of Rwanda Land Use and Development Master Plan. The survey produced digital orthophoto images with a resolution of 0,25 meters using the photographs. In addition, the images were used to produce a base map at 1:50 000.

4.2.2. Results

The following map (see Appendix C for bigger map) has been defined based on the aerial survey. The reservoir has been drawn at FWL for the 14m dam as planed in the ToR. The resolution of the LiDAR data is convenient for the purpose of this study. However, it is less detailed than the data got from Southern Mapping for the other countries of this study.

Figure 9: Topographical map of Taba-Gakomeye reservoir



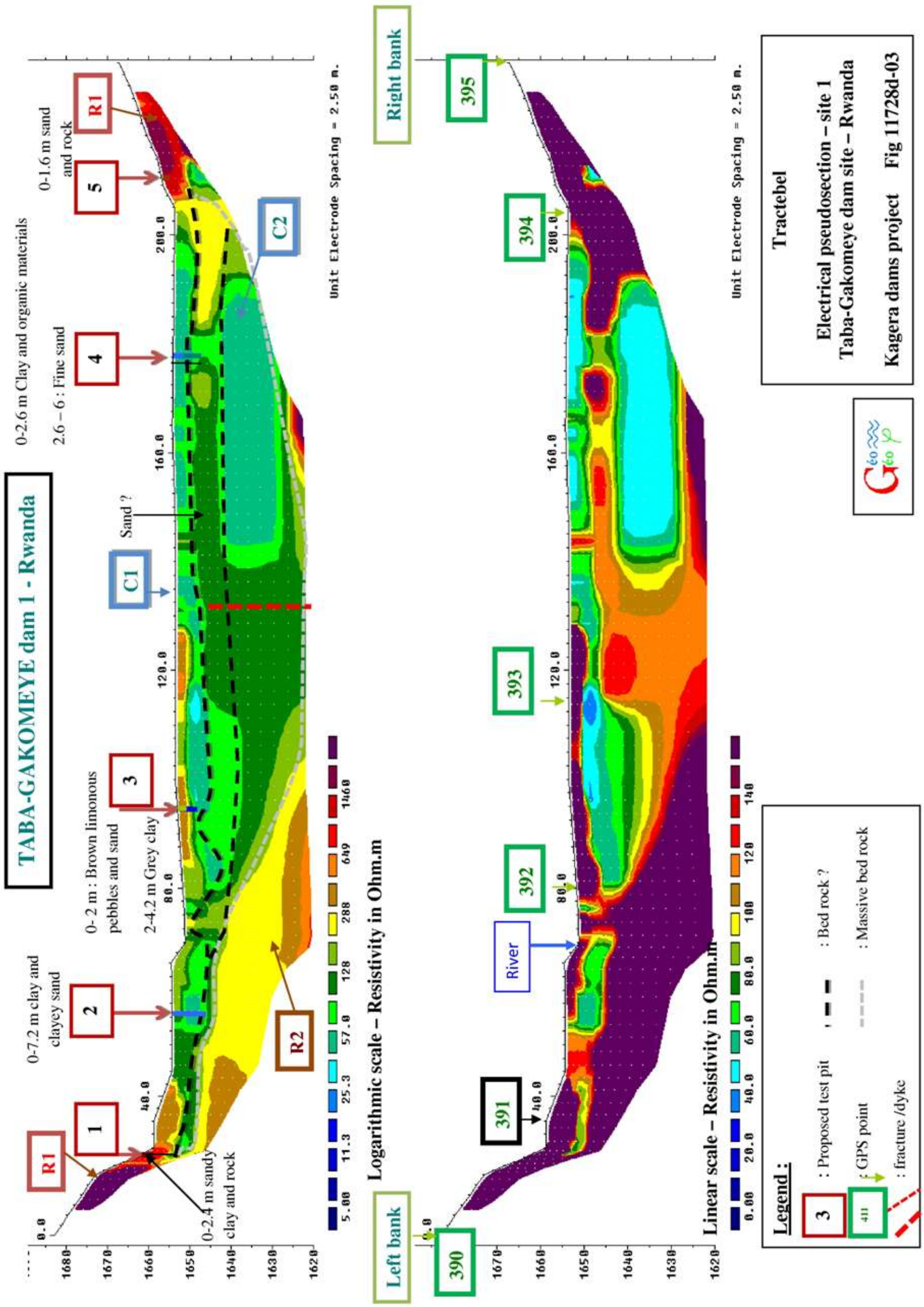
4.3. Geophysical and Geotechnical Investigations

The geophysical survey carried out at Taba-Gakomeye dam site was calibrated by five (axe 1) or four (axe 2) boreholes and tests pits located along the two proposed dam axis (see Figure 10). The appendix I includes all the results of the investigations.

In the valley, it can be found roughly 0 – 5 meters of clay and sandy clay, not fully calibrated by the geotechnical investigations. The weathered substratum should start by a layer of 5 meters composed by sand and/or cemented sand sandstones. On the banks, between 0 and10 meters of reddish sand and rock are expected, which correspond to lateritic soils. There are laying on a small thickness of C2, then R2 entity attributed to massive rock.

The overlaying material is suitable for dam core as it is practically impervious (< 10-8 m/s) after compaction while still plastic. Its grain size properties display a percentage of fines below 80 microns in many of the augers drilled. The plasticity index is lower than 5 (except auger 2 of the axe 2) and the liquid limit varies between 21 and 37.

Figure 10: Geophysical profile of Taba-Gakomeye dam axis



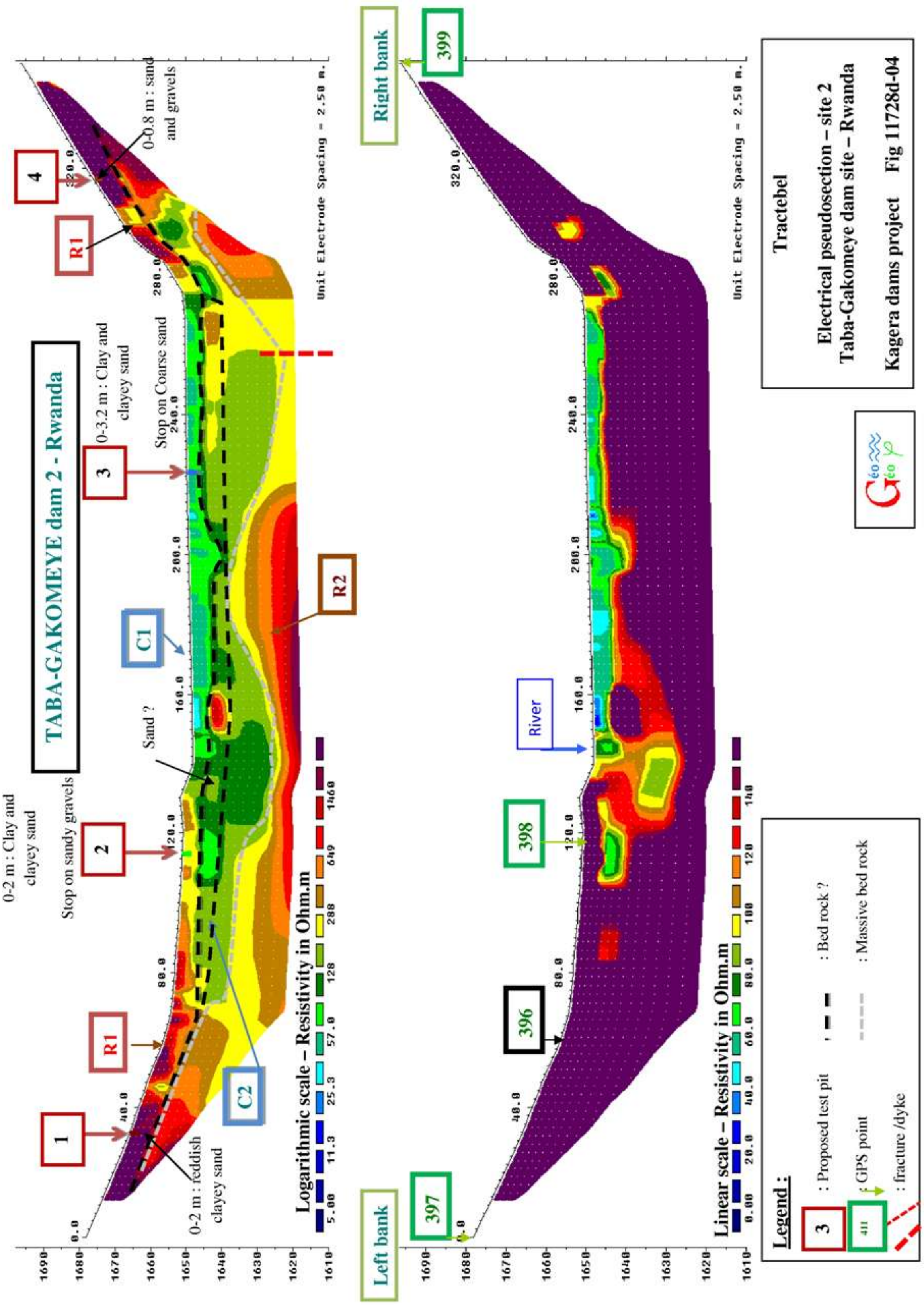
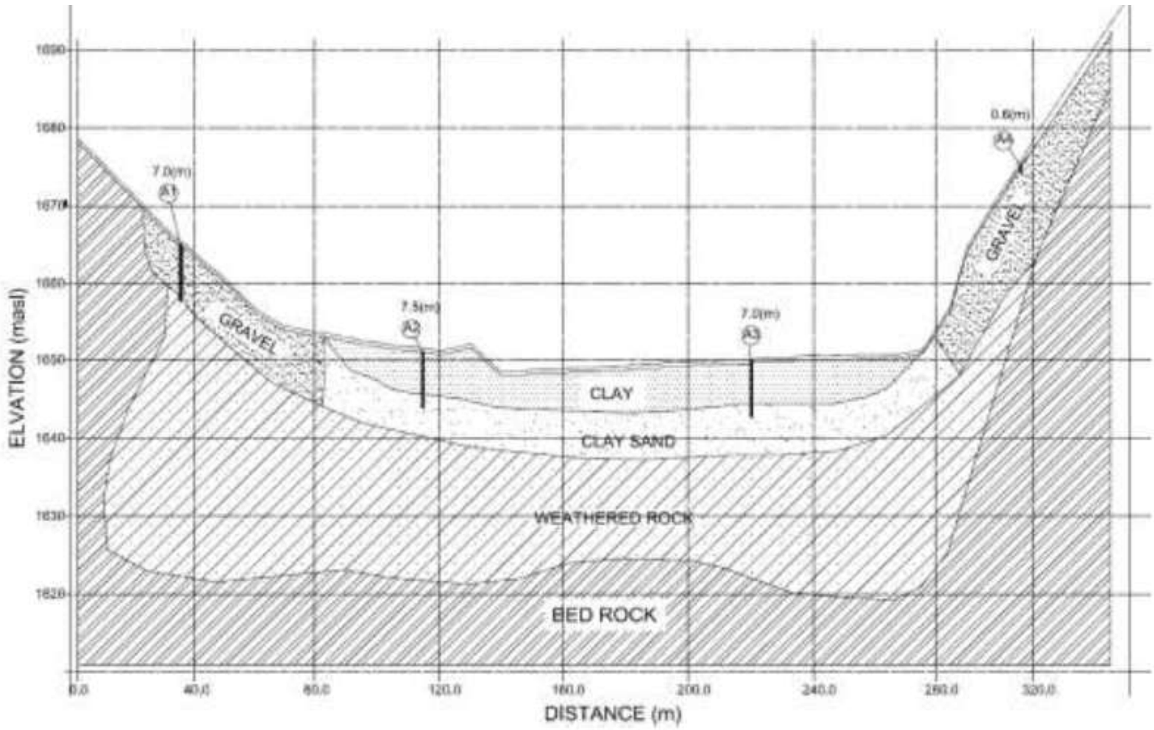

TABA-GAKOMEYE dam 2 - Rwanda
0-2 m : Clay and clayey sand
Stop on sandy gravels
0-3.2 m : Clay and clayey sand
Stop on Coarse sand
0-0.8 m : sand and gravels
0-2 m : reddish clayey sand
Sand ?
Unit Electrode Spacing = 2.50 m.
Logarithmic scale – Resistivity in Ohm.m
Left bank
Right bank
River
Linear scale – Resistivity in Ohm.m
Legend :
: Proposed test pit
: GPS point
: fracture /dyke
: Bed rock ?
: Massive bed rock
Tractebel
Electrical pseudosection – site 2
Taba-Gakomeye dam site – Rwanda
Kagera dams project Fig 11728d-04

Figure 11: Geological profile of ToR dam axis (axis 2)



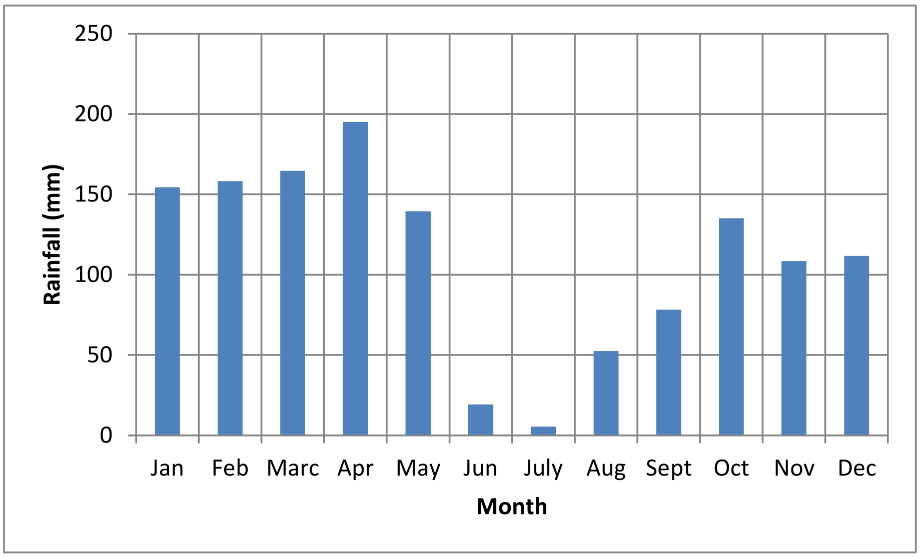
4.4. Hydrological results for Taba-Gakomeye site

4.4.1. Context

The dam site is located on Mwogo River, which is a tributary of Nyabarongo River. Two dam sites have been identified and referred as ToR and Alternative. The Taba-Gakomeye Alternative dam site is located upstream. Concerning the hydrology, ToR and Alternative dam sites are similar.

Catchment area is 101 km² (ToR) (93 km² for Alternative) and altitude is in the range 2 300 – 1 630 m above sea level (2 300 – 1 640 m for Alternative). Average annual rainfall is about 1 440 mm/an. There are two rainy seasons with the longer south-easterly monsoon between February and May with the peak occurring in April and the shorter north-easterly monsoon from about September to November as represented in the following Figure 12.

Figure 12: Monthly rainfall at Gikongoro meteorological station in the vicinity of Taba-Gakomeye dam site.



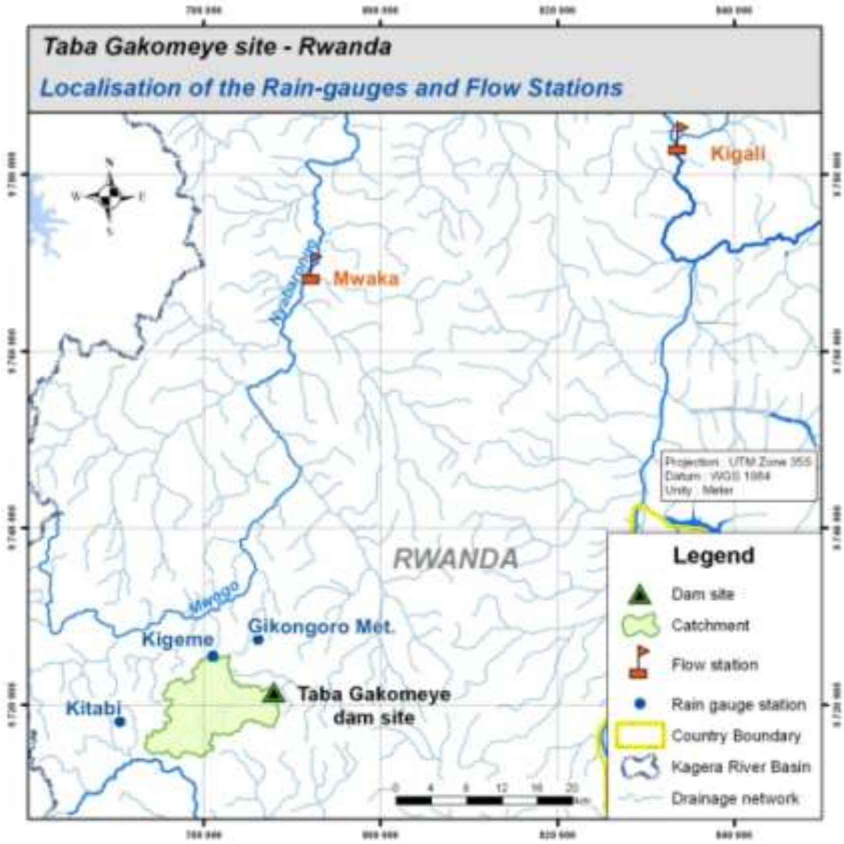
4.4.2. Data

Hydrological and rainfall information has been collected from the AQUALIUM database provided by the Client:

- Rainfall stations are Kitabi, Kigeme and Gikongoro stations, all located in the close vicinity of the catchment (Figure 13).
- Gauging stations of interest are Mwaka (2 800 km²), Kigali (8 500 km²) and Rusumo Falls (30 700 km²).

The rating curve at Mwaka station has been established based on 9 gaugings from June 1972 to May 1974. Then the rating curve has been applied to the gauge record in order to obtain daily and monthly discharges for the observation period (1971-1996). The monthly record at Mwaka has been extended to the 1940-2009 period by correlation between Mwaka, Kigali and Rusumo Falls monthly discharge record.

Figure 13: Localisation of rain gauges and gauging stations for Taba-Gakomeye dam site



4.4.3. Inflows

For Taba-Gakomeye dam site, no direct discharge data exist. Inflows at dam site are estimated at a monthly time step using Mwaka gauging station as a reference. The discharge regionalisation model includes a ratio equal to the mean annual discharge (Qyr) at Taba-Gakomeye dam site to the mean annual discharge at Mwaka:

$$Q\ Taba - Gakomeye \quad = \frac{Qyr\ (Taba - Gakomeye)}{Qyr\ (Mwaka)} \times Q(Mwaka)$$

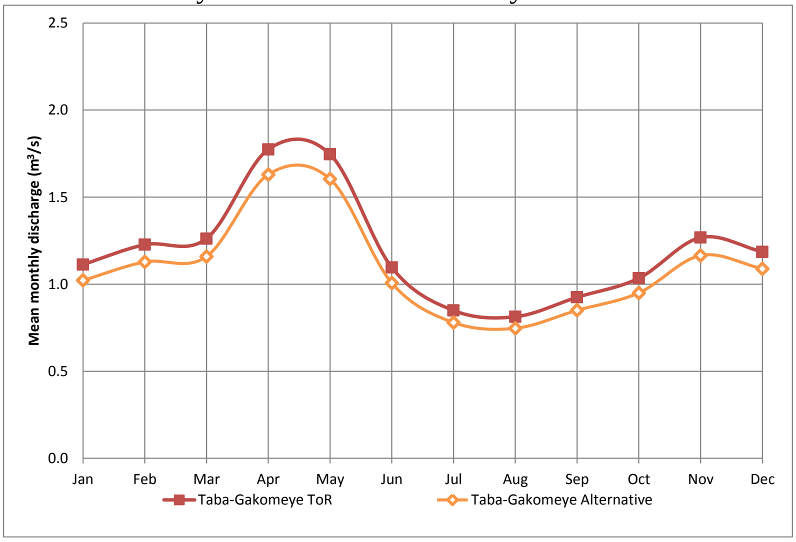
The mean annual discharge at Taba-Gakomeye has been previously estimated (Table 5). It relies on water balance with mean annual rainfall equal to 1 440 mm/year and a runoff coefficient equal to the one calculated for Mwaka gauging station (0,267). As a consequence, the ratio in the regionalisation model is equivalent to the product of a ratio of mean annual rainfalls and of a ratio of catchment areas.

Table 5: Reference for Taba-Gakomeye dam site inflows estimates

Dam site (DS)	Area	Pyr	Period	Reference	Reference Area	Reference Pyr	Reference Qyr	Runoff Coefficient CRO
	(km²)	(mm/yr)			(km²)	(mm/yr)	(m3/s)	-
Taba-Gakomeye (ToR)	101	1 440	1940-2009	Mwaka station	2 800	1 340	31.79	0.267
Taba-Gakomeye (Alternative)	93	1 440	1940-2009	Mwaka station	2 800	1 340	31.79	0.267

Mean monthly inflows are presented in Figure 14. Two peaks corresponding to rainy seasons can be observed in April and in November. This focuses on the strong response to rainfall for Taba-Gakomeye catchment, which is generally observed for Kagera upper tributaries. Otherwise, the hydrological regime is rather smooth. Flows occur all along the year. Maximum discharge occurs in April but discharge in May is quite as important. Minimum discharge occurs in August. The ratio of maximum monthly discharge (April) to minimum monthly discharge (August) is equal to 2,18.

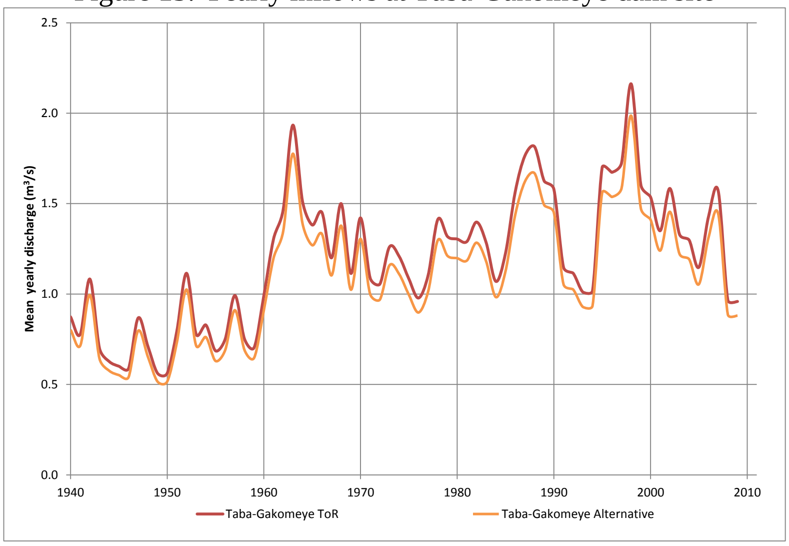
Figure 14: Mean monthly inflows at Taba-Gakomeye site for the 1940-2009 period



Yearly inflows at Taba-Gakomeye dam site are presented in the below Figure 15. The rise in runoff observed in the Nile Equatorial Lakes region in the early 1960ies appears clearly. Two periods can be distinguished: a pre-1960 period with moderate runoff level (mean discharge = 0,78 m^3/s (ToR)) and a post-1960 period with a high runoff level (mean discharge = 1,37 m^3/s (ToR)).

Annual variability is rather high. Maximum mean yearly discharge (2,16 m^3/s for ToR in 1998) represents a +82% increase of the mean discharge (1,19 m^3/s), and minimum mean yearly discharge (0,56 m^3/s in 1950) a -53% decrease of the mean discharge.

Figure 15: Yearly inflows at Taba-Gakomeye dam site

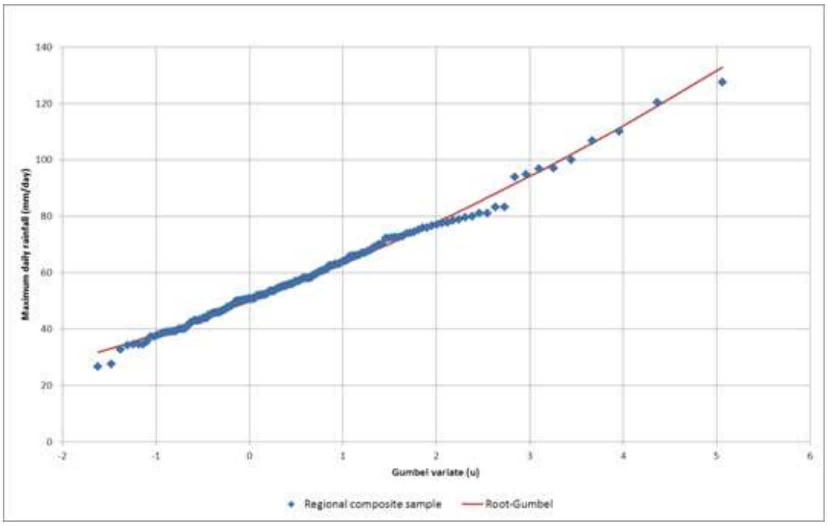


4.4.4. Floods

4.4.4.1. MAXIMUM DAILY RAINFALL

For Taba-Gakomeye dam site, daily rainfall records at 6 rainfall stations located in Rwanda and Burundi are processed. The station year method is applied to establish one regional composite sample of maximum daily rainfall. The sample has a size of 158 station-years. A root-Gumbel distribution is convenient to describe this sample (Figure 16).

Figure 16: Taba-Gakomeye dam site - Regional composite sample of maximum daily rainfall and Root-Gumbel distribution



Maximum daily rainfall for return periods ranging from 2 to 10 000 years are deducted from the root-Gumbel distribution. PMP is calculated using the Hershfield's formula.

The 24-hour rainfall over the catchment is deducted from maximum daily rainfall by applying both an area reduction factor and the Weiss correction factor equal to 1.13 (Table 6).

Table 6: 24-hour rainfall over Taba-Gakomeye catchment for different return periods

T	Pdmx(T)	P24(T)	P24-Taba-Gakomeye (ToR)	P24-Taba-Gakomeye (Alt)
(year)	(mm/day)	(mm)	(mm)	(mm)
2	55	62	52	52
5	70	79	67	67
10	82	92	78	78
20	94	106	89	90
50	110	125	105	106
100	124	140	118	118
200	138	155	131	132
500	157	178	150	150
1 000	173	195	165	165
2 000	189	214	180	181
5 000	212	240	202	203
10 000	230	260	220	221
PMP	350	396	334	335

4.4.4.2. FLOOD HYDROGRAPHS

The Consultant made use of the USSCS approach to compute the flood hydrographs. Broadly speaking, this approach consisted in deducting flood hydrographs from 24-hour rainfall distributed according to a given storm profile. Results are given in Table 7. The Francou-Rodier's indexes for peak discharge have been calculated. They are in the range 1.96 (return period T=20 years) – 4.12 (PMF).

Table 7: Taba-Gakomeye (ToR) dam site - Discharge

Return period T	T=20	T=50	T=100	T=1000	T=10000	PMF
t (hours)	Hourly discharge (m3/s)					
Peak discharge (Qp) (m3/s)	15	24	35	96	196	298
Mean daily discharge (Q24) (m3/s)	8	13	18	43	81	122
Qp/Q24	1.90	1.84	1.90	2.22	2.44	2.44
K(Qp)	1.96	2.30	2.56	3.30	3.82	4.12

4.4.5. Sedimentation

Due to the lack of local sediment sampling data (see chapter 3.3), the Consultant made use of a regional sediment database and an empirical formula to estimate the sediment yields at Taba-Gakomeye dam site. Broadly speaking, the empirical formula is a relation between the sediment yields and the runoff. The catchment area is also taken into account.

The regional sediment database is first processed in order to calibrate this relation. Then, the relation is applied to Taba-Gakomeye catchment in order to estimate the sediment yields. Eventually, the sedimentation rate of the reservoir is assessed by applying Brune's approach. We should keep in mind that the sedimentation rate is highly dependent of the storage capacity of the reservoir. Thus, these results should be revisited when the design changes. Main results are given in Table 8 below.

With a storage capacity of about 3,1 Mm^3 (14 meters dam height), the ratio of storage capacity to mean annual inflows is very low (8%). As a consequence, the annual sedimentation rate is quite important and the site is rather exposed to siltation.

Table 8: Taba-Gakomeye - Sediment yields and sedimentation rate of the reservoir

Dam Site	Area	Rainfall	Runoff	Sediment Yield (in suspension)	Total sediment Volume	Dam Height	Storage Capacity (C)	Mean annual inflows (I)	Capacity Inflow ratio (C/I)	Trap efficiency (Brune)	Annual sedimentation rate
	(km²)	(mm)	(mm)	(t/km²/year)	(m3/year)	(m)	Mm3	Mm3	-		
Taba Gakomeye (ToR)	101	1 440	372	848	75 731	14	3.1	38	0.08	80%	2.0%
						18	5.9	38	0.16	90%	1.1%
						26	13.9	38	0.37	95%	0.5%

4.4.6. Optimization of the reservoir capacity for Taba-Gakomeye site in Rwanda

4.4.6.1. OBJECTIVE OF THE OPTIMIZATION

Dams mainly serve to ensure an adequate supply of water by storing water in times of surplus and releasing it in times of scarcity, thus also preventing or mitigating floods. Dams that have small storage capacity in relation to the gross Mean Annual Runoff (MAR) are known as “annual dams”. They are likely to fill from empty every year except the very worst seasons or even single floods.

The methodology adopted (see chapter 3.3) is a Sequential Steam flow Routing (SSR) and according to this method a continuity equation of the water volumes is applied to calculate reservoir levels and therefore reservoir volumes, evaporation and outflows from spillway and outlet structure.

The erratic inflow of the river passes through the storage reservoir will be delayed and attenuated as it enters and spreads over the reservoir surface. Water is then released through a controlled outlet.

The optimization consists of determining the minimum reservoir capacity which allows an average constant water release with an acceptable deficiency.

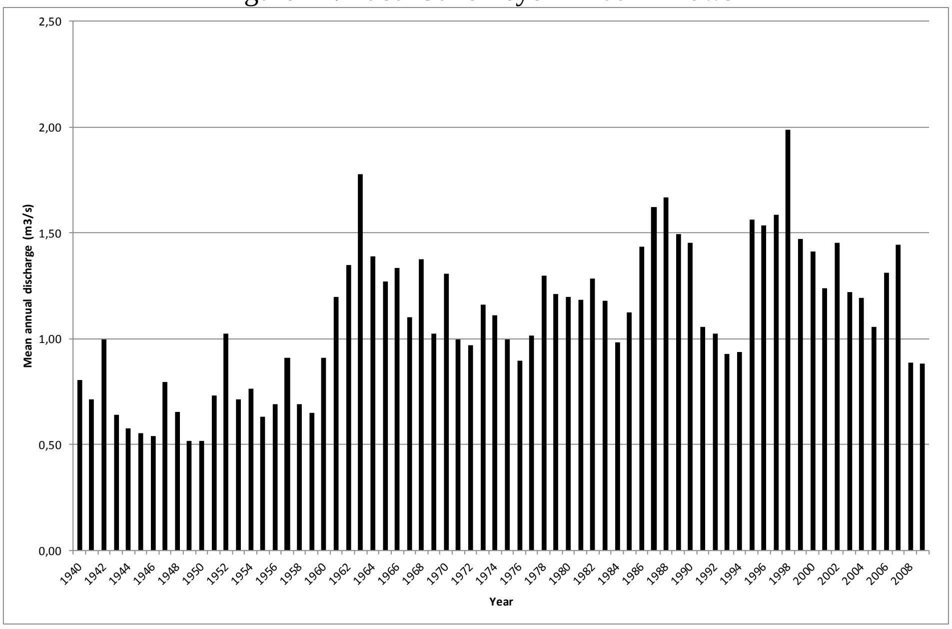
4.4.6.2. RUNOFF

For the proposed dam site at Taba-Gakomeye dam site, the monthly discharges have been deduced from the monthly discharges of Mwogo River at Mwaka.

As observed in the region since 1940, the rise in runoff in the early 1960ies appears clearly. Two periods should be distinguished: a pre-1960 period with a moderate runoff level and a post-1960 period with a high runoff level.

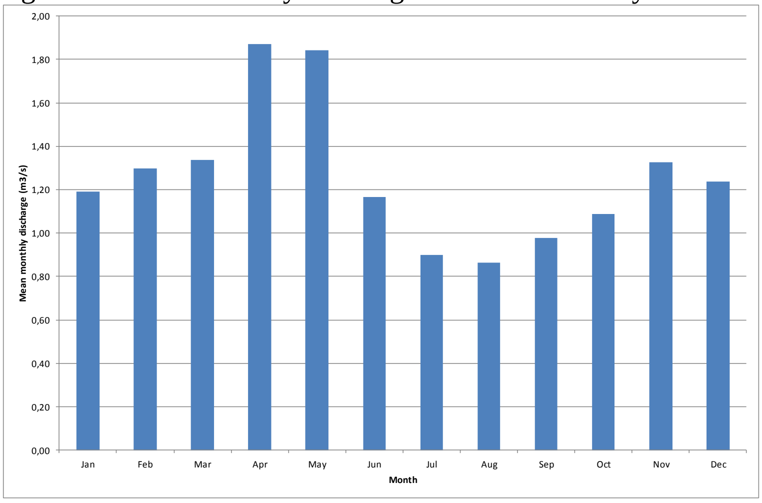
It has therefore been decided to simulate the reservoir only over the period 1962-2009, corresponding to a long series of 48 years.

Figure 17: Taba-Gakomeye Annual Inflows



The annual runoff within the period 1962-2009 is about 1,25 m^3/s. Two peaks corresponding to rainy seasons is clearly identified. However the hydrological regime is rather smooth. The ratio of maximum monthly discharge to minimum monthly discharge is equal to 2,18.

Figure 18: Mean monthly discharges at Taba-Gakomeye dam site



4.4.6.3. EVAPORATION

The following table summarize the result of the computed Net Evaporation at the Taba-Gakomeye dam site. The net losses due to evaporation is about 0,5% of the annual inflow.

Table 9: Estimated evaporation at Taba-Gakomeye reservoir

	Taba-Gakomeye	Precipitation		Original evapotranspiration (mm)	Evaporation (mm)	Net Evaporation (mm)	Catchment Area (km²)	Runoff (mm)	Reservoir Surface Area (km²)	Net losses due to evaporation /Inflows
	Altitude (m)	Yearly Amount(mm)	Distribution (%)	based on CRO=	Upper Ruvubu Reservoir					
	1664	1440		0,267			101	372	1	0,5%
January		168	11,7%	123	101	-22				
February		172	12,0%	126	91	-35				
March		179	12,4%	131	98	-33				
April		212	14,8%	156	89	-67				
May		152	10,5%	111	96	-15				
June		21	1,4%	15	104	89				
July		6	0,4%	4	122	118				
August		57	4,0%	42	136	94				
September		85	5,9%	62	114	52				
October		147	10,2%	108	106	-2				
November		118	8,2%	87	92	5				
December		122	8,4%	89	98	9				
Total		1440	100%		1 247	191				

4.4.6.4. MAXIMUM MEAN WATER RELEASE

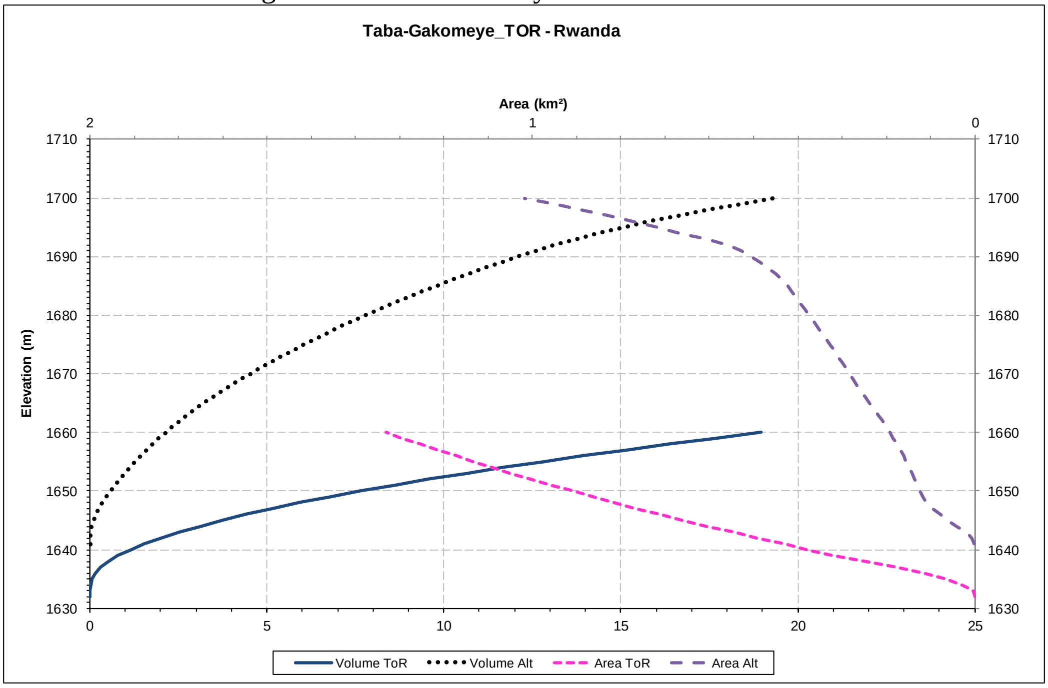
The objective of the optimization is to determine what should be the reservoir capacity which will allow the complete runoff hydrograph to be routed through the reservoir. The maximum water release is therefore the mean annual Inflow minus the loss due to the evaporation. According to the two previous chapters, the maximum discharge is 1,24 m^3/s (1,75 – 0,5%).

4.4.6.5. RESERVOIR DATA

During the inception mission in October 2011, an alternative dam location has been proposed to limit the social impact. The new dam axis has been located upstream of the one described in the ToR.

Based on the new topographical data, the surface and the volume of the reservoir versus the height of the dam for both sites were determined according to the height-volume-surface (HSV) curve as follows.

Figure 19: Taba-Gakomeye Reservoir HSV Data



The alternative position offers a very small reservoir (less than 2% of the annual runoff). In average, the alternative capacity represents less than one third of the original capacity. With such a small capacity, the reservoir has nearly no impact on the natural inflow distribution.

Moreover, the alternative reservoir will be completely filled with sediment in less than 15 years.

For these reasons, the alternative position is abandoned and the simulation has been done keeping the original proposal as per the ToR.

4.4.6.6. MINIMUM OPERATION LEVEL

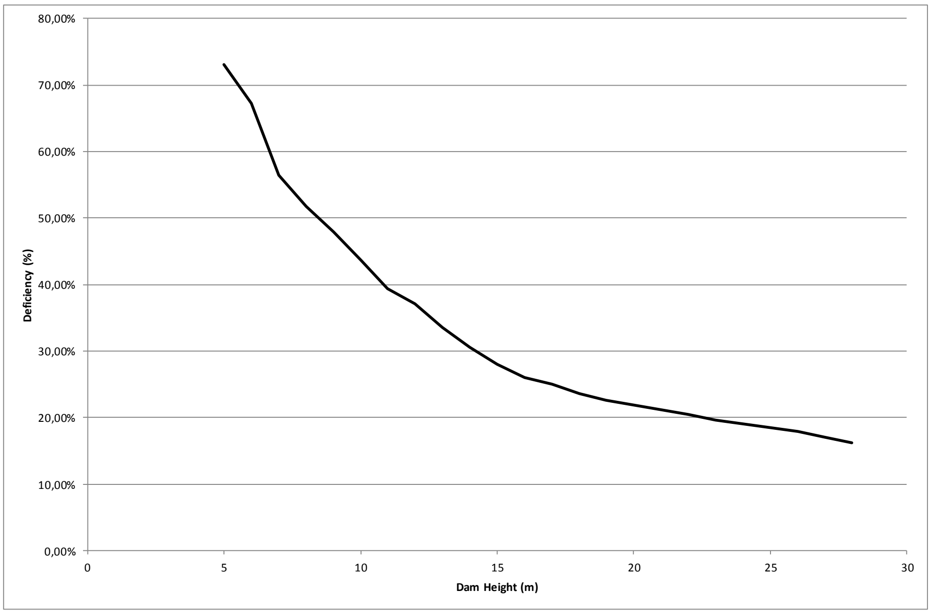
As sediment will be trapped, the reservoir storage capacity will decrease. Therefore, the outlet structure of potential dam should be set at an elevation above the expected siltation level. Under this level, the stored water will not be used and commonly called as “dead storage”.

The annual sedimentation rate at Taba-Gakomeye site is about 0,075 Mm^3 per year. Therefore, the outlet threshold should be set 7m above the minimum ground elevation, giving a dead storage of 0,79 Mm^3 representing more than 10 years of sedimentation storage.

4.4.6.7. DEFICIENCY AND GUARANTEED DISCHARGE

The following figure represents the deficiency (percentage of months when the demand is not satisfy) versus the dam height. Of course, more the reservoir capacity is big, more reliable will be the reservoir to satisfy the demand.

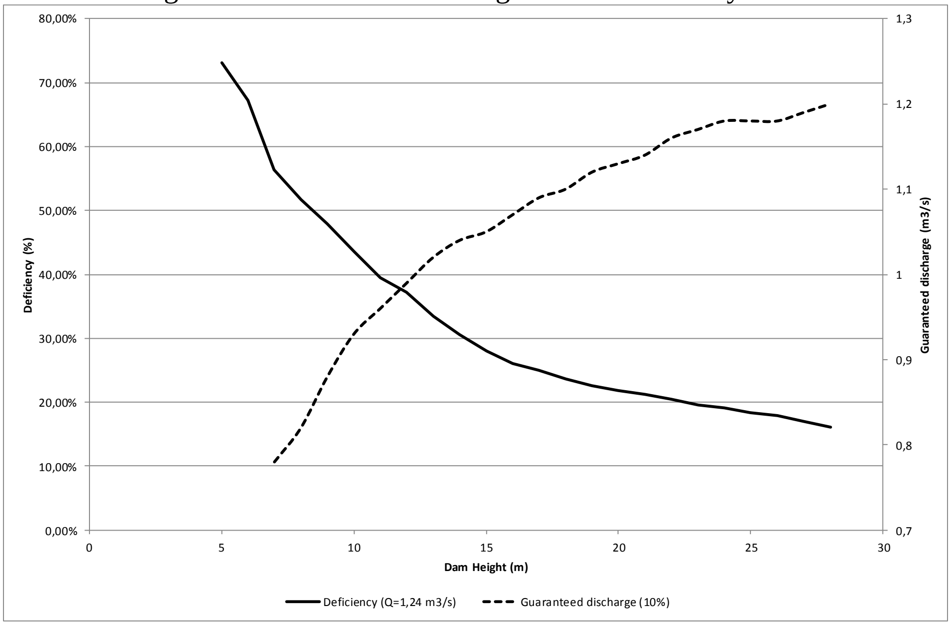
Figure 20: Deficiency versus Dam Height of Taba-Gakomeye



This curve clearly shows that the deficiency is quite high. Usually, the recommended yield risk level is 10% for irrigation dams. Thus, the optimise Full Supply level should be 25m above the natural ground level.

The following figure shows the guaranteed discharge depending on the Full Supply Level. The guarantee is variable from 0,78 to 1,2 m3/s respectively for a Full supply Level from 7 to 28 meters.

Figure 21: Guaranteed discharge at Taba-Gakomeye dam



4.5. Water uses and water demand for Taba-Gakomeye site

4.5.1. Context

As seen in the previous chapter about the optimization of the reservoir (see chapter 4.4.6), the objective of the dam, and consequently the scenarios are mainly dependant on the size of the dam. Thus, each of the development scenarios will be optimized with determination of the best reservoir operating rule.

4.5.2. Irrigation

4.5.2.1. POLICY FRAMEWORK

The agriculture sector strategies, polices and action plan are found in these below texts:

- The National Agriculture Policy of 2004.
- PSTA II – Strategic Plan for the Transformation of Agriculture in Rwanda of 2008
- Agricultural Transformation Strategic Plan Support Project – ATSPSP 2005
- Linkages between CAADP and PSTAII – July 2009
- Agriculture Policy Synthesis 2002
- Vision 2020 – one of the 6 pillars is the Modernization of Agriculture and Animal Husbandry

The objective of irrigated land is 24 000 ha for 2012.

4.5.2.2. WATER USES FOR IRRIGATION

Literacy context

According to the *Rwandan Irrigation Master Plan* (MINAGRI, [c]), data about crops cultivated in the Central Plateau zone dates back to 1974. This Plan proposes a selection of best regional crops to develop irrigation scheme in the Central Plateau zone, in the decreasing order of priority: (1) Coffee, (2) Beans, (3) Potato or rice, (4) Cassava or maize or groundnut, (5) Beans or tea or triticale.

According to the *Rwandan Irrigation Master Plan*, [c] four dam sites are selected in Huye district. Below are the different features found concerning these dams.

Table 27: Potential dams for irrigation in Rwanda

District	Water source/name	Command Area (ha) Slope categories 0-6%	6-16%	16-40%	Total Potential command area (ha)	Coordinates (using the modified Gauss Projection adopted by Rwanda and Burundi) X coordinate	Y coordinate	Water catchment areas (km²)
	Dam/43	53	121	152	326	481106.85	9720114.57	1013
	Dam/44	28	107	198	333	476717.93	9722715.6	1013
Huye	Dam/36	89	146	106	341	460062.34	9721634.69	2436
Huye	Dam/37	66	145	150	361	463409.67	9713129.44	472
Huye	Dam/38	44	95	73	212	459272.26	9728376.55	2045
Huye	Dam/39	96	187	80	363	472201.13	9736119.45	2037

Source: Dr Ntale [b]

Several micro-hydro power projects such as Ruramba have been already planned all across the Rwanda, as the *Rwandan Irrigation Master Plan* [e] highlights it. Moreover, in Nyanza district, hillside irrigation has been developed.

Field context based on the field mission carried out in February 2012

Several irrigation perimeters have been developed until now in Huye and Nyamagabe districts. One scheme is currently being built under a German Agro Action-funded project, on Mwogo marshland near Butare, downstream the project site. It is designed as a surface irrigation scheme for rice cultivation. Another irrigation scheme was studied upstream the dam site, named Ruramba.

<u>The Mwogo valley</u>:

At this upper part, the River flows from west to east at an altitude of about 1600 m and in a landscape of high hills of roughly 2000 m of altitude. Here, the river receives numerous short tributaries. Around 5 km from the dam site, the Mwogo River suddenly flows toward northeast and then north direction, until merging into the Nyabarongo River, around 100 km farther.

The bottom of the valley is around 100 m wide at the level of the upper dam site; some five hundred meters downstream, it widens to 200 m over 2.4 km farther. Then, excepted at restricted parts of some confluences with tributaries, the valley is narrower, less than 100 m wide, along the 3 following km. The Mwogo valley becomes really wide and swampy 10 km away from the upper dam site.

The River bed is deep. In the upper part of the project area, the river flows in the middle of the plain and then it flows on the right side of the valley. The River is bordered by natural levees which are used for sand extraction.

<u>Soils and land present use</u>:

The valley is built with alluvial-colluvial deposits forming a slightly undulated valley bottom. Soils belong to the Ruko serie [3]. These soils are yellow, mainly with coarse-loamy texture and imperfectly drained.

However, due to the differential sedimentation of the deposits, with the coarsest ones the closer to the river, and due to the divagation of the river, the soil texture is very variable in both horizontal and vertical direction.

The natural fertility of these soils is low. It is required to increase their organic and phosphorus content, and to correct their acidity. Hills bear red ferrallitic soils with a strong contrast with the valley.

The whole valley is already cultivated, mainly with maize and, in a lesser extent, with some soybeans, sorghum and vegetables (see the following figures):

- Maize is usually sown in September/October and harvested in February/March. Yield may reach 4 t/ha. Sowing in February/March with earlier varieties harvested in June provides a lower yield of 3 t/ha.
- There is no rice cultivation in the district of Nyamagabe because of the possible occurrence of too cold temperatures.

[3] Ministère de l’Agriculture du Rwanda, Université de Gand (Belgique), 2001 – *Carte pédologique du Rwanda au 1/50000e – Planchette n°40 Butare*.

A former weir had been built on the Mwogo River 2000 m upstream of the dam site. It is no longer working since around ten years, as the river overflowed it and changed its course. It was used to irrigate maize, soybeans, beans and potatoes.

Figure 22 : Mwogo valley, downstream of the upper dam site

Several fishponds in good condition can be seen downstream of the dam site on the below picture.

Figure 23 : Mwogo valley, downstream of the lower dam site

Figure 24 : Mwogo valley, around 0.6 km downstream of the lower dam site

Figure 25 : Mwogo valley, around 2.4 km downstream of the lower dam site

4.5.2.3. IRRIGATION POTENTIAL ASSESSMENT

Land availability based on 1/50 000 map and the field mission in February 2012:

Due to the narrowness of the valley, the potential command area for irrigation purpose is somewhat limited. The rough extent of this command area could be as follows (see the following map) with dam located as defined in the ToR:

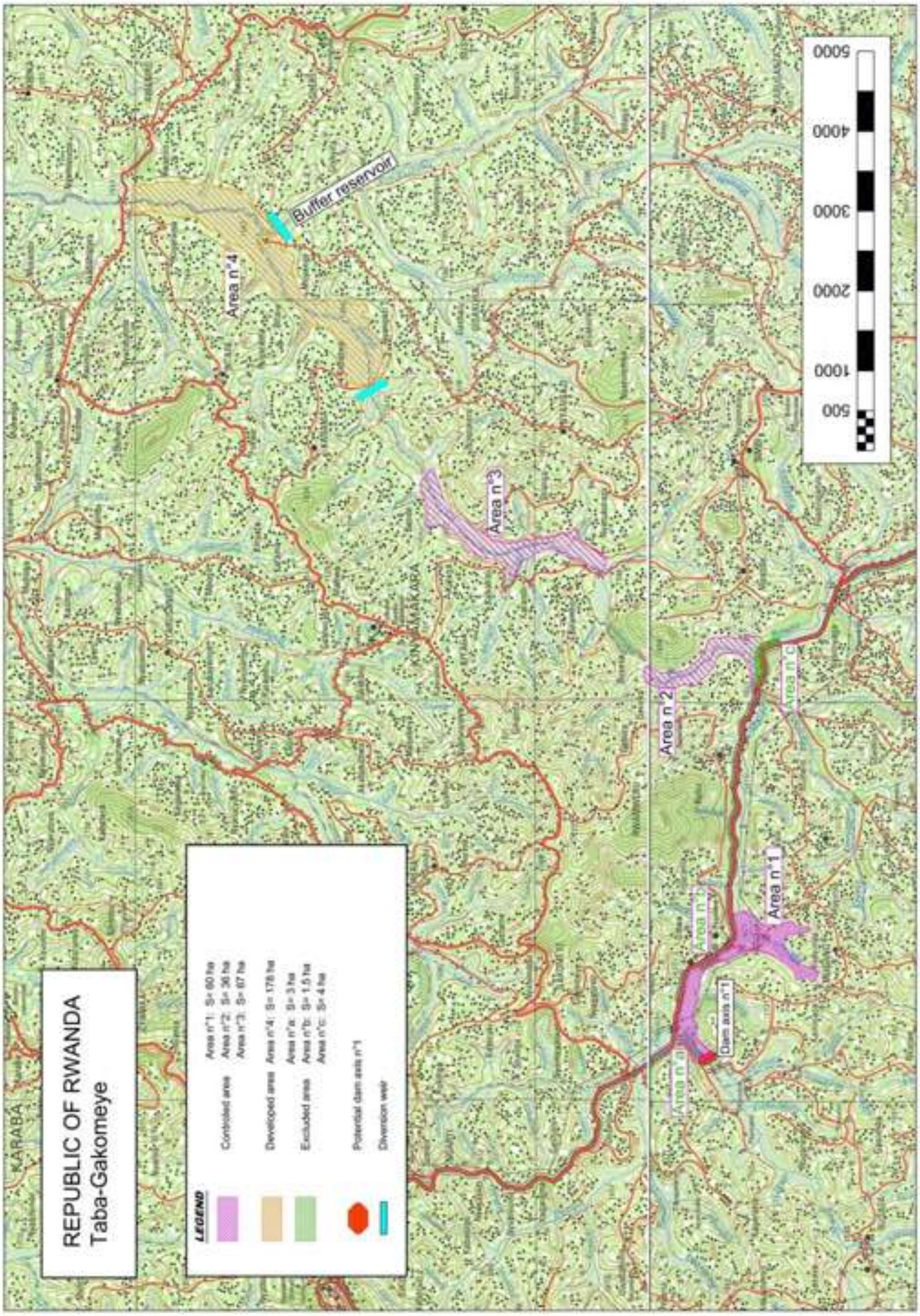
- Around 60 ha (area n°1) more 2,7 km downstream from the dam site, i.e. down to the gorge that begins after the bridge on the main road, downstream the village of Karambi;
- Going downstream, the River flows in a 7 km long gorge along the main road then turns South and reaches a new swampy area (area n°2) of approximately 36 ha.
- Then it goes through a second gorge and flows through a new plain where 57 ha (area n°3) could be develop. Only the upstream section of this plain could be develop because of the existence of a diversion weir, built to supply area 4, already developed by a KFW funded project for a total of 178 ha. An extension is under construction down to the second bridge.
- Finally, the area far downstream the dam (area n°4) is developable for irrigation. The distance between this area and the dam will be around 40 km therefore several critical issues will have to be addressed prior to development:
    - Water release from the dam will have to be managed according to all downstream needs. No institution which can play that role is present for the time being.
    - It will be important to check if the River bed and the current uses (sand mining for instance) could be preserved with the new discharge to be conveyed through this section.

These estimates are taking into account a gross area. If developed, it is expected that the reduction between gross controlled area and net irrigated area is in the range of -20% to –40%. Therefore, the net irrigated area for the area n°1+2+3 could be:

Maximum net irrigated area	Minimum net irrigated area
122 ha	92 ha

However, it shall be kept in mind that all this land is already grown. Thus, any improvement shall be previously discussed with the farmers.

Figure 26: Irrigation potential areas for Taba-Gakomeye dam project



Rwandan government tries to promote the cultivation of rice, maize, potato and beans as high nutritional value crops, for their importance in the cropping patterns, their good possibility of intensification and the town's marketing opportunities.

Due to the risk of cold temperatures, to the risk of too high permeability of the soils, and to the close presence of large competitive rice perimeters in the district of Huye/Butare, it is proposed to avoid rice cropping for the areas n°1 to 3. For potential downstream area n°4 developments, rice could be grown.

Thus, the project will be orientated toward maize, beans and potato production, so as toward production of vegetables. Furthermore, fruit trees could be planted at the edges of the perimeter: for example, plum trees, lemon trees and orange trees would be suitable for planting. The irrigation possibility will allow the farmers to grow three crops in a year.

<u>Potential crops and cropping pattern:</u>

Three cropping seasons are usually recognized in Rwanda, which are called A, B and C:

- A season takes place during the small rainy season, i.e. from September/October up to December/January,
- B season occurs during the big rainy season, i.e. from February up to May/June,
- C season is completed during the big dry season, i.e. from June up to August/September.

It is proposed to grow an equal area of maize, potatoes, beans and soybeans during the A and B seasons, while introducing a crop rotation.

During the B season and thanks to irrigation, farmers will be able to shift from their early maize varieties to later hybrid and more productive varieties they use during the A season.

C season will be mostly dedicated to vegetables, as the weather is drier and then less prone to pest development. Two cropping patterns options will be analysed, a first one with 100% vegetables during the dry season, and a second one only with 50%, because of the heavy workforce required for growing vegetables.

Growing periods of the different crops may present certain flexibility in time. Nevertheless, at this feasibility stage and in order to make it more simple, it is considered a fixed date for the beginning of each cropping season: 1st of September for the A one, 1st of February for the B one, and 1st of May or June for the C one. Anyway, it will be required to make sure 3 growing seasons during the year.

It is expected to reach a yield of 5 t/ha for maize, 1.6 t/ha for beans and soybeans, 15.0 t/ha for potatoes, and from 2 to 6.0 t/ha for vegetables, depending on the crop which will be grown. These yield figures may be found in various statistics from the Minagri; the higher yield for maize comes from the district agronomist in Nyamagabe.

4.5.2.4. IRRIGATION WATER DEMAND

Crops water requirements:

Irrigation water requirements are computed by calculating a water balance for every period of 10 days (hereafter called a decade). The Reference Evapotranspiration ETo (Penman-Monteith formula) is very close for all regions of the four dams and it has been taken an average of 5 stations of the FAO climwat database: Rubona and Butare in Rwanda, Biharamulo and Bukoba in Tanzania, Mbarara in Uganda. The nearest station Muyinga in Burundi has not been taken into account, because it has very high figures during the dry season, which seem over estimated.

The mean annual ETo reaches 3.6 mm/day. The total annual ETo reaches 1297 mm (see the following figure). ETo is slightly lower during the rainy months and slightly higher during the driest ones.

Rainfall has been considered at the station of Butare in Rwanda (altitude 1768 m, latitude -2.60°, longitude 29.73°) (see Figure 28). The total annual rainfall reaches 1256 mm and the effective rainfall (Pe) reaches 991 mm after correction using the FAO method.

In Rwanda, the meteorological year is usually divided into four periods: a short dry season from December until February, the long wet season from March until May, the dry season from June until September and a short wet season from October until December. The chart (Figure 28) shows that the “short” seasons are little marked on site.

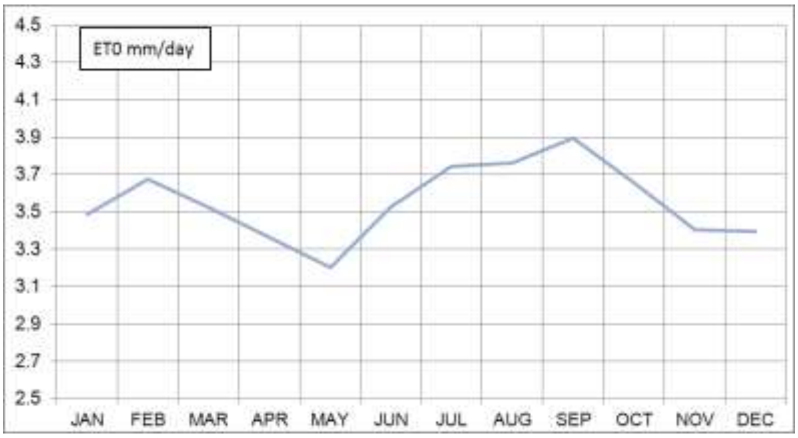
A set of crop coefficients was selected for each crop all along the crop development.

The irrigation water requirements (I) are calculated as follows:

I = kc Eto – Pe where kc is the crop coefficient

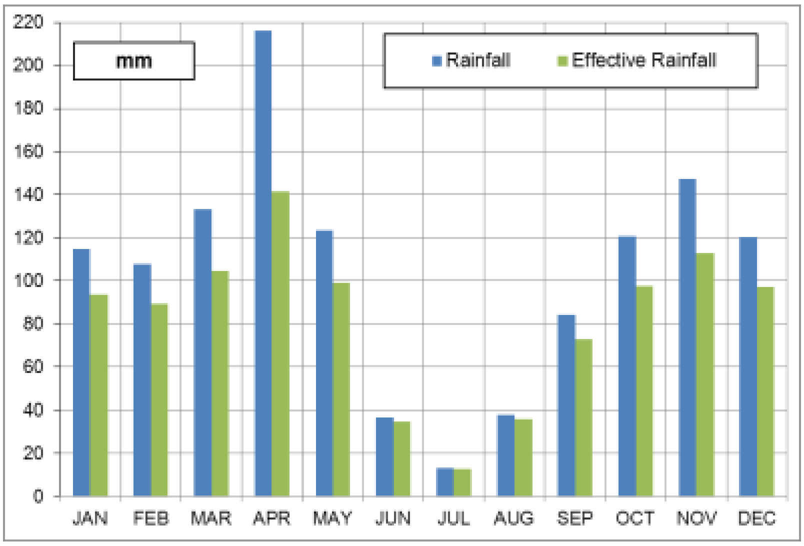
I = 0 if Pe of the considered decade > kc Eto

Figure 27 : Mean daily reference evapotranspiration in the region of the projects



(source: Climwat FAO)

Figure 28 : Rainfall and effective rainfall at Butare, Rwanda



(source: Climwat FAO)

For each possible crop, the following table summarizes the total irrigation water requirement, expressed in m^3/ha for the whole crop cycle, and the maximum base flow in l/s/ha.

The base flow (specific flow) is the hypothetic flow which would be required to meet the irrigation amount of the decade while taking into account a daily irrigation duration of 24 hours. It is expressed in l/s/ha (litre per second per hectare).

This basic unit flow will be later proportionally increased while considering the real possible daily irrigation time to define the irrigation duty. This later depends on the way which is chosen to irrigate.

Although maize, potatoes and beans are supposed to be mostly grown during the A and B seasons, their irrigation requirements have been also computed during the C growing season in case of some of these crops will make up the area with vegetables in the scheme.

Table 10: Crops, expected yields and water requirements

Crop - season	planting time	length of development	expected yield	irrigation water per ha	maximum unit flow l/s/ha
		days	t / ha	m^3 / ha	at 24 h / day
Maize - A	1st Sep	150	5.0	300	0.1
Maize - B	1st Feb	150	5.0	600	0.3
Maize - C	1st May	150	5.0	2 900	0.5
Beans - A	1st Sep	120	1.6	200	0.1
Beans - B	1st Feb	120	1.6	100	0.1
Beans - C	1st May	120	1.6	2 500	0.5
Potatoes – A	1st Sep	130	15.0	400	0.1
Potatoes - B	1st Feb	130	15.0	400	0.2
Potatoes - C	1st May	130	15.0	2 800	0.5
Vegetables - C	1st Jun	120	2 to 6	2 600	0.4

NB: A, B or C : Rwandan growing season

Volume of irrigation water:

Irrigation water requirements are low during the A and B growing seasons, which is understandable during rainy seasons. Nevertheless, two points shall be kept in mind proving the importance of irrigation:

- in the case of these seasons, irrigation is usually required at the beginning and at the end of the crop cycle, and this is essential for the success of the cultivation,
- while avoiding the uncertainty of rains, irrigation is compulsory to secure 3 crops a year and thus to implement the agricultural intensification which is a strong request of the Rwandan government

The required volume of irrigation water is markedly higher in the case of every crop grown during the dry season C. During this season, irrigation requirements are more or less the same one whatever the crop.

Irrigation requirements have been computed with mean rainfall. During drier years, it may be more important.

Base flow (specific flow)

It reaches a low level of 0,1 to 0,3 l/s/ha in the case of rainy A and B seasons cropping. It is higher during the C dry season and reaches from 0,4 to 0,5 l/s/ha. Thus, a base flow of 0,5 l/s/ha is required if we want to provide the possibility of 3 crops a year.

Cropping pattern

The cycles of the proposed crops do not overlap provided they can be sown following a planned schedule. In consideration of this latter, it is assumed 3 crops a year and a main orientation toward vegetables during the dry season.

The cropping patterns of the rainy seasons have been equally shared among maize, potatoes, beans and soybeans, but a lot of other scenario are possible as the length of crop cycles are close.

Two hypothesis could be drawn for the dry season cropping C: a first one supposing the complete use of the area with vegetables, while the second one 2 gives over only the half to them, because of the high workforce and organization required by this kind of crops.

Project discharge:

Canals system should be designed to meet the peak base flow by taking into account both real possible irrigation duration and system efficiency. This will define the scheme irrigation duty.

With a surface irrigation system, it is usually preferable to avoid night time irrigation because human presence is required for controlling the flows in the furrows or basins. Thus, the maximum duration is set at 12 hours per day.

Regarding efficiency, which is the ratio of water delivered at the plot to water withdrawn from the reservoir, thus revealing the overall transfer losses, it is proposed to take 60% efficiency into account.

Then, the irrigation duty is computed as follows:

Irrigation duty = Specific flow (24 hours l/s/ha) / Irrigation duration (hours/24) / Efficiency

Table 11: Irrigation duty

Irrigation system	Maximum irrigation duration	Efficiency	**Irrigation duty**
	hours	%	l/s/ha
Surface irrigation	12	60	**1.5**

Use of water for irrigation:

Assuming the two cropping pattern scenarios, the water used for irrigation has been evaluated for an irrigated area of 100 ha.

The total water requirement is quite the same one in the two cases, showing a broad possible choice of crops and scenarios once the irrigation scheme will be completed.

Table 12: Detailed yearly irrigation water consumption for a100 ha scheme

Cropping pattern	Growing season	***% of crops* and gross volume of water m^3 ***					
		Maize	**Potato**	**Beans**	**Soybeans**	**Vegetables**	**TOTAL**
1[4]	**A**	*25%*	*25%*	*25%*	*25%*		*100%*
		7 500	10 000	5 000	5 000		27 500
	B	*25%*	*25%*	*25%*	*25%*		*100%*
		15 000	10 000	2 500	2 500		30 000
	C					*100%*	*100%*
						260 000	260 000
	TOTAL	22 500	20 000	7 500	7 500	260 000	**317 500**
2[5]	**A**	*25%*	*25%*	*25%*	*25%*		*100%*
		7 500	10 000	5 000	5 000		27 500
	B	*25%*	*25%*	*25%*	*25%*		*100%*
		15 000	10 000	2 500	2 500		30 000
	C		*25%*	*25%*		*50%*	*100%*
			70 000	62 500		130 000	262 500
	TOTAL	22 500	90 000	70 000	7 500	130 000	**320 000**

* *taking into account the conveyance efficiency*

Total water consumption of the scheme could then be estimated as follows:

Table 13: Total yearly irrigation water consumption for the scheme

Irrigated area	**Gross volume of water** (m^3)*	
(ha)	Cropping pattern 1	Cropping pattern 2
92	292 100	294 400
122	387 350	390 400

* *taking into account the conveyance efficiency*

[4] Cropping pattern 1 : 100% vegetables during dry season

[5] Cropping pattern 2 : 50% vegetables during dry season

The Table 13 shows water availability for increasing the water resources of downstream perimeters and potentially developed additional downstream perimeters.

4.5.2.5. ENVIRONMENTAL AND SOCIAL ISSUES IN CASE OF IRRIGATION

The main constraints for the future development of Taba-Gakomeye area are identified as follows.

- Land tenure: Most of the valley is cultivated at present. Other uses, such as fish farming, are present within the project area. The current option is to exclude any area used for other purposes from the project. This option will have to be confirmed by the client with the beneficiaries.
- Environment: sand is extracted from the river bed downstream the planned dam. After the completion of the dam, sand will be silting upstream the dam. The impact of that siltation on the river behaviour and on social activity will have to be assessed.
- Social: should far downstream development deemed useful for the project, an local institution in charge of water management will have to be created. Several governance options are relevant for managing that institution (water user association, public agency, private company, intermediate institution gathering part or all the previously mentioned stakeholders).

4.5.3. Livestock watering

4.5.3.1. CONTEXT

In 2005, the Rwandan MINAGRI has proposed the “One Cow for One family” project: this program gives one cow for one family and aims at extending the project of Heifer Project International, a NGO developing livestock in former Byumba, Ruhengri and Kigali Ngari provinces. This program should be considered in the coming study.

Very few cattle were observed in the Project area due to the use of land for agriculture. It would be noticed as well that the zero grazing policy is developed in Rwanda.

4.5.3.2. LIVESTOCK RESOURCES

The CountrySTAT Rwanda reports that the country in 2009 had following livestock population: cattle (1 334 820), goats (2 550 521), sheep (745 813), pigs (641 890), poultry (2 550 521) and rabbits (747 696).

An assumption is made to apportion the national livestock in the same proportion as the population. Thus, the livestock population in the project area is assumed to be 1.95% of the total Rwanda figures as follows. A flat rate 25% increase is assumed to year 2037.

- Indigenous cows: 26 000
- Goats: 50 000
- Sheep: 15 000
- Pigs: 13 000
- Poultry: 50 000
- Rabbits: 15 000

4.5.3.3. LIVESTOCK WATER DEMAND ASSESSMENT

Livestock water demand

The forecasting of the future water demand for livestock has been calculated using the design criteria adopted for this assignment as given in the chapter 3.4.1.3. Based on the estimation of livestock population, the present and future livestock water demand is estimated as follows assuming that 40% of the livestock is in the Project area. The hypothesis taken in 2037 is an increase of the population by 25%.

Table 14: Livestock water demand estimation at Taba-Gakomeye site

Type	Demand lpd	2012		2037	
		Number	m3/day	Number	m3/day
Beef Cattle	25	26 000	650	32 500	813
Dairy Cattle	40	0	0	0	0
Pigs	10	13 000	130	16 250	163
Sheep and Goats	5	65 000	325	81 250	406
Poultry	30 per 100 birds	50 000	15	62 500	19
TOTAL m3/d			1 120		1 400
Annual Demand (million m3/year)			0,41 M m^3		0,51 M m^3

This estimation should be considered cautiously due to the lack of data in the Project area.

Technical constraints

As seen above, the Project area is mainly dedicated to agricultural use. Thus, implementing livestock watering should be considered with cautious. Technical assessment should be reviewed at later stager in case of implementing this use.

4.5.4. Aquaculture

4.5.4.1. WATER USES FOR AQUACULTURE

The fish stocks in the majority of lakes in Rwanda side have been over-exploited. To ensure sustainable fish production and environmental protection, aquaculture is being currently initiated through support from the MINAGRI projects. In 2007, there were already 37 cooperatives and associations which had constructed 260 fish ponds [b], including 15 cooperatives and 73 fish ponds in Southern Province. Some fishponds operating with rabbit rearing could be observed nearby the Project site as shown on the following picture.

Figure 29: Fishpond near the Taba-Gakomeye site

Source: Tractebel Engineering inception mission – October 2011

4.5.4.2. DEMAND FOR FISH AND FISH PONDS

Based on the estimation of the population density in the project area of about 364 persons per km^2 increasing to 727 in year 2037, the table below gives two options of ponds, subsistence or commercial fish farming.

Table 15: Estimation of water ponds need

	2012		2037	
	subsistence 2 km radius 2t/Ha/year size 0,04Ha	commercial 4 km radius 3 t/Ha/year size 0,4 Ha	subsistence 2 km radius 2t/Ha/year size 0,04Ha	commercial 4 km radius 3 t/Ha/year size 0,4 Ha
population density	364	364	727	727
Population	4,575	18,299	9,137	36,548
fish consumption kg @ 1kg/person/year	4,575	18,299	9,137	36,548
Pond Area Ha	2,29	6,10	4,57	12,18
Numbers of ponds	57	15	114	30

These data should be reviewed taking into consideration the existing fish ponds.

In the table, the hypothesis for the development of commercial fish ponds, has taken account the high level of the population density.

4.5.4.3. WATER REQUIREMENT FOR AQUACULTURE

Taking into consideration that each pond has an average depth of 1,20m, that the annual evaporation is assumed to be 1300 mm, that soil percolation is assumed to be 1500 mm/year for sandy clays at a percolation rate of 0.5 x 10^{-7}/sec., the fish farming is estimated therefore as follows and the maximum volume of required water for fish farming is also calculated as follows:

Table 16: Estimation of maximum water demand for aquaculture

Parameters	2012		2037	
	subsistence size 0,04 Ha	commercial size 0,4 Ha	subsistence size 0,04 Ha	commercial size 0,4 Ha
Numbers of ponds	57	0	80	9
Volume	27 449	-	38 400	43 791
10% exchange daily / annually	1 001 871	-	1 401 600	1 598 371
Evaporation 1.3m/ year	29 736	-	41 600	47 440
Seepage 1.5m/year	34 311	-	48 000	54 739
Volume m3/year	1 093 366	-	1 529 600	1 744 341
Total Volume m3/year	1,1 Mm3		3,3 Mm3	

These volumes should be reviewed taking into consideration the existing fish ponds and the phases of the implementation of such project.

4.5.5. Hydropower development

4.5.5.1. CONTEXT

According to the *Rwandan State of Environment* [c], the major part of the energy consumed in Rwanda still comes from wood (80.4 per cent)

These below tables, issued from the *Rwandan State of Environment* [g], present the available electricity capacity in 2009.

Table 17: Current electricity generation capacity

Category	Name	Installed capacity (MW)	Available capacity (MW)
In house hydropower	Ntaruka	11.76	6
	Mukungwa	12.5	11
	Gihira	1.8	1.8
	Gisenyi	1.2	1.2
Imported hydropower	Rusizi 1 (SNEL)	3.5	3.5
	Rusizi 2 (SINELAC)	12	8
Micro hydropower	Nyamyotsi	0.075	0.075
In house thermal power	Jabana	7.8	7.8
	Gatsata 2	4.77	0
	Gatsata 1	1.8	0
Rental thermal power	Aggreko 1 (Gikondo)	10	10
	Aggreko 2 (Mukungwa)	5	5
Solar power	Kigali solar	0.25	0.25
Total		72.445	54.625

Source: MININFRA 2009a

4.5.5.2. ENERGY SUPPLY

Less than 2% of the households have electricity in the Project area. Between 70 and 85% of the households use firewood and charcoal as source of energy.

In the vicinity of the dam site, electricity supply lines did not exist.

4.5.5.3. HYDROPOWER POTENTIAL ASSESSMENT

The used methodology is the same as described in the chapter 3.4.1.4.

a) Energy production

The results are summarized in the following table for dam height of 14, 18 and 26m:

Table 18: Energy production results for Taba Gakomeye site

Country	Name	Full Supply Level (m)	Firm Power (kW)	Mean Power (kW)
		12	64	101
Rwanda	TABA-GAKOMERE	16	92	130
		24	130	204

b) Economic analysis

The aim is to present the economic profitability of the project through simple criteria such as cost per kWh delivered and the benefit / cost ratio.

The economic analysis requires two assumptions which are the discount rate and the selling price per KWh.

The discount rate "a" compares expenditures or revenues that are not performed at the same time. It represents an interest rate reflecting the preference for the present of any investor. Thus a cash flow occurring in n years will be the same value as the same financial flows occurring in the current year divided by (1 + a)n. The discount rate is usually set by the authorities for its investments by domestic companies or financial institutions. It usually ranges between 5% and 15% and is even higher than the financial resources are scarce. The update makes it possible to make comparable financial flows including schedules of revenues and expenses are different.

In this study, the hypothesis was a value of 10% for the discount rate which is often taken as a reference.

The cost per kWh is estimated equal to 0,15 Euro/kWh. The benefit after 30 years of exploitation is given in the following table:

Table 19: Benefit of energy selling for Taba-Gakomeye site

Name	Full Supply Level (m)	Firm Energy (kWh/year)	Benefit after 30 years (Euro)
	12	561 024	872 042
TABA-GAKOMERE	16	806 472	1 253 561
	24	1 139 580	1 771 336

Each of these potential benefits must be compared to the overall cost of investment cost of the construction of the micro-powerhouse (civil engineering, site facilities, access road, civil works, hydro-mechanical equipment, transmission line…) plus the annual expenses required for the maintenance. According the experience of the consultant on similar project, all these cost will not be less than 1,2 millions of Euros.

Thus the site would be not viable economically, leading not to take into account this use in the below detailed description for the proposed development.

It should be noticed that another hydroelectric project named Ruramba has been studied upstream the project site.

4.5.6. Water supply

4.5.6.1. LEGISLATIVE CONTEXT

The Rwanda water policies comprise the following texts:

- Sectoral Policy on Water and Sanitation of 2004;
- National Policy for Water Resources Management of 2011.

4.5.6.2. WATER SUPPLY

Nyamagabe District is among several zones in the country with sufficient water sources. However, the majority of the population use dirty water from streams, dams, valleys or swamps. However, Huye District would have a better coverage in drinking water.

In the Project area, the source of water come from drinking water supply (3 to 37%), protected springs (33 to 66%) or lakes/rivers/unprotected springs (22 to 50%).

The fetching distance to catch water is estimated to be 2 to 5 kms. The majority of the houses are located at the upper reaches of the hills.

4.5.6.3. WATER DEMAND

For rural water supply, Rwanda’s national water sector policies have a target per capita water demand of 20 litres/person/day (lpd).

The present and future water demand has been estimated based on the population in Nyamagabe, Huye and Nyaruguru Districts as follows:

Table 20: Estimation of maximum water demand for Taba-Gakomeye water supply

Water Supply	Urban	Peri-urban	Rural	2012			2037		
				Urban	Peri-urban	Rural	Urban	Peri-urban	Rural
Population	levels of services			58,000	23,719	134,410	174,315	43,974	249,188
Communal Water Points / others	30%	60%	80%	17,400	14,231	107,528	52,295	15,180	199,350
Yard Taps	20%	20%	20%	3,480	2,846	21,506	34,863	5,060	49,838
Multiple Taps House Connection	50%	20%	0%	1,740	569	0	87,158	5,060	0
Water Demand m3/d	per capita lpd			m3/d	m3/d	m3/d	m3/d	m3/d	m3/d
Communal Water Points / others	25			435	356	2,688	1307	380	4984
Yard Taps	60			209	171	1,290	2092	304	2990
Multiple Taps House Connection	120			209	68	-	10459	607	0
Sub-Total m3/d				853	595	3,979	13,858	1,290	7,974
Non-domestic 30% m3/d				256	178	1,194	4,157	387	2,392
Total m3/d				1,108	773	5,172	18,015	1,677	10,366
30% losses m3/d				333	232	1,552	5,405	503	3,110
Grand Total m3/d				1,441	1,005	6,724	23,420	2,181	13,476
				9,170 m3/d			39,077 m3/d		
Annual demand including Gikongoro, Butare & Nyanza towns				3,35 million m3			14,26 million m3		
Annual demand option without towns (m3/year)				2.82 million m3			5,71 million m3		

These data should be considered with cautious and should be considered as a maximum.

4.5.6.4. WATER SUPPLY ASSESSMENT

The availability of water because of the proposed dam will actually allow supporting water infrastructures feeding standpipes and / or private connections and including water abstraction, transmission, distribution, storage, pumping and treatment components. Separately from water systems, hand pumps using groundwater and managed springs could as well benefit from the project.

Further investigations should be carried out to define the best technical approach for such water supply.

4.5.7. Environmental flow requirement

Following the methodology mentioned in the chapter 3.4.1.6, the environmental flow has been estimated to 3,94 Mm^3 taking into account the mean annual flow of 39,40 Mm^3.

4.5.8. Evaluation of development scenarios

During the socio-economic survey, the local communities expressed the following point of view about the priorities water uses:

1) potable water supply
2) electricity
3) irrigation
4) aquaculture

The below table summarizes the merits and demerits of each water uses based on the above chapters. The main uses will be analysed.

Table 21: Evaluation of the water uses scenarios for Taba-Gakomeye site

Water uses	**Existing Use**	**Demand assessment**	**Feasibility of installation**
Water supply	**Medium**	**High**	**Medium**
Irrigation	**Medium**	**Medium**	**Low**
Livestock watering	**Low**	**Low**	**Low**
Aquaculture	**Medium**	**Medium**	**Medium**
Hydropower	**Low**	**Medium**	**Low**

Thus, livestock watering and hydropower seems to be the less relevant use to implement for this site.

4.5.9. Analysis of findings and selection of best development scenario for Taba-Gakomeye site

The water use review allows estimating the appropriate dam height to deliver the required water demand with an acceptable deficiency.

The following table gives the maximum water demand option excluding the urban towns such as Butare, Nyanza and Gikongoro towns with existing and/or already planned water supply system or technically too expensive due to the distance.

Table 22: Summary of water demand for Taba-Gakomeye site

Water Use Type	Water demand (m3/year)	
	2012	2037
Water supply demand	2 820 000	5 710 000
Irrigation water demand	294 400	390 400
Livestock water demand	410 000	510 000
Aquaculture demand	1 110 000	3 300 000
Environmental requirement	3 940 000	3 940 000
Total (m3/year)	**8 574 400**	**13 850 400**
Total (m3/s)	0,27	0,44

However, the natural guaranteed discharge of the Mwogo River is 0,79 m^3/s. It would be therefore possible to provide all the above mentioned water demand with the River without dam as the natural inflows is sufficient all the year to satisfy the maximum water demand.

For energy supply, the site would be not viable economically as mentioned due to the small discharge capacity.

It should be noticed as well that the potential irrigation area is limited due to the narrowness of the valley and the existing cultivated area.

The flood protection of the downstream areas will be as well studied during the design of the project.

As mentioned above, the development of multipurpose use for this River, meaning the aim of this project could be reached without dam. Thus, following the recommendation of the Consultant, the client has decided improving the irrigation perimeters with multiple dikes, developing fish ponds and upgrading the water supply for rural areas without building dam. It has then requested to study the flood protection of the downstream areas.

5. DETAILED DESCRIPTION OF THE PROPOSED DEVELOPMENT SCHEMES

5.1. Introduction

The most likely scenario is the development of multipurpose activities in the site valley without construction of dam. Thus, this scenario has been studied and detailed following the request of the client on the 6 August 2012.

5.2. Irrigation scheme

The first assessment was carried out for a project with dam as described in the chapter about the water demand (chapter 4.5.2). Thus, the first step will be to update this previous chapter by the findings without dam which increase the potential irrigation area.

5.2.1. Main outcomes for project without dam

Due to the narrowness of the valley, the potential command area for irrigation purpose is somewhat limited. The rough extent of this command area is about 204Ha as described below and reported on the Figure 30:

- “Area 110”, about 50 ha irrigable area,
- “Area 1”, around 83 ha down to the gorge that begins after the bridge on the main road, downstream the village of Karambi,
- Going downstream, the rivers flows in a 7 km long gorge along the main road then turns South and reaches a new swampy area (“Area 2”) of approximately 17 ha.
- Then it goes through a second gorge and flows through a new plain where 54 ha (“Area 3”) could be develop. Only the upstream section of this plain could be develop because of the existence of a diversion weir, built to supply area 4, already developed by a KFW funded project for a total of 178 ha. An extension is under construction down to the second bridge.
- Finally, the area far downstream the dam is developable for irrigation. The distance between this area and the dam will be around 40 km therefore several critical issues will have to be addressed prior to development:
    - Water release from the dam will have to be managed according to all downstream needs. No institution which can play that role is present for the time being.
    - It will be important to check if the River bed and the current uses (sand mining for instance) could be preserved with the new discharge to be conveyed through this section.

It shall be kept in mind that all this land is already grown. Thus, any improvement shall be previously discussed with the farmers.

Topographical data review

Switching from low accuracy 1/50 000° topographical map to high resolution LIDAR surveys associated with orthophotographs lead to review the controlled area as follows. To estimate the developed area, an assumption of 10% reduction between controlled area and net irrigated area was taken into account as follows.

Table 23: controlled area without dam project based on LiDAR data

Ha	Area 110	Area 1	Area 2	Area 3	Total
Bulk controlled area	49,5	82,7	17,0	54,3	203,5
Expected net irrigable area	44,55	74,43	15,3	48,87	183,15

Based on this total net area, the following water demand over the year has been estimated as follows. The results do not change the conclusions about the availability of water for all the uses.

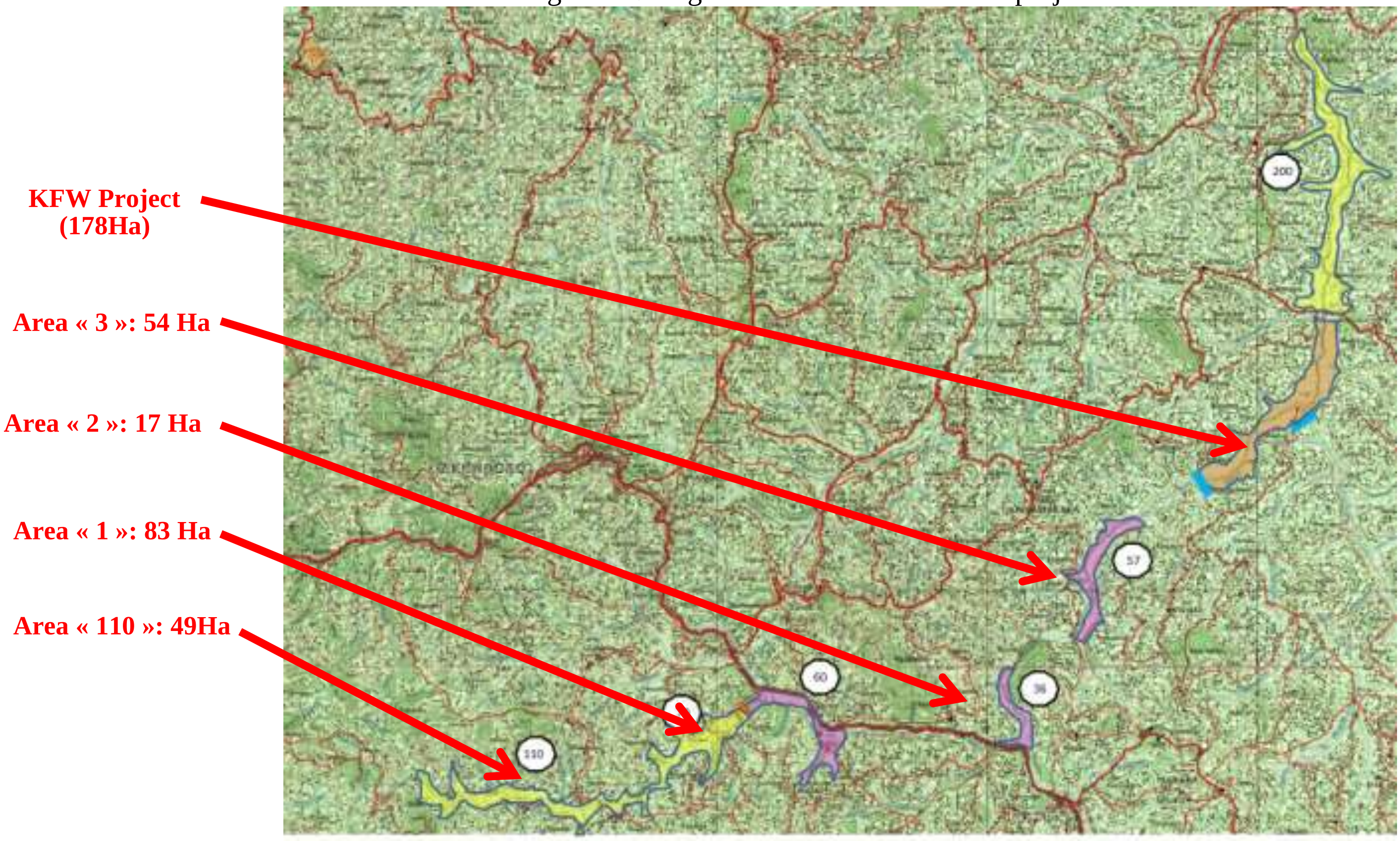
Table 24: Total yearly irrigation water consumption for the scheme

Irrigated area	Gross volume of water m^3 *	
Ha	Cropping pattern 1	Cropping pattern 2
183,15	581 501	586 080

* *taking into account the conveyance efficiency*

Without dam, the construction of several diversion structures across the Mwogo to supply water to main canals is becoming compulsory to (i) raise the elevation of water to allow the main canals to control the whole marshland area and (ii) create a buffer water body, so that irrigation could be run only 12 hours a day with a discharge superior to the available discharge of the river (using a night storage / daily release cycle).

Figure 30: Irrigation scheme without dam project



5.2.2. Design standards without dam project

Based on the findings in the chapter 4.5.9, the irrigation scheme without dam project was detailed as follows.

- **<u>Irrigation duty</u>**

As shown above, the first estimate of the irrigation duty gave a value of 1,5 l/s. This estimate has been calculating using the following assumptions:

- Vegetable + maize cropping on the whole area (no rice cropping)
- Irrigation time: 12 hours a day
- Overall efficiency (canals + on plot): 60%

This value has been kept at feasibility stage, because rice cultivation is not performed by farmers in all 4 areas planned to be developed.

- **<u>Diversion weir / water level control structure</u>**

<u>Hydraulic design</u>
The diversion weir will be designed for routing without damage or overtopping of earth sections a flood of 50 years return period. The weir will certainly operate downstream submerged for high floods, but at that early stage energy dissipation is calibrated to dissipate the energy of 50 years flood.

<u>Cross section</u>
Crest width will be 4 m for earth sections. Concrete sections will be 1,5 m wide as no road is planned to cross the river.

In the earth section, side slopes will be 1,5/1. Minimum freeboard will be 0,3 m. Compaction criteria will be 95% OPM except for fill around or under concrete structures, where it will be 98%.

Diversion structures for area “110”, 2 and 3 will consist in 4 sections, from right bank to left bank:

- Earth section with (if relevant) right bank canal intake (trashracks, upstream or central shaft, sliding gate, culvert);
- Security spillway, masonry made and including a downstream stilling basin made also of masonry;
- Desilting and/or drainage sliding gate;
- Earth section with (if relevant) left bank canal intake (trashracks, upstream or central shaft, sliding gate, culvert).

The diversion structure for area “1” will be built on a rock sill that provides enough head to control all the downstream area. Therefore its height will be reduced (only 30 cm) and its cross section small: it will be built with an upstream and downstream slope of 1/1 and a crest width of 30 cm, therefore a width of 90 cm at rock level.

Not all structures will have a left bank and right bank canal. In that case one intake will not be built.

Foundation is not known at this early stage, to be conservative a 1 m deep cut off trench has been taken into account in the design.

- **Canals**

Main canals

General arrangement / longitudinal slope
Main canals are designed for an irrigation duty of 1,5 l/s/ha, taking into account all losses and irrigation needs of the chosen cropping pattern. Longitudinal slopes will range between 1/1000 to 3/1000. For the flattest slopes construction will be challenging (only 50 cm difference in elevation for 500 m length) but compulsory to actually control the whole area.

Construction materials
Main canals will be built with selected materials, with some minimum requirements in terms of plasticity index and watertightness. These values should be given during final design.

Freeboard
Standard freeboard is taken equal to 0,3 m.

Standard section
In cut and fill

While building in cut and fill (ie. along a contour line), main canal will have the following features:

- Side slopes 1/1
- Crest width : 0,5 m upstream, 0,5 m downstream

In fill

While building in fill (ie. across a trough), main canal will have the following features:

- Side slopes 1/1
- Crest width : 0,5 m upstream, 0,5 m downstream

Secondary canals

General arrangement / longitudinal slope
Secondary canal are mainly built perpendicular to the river, to supply water to tertiary canals parallel to the general direction of the river. The longitudinal slope will follow the natural transverse slope of the marshland (1/1000 to 3/1000), except if water speed is too high. In that case, drop structures will be built. Secondary canals are designed to supply tertiary canals with a minimum 20 cm elevation difference in the worst case.

Construction materials
Construction materials will be built using materials locally extracted, especially from drains, to minimize transport and increase production. Hence, maintenance requirements and infiltration rate are likely to be higher. However, the short length of theses canals will keep the efficiency to acceptable values.

Freeboard
Standard freeboard is taken equal to 0,2 m.

Standard section
Fill and cut and fill sections will be similar.

- Side slopes 1/1
- Crest width : 0,3 m both banks

Tertiary canals

General arrangement / longitudinal slope
Tertiary canal are mainly built parallel to the general direction of the river. Others canal are built along contour lines, especially along the lateral troughs. The longitudinal slope will follow the natural long slope of the marshland (1/1000 to 2/1000), except if water speed is too high. In that case, drop structures will be built. Tertiary canals are built with a water level 30 cm above the natural ground, to allow for a headloss of 10 cm and a water level inside the basins of 20 cm.

Construction materials
Construction materials will be built using materials locally extracted, especially from drains, to minimize transport and increase production. Hence, maintenance requirements and infiltration rate are likely to be higher. However, the short length of theses canals will keep the efficiency to acceptable values.

Freeboard
Standard freeboard is taken equal to 0,2 m.

Standard section
Fill and cut and fill sections will be similar.

- Side slopes 1/1
- Crest width : 0,3 m both banks

- **Crossing structures**

Culverts or box culverts
These structures are used for road and drain crossings, the design is made according to pilot drawing in the Appendix D.

Siphons
Siphons are used to cross major lateral troughs, where the cost of construction of a canal is prohibitive because of its height above natural ground. They comprise one inlet shaft with silting facility and trashracks, a concrete pipe with eventually manholes every 100 m, an outlet shaft. In principle, the inside diameter is more than 800 mm to allow human visits for cleaning or maintenance purposes. Typical long section of a siphon is given in drawing in the Appendix D.

- **Control and security structures**

Security spillways
Security spillways are inserted at the end of canals and on the main canal, when the section is reduced. It consists in a surface weir and an evacuation canal to the nearest drain. It could be associated to a discharge limitation structure to limit the downstream discharge to the capacity of the reach.

Division boxes
Division boxes are used for regulating the discharge at secondary and tertiary canals intakes. A typical drawing described the structure in the Appendix D.

Drop structures
Drop structures are used to accommodate too high slopes on canals. In this project, they will mainly be used between main and secondary or tertiary canals, downstream the division boxes. Drop structures are described by typical drawing in the Appendix D.

5.2.3. Layout of the scheme

- **Main features of the perimeter**

The scheme (see Figure 30) will be divided in 4 areas, named upstream to downstream:
- Area 110
- Area n°1
- Area n°2
- Area n°3

All these areas are separated by gorges where irrigation is not possible. Hence, these areas will be developed separately.

- **Area 110**

Diversion weir will be a 27 m wide concrete and masonry weir, with a maximum 2 m height above the river bed. It will comprise a central sliding gate for desilting purposes and 2 lateral intakes for main canals. The choice of this section has been made because of its narrowness and its upstream position.

Off this structure, two main canals will flow on both banks. Right bank canal will have a length of approximately 1 600 m and a discharge of 11,6 l/s. Left bank canal will have a length of 3 370 m and a discharge of 62,6 l/s. Left bank canal will, through a siphon crossing the river (diameter 200 mm, length 131 m), supply water to the downstream section of the left bank canal which will have a length of 1 300 m and a discharge of 18,4 l/s.

As the perimeter is very narrow, the length of secondary canals will be short. They will be built perpendicular to the general direction of the valley.

Tertiary development includes tertiary canals and drains, basins terracing (form dykes and field ditches), as well as land levelling (+/- 10 cm). Elementary plots dimensions are taken equal to 25 m x 20 m for a hectareage of 0,05 ha. Typical arrangement of a block is given in drawing in the Appendix D.

Drainage system will consist in the remodelling of Mwogo River bed, so that it is possible to route a 10 years flow without submersion of plots for more than 3 days. A secondary and tertiary drainage system will be collecting water coming from the plots as well as the tributaries. 9 crossings will be built under the main canal to allow tributaries to flow in the Mwogo without damaging the canal.

The bulk controlled area will be 49,5 ha while the expected net irrigated area is expected to be 44,6 ha.

- **Area 1**

Diversion weir will be a 10 m wide concrete and masonry weir, with a maximum 0,3 m height above the river bed. The choice of this section has been made because of its narrowness, the presence of a rock sill and its upstream position. One lateral intake is planned on left bank, with a 70 m long spillway, then a silting basin, a discharge control structure and the main canal.

Due to the narrowness of the valley, it is intended to build only one main canal. It will have a length of approximately 8 400 m and a discharge of 124 l/s. 3 siphons, diameters ranging from 150 mm to 300 mm for a total length of 424 m will be built to cross the valley. Only one bank of the valley will be developed except on the downstream section, where both banks can be developed.

As the perimeter is very narrow, the length of secondary canals will be short. They will be built perpendicular to the general direction of the valley.

Tertiary development includes tertiary canals and drains, basins terracing (form dykes and field ditches), as well as land levelling (+/- 10 cm). Elementary plots dimensions are taken equal to 25 m x 20 m for a hectareage of 0,05 ha. Typical arrangement of a block is given in drawing in the Appendix D.

Drainage system will consist in the remodelling of Mwogo river bed, so that it is possible to route a 10 years flow without submersion of plots for more than 3 days. A secondary and tertiary drainage system will be collecting water coming from the plots as well as the tributaries. 10 crossings will be built under the main canal to allow tributaries to flow in the Mwogo without damaging the canal.

The bulk controlled area will be 82,7 ha while the expected net irrigated area is expected to be 74,4 ha.

- **Area 2**

Diversion weir will be a 24 m wide concrete and masonry weir, with a maximum 2,6 m height above the river bed. The choice of this section has been made because of its narrowness and its upstream position. One lateral intake is planned on right bank, with a control gate, then a stilling basin and the main canal. It is necessary to build the weir upstream the main road, hence a culvert will be necessary to cross the road

Due to the narrowness of the valley, it is intended to build only one main canal. It will have a length of approximately 2 800 m and a discharge of 25,5 l/s. 4 siphons, diameter ranging from 200 mm to 80 mm for a total length of 358 m will be built to cross the valley. Only one bank of the valley will be developed.

As the perimeter is very narrow, the length of secondary canals will be short. They will be built perpendicular to the general direction of the valley.

Tertiary development includes tertiary canals and drains, basins terracing (form dykes and field ditches), as well as land levelling (+/- 10 cm). Elementary plots dimensions are taken equal to 25 m x 20 m for a hectareage of 0,05 ha. Typical arrangement of a block is given in drawing in the appendix D.

Drainage system will consist in the remodelling of Mwogo river bed, so that it is possible to route a 10 years flow without submersion of plots for more than 3 days. A secondary and tertiary drainage system will be collecting water coming from the plots as well as the tributaries. 7 crossings will be built under the main canal to allow tributaries to flow in the Mwogo without damaging the canal.

The bulk controlled area will be 17 ha while the expected net irrigated area is expected to be 15,3 ha.

- **Area 3**

Diversion weir will be a 50 m wide concrete and masonry weir, with a maximum 3,6 m height above the river bed. The choice of this section has been made because it's the end of the upstream gorge. Two lateral intakes are planned, with a control gate, then a stilling basin and the main canal.

Left bank canal will have a length of approximately 685 m and a discharge of 8,5 l/s.

Right bank canal will be the main canal: the first reach will have a length of approximately 1440 m and a discharge of 72,9 l/s. 1 siphon, diameter 300 mm length of 141 m will be built to cross the valley. Then, the main canal will continue with a second reach of left bank (length approximately 830 m). A second siphon will cross the valley back to the right bank, to a third reach of the main canal (length approximately 945 m). Then, one last siphon will cross the valley to the left bank while another canal is built on the right bank to develop both sides of the river.

As the perimeter is very narrow, the length of secondary canals will be short. They will be built perpendicular to the general direction of the valley.

Tertiary development includes tertiary canals and drains, basins terracing (form dykes and field ditches), as well as land levelling (+/- 10 cm). Elementary plots dimensions are taken equal to 25 m x 20 m for a hectareage of 0,05 ha. Typical arrangement of a block is given in drawing in the Appendix D.

Drainage system will consist in the remodelling of Mwogo river bed, so that it is possible to route a 10 years flow without submersion of plots for more than 3 days. A secondary and tertiary drainage system will be collecting water coming from the plots as well as the tributaries. 24 crossings will be built under the main canal to allow tributaries to flow in the Mwogo without damaging the canal.

The bulk controlled area will be 54,3 ha while the expected net irrigated area is expected to be 48,9 ha.

5.2.4. Flood protection

In order to take into account the flood protection of the downstream area, the irrigation scheme has been designed as follows:

- Hydraulic design: The diversion weir is designed for routing without damage or overtopping of earth sections a flood of 50 years return period. The weir will certainly operate downstream submerged for high floods, but at that early stage energy dissipation is calibrated to dissipate the energy of 50 years flood. In the first area, named “110”, diversion weir will be a 27 m wide concrete and masonry weir, with a maximum 2 m height above the river bed. It will comprise a central sliding gate for desilting purposes and 2 lateral intakes for main canals. The choice of this section has been made because of its narrowness and its upstream position.
- Drainage system consists in the remodelling of Mwogo River bed, so that it is possible to route a 10 years flow without submersion of plots for more than 3 days. A secondary and tertiary drainage system collects water coming from the plots as well as the tributaries.
- Security spillways: Security spillways are inserted at the end of canals and on the main canal, when the section is reduced. It consists in a surface weir and an evacuation canal to the nearest drain. It could be associated to a discharge limitation structure to limit the downstream discharge to the capacity of the reach.
- Drop structures: Drop structures are used to accommodate too high slopes on canals. In this project, they will mainly be used between main and secondary or tertiary canals, downstream the division boxes

5.2.5. Cost estimate

Without the dam, the irrigation concerns 183 Ha (net area), and the associated costs are evaluate to US $ 5 534 000

The proposed BOQ is presented hereafter.

Items	Unit	Quantity	Unit Price US $	Total Cost
Preliminary and general items (15% of total cost)				
Miscellaneous	15%	1	721 826	721 826
Sub total				**721 826**
Canals & drains (main - primary - secondary)				
Clearing and grubbing area of works	m^2	172 000	3,8	661 512
Common excavation in canal and form compacted embankments (OPM 95%)	m^3	96 000	17,0	1 632 000
Formwork rough face	m^2	2 300	16,0	36 800
Class C25/C30 concrete for reinforced concrete - supply and placement	m^3	206	450	92 700
Reinforcement	T	19	3 000	55 500
Concrete pipe DN 300	ml	350	150	52 500
Concrete culverts DN 400	ml	323	90	29 070
Miscellaneous	15%	1	384 012	384 012
Sub total				**2 944 094**
Tertiary development				
Form tertiary canals and drains	m^3	14 100	10	141 000
Land levelling +/- 10 cm without topspoil removing	ha	187	5 000	935 000
Land levelling +/- 10 cm with topspoil removing	ha	0	15 000	0
Miscellaneous	15%	1	161 400	161 400
Sub total				**1 237 400**
Diversion weir				
Clearing and grubbing	m^2	3 850	3,8	14 807
Excavation in loose material	m^3	2 150	5	10 750
Class C20 mass concrete - supply and placement	m^3	810	425	344 250
Class C25/C30 concrete for reinforced concrete - supply and placement	m^3	176	450	79 200
Reinforcement	T	17	3 000	49 500
Backfill homegeneous material (sandy clay) using excavated	m^3	1 940	8	15 520
Backfill Transition/Filter	m^3	190	100	19 000
Rip Rap	m^3	95	162	15 390
Miscellaneous	15%	1	82 263	82 263
Sub total				**630 680**
			Total	**5 534 000**

For each perimeter, the unit cost has been estimated as follows.

Table 25: Unit costs for each perimeter

Area	Unit cost of development ($/ha)
110	25 200
1	19 700
2	43 800
3	29 800

The range of costs is high. It should be noticed that area “2” development is very expensive due to its small area and the weight of all headworks (weir + aqueduct under the road).

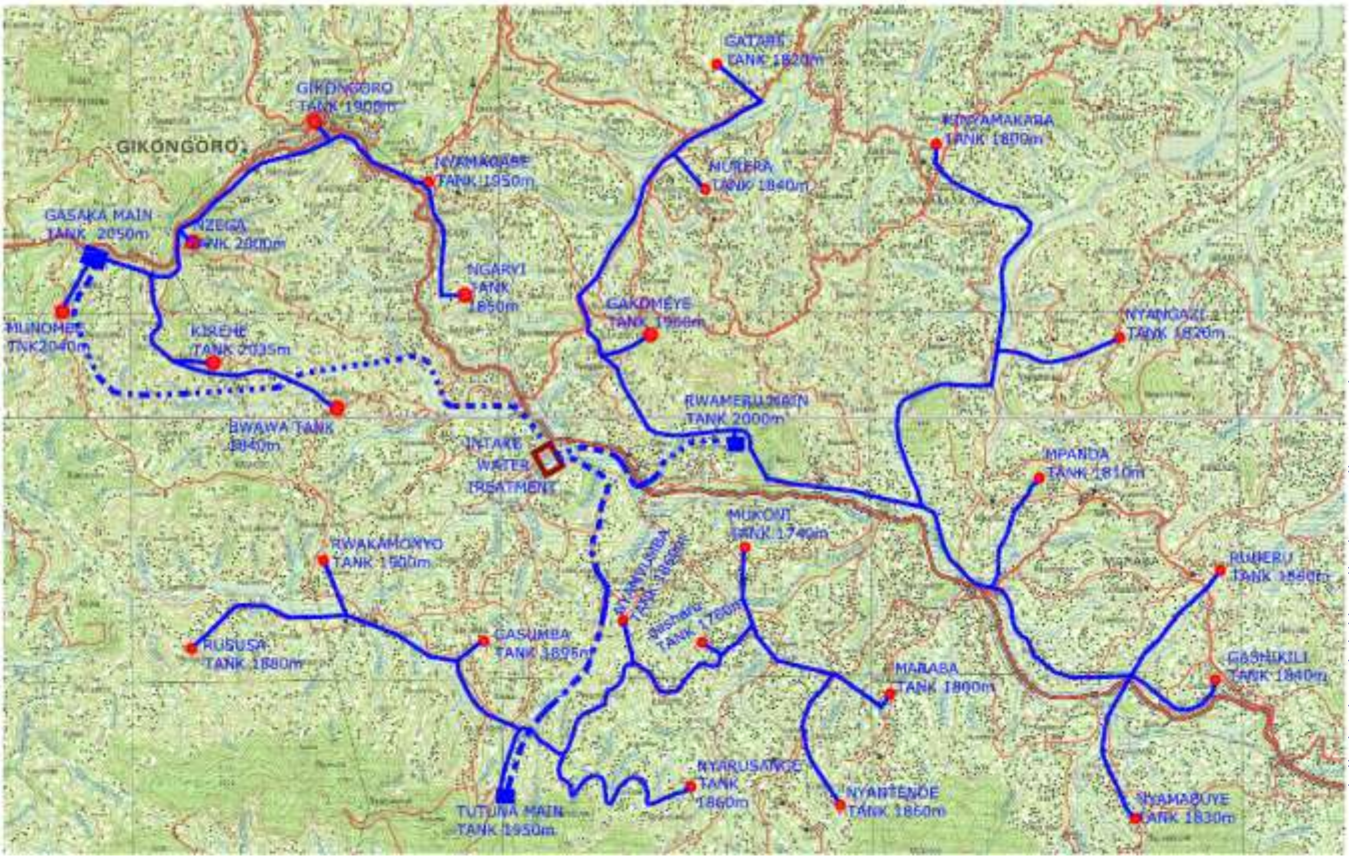
With dam, the cost of the irrigated scheme could be estimated to about 3 million US$ for around 100Ha as net irrigable area.

5.3. Water supply scheme

5.3.1. Layout of the scheme

The scheme for the development of the water supply has been designed as follows following the findings and the recommendations of the client. Details designs should be carried out at later stage during the detailed design.

Figure 31: water supply scheme



5.3.2. Design of the water supply

The proposed scheme as shown above covers the following districts and sectors:

- Nyamagabe District [Kamugeri, Gasaka, Tare Sectors]
- Nyaruguru District [Mata, Ruramba Sectors]
- Huye District [Maraba, Kigoma, Simbi Sectors]

The water supply project includes the following equipment:

- Intake on Mwogo River with a capacity of 0.19 m^3/s in Phase I,
- Water treatment plant with a total capacity of 16,000 m^3/d in Phase I,
- Low lift pumps – 0.19 m3/s, 5 pumps (each Q – 0.045 m^3/s, H – 15m and Power 10 Kw – 4 in duty and 1 in standby) in Phase I,
- High lift pumps following three stations (the static heads are too high. As the flows are small, no booster pumps are proposed along the transmission mains)

- Gasaka Pump Stations (for Nyamagabe) – (0.04 m^3/s capacity) at River level 1630 masl with 3 pumps (each Q – 0.02 m^3/s, H – 500m and Power 150 Kw – 2 in duty and 1 in standby);
- Rutuna Pump Stations (for Nyaruguru) – (0.06 m3/s capacity) at River level 1630 masl, second to have 3 pumps (each Q – 0.03 m^3/s, H – 340m and Power 155 Kw – 2 in duty and 1 in standby);
- Ramweru Pump Stations (for Gakomeye Huye) – (0.08 m^3/s capacity) at River level 1630 masl – station to have 3 pumps (each Q – 0.04 m^3/s, H – 380m and Power 230 Kw – 2 duty and 1 standby).

- Transmission mains – three sets as follows :
  - Gasaka Transmission Main: 250 mm and length 9 km to Gasaka Main Tank 2050 masl
  - Rutuna Transmission Main: 300 mm and length 6 km to Rutuna Main Tank 1950 masl
  - Ramweru Transmission Main: 350 mm and 4 km to Ramweru Main Tank 1920 masl
- Main Storage tank – 3 tanks r.c concrete tanks (Gasaka 700 m^3, Rutuna 1,000 m^3, Ramweru 1,400 m^3)
- Distribution - Gravity mains from main tanks to village tanks

Pipe diameter (mm)	Length (m)
100	29,550
150	17,600
175	0
200	12,900
250	13,200
300	1,000
350	200
Total	74,450

- Villages storage tanks are elevated masonry tanks comprising as follows
  - 180 m3: 7
  - 200 m3: 9
  - 270 m3: 9
- Secondary & tertiary mains:

Pipe diameter (mm)	Length (km)
50	24
75	16
90	16
150	8
Total	64

- Meters and communal kiosks
  - Zonal meter: 31
  - Domestic meters: 800
  - Communal kiosks:720
- Electrical Transmission
  - transmission cable: 5 km
  - sub-station with transformers: 1 set

As the project is small, it could be implemented in one phase.

5.3.3. Cost estimate for the water supply

The total investment costs for water supply have been evaluated as US $ 21 930 000 as described in the following table.

Table 26: costs estimate for water supply

	Components	NYAMAGABE	NYAMAGABE HUYE	NYAMAGABE NYARUGURU	TOTAL
A	Water Treatment	794,400	1,986,000	1,191,600	3,972,000
B	Pumping Stations	388,500	562,100	365,750	1,316,350
C	Transmission Mains	1,863,000	1,176,000	1,494,000	4,533,000
D	Storage Tanks	722,000	1,000,000	1,324,000	3,046,000
E	Gravity Transfer Mains	946,500	2,402,400	1,474,400	4,823,300
F	Secondary & Tertiary Distribution Mains	1,824,000	0	0	1,824,000
G	Meters and Communal Kiosks	497,500	726,000	959,000	2,182,500
H	Power to WTW and PS	229,500	0	0	229,500
	TOTAL	**7,265,400**	**7,852,500**	**6,808,750**	**21,926,650**

5.4. Livestock water points

5.4.1. Design for the livestock water points

The water supply scheme as presented in the above chapter will be used to provide water for livestock.

The design has taken into consideration the water demand for livestock as estimated in the chapter 3.4.1.3, meaning an annual demand of 410 000m^3 for 2012 with an increase to 510 000m^3 in 2037.

5.4.2. Cost estimate for the livestock water points

The cost of such supply has been removed to include the water demand in the water supply system as Rwanda has a zero grazing policy and as the public watering of livestock is discouraged.

5.5. Fish farming

5.5.1. Design for fish farming

The communities have already some fish ponds. Thus, pilot projects will not be necessary. The fish ponds could be implemented in two phases.

The number of the required ponds was based on the population density which is about 470 persons per km^2 and could increase to 850 persons/km^2 in year 2037.

The following table gives two options of ponds, subsistence or commercial fish farming.

Table 27: Estimated number of fish ponds

	2012		2037	
	subsistence 2 km radius 2t/Ha/year size 0.04Ha	**commercial 4 km radius 3 t/Ha/year size 0.4 Ha**	**subsistence 2 km radius 2t/Ha/year size 0.04Ha**	**commercial 4 km radius 3 t/Ha/year size 0.4 Ha**
population density	364	364	727	727
Population	4,575	18,299	9,137	36,548
fish consumption kg @ 1kg/person/year	4,575	18,299	9,137	36,548
Pond Area Ha	2.29	6.10	4.57	12.18
Numbers of ponds	57	nil	114	30

However, about 27 locations have been identified as shown on the maps in the Appendix F. The required gross area for the ponds may be 2 to 3 times the net pond area. The main irrigation canals would have outlets in the opposite side (away from irrigation) for filling up the fish ponds. The fish ponds are located in areas without use for irrigation.

The ponds are made with earthwork of cut which are used to form the dykes. The ponds do not exceed one meter deep. Each subsistence pond is 15m x 30m in plan size while the commercial pond is about 45m x 90m depending on space available. Lime is added at the bottom to neutralize the acidic soils.

Feed for fish include cattle manure, vegetables or fish feed made of cotton seed cake, wheat bran, rice bran and shrimps. Fertilizers such as urea and di-ammonium phosphates could be added every week.

The species of fish could be sardine type (dagaa), fillet stripped, tilapia, catfish, Nile perch, and trout. The average fish yields for tilapia could reach 5 – 8 tons/Ha/year while for catfish 15 – 20 tons/Ha/year.

5.5.2. Cost estimate for fish farming

The estimated cost is about US $ 48 000 for each small pond (0,04 Ha) as described in the Appendix L. The total cost for 27 ponds (1,08Ha) would be about US$ 1 210 000 as described in the following table.

Table 28: Costs for fish ponds project

Fish Farm	**Rate US $**	**Phase I**	
		Quantityty	**Amount US $**
Small Ponds	44 811	27	1 209 897

6. DETAILED DESIGN AND COSTING FOR DAM

6.1.1. Introduction

This chapter presents the operational characteristics of Taba Gakomeye dam based on the description in the terms of reference. However, it should be kept in mind that all the water demand could be kept without building a dam.

The main dam characteristic is as follows and the drawings in the Appendix E:

Table 29: Main characteristics of Taba Gakomeye dam

TABA GAKOMEYE	***Dam design***
Dam height (m)	**14,00**
Storage capacity at FWL (Mm^3)	**3,09**
Crest Width (m)	**6,00**
Dam crest Length (m)	**265,00**
Reservoir Width maximum (km)	**0,8**
Reservoir Lenght maximum (km)	**2,2**
Full Supply Level (m)	**1644,00**
Maximum Water Level (m)	**1645,10**
Reservoir surface area at FSL (km^2)	**0,6**

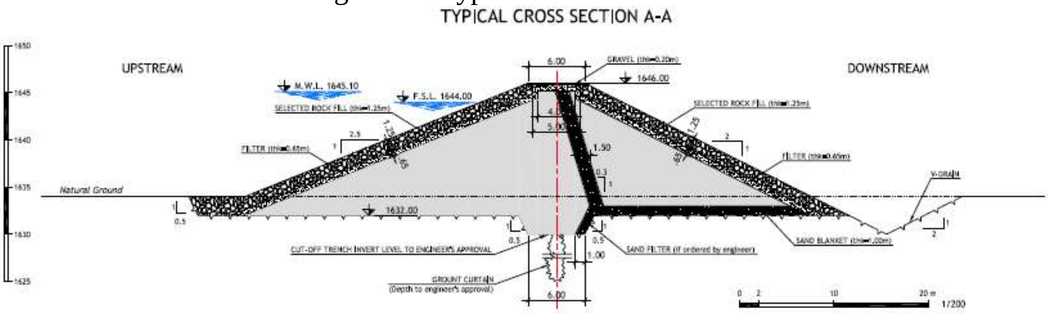
6.1.2. Detailed design of the dam

6.1.2.1. TYPICAL CROSS SECTION

The cross section of the dam consists of homogeneous earthfill material protected by a layer of filter material which in turn is protected by 1.25m thick riprap on both upstream and downstream faces. An internal filter zone accepts seepage flows from fill materials without the build-up of excess hydrostatic pressure.

The crest width is 6m, the upstream slope is 2.5H:1V, and the downstream slope is 2H:1V.

Figure 32: Typical cross section of the dam



6.1.2.2. FOUNDATION DESIGN

The dam footprint is stripped of all grass, trees, excessively plastic soil and any deleterious material. Thereafter the cut-off trench is excavated to a minimum depth of 3 m or to groutable rock foundation.

Although the maximum head of water at full supply level is only 10,0 m, this head of water is capable of causing piping problems within a short space of time, hence the relatively deep cut-off which will lengthen the seepage path.

Badly broken areas on the downstream side of the cut-off-trench are covered with a 500mm thick sand filter to prevent the migration of fine particles under seepage forces. Areas which have negative slopes on the sides of the cut-off trench are treated with masonry. Shotcrete, dental concrete and slush grout is applied where necessary.

Grouting is undertaken to a maximum depth of 10m. The grouting procedure follows the “stage grout split spacing method” with primary holes at 12m centres, secondary holes at 12m centres and tertiary holes at 6m centres. All primary holes are drilled to a depth of 12m and all other holes will be drilled to 6m. Control holes are drilled to depths up to 18m to check on effectiveness of grouting.

6.1.2.3. INSTRUMENTATION

Instrumentation on the dam is in the form of settlement studs, which will be positioned along the downstream edge of the embankment crest at 50m intervals.

There is a V-drain running along the downstream toe of the dam. Seepage water accumulating in the drain is measured by 3 V-notches. The two first are in the toe drain while the third one is in the exit channel leading to a suitable discharge point.

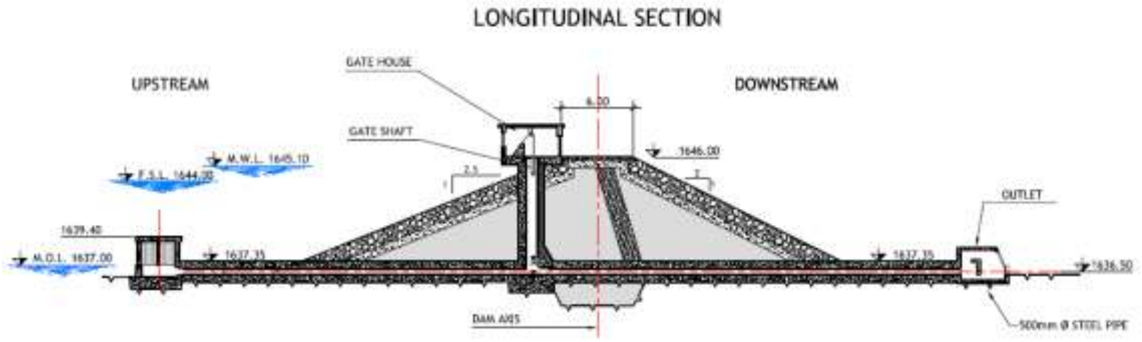
6.1.2.4. OUTLET WORKS

Description

The outlet works at each dam comprise:

- Intake trash screen
- Upstream pressure conduit
- Gate shaft and gate house
- Downstream pressure conduit
- Stilling basin

Figure 33: Example of longitudinal section for the outlet structure



Intake and trash screen

The bottom of the intake and trash screen is at the minimum operation level (MOL) of each reservoir. The intake is 2,8m square in plan with the trash racks axes positioned on a 3,30m square.

The trash screen consists of 2m long 110mm outside diameter PVC pipes filled with reinforced concrete placed at 292mm centres. There are eight 300mm-diameter reinforced concrete columns supporting the concrete bulkhead which will be on top of the trash rack pipes. A bay of removable trash rack pipes is provided to facilitate entry into the intake should the need arise. These removable racks are provided with lifting lugs to facilitate removal from their position.

The clear spacing between the trash rack pipes is 182 mm and there are 40 of these spaces giving net area of flow of 14.56 m2. The velocity through the trash screen is 0.2 m/s. Assuming a 50% clogging of the trash screen, the velocity through it for the peak discharge would be 0,4 m/s, quite below the limiting velocities between 0.9 m/s and 1.22 m/s (Ref. Advanced Dam Engineering, page 689).

The velocity inside the intake is about 0,5 m/s.

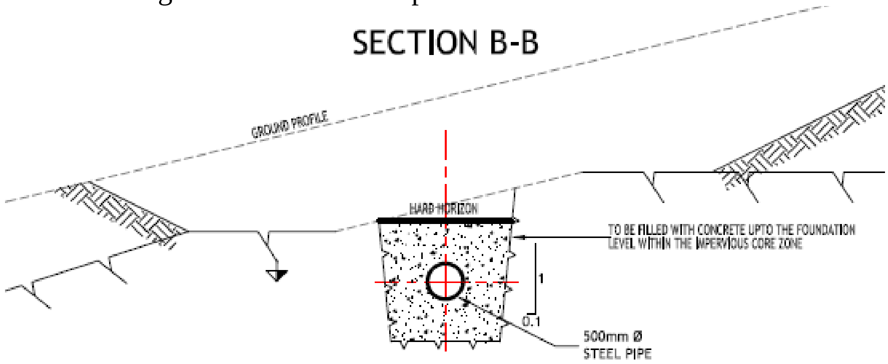
Figure 34: Example of similar intake (Swaziland)

As the ratio of storage capacity to mean annual inflows is very low (8%), the site is rather exposed to siltation. In case of confirmation of the study’s results, siltation may represent a real problem for the intake structure. In this case, it must be previewed a plan of regular dragging, estimated in once per five years.

Upstream conduit

The upstream conduit consists of a steel pipe encased in reinforced concrete, founded on rock throughout. The upstream end will be slightly flared to reduce entry losses. The conduit will discharge water into the gate shaft positioned 5,5m upstream of the dam axis.

Figure 35: Illustrative upstream conduit cross-section

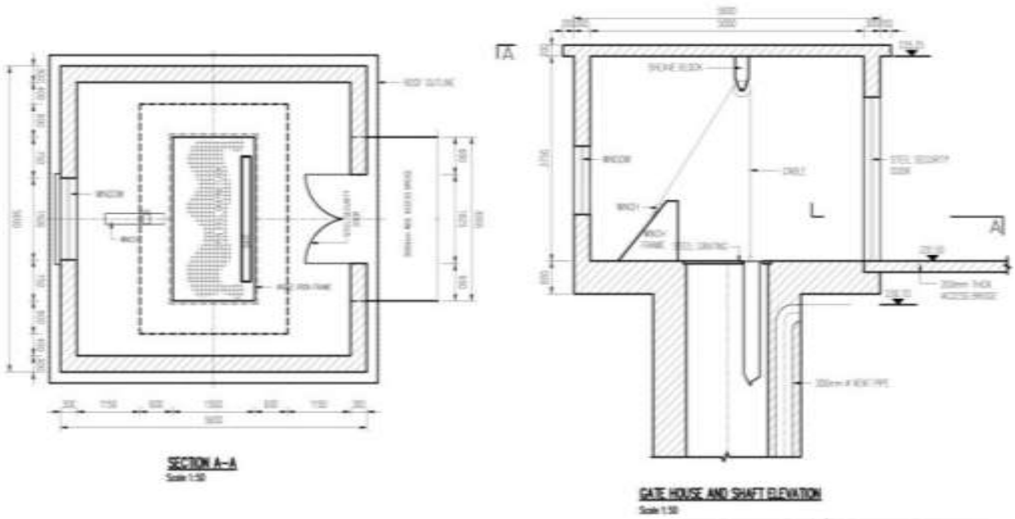


Gate shaft and gate house

The gate shaft is 3m by 2m with 600mm thick reinforced concrete walls. The service gate to close the downstream conduit is lowered through the gate shaft.

The service gate house is on top of the gate shaft with a floor level equal to the settled crest level of the embankment. The gate house is 5m in diameter and 2.5m high with a 200mm thick reinforced concrete roof. The gate house walls are 300mm thick. The gate house contains the steel service gate which is suspended at the floor level from a winch system and two supports.

Figure 36: Illustrative gate chamber details



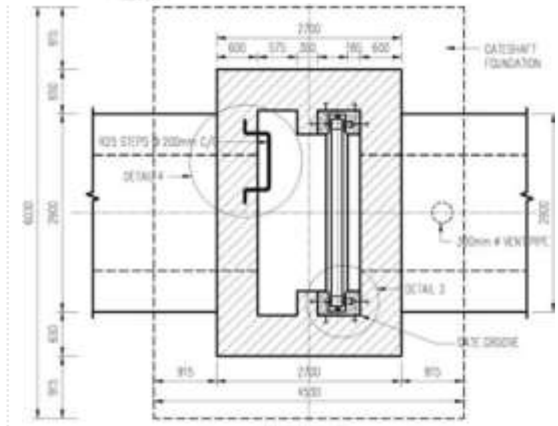
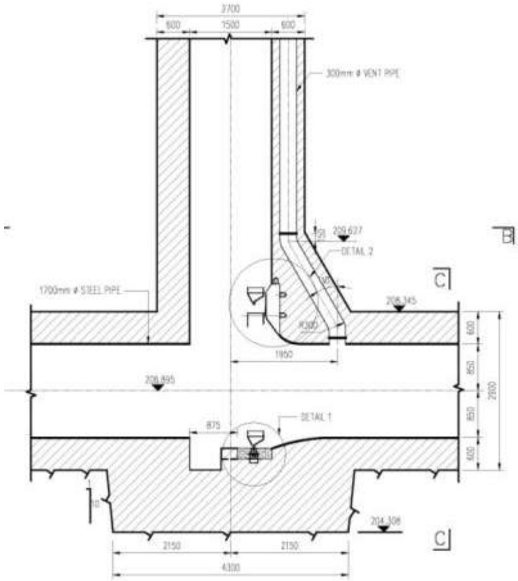


Figure 37: Illustrative gate shaft details

Downstream pressure conduit

The downstream pressure conduit starts at the gate shaft. The upstream end is bellmouthed to provide good entry conditions. There is a striker plate below the bellmouth where the gate rests when lowered down. The gate is on-seating, i.e. kept in place by the water pressure.

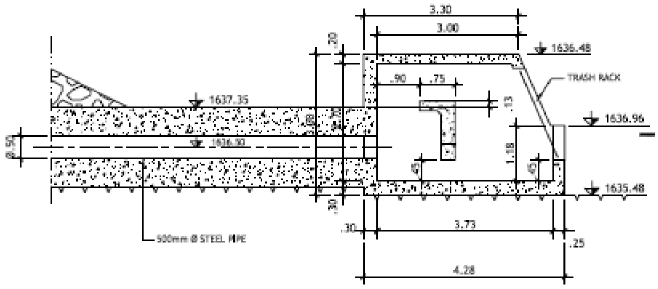
Figure 38: Illustrative bottom of the gate shaft



The pressure conduit is encased in 600mm thick reinforced concrete which is cast in a purpose made trench, excavated into rock.

Stilling Basin

The pipe discharges into a stilling basin. The water jet hits a baffle wall. The energy is dissipated in the stilling basin before its restitution to downstream. Trashrack is placed at the far end of the stilling basin in order to achieve the dissipation and to protect the structure against human aggression.



6.1.3. Dam cost estimation

The costs presented hereafter are the average of several prices applied in works done in different African countries. It was privileged to consider projects which present similar geographical conditions.

As the quantities are small for this type of work, the cost of provision of machinery may represent a significant portion of the total cost and is not included in this analysis.

A summary is presented in the following table (in US$):

Table 30: Cost of the dam

Components	Cost US $
Preliminary & General	1 294 000
Dam	7 591 000
Spillway	1 053 000
Bottom Outlet	135 000
HSS Equipment	81 000
Total	**10 154 000**

On this total should be added the total cost of the environmental and social management plan (ESMP) and the resettlement action plan (RAP) that has been estimated by the ESIA carried out by Newplan in parallel of this study as 1 454 000 US$, meaning around 14% of the total cost of the dam.

6.1.4. Development schemes with Taba-Gakomeye dam

Taking into consideration the detailed description in the previous chapter 1, the main change will concern the irrigation scheme. With dam project, the upstream area (area “110” and half of the area “1”) should be removed from the total irrigated area leading to a total net irrigation area of around 100 Ha, divided in 3 different areas as shown in the Figure 26. Irrigation scheme as presented should be adapted to the dam option.

7. INITIAL ENVIRONMENTAL AND SOCIAL EXAMINATION FOR TABA-GAKOMEYE SITE

7.1. National legislative and institutional framework

7.1.1. Environment

Institutional context in Rwanda

The Ministry of Natural Resources (MINIRENA or MINELA) is in charge of environmental issues as well as land management and water resources. Within MINIRENA, two agencies deal with environmental issues:

- The Rwanda Environment Management Agency (REMA), which is mandated to facilitate coordination and oversight of the implementation of national environmental policy and the subsequent legislation.
- The Rwanda Natural Resources Authority is an authority that heads the management of promotion of natural resources composed of land, water, forests, mines and geology. It is entrusted with supervision, monitoring and to ensure the implementation of all issues relating to promotion and protection of natural resources.

It is important to notice that the Community Development Committees are currently key committees to implement environment management plans.

Legislative context in Rwanda

The legislative framework is defined by:

- The Constitution of Rwanda, 2003, which ensures the protection and sustainable management of environment and encourages rational use of natural resources;
- The National Policy on Environment, 2003;
- The Organic Law n°04/2005 of 08/04/2005, which determines the modalities of protection, conservation and promotion of environment in Rwanda.

Regulations regarding environmental impact studies in Rwanda

According to the National Policy on Environment 2003 and the Organic Law n°04/2005 (articles 67 & 69), EIAs must be carried out prior to development of infrastructures projects and REMA has to implement this policy.

EIAs guidelines were issued in 2006 by REMA: “General Guidelines and Procedure for Environmental Impact Assessment”, which detail EIA’s process and the role of the different stakeholders.

7.1.2. Water management

7.1.2.1. INSTITUTIONAL CONTEXT IN RWANDA

The following ministries are in charge of water resources management at different levels:

- The Ministry of Infrastructures (MININFRA) is in charge of the water and sanitation sector. Under MININFRA, the Minister of State in charge of Energy and Water is responsible for development and maintenance of infrastructure for water supply and sanitation.
- The Ministry of Natural Resources (MINIRENA or MINELA) is in charge of designing policies concerning, inter alia, water resources management and protection. It also follows up water distribution programs and promotes incentives to fund water resources development projects.
- The Ministry of Agriculture and Animal Resources (MINAGRI) is responsible for the rational use of water potential for agricultural purposes. The Government of Rwanda created in 2010 a Task Force on Irrigation and Mechanization, which should "oversee, and implement where necessary, all irrigation and marshland development programs in Rwanda."

7.1.2.2. LEGISLATIVE CONTEXT IN RWANDA

The following laws should be taken into account about the water resources management:

- The "Water law, 2008": the Organic law n° 62/2008 of 10/09/2008 put in place the use, conservation, protection and management of water resources regulations. It details the institutional framework, the regimes of water and concessions systems, sanitation of water use for domestic purposes and animals.
- The Organic Law n°04/2005 of 08/04/2005 describes environment as a whole, but it provides specific measures to protect watersheds in order to prevent wetland deterioration.
- The Sectorial Policy on Water and Sanitation, 2004 states objectives, inter alia, to improve access to safe drinking water, access to water for agricultural source and the use of water as energy source.

7.1.3. Land tenure management

a) Legislative and institutional context in Rwanda

MINIRENA is the ministry in charge of managing land administration and maintaining land records.

The National Land Center is a center under the Rwanda Natural Resources Authority, which is under MINIRENA. The National Land Center of the Register of Land Titles implements the National Land Tenure Reform Program as provided for by the National Land Policy and the Organic Law determining the use and management of land in Rwanda. This program "aimed at improving land tenure security by putting in place an efficient, transparent and equitable system of land administration".

Under the National Land Center, the National Land Commission is in charge of “monitoring and approving of expropriation of land repossessed in public interest to accommodate activities with a national character”.

b) Regulations regarding land tenure in Rwanda

The regulations regarding land tenure in Rwanda are defined by the following texts:

- The 2003 Rwanda Constitution: The Article 29 grants every person the right to property, and stipulates that the right to property may be overruled in the case of public interest
- The 2005 Organic Land Law (n°08/2005): determines the use and management of land in Rwanda.
- The National Land Policy, 2004: considers the system of land administration.
- The Statutory Land Laws (draft 2004): legalize customary land tenure system. In Southern areas of Rwanda, according to the Igikingi system, land was distributed by the Mwami or his chiefs, on the approval of the Mwami to individuals commanding respect in society. The holders of Igikingi had full control over the land and could allot plots to others to cultivate them.
- The Expropriation law (Law N° 18/2007 of 19/04/2007 relating to expropriation in the public interest): requires prior consultative meetings and examination of the project proposal involving expropriation, with a view to avoid eventual prejudice on the person or entity subject to expropriation.
- The Valuation Law 2007: stipulates valuation methods to be applied to those assets expropriated.

Land ownership is divided into two categories:

- Individual owned land acquired through custom, written law, acquisition from competent authorities, purchase, gift, exchange and sharing;
- State lands which are categorized into two sub-categories: public domains and private State owned lands. It is to be mentioned that state land for public domain comprises land reserved for public use, for use by organs of state services or for environmental protection.

7.2. Preliminary description of existing environmental and socio-economic conditions

7.2.1. Physical environment

a) Climate

Rwanda has a temperate tropical highland climate, with lower temperatures that is typical for equatorial countries due to the high elevation.

The average rainfall at the dam site is 1440 mm.

b) Hydrology

This part is included in the hydrology report (see chapter 4.2). It is noted that the annual sedimentation rate is quite important and the site is rather exposed to siltation.

c) Ground water

According to Dr. Mkhandi S.H. [a], exploitation of groundwater dates back to 1955-1959 in Rwanda. Nevertheless, there is no formalized groundwater monitoring in the country.

d) Water quality

According to Dr. Mkhandi S.H. report [a], apart from specific water quality analyses, there is no system for collection, checking and archiving water quality information in Rwanda in general and Kagera River Basin in particular. Based on the results obtained from the rapid water quality assessment carried out in Rwanda, Dr. Mkhandi S.H. [a] concluded that there was no evidence of degradation in the surface water resources on the Rwandan side of Kagera River Basin.

According to the Rwandan Irrigation Master Plan (MINAGRI [d]), 3% of river waters are heavily polluted by nitrates, 44% by bacteriological pollutants (mostly faecal).

However, due to the lack of information about Mwogo River, it is recommended to carry out a water quality survey on this River during the ESIA as water quality determination is an important element towards an understanding of River ecosystem health.

e) Geology

Rwanda’s soils are a result of the physical and chemical alteration of schistose, quartzite, gneiss, granite, and volcanic rocks which form the surface geology of the country.

Following the site visit, at the dam site, the rocks are outcropping in the river bed in some places. It is weathered and fractured gneiss with a lot of black micas. The sediments could be gravels and sands. Some borrow areas exist along the river for white sands. On the two banks, the soil is made with lateritic clay and sandy gravels. In the valley, the soils are sandy or clayey.

f) Earthquake

Rwanda is located in a tectonic region whose epicentre is located in Lake Kivu. The northwest part of the country is occupied by a volcanic chain that a seismically active. This location makes Rwanda, especially the western region, susceptible to earthquake. However, the Project is located in the Southern part of Rwanda.

7.2.2. Biological environment

a) Flora and fauna

The major part of the Southern Province is made up of forests which occupy an area of more than 404 km ^{2}. However, the project site is located in an agriculture area, with mainly savannah around.

The presence of wetlands near the Project site should be considered during the ESIA.

The water hyacinth plant (Eichhornia crassipes) is the world's worst aquatic weed species. It was officially recognized in the Kagera River in Rwanda in 1991. The major problems associated with water hyacinth is that it forms a dense mat of enlarged plants which impede light penetration to the water below and thus affects growth of other aquatic plants. The decaying water hyacinth plants tend to reduce oxygen for other aquatic flora and fauna, hence contribute to loss of biodiversity. The presence of a dense mat of water hyacinth also leads to increased evapotranspiration.

b) Protected area

The Akagera National Park (85 000 ha) is located in eastern Rwanda along the Tanzania border in the Kagera River Basin. The northern portion of the park is sharing border with Ibanda Game Reserve, which is in the Tanzania side. The Park contains Lakes Rwanyikizinga, Mihindi, Hago, Kiyumbo and most parts of Lake Ihema. The National Park is also important for supporting unique biodiversity in the area. However, the National Park has been reduced to one third of its original size [b]. (See Appendix A – Map MA04)

Nyamagabe district contains the eastern half of Nyungwe Forest, being one of the last remaining forest areas of Rwanda and home to chimpanzees and many other species of primate. The Nyungwe National Park (90 000 ha, established as a National Park in 2004) is located in the south-western region of Rwanda and shares common border with Kibira National Park in the Burundi side. The reserve has been affected by clearing of land for agriculture, bush fires, over-exploitation of forest resources. Gold washing and saw milling activities were been found to be another problems leading into serious environmental degradation in the National Park [b].

7.2.3. Socio-economic environment

a) Characteristics of the population

According to the Southern Province's website, Southern Province's population was 2 376 741 inhabitants in July 2010.

According to the 2007 Household Survey in Rwanda, the population was 285 804 in Nyamagabe District and 246 445 in Huye District. The population was 302 inhabitants at Taba and 522 inhabitants at Gakomeye following a survey in September 2007. The medium growth rate is estimated to be 2,9 % per year.

The estimated size of household is about 4,5 persons /household in the Project area.

The languages are Kiswahili and Kinyarwanda.

b) Social environment

<u>Housing in the Project area:</u>

More than 75% of the dwellings are made of mud and poles, with thatch roofs and mud floors. The remaining ones have mud or burnt bricks with metal roof sheets and cement or bricks floor.

More than 80% of the households own their houses. The size of their dwelling is one room for about 25% of them, two rooms for 44%, and more than two rooms for about 31% of households.

No cultural heritage site has been found in the Project area.

Health facilities and health situation

There are 2 district hospitals in Nyamagabe (Kijemi hospital and Military Hospital). Health centres are 16 and a 17th one is under construction. There is one doctor per 33 655 persons.

Malaria and intestinal problems are the main diseases reported in the two districts. 63% of the people in the Project area have reported to have a mosquito net.

Education facilities

In the project area, the average rate of literacy is 47%. 1 out of 4 people drop out school.

Land tenure

All the land in the Project area is owned by title deed. Every family member is a joint owner of a land. Land can be obtained by inheritance or procurement.

c) Economic activities

Agriculture

The economy is based mostly on subsistence agriculture. The rain fed crops are beans, ground nuts, peas, maize, bananas, Irish potatoes, sweet potatoes, cassava millet and vegetables like cabbages, onions, tomatoes, spinach. The average agricultural plot is 1 to 3 acres per household in the Project area.

Coffee and tea are the major cash crops for export.

The valley is covered by alluvial supporting agricultural activities in the valley and collucial deposits supporting the sand mining activities along the banks of the river.

However, no irrigation is being practiced in the Project area. An old irrigation scheme was found abandoned and it reported that after the 1996 floods, the river changed its course bypassing the irrigation head works. The flood plain is irrigated with among others cassava fields, paddy fields, beans.

Animal production

Livestock is little in the project area: 0,5 cattle per household has been estimated in the project area during the socio-economic study: less than 5 households have more than 10 cows; around 40% of households have goats and 30% have pigs.

Other activities

Within the district of Huye lies the Huye Mountain, giving its name to the district. The Huye mountain is an important source of mineral water, supplying both the Huye bottled water brand sold throughout Rwanda and the nearby Maraba fair trade coffee plant, whose washing station receives Huye water via a pipeline built in 2002.

A project about masonry, carpentry, sewing (namely CFWP Mwogo) is located in the vicinity of the Project.

7.3. Preliminary identification and assessment of potential impacts

Project with dam

The preliminary potential impact examination has identified the following impacts if dam is build.

- About physical environment:
  - The erosion of river banks could be an issue due to the Project.
  - Sediment transport might be a problem for this river due to the turbidity of water.
  - Loss of water resources through evaporation should be studied as a consequence of the Project.

- About biological environment:
  - No major issue has been identified at the stage of the study;
  - Due to the change of the hydrology of the River, the aquatic environment as well as the wetlands near the Project area should be taken in consideration during the ESIA;
  - No protected area should be impacted due to the Project. However, the Nyungwe Forest is in the Project District and should be taken into consideration;
  - The water hyacinth plant should be studied in case of presence in the area, especially upstream, as it could spread within the reservoir due to its presence in Rwanda in Kagera River Basin.

- About socio-economic environment:
  - The major impact will be the loss of land depending on the dam size as follows (see map MA16 in the Appendix C):

Figure 39: Flooded area by the reservoir according to Taba-Gakomeye dam size

Country Dam name	Dam Height (m)	Full Supply Level		*Surface area of the reservoir* *(km²)*	*Reservoir volume* *(Mm3)*	*Length max reservoir (km)*	*Width max reservoir (km)*
			(m)				
Rwanda	14	+12m	1 644	0,60	3,09	2,2	0,8
	# 16	+16m	1 648	0,82	5,94	2,4	1,0
Taba Gakomeye	# 26	+24m	1 656	1,17	13,94	2,5	1,8

  - An estimated population of 500 people could be affected by the reservoir according to the ESIA survey for a dam high of 14m;
  - The land uses and the buildings being flooded could be estimated with the orthoimages. The first data provided by the ESIA team has been reported on the map MA06 in the Appendix C.
  - Other economic impact will be the sand mining along the river banks;
  - Among the infrastructures potentially lost, a bridge and two major trails could be flooded by the reservoir of the ToR dam. To be notified as well, the presence of an asphalted road just downstream the ToR dam.
  - No cultural heritage site should be impacted;
  - Water diseases should be studied with the presence of the reservoir;

- Due to the change of hydrology, impacts of other irrigation projects should be studied.

Project without dam

- The erosion of river banks could be an issue due to the Project with the high agricultural activities in the area;
- No infrastructure should be affected by the Project. However, the diversion structure, canals and drains will use area of the agricultural land or sand mining area. This area should be however limited to some areas.

7.4. Elements of an environmental and social management plan

7.4.1. Elements for environmental measures

Measures against erosion should be taken into consideration such as the improvement and restoration of the watershed to reduce erosion and sediment ingress with land management measures as described hereafter.

In Rwanda, a recent study in the project area shows that communities are aware of soil erosion and thus topsoil loss, but are not effective in taking mitigation measures as it is not carried out in an integrated manner.

Socio-economic Parameter	Nyamagabe District / Wards			Huye District / Wards			Nyaruguru District / Wards	
as in 2007	Kamegeri	Gasaka	Tare	Maraba	Kigoma	Simbi	Mata	Ruramba
Population	12,286	19,729	19,608	20,879	20,293	18,904	11,928	16,136
Farm ownership								
<1/2 Ha	29.5%	31.1%	47.0%	60.8%	36.4%	35.9%	26.3%	32.0%
0.5 to1 ha	16.9%	20.4%	18.6%	13.2%	16.7%	20.7%	15.6%	20.9%
> 1 ha	12.0%	12.1%	6.4%	8.7%	8.3%	7.6%	4.2%	8.7%
none	41.6%	36.4%	28%	12.3%	38.6%	35.8%	53.9%	57.3%
Farming practice								
Fertilizers chemical	3.6%	10.2%	18.2%	15.1%	8.3%	12.5%	3%	12.1%
Natural fertilizer	84.9%	75.7%	85.6%	82.3%	70.7%	76.6%	85%	86.9%
Irrigation	0%	4.9%	0%	1.0%	2.2%	0.6%	0%	0%
erosion control	29.5%	25.7%	28%	27.3%	21.0%	32.5%	27.5%	34.0%
other	4.2%	5.8%	8%	12.9%	11.7%	5.5%	4.8%	6.8%
Erosion control method								
drainage	49.4%	50.5%	61.0%	77.8%	52.2%	71.7%	35.3%	52.9%
trees planting	53.0%	41.3%	66.3%	36.3%	42.0%	41.9%	64.1%	63.6%
terraces	1.2%	2.9%	5.7%	2.6%	1.9%	1.5%	3.6%	4.4%

Present erosion control methods include drainage system, trees planting and terracing. The latter one being expensive is not carried out.

For the project area, Land Management Measures are more appropriate in Rwanda due to the high population density.

7.4.1.1. SHEET AND RILL EROSION

7.4.1.1.1. Non-structural measures

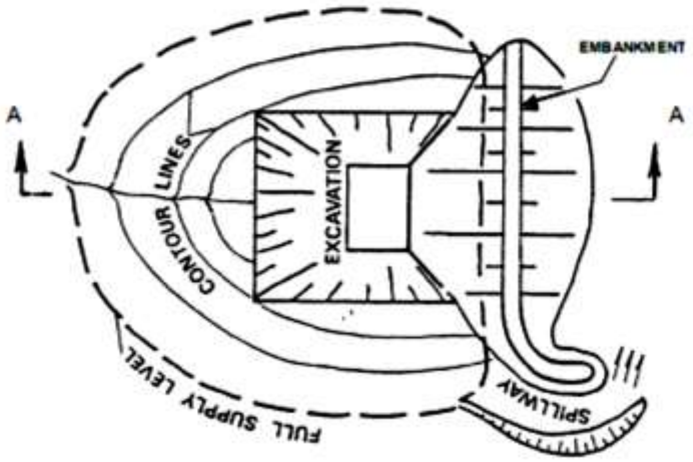
The most basic requirement for the control of sheet and rill erosion is to provide and maintain a dense, protective vegetative cover for as much of the time as possible.

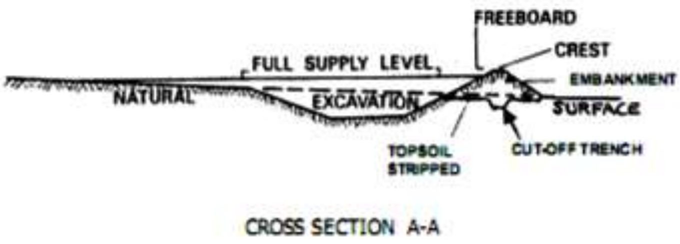
Special cropping methods and tillage (low till or no till to reduce breakdown of soils) cultivation practices can be employed to minimize the time periods during which the ground must be unprotected during land preparation and seed planting or after harvesting, or to reduce the total area of ground exposed to erosive rainfall at any time. In addition, farming practices or small-scale structural measures can be employed to improve infiltration, retard run-off and reduce the erosive energy of overland flow.

The retention of crop residues and stubble, or vegetative mulches provide a protective soil surface cover. Also cover crops, mixed crops where one crop provides protection for the other during cultivation or germination, or the use of green manure crops for incorporation into the soil, are commonly used for erosion control, particularly where intense rainfalls are experienced during wet seasons or where crops must be grown on steep side slopes. Rotational cropping can be employed for the dual purposes of erosion control, soil moisture control and the enhancement of soil fertility. Strip cropping and alley cropping, where alternating strips of different crop types and different stages of the cropping cycle are planted, are effective methods of erosion control which act not only to maintain effective crop cover but also to retard overland flow and reduce the erosive energy of run-off. All the above techniques are normally termed as “conservation farming”.

7.4.1.1.2. Structural Measures

Special cultivation techniques such as contour ploughing, listing or ridging with alternate furrows, provide the simplest and cheapest means of structural erosion control. Other methods for water control include basin listing or tied listing, which involves formation of small dams along the furrow to produce a multitude of small water-holding basins.





Terrace-like structures comprising earth embankments, combined with channels that are constructed across sloping land at fixed intervals down the slope for run-off diversion, run-off detention, the slowing-down of overland flow velocity, the reduction of erosive slope length, improved infiltration and soil moisture retention and for slope stabilization. Other terraces types include: channel terraces (20% slope), contour or graded or bank terraces (gentle slope) and bench or step terraces (more common).

On grazing lands, ground cover can be improved by: management of stocking rates, the distribution of grazing pressures by installing more watering points, applying fertilizers, including trace elements for known deficiencies, and removing stock when ground cover levels fall below critical limits or if erosion levels are severe.

7.4.1.2. GULLY EROSION

The control and rehabilitation of gully erosion is undertaken in two phases:

- First: introduce land management measures (dense vegetation cover or strip cropping or grassed graded terraces) and install diversion structures (channels) upstream of the eroded gully area, to reduce the volume and velocity of run-off entering the eroded site.
- Second: structural measures in the gully itself – stabilization and restoration of side slopes and bottom with energy dissipaters at intervals. If severe and deep, then sand bags, timber logs, geotextile, gabions, concrete drop spillways, chute spillways or flumes may be necessary.

For extreme level of gully erosion, it may be necessary to change land use, such as stop cultivation and use as grazing land or natural vegetation / reforestation.

7.4.1.3. WIND EROSION

A good vegetative cover is the best protection against wind erosion but land use planning and control (changing of crop types or farming practices, replacement of arable farming with pastoral activities, and prevention of any kind of intensive land use) achieves better result at watershed scale. Two broad categories are proposed:

- use vegetative “structural” devices (wind breaks made of shrubs / trees, strip or alley cropping) to reduce wind velocities and control erosive forces;
- use of special tillage and farming practices aimed at reducing wind erosion by managing the aerodynamic nature of the ground surface.

Other techniques include: stubble retention, mulch incorporation, low till and no till cultivation as for sheet erosion.

On grazing lands, wind erosion control is effected principally through vegetative cover and management of stocking rates.

7.4.1.4. MASS MOVEMENT – LAND SLIDES

Again a range of non-structural and structural or mechanical means are used. Land-use zoning (prohibition or restriction of agricultural development or urban settlement) in susceptible areas is most cost effective and least costly provide demand for productive land allows it.

There is a variety of structural or mechanical measures that can be used where prohibition is not practical:

- preventing or diverting run-off flows around critical sites
- de-watering sites using drainage systems
- planting trees or shrubs which remove sub-surface water by transpiration
- planting deep-rooted vegetation to bind sub-soil material
- underpinning foundations to stable rock
- battering slopes to stable grades
- constructing retaining walls along the toes of critical slopes

7.4.2. Elements for a social management plan

No resettlement action plan should be carried out due to the project without dam as no people should be resettled. However, the compensation for the lost lands due to some components of the different schemes should be carried out.

8. ECONOMIC AND FINANCIAL ANALYSIS

8.1. Introduction

Following the findings in the chapter 5, the economic analysis has been carried out for each development scheme as the development of each component of the project will be carried out by different institutional departments. Detailed analysis is included in the Appendix L.

To show the viability of the project, economic benefits have to exceed economic costs.

The costs are divided between investments costs and Operations and Maintenance Costs.

The benefits accrued from such a multipurpose water resources development project involving mainly irrigation and water supply are improved food security, improved livelihood and therefore living conditions.

The economic analyses has been carried out with the following indicators: the Economic Benefit to Cost Ratio (EBCR) that should reach more than unity; the Economic Internal Rate of Return (EIRR) that should be greater than 12% being the opportunity cost of capital; the Economic Net Present Value (ENPV) that should be positive when investments are discounted at a rate of 12%. A discount rate of 12% is appropriate assessed from the cost of capital based on interest rates, inflation rate and shadow pricing effect (government regulating prices).

8.2. For irrigation development

The economic analysis is based on costs (investments, operations and maintenance) and benefits of the project. Benefits take into account the comparison of two situations: with or without project.

8.2.1. Investments Costs

The costs of the irrigation scheme have been evaluated according to the unit cost method. Unit costs have been derived from similar projects carried out in the lake region and elsewhere by applying remoteness factors.

For an net irrigable area of 183 Ha, the cost of the scheme are evaluated to US $ 5 534 000. For each perimeter, the unit cost was estimated as follows.

Table 31: Unit costs for each perimeter

Area	Unit cost of development ($/ha)
110	25 200
1	19 700
2	43 800
3	29 800

The range of costs is high. It should be noticed that area “2” development is very expensive due to its small area and the weight of all headworks (weir + aqueduct under the road).

8.2.2. Operating & Maintenance Costs

Maintenance costs cover for parts, spares, sundries and labour for the normal routine and periodic maintenance and also repairs. On the other hand operating costs are costs related to the operation of the irrigation scheme. This is not duplicated with the input required for the crops. These costs can be firstly estimated to around 3% of initial investment, meaning about US$ 166 020.

8.2.3. Conversion Factors – Financial to Economic Costs

Economic costs are net of market distortions resulting from transfers such as taxes, levies, fees and/or subsidies, for which shadow values are applied. VAT and import duty on components has therefore not been considered in unit costs. Also rent for leasing land and repayment of loan have been considered as transfer payments and therefore not included in the costs.

On the other hand, the proportion of crops grown that is consumed at home is also considered as a benefit and thus as sales revenue. Farm-gate sales are considered for the analyses against farm exported prices to city centres which may be 2 to 3 times more but would be distorting the sale prices.

Each category of capital costs and operating and maintenance (O&M) costs are broken down into categories such as traded material, non-traded material, skilled labour, unskilled labour, others (such as transport, overhead costs) and transfer cost (taxes, subsidies, levies). These financial costs have been converted from domestic currency to US dollars currency and multiplied with respective conversion factors, to obtain economic prices.

It is noted that the five countries Tanzania, Uganda, Kenya, Rwanda and Burundi have harmonized all their taxes, duties and levies.

Detailed information is not available to calculate accurately the conversion factors and they are therefore estimated as follows.

- Traded Materials (imported / exported goods) - 1.31 (The Standard Conversion Factor = 1 / 1.31 = 0.763 (includes fertilizers, pesticides, tools)
- Energy including electricity (subsidized otherwise unaffordable) – 1.25
- Non-Traded Materials (road, water, drainage etc) - 1.00
- Unskilled Labour - 0.70 reflected from high unemployment in the country and the readily available unskilled labour – the market wage rate is lower than the recommended wages (it is noted that the legislated minimum wage is BFr 160/day, unreasonably low last established in 1990s while the government recommends BFr 1,500/day to investors, while it the market wage was BFr 1,000/day). The shadow wage factor = 0.7
- Skilled Labour - 1.00
- Transfer Costs (taxes) - 0.00

For the project, therefore the composite conversion factors used will be:

- Capital Costs: 0.9
- O & M Costs: 0.85

The economic costs are obtained from financial capital costs and O & M costs of the project by multiplying with the conversion factors discussed above as shown in the following table:

Financial Costs		Economic costs	
Capital Cost US $	Annual O &M Costs US $	Capital Costs US $ CF 0.9	Annual O & M Costs US $ CF 0.85
5,534,000	166,020	4,980,600	141,117

8.2.4. Benefits

8.2.4.1. CROPS

For this valley, three seasons crops are proposed annually and include maize, Irish potatoes, beans and vegetables (dry season).

Without the project, the crop yields are less and two seasons (Sept/Oct and Feb/Mar) crops are grown comprising maize, beans and potatoes.

Based on the findings in the chapter 4.5.2, and taking into account that the existing cropping pattern is voluntarily simplified, with three main crops, other ones representing only very small areas. Cultivation of sorghum only allows one season cropping as it cycle lasts for six months.

The with-project allows a more diversified cropping pattern and a greater intensification with three season cropping. Potatoes may be grown on a greater extent and vegetables are introduced during the dry season C.

Two cases have been considered: while with-project 1 introduces vegetables on the whole area during the dry season, with-project 2 is more careful with only half of the area with vegetables.

Table 32: Cropping pattern with and without irrigation

Crops	Without project			With project 1			With project 2		
	%	ha	yield t/ha	%	ha	yield t/ha	%	ha	yield t/ha
A season									
Maize	80%	150	4,0	25%	47	5,0	25%	47	5,0
Sorghum	10%	19	1,5						
Beans	10%	19	1,3	25%	47	1,6	25%	47	1,6
Soybeans				25%	47	1,6	25%	47	1,6
Potatoes				25%	47	15,0	25%	47	15,0
B season									
Maize	80%	150	3,0	25%	47	5,0	25%	47	5,0
Sorghum									
Beans	10%	19	1,3	25%	47	1,6	25%	47	1,6
Soybeans				25%	47	1,6	25%	47	1,6
Potatoes				25%	47	15,0	25%	47	15,0
C season									
Beans				0%	0	1,6	25%	47	1,6
Potatoes				0%	0	15,0	25%	47	15,0
Vegetables				100%	187	4,0	50%	94	4,0
Total cropped ha		355			561			561	
Cropping intensity %		190%			300%			300%	

Different sources (FAO, USAID, Ngono perimeter, Rwandan Minagri etc.) provide a range of prices for the same product. It has been taken an average of those. Variable costs for the with-project have been taken from the Ngono study in Tanzania and have been arbitrarily reduced in the case of the without project.

Table 33: estimated income with/without irrigation

crop	price $/kg	Without project				With project			
		yield t/ha	income $/ha	variable cost $/ha	gross margin $/ha	yield t/ha	income $/ha	variable cost $/ha	gross margin $/ha
Maize	0,5	4,0	2 000	800	1 200	5,0	2 500	1 000	1 500
Sorghum	0,4	1,5	600	100	500				
Beans	0,6	1,3	780	250	530	1,6	960	350	610
Soybeans	0,8					1,6	1 280	350	930
Potatoes	0,3					15,0	3 750	650	3 100
Vegetables	0,7					5,0	3 500	650	2 850

In the case of irrigation, the variable costs include the land preparation and irrigation labour costs at the plot level. Annual operation and maintenance costs of the scheme are counted apart and shall be added to the investment cost spread across the depreciation period of the improvement.

Table 34: estimated income with/ without irrigation

crop	Without project				With project 1				With project 2				net income difference	
	dev. area	total prod.	gross income	net income	dev. area	total prod.	gross income	net income	dev. area	total prod.	gross income	net income	1	2
	ha	t / year	US $ / year	US $ / year	ha	t / year	US $ / year	US $ / year	ha	t / year	US $ / year	US $ / year	US $ / year	
Maize	299	1 047	523 600	359 040	94	468	233 750	140 250	94	468	233 750	140 250		
Sorghum	19	28	11 220	9 350										
Beans	37	49	29 172	19 822	94	150	89 760	57 035	140	224	134 640	85 553		
Soybeans					94	150	119 680	86 955	94	150	119 680	86 955		
Potatoes					94	1 403	350 625	289 850	140	2 104	525 938	434 775		
Vegetables					187	748	523 600	532 950	94	374	261 800	266 475		
TOTAL	355	1 124	563 992	**388 212**	561	2 917	1 317 415	**1 107 040**	561	3 319	1 275 808	**1 014 008**	**718 828**	**625 796**

The irrigation scheme shows to increase the farmers' annual revenue with more than US $ 625 000 annually. It is linked with the introduction of vegetables.

8.2.4.2. LAND APPRECIATION

The irrigation project will result in increased yield and therefore appreciate in value. The present average valley farm land market prices are assumed to be US$ 4000/Ha. With irrigation development, it is assumed an increase of land value by at least 25%, meaning by US$ 1 000/Ha.

A total of US $ 183 000 as one-time benefit is estimated.

8.2.4.3. INCREASED INCOME DUE TO ECONOMIC GROWTH

The enhanced economic growth due to irrigation project will create more jobs or opportunities in business including chain value support for farm inputs and transportation of products. It is estimated a benefit of US$ 1 138 800/year.

8.2.4.4. INCREASED INCOME DUE TO PROJECT CONSTRUCTION ACTIVITIES

The construction in the villages and the town could create job opportunity for the communities. It is estimated that 20% of the project costs and O&M activities require unskilled labour.

Financial Costs		**Financial Benefits X = 20% x Cost**	
Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
5,534,000	166,020	1,106,800	33,204

8.2.4.5. VAT BENEFIT

It is assumed that 10% of the construction costs and annual O & M costs remain at source attracting 18% VAT, making it a benefit as follows:

Financial Costs		**Financial Benefits to HHs X = 10% x 18% x Cost**	
Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
5,534,000	166,020	99,612	2,988

8.2.4.6. SUMMARY OF ALL BENEFITS

The total economic benefits are summarized in the following table:

Table 35: Summary of benefits for irrigation

	US $ / year	**US $ once**
Irrigation Increased Yield	625,000	
Land Appreciation		183,000
Increased Income – Economic Growth	1,139,000	
Project Construction Activities	33,000	1,107,000
VAT remain in district	3,000	100,000
TOTAL Benefits	1,800,000	1,390,000
Economic Benefits with conversion factor = 0.8	1,440,000	1,112,000

8.2.5. Economic analysis

For the economic analysis, outlay of costs and benefits from the earlier sections are presented over 25 years to year 2037. Three economic indicators are calculated:

- Economic Internal Rate of Return (EIRR) that has to exceed 12% the economic cost of capital,
- Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

In addition, four sensitivity analyses are carried out as follows:

- Scenario I : increase costs by 15%;
- Sensitivity II : decrease benefits by 15%;
- Sensitivity III : increase cost by 15% and decrease benefits by 15%;

The above sensitivity analyses will remove all the uncertainties in prices, quantities etc. used in the analysis.

	Variations		**EIRR**	**ENPV (US $)**	**EBCR**
	Costs	**Benefits**			
Basic	-	-	31.9%	5 164 000	2.01
Scenario I	+15%	-	26.6%	4 398 000	1.75
Scenario II	-	-15%	25.8%	3 633 000	1.71
Scenario III	+15%	-15%	21.5%	2 857 000	1.49

The proposed irrigation project is viable and shows positive economic indicators as shows the above indicators.

With dam, the irrigation component would not be viable due to the weight of all headworks compared to the available net irrigable area.

8.3. For water supply

8.3.1. Investments Costs

The investment costs for water supply have been evaluated as US$ 21 930 000 (see chapter 5.3.3).

8.3.2. Operation & Maintenance Costs

These costs have been estimated according to the review of financial performances of similar project in the region (Tanzanie, Kenya, Gambia,…).

Maintenance costs are estimated to 19% of investment.

Investments costs	**O&M costs**	
US $ 21,930,000	19%	US $ 4,166,700

8.3.3. Conversion Factors – Financial to Economic Costs

The conversion factors have been determined as follows:

- Capital Costs: 0.96
- O & M Costs: 0.88

Financial Costs		**Economic Costs**	
Capital Cost US $	Annual O &M Costs US $	Capital Costs US $ CF 0.96	Annual O & M Costs US $ CF 0.88
21,930,000	4,166,700	21,052,800	3,666,696

8.3.4. Benefits

The benefits accrued from a water supply projects are simply that people obtain an improved, healthy and secure living environment without being displaced. Water supply projects have been proved to be effective entry point for poverty alleviation. The investments they have already made to their properties are actually enhanced. Recognizing title and security of tenure makes a positive contribution to both the economic prospects of the poor, as well as to the national economy. Experience has shown in similar water supply and sanitation projects are associated with social and economic benefits that are particularly high, are significant in fall in infant mortality rates, fall in crime rates in other countries, and regularization of land tenure results significant private investments.

Benefits include:

- community empowerment resulting from participatory approach and forming community based organizations – enabling the community to identify, organize and manage future projects, thus enhancing future development and reducing risks and generally resulting in economic growth
- improved water supply connection to those who do not have presently – reduced fetching distance and therefore time saving. After the implementation of the water supply project, the domestic water points will be closer within 200m walking distance, and the fetching time is estimated to be about 10 min
- improved power supply to those who do have at present
- improved environmental condition and standard of living
- improved health conditions, reduction in diseases and savings in health bills
- increased investments and economic development activities, improved livelihood
- increased land and property values
- employment during construction period

About 158 000 people (35 140 HHs) are expected to benefit from the project. The household incomes are assumed to be less than $90 per month.

8.3.4.1. TIME SAVING FOR FETCHING WATER

Improved water supply creates cost savings to the community due to time saving in fetching (walking + waiting) for water, reduced storage requirements and no boiling and are considered where they are significant. The household size is 4,5 persons.

It is assumed more than 60% households use wells, water holes, ponds and direct rivers and streams. The per capita consumption in rural areas is estimated at 25 litre per day and per person. The average fetching distance is assessed as about 50 minutes for every 20 litres bucket. If the government recommended wage US$ 1.2/day, the productive time value gained is as follows:

The saving therefore is = 60% x 50/60 (time) x (25)/(20) (volume) x 1.2/8 (US $ wage/hour) x 4.5pp/HH = US $ 0.47 per HH / day x 365 = US $ 168/HH/Year

8.3.4.2. HEALTH BENEFITS

Health benefits from reduced health bills, reduced deaths and increased productive times resulting from this project.

Health Bills

ESIA survey records 18% of monthly income (making it US $ 18/HH/month) is spent on medical and health related expenses. The proportion is high implying that at least one member of the household is sick every two weeks. The district statistician expressed that diahorrea and intestinal worms are common after malaria.

The medical expenses are assumed to about US $ 13.5/HH/month in the project area. With the implementation of the water supply, the saving in medical expenses could reduce by 30% due to safe and reliable water supply, than the annual saving per HH = US $ 13.5 x 12 x 30% = US $ 48.6 / HH/ year.

Productive time

The ESIA survey showed high proportion of medical expense implying that at least one member is sick every two weeks. A lower figure is assumed for analyses. It is assumed 30% of the households reported to have a person sick every two weeks.

The lost productive time = 30% x 4.5 pp/HH x 4/2 weeks x 12 months = 32.4 person days/HH/year of lost productive time. If the water supply project improves health by 30%, the lost time will be reduced by 30% and thus a saving of 10.8 person days/HH/year. This saving is valued as = US $ 1.3 x 9.72 = US $ 12.6/HH/year.

The total health saving is estimated to US $ 61.2/HH/year.

8.3.4.3. SALE OF WATER SERVICE AS BENEFIT

The project is targeting rural areas where the existing water supply is assumed to be 20% coverage. The new proposed water supply project will therefore have non-incremental supply of 20% and incremental supply of 80%. The existing water supply is presently subsidized either free or with very low payments. In economic analysis, economic price of water has to be taken into account even if it is subsidized. In this analysis, 100% of the project supply is considered as incremental and at a price Willingness to Pay which with sensitization is at the Affordability or Ability to Pay being 4% of disposable income.

Based on a household water consumption of 3.375 litres per month, each household would have to pay $1.067/m3. Thus, the water sales should provide US$ 43.2/HH/year.

8.3.4.4. APPRECIATION OF LAND VALUES

It was estimated that about 25% of the properties which are located near water points and along the pipe lines will increase in value incrementally by 25% after the water supply project is implemented.

It is assumed that the present land value in the project area is $0.2/m2. A 25% increase is $0.05/m2. Each household plot or premise is assumed to be 1 800 m2.

The net increase in land value per HH is estimated to be US $ 22.5/HH once only.

8.3.4.5. INCREASED INCOME DUE TO ECONOMIC GROWTH

The enhanced economic growth due to water supply project will create more jobs or opportunities in business. About 30% of the population being working age are unemployed in the project area, meaning 1.35 persons unemployed per HH. Estimating that about 10% of the unemployed would acquire job from the economic growth, the benefit could be estimated to US $ 64.05/HH/Year.

8.3.4.6. INCREASED INCOME DUE TO PROJECT CONSTRUCTION ACTIVITIES

The construction in the villages could create job opportunity for the communities. It is estimated that 20% of the project costs and during O&M require unskilled labour, meaning the following benefits.

Financial Costs		**Financial Benefits to HHs X = 20% x Cost/(35,140 HH)**	
Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
21,930,000	4,166,700	124.8/HH	23.7/HH/Yr

8.3.4.7. VAT BENEFIT

It is assumed that 10% of the construction costs and annual O & M costs remain at source attracting 18% VAT, making it a benefit as follows:

Financial Costs		**Financial Benefits to HHs X = 10% x 18% x Cost/(35,140 HH)**	
Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
21,930,000	4,166,700	11.2/HH	2.1/HH/Year

8.3.4.8. SUMMARY OF ALL BENEFITS

The total economic benefits are summarized in the following table:

Benefit Type	**US $ / HH/year**	**US $ /HH once**	**Total Benefits for 35,140 HHs**
Fetching Distance Saving	168		US $ 5,903,520 / year
Health Improved	61.2		US $ 2,150,568 / year
Sales of Water Annual increase 1.7%	43.2		US $ 1,518,048 / year phased Annual increase 1.7% US $ 25,806
Land Appreciation		22.5	US $ 790,650 once
Increased Income – Economic Growth	64.1		US $ 2,250,717/ year
Project Construction Activities	23.7	124.8	US $ 833,340 / year and US $ 4,386,000 once
VAT remain in district	2.1	11.2	US $ 75,000 / year and US $ 394,740 once
TOTAL Benefits	362.3	158.5	US $ 12,731,194 / year and US $ 5,571,390 once Annual increase 1.7% US $ 25,806
Conversion Factor 0.88	0.88	0.88	0.88
Economic Benefits	318.8	139.5	US $ 11,203,450/ year and US $ 4,902,823 once Annual increase 1.7% US $ 22,710

8.3.5. Economic analysis

For the economic analysis, outlay of costs and benefits from the earlier sections are presented over 25 years to year 2037. Three economic indicators are calculated:

- Economic Internal Rate of Return (EIRR) that has to exceed 12% the economic cost of capital,
- Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

In addition, four sensitivity analyses are carried out as follows:

- Scenario I : increase costs by 15%
- Sensitivity II : decrease benefits by 15%
- Sensitivity III : increase cost by 15% and decrease benefits by 15%.

Table 36: Economic analysis for water supply

	Variations		EIRR	ENPV (US $)	EBCR
	Cost	Benefit			
Basic	-	-	44.2%	36,733,846	1.88
Scenario I	+15%	-	35.1%	30,476,972	1.64
Scenario II	-	-15%	33.8%	24,966,896	1.60
Scenario III	+15%	-15%	26.2%	18,710,022	1.39

All scenarios show that the water supply is economically viable. However the sales water corresponds to about 10 % of all benefits. The financial analysis for sale of water will not be positive, meaning that the water supply shall be performed by public funds, with high indirect benefits.

8.4. For aquaculture

8.4.1. Investments Costs

The investment costs for 27 small ponds (1,08Ha) as presented on the scheme is about US$ 1 210 000

8.4.2. Operation & Maintenance Costs

These costs have been estimated according to the review of financial performances of similar project in the region (Tanzanie, Kenya, Gambia,…).

Maintenance costs cover for parts, spares, sundries and labour for the normal routine and periodic maintenance and also repairs. These costs can be estimated to 3,33% of initial investment.

Investments costs	**O&M costs**	
US $ 1 210 000	3,33%	US $ 40 300

8.4.3. Conversion Factors – Financial to Economic Costs

The conversion factors have been determined as follows:

- Capital Costs: 0.9
- O & M Costs: 0.84

Financial Costs		**Economic Costs**	
Capital Cost US $	Annual O &M Costs US $	Capital Costs US $ CF 0.9	Annual O & M Costs US $ CF 0.84
1 210 000	40 300	1 089 000	33 850

8.4.4. Benefits

8.4.4.1. FISH PRODUCT

The fish yield is assumed to reach 4 tons/ha/year. The estimated producer fish price is about US$ 2/kg, assumed to be 20% as net fish value, meaning US$1.6/kg. Thus one fish pond could produce 160 kg per year, meaning US$256.

8.4.4.2. OTHER BENEFITS

As described in the appendix L, the other benefits could be as follows:

- Increased income due to economic growth, estimated to US$ 25 000;
- Increased income due to project construction activities, estimated to US$ 484 000 in one time and US$ 16 120 per year;
- VAT benefit, estimated to US$ 363 000 in one time and US$ 12 090 per year.

8.4.4.3. TOTAL BENEFITS

The total economic benefits are estimated as follows:

Table 37: Summary of benefits for fish ponds

	US $ / year	**US $ once**
Fish product	6 912	
Increased Income – Economic Growth	25 000	
Project Construction Activities	16 120	484 000
VAT remain in district	12 090	363 000
TOTAL Benefits	60 122	847 000
Economic Benefits after 0.874 conversion factor	52 550	740 280

8.4.5. Economic analysis

For the economic analysis, outlay of costs and benefits from the earlier sections are presented over 25 years to year 2037. Three economic indicators are calculated:

- Economic Internal Rate of Return (EIRR) that has to exceed 12% the economic cost of capital,
- Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

The following results show that such component would not be economically viable:

Aquaculture Economic analysis	**EIRR**	**ENPV (US $)**	**EBCR**
Basic	1,69	- 233 976	0.794

8.5. Summary of economic analysis

The following summary presents the project without dam construction as the water demand could be reached without dam.

The summary of costs for all the projects is included in the following table.

Table 38: Summary of costs

Water Use Component	**Capital Investment Costs (US $)**
Irrigation	5 534 000
Potable water supply	21 930 000
Aquaculture	1 210 000
Sub-total	**28 674 000**

For the economic analysis, three economic indicators are calculated:

- Economic Internal Rate of Return (EIRR) that has to exceed 12% the economic cost of capital,
- Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

The irrigation component shows the following economic performances:

- EIRR: 31,9%
- ENPV: + 5 164 000 US$
- EBCR: 2,01

The water supply component shows the following economic performances:

- EIRR: 44,2%
- ENPV: + 36 734 000 US$
- EBCR: 1,88

The aquaculture component shows the following economic performances:

- EIRR: 1,69%
- ENPV: - 234 000 US$
- EBCR: 0,79

Irrigation show positive economic performances taking into account direct revenues. Water supply show economic performances taking into consideration indirect revenues and collective increased incomes related to project nature and activities (such as appreciation of land, economic growth, employment). However, the fish farming project as presented is not viable.

The main changes in the project if the option with dam is chosen are as follows:

- The cost for the 14m earthfill dam is about 10 million US $. On this total should be added the total cost of the environmental and social management plan (ESMP) and the resettlement action plan (RAP) that has been estimated by the ESIA carried out by Newplan in parallel of this study as 1 454 000 US$.

- The irrigation component will have an area reduced compared to the option without dam as the upstream areas will be flooded by the reservoir of the dam. The net irrigable area would be around 100Ha divided in three different areas. The cost of the irrigated scheme could be estimated to about 3 million US$ for around 100Ha as net irrigable area This component would not be economically viable due to the weight of all headwork compared to the available net irrigable area.

9. TOR FOR DETAILED DESIGN AND TENDER DOCUMENTS

This activity should be implemented in case of dam construction. However, as stated before, the proposed development schemes do not include the construction of dam. Thus, it is possible to implement each component of the project by each administrative department without taking into consideration the dam detailed design. It should be noticed that the irrigation scheme has been provided with detailed design due to the available LiDAR data.

REFERENCES

[a] NELSAP: Rapid identification and assessment of potential sites for multi-purpose storage reservoirs; Eng. Dr. Henry K. Ntale; March 2011.

[b] BRL: The Kagera River Basin monograph, July 2008

[c] REMA: Rwanda state of environment and outlook, 2009.

[d] MINAGRI: Rwanda irrigation master plan, 2010.

The socio economic survey used the following documents:

S/No	Report Titles
A	**GENERAL**
1	A Report on the Assessment of Stakeholder Involvement in the Nile Equatorial Lakes Subsidiary Action Program and Projects – 2011 by Lucy Daxbacher
2	Country assessments on Environmental and Social Policies in the Nile Equatorial Lakes Region – Draft Country Report January 2012 by Judy Obitre-Gama Consultant
B	**RWANDA**
49	General Census of 2002
50	National Population Project 2007 – 2022 by National Institute of Statistics Rwanda (English)
51	Baseline 2007 Socio-economic Status for Sectors in following districts by National Institute of Statistics Rwanda (French) for EDPRS (Poverty Reduction Strategy) and OMD (Millennium Development Goals) in the Vision 2020 Umurenge Program (VUP) (French)
52	Resultat de L'enquete sur le Fonctionnement Actuel de L'etat Civil Rwadais 2008 by National Institute of Statistics Rwanda (French)
53	Service Provision Assessment Survey 2007 by National Institute of Statistics Rwanda and Ministry of Health – Health Sector - (English)
54	Rwanda National Child Labour Survey – 2008 by National Institute of Statistics Rwanda and Ministry of Public Service and Labour (English)
55	Rwanda Demographic and Health Survey 2010 – Preliminary Report by National Institute of Statistics Rwanda and Ministry of Health – Health Sector - (English)
56	Economic Development and Poverty Reduction Strategy (EDPRS) – 2008 to 2012-02-27 Millennium Development Goals 2008 to 2015
57	Vision 2020 : 2008 to 2020
58	Vision 2020 Umurenge Program VUP – Baselne Survey Final Report 2008 by National Institute of Statistics Rwanda and Ministry of Local Government - (English)
59	The National Agriculture Policy of 2004.
60	PSTA II – Strategic Plan for the Transformation of Agriculture in Rwanda of 2008
61	Agricultural Transformation Strategic Plan Support Project – ATSPSP 2005
62	Linkages between CAADP and PSTAII – July 2009
63	Agriculture Policy Synthesis 2002
64	Vision 2020 – one of the 6 pillars is the Modernization of Agriculture and Animal Husbandry
65	Sectoral Policy on Water and Sanitation of 2004
66	National Policy for Water Resources Management of 2011
67	Energy Policy for Rwanda 2004
68	National Energy Policy and National Energy Strategy 2008 – 2012 dated 2009

69	Rwanda – Sustainable Energy Development Project – SEDP – Project Appraisal 2009
70	Efficient Water Use for Agricultural Production (EWUAP) Project, Agricultural Water in the Nile Basin – Rwanda Country Overview Annex F – April 2008
71	Socio-economic development and Benefit Sharing Project – The Impact of Regional Power trade on Poor Communities in the Nile Basin Countries – Rwanda – 2008

The water use and water demand assessment used the following documents:

- *Power Sector:*

S/No	Report Title
A	**GENERAL**
1A	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2A	Kagera River Basin Monograph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenieur – Socioeconomic (pg 63 – 85), Energy & hydropower (pg 191 to 207), pg 192, 193, 205,
3A	Strategic / Sectoral, Social and environmental Assessment of Power Development Options in the Nile Equatorial Lakes Region – Synopsis Report – Stage 1 – Burundi, Rwanda and Western Tanzania – Feb 2005 by SNC Lavalin for NBI NELSAP
4A	An Infrastructure Action plan for Burundi – Accelerating Regional Integration by African Development Bank – 2009 pg 46, 55, 59, 62, 77 – 79, 90 – 91, 134 – 139, 156,
5A	Hydropower Development – Small Scale Hydropower for Rural Development – Nile Basin Capacity Building Network - 2005
B	**RWANDA**
11A	Hydropower in Rwanda – Ongoing Initiatives & New Investment Opportunities – Yves Muyange – DG EWSA
12A	Energy – The Opportunity in Rwanda by Rwanda Development Board
13A	Energy Policy for Rwanda 2004 by Ministry of Infrastructure
14A	National Energy Policy and National Energy Strategy 2008 – 2012 dated 2009 by Ministry of Infrastructure. Pg 22, 23, 26, 41, 42, 46, 70, 71,
15A	Rwanda – Sustainable Energy Development Project – SEDP – Project Appraisal 2009

- *Irrigation Sector:*

S/No	Report Title
A	**GENERAL**
1B	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2B	Kagera River Basin Monograph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenieur – Socioeconomic (pg 63 – 85), Agriculture Livestock and forestry (pg 121 – 167), pg 124, 126, 132, 138, 143, 145, 148 to 152
3B	Agriculture Water in the Nile Basin - Efficient Water Use for Agricultural Production (EWUAP) Project – for NBI by Ian McAllister Anderson – April 2008 Agriculture Water Use (pg 35 to 67) and Best Practices (pg 70 to 91)
4B	Large Scale Irrigation Practices in the Nile Basin - Efficient Water Use for Agricultural Production (EWUAP - NBI – Jan 2009 by Bastiaanssen and Perry pg 22, 25, 34, 44, 55 - 59, 71, 74, 76, 77, 136 – 140, Annex D, H, J and K.

5B	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82),
	Farm Management Handbook of Kenya Vol II Natural conditions and Farm Management Information – Part A West Kenya
B	**RWANDA**
18B	Rwanda Irrigation Master Plan by Ebony Enterprise ICRAF 2010 pg 29 – 36, 54, 70 - 72, 73 – 92, 114, 115, 198, 201, 203, 214 - 220
19B	Annex F – Rwanda Country Overview - Efficient Water Use for Agricultural Production (EWUAP) Project, Agriculture Water in the Nile Basin April 2008 – pg 2, 4, 6 to 9
20B	Rwanda Marshland Irrigation Master Plan by Hydroplan Ingenieur GmbH, SHER Ingenieurs, Conseils s.a for Rivers Muzi, Mwogo, Ruboroga and Rwondo 2002 (French)
21B	National Agricultural Survey 2008 – National Institute of Statistics of Rwanda. Agricultural households (pg 20-34), Farm characteristics (pg 35-40), Agricultural practices (pg 41-56), Livestock practices (pg 57-64), Fihery , aquaculture (pg 65-67)
22B	The National Agriculture Policy of 2004 Rwanda
23B	Strategic Plan for the Transformation of Agriculture in Rwanda – Financing, Coordination and monitoring and Evaluation in the Agricultural Sector – by Dr. Kanyarukiga GECAD Oct 2004.
24B	PSTA II – Strategic Plan for the Transformation of Agriculture in Rwanda of 2008
25B	Agricultural Transformation Strategic Plan Support Project – ATSPSP 2005
26B	Linkages between CAADP and PSTAII – July 2009 pg 16-25,
27B	Agriculture Policy Synthesis 2002
28B	Vision 2020 – one of the 6 pillars is the Modernization of Agriculture and Animal Husbandry

> *Livestock Development Sector:*

S/No	Report Title
A	**GENERAL**
1C	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2C	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenieur – Socioeconomic (pg 63 – 85), Agriculture Livestock and forestry (pg 121 – 167), pg 134, 135, 153,
3C	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82),
B	**RWANDA**
14C	National Agricultural Survey 2008 – National Institute of Statistics of Rwanda. Agricultural households (pg 20-34), Farm characteristics (pg 35-40), Agricultural practices (pg 41-56), Livestock practices (pg 57-64), Fihery , aquaculture (pg 65-67)
15C	The National Agriculture Policy of 2004 Rwanda.

> *Fisheries and Aquaculture Sector:*

S/No	Report Title
A	**GENERAL**

1D	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2D	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenirie – Socioeconomic (pg 63 – 85), Fisheries and Aquaculture (pg 185 to 190), pg 188,
3D	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82),
	Fingerponds – Seasonal Integrated Aquaculture in East African Freshwater Wetlands – PhD Thesis by Julius Kipkemboi 2006
	Guiding Principles for Promoting Aquaculture in Africa – benchmarks for sustainable development - FAO and Worldfish Paper No 28 – 2006 pg 91 Design Procedure
B	**RWANDA**
12D	National Agricultural Survey 2008 – National Institute of Statistics of Rwanda. Agricultural households (pg 20-34), Farm characteristics (pg 35-40), Agricultural practices (pg 41-56), Livestock practices (pg 57-64), Fihery , aquaculture (pg 65-67)
13D	Rwanda National Fish Culture Project – International Centre for Aquaculture – July 1989
14D	Rwanda Women in Aquaculture – Context, Contributions and Constraints by Women in International Development Jan 1993
15D	The National Agriculture Policy of 2004 Rwanda.

> *Water Supply Sector:*

S/No	Report Title
A	**GENERAL**
1E	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2E	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenirie – Socioeconomic (pg 63 – 85), Potable water (pg 209 to 221), pg 210, 211, 213, 216, 218, 221,
3E	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Rural Domestic Water Demand and Use (pg 85 to 105), Industrial Water Demand and Use (pg 107 to 120), Urban Water Demand and Use (pg 121 to 156)
4E	Practice Manual for Water Supply Services in Kenya – Part A Water Supply Nov 2005 Chap 2 Water Demand – all sectors
B	**RWANDA**
11E	National Policy & Strategy for Water Supply and Sanitation Services - by Ministry of Infrastructure Feb 2010 Sec 2.2.2, 6.2, 6.3, 7.2, 7.3,
12E	Guidelines for the Development of Small Scale Rural Water Supply and Sanitation Projects in East Africa – Catholic Relief Services – Aug 2005
13E	Sectorial Policy on Water and Sanitation of 2004 by Ministry of Lands, Environment, forests, Water and Natural Resources.
14E	National Policy for Water Resources Management of 2011 by Ministry of Environment and Lands pg 5 to 7,

> *Common Sectors:*

S/No	Report Title
A	**GENERAL**
1F	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2F	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenirie – Socioeconomic (pg 63 – 85), Agriculture Livestock and forestry (pg 121 – 167), Environmental use (pg 169 to 183), Fisheries and Aquaculture (pg 185 to 190), Energy & hydropower (pg 191 to 207), Potable water (pg 209 to 221), Transport & navigation (pg 223 to 230), Tourism (pg 231 to 238), Mining (pg 239 to 245),
3F	Development of Kagera Integrated River Basin Management and Development Strategy – Main Report – May 2010 by SWECO for NELSAP – Socioeconomic (pg 14-21), priority areas (pg 26), water use (pg 36-39), Water Demand (pg 54-59), pg 112, 117, Annex F,
4F	Country Assessments on Environmental and Social Policies in the Nile Equatorial Lake Regions – Draft Country Report – for NBI NELSAP by Judy Obitre-Gama Jan 2012. Sections 2.1 – Burundi, Sec 2.4 – Rwanda, Sec 2.5 – Tanzania, Sec 2.6 - Uganda
5F	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82), Rural Domestic Water Demand and Use (pg 85 to 105), Industrial Water Demand and Use (pg 107 to 120), Urban Water Demand and Use (pg 121 to 156)
6F	Regional Transboundary Diagnostic Analysis of the Lake Victoria Basin – Lake Victoria Basin Commission – EAC March 2007
7F	Water and Agriculture in the Nile Basin – FAO 2000
8F	Environmental Water Requirements Rapid Assessment – by Tshimanga and Ndomba 2008
B	**RWANDA**
16F	Rwanda Economic Development & Poverty Reduction Strategy 2008 – 2012 – Sept 2007
17F	Millennium Development Goals – Rwanda Country Reports 2007 and 2010
18F	Economic Development and Poverty Reduction Strategy (EDPRS) – 2008 to 2012-02-27 Millennium Development Goals 2008 to 2015
19F	Vision 2020 : 2008 to 2020
20F	Vision 2020 Umurenge Program VUP – Baselne Survey Final Report 2008 by National Institute of Statistics Rwanda and Ministry of Local Government - (English)