NILE BASIN CAPACITY BUILDING NETWORK FOR RIVER ENGINEERING (NBCBN-RE)

FLOOD AND CATCHMENT MANAGEMENT

FINAL REPORT FIRST PROJECT PHASE

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List of abbreviations and acronyms

AICAD-Africa Institute for Capacity Development
ASL-Above Sea Level
ATP-Applied Training Program
DEM-Digital Elevation Model
FRIEND-NILE-Flow Regimes from International Experimental and Network Data of the Nile
GDP-Gross Domestic Product
GEV-General Extreme Value
GIS-Geographical Information System
GPS- Global Position System
HAD- High Dam Aswan
ICRAF-International Centre for Research in Agroforestry
IMTR-Institute for Meteorological Training and Research
IWRM-Integrated Water Resources Management
JICA-Japan International Cooperation Agency
MLKF-Mitigation of Lake Kyoga Floods
MWD-Ministry of Water Development
MWRMD-Ministry of Water Resources Management and Development
NBCBN-RE-Nile Basin Capacity Building Network For River Engineering
NBI- Nile Basin Initiative
RS- Remote Sensing
TIN-Triangulated Irregular Network
WRMD-Water Resource Management Department

Preface

Part of the overall vision of the Nile Basin Initiative (NBI) has been to develop and strengthen human capacity in the Nile riparian countries for the sustainable development and management of river basins. This is being achieved through the creation of opportunities for the riparian countries to have equal access to information and knowledge through research, training and transfer of knowledge.

The Nile Basin Capacity Building Network for River Engineering (NBCBN-RE) therefore provides a platform where river engineers and water professionals are meeting, interacting, and exchanging experiences and lessons learned and are developing a common understanding and vision for the management and sustainable utilization of the Nile basin river resource. It is within this framework that so far six research clusters have been initiated, being: River Structures, hosted in Ethiopia; River Morphology, hosted in Sudan; Hydropower, hosted in Tanzania; Environmental Aspects, hosted in Uganda; GIS and Modelling, hosted in Egypt; and Flood Management, hosted in Kenya.

The Kenyan Ministry of Water Resources Management and Development (MWRMD), the University of Nairobi and NBCBN-RE organized the first regional workshop at AICAD (Africa Institute For Capacity Development) on 24th September 2003 to inaugurate the cluster on Flood Management. Two research areas; Flood Forecasting and Early Warning and Flood and Catchment Management were identified, research objectives formulated and two groups formed to start the research activities. The Flood and Catchment Management group identified four research thematic areas covering: Catchment Characteristics; Flood Hazard Mapping; Flood Control Measures; and Catchment Management Strategies.

A second regional workshop was held at Milimani Hotel in Nairobi from 3rd to 6th May 2004 where the outputs by the two groups from the start up phase were reviewed and documented. The Flood and Catchment Management group presented its output comprising of an inventory of available documents, a database of human capacity, equipment available for the researchers, working operational models and existing maps of their identified research basins.

Five research basins of Nyando and Nzoia in Kenya, Lake Kyoga in Uganda, Simiyu in Tanzania and Nyabarongo in Rwanda have been selected as research areas as they experience frequent floods. The capacity of the Toshka spillway in Egypt is being re-evaluated to increase its capacity to handle higher levels of floods.

This report highlights the activities of the Flood and Catchment Management research team and discusses the preliminary results from the first project phase. It also maps the way forward by identifying key research areas in these basins, which will be covered in the second phase of the project.

Executive Summary

Problem Definition and Problem Analysis

In many areas of the Nile Basin there is inadequate water resources management and related disaster management capacity in terms of facilities, information, manpower and funding. Poor land use practices, deforestation and catchment degradation exacerbate the effects of floods and droughts. There are hardly any effective flood control and land management practices in the Nile basin, therefore there is a need for the development of regional capacity in flood and catchment management for the benefit of all the participating countries.

Objectives

The main objectives of the first project phase are defined as follows:
- Characterizing and modelling of a selected set of catchments;
- Modelling and mapping of the flood hazard areas within these catchments;
- Documentation and assessment of the existing and proposed flood control measures and structures;
- Documentation, assessment and modelling of the existing and proposed catchment management strategies; and
- Documentation and assessment of existing land and floodwater use practices.

Achievements

Since the inception of the Flood Management node, the Flood and Catchment Management group has achieved the following:

Literature review
A literature review was undertaken by researchers and resulted in the following achievements:
- Characterizing catchments by identifying basins that are prone to annual and cyclic flooding. As a result the following basins have been selected: Nyando and Nzoia River Basins in Kenya; Simiyu River Basin in Tanzania; Lake Kyoga Basin in Uganda; Toshka Spillway in Egypt; and Nyabarongo River Basin in Rwanda.
- Statistical tools and models have been identified to verify flood hazard mapping data. The available literature indicates that in the recent past flood prediction models have been tested in the region. Relevant and/or ideal models and survey protocols to be used for flood prediction and hazard mapping have been identified and selected.
- Existing structural (construction of dykes, floodwalls, levees and embankments) and non-structural approaches on flood mitigation and management have been identified:
  - *Structural measures*: the present flood protection works consist of dykes, floodwalls, levees and embankments to confine floodwater within the river channel. Some isolated cases of cut-off ditches and drainage canals to contain floodwater can be found in the area. Cases of dikes being washed away or destroyed by pedestrians and animals are common. Lack of adequate maintenance of the dikes compromises the function of flood prevention.
  - *Non-structural measures:* a common non-structural measure has been to relocate people to higher ground so as to avoid the floods.

Traditionally, people in flood-prone areas have been living by adopting a flood proof life style such as raising banks around their houses and lands, building houses on higher grounds or raised floors, coordinating works for river bank construction and evacuation at a flood time to higher and safe grounds by village chiefs.

- The following proposed structural and non-structural measures for flood mitigation have been identified:
  - *Non-structural measures*:
    - ⇒ Development of surveillance protocol using Geospatial technologies such as Satellite imagery, Photogrammetry, Geographical Information Systems (GIS) and Global Positioning Systems (GPS) on flood warning and mapping. Such maps would indicate areas that are highly vulnerable to frequent flooding and the levels of flood protection that would be appropriate;
    - ⇒ Formulation of policies on settlement in flood prone areas; and
    - ⇒ Better design of drainage systems for roads, bridges and agricultural fields to withstand and allow for fast flow of floodwaters, improvement of catchment conservation and protection and application of appropriate onsite rainwater harvesting to reduce surface run-off; and rehabilitation of deforested catchments.
    - ⇒ Zoning is being considered by the authorities i.e. well thought-out development and settlement on natural floodplains. Restrictions are being placed on the use of low-lying lands.
    - ⇒ Flood proofing and structural changes are approaches being adopted to mitigate flood damages. Improvements are made to traditional structures to make them more resistant to occasional floods.
    - ⇒ Another way of coping with floods in these basins is flood forecasting; preparedness through early warning in order to save lives and property;
    - ⇒ A common practice is the immediate removal (evacuation) of persons and property from flood threatened areas.
  - *Structural measures*:
    - ⇒ There is a need to evaluate the current designs and to recommend standards to which permissible structures on the floodplains should comply with.
- The key problems noted in catchment management are degradation arising from deforestation caused by resettlement, dependence on wood fuel, illegal logging and encroachment. These problems are due to lack of coordination policies on land-use, water, and environment. From the literature, a terrain-based model Topog has been identified for estimating water yield, storm flow, runoff and sediment procession, and soil moisture dynamics and to simulate the responses of these processes to vegetation change.
- The floodwaters in the identified catchments are commonly used in the following ways: paddy fields for rice growing, fertility renewal through silt transported by floodwater, sand mining and fish farming and harvesting.

Proposed strategies

In the second phase of the project the Flood Management cluster, as a whole will extend its scope to the integration of flood as well as drought forecasting and management. In the same time it will increase its cooperation and try to link-up with other networks and initiatives within the Nile Basin. Furthermore studies and initiatives will be undertaken to:

- Analyse the changes in land use, climate and flood hazard areas in the identified catchments;

- Assess the effectiveness of existing flood control measures and propose appropriate actions to increase flood mitigation efforts;
- Review existing proposals for flood control and/or mitigation measures and recommend appropriate actions;
- Assess catchment management strategies, including: zoning and minimization of floodplain occupancy, reliable hydrologic definition of floodplains, and introduction of sustainable and environmentally friendly practices;
- Develop guidelines for sustainable floodplain and catchment management; develop, test and validate various models for catchment characterization and management, and liaise with the flood-forecasting group for the mapping and prediction activities.
- Develop individual and institutional capacity building through, education and training programmes for researchers in appropriate areas of river engineering that include:
    - Practical GIS applications;
    - Short courses and group trainings in Integrated Water Resources Management (IWRM), focusing on catchment management, flood and drought management, river training and river modelling; and
    - The exploration of possibilities for post-graduate curricula development in IWRM.
- Start pilot projects in the basin.

Bottlenecks and remedies
The following are major bottlenecks appeared during the first phase of the project, hindering the continuity of the project:

- Poor communication between group members and other parties involved in the Nile Basin; and
- Lack of supporting facilities such as computers, scanners, Internet systems and stationeries.

Remedies to alleviate the stated bottlenecks have to be sought in; improving communication between members by provision of functional Internet and telephone facilities; and harmonization of activities and data availability within the Nile Basin, by developing a meteorological and hydrological database, which is assessable for all NBCBN-RE researchers.

1. Background

Floods are the most common and widespread of all natural disasters except fire. Floods can be slow, or fast rising but generally develop over a period of days. Floods have caused a greater loss of life and property, and have disrupted more families and communities in the world than all other natural hazards combined. Property damage from flooding totals billions each year in the world.

There is a history of flooding of rivers in Kenya, Tanzania, Rwanda and Uganda, particularly rivers located in the Nile Basin (Figure 1.1). There hardly passes a rainy season without flooding events in the floodplains of rivers such as Nzoia, Nyando, Simiyu, Lake Kyoga and Nyabarongo.

The flooding normally disrupts human activities in floodplains. It also results in loss of life - human and livestock, damage to property, crops and infrastructure. The frequency of flooding seems to have increased with time. The Governments of the Nile riparian countries are much concerned about the flood menace, particularly in the Nile basin, due to social-economic losses associated with the flooding. There is therefore an urgent need to develop proper flood and river catchment management practices in the Nile basin.

To be able to achieve this goal, studies need to be carried out in the Nile basin in order to identify these flood and catchment management strategies or practices that can be adopted to address specific flooding problems. For example, to be able to recommend what type of measures should be developed and implemented - structural and/or non-structural - so as to contribute to flood damage reduction, there is a need to study the catchment characteristics, climatic time series (climate variability and climate change), floodplain zoning and mapping, etc. Proper delineation of the floodplain can lead to the reduction of future flood losses through regulation of developments in high risk areas, while identification of the magnitude of existing flood risks makes it possible to consider remedial measures such as diking or flood proofing to correct and/or mitigate existing problems.

Part of the overall vision of the Nile Basin Initiative (NBI) has been to develop and strengthen human capacity in the Nile riparian countries to sustainably develop and manage river basins. This is being achieved through the creation of opportunities for the riparian countries to have equal access to information and knowledge through research, training, and transfer of knowledge.

This report is prepared in line with the stated objective of identifying proper flood and catchment management strategies or practices that can be adopted to address flooding problems. In an effort to identify the existing flood control structures, land-use practices and floodwater use practices, a fact-finding mission was carried out through literature survey, interviews and site visits to some sub-basins within the Nile basin. An inventory is prepared based on the geographical areas under this specific study.

Figure 1.1: Map of Nile Basin

1.1 Identified Research Catchments

Within the Lake Victoria basin, four sub-basins are identified as research basins based on the frequency and magnitude of flood damage experienced over the years. These are the Nzoia and Nyando River Basin in Kenya, Simiyu River Basin in Tanzania, Nyabarongo River Basin in Rwanda, Kyoga River Basin in Uganda and the Toshka Spillway in Egypt.

These river basins are subject to further research in this project. A detailed description of these basins and their characteristics is presented in Chapter 4.

2. Problem Definition and Analysis

2.1 Introduction

Poor land-use practices and deforestation caused by resettlement, dependence on wood fuel, illegal logging and encroachment lead to catchment degradation (plates 1 and 2) and exacerbates the effects of floods within the Nile Basin. Lack of coordination policies on land-use, water, and environment augments the severe soil erosion and land degradation problems resulting into floods experienced periodically within the selected research basins as outlined in section 1.1.

The effects of degradation arising from poor land-use practices like deforestation are accelerating runoff and sheet erosion within the catchment area, leading to severe rill, gully, and stream bank erosion and sedimentation. Increased sediment loads cause deposition in the lower reaches of the rivers, hence accentuating flooding probabilities as shown in the plates 3 and 4. Notably erosion and runoff flows are generated over large areas where:

a) Shallow soils occur on hill slopes;
b) Fragile soils have been inadequately protected even on slightly sloping land;
c) Watershed filtering functions have reduced; and
d) The release of high discharges in downstream stretches, especially in the vicinity of the Aswan High Dam (AHD) in the Nile River, affects the safety of hydraulic structures and stability of riverbanks.

Only a minimal level of capacity in terms of facilities, information, manpower and funding for effective flood control and mitigation as well as land and water related disaster management practices exist within the Nile basin. Therefore there is an urgent need for the development of regional capacity in flood and catchment management for the benefit of all the riparian countries.

Plate 1: Deforestation

Plate 2: Forest excision or burning

Plate 3: Surface runoff **Plate 4:** Flooding (*Photos ICRAF)*

2.2 Problem Definition

In many areas of the Nile Basin there is inadequate water resources management and related disaster management capacity in terms of facilities, information, manpower and funding. The policies in place do not address flood management issues adequately and where they exist they have not been operationalized effectively. The problems are accentuated by lack of proper coordination mechanisms for sector institutions; inadequate institutional capacity; and lack of adequate skills on parts of the managers.

Further the financial resources channeled to the water sector, particularly public funding, has been decreasing with time.

These problems can be addressed through the development of human capacity by:

- Equipping human resources with the right skills;
- Providing adequate incentives and resources for performance; and
- Development of water resources management strategies for the areas that discriminates between management issues and service provision issues. For flood management issues provision for adequate and relevant information on hydrological surveys, water resources assessment, water allocation, utilization, and standard setting are necessary. This calls for documentation of existing information and setting research strategies to glean and utilize necessary information (MWRMD, 2003).

The flood problem in the Nile Basin has become endemic with time. Most of the areas in this region lack the buffering capacity to deal with the shocks of too much or too little rainfall. There is rapid destruction of the buffering zones in the basin (catchment, wetlands, and lakes) and a marked under investment in water storage infrastructure to deal with the shocks from extreme hydrological events.

Catchment degradation, encroachment into aquifer recharge areas, wetlands and lakes are features common in the basin.

Poor management of the water catchment areas have led to excessive soil erosion, rapid siltation of reservoirs, reduced hydraulic capacity of conveyance systems and water ways leading to floods in the flood plains.

The lack of investment in storage infrastructure on the other hand has led to the decline in water storage capacity. In Kenya for instance this has reduced from 11.4 m^3 per capita in 1969 to the alarming low value of only 4.3 m^3 per capita in 1999. This points to a lack of investments in drought management and/or flood protection and management. A mixture of measures can provide the buffering capacity including structural (dams, dykes, detention basins, shallow wells, boreholes, etc.) and non-structural (catchment, wetlands and floodplain management, agricultural policy, land use policy, zoning, flood proofing, flood insurance, etc.). These instruments have not been considered as a strategic part of development and planning by the involved countries within the Nile Basin.

Impacts of past and recent droughts and floods have therefore been so severe that the fragile economies will be devastated within a few months, thereby continuing to increase poverty and undoing the years of economic growth. The floods of 2004, 2003, the La Nina drought of 1998-2000 and the El Nino floods of 1997-1998 had devastating economy-wide and society-wide impacts. In Kenya for instance, the La Nina drought caused significant damages equivalent to at least 16% of the GDP in each of the 1998-1999 and 1999-2000 periods, while the 1997-1998 El Nino floods caused damages equivalent to 11% of the GDP. It is estimated that the damage to infrastructure had a replacement value of Kshs. 62 billion (US$ 777 million), water supply infrastructure damage equivalent to Kshs. 3.6 billion (US$ 45 million) and health sector costs equivalent to Kshs.4.5 billion (US$ 56 million) (MWRMD, 2003).

The damages caused by the 2003 and 2004 floods are yet to be quantified, amplifying the need for putting in place a flood management system that would both qualify and quantify the magnitude and extent of damages caused by floods.

The impacts of floods and drought has been magnified because of poor management of the land and the water resources; poor preparation for these events and; a lack of investments in storage infrastructure.

The trans boundary character of the Nile River implies that its management responsibilities cut across many nations to both controlling (flood) waters and associated natural resources management in the basin. The capacity and frame work for cooperative development and management in the basin needs to be strengthened to effectively tap on the opportunities available in the basin.

There are hardly any effective flood and land management practices in the Nile Basin and this call for the development of regional capacity in flood and catchment management for the benefit of all the participating countries. Networking, cross linkages between countries and within countries to share information and marshal resources for the development of the basin is possibilities that can redress this anomaly.

2.3 Objectives

The objectives of the first project phase are defined as follows:

- Characterizing and modelling of a selected set of catchments;
- Modelling and mapping of the flood hazard areas within these catchments;
- Documentation and assessment of the existing and proposed flood control measures and structures;
- Documentation, assessment and modelling of the existing and proposed catchment management strategies;
- Documentation and assessment of existing land and floodwater use practices.

2.4 Research Items and Methodology

Various research items have been derived from the objectives as described in section 2.2. The necessary and relevant information and data were collected by literature reviews and Internet searches. Due to the relative short time available (September 2003 – May 2004), these activities were not exhausted and were proposed to be continued in the second phase of the project.

A further refining of the problem analysis, objectives and outputs also depends on the availability and accessibility of information and data.

The various members of the research group have been carrying out the following activities in parallel sequence:

- *Characterization of catchments:*
  - Identifying and classifying flood prone sub-basins;
  - Reviewing the physical and climatologic factors of the selected sub-basins; and
  - Reviewing and documenting (hydrological and climatologic) historical trends with time series analysis in the sub-basins.
- *Mapping of flood hazard areas:*
  - Reviewing maps and data on flood-prone areas for the selected sub-basins;
  - Performing rainfall and flood frequency analysis;
  - Delineating and classifying flood and hazard areas; and
  - Reviewing existing flood mapping techniques and protocols.
- *Documentation of the existing and proposed flood control measures:*
  - Documenting existing flood control structures; and
  - Assessing the efficiency of existing facilities.
- *Documentation of catchment management strategies:*
  - Documenting existing land-use practices within the selected basins;
  - Documenting existing floodwater use practices in the selected basins;
  - Assessing the adequacy of the existing floodwater use practices;
  - Assessing the existing catchment management strategies; and
  - Proposing measures to increase the efficiency of catchment management strategies (including the use of models).

3. State of the Art

3.1 Characterizing and Modelling of Catchments

The most important catchment characteristics that influence the occurrence and management of floods are; catchment boundaries, geology and soil cover, land cover, altitude, aspect (orientation of land to the sun’s east-west circuit), slope and the layout of streams and rivers (routing)

Jaetzold (1983) characterized catchments into the following three zones based on slope: 0 -12% (Lowlands); 12 - 46 % (Midlands); and above 46% (uplands).

3.2 Modelling and Mapping of Flood Hazard Areas

Flooding arises as a result of river flows overtopping the banks and inundating the adjacent low-lying areas. This condition often causes a lot of damage to property and crops and may result in loss of life and disruption of human settlement and comfort. In Kenya, flooding occurs very frequently especially in the Lake Victoria basin.

Flood mapping of historical floods and design events can be combined with other geographical information in a detailed assessment of the risk and potential damage of floods. Maps showing the potential flood extent, duration, depths or velocities form a sound basis for floodplain management and development, emergency planning and for raising the awareness of authorities and the endangered population.

3.2.1 Development and Selection of Models

There are different practical and scientific criteria that influence the development or the choice of an appropriate model structure. Spreafico (2000) categorizes them as follows:

- Model structures as a function of the goal of the study;
- Model structure as a function of resolution;
- Model structure as a function of catchment characteristics;
- Model structure as a function of available data;
- Model structure as a function of process knowledge; and
- Model structure as a function of available means.

Modelling Approaches
Generally the hydrological models available today can be categorized in two dimensions: the first dimension is whether a deterministic or stochastic approach is chosen. A stochastic model produces an outcome accounting for randomness and uncertainty of the predictions. This means that the simulations will not give the same results when repeated with the same input data.
With most stochastic models the approach is to conduct a multitude of simulations, the so-called Monte Carlo technique, and produce average estimates with specified confidence intervals. Where as deterministic models produce a single outcome for one set of input data and parameters.

A second dimension is the extent to which a model goes into detail: we distinguish so-called ‘lumped’ and ‘distributed’ models.
The models can also be classified whether the description of the hydrological process is empirical or physically based.

There are three major types of deterministic models: empirical lumped models, empirical distributed models, and physically based distributed models. The fourth combinatory type would be the physical lumped model, but this concept is somewhat contradictory, since physical models require measurable input data whereas lumped models use average for an entire catchment.

Olsson and Pilesjo (nd) have reviewed approaches on spatially distributed hydrological modelling under a GIS environment and recommended Physical based models as the most suitable for studying internal catchment change scenarios. Examples of this are irrigation and ground water use development. The prediction of discharge from catchments including monitoring of pollutants and sediments dispersed by water is also well suited for a physical model. Olsson and Pilesjo also cite the suitability of lumped models in rainfall-runoff modelling and state that distributed hydrological models have particular advantages in the study of the effects of land use changes. The models not only provide a single outlet discharge, but multiple outputs on a temporally and spatially distributed basis. The disadvantage with this form of modelling is the large amounts of data and the heavy computational requirements. The model type also includes a large number of parameters and variables, which have to be evaluated.

It is therefore important that during the selection of the model(s) to be used in the second phase of the project the above-mentioned criteria are taken into account. However, specific model(s) are still being reviewed; a process which will be continued in the second phase of the project, therefore no selection has been executed yet.

Application of GIS, GPS, RS in modelling and mapping of flood hazard areas
There is growing evidence that the closer integration of GIS with hydraulic modelling software can assist water authorities to meet regulatory requirements, achieve financial targets, carry out design work, and improve the operational and environmental management of rivers. The key data requirements for river models are the cross sectional profiles and elevation data relating to the river flood plain. Profile data represented by a series of x, y, z-values (z representing elevation) does not have to be managed and served to the modelling system using a GIS, but the preparation of a digital elevation ‘ground model’ of the floodplain is perhaps the clearest example of the necessity for integrating GIS technology. In order to analyse, display terrain features and fit surfaces to the elevation data, the grid data is converted using GIS technology to a “triangulated irregular network” (TIN) dataset. A TIN dataset represents a surface derived from irregularly spaced sample points and breakline features, with the points comprising x, y, and surface or z-values, and a series of edges joining these points to form non-overlapping triangles. Using TIN/GRIDDED elevation data in modelling software enables the direct take-off of elevation data to facilitate the extraction of model sections and floodplain storage properties based on overlaid section locations and boundaries. The TIN/GRID is also used to generate and display ground level contours, and forms the basis for dynamic flood mapping. River modelling products now have full flood-mapping capability based on sophisticated flood-interpolation models overlaid onto a TIN/GRID based ground model (Wallingford, 2002). Space technology therefore provides a means for mapping and analysing flood-affected areas and facilitates the running of a system

for disseminating earliest information to various agencies for carrying out relief rehabilitation measures and for restoration of normalcy.

The establishments of efficient flood management strategies require comparative assessments of potential financial benefits of flood management scenarios in terms of avoidance of damage to property and infrastructure, loss of income, etc. The assessments could be done efficiently and in a timely manner on the basis of GIS tools in combination with other information systems and hydraulic models. Damage assessments can be made using tools that relate the modelled flood levels and extent to the property affected.

In the long-term, decision makers need to assess the risk as well as the cost and benefit of alternate strategies such as zoning controls, regulation of construction and developments on floodplains, flood proofing, optimisation of reservoir and structure operation, flood insurance, embankments, polders, flood diversion channels, real-time monitoring, etc.

Flood management strategies are often developed with the objective to reduce the impact of flooding on a community. The financial benefit in terms of flood damage reduction is an important criterion for the evaluation, ranking and selection of appropriate flood mitigation options. Islam and Sado (2000a) have developed a GIS toolkit for mapping flood hazard areas and to assess potential damages by floods. Islam and Sado (2000b) found that the combination of land cover, physiography and geology gives a good combination of a GIS database for producing a flood hazard map with details on flood depth and flood-affected frequency.

Cross-indexing of hydro meteorological information between catchments clearly merits investigation, especially between catchments in the same general hydro climatic region. It will likely to be aided by the existence of some remotely sensed data to help with the scaling issues and to act as a bridge from ungauged to gauged catchments.

3.2.2 Flood Hazard Mapping in Gauged and Ungauged Catchments

3.2.2.1 Introduction

Flood hazard maps form the basic tools for planning, designing and implementing engineering projects for the purpose of flood and drought mitigation and defence.
Foremost the Flood and Catchment Management research group envisages the application of flood hazard maps for the purpose of developing and assessing flood and catchment management strategies and to disseminate relevant information before, during and after flood disasters on a regional scale.

The following river basins, Nyando and Nzoia in Kenya, Simiyu in Tanzania, Nyabarongo in Rwanda and Toshka in Egypt are selected for the study and they are all being considered as gauged. The Nzoia Basin had 62 gauging stations by the year 1960 of which 30 have been closed while the remaining 32 are still operational. In the Nyando Basin there were 41 gauging stations by 1960. In 1980 only 10 gauging stations were operational with the remaining 31 stations closed due to lacking finances for maintenance and operation.

Flood hazard maps are very data intensive in nature and primary depend upon very high-resolution terrain data. For the purpose of this project, flood hazard mapping will be addressed from the perspective of different mapping scales in a GIS environment. The study will be done in a regional and sub-regional scale. Administrative units will be selected as the units of investigations. This will be a proof to planners and administrators for the formulation of remedial actions. It will also make the process of resource allocation simple resulting in smooth and effective implementation of the adopted flood management strategy. The regional study will however identify the high hazard areas in the river basins of the study. In Kenya for example sub locations are the smallest administration units. It is also the highest spatial resolution of census data collection. They will therefore form the units of data input for the sub-regional scale.

The choice of variables

On a regional scale five factors will be taken into consideration for developing a composite flood hazards index. Different weights will be assigned to each of the factors to quantify the severity of the hazard.

i. A *Flood frequency analysis* will be carried out. The frequency of flood occurrence in the last 50 years will be considered as the measure of flood proneness of a particular area. The variable will be named ‘flood prone’.
ii. *Economic assets and population density*: Population density figures will be calculated from the latest census data (1999 for Kenya). This variable will be used to quantify economic assets under potential flood threats and also to show the intensity of land-use.
iii. *Road Network*: One component of the flood mitigation strategy is a fast evacuation during severe floods. Availability of surfaced road per e.g. km will be considered to quantify the ease of movement. Statistical handbooks and National ministries in charge of roads will provide this key data.
iv. *Water supply*: Access to safe drinking water will be considered as a key factor to prevent hazards like out break of water borne diseases. The variable will present data on the percentage of villages or households having no access to safe drinking water in relation to the total number of villages and households in the unit of study.
v. *High ground/Shelter*: During time of inundation affected population may be required to be evacuated to a safe place for temporary shelter. Relatively higher grounds not likely to be submerged by floodwaters can serve as temporary flood shelters. Availability of such high grounds will be derived from digital elevation models to be developed from toposheets and Landsat TM Imagery. The spatial revolution of this data is 30 m and elevation data stored in each of the pixels will not be absolute but the difference in elevation between two pixels will be absolute. Therefore the dataset will be used to extract topographic features like (peaks), high grounds and will be treated as potential shelters from floods.

A principal analysis of the above-mentioned factors will be used to formulate a composite hazard index, since its objective judgment is based purely on mathematical criteria.

3.2.2.2 Data Collection and Analysis for Rainfall Runoff Modelling

Data collection Systems

A well designed data collection system and instrumentation is a prerequisite for an effective flood hazard mapping processes. Real time stream gauging and precipitation measurements and historical data will have to be collected to collate, review and record information. A hydro-metrological data acquisition system and existing maps will have to be applied to provide key information of three different types:

a) Water surface elevations at chosen locations through out the river system in the selected catchments;
b) Rainfall data from the gauge networks for the ungauged sub catchment areas;
c) Information on watershed physiographic characteristics from maps and ground surveys that describe soils, land-use, geology and topography.

Secondary, data from the NBCBN-RE River Morphology cluster data will be used to characterize the rivers in hydrological, morphological, ecological and functional points of view of the individual river system at the critical points of study.

Gauged catchments

The application of GIS that incorporates the use of remote sensing in hydrology would be applied to derive physical model parameters from the geo characteristics data such as toposheets, soil maps and gauged stations. Conceptual parameters however, will be calibrated using available rainfall and runoff data with the help of optimisation algorithms. The optimisation parameters would be determined and used by models to improve data records in gauged catchments using available rainfall data for missing runoff data.

Sub-catchment areas will be selected within each basin of study and stratified in terms of altitude as high, medium and low land. Areas with high rainfall that experience denudation will be selected against areas with low denudation and high siltation processes.

The ‘Bochum model’ (Onyando, 2000) could be used, since its conceptual parameters can be correlated to catchment characteristics. Further more it simulates interflow in addition to surface run off. The physical parameters in the model will be derived from catchment characteristics using GIS, while conceptual parameters will be calibrated with the help of optimisation algorithms using half of the rainfall-run off data. The remaining data will be used for validation.
The ‘Bochum rainfall-runoff model’ has 19 parameters. Six of these are conceptual parameters while 13 are physically based as listed in Onyando (2000).
Onyando (2000) found the ‘Bochum rainfall-runoff model’ to be more suitable in generating runoff and stream flow inputs in humid zones. The model is found to be suitable in areas with drainage and excess erosion from surface runoff, factors that are prevalent in the study areas proposed for this project.

The cross section geometry will be obtained from the NBCBN-RE River Morphology cluster and also gleaned from a Digital Elevation Model (DEM) to be created from Land sat TM Imageries.
The geometry of rivers and structures will also be studied and indicated through site visits.
Values of river slope and Manning’s roughness coefficients will be obtained from existing literature and also gleaned from digital photographs to be taken during field visits.

Ungauged catchments

One way of generating data in ungauged catchments is through the use of regionalized rainfall-runoff models. The process will involve the correlation of conceptual parameters to catchment characteristics from several gauged catchments. GIS will be used to derive the physical parameters, which are needed for correlation. Correlation equations will then be used to derive the conceptual model parameters from ungauged catchments in the same climatic and geographic area. Once all the parameters are determined, direct runoff in ungauged catchments will be determined with rainfall data. Onyando (2000) successfully regionalized data acquisition and used a mesh-cascade-Diskin infiltration model in simulating rainfall-run off processes in humid areas of ungauged catchments in Kenya.

Data acquisition will involve keyboard entry of tables and digitisation of maps in suitable digital formats. Tabular data will be acquired by file transfers from various databases, owned and maintained by national organizations and institutes. Key geo-data for designing spatial catchment characteristics will be soil data, land-use data and toposheets.

Soil data

The soil data required would be obtained from reports of past field surveys and this will be augmented by site evaluations. Soil types and hydraulic conductivities will be established while other soil characteristics will be obtained from standard tables based on the soil texture.

Land-use data

Land use data will be derived from aerial photographs and Land Sat TM data. Satellite imagery will be obtained from USGSS as appropriate while the aerial photographs will be obtained from national survey offices. Data on soil depths that are necessary in land-use studies will be derived from general guidelines given by Onyando (2000).

Toposheets

The toposheets for the catchment will be used to derive contour and stream coverages necessary for determining digital elevation models.

Imagery Processing

Data from satellite imagery will be processed using suitable software (ERDAS, ILWIS, IDRISI) to extract relevant information for hydrological purposes.

The process of rationalization relates flow characteristics at gauging stations to physical and climatic characteristics of the drainage basins. Hence, rationalisation derives transfer functions between model parameters and catchment characteristics to use such functions in ungauged catchments. These characteristics are obtained from maps and weather records, and therefore could also be extracted for ungauged catchments, to enable the use of derived relationship to estimate flow characteristics in the ungauged catchment.

Data collection required for ungauged catchments

In order to simulate runoff and stream flow in ungauged areas, the following will be assembled (Pitman, 1973):

a) Monthly rainfall totals at selected gauges within the catchment.
b) Mean monthly pan evaporation for the catchment.

c) Model parameters for the mesh-cascade-Diskin Infiltration model consisting of surface runoff generation and runoff routing components. The model structure is illustrated in Onyando (2000). The model has only one physical parameter, which is derived from catchment characteristics, and flow conceptual parameters optimised for every catchment.

Table 3.1: Parameters for mesh cascade-Diskin Infiltration model

Parameter	Description	Method of Determination
Run off variance parameters		
S_m	Maximum soil storage capacity	Land-use and soil types with the help of GIS
S_0	Initial Mc of upper soil zone	Optimised
f_0	Initial infiltration capacity	Optimised
f_C	Minimum rate of infiltration capacity	Optimised
Run off routing parameter		
n	Number of linear reservoir cascade	Optimised
k	Storage constant of proportionality	Optimised

Routing will be achieved through the mesh model that uses parameters n and k (Table 3.1) in a cascade form to route the flow. For tropical catchments, the method of moments and optimisation are found to give better estimates of the parameters and will therefore be adopted for this work (Onyando, 2000). Both parameters will be optimised using the SCE-UA global optimisation algorithm as described in (Onyando, 2000).

3.2.2.3 Flood Frequency Analysis

The methods of estimating design floods fall into two main categories; those which are deterministically based which treat floods as the product of specified precipitation falling upon a specified catchment area, and those which are probabilistically based, which treat floods as almost purely random events susceptible to statistical analysis.

Data acquisition, verification and analysis
For homogeneous rainfall zones several delineation methods, such as the principle component analysis (Basalirwa, 1995) can be used. In selecting the necessary data, a distinction has to be made between site statistics and at-site characteristics. At-site statistics are quantiles calculated from at-site measurements of discharge (Q). Site characteristics include all other physical properties associated with the location. These include the geographical location of the site, its elevation, time of the year when the annual maximum event (flood or rainfall) occurs, etc. It is usually advisable to base the formation of regions on site characteristics and to use the at-site statistics only for subsequent testing of the homogeneity of a proposed set of regions (Cavadias et al., 2001). A statistical test can be employed in order to ensure that the regions obtained are indeed homogeneous. The underlying distributions for each region can then be identified using the L-moment ratio diagram coupled with the goodness of fit test statistics (Chowdhury et al., 1991). The identified frequency distributions are then subjected to predictive ability tests to verify their robustness in estimating the real life behaviour of the catchments. Regional parameters of the identified distribution are estimated and the frequency curves (flood magnitudes or flow ratios versus return period, Q-T) are drawn for each region.
The curves are used to design an economic appraisal of civil engineering structures to estimate flood risk and for environmental purposes, particularly floodplain management (Mkhandi and

Kachroo, 1997). Regression analyses are carried out to generate a model for estimating the mean annual flood from correlation matrices of catchment characteristics such as area, slope, and length and mean annual rainfall.

Gauged catchments

Determination of design floods

Flood discharges with a return period of 50 years will be estimated using regression equations that will be developed using data from the stream flow stations. The minimum length of required time series is 10 years of annual peak flow records. Furthermore, historical water level and discharge data has to be homogenised to ensure that the sample elements (single peak flows) belong to the same population (entire data set).

Homogenisation of data excludes the effects of human interference in the river system.

Design water levels for levees and embankments

Exceedance frequencies have to be determined to compute and assess design water levels. The design water levels will be based on the design discharge to be set during phase two of the project and in liaison with the country water bodies and Ministries by applying standardized statistical frequency analysis of the available historic discharge records within the river basins. River management strategies will be developed to factor in existing floodplain projects and also to make improvements to cater for changed discharge regimes that may be occasioned by climate changes. Assessment criteria for safety against flooding will be instituted. These criteria could be based on the design water levels and could factor the length of the river stretch that is prone to flooding.

Ungauged catchments

The use of regional information to estimate flood magnitudes at sites with little or no observed data has become increasingly important because many projects, which require design flood information are located in areas where observed flood data are either missing or inadequate (Mkhandi and Kachroo, 1997).

The sub catchments in which the gauging stations have been closed will be considered as being ungauged. The flood prediction within the catchments will be done in line with the following principals:

- Stochastic properties of hydro meteorological entities determined in gauged catchments are transferred to ungauged catchments using new scaling methodologies, drawing on any available relevant information on land cover and topography.
- Stream flow in the ungauged catchment can be simulated by a desegregation procedure utilizing the stream flow data from the larger gauged catchment in which the assumption that the stream flow contribution from each sub catchment to the total catchment yield is proportional to a ratio of the catchment area and its average slope. The modeled stream flow can be compared with the measured data to establish the accuracy of the relative error on a selected time step and location.
- The estimation of the mean annual flood will be useful for ungauged catchments. The efficiency of the estimation will be assessed by the sample coefficient of determination and the standard error of estimate.

For flood hazard mapping in the flood frequency analysis aspect, the studies can be carried out through regional flood frequency analysis using L-moment ratios, which involves data quality checks followed by a definition of hydrological homogeneous regions. For data quality checks, the sample L-moment ratio for different sites can be compared. In this way incorrect data values and outliers, trends and shifts in the mean can all be reflected in the L-moments of the sample (Hosking and Wallis, 1997). As for identification of homogeneous regions, the aim is to form groups of sites that approximately satisfy the homogeneity condition, i.e. that the site's frequency distributions are identical apart from a site-specific scale factor. This is usually achieved by partitioning the sites into adjoint groups. Alternatively, each site of interest can be defined as a region containing those sites whose data can advantageously be used in the estimation of the frequency distribution at the site of interest. This is called the 'region of influence' approach (Zrinji and Burn, 1994).

The basis of the deterministic approach is that floods are physical phenomena, which result from an input of precipitation and drainage basin characteristics. Many attempts have been made to relate precipitation and catchment variables in order to estimate the maximum flood discharges in ungauged basins. The simplest empirical formulae for flood discharge use the simple parameter of drainage area and take the following forms (Gray and Wigham, 1970):

- $Q_m = CA^n$;
- $Q_m = CA^{mA^{-n}}$
- $Q_m = \{CA/(a+bA)\}\ m+dA$

Where Q_m is the maximum flood discharge, *A* catchment area, n and m are exponents and C, a, b, d are coefficients, which must be evaluated for an area depending upon its geographical and climatologic characteristics.

These types of empirical formulae do not contain a specification of the expected frequency of the calculated flood. However, in some cases, an explicit frequency term is included to yield formulae of the general type, such as (Gray and Wigham, 1970) :

$$Q_t = CA^{\,n}T$$

Where Q_t is the flood discharge having a return period of T years.

Other more elaborated empirical formulae rely on a broader and/or more detailed data base and have incorporated additional characteristics, such as precipitation characteristics, hydrograph shape, and mean catchment slope, and have often included an explicit frequency term. Rodda (1969) combined various catchment and precipitation characteristics in regression analyses and found that the most satisfactory prediction of the mean annual flood for UK was obtained from:

$$Q = 1.08A^{o.77}\ R^{2..92}\ D^{0.81}$$

Where Q is the mean annual flood, *A* is catchment area in square miles, *R* is mean annual daily maximum rainfall and *D* is drainage density in miles per square miles. A regression analysis was repeated to determine the T-year flood using daily maximum rainfall for appropriate recurrence intervals and assuming equality between rainfall and discharge recurrence intervals, which resulted in:

$Q_{10 = 1.22}A^{0.69} R^{1.63} D^{1.06}$ $\qquad\qquad$ $Q^{50} = 1.24A^{0.51} R^{2.02} D^{0.94}$

However, the assumption of equality between rainfall and discharge recurrence intervals introduces a major inaccuracy in the determination of the T-year flood, since catchment characteristics and rainfall runoff have not been taken into account.

In Kenya various studies have been done to predict the probability of occurrence with a certain magnitude of peak flows. The main objective of the studies was to identify the most appropriate mathematical probability functions that could well describe the high flows in Kenya.

Ilaco (1975) fitted lognormal, extreme type 1 and log extreme type 2 distributions to annual maximum floods at various stations in the Yala River. He used the method of least squares and found that the two parameter lognormal distribution gave good results (best fit). Mutua (1986) investigated and modelled the following distributions using annual peak discharges from several stations in the country: Three-parameter lognormal, Pearson type III, Log Pearson type III, Fisher Tippet type, Log Fisher Tippet Type, Walter Boughton, Log Walter Bought, Wakeby and log Wakeby distributions. His study revealed that unlike the Log Pearson type III, which is found to fit data in many countries, the Wakeby distribution fitted well the selected peak discharges in Kenyan rivers. He recommended the use of the Wakeby distribution wherever possible. An earlier study by Mutua (1985) on the adequacy of the Walter Boughton distribution for Kenyan river data showed that the log Pearson distribution could not be satisfactorily applied to all the catchments due to a negative skew in maximum value data. The Walter Boughton distribution fitted all the data very satisfactorily in all catchments of five drainage basins.

Lugania (1987(a) and (b)) applied the flood index method to three major river basins (i.e. Lake Victoria, Arthi River and Tana River). Regional frequency curves for the Lake Victoria Basin and Tana River Basin were developed. Lugania studied the two- and three-parameter lognormal; two- and three-parameter Gamma; and Fisher Tippet or extremal distributions with the objective of deriving a distribution that may be applied in flood frequency analysis at single sites in Kenya. He found that the three-parameter lognormal distribution, using the method of maximum likelihood, performed well. Opere (1998), after modelling a General extreme value (GEV) distribution, using probability weighted moments, recommended GEV and 4 parameter Wakeby distributions for the use in regional flood frequency analysis. The study carried out by Ogallo et al (1987) on observed annual maximum rainfall series in Kenya indicated that high values of rainfall are found along the coastal belt, Lake Victoria and most parts of northern Central Kenya. Extreme values of 100-year, 200-year and 500-year return period were computed. No studies have been carried out on flood plain mapping in the country.

3.2.2.4 Hydrodynamic Modelling

Data synthesis and analysis

In order to develop a hydrodynamic model for flood hazard mapping, the following data synthesis and analysis has to be performed:

1) Characterize rivers on the basis of data and outputs from the NBCBN-RE River Morphology cluster. Important characteristics like channel lengths and widths, width and number of floodplains have to be delineated.
2) Water levels and meteorological data have to be used to determine the flow rate at each site using rating tables;
3) Runoff characteristics have to be estimated using physiographic characteristics of the catchment.

Model characteristics

The flow of water through the soil and stream channels of the catchment areas will be treated as a distributed process because the flow rate, velocity and depth will be assumed to vary in space through out the catchment (Chow et al., 1988)

Estimates of the flow rates or water levels at selected locations in the channel system will be produced by using a distributed flow routing model. The model, which is based on the Saint-Venant equation for one-dimensional flow computes the flow rate and water levels as a function of time and space.

The advantage of using a distributed flow routing model is that it will compare the flow rate and water levels simultaneously and therefore approximates the actual unsteady non-uniform nature of the flow propagation in the river channel.

The computed flood flow rate will be used to determine flood water levels and could also de applied to establish inflow hydrographs for the design of flood storage structures such as detention pond or reservoirs.

The computed flood water levels are used to delineate the floodplain and later on in the project could determine the required height of structures such as bridges and levees.

Schematisation

Since the length of the coverage areas is much bigger than their width, a one-dimensional hydrodynamic model will be used. This will be developed with a GIS. Different sources of data will be collected, digitally stored in a shape file database and converted to grid files. The data will include main channel bed levels, floodplain elevations, crest elevations of (natural) levees and embankments, and location of groins and submergible embankments, floodplain lakes and flow characteristics. The use of grid files will allow for a simple combination of different types of spatial information to generate imagery, out representative and cross sections for every compartment of the hydrodynamic model. Each cross section will delineate three elements: a main section (main channel), a bank section (groin section) and a floodplain section. These separations will allow for allocation of different hydraulic roughness values to each section.

3.2.2.5 Flood Inundation Maps

GIS coverages of the flood prone areas with delineation boundaries for various flood frequencies, inundation depths, flow velocities, etc. will be processed with the results from the hydraulic model.

Water surface profile of the 50-year flood

Based on the 50-year flood discharge estimations, water surface profile elevations along the rivers will be computed with a step back water model and will be used to generate flood inundation maps. A one-dimensional steady flow model for computing water surface profiles in open channels will be used. The U.S Army Corps of Engineers HEC-RAS modelling system will be applied for this purpose. Input data of stream discharges, river and floodplain cross sections (geometry) perpendicular to the direction of the flow, bridge and levee geometry and Manning roughness values will be derived from the hydrological routing and hydrodynamic models.

Water surface elevations will be converted into topographic TIN files. A Digital Elevation Model (DEM) will be produced with Land Sat TM data. The coverage will then be overlaid with the existing digital raster graphic maps, which will be obtained from topographic maps.

The depth of inundation for the 50-year (design) flood will be computed by subtracting the topographic TIN file from the computed water surface elevation TIN to produce a grid with a certain cell size.

3.3 Flood Mitigation Measures and Structures

Flood mitigation refers to measures adopted to reduce damages to life and property by floods. Complete control of a flood event to a zero loss level is neither physically possible nor economically feasible (Chow, 1964). The flood mitigation measures that are in use in the Nyando and Nzoia river basins can be classified as structural (levees or dykes, flood ways, channel improvements, storage and detention reservoirs, soil conservation and channel improvement; JICA, 1992a) and non-structural (evacuation, relocation, and watershed management (Kraijenhoff and van der Laur, 1973).

In the world, humans have built an elaborate network of structures in order to control flooding. Many of these structures have been very successful and have helped to improve human life.

Flood control on major streams should be developed by engineering analysis, based on a holistic and integrated approach, taking the whole basin into account. To be complete, the flood control aspects must include floodplain management.

3.4 Catchment Management Strategies

The largest change in terms of hydrology often arises from channelling, deforestation and afforestation. There is a strong relation between the land-use, runoff, and sedimentation from drainage basins, which are the initial point sources for floods downstream. Catchment degradation is a result of the non-sustainable use of land and natural vegetation, such as poor farming practices (over cultivation and over grazing), deforestation and badly planned urban and infrastructure developments.

Some zones, particularly upper-catchment areas with high rainfall amounts, are particularly sensitive to degradation and have major impacts on water resources. The natural vegetation in these areas could either be forest or farm lands. The causes of deforestation include resettlement, dependence on wood fuel, illegal logging and encroachment. Forest excisions as witnessed in the years 2000 to 2002 in the five major catchments of Kenya have aggravated the problems further.

Given their already degraded conditions, their impact on runoff and infiltration is likely to be very significant and will undermine the limited sustainable water resources base that is remaining in Kenya. Effective catchment management should involve the formulation of harmonized policies on land-use and spatial planning for agriculture, wildlife, environment, industry, forests, soils and water as well as the improvement of coordination and collaboration in catchment management across Government ministries and Departments.

Catchment management practices and their effects on runoff can be assessed using terrain-based physical models like the ‘TOPOG’ and ‘Bochum’ models. ‘TOPOG’ is a process-based model for producing water yields, storm flows, runoff, sediment processes and soil moisture dynamics. The model also generates the output parameters in relation to changes in vegetation cover. It covers small catchments of less than 10 km^2 and is therefore suitable for site-specific studies. The ‘Bochum model’ covers bigger areas and could be used on larger scales.

4. Research Results First Project Phase

4.1 Catchment Characteristics

Within the lake Victoria basin, four sub-basins are identified as research basins based on the frequency and magnitude of flood damage experienced over the years. These are Nzoia and Nyando River Basin in Kenya, Simiyu River Basin in Tanzania, Nyabarongo River Basin in Rwanda, Kyoga River Basin in Uganda and the Toshka Spillway in Egypt.

4.2 Nzoia Basin (Kenya)

The Nzoia River originates at an elevation of about 2,300 m a.s.l. In the South Eastern parts of the Mt. Elgon and Western slopes of the Cherangani Hills (Figure 4.1). It discharges into Lake Victoria just a short distance north of Yala swamp in Bunyala, Budalangi Division, and Busia District. The basin covers a catchment area of about 12,696 km^2 with a heavy forest cover in the upper parts of the catchment and low trees and bushes in the lower reaches. The catchment area is bounded by latitudes 1^o 30'N and 0^o 30'S and longitude 34^o E and 35^o 45'E.

The catchment area may be divided into two sub-catchments. The Lower Nzoia sub-basin, bounded by latitude 0^o 04'N and 0^o 11'S and longitude 33^o 57'E and 34^o 14'E covering an area of 8,500 km^2 with an altitude varying between 1,130 m and 1,225 m a.s.l. The area is generally flat and swampy. The permanent swamps cover a total area of 25 km^2. The Upper Nzoia sub-basin is bounded by latitude 0^o 04'N and 0^o 55'S and longitude 34^o 55'E and 35^o 10'E and covers a total area of 1,500 km^2. The landform is hilly with steep slopes. The altitude of the sub-basin varies between 1,625 m and 1,825 m a.s.l. The minimum and maximum elevations are respectively 1,917 m a.s.l. and 4,300 m a.s.l. The middle Nzoia at Moi's bridge has a catchment area of 1,470 km^2.

The main streams within the Nzoia Basin are River Nzoia, River Kuywa and River Moiben. Both rivers Kuywa and Moiben drain into the Nzoia River. The Moiben River has a catchment area of 262 km^2.

Hydrology and climate

The mean monthly rainfall trend represents two maxima and minima over the year. The first and second maxima occur from April to May and July to November respectively. The minimum and maximum mean monthly rainfall is 20 mm and 200 mm respectively. The mean annual rainfall varies between 1,000 to 1,500 mm. The upper catchment is characterized as a high rainfall zone with a mean annual rainfall varying between 1,500 to 1,700 mm.

The length of the main stream is about 252 km with a fall of about 1,200 m giving a 0.5% slope in the upper reaches, which reduces to 0.04% in the lower reaches over the last 30 km. Over this stretch the river meanders and causes deposition of silt due to the low gradients. The sediment accumulates and reduces the discharge capacity of the river channel so that it over flows its banks causing flooding in the lower reaches of the basin.

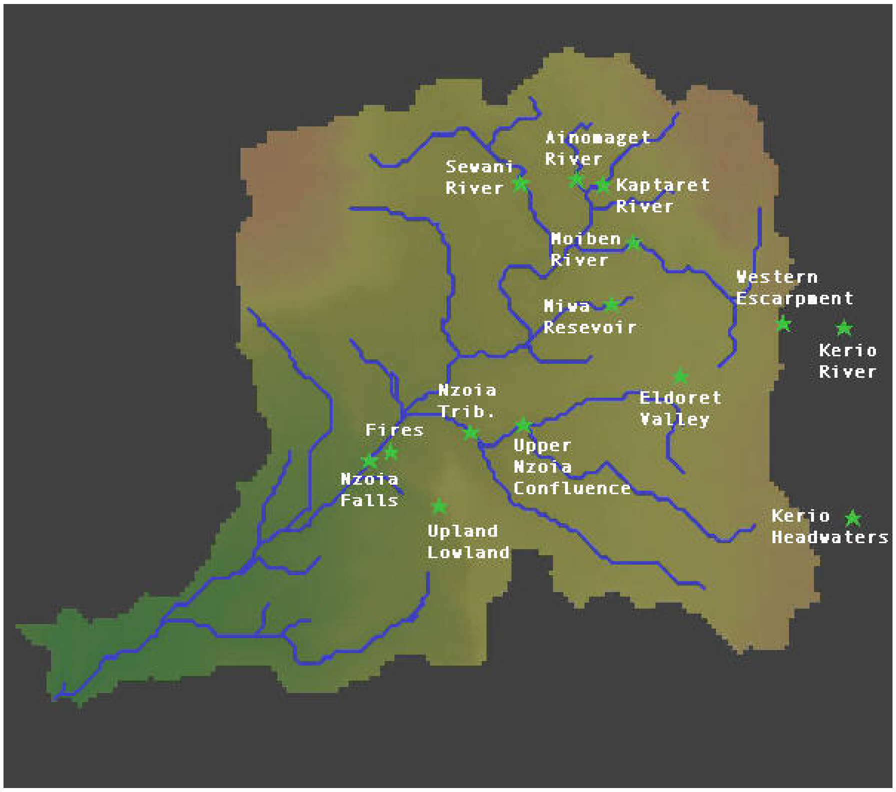

Figure 4.1: Map of Nzoia Basin

The discharge varies from low flow of 28 m^3/s to maximum of 930 m^3/s. The highest river discharges occur between May and September while the lowest river discharges occur between January and March. The annual runoff amounts approximately 310 mm with a runoff ratio of 21.7%.

Soils

The soils of the floodplains in the lower reaches of the Nzoia River are all of alluvial type. The river meanders in the floodplain depositing silt during seasonal floods. The major parts contain black cotton soils while other areas have coarse textured sand silt mixtures. In some places, saline soils exist. The upper Nzoia basin contains extensive seasonal swamp areas in the high and medium rainfall zones that are mainly utilized for grazing due to poor drainage.

4.3 Nyando Basin (Kenya)

The catchment area of the Nyando river system (Figure 4.2) is situated in Kericho and Nandi Districts, approximately 2000 m a.s.l. With a mean annual rainfall, varying between 1,800 mm and 2,000 mm. The basin covers an area of about 4,480 km^2.The rivers in the basin have steep defined courses in their upper reaches, but after reaching the flat low-lying areas downstream they meander and periodically overflow their banks before terminating into swamps neighbouring Lake Victoria. The vegetation cover of the upper catchment mainly consists of forest (Tinderet forest), while the middle part of the catchment may be classified as vegetative i.e. scattered trees and grass, which has greatly been modified by clearing, cultivation and burning due to human settlement. There are two major irrigation schemes in the Nyando area: Ahero scheme and West Kano scheme.

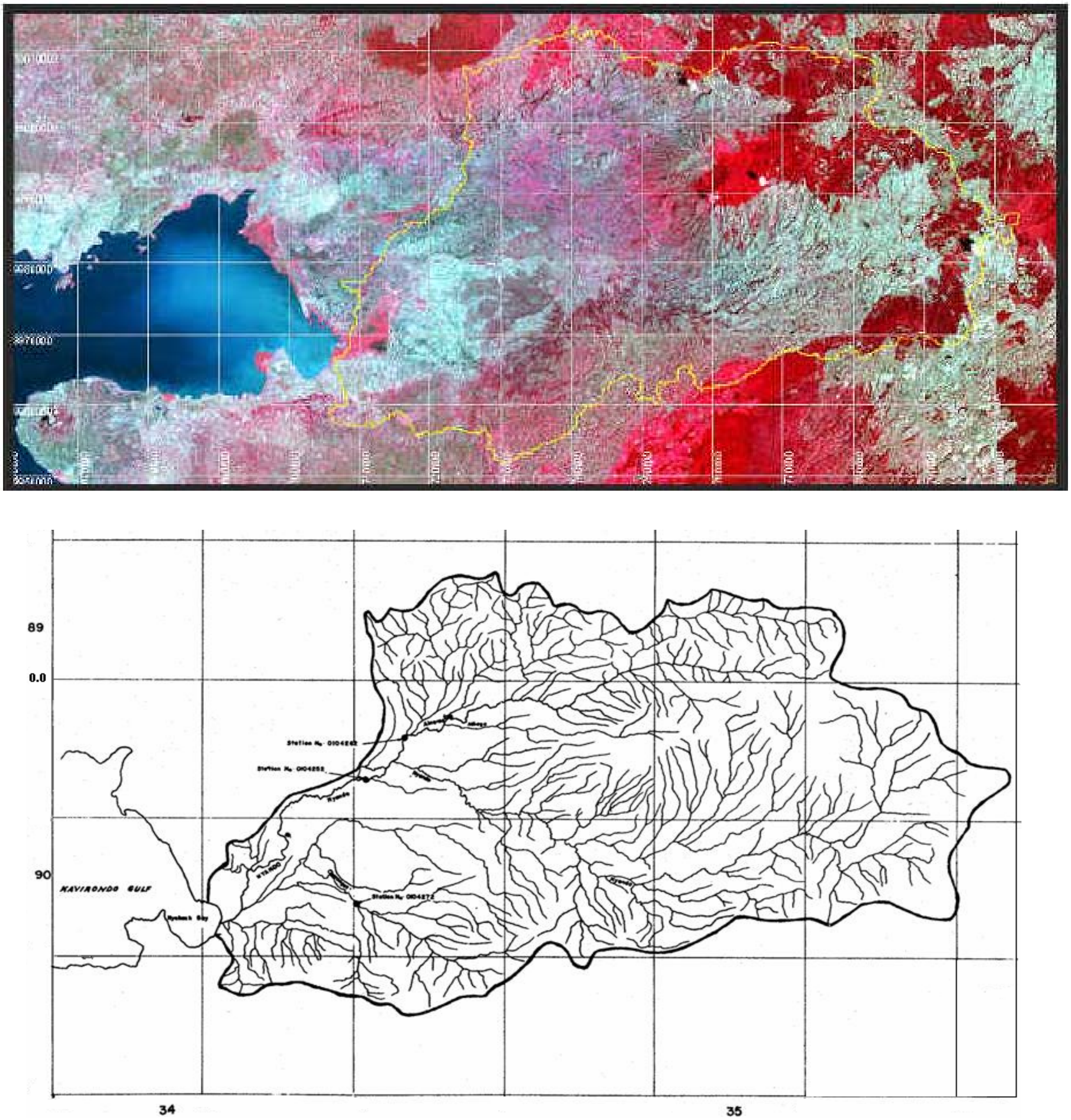

Figure 4.2: Nyando River Basin (Satellite image and Hydromet)

Hydrology and Climate

The main rivers in the lower plains are the Kibos and Nyando. Other smaller rivers are Luanda, Nyaidho, Miriu and Awach. The length of the Nyando River is around 142 km and its discharge ranges from a minimum of 2 m^3/s to the extreme flood of 850 m^3/s, which occurred in 1961. The river has a relatively high silt load.

The lower plain experiences a mean annual rainfall of 1,260 mm, most of it falling between March and May and a smaller peak between September and November. Extreme droughts occur in January and February. Severe convectional rains occur near the shores of Lake Victoria and the highest recorded intensity has been 23 mm during a five-minute period in 1961. The mean annual maximum temperature ranges between 25 and 30°C while the minimum is between 9 and 18°C.

Soils

The soils are recent alluvial medium to heavy clays of poor drainage and structure and are therefore well suited for rice production. An analysis of soil infiltration in the Nyando Basin show average rates of hydraulic conductivity in the range from 7.26 m/d in bush land on the scarp to 5.445 m/d in bush lands in the hills to 0.359 m/d in the piedmont plains. A rate of only 0.029 m/d meters per day was found for sub-surface soils in the piedmont plains. The infiltration rates for cropland are higher than grassland or grazing lands in the piedmont plains. This low permeability explains the occurrence of inundations in these plains as the floodwaters are impeded from infiltrating into the ground.

4.4 Simiyu Basin (Tanzania)

The Simiyu catchment covers an area of 5,320 km^2 and is located between 33° 15' – 35^o 00' E and 2° 30' – 3° 30' S. in the lake Victoria basin. Figure 4.3 shows the location of hydro-climatic stations that will be used in this study. The Simiyu River drains from the Serengeti National Park plains to Lake Victoria. The Duma River, which receives water from the Ngasamo and Bariadi rivers, forms a main tributary to the Simiyu River. Most downstream areas of the catchment are flat and are prone to flooding. After the confluence of the Simiyu and Duma rivers, there is a vast swamp area, which may have an effect on the hydrology and flooding of the Simiyu River. The terrain of the catchment is categorized as mild with minimum and maximum elevations ranging from 1,132 m a.s.l. in the downstream area to 1,882 m a.s.l. on the headwaters respectively.

Hydrology

The rainfall and discharge pattern is bimodal and on the average peaks around April and November. Based on the general information and remote sensed data, the land cover in Simiyu catchment is dominated by grassland, woodland and cultivated land.

Soils

The major soil types in the catchment can be categorized as either shallow loess or sandy loam, with moderate infiltration rates if thoroughly wetted and therefore have a moderate rate of water transmission. Based on the geological map of Tanzania (GURT, 1967), the Simiyu catchment is dominated by granite (Syn-orogenicand migmatite) and, sedimentary and metamorphic rocks (Nyanzian). Volcanic rocks (Neogene) cover a small part of the Simiyu catchment around the Serengeti plains.

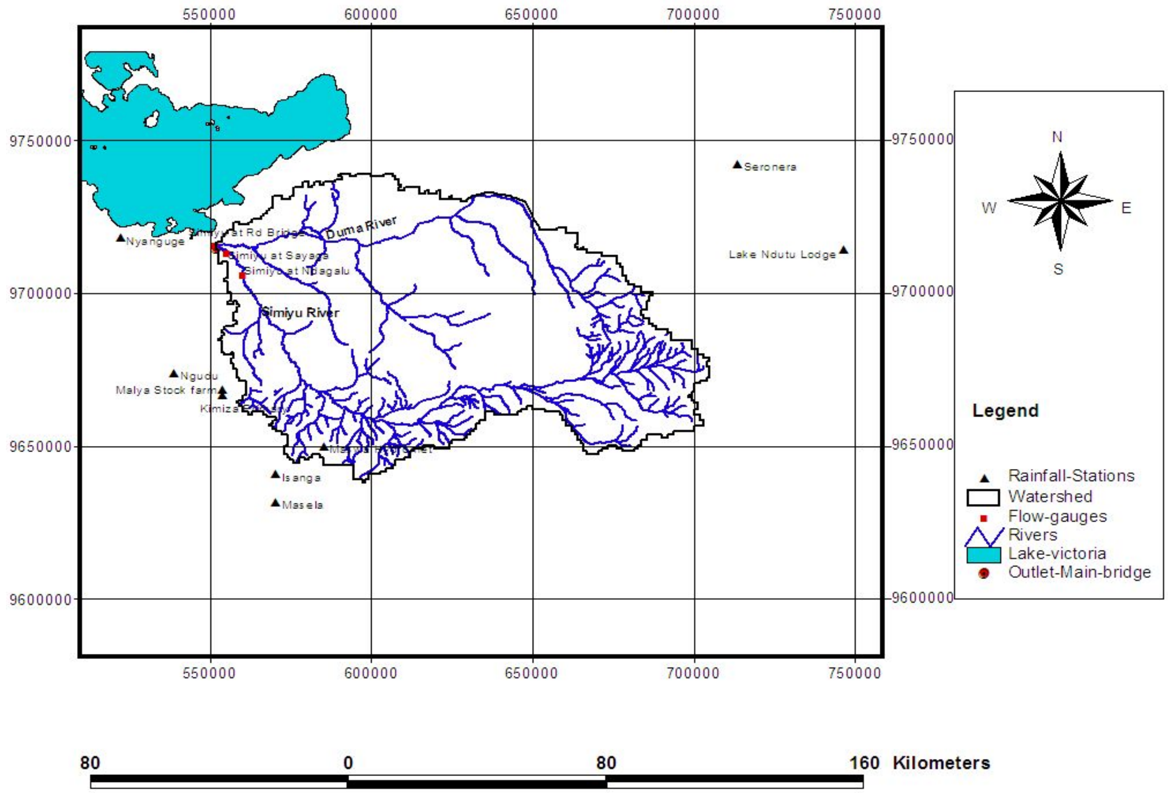

Figure 4.3: Locations of hydro-climatic stations in the Simiyu River Basin

4.5 Lake Kyoga (Uganda)

Lake Kyoga Basin is situated to the north of Lake Victoria (Figure 4.4) and it drains via the Kafu river southwards and via the Victoria Nile River northwards through Murchison falls into Lake Albert, where the Albert Nile originates to form the white Nile in Sudan. The lake is shallow and swampy, engulfed by masses of papyrus reeded shores. The physiography of the lake was formed as a result of volcanic activities, which erupted in the region in the recent past. Lake Kyoga has an average depth of 7.3 m and the catchment area is located between 1^{o} and 2^{o} N and 33^{o} and 34^{o} E. The surface area of the catchment is 2,194 km^2. The water level fluctuates from season to season. Mt. Elgon provides a source of clean water, which is crucial for the several millions of inhabitants of eastern Uganda and western parts of

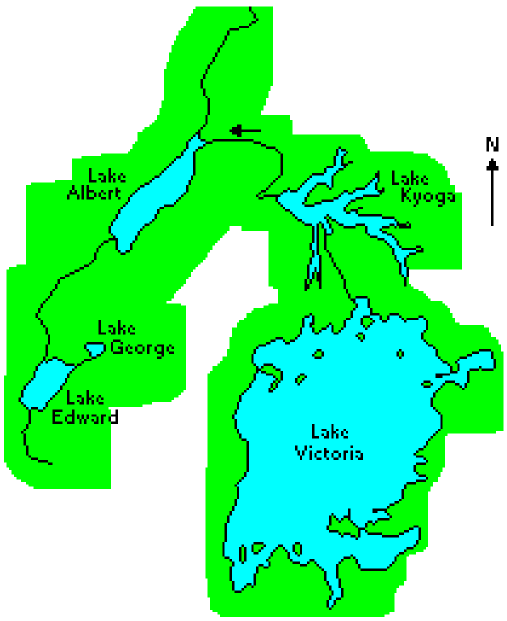

Figure 4.4: Lake Kyoga Basin

Kenya. Mt. Elgon as a major catchment area for Lake Kyoga and the Nile River. The Sio River originates from the highlands at the foot of Mt. Elgon in Kenya and drains into Lake Victoria through Uganda.

4.6 Toshka Spillway (Egypt)

The Toshka project was constructed in 1978 as a complementary safety measure for the High Aswan Dam. The project (Figure 4.5) consists of the Toshka Spillway, Toshka canal and an ogee weir (Figure 4.6). The Toshka spillway is located 270 km upstream of the High Aswan Dam.

The spillway consists of a concrete sill with a level of 178 m a.s.l. The flow passes over the sill when the upstream water level exceeds 178 m a.s.l.

The Toshka spillway canal starts at the end of the Khor Toshka (Figure 4.7). An ogee weir with a crest level of 176 m a.s.l. is constructed at the end of the Toshka spillway canal at Km 20.5.

The functions of the weir are to measure the discharge, control the flow, and maintain the stability of the upstream canal. The drop structure has a bed level at its upstream point of 175 m a.s.l. and at its downstream point of 172.5 m a.s.l. The water level upstream of the High Aswan Dam will increase up to the maximum allowable water level of 182 m a.s.l., which threatens the safety of the dam due to accumulated storage. The maximum discharges released downstream of the High Aswan Dam, conveyed through the Nile River is 240 Mm^3/day in the period of high water demands while it reaches 70 Mm^3/day in the period of low water demands. The release of high discharges downstream of the High Aswan Dam affects the safety of hydraulic structures and stability of riverbanks due to bed degradation and bank erosion.

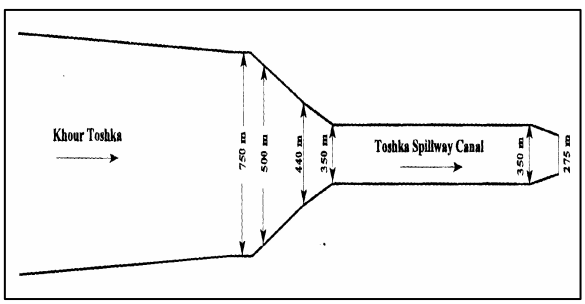

Figure 4.6: Plan View of Toshka spillway

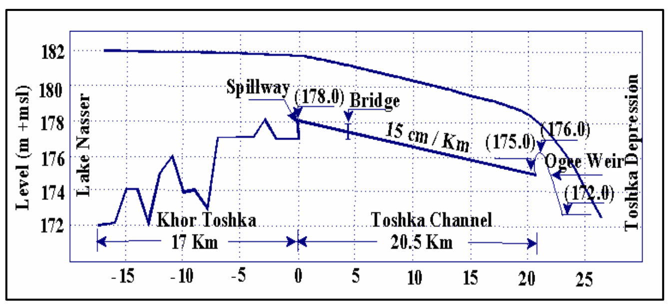

Figure 4.7: Longitudinal sections through Toshka spillway

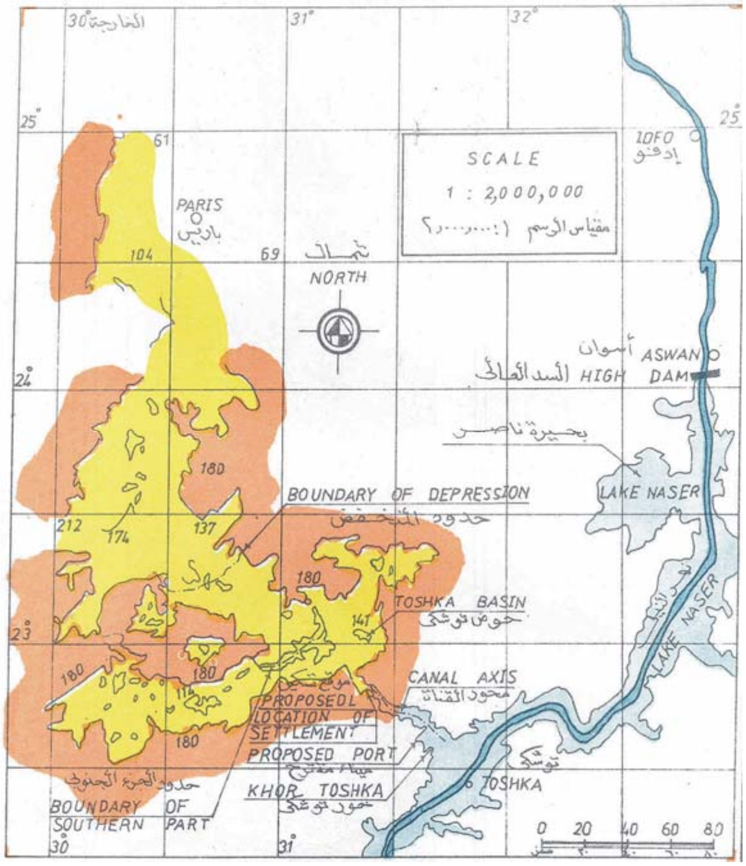

Figure 4.5: Overview Toshka Project

4.7 Nyabarongo Basin (Rwanda)

The Nyabarongo River (Figure 4.8) is called Akagera River in its downstream stretches when it is discharging into Lake Victoria. The Nyabarongo River is recognized as the source of the White Nile and it crosses 9 out of 12 provinces of Rwanda. The Nyabarongo River Basin has a catchment area of 8,900 km^2; an annual rainfall of about 1,350 mm and its altitude varies between 3,000 m upstream and 1,350 m downstream, with an average altitude of 2,176 m. The river has a slope of about 0.8 % with an annual average discharge of 83 m^3/s. The basins runoff coefficient is about 22 % and the specific discharge 9.3 l/s/km.

Hydrology

Rwanda is divided into two major hydrological basins by a vertical line from the north to south. The eastern part is called Nile catchment and it occupies 67% of the country and drains 90 % of the country's water into the Nile through Akagera River. The western part is the Congo catchment; it occupies 33% of the country and drains only 10% of the country's water into the Congo Basin.

On April 29, 2003 the maximum water level since 1972 was measured at the hydrological station at Kigali. The gauge showed a level of 4,607 m, which corresponds with a flow of 283 m^3/s.

Furthermore the physical character of the basin is influenced by the fact that:

- There is no cold season, except in the north west part of the country where the sub catchments of the river are situated in a volcanoes area with altitudes higher than 2,500 m;
- There is not a net difference between rainy and dry seasons; and
- The spatial variation of rain is heterogeneous and precipitation patterns are characterized by thunderstorms, due to slowly moving humid air masses climbing against the hilly terrain.

Temperature and air humidity create an intense evaporation, which is sometimes leading to droughts in several parts of the basin.

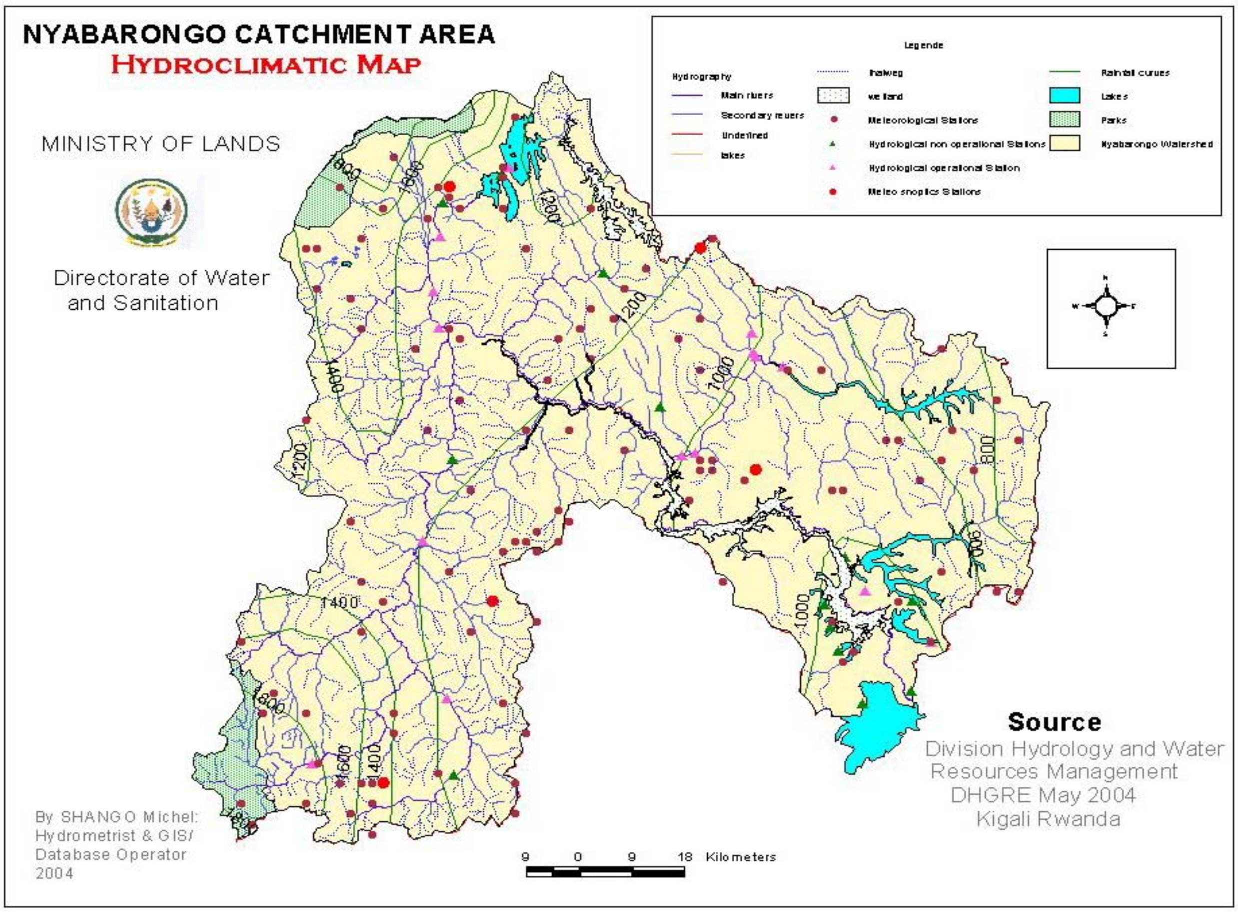

Figure 4.8: Nyabarongo Catchment

4.8 Flood Control Measures and Structures in the Nzoia and Nyando River Basins

Floods occasionally cause disasters in Kenya. Areas of Kano plains in Nyanza Province, Budalangi in Western Province and the lower parts of the Tana River are susceptible to floods.
Arid and semi-arid areas of the country also experience flash floods. In 1997/98 the El Nino phenomenon affected many parts of Kenya causing damages and destruction to property, loss of lives, famine and waterborne disease epidemics. With inadequate preparation for the El Nino floods national resources were over-stretched in the response phase. The El Nino induced floods

of 1997-1998 caused some US$ 151.4 million in public and private property damage. This figure does not include the number of people who lost family members, savings, property and economic opportunities (MWRMD, 2003).
Flooding arises as a result of river flows overtopping the banks and inundating the adjacent low-lying areas. This condition causes a lot of damage to property and crops and may result in loss of life and disruption of human settlement/comfort. In Kenya, flooding occurs very frequently especially in the Lake Victoria basin. River Nzoia is characterized with flooding in its lower reaches. The river floods frequently, annually. This is due to the large catchment area versus one river outlet that discharges the water into the lake. There is intense erosion in the upstream region due to deforestation. The soil blocks the channel or fills it, hindering the free flow of water. Deposition of the material eroded in the upstream areas takes place in the downstream stretches of the river. The deposition is intensive due to the low gradient of the riverbed. The deposition reduces the depth and thus the capacity of the river, which eventually results into flooding. In the river Nzoia dykes have been constructed in a downstream stretch over 32 km to contain the flood problem.

The flood control measures that are in use in the Nzoia and Nyando basins can be classified as structural. Of these measures only small stretches of dykes have been implemented and there has not been any success to mitigate the flood impacts in the lower parts of the Nzoia and Nyando rivers basins. Many parts of the dykes have been washed away or destroyed by pedestrians and animals (due to poor maintenance). At the time of floods, emergency measures normally include relocation of people to higher grounds.

Erosion and Sedimentation
Erosion in the upper catchment area of the basins is due largely to deforestation. The progressive movement of the meanders causing bank materials to be moved downstream causes erosion in the lower reaches of the basins. Erosion in the upper catchment area leads to mass sedimentation in the lower areas. Large-scale measures to control the erosion in the upper catchment have to be implemented. The Annual sediment delivery in the river Nzoia used to be between 158,400 to 326,350 tonnes in 1974 (Dunnes, 1974).

Structural and non-structural flood mitigation measures
In the intermediate middle zone of the Nzoia River potential sites for future dam construction as a tool for river regulation and flood control have been identified (JICA, 1992b) calling for pre-investment and pre-feasibility studies and/or detailed research for Integrated Water Resources Management in the basins. Previous studies have suggested the following structural and non-structural flood mitigation measures:

i. Construction of dams for the purpose of river regulation;
ii. Construction of flood protection dykes as a short term measure;
iii. Construction of drainage channels;
iv. Undertaking river training works;
v. Undertaking soil conservation measures;
vi. Establishment of early warning system;
vii. Assessment of climatic time series (climate variability and climate change);
viii. Study of the catchment characteristics;
ix. Floodplain mapping; and
x. Proper delineation of the floodplain.

The potential and existing dam sites in the River Nzoia Basin are illustrated in Figure 4.9.

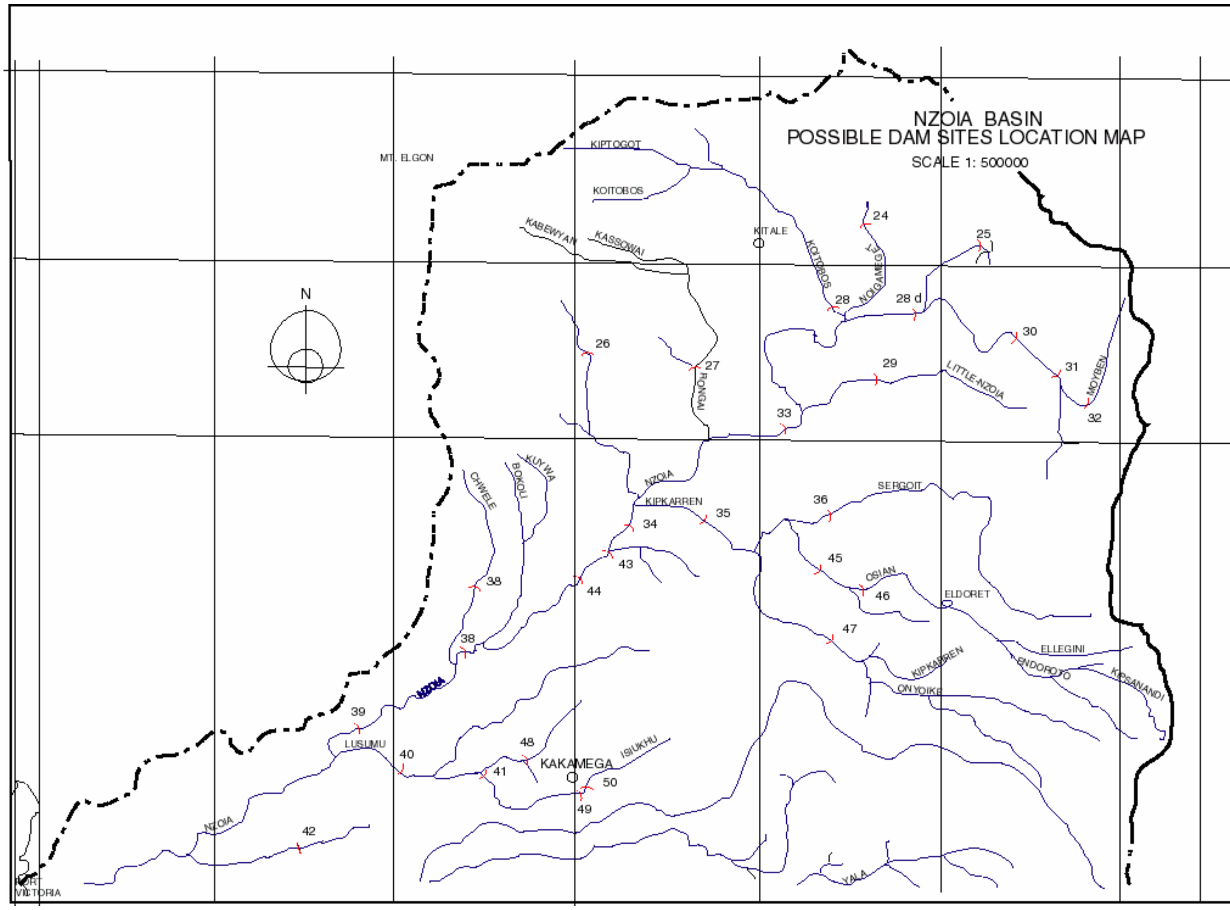

Figure 4.9: Potential and existing dam sites in the River Nzoia Basin

Existing dam sites	*Potential dam sites*
Twin Rivers	Kipkaren
Ellegirini	Kiboro
	Mukulusi
	Moiben
	Lower Moiben
	Moi's Bridge
	Hemsted Bridge

By the existing physical nature of the Lake Kyoga, the basin does not have many canals and embankments. National Environment Management Authority (NEMA) has revealed that Lake Kyoga is now, more than ever before, prone to frequent flooding. The National Water Resource Management Programme in Uganda, notably with the support of the Water Resource Management Department (WRMD), and also the Mitigation of Lake Kyoga Floods projects (MLKF) has undertaken two initiatives. The above-mentioned programme and project are under the authority of the Water Resource Management Department of the Ministry of Water, Lands and Environment of Uganda.

Floodwater uses

The following are the existing floodwater uses:

i. Floodwater allowed to flow on paddy fields for rice production;

ii. Retaining the water by constructing buds in the paddy fields after recession of the flood; and

iii. Fertility renewal through silt deposition, transported by floodwater.

The National Irrigation Board manages two irrigation schemes, namely: Ahero – 860 ha under pumped water from river Nyando with 490 tenants; and west Kano Scheme – 810 ha with 500 tenants and irrigation water pumped from Lake Victoria and drainage water pumped back to Lake Victora.

4.9 Catchment Management Strategies

4.9.1 Kenya

Kenya's forests cover amounts approximately 2-3% of its land surface, which plays an important role in the country's water resources. All major rivers in Kenya originate in forests, which are maintaining the base-flows. Deforestation prevents a range of natural processes from occurring and results into significant reduction in the volume of water that infiltrates into the ground and hence recharges the groundwater. The negative effects also include; a reduction in the base flow which sustains the dry season low-flows of streams and rivers; reduced ability of the land to survive and recover from droughts; increased rainfall runoff resulting in floods; and intensified erosion and sedimentation.

Nzoia River Basin
Crops are generally grown on scattered hillside plots separated by extensive rangeland. Main crop grown is hybrid maize, followed by sunflower. Other crops are beans and cassava. Cattle rearing are also practiced. The roads in the upper Nzoia Basin are in fair condition, making communication fair.

Livestock rearing and fish farming are common activities. Agro-economic conditions are generally poor throughout the sub-area with exception of Bunyala pilot irrigation scheme. Cotton is practically the only crop produced for the market. Maize farming is done on small scale for the local market only. Sugar-cane farming is practiced on small farms.

Nyando River Basin
Deforestation in this area appears in three distinct forms – expansion of agricultural areas into the forests, reduction in tree density within the forests, and reduction in the density of trees in forest remnants outside of the gazetted forests. Afforestation, on the other hand, occurred within certain parts of the forests and within the agricultural landscapes outside of the forests. Overall, it appears that forests are being lost while total tree cover is remaining more stable. Soil degradation and soil nutrient mining characterize many land-use types, including grazing areas and agricultural land. The most degraded parts of the landscape, both in terms of nutrient deficiencies and physical soil degradation are areas currently used for open grazing and extraction of fuel wood.

Land-use changes in the Nyando Basin preliminary took place between 1961-2000. It shows the following variations; cultivated land increased by 67.1%; degraded land increased by 9.8%; homesteads increased by 64.2%; while paths and roads increased by 198.8%. These indicative results show an increased trend in cultivated land, homesteads, and paths and roads, which open fragile lands and increase runoff (ICRAF, 2002).

Across the Lake Victoria Basin, there is very little evidence of conservation structures or agro-forestry. Only 2.7% of the area had any soil conservation structures. Agro-forestry practices tend to be restricted to the establishment of eucalypt woodlots and improved fallows associated with agro-forestry projects. Data collected in 1999 / 2000 show that the National Soil and Water Conservation Programme covered 175 catchments between 1988 and 2000 in the Nyando River Basin. These 175 catchments covered 17.2% of the river basin, while farms that are reported to have implemented some type of soil conservation structure on some part of their farms covered 7.7% of the river basin.

Approximately 46% of the 3,516 km^2 Nyando River Basin has experienced severe physical soil degradation. The most dramatic forms of soil degradation in the Nyando River Basin are related to soil erosion. This includes the formation of gullies and badlands in parts of the Kano plain and often-severe sheet erosion, rill erosion as well as landslides in the upper parts of the river basin in proximity to Tinderet and Londiani. It is estimated that 1,443–1,932km^2 (39.5–52.9%) of the river basin are currently affected by visibly apparent physical soil degradation of various types.

Lake Kyoga Basin

Human activities within the basin have led to increased deforestation for settlement and agriculture. The Rice production undertaken in the area affected by the recession of the flood waters flowing from the river Malaba on the paddy fields extending up to the Kibimba Kibimba Rice Scheme in the Busia district. Continued fertility renewal is through silt deposition from the transported flood soil. The rapid, unpredictable land use patterns experienced in the Kayunga and Nakasongola districts, is as a result of unsustainable agricultural and methods in the area. Activities here are a mixture of crop production and livestock rearing. Land degradation is characterized by soil erosion and subsequent sedimentation, deforestation is due to uncontrolled charcoal burning which is on high demand in the neighbouring towns of Jinja, Luwero, and up to the capital city of Kampala.

5. Proposed Strategies Second Project Phase

5.1 Introduction

The problems of floods and droughts have become cyclic and endemic in the Nile basin leading to loss of lives and social disorder, destruction of infrastructure, reversal of gains on economic and social development, health and degradation of the environment. Critical to these problems are the cyclic nature of the La Nina and El Nino events operating on degraded catchments and changes in river regimes. The variation in climatic order is also eluded to have a causal effect of these human accelerated natural disasters. The problems of floods and droughts in the region could be attributed to:

- Lack of water resources management and related disaster management capacity in terms of facilities, information and manpower:
  a) Lack of sufficient or relevant facilities such as tools, models, forecasting techniques, evacuation, relocation and control measures.
  b) Lack or inaccessibility to information. There is no databank with sufficient information in a form that could be retrieved easily and efficiently for decision support creating a critical need for the development of such a databank.
  c) Manpower: The available manpower lacks relevant training and where there exist such capacity, there lacks incentives and facilities to mobilize the human resources to deal adequately with the flood and drought problems in the region.
     There is therefore a need to train the existing manpower and to equip them with modern technological capacity that is relevant and rapid in use like the application of integrated water resources management practices, river engineering, GIS/GPS, Photogrammetry and remote sensing and modelling techniques. There is also a need to provide incentives for work and resources to perform.
- Inadequate and decreasing financial investments in resources for the development of human capacity and storage infrastructure to mitigate the effects of floods and droughts. Funding and investing into implementing water resources management practices, particularly to create buffering capacity to deal with the effects of droughts and floods e.g. construction and expansion of storage infrastructure, ground water recharging facilities and effective utilization of floodwaters is needed.
- Inadequate mitigation measures, both structural and non-structural, within the flood plains to quantify and qualify the characteristics and impacts of floods and droughts. There is need to institute hazard mapping techniques to help warn and inform on the extent, duration and damages caused by floods and droughts.
- Accelerated degradation of catchments. There is lack of adequate studies and information on the effects and influence of catchment degradation on occurrence of floods and droughts in the region. There is therefore a need for research and pilot studies to synthesize and characterize the relationship between catchment degradation and their effects on floods and droughts to generate and formulate principals and guidelines on catchment management. These studies should focus on effects of this degradation on soils and soil erosion, land cover and land-use changes and their effects on the hydrological processes as point source for floods and droughts.

- Inadequate networking between regional institutions to collectively manage the floods and drought.
- There are hardly any effective flood and land-use management practices in the Nile Basin and this calls for the development of regional capacity in flood and catchment management for the benefit of all the participating countries.

Several flood mitigation measures have been proposed from past studies but were never implemented due to a lack of clear and/or non-operationalised existing policies on water resource management and low capital investment in water resources development in the flood and drought management sector.
There is therefore a need to revisit and review the proposed measures and make them relevant to address the current floods and droughts in the basin; build institutional capacity and a framework for mobilization of resources and finances required to effectively implement and operationalise the proposed measures; and build the capacity and institutionalise research and development activities in the basin that would address and manage floods and drought effectively.

The flood and catchment management group proposes a minor redraw and adjustment of its mandate to address these needs by focusing its attention to the issues beyond fundamental research objects. The work will therefore call for:

- Fund raising and seeking donors for the continuation of its work;
- Intensified collaboration and cooperation within Kenya (IMTR vs. water and climate vs. floods and droughts) and other flood and drought related institutions and ministries;
- Intensified collaboration and cooperation with other networks within the Nile Basin (NBI (-ATP), Nile FRIEND, Nile Net, etc.);
- Integration and collaboration within the Flood Management node and between the various research clusters of NBCBN-RE; and
- Building capacity and intensified cooperation to create a 'Nile database' for data availability.

5.2 Objectives of Second Project Phase

The scope and the subsequent objectives of the second phase of the project are as outlined hereafter.

1. Build individual and institutional capacity on water resources management and related disaster management in the region through:
   - Identification and sourcing of relevant facilities;
   - Starting a database for information storage and dissemination;
   - Training of researchers and managers in Integrated Water Resources Management (IWRM), Geographical Information Systems (GIS), Global Positioning System (GPS) and Remote Sensing (RS);
   - Fund raising initiatives to meet obligations and form a forum for the region to source for funds to address the flood and drought problems; and
   - Policy advocacy to critically review and operationalise policies on floods and drought.
2. Undertake research initiatives to address the technical issues related to floods and droughts in the region:
   a) Catchment characteristics:

- Characterize and document the salient catchment characteristics.
- Qualifying and quantifying parameters such as land-use changes, drainage patterns and systems, soils, flood zones as they impact on floods and droughts;

b) Flood Hazard Mapping:
- Initiate, develop and institute techniques and models for flood hazard mapping that integrate information from FEWS.
- Develop protocols for disaster management through quantification of extent and cost of floods and drought disasters risks, vulnerability and hazards.

c) Flood and drought mitigation structures and measures by assessing and re-evaluating the efficiency of existing and previously proposed measures; and designing structures and measures necessary for flood and drought mitigation.

d) Catchment Management Strategies:
- Developing appropriate catchment management strategies to institute point source mitigation measures against floods and drought;
- Instituting and test efficiency of proposed strategies through implementation at pilot scale; and
- Developing adaptation strategies and policies to increase resilience of catchments and basins.

3. Integration with other NBCBN-RE research groups and clusters as indicated in the matrix in Table 5.1.

Table 5.1 Integration matrix

<table>
<tr><th rowspan="2">NBCBN-RE Clusters</th><th colspan="2">Flood Management Cluster</th></tr>
<tr><th>Flood Forecasting and Early Warning</th><th>Flood and Catchment Management</th></tr>
<tr><td rowspan="2">GIS & Modelling</td><td colspan="2">• Database and model development
• Development of flood hazard and inundation maps</td></tr>
<tr><td></td><td>• Flood risk assessment (incl. dynamics of land-use patterns)
• Flood & drought vulnerability index’s
• Catchment and floodplain management
• Impact assessment</td></tr>
<tr><td>River Structures</td><td></td><td>• Design and implementation sustainable river training structure(s) schemes</td></tr>
<tr><td rowspan="2">Environmental Aspects</td><td colspan="2">• Environmental impacts and implications of flood and drought events</td></tr>
<tr><td></td><td>• Effects of deteriorating catchments
• Development sustainable coping and adaptation strategies</td></tr>
<tr><td>River Morphology</td><td colspan="2">• Predict effects of increasing soil/bank erosion and reservoir sedimentation on flood routing and (design) water levels</td></tr>
<tr><td>Hydropower</td><td colspan="2">• Re-design reservoir operation schemes for multi-purpose use
• Develop small-scale hydropower schemes for retention of flood waters (water harvesting/storage)</td></tr>
</table>

5.3 Activities and Work Plan

Characterize the Catchments

- Physical and Climatological factors. Current and historical trends of flood and drought events have to be analysed in order to develop a database and model to monitor and simulate climatic changes within the basins. This activity will also be of interest for the Flood Forecasting and Early Warning group and the GIS and Modelling cluster; therefore close cooperation will be envisaged.
- River Morphology. In this regard cooperation with the River Morphology cluster is needed to predict the effects of increasing soil erosion and sediment fluxes into channels and streams on (design) water levels and existing flood defence structures.

Mapping of Flood Hazard Areas

- Development of flood hazard and inundation maps. The activities of the Flood and Catchment Management group necessitate a firm support from the Flood Forecasting and Early Warning group and GIS and Modelling cluster. Integration is foreseen in the area of database and model development, development of flood hazard and inundation maps, flood risk assessment (incl. the dynamics of land-use patterns), catchment management and impact studies.
- The outputs from the Flood Forecasting and Early Warning group will form the input to delineate possible flood hazard areas and also review the suitability of existing flood defence structures and to institute appropriate catchment and flood plain management.
- The outputs from the Flood and Catchment Management group on dynamics of land-use patterns and runoff generations will form inputs to the Flood Forecasting and Early Warning group for forecasting floods and droughts.

Documentation of the existing and Proposed Flood Control Measures

- Documentation of existing flood control structures. The implementation of sustainable river training structure(s) schemes in order to mitigate flood damages necessitates the cooperation with, and integration of NBCBN-RE River Structures cluster activities;
- The outputs on sediment and water yields from catchments by the Flood and Catchment Management group will form input data to the River Morphology cluster for the reduction of effects of increasing soil/bank erosion and reservoir sedimentation on flood routing and (design) water levels. Actual values of reservoir sedimentation and bank erosion will form input data to the Flood and Catchment Management group on floodplain management; and
- Assessment of efficiency of existing facilities.

Documentation of Catchment Management Strategies

- Documentation of existing land-use practices;
- Documentation and assessment of adequacy of existing floodwater use practices. Cooperation with the NBCBN-RE Hydropower cluster is needed to re-design reservoir operation schemes for multi-purpose use and to develop small-scale hydropower schemes for temporary retention of floodwaters;
- Assessment of catchment management strategies. The environmental impacts and implications of flood (and drought) events, the effects of deteriorating catchments on those events and the development of sustainable coping and adaptation strategies are to be assessed in cooperation with the Environmental Aspects cluster. In this regard cooperation with the River Morphology

cluster is needed to predict the effects of increasing soil erosion and sediment fluxes into channels and streams on (design) water levels and existing flood defence structures; and

- Proposed measures (use of modelling). The activities of the Flood Management cluster (both Flood Forecasting and Early Warning and Flood and Catchment Management) necessitate a firm support from the GIS and Modelling cluster. Integration is foreseen in the area of database and model development.

5.4 Expected Outputs Second Project Phase

The following outputs are expected in the second phase of the project:

- River sub basin (Nyando, Nzoia, Simiyu, Lake Kyoga, Nyabarongo and Toshka). Database on river basin characteristics capturing soils, land cover and drainage patterns.
- Historical trends, physical and climatological change characterization within the basins.
- Development of flood hazard and inundation maps.
- Planning and management models and guidelines.
- Existing flood control structures, efficiency and remedial measures: recommended designs and design standards for defence structures.
- Existing land and floodwater use practices: review of existing land and floodwater use practices and effective flood plain management.
- Catchment management strategies: effects of deteriorating catchments; and sustainable coping and adaptation strategies on catchment scale.

5.5 Expected inputs (staff time, investments)

Table 5.2: Budget matrix

Items	**Country**	**Researchers Numbers**	**Research Assistants**	**Support staff**	**Duration (Days)**	**Unit cost (US$)**	**Man days**	**Costs (US$)**
Training		15			4 x 2	15,000		30,000
		17	-	-	88	10	1,496	14,960
			34		88	10	2,992	29,920
			-	34	44	8	1,496	11,968
Data manager			1		156	18	156	1,560
Transport	Rwanda							6,000
	Kenya							65,000
	Uganda							6,000
	Tanzania							9,000
	Egypt							5,000
Subsistence	Rwanda	1	2	-	20	75		4,500
	Kenya	17	9		20	75		39,000
	Uganda	1	2		20	75		4,500
	Tanzania	1	1		20	75		3,000
	Egypt	1	1		20	75		3,000
Sub Total								341,120
Facilities								
Items	**Quantity**	**Researchers Numbers**	**Research Assistants**			**Unit cost $**		**Costs (USD)**
Support facilities		17				500		8,500
Communication		17				500		8,500
Laptops	8					1,700		13,600
Video/digital cameras	4					2,000		8,000
Data acquisition								10,000
Security								
Sub Total								48,600
20% Contingencies								19,408
Total Budget								409,128

6. Conclusions and Recommendations

6.1 Conclusions

The major conclusions of the first phase of the project are:

- The Nile basin is always impacted negatively by the La-Nina and El Nino phenomenon that affects the region through cyclic occurrence of floods followed by droughts. The problems of floods and droughts have become endemic in the Nile basin leading to loss of lives and social disorder, destruction of infrastructure, reversal of gains on economic and social development, health and degradation of the environment. There is a need to undertake studies on climate change in the region over a period of time to understand the frequency and occurrence of floods and droughts in order to develop mitigation and coping strategies.
- There is indicative evidence that the changes in land-use and/or climate variability may have resulted into an increased frequency and magnitude of flooding in some areas of the Nile Basin.
- Within the lake Victoria basin, four sub-basins have been identified as research basins based on the frequency and magnitude of flood damage experienced over the years. These are the Nzoia and Nyando River Basin in Kenya, Simiyu River Basin in Tanzania, Nyabarongo River Basin in Rwanda, Kyoga River Basin in Uganda and the Toshka Spillway in Egypt. These river basins are subject to further research in the second phase of this project.
- Some efforts such as construction of dams for the purpose of river regulation, construction of small stretches of dykes as a short-term measure and the construction of drainage channels have been undertaken to mitigate floods, but these have not been successful to mitigate the flood impacts in the lower parts of the Nzoia and Nyando river basins. Many parts of the dykes have been washed away or destroyed by pedestrians and animals due to poor maintenance. Other measures such as soil conservation practices have been put in place in some parts of the Nzoia and Nyando catchments, but their effects have been marginal since they cover only a small portion of the catchment. There is a need to evaluate the design of existing structures, undertake, and institute proper design standards for flood defence structures.
- Mitigation measures such as construction of dams for the purpose of river regulation, construction of drainage channels and undertaking soil conservation measures, have been proposed in the past for the Nzoia and Nyando river basins but have not been implemented due to a lack of funds, low incentives to staff and a lack of human capacity by implementing agencies.
- Some of the existing land use practices such as deforestation and urbanization enhance flooding. For instance, increased urbanization and deforestation result in reduced infiltration with increased run off in built and urban areas leading to flooding in the lower parts of the Nzoia and Nyando river basins.
- There is need to enhance capacity building through training the existing manpower and equipping them with modern technological capacity that is relevant and rapid in use like the application of integrated water resources management practices, river engineering, GIS/GPS, photogrammetry and remote sensing and modelling techniques. There is also a need to provide relevant facilities, tools and incentives for work and resources to perform.

- Some bottlenecks, such as lacking proper communication among members have been identified that can affect the output of the results. Improving communication by provision of functional Internet and/or telephone facilities to members, which are located far away from the note office secretariat at the University in Nairobi.
- There is lack of coordinated research activities and a meteorological and hydrological databank with sufficient information that is assessable and that could be retrieved easily and efficiently for all NBCBN-RE researchers is needed. Harmonization of activities and data availability within the Nile Basin, by developing a meteorological and hydrological database and collective research for all NBCBN-RE researchers is of utmost importance.

6.2 Recommendations

Based on the results of the first phase and on the outlook towards the second phase of the project, the Flood and Catchment Management research group recommend the following:

- Need to undertake further studies in the changes in land-use, changes in climate and flood and drought prone areas in the identified river basins and propose appropriate actions.
- Assess the effectiveness of the existing flood and drought control measures and propose appropriate actions.
- Review of the existing proposals for flood and drought control and/or mitigation measures and recommend appropriate actions.
- Equip and operationalise the node office.
- Training of researchers in appropriate areas in river engineering.
- Need to assign a ‘data manager’ at the node office to manage and disseminate the data to the researchers whenever they need the data. The person should be available in the office for three days a week.

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Annex III Input NBCBN Declaration from Flood Management cluster

General

- A critical element in the contingency of the clusters and research groups, hence the NBCBN network, and the continuation and progress of activities is the facilitation and support of a minimal level of communication instruments and tools.
- The establishment of a knowledge and training center for flood and drought management in East Africa is considered to be a long term solution for upgrading human capacity and resources, sustainable access to and standardization of hydrologic, hydraulic and meteorological data and initiating research and development activities.
- The organization of follow up workshops in ‘pilot catchments’, in which the participation of research group members, their higher management and, from data acquisition point of view, crucial regional flood and drought management institutes (ministries, agencies, etc.) is foreseen, could significantly contribute to the sustainable continuation of research activities, leading to tangible outputs beneficiary for the local communities and the NBCBN network as a whole.
- The possibilities for retrieving fellow and scholarships for capacity building, training and education should be improved. This is considered inside as well as outside the NBCBN network.
- The clusters and research groups will have to increase their own fund raising activities outside the NBCBN network. However, the NBCBN project management and scientific advisors should increase their support activities by assistance and guidance of proposal and tender development and informing individual clusters and research groups of cooperation possibilities and opportunities by linking up with other networks and programmes.

Integration

- The activities of the Flood Management cluster (both flood forecasting and early warning and flood and catchment management) necessitate a firm support from the GIS and modelling cluster. Integration is foreseen in the area of database and model development, development of flood hazard and inundation maps, flood risk assessment (incl. the dynamics of land-use patterns), catchment management and impact studies.
- The implementation of sustainable river training structure(s) schemes in order to mitigate flood damages necessitates the cooperation with, and integration of river structures cluster activities.
- The environmental impacts and implications of flood (and drought) events, the effects of deteriorating catchments on those events and the development of sustainable coping and adaptation strategies have to be assessed in cooperation with the Environmental Aspects cluster. In this regard cooperation with the River Morphology cluster is needed to predict the effects of increasing soil erosion and sediment fluxes into channels and streams on (design) water levels and existing flood defence structures.
- Cooperation with the hydropower cluster is needed to re-design reservoir operation schemes for multi-purpose use and to develop small-scale hydropower schemes for temporary retention of flood waters.

Crosscutting issues

- The current scenarios on the impacts of climate change and increased climate variability will call upon an urgent need for flood forecasting and early warning tools.
- Increasing climate variability will lead to an increase (of the magnitude and frequency) of extreme events. The future need for an integration of drought and flood forecasting and early warning is obvious. Besides, many structural and non-structural flood mitigation measures and strategies are also applicable for drought mitigation; hence integration of strategies and policies will increase efficiency rates and benefits larger parts of society.
- The sustainable development of adaptation strategies to cope with increased climate variability will rely heavily on flood and drought forecasting and early warning as well as (pro-active) catchment management practices (adaptive river management).
- Coping with present and future river (engineering) related problems on a basin scale would need the implementation of an international river basin organization.