THE REPUBLIC OF UGANDA

UGANDA WATER ACTION PLAN

WATER RESOURCES DEVELOPMENT AND MANAGEMENT

RAPID WATER RESOURCES ASSESSMENT

(DOC. 007)

MINISTRY OF NATURAL RESOURCES

DIRECTORATE OF WATER DEVELOPMENT

1995

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LIST OF CONTENTS

APPENDIX 1.1 Water Action Plan documents.

APPENDIX 2.1 Location and length of records of selected flow stations.

APPENDIX 2.2 Annual water balance for selected catchments

APPENDIX 2.3 Low flow analysis

APPENDIX 2.4 Maximum flow analysis

APPENDIX 2.5 Trends and variations in hydrometeorological parameters

APPENDIX 6.1 Population data and forecasts

APPENDIX 6.2 Livestock data and forecasts

APPENDIX 6.3 Urban and rural water demands

APPENDIX 6.4 Livestock water demands

APPENDIX 6.5 Present and potential irrigation water use

LIST OF ABBREVIATIONS

AfDB	African Development Bank
CIDA	Canadian International Development Agency
Danida	Danish International Development Assistance
DOM	Department of Meteorology
DWD	Directorate of Water Development
EIA	Environmental Impact Assessment
FAO	Food and Agricultural Organization (of United Nations)
GEMS	Global Environmental Monitoring System
GDP	Gross Domestic Product
GSMD	Geological Survey and Mining Department
HYDROMET	Hydrometeorological Survey of the Catchments of Lakes Victoria, Kyoga and Albert
IDA	International Development Association
IDRC	International Development Research Centre
KDA	Karamoja Development Agency
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
mbgl	Metres below ground level
NEAP	National Environmental Action Plan
NEMA	National Environmental Management Authority
NGO	Non-Governmental Organisation
NWSC	National Water and Sewerage Corporation
PEPD	Petroleum Exploration and Production Department
RC	Resistance Council
RTWSP	Rural Towns and Sanitation Programme
RUWASA	Rural Water and Sanitation (East Uganda Project)
SIDA	Swedish International Development Authority
SWIP	South-West Integrated Health and Water Programme
TECCONILE	Technical Co-operation Committee for the Promotion of the Development and Environmental Protection of the Nile Basin
UNDP	United Nations Development Programme
UNICEF	United Nations Childrens' Fund
WAP	Water Action Plan
WATSAN	National Water and Sanitation Programme (a national UNICEF programme)
WHO	World Health Organization

0 SUMMARY OF WATER RESOURCES ASSESSMENT

0.1 Approach to assessment

The assessment of available water resources, as seen from the perspective of future demands, has been based on rapid assessments of both groundwater and surface water resources. The surface water resources have been described on the basis of data from 54 selected catchments. The data have been extrapolated to cover the entire territory. Groundwater resources have been assessed district by district. The domestic and livestock demands have likewise been estimated both on a district and on a catchment basis. Irrigation demand has been estimated on a catchment basis.

A detailed assessment of the requirements of surface water resources would necessitate knowledge of the exact location of demands/requirements and an estimate of the catchment yield at that particular location. The demands/requirements of groundwater would likewise necessitate a knowledge of groundwater resources and population/livestock densities within an area of a few square kilometers. Such detail has not been considere relevant in the context of this assessment.

0.2 Surface water resources and demands/requirements

0.2.1 The Upper Nile system

The Upper Nile system, comprised of the Equatorial Lakes and the Nile from the outlet at Lake Victoria to the Sudanese border, represents a huge water resource and is the basis for a broad range of development activities.

<u>Lake Victoria</u>
This lake is the basis of the water supply for Entebbe, Jinja and Kampala. Although these towns have a significant water demand now and an anticipated future demand totalling 56 mill.m3/year (1.8 m3/sec), this usage is only 0.2% of the average outflow from the lake. The requirement for the lake to act as a recipient for wastewater from Kampala is, however, more critical. At Kampala, wastewater is discharged into Nakivubo swamp and from there into Murchison Bay. At Jinja a some wastewater is discharged into the lake, while the majority of the wastewater is discharged into the Victoria Nile (ref. Subsection 3.3.6).

Ugandan waste discharge alone would not be critical for the lake. However, in combination with other pollution loads from the upper riparian countries, the Ugandan discharge contributes to major quality changes in the lake. These quality changes seriously affect the fishery in the lake as well as its use for water supply (ref. Subsection 3.4.1). Although very large in volume and area, the lake cannot meet the present demands for sustained use as recipient for untreated urban and industrial wastewater.

Presently, irrigation use of water from Lake Victoria is not widespread. One major agricultural user however, is the the Kakira Sugar Plantation east of Jinja. Thus, there remains the potential for future water demands for irrigation purposes.

Future hydropower demand for constant high outflows from Lake Victoria may require variations in lake levels, as it may be desirable to use the lake as a storage reservoir. Lake level variations will be constrained by the impacts of increased levels on the lakeshore infrastructure, villages and lake and wetland ecology.

The economic requirement of Lake Victoria as a basis for sustained fishery is substantial. The present catch is approx. 300,000 tonnes/year, out of which 120,000 tonnes are landed in Uganda. However, the annual catch is decreasing and with continuing eutrophication the Lake will not be able to sustain this requirement at the current levels.

The demand by the lake transport for maintenance of levels within design intervals for the ports and other facilities are met by the present lake regulation schedule ("natural" outflow). Recurrence of years with high rainfall over the lake may create a situation of consistent high levels as occured in the early 1960's. Such water level increases could have a significant impact on the use of the port facilities. The water hyacinth has a negative impact on the lake transport, making access to ports difficult and blocking landing sites for fishing boats. The proliferation of the water hyacinth is enhanced by the deteriorating water quality.

Demands/requirements from recreation and tourism, health and environment will be constrained by the negative development in lake water quality.

Lake Kyoga and Lake Albert

The demands/requirements on the two other very large lakes in the upper Nile system, Lake Kyoga and Lake Albert, relate primarily to fisheries Lake Kyoga has the largest catch off the two lakes. These lakes can generally respond to present requirements. However, a continued deterioration of the water quality of Lake Victoria will mean inflow water to the two lakes of inferior quality, Lake Kyoga (and later Lake Albert) will undergo quality changes due to Lake Victoria's impact. However, no quantitative estimates of the possible deterioration are available. Lake Kyoga may, in the future, be outer source for irrigation projects. Presently, the lake is not considered a constraint for development.

Victoria Nile
The Nile from Lake Victoria towards the border of Sudan is a vast resource in terms of hydropower potential. The identified potential is 2700 MW out of which only 180 MW is installed at the moment. Extensions are proposed, which would bring installed capacity to 270 MW and 300 MW. Demands/requirements for hydropower can thus be satisfied for quite some time. However, the recreation and tourism requirements will have to be satisfied as part of any hydropower development, preserving the asthetic quality of water falls such as Murchison Falls and Bujagali Falls.

The Victoria Nile acts as a recipient for most of the sewage from Jinja which is comprised of both domestic and industrial wastewater. Due to the very large and almost constant flows of the Victoria Nile, requirements of the river as a wastewater recipient will be met now and in the forseable future.

0.2.2 The Ugandan catchments

The demands/requirements on the surface water resources of the Ugandan catchments are predominantly for water supply (domestic and livestock), irrigation, sewerage and fisheries.

Water supply
The structure of the water supply sector is such that the dominant source of larger urban supplies is surface water, with smaller towns being supplied by groundwater (and in some cases supplemented by surface water). Rural supplies are based on groundwater including springs. Livestock demands are primarily satisfied through surface water sources.

In general, the surface water resources will be able to satisfy the present and future urban and livestock demands. The total future (2010) urban and livestock demand is approximately 325 mill. m^3/year or 10.3 m3/sec as compared to the total resulting runoff of the Ugandan catchments of 220 m^3/sec. However, the distribution of the surface water resources means that on a local scale there will be competition for the water in several cases. This will particularly be the case where large annual variations in flow occur or where streams are non-perennial. Figs 2.7 and 2.8 give an idea about which areas that are critical in these respects. From Fig 2.7 it appears that the lowest annual runoff volumes (less than 10 mm) are found in parts of the Mbarara, Mubende, Rakai and Masaka and Luwero Districts as well as in Kotido and Moroto Districts. From Fig 2.8 it appears that the highest incidence of non-perennial streams are found in parts of the Masaka, Rakai, Mbarara and Mubende Disticts in the Southwest and in parts of Kitgum, Kotido, Moroto, Lira, Soroti, Kumi and Mbale Districts in the East and Northeast.

Irrigation

The irrigation water demands may increase to substantial amounts which would be drawn from surface water. Due to the relatively large volumes required during the driest parts of the year, irrigation schemes will often be competing for water with other uses. For instance, irrigation demands of 10,000 m3/ha would mean that for each hectare irrigated (one season) the scheme is using an amount of water corresponding to the domestic demands of more than approximately 350 urban dwellers over a year.

Irrigation schemes are found primarily around Lake Kyoga and in the area between the lake and Tororo. These areas are also the areas where the highest minimum dependable yields are found (ref. Fig 2.8). The irrigation water demands on the surface water resources may increase, depending on the agricultural development trends in the country. Due to the relatively large amounts required during the driest parts of the year, irrigation schemes may be competing for the water with other users. Presently, the total area under irrigation in Uganda is some 30,000 ha. Estimates of future irrigation potential vary considerably. At one end of the scale FAO estimates a potential irrigation area of 410,000 ha, which would consume more than 50% of the total runoff from Ugandan catchments. A study by Halcrows estimates the figure at 186,000 ha while a study under HYDROMET (1977) established the potential irrigated area as 247,000 ha. These estimates are based on considerations of what is technically possible. However, the economic, financial and social feasibility of large scale irrigation in Uganda as compared to alternative forms of agricultural development is disputable, and demands for irrigation water are not likely to be significant in the near future.

Sewerage

Presently only 13 large, towns including Entebbe, Jinja and Kampala have waterborne sewerage systems. Other urbanized areas are served by combinations of septic tanks and pit latrines. The requirement for dilution of effluent can hardly be met on a year round basis in areas of low dependable yield where even non-perennial streams are frequent. Downstream water intakes will be seriously affected and health hazards will occur, depending on efficiency of treatment.

Fisheries

Land based fish ponds and aquaculture are gaining popularity in part due to support from the Agricultural authorities. An estimated 2000 ponds are presently stocked with fish. The water requirements and the organic pollution from such ponds pose requirements for volume, dilution and purifying from the stream in use. With current knowledge and information it is not possible to estimate whether the ponds will present major requirements to the water resources.

Others

Hydropower in the Ugandan catchments will only occur at the mini-hydro scale and requirements on the resource are closely linked to the topography and proximity of a power demand. Thus, a general statement on the adequacy of the resource in relation to a distributed power demand in areas not served by the national grid cannot be made. Health, recreation and tourism, and environmental demands/requirements can generally be met, but will ultimately be dependent on the priorities of the decision makers.

0.3 Groundwater resources and demands

The demands on groundwater resources are presently from rural water supplies and, to a certain degree, from the planned provision of water supplies to the towns under the Rural Towns Water and Sanitation Programme. The total rural demand (2010) has been estimated at approximately 219 mill. m3/year or 6.9 m3/sec (ref. Appendix 6.3) while the rural towns may need another 20 mill m3/year or 0.6 m3/sec. On a national and sustainable basis this would correspond to an annual recharge of 1.2 mm over the total territory. In Chapter 4 recharge is estimated at approximately 10% of the annual rainfall at values around 1000 mm. Average demands are thus only a few percent of the recharge and not considered critical in light of a dispersed demand.

The groundwater quality problems are connected to the corrosiveness of the deep groundwater in large parts of Uganda and the localised occurrences of high fluoride.

0.4 Summary of demands and resources

The table below summarizes the consumptive demand and displays estimates for available resource for comparison. (Water for irrigation is assumed to be drawn mainly from Ugandan streams and only to a small degree from Lake Victoria and Lake Kyoga).

Table 0.1 - Projected water demands for consumptive use and resource availability

SECTOR/RESOURCE	LAKE VICTORIA	UGANDAN CATCHMENTS
WATER SUPPLY DEMANDS		
Jinja & Kampala	1.8 m^3/sec	
Medium & small urban	-	1.4 m^3/sec
Rural domestic	-	6.9 m^3/sec
Livestock	-	7.1 m^3/sec
IRRIGATION DEMANDS		
410,000 ha (FAO) or	-	126 m^3/sec
247,000 ha (HYDROMET) or,	-	78 m^3/sec
186,800 ha (Halcrow)		57 m^3/sec
RESOURCE AVAILABILITY	914 m3/sec	220 m^3/sec

It is emphasized that the demand figures for irrigation represent estimates of what is technically possible, not necessarily what is realistic in a socio-economic development context. It appears from the table above that comparing total consumptive use and resource availability on a national basis, demands (except for irrigation demands) are only small fractions of the total resource. However, the water resources are unevenly distributed and high source development costs may give a perception of water scarcity.

The distribution of ultimate total consumtive demands (population (2010), livestock (2010),irrigation (potential), as estimated by HYDROMET 1977) on the eight major catchments, is given in Table 0.2 below.

Table 0.2 - Comparison of dependable yield (1 in 5 year monthly minimum) and consumptive demand

Basin	Dependable Yield (m^3/sec)	Ultimate Demand (m^3/sec)
Lake Victoria	76.09	15.80
Lake Kyoga	48.64	47,49
R. Kyoga Nile	18.04	10.00
Lakes Edward and George	52.27	7.90
Lake Alberg	23.10	0.97
R. Aswa	1.06	2.60
R. Albert Nile	15.89	9.70
Kidepo Basin	0.08	0.40
Other	0.34	0.20
TOTAL		95.97

1 INTRODUCTION

1.1 Background

1.1.1 Water Action Plan development

Project documents entitled "Water Action Plan for Water Resources Development and Management (WAP)", dated January 1993 and October 1993, were agreed between the Government of Uganda and the Government of Denmark (acting through the Ministry of Foreign Affairs - Danida).

The project documents describe two phases of a planning process aiming to develop a Water Action Plan for Uganda.

CONTENTS OF WAP PHASE I
- a rapid assessment of the water resources situation in the physical and management context - a preliminary proposal for the establishment of an enabling environment for flexible water resources management with linkages between land and water resources, and including suggestions for management roles and functions at various levels, and suitable institutional structures - a preliminary outline of a national water resources policy - preparation of detailed project proposals for specific projects in the water resources sector

CONTENTS OF WAP PHASE II
- a draft national water resources policy accompanied by target descriptions and brief guidelines - an outline proposal for appropriate local water resources management levels based on district studies - an outline proposal for management procedures providing the administrative machinery at national and district levels with guidelines for sustainable water resources management - a design of a groundwater database and a plan/guidelines for interaction between the various existing and future computerized systems relevant to water resources management - support to the preparation of regulations supporting the Water Resource Statute regarding surface water and groundwater abstraction as well as wastewater discharge - an outline of training and capacity building activities supporting the appropriate sectors in water resources management - a project catalogue with proposed priorities for projects identified during the Water Action Plan Phases I & II - a draft Water Action Plan synthesizing the activities carried out in a coherent presentation - implementation and monitoring guidelines for the subsequent Water Action Plan implementation - a National Seminar for discussion of the draft Water Action Plan by concerned parties

The implementing agency in Uganda is the Directorate of Water Development (DWD) within the Ministry of Natural Resources. A team of Danish consultants has been engaged by Danida to work within the DWD in the execution of the project. The consultant team has been composed of staff members from the VKI Water Quality Institute (leading partner), COWIconsult, Nordic Consulting Group and the Danish Hydraulic Institute.

1.2 Guiding principles for the Water Action Plan

The Uganda Water Action Plan is intended to provide a framework for the protection and development of Uganda's water resources. It will provide a flexible and dynamic framework for development and management of the water resources of the country, rather than a traditional prescriptive master plan.

The Water Action Plan deals with aspects of integrated water resources development and management, recognizing the guiding principles emerging from discussions at international conferences, consultations and workshops in Copenhagen (November 1991), Dublin (January 1992) and Rio (UN Conference on Environment and Development, UNCED, June 1992).

GUIDING PRINCIPLES FOR THE WATER ACTION PLAN
- fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment - land and water resources should be managed at the lowest appropriate levels - the government has an essential role as an enabler in a participatory, demand-driven approach to development - water should be considered as a social and economic good, with a value reflecting its most valuable potential use - water and land use management should be integrated - women play a central part in the provision, management and safeguarding of water - the private sector has an important role in water management

1.3 Documentation

During the background studies and drafting of the Water Action Plan a number of working documents have been prepared in draft, and comments to these have been obtained from various relevant parties. In concert with the developments in the Water Action Plan process, parts of these documents have become obsolete after having served their purpose of raising points for discussion and explaining status and contents of the work.

The experience and consensus obtained from those drafts have thus been carried over into a number final documents. These are also drawing heavily on excerpts from the working papers and the draft reports from WAP Phase I and Consolidation Phase I. The resulting list of final documents is given in Appendix 1.1. The set of documents constituting the core of the Water Action Plan are nos. 005 to 014.

1.4 Rapid Water Resources Assessment Report

The report is an assessment of the availability in time and space of the surface and groundwater resources of Uganda. The water demands and the future needs are assessed and compared to the water availability.

Chapter 2 summarizes the surface water quantity aspects and gives the distribution of the elements of the water balance. The Nile system and its levels, flows and regulation is briefly described and the dynamics of main hydrologic parameters is studied. In Chapter 3, surface water quality is the theme. Recent water quality impacts from natural factors and human activities are briefly described and problems assessed.

The availability of groundwater and the annual recharge are the main topics of Chapter 4, where the main problems of groundwater development are also outlined. Groundwater quality and the relation between various quality parameters and uses of the groundwater are summarized in Chapter 5. Finally in Chapter 6, the demands of the most important sectors are described and development trends are forecasted in order to prepare a comparison between demands and resources.

2 SURFACE WATER QUANTITY

2.1 Introduction to Uganda's hydrology

2.1.1 The Nile system and the Equatorial Lakes

The Ugandan territory is situated entirely within the Nile Basin. The Nile and the Equatorial Lakes are dominant features of the surface water resources in the Upper Nile Region. The Ugandan catchments, which drain to the Nile, are very small contributors to the total Nile flow, but their yields dominate the water resources potential within Uganda.

Fig 2.1 illustrates schematically the major components and average flows of the Nile system within the Ugandan territory.

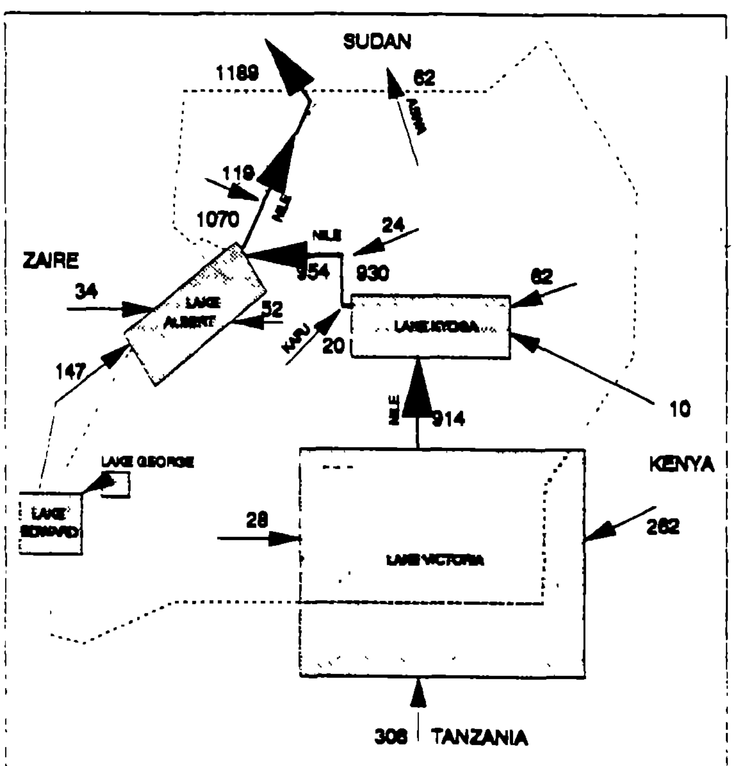

Figure 2.1 - The Nile system components within Uganda (flow rates are 1948-70 averages in m^3/s, source: HYDROMET).

While the Nile and its flow characteristics are important from both an international and national point of view, the Ugandan catchments are important from a national, regional and local viewpoint.

The source of the Nile is considered to be where Lake Victoria spills over Rippon Falls, now submerged due to the construction of the Owen Falls Dam. This is the only outlet of the Lake Victoria. The most notable rivers flowing into the Lake Victoria are the Nzoia River from Kenya, the Mara River from Tanzania and the Kagera River from Tanzania, Uganda and Rwanda-Burundi. The 130 km stretch of the Nile from Lake Victoria to Lake Kyoga is termed the Victoria Nile. This part of the Nile falls approximately 105 m total over both the Owen Falls Dam (20 m) and a series of rapids. Lake Kyoga is drained through the Kyoga Nile which, after a relatively flat reach downstream from lake, enters a series of rapids and falls, before it flows into Lake Albert at a level 410 metres lower than Lake Kyoga.

In Lake Albert, the Nile is joined by the only major tributary within the Ugandan territory namely the Semliki River. This river drains Lakes George and Edward, both lakes found in the Rift Valley and the high rainfall area of the Rwenzori Mountains. Lake George and Lake Edward are connected through the Kazinga Channel.

The Nile flows from Lake Albert with a gentle slope to the Sudanese border. This reach of the river is called the Albert Nile. The branch of the Nile originating at the outlet of Lake Victoria is called the White Nile while the branch originating in Ethiopia is called the Blue Nile up to the confluence of the two branches at Khartoum in Sudan after which it is called the Main Nile.

The main parameters of the Equatorial Lakes are given in Table 2.1 below.

Table 2.1 - Main characteristics of the Equatorial Lakes

LAKE	LAND CATCHMENT (1000 KM2)	LAKE SURFACE (1000 KM2)	MAX DEPTH (M)	REGULATION
Lake Victoria	193	69.0	79	Owen Falls Dam
Lake Kyoga	75	6.3	50	None
Lake Albert	17	5.3	-	None
Lake George	8	2.2	-	None
Lake Edward	12	0.3		None

Source: Shanin, 1985

Lake Victoria, having a surface area of 69,000 km2, is one of the largest lakes in the world, while Lake Kyoga and Lake Albert are each only approximately 10% of the size of Lake Victoria in terms of surface area. Lake Kyoga is a relatively shallow lake. The only structure in the entire system which can regulate lake levels is the Owen Falls Dam designed for hydropower production.

The regulation is done in such a way that the flows resemble the natural flows which once were measured at Rippon Falls as a function of the water level in Lake Victoria. Thus, given a certain water level in Lake Victoria, a corresponding amount of water is released through the dam.

The water balances of the three major lakes are given in Tables 2.2 to 2.4. The storage component appears due to a net storage having taken place during the period considered (1948-70).

Table 2.2 - Average annual water balance (1948-1970) for Lake Victoria.

PARAMETER	VOLUME (1000 MILL. M^3)	AVERAGE RATE (M^3/SEC)	% OF TOTAL INPUT
Rainfall on Lake	114	3625	86
Land catchment contribution	19	596	14
Total input	133	4221	100
Evaporation from Lake	100	3157	75
Outflow from Lake	29	914	22
Storage	5	150	3

Source: HYDROMET, 1974

Table 2.3 - Average annual water balance (1948-1970) for Lake Kyoga

PARAMETER	VOLUME (1000 MILL. M3)	AVERAGE RATE (M3/SEC)	% OF TOTAL INPUT
Rainfall on Lake	6	176	15
Inflow from Lake Victoria	29	914	77
Land catchment contribution	3	92	8
Total input	37	1182	100
Evaporation from Lake	7	242	20
Outflow from Lake	29	930	79
Storage	0	10	1

Source: HYDROMET, 1974

Table 2.4 - Average annual water balance (1948-1970) for Lake Albert

PARAMETER	VOLUME (1000 MILL. M3)	AVERAGE RATE (M3/SEC)	% OF TOTAL INPUT
Rainfall on Lake	4	121	9
Inflow from Semliki River	5	147	11
Inflow from Lake Kyoga	30	954	73
Land catchment contribution	3	86	7
Total input	41	1308	100
Evaporation from Lake	8	263	20
Outflow from Lake	34	1070	82
Storage	-1	-25	-2

Source: HYDROMET, 1974

2.1.2 The Ugandan catchments

For operational purposes DWD has divided the country into eight subbasins of which six are draining into different reaches of the Nile or the Equatorial Lakes.

- Basin no. 1 — Catchments discharging into Lake Victoria (area 59,858 km2, incl. Ugandan part of Lake Victoria)
- Basin no. 2 — Catchments downstream of Lake Victoria discharging into Lake Kyoga (57,669 km2)
- Basin no. 3 — Catchments contributing to the Kyoga Nile downstream of Lake Kyoga (26,796 km2)
- Basin no. 4 — Catchments discharging into Lake Edward and Lake George (18,624 km2)
- Basin no. 5 — Catchments downstream of Lake Edward discharging into Lake Albert (18,223 km2)
- Basin no. 6 — The Aswa Basin discharging to the Albert Nile downstream of the Sudanese border (26,868 km2)
- Basin no. 7 — Catchments contributing to the Albert Nile within the Ugandan territory (20,004 km2)
- Basin no. 8 — The Kidepo Basin in the extreme northwestern part of the country (3,129 km2)

The basins and the drainage network are shown in Fig 2.2.

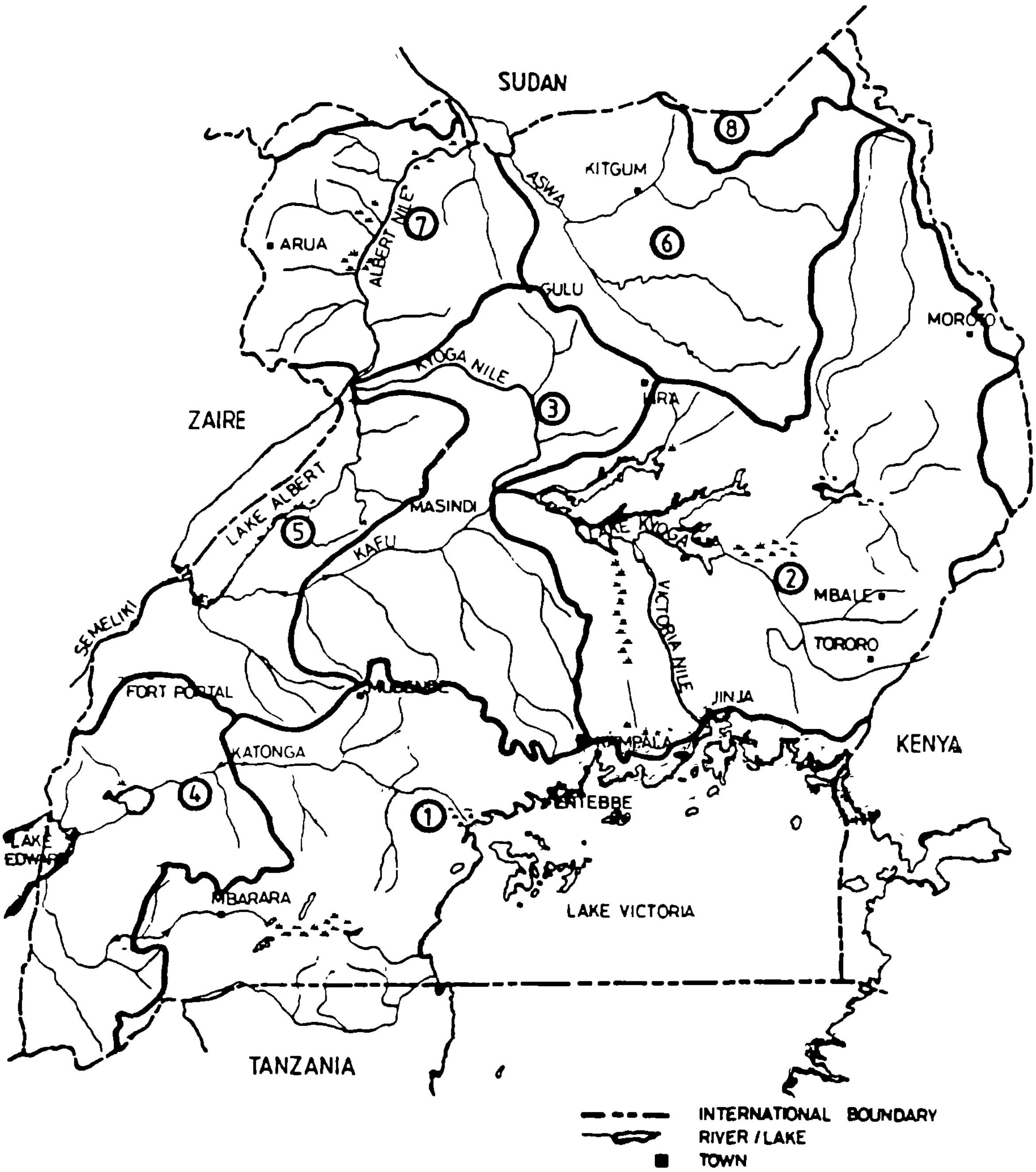

Figure 2.2 - Main basins and features of the Ugandan drainage network

2.2 Approach to assessment

The prominent feature of the Ugandan hydrology is that it includes both the Nile and the Equatorial Lakes (national and international significance) and the Ugandan catchments (national, regional and local significance). Data availability varies widely. For the Nile flows and lake levels, long data series and detailed information exist. Data has been collected through such agencies as the HYDROMET cooperation. The data for the Ugandan catchments is scattered. Discharge recordings have been interrupted during the period of civil unrest and have not been started again.

Thus the Nile flows and lake levels have been assessed using existing data. The assessment of the local water resources has been based on a hydrologic/climatic classification of the territory and extrapolation of results obtained from an analysis of 54 catchments.

As part of the present assessment, data from the 54 catchments have been computerized and screened for obvious errors in the series. However, a complete quality checking of the series including comparison to neighbouring stations and meteorological data has been beyond the scope of this study.

The climatic/hydrologic classification is described in Section 2.3 and the extrapolations from data from the 54 catchments have been described in Subsection 2.4.2.

2.3 Rainfall and evapotranspiration

2.3.1 Rainfall

Direct rainfall is the most important water resource in Uganda and the rainfall pattern has always determined the local land use potential and management and hereby also influenced the population distribution. Even though development of water resources for uses such as irrigated agriculture may gain importance, the rainfall availability will still be a crucial parameter for the development potential.

Prior to the period of civil unrest Uganda had a well functioning system for collection of meteorological information, including a dense raingauge network. This system has virtually collapsed leaving only a few stations in operation. As computerized rainfall data have not been readily available, the assessment of the rainfall patterns has been based on already processed information in the form of isohyetal maps of long term rainfall averages.

A detailed map of mean annual rainfall distribution based on all information up to 1965 is shown in Fig 2.3 (Atlas of Uganda, 1965). Although more recent maps have been produced, e.g. as part of the Sub-Saharan Hydrological Assessment (Gibb, 1989) the data for these lack recent rainfall information. They are based on data from a smaller number of stations and the former map is considered the most detailed source of average annual rainfall information and has consequently been used in the assessment.

Figure 2.3 - Mean annual rainfall distribution (figures in mm/year)

As indicated in Fig 2.4 (Atlas of Uganda, 1965) the rainfall pattern has two peaks (bimodal) for almost all stations. The pattern is linked to the double passage of the Inter Tropical Convergence Zone (ITCZ).

The spatial rainfall distribution is also influenced by the presence of Lake Victoria as well as the local topography. Generally, the rainfall decreases with distance from the lake, while the local topography results in higher rainfall depending on altitude, with the highest precipitation values found in the mountain ranges.

During the early sixties (1961-64) the region experienced a sequence of very wet years with annual rainfalls 17-27% above the long term annual average. This resulted in remarkable water level rises in the Equatorial Lakes (e.g. Lake Victoria levels rose more than two metres during the three year period 1961-63), with adverse effects for the infrastructure (ports, roads, villages) in the riparian countries.

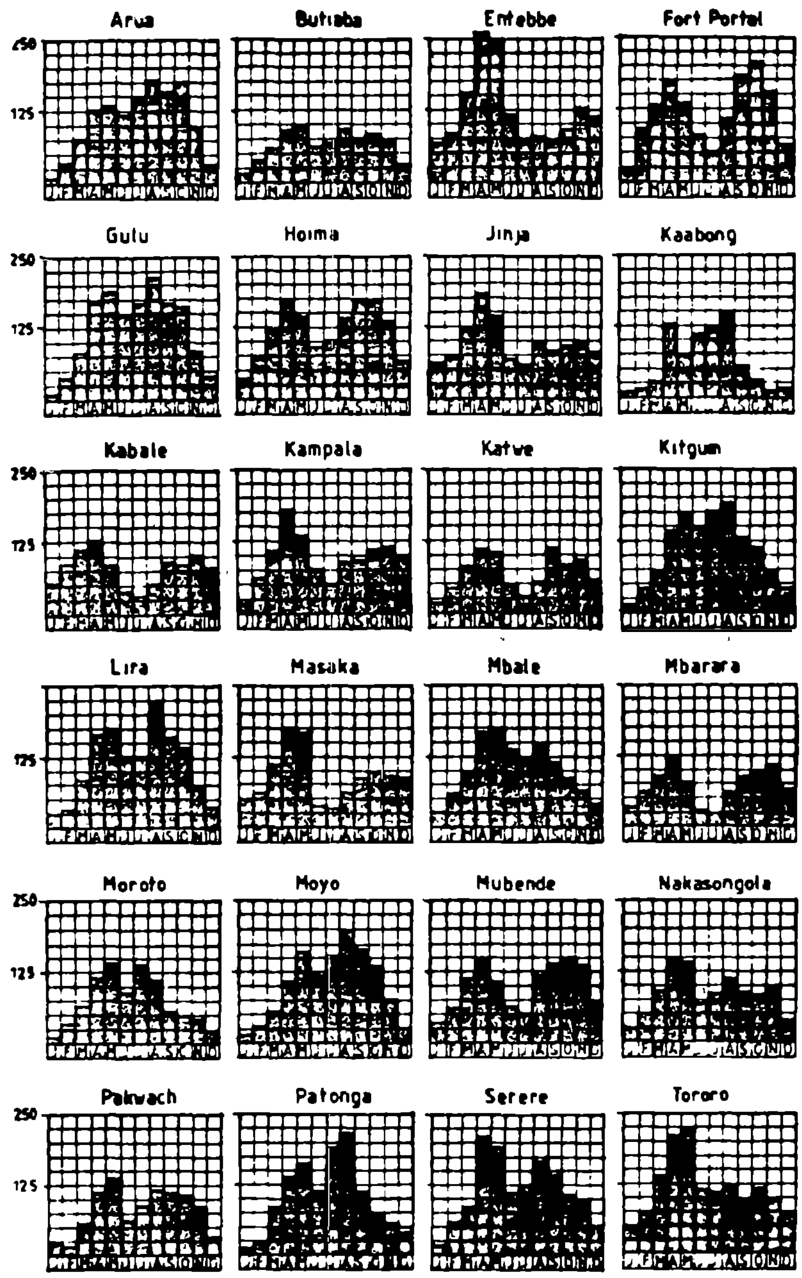

Figure 2.4 - Seasonal rainfall variations (mm)

2.3.2 Evapotranspiration

Measurements of pan evaporation and parameters for calculation of evapotranspiration (i.e. sunshine duration, air humidity and wind speed) have been carried out at a number of stations in the country operated by HYDROMET and Department of Meteorology (DOM). A thorough study of open water evaporation was calculated according to Penman's formula (Rijks, 1970). Fig 2.5 shows the long term average of annual Penman evaporation, which varies between less than 1400 mm in the Southwestern part and more than 2200 mm in the Northeastern part of the country. The seasonal variation of the potential evaporation is generally small (less than 10 %) in any part of the country.

The potential evapotranspiration (Ept) is estimated from Penman's open water evaporation (E0) using the following formula, which is based on measurements from a number of stations in Rwanda, Burundi and Zaire (Shanin, 1985)

$$Ept = 0.91 * E0 + 2.5$$

Rainfall and evapotranspiration dominate the generated runoff patterns. The rainfall reflects, to a certain extent, the catchment topography. A climatic classification based on these two parameters would be expected to give a fairly good indication of the spatial variation in runoff.

A climatic classification of the country prepared by HYDROMET is included as Fig 2.6. It is based on Thorntwaites moisture index (Im) as calculated from the formula:

$$Im = 100(S - 0.6D)/Ept$$, where:

S = (P - Ept) in months with rainfall surplus (mm)
D = (Ept - P) in months with rainfall deficit (mm)
P = monthly rainfall in an average year (mm)
Ept = potential evapotranspiration (mm)

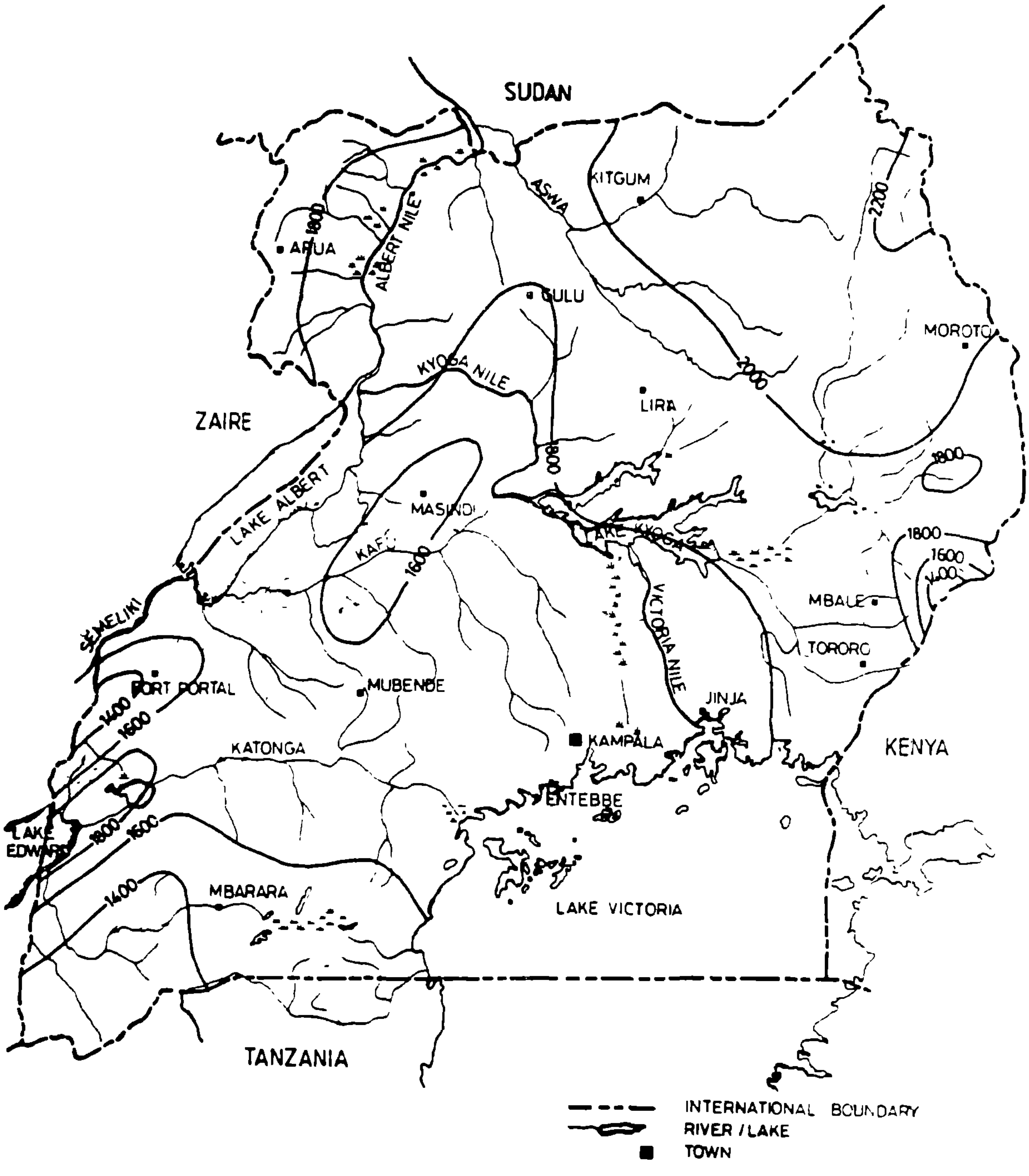

Figure 2.5 - Mean annual potential open water evaporation (Penman Method)

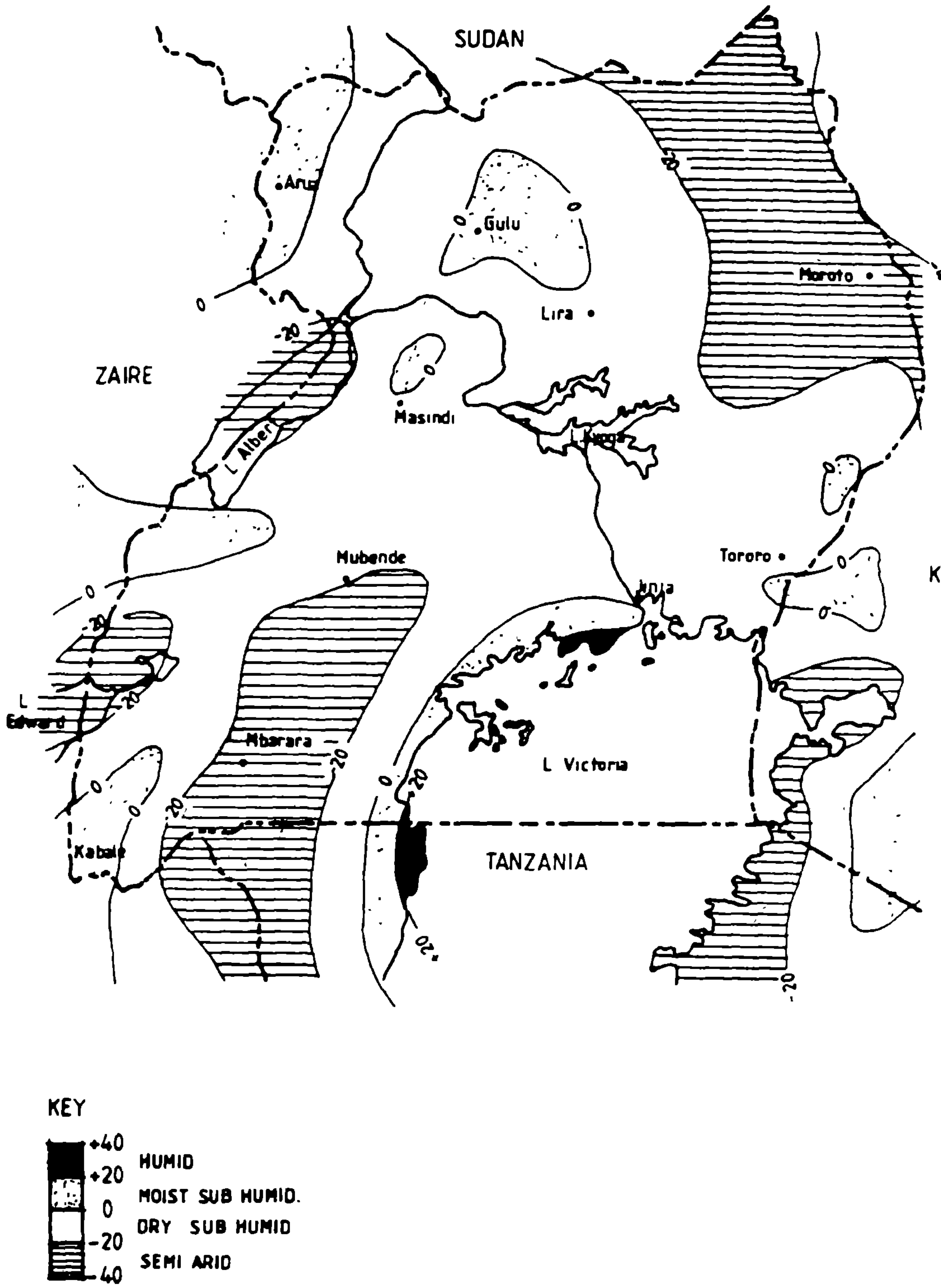

Figure 2.6 - Climatic classification of the Equatorial Lakes and their basins

Climatic types corresponding to different moisture index (Im) intervals are shown in Table 2.5.

Table 2.5 - Climatic types and moisture index intervals

CLIMATIC TYPE	MOISTURE INDEX (Im)
Perhumid	> 100
Humid	20 to 100
Moist sub-humid	0 to 20
Dry sub-humid	-20 to 0
Semi-arid	-40 to -20
Arid.	< -40

Source: HYDROMET

2.4 Streamflow and water balance assessments

2.4.1 Catchment selection

Streamflow data in the DWD database from 54 different catchments (ref. Appendix 2.1) has been analyzed. Catchments have been selected that:

- have computerized data readily available
- represent the different climatic zones of the country
- have country-wide and well spaced distribution
- represent different catchment types (e.g. smaller top catchments, larger basins and catchments with/without swamps).

In order to present a countrywide assessment, it was necessary to extrapolate the results from the 54 catchments to locations outside their boundaries. The extrapolation is based on broad hydrological interpretation of the available data and the climatic classification described above. It can be regarded as the best possible estimate at this stage. However, caution should be applied when using these estimates for uses other than overall planning purposes.

2.4.2 Water balances

For each selected catchment the flows have been analyzed on a monthly basis, and annual mean areal rainfall has been estimated from the isohyets presented in Fig 2.3. Average annual water balances are given in Appendix 2.2.

It appears that there are very large variations in both specific runoff and runoff coefficients between the individual catchments. Runoff coefficients vary between almost zero and 85% (lowest in the flat dry areas and highest for the steep mountain ranges with high rainfall.

Actual evaporation ranges from around 45% of potential evaporation for dry areas and areas with flashy mountain streams, to 92% in the catchments of the most persistent streams in the Masindi area. The extrapolated distribution of annual runoff is shown for the whole country in Fig 2.7.

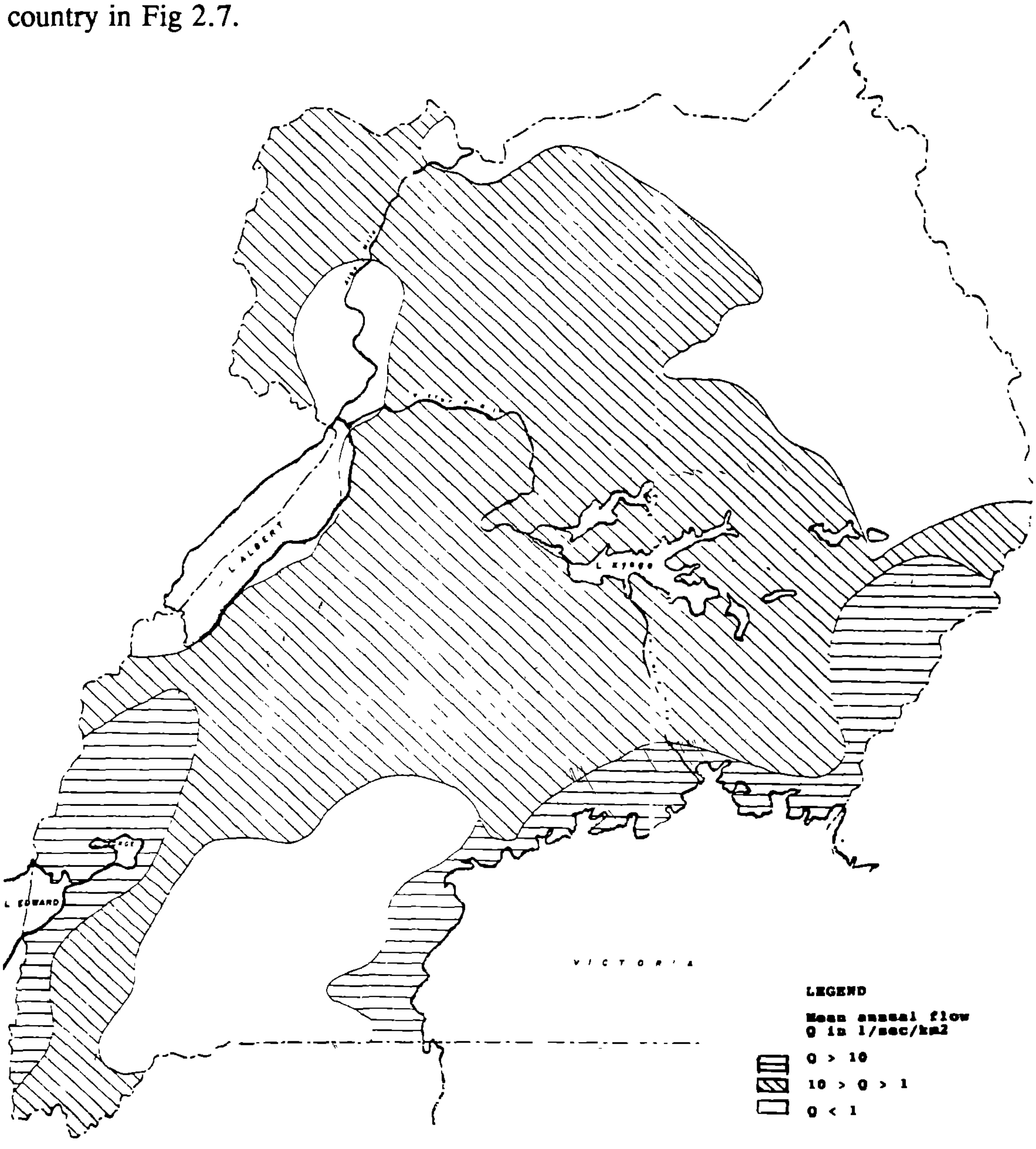

Figure 2.7 - Spatial variation of annual runoff

2.4.3 Low flow analysis

A low flow analysis based on monthly totals is presented in Appendix 2.3. Three different key parameters have been calculated:

- average (over the period of record) flow in the driest month of the year
- lowest monthly flow on record
- one in five year minimum monthly flow as a measure of the dependable yield

The spatial variation of the dependable yield is illustrated in Fig 2.8.

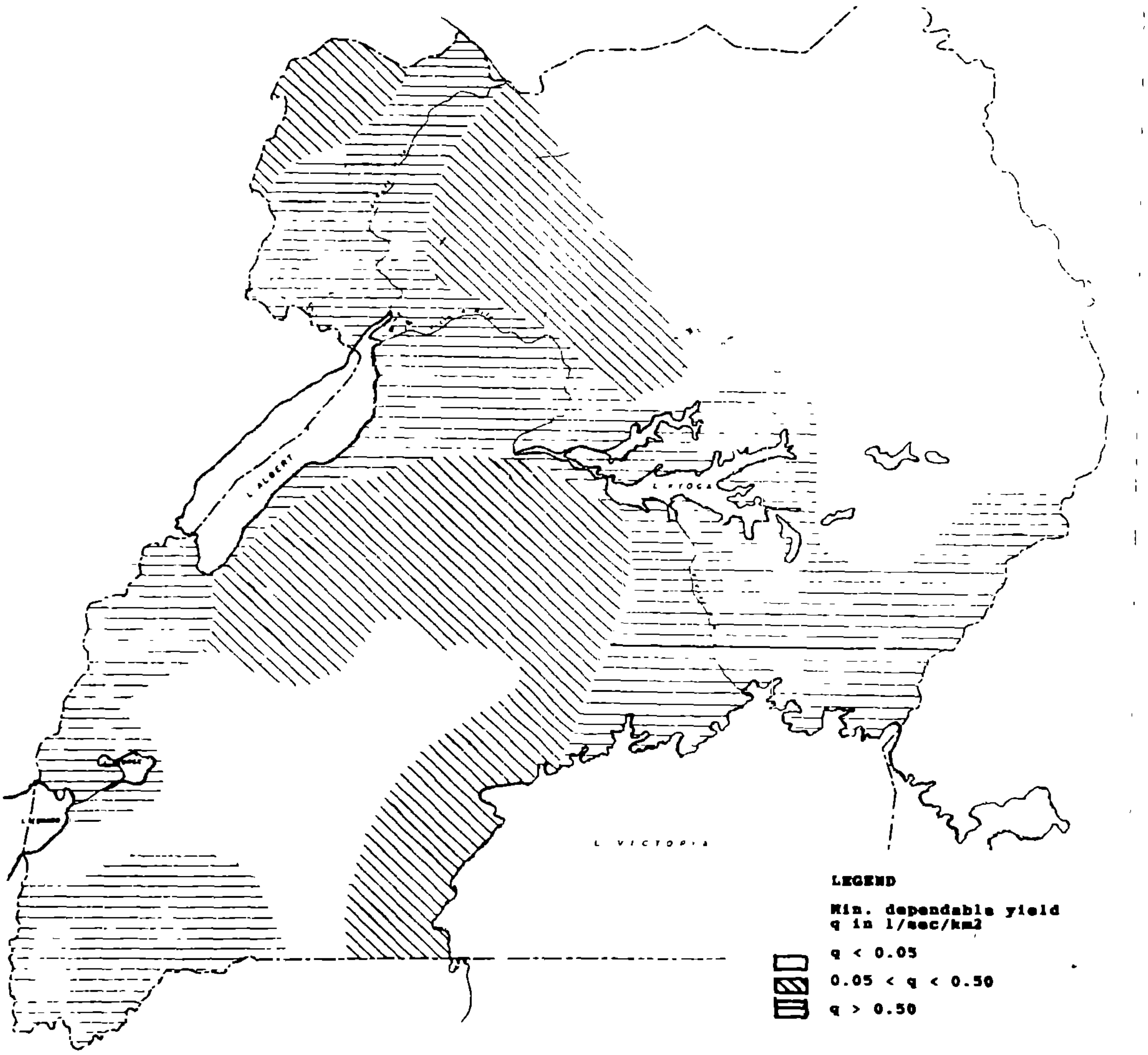

Figure 2.8 - Spatial variation in dependable yield (the one in five year minimum monthly flow)

Generally, the driest period is from January to April where February most frequently has the lowest flows. However, a few stations experience the driest month in the August-October period. While some of the Northern areas were found to have a substantial discharge averaged over the year, the shorter and more intensive wet season in those areas is obviously affecting the low flows. Hence the dependable flows are very small in the Northern part of the country. The wet areas in the Western Regions, at the shores of Lake Victoria and near Mount Elgon, appear to have higher minimum dependable yields.

2.4.4 Flood analysis

Although many rivers in the country are known to have very large flows during periods of high rainfall, only sparse information has been available on frequently flooded areas. The large storage capacity in the swamps and the traditional acceptance of annual flooding of the swamp margins has undoubtedly influenced the perception of what is actually flooding.

An assessment of the daily maximum flows has been made. For each station a series consisting of the maximum annual flows has been extracted and flows with return periods of 2, 5 and 10 years have been estimated by simple interpolation in the ranked series. The estimates are given in Appendix 2.4.

Two flood indices have been calculated:

- flow corresponding to a ten year return period divided by the average flow in the river and

- flow corresponding to a ten year return period divided by the flow with a return period of two years

These indices are merely indicators of variations in flows. An in-depth analysis of flooding risks can not be carried out on the basis of streamflows alone, but has to include the topography of the areas adjacent to the river.

2.5 Water levels and flows in the Nile system

2.5.1 Water levels

After a long period (1900-1960) of fluctuations around a fairly constant level, water levels in Lake Victoria rose rapidly by 2.5 m in three years (1961-64) as a consequence of extraordinary high rainfall. This sudden rise had serious implications for the infrastructure around the lake and even raised questions about the possibility of overtopping of the Owen Falls Dam. The event highlighted the importance of the hydrology of the lake and a series of detailed studies have been made during the last 30 years.

The increased flows experienced in the White Nile as a consequence of the higher rainfall and lake levels coincided with a period of decreased flows in the Blue Nile. While the average contribution of the White Nile during the period 1912-61 was 33% of the combined flow of the two rivers, it was 44% during 1965-86 (Howell & Allan, 1990).

The Hydro-meteorological Survey of the Catchments of Lakes Victoria, Kyoga and Albert (HYDROMET, 1974) started a large scale data collection programme in 1967 and has carried out detailed hydro-meteorological analyses of the three lakes and their inflows.

Notable contributions to the understanding of the hydrology of Lake Victoria were made by the Institute of Hydrology, Wallingford (IoH) (1985) through statistical modelling leading to estimated probabilities of extreme water levels. It was found that the probability of the water level falling below the lowest recorded level (10.22 m on the Jinja Gauge) is 1.1% in any one year. The corresponding probabilities of the water level rising above the highest historical level of 13.28 m was found to be as low as 0.04% for exceedance in any one year.

Futher model studies have indicated that the lake level is independent of the starting level after a period of 6-12 years. Thus, the extreme high water levels between 1961 and 1964 cannot be the cause of the continuing high levels of the lake during the 1970'ies. These were due to the general increase in rainfall over the basin.

Influence of Owen Falls Dam on lake levels

Prior to the construction of the Owen Falls Dam at the outlet of the lake it was agreed by the riparian countries, that the dam should be operated in accordance with the streamflow rating curve constructed for The Rippon Falls, which previously controlled the outflow from the lake. Consequently, since 1954 the dam has been operated as if natural conditions still governed the outflow. Hence, the flow in the Victoria Nile remains purely a function of the levels in Lake Victoria.

A recent study (Acres, 1990) argues, that the agreed rating curve for the now submerged Rippon Falls, which constitutes the operating policy for Owen Falls Dam, may considerably underestimate the virgin flows at site. Therefore, the operation schedule should be the cause of increased water levels in the lake. The study further concludes, that the average flows in the recent part of the outflow series from Lake Victoria are more representative for a long term average of outflow than the pre-1961 period.

The conclusions in the Acres study are contradicting the findings of other studies (e.g. IoH, 1985). Acres bases conclusions on calculation of an 'analytical' rating curve for the original Rippon Falls, an exercise which is related to very large uncertainty and neglects the higher rainfall during the recent period as well as an identified rise in the discharge of the Kagera River (the largest tributary to Lake Victoria). Furthermore the findings of Acres are not consistent with the water level variations in the downstream lakes. Hence the most consistent conclusions are those of IoH and Evans, namely:

- the Nile flows increased during the sixties and were maintained at rates higher than normal by increased rainfall during the sixties and seventies,

- the operation of the Owen Falls Dam has not had a significant effect on the lake levels,

- there is no evidence that the Nile flows will stabilize around a level higher than the long term average.

The latest larger hydrological modelling study (Seue, 1994) of Lake Victoria concludes that the 1961-64 jump in water levels, and subsequent outflow can be explained by a change in rainfall pattern over the lake and that the continued high levels can be returned to a sustained increase in lake rainfall. Furthermore, the study suggests that the lake response this century has been governed by a small number of climatologically homogeneous periods with abrupt and unpredictable shifts between each period. Due to the small number of events analysed, it is very difficult to predict the future trend in water levels.

The annual variations of the water levels of the three major lakes are shown in Fig 2.9.

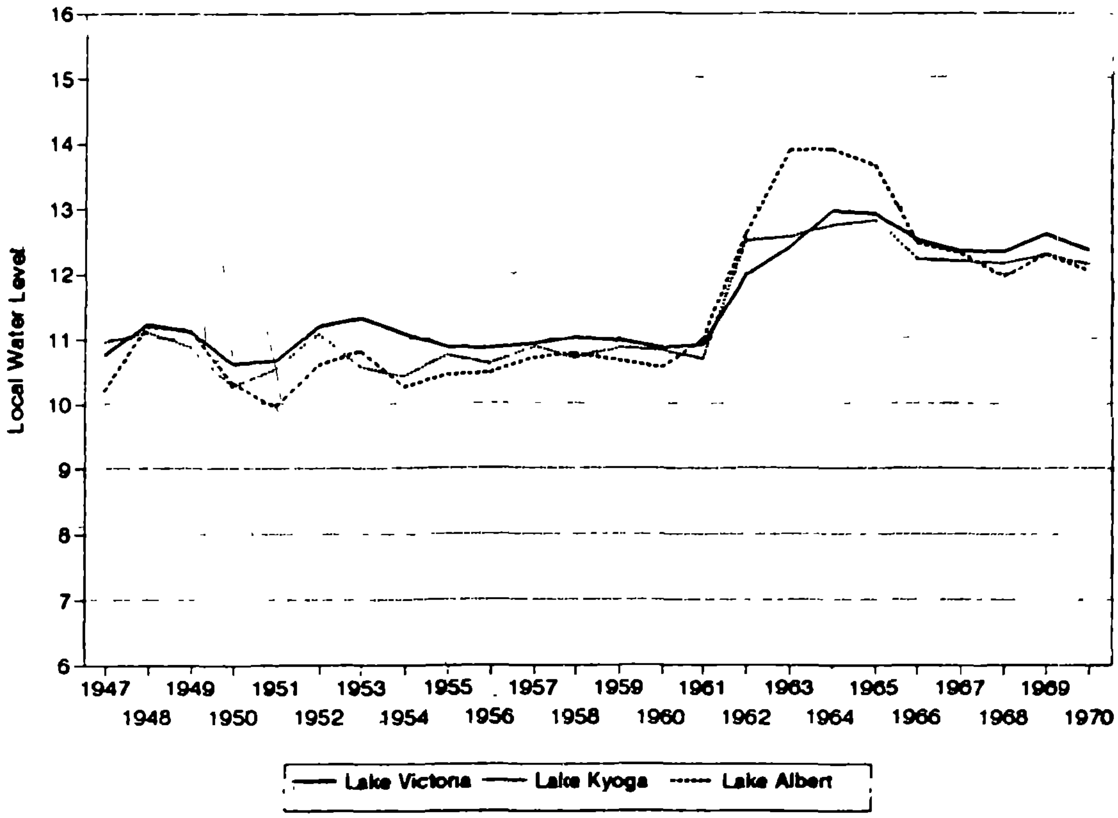

Figure 2.9 - Annual water level variations in the Equatorial Lakes

Due to the near-shore topography and the outflow controls, the general rise of the Lake Victoria water level during the early 60'ies lead to an even higher rise in the levels in Lake Albert. The level increase of Lake Kyoga was almost the same as in Lake Victoria.

The seasonal level variations of the three lakes are shown in Fig 2.10. It appears that seasonal variation is largest in Lake Albert.

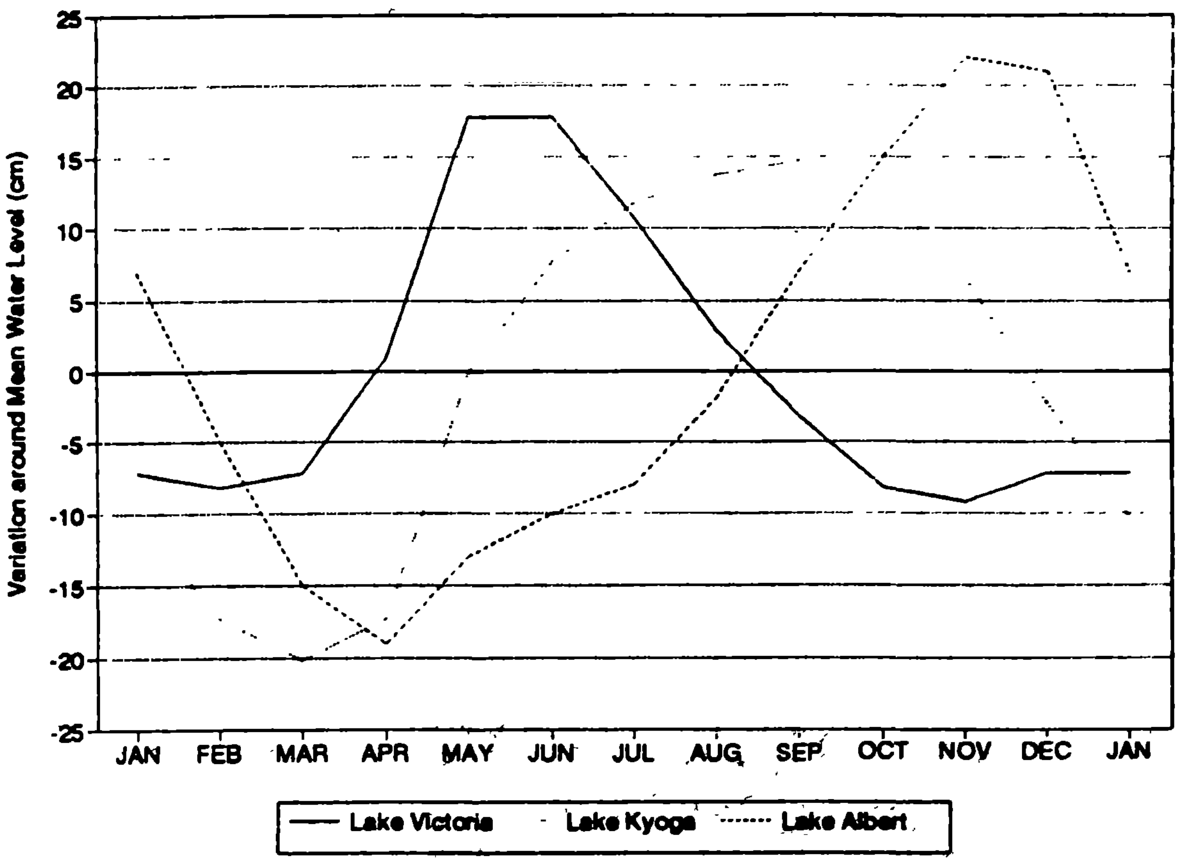

Figure 2.10 - Seasonal water level variations in Lakes Victoria, Albert and Kyoga

2.5.2 Nile flows

The recent decreasing trend in the moving average flows shown in Fig 2.11 suggests, that the lake outflow is approaching an average value lower than that of the 60-70's, and indicate that this value might very well be lower than the average of the 1961-88 flows.

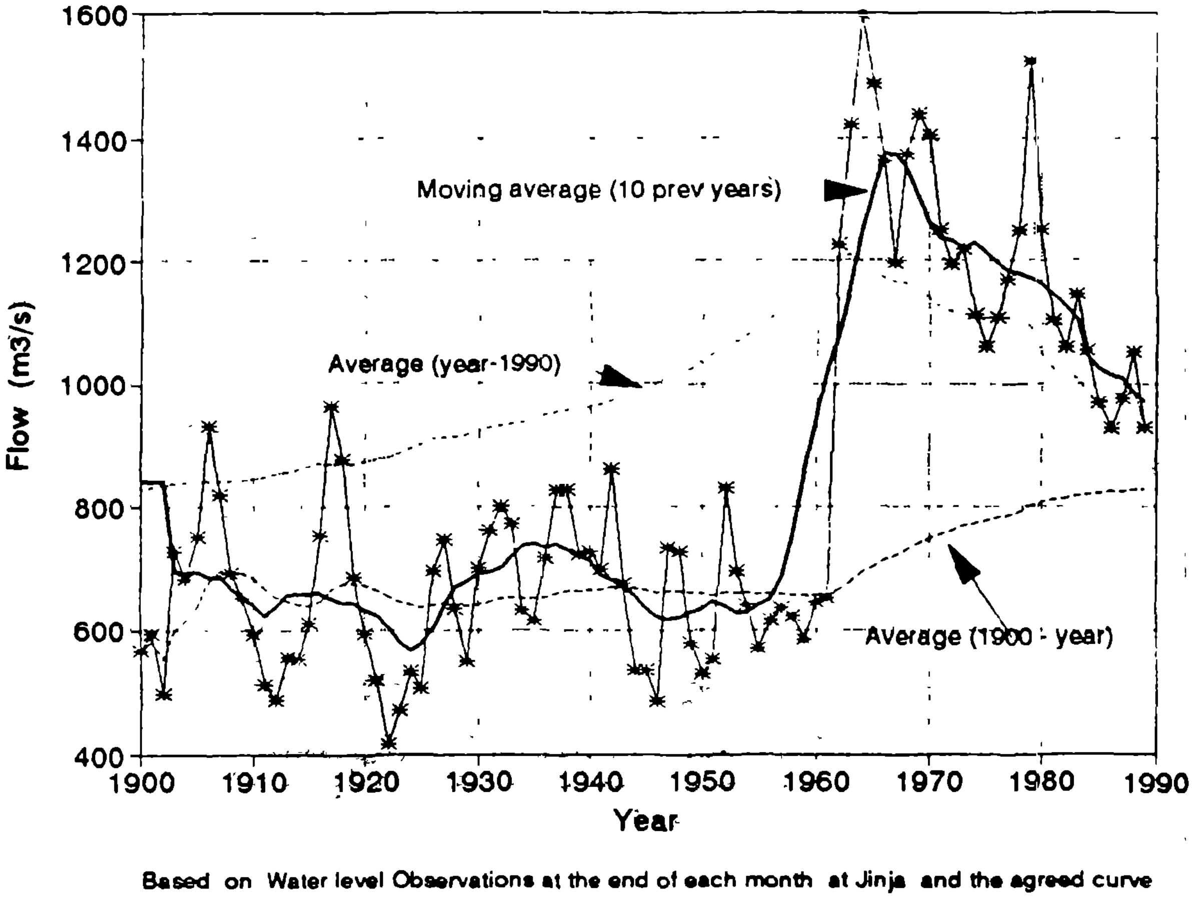

Figure 2.11 - Annual outflow from Lake Victoria

Fig 2.12 shows the seasonal flow variation of the Nile channels and the Semliki River. It appears, that even though the two downstream lakes are much smaller in areas than Lake Victoria, they have a significant influence on the time of arrival of the peak flows of the Nile waters.

The very high level of 'natural regulation' is noted. For instance, the range of mean monthly flows in the Albert Nile is less than 15% of the average flow.

The severe difficulties in predicting the lake levels and corresponding outflows from Lake Victoria have serious implications for planning, design and operation of water resources development projects. The largest water resources development project is probably the hydropower plant at Owen Falls Dam including the planned extensions. In order to assess the performance and suitability of such water resources development projects it is recommended to calculate performance parameters for different scenarios (for instance flow series before 1960, after 1960, and the full series). The result can then be compared and benefits, costs and risks evaluated.

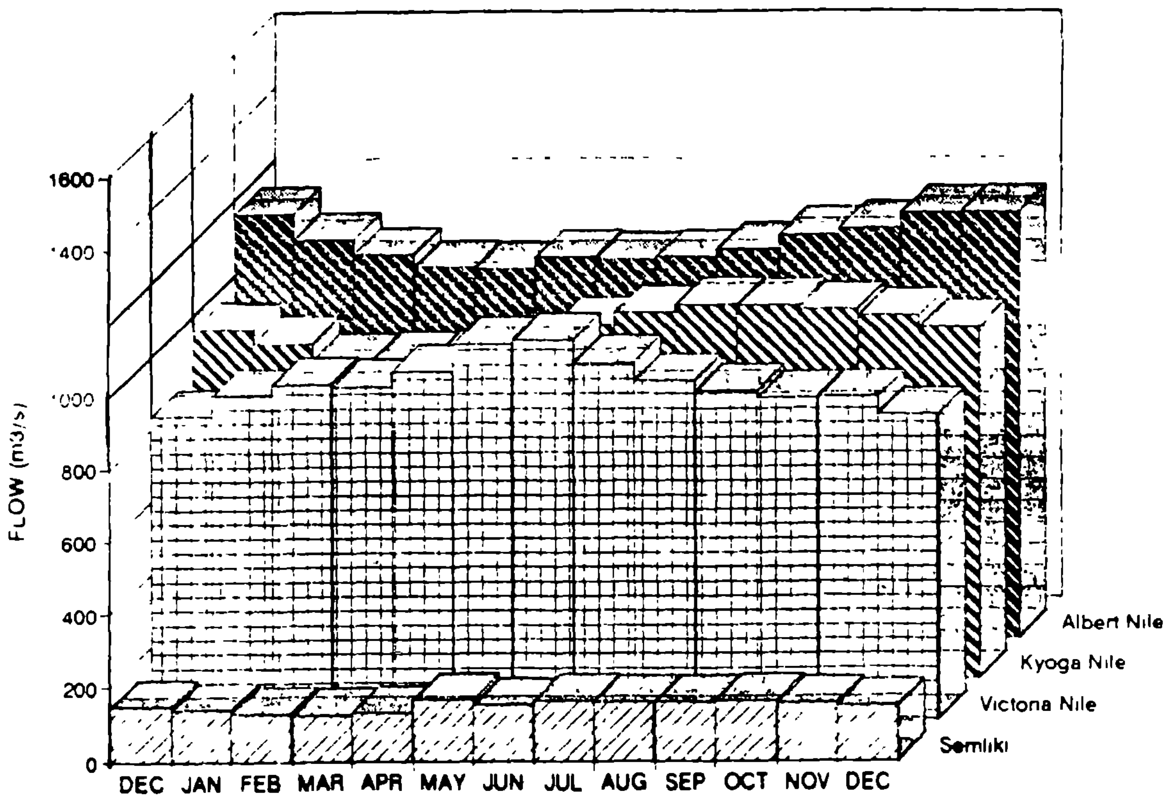

Figure 2.12 - Seasonal flow in Nile channels (average 1948-70)

2.6 Present and planned regulation of the Nile within Uganda

2.6.1 Present regulation

The Nile is only regulated in one place within the Ugandan territory, namely at the Owen Falls Dam, constructed for hydropower generation. Owen Falls Dam is situated a short distance downstream from "the source of the Nile". The source is considered to be the submerged Rippon Falls, which acted as the control of the inflow from Lake Victoria, before the construction of the dam. As described in Subsection 2.5.1, the operation schedule for the Owen Falls Dam is designed to yield flows which would occur if the dam had not been constructed ("natural" flows). This was agreed upon between Uganda and Egypt in 1949. Adherence to the operation policy is controlled by representatives of the major downstream user, Egypt.

2.6.2 Regulation plans

Historical plans

The first plans to regulate and control the Equatorial Lakes of the Nile Basin, and thereby increase the reliability and usefulness of river flows for the benefits to the riparian population, were prepared in the early twentieth century. Since that time other regulation plans have been designed with similar or slightly varied objectives, but none of these have been implemented.

In 1928 and again in 1938 a plan for the Equatorial Nile Project was submitted by the Government of Egypt to the Government of Sudan. The plan would provide more water for irrigation during that portion of the year (January to June) when flows from the Blue Nile were low. The increased flow was to be obtained from the White Nile by storing water in Lakes Victoria, Kyoga and Albert (termed "Century Storage" because of the design period of the reservoirs) and by diverting the flow of the White Nile around the extensive swamp area the Sudd in southern Sudan, through two canals.

Following an 8-year study period the equatorial Nile project was abandoned. Egypt and Sudan signed the Nile Waters Agreement in 1959 allocating available waters between the two countries. Egypt followed an alternative path of development by constructing the Aswan High Dam with its large reservoir capable of over-year storage.

Another regulation plan was designed in 1972 by the Egyptian Organization for Nile Waters and planned to operate with a discharge from Lake Victoria, depending on the lake level, while Lake Kyoga levels were held constant except for years of very high/low flow. Lake Albert should then be operated with an outflow dependent on the combined storage in Lake Victoria and Lake Kyoga.

This operation schedule would be initiated when high levels were reached, so as to provide some safety factor against a series of low supply years. Under these conditions a computer simulation run showed that the plan operated well over the period 1912 to 1974 although the minimum level reached in Lake Victoria was 1133.24m, just lower than the minimum allowable level of 1133.26 m. The maximum level reached on Lake Albert was simulated to 637.46 m, 13 m higher than the maximum recorded level of 623.97 m.

New regulation plans

The most recent plans for regulation are based on the objectives used for historical regulation plans and on the studies of water resources in the lake catchments, and may be summarized as follows:

- maximize the power output at the Owen Falls dam at Jinja;
- maximize power potential in the Kyoga Nile
- meet the foreseeable water resources requirements of the riparian countries of the Upper Nile Basin.
- provide maximum guaranteed annual yield downstream of Lake Albert and
- provide flood control

The latest plan (Plan K8) has been developed by HYDROMET. This plan satisfies all the above objectives and the constraint that the levels of the lakes and the flows in the connecting channels should generally be kept within the ranges of the historical records listed in Table 2.6. The plan suggests regulatory structures at the outlet of all the lakes Victoria, Kyoga and Albert, to control the mean monthly flows and water levels within the ranges specified in Table 2.7.

Table 2.6 - Historical maximum and minimum lake levels and outflows

LAKE	MIN. LEVEL (M)	MAX. LEVEL (M)	MIN. OUTFLOW (M3/SEC)	MAX. OUTFLOW (M3/SEC)
Victoria	1133.08	1136.28	347	1721
Kyoga	1130.31	1134.11	280	1991
Albert	618.75	623.97	343	2050

Source: HYDROMET

Computer simulations over the historical record as well as over a synthetic series of hydrologic events, show that K8 would yield ranges of levels and outflows comparable to those recorded. However, in the case of Lake Albert, where the range of outflows is restricted to those specified K8 did not produce such comparable results. K8 showed a good performance when evaluated against parameters like time of exceedance of the required outflow, time of exceedance of the required draft volume, hydroelectric efficiency (min. water loss over the spillway) and non-exceedance of damaging flood flow.

Comparing the regulated water levels with the recorded water levels it becomes apparent that level increases of approximately 1 m will be experienced in Lake Victoria and Lake Kyoga while Lake Albert will experience level increases of up to 5 m.

Table 2.7 - Regulations suggested in Plan K8

LAKE	REGULATION PARAMETER		MONTHS	REGULATED FLOW (M3/SEC)
	WATER LEVEL (M)	COMBINED ACTIVE STORAGE LAKES VICTORIA AND KYOGA ($10^9 M^3$)		
Victoria	<1133.5 1133.5-1136.0 >1136	-	Jan-Dec Jan-Dec Jan-Dec	Natural 700 Natural
Kyoga	<1030.75 1030.75-1034.0 >1034.0	-	Jan-Dec Jan-Dec Jan-Dec	Natural 650 Natural
Albert		<85 85-150 >85	Jan-Jun Jul-Dec Jan-Jun Jul-Dec Jan-Jun Jul-Dec	650 850 450 650 1500 650

Source: HYDROMET

Requirements for assessments

The different regulation schemes have been evaluated on the basis of their hydraulic efficiencies during their preparation and analysis. Obviously no attempt has been made as yet to assess the full economic and environmental consequences for the system as a whole and for the riparian countries seen as single entities. In this context Uganda has a unique position as the country in which the major part of the environmental consequences will be felt.

2.7 Water resources dynamics

2.7.1 Trends and variations in hydrometeorological parameters

During the last few years grave concern has been expressed by many authorities and private persons over declining water levels of surface water bodies and reduced water resources availability in Uganda. springs, wells and boreholes are reported to have shown signs of declining yields and levels.

Lake Wamala, River Kafu and Sezibwa River have been reported to have reduced resource availability. Also Lake Victoria levels have been lower than average and with a decreasing trend. There has been concern that these changes in water resources availability are results of permanent changes in climate. The reasons for such climatic change are believed to include changes in land-use and general environmental degradation - especially deforestation, cultivation of swamps and overgrazing.

On this background it was deemed relevant to preprare an assessment of water resources through a case study of the time series of important hydrometeorologic parameters in order to detect possible climatic trends and some of their effects. The catchment chosen for the study was the Kafu river basin (National Sub-basin no. 8) which has a central location in Uganda.

The objective of the study has thus been to quantify and assess any long term trends in surface water resources occurrence based on an analysis of trends in rainfall and the correlation between rainfall and runoff for a selected basin.

The main findings of the study of rainfall and runoff in the Kafu river basin can be summarized as follows:

- long term variation in rainfall over Kafu basin shows a cyclic behaviour with a tendency of years of below average or above average to persist for periods of up to six years

- in terms of rainfall there is no evidence of significant climatic change

- during periods of above average rainfall the increase appears during September to November with the highest increases in November. Similarly, increases occur during March to May with highest increases in March

- during dry periods the first rainy season has a delayed onset and is reduced to the months of April and May only. The second rainy season has an early onset and is beginning during the month of July and ending in October

- the long term trends in rainfall and runoff are correlated and the decline in water resources availability is explained by the decline in rainfall

- there is no significant change in land-use or environmental degradation and increase in consumptive water demand that can explain the decline in water resources availability. The most serious water deficit of the 1940/50's occurred, when the water demand was insignificant and when the landcover was not degraded

Fig 2.13 below illustrates the long-term variations in rainfall over the Kafu river basin. The long term variations show a cyclical behaviour, and present departures from the norm are much less serious than those experienced in the forties, fifties and early eighties. The observations are in harmony with the general pattern of Lake Victoria level variations, and it can be assumed that the graph is representative of much larger areas of Uganda. More details from the study are found in Appendix 2.5.

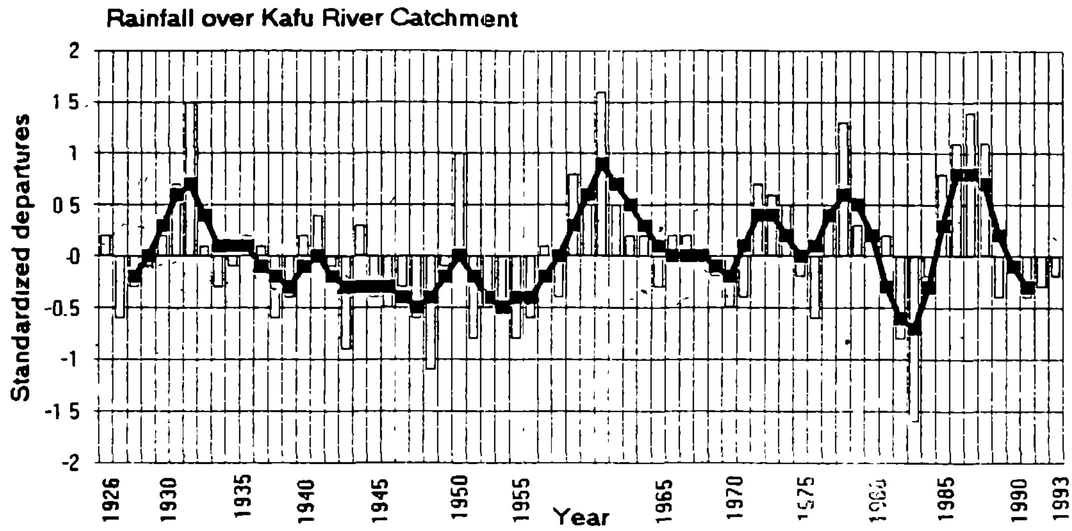

Figure 2.13 - Rainfall variations over the Kafu river basin

2.8 Significant influencing factors

2.8.1 Wetlands

Large parts of the Ugandan territory are wetlands; areas, which are seasonally or permanently flooded. Old inventories (from the 1960's) estimate the total extent of wetlands at about 10% of the country's land area. About one third of the wetlands are permanently flooded.

The wetlands are predominantly located along the shores of the Equatorial Lakes and at the lower reaches of the national river basins. Hence many rivers flow through extensive swamps before discharging into the lakes or the Nile River.

The presence of these extensive wetlands has significant influence on the discharge from the Ugandan river basins. The main hydrological effects relate to their large water retaining capacity which:

- reduces peak flows
- causes suspended sediment to settle
- increases evapotranspiration.

The shallow depth of the swamps and the dense vegetation lead to losses of very large quantities of water through evapotranspiration and the river flows are generally significantly reduced through the swampy areas.

The characteristic influence from wetlands is exemplified by a comparison of the flow statistics for the catchments Ruizi (Station no. 81324) and Kibale (Station 81333) given in Appendices 2.2 to 2.4.

The Ruizi catchment is only marginally influenced by wetlands and constitutes, as a subcatchment, about half of the Kibale catchment, of which the remaining part is mainly wetlands.

Appendix 2.2 shows that the average annual wetland inflow of 7.8 m3/s is reduced by passage of the wetland area to only 2.9 m3/s at Kibale.

The characteristic water consumption of wetlands is also illustrated by the very low average runoff coefficient (3%) of the large and swampy Kafu Basin (Station no. 83313).

The wetlands have been thought to increase the low flows of the downstream river reaches (UNEP, 1988). However, the low flow characteristics of the Ruizi and Kibale catchments (Appendix 2.3) do not support this theory.

The peak flow reducing effects of the wetlands are apparent when comparing the maximum flows of the two above catchments (Appendix 2.4). The analysis suggests reductions by passage of the wetlands of 85% and 47% for the one in two years and one in ten years high flows, respectively.

2.8.2 Erosion and sedimentation

Interactions between land use practice and water resources

The water available in various water bodies (streams/rivers, groundwater reservoirs, lakes/-reservoirs, wetlands etc.) originates from rainfall running off or infiltrating through the soil surface, on which a particular land use is practised. This land use practice will control:

- to which of the water bodies the rainfall will be directed
- when and at what velocity the rainfall is directed to the water body
- the condition (quality) of the water entering the water body

Hence, it is obvious that water management necessarily has a strong link to land management to the extent that land management measures affect the quantity and quality of the water resources.

Poor agricultural practice, such as cultivation on steep slopes which are not suitable for crop production and overgrazing may lead to increased surface runoff and soil erosion and thus have a negative effect on the water resources in terms of quantity and quality, e.g.:

- transport of soil/sediment to water reservoirs, intakes and pipelines, causing siltation, increased turbidity and technical difficulties
- poor soil structure and decreasing infiltration rates resulting in reduced ground-water recharge and reduced flow during dry seasons
- increased peak flow during months with heavy rains

The main hydrological processes in non-eroded and eroded soil systems and their consequences for a catchment are summarized in Fig 2.14.

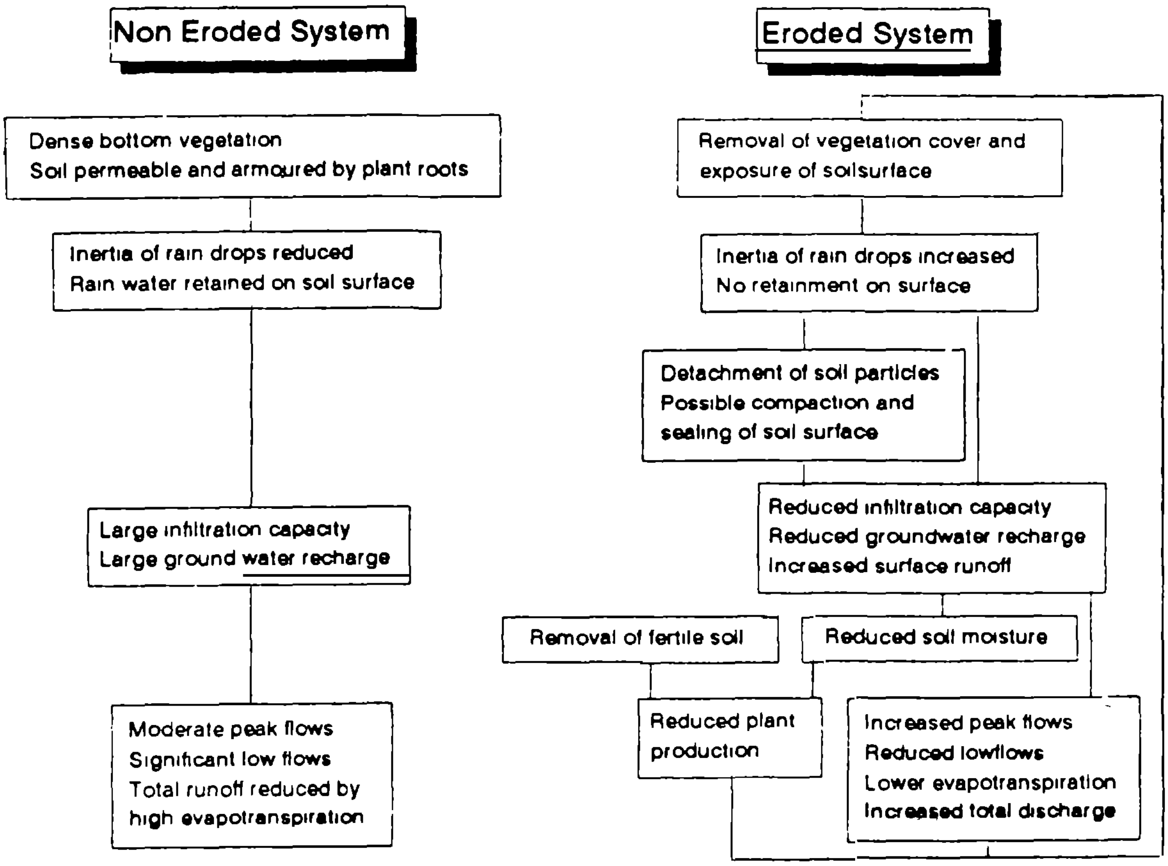

Figure 2.14. - Hydrological processes in eroded and non-eroded soil systems

Soil erosion and sediment load information

The present water resources situation in Uganda with respect to sediment loads and siltation as well as the relation to actual land-use practices, is virtually unknown due to lack of quantitative data. Sediment measurements in rivers are not carried out presently, but some few measurements were taken during the period 1971-72 under HYDROMET. At two sites, Namatala and Waki, sediment load was related to discharge and estimated from monthly mean discharges for one year as 13,000 and 5,000 tons/year, respectively. This corresponds to 98 and 10 tons/km^2, which are considered as moderate and low values, respectively. However, only a total number of 22 sediment concentration analyses were carried out, which is far too few to use for assessments. In a UNEP study made in 1987, a Soil Erosion Hazard map was compiled using GIS technology. The map was based on rainfall erosivity (Fournier's index), soil erodibility (based on soil texture and other soil properties available), slope, land use pressure and population density. This type of mapping where factors are multiplied as in the Universal Soil Loss Equation (USLE), can only give some very rough estimates, it should be supported by field observations and/or measurements. The study did not include any evaluation of the impact of soil erosion on the water resources of Uganda.

Regional Soil erosion impact on water resources

Uganda has been divided into 7 zones according to the negative impact of land processes, primarily soil erosion, on the water resources (see Fig 2.15 and Table 2.8). The division is based on:

- topography
- land use, which is subdivided into
  - percentage of area cultivated
  - livestock density
  - vegetation cover
- soil erodibility
- population density
- rainfall erosivity (only partially included as no proper data existed)

The most severe erosion is experienced in the 3 mountainous areas, Mt. Elgon and surrounding foothills, the Ruwenzoris, and the south-western mountainous region (Kabale and Kisoro districts). Intensive cultivation on steep slopes with no or only few and inadequate soil and water conservation measures has resulted in extensive erosion in parts of these areas. Accelerated erosion (where the soil removed by erosion exceeds the soil formed by weathering of the bedrock) is taking place in major parts of all three mountainous areas, - thus the situation will worsen if no measures are undertaken.

Next to these mountainous areas there are the two major semi-arid regions, namely the north-eastern pastoral area in Karamoja (Area 2A) and the south-western pastoral area (Area 2B). The low amount of rainfall and overgrazing caused by the large number of cattle result in poor vegetation cover, especially towards the end of the dry season - leaving the ground exposed to erosion by rainfall and surface runoff.

In the remaining part of Uganda the impact of soil erosion on water resources is not severe, although in certain specific areas there might be a significant impact e.g. in hilly areas in Arua with high population density.

A more detailed describtion of the land and water management issues and relations are found in the Land and Water Management Study in Appendix Report Volume 3, Annex 1.

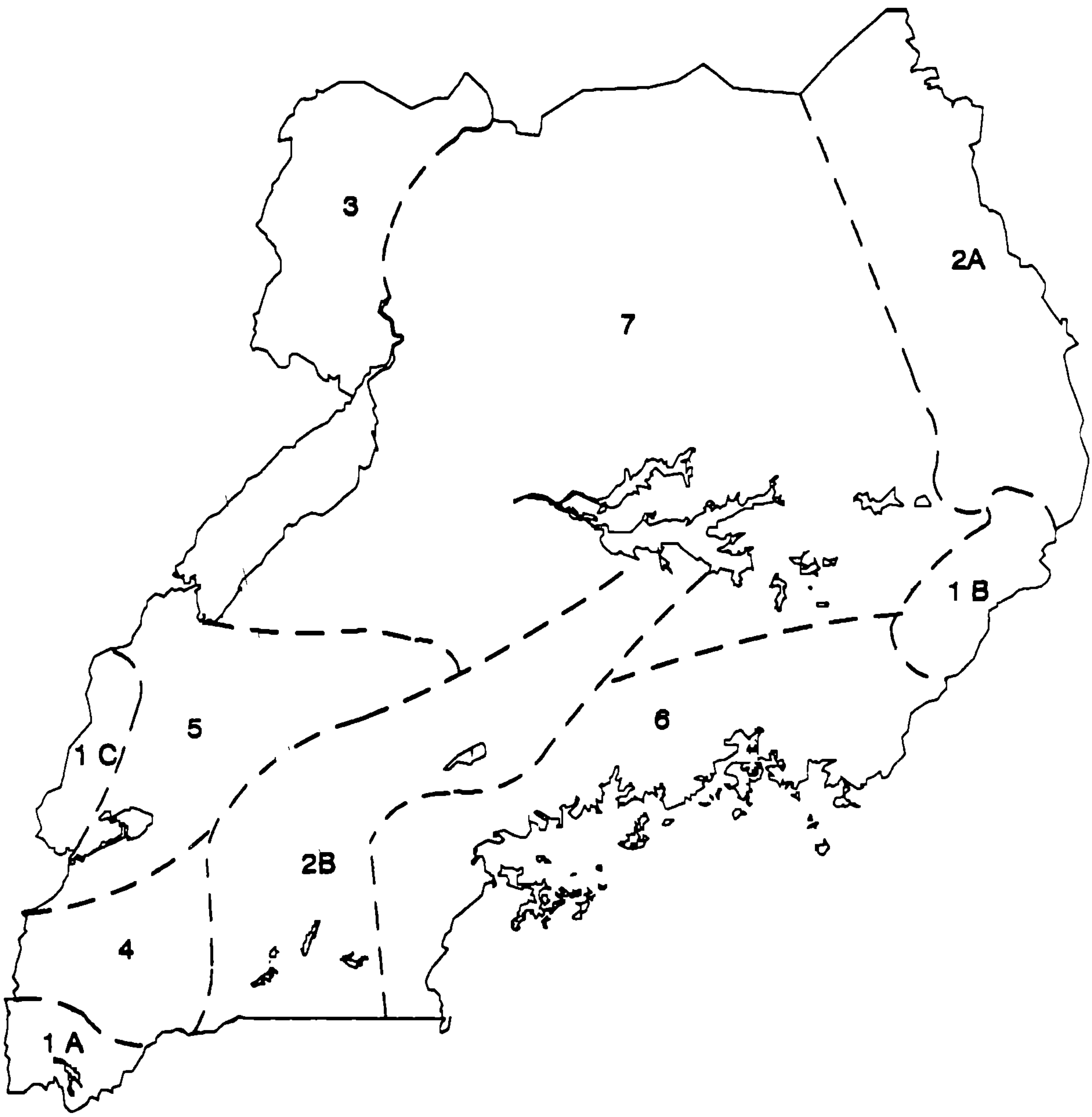

Figure 2.15 - Main erosion zones in Uganda according to severity and impact on water resources

2.9 Major local surface water quantity problems

Dry areas
The dry areas include parts of the Southwestern and Central districts (Mbarara, Rakai, Masaka, Mpigi, Mubende and Luwero), Albert Nile Valley, Lakes George and Edward plains and the Northeast. These areas are predominantly rangelands.

The main problem is that the rivers in these areas are generally seasonal, ground water potential is limited and low yields and small recharge rates are found. Surface storage reservoirs (dams and valley tanks) often receive insufficient inflow or have too little storage capacity (often due to siltation) to maintain a water level. These problems increase the strain on the few perennial reservoirs where big herds gather. Overgrazing and degradation of the surrounding areas are among the consequences. Shallow well spring potential is low in these areas.

Hilly areas
Problems of flooding from flashy mountain streams on Mountains Elgon and Rwenzori are reported, e.g river Nyamwamba flooding lower valleys in Kilembe and the airfield. Other problems include supply of water to settlements uphill, and sedimentation of water intakes. At the national level these problems are not considered to be major and can be addressed at the local level.

Swampy basins
Retainment and evaporation of large parts of the runoff from upstream catchments in swamps reduce the dependable yield downstream and thus also the potential for irrigated agriculture in these areas.

Drainage of swamps for agricultural benefits has in a few cases caused problems for town water supply which relied on the swamp as water reservoir.

The water balance of the swamps is sensitive to climatic variations. Some previously permanent swamps (e.g. Lake Mawala in the South-central Region) has dried out during the most recent period.

Lack of hydrometeorological data
Information on runoff, rainfall and evaporation especially in minor catchments in the dry areas is lacking. Up-to-date and processed hydrometeorological data on rainfall and evaporation is also lacking and the national hydrometric data collection system has virtually collapsed, leaving only a few operational stations and big gaps in the historical series.

2.10 Tentative conclusions and action areas.

The rapid assessment of the surface water resources in terms of quantities tentatively reveals that:

- direct rainfall is the most important water resource in Uganda and determines the local land use potential and the population distribution,

- spatial variation of mean annual rainfall is very large over the country (625 - 2000mm) and depends on the distance from Lake Victoria as well as the local topography. Two wet seasons are experienced all over the country except in the Northern Regions,

- the annual potential evaporation is generally higher than the annual rainfall, but its seasonal variation is smaller,

- although Uganda seems to have abundant water resources at the national level, very large differences are found in the discharge characteristics of the various catchments,

- dependable yields are very low in the North Western areas, whereas they are higher in the Western Regions, around Lake Victoria and in the mountains.

- the extensive wetlands affect the river flows by their retainment of water and large parts of the runoff from upstream catchments evaporate there,

- although high peak flows occur in the country's rivers, only sparse information is available on flood damage. Reported flooding problems are localized and must be dealt with at the local level,

- the national hydrometric network has virtually collapsed since 1979 leaving a gap in the knowledge of the current status of the water resources of the country. The existing network in the dry areas and around Lake Kyoga is not adequate for assessment of the local water resources in those,

- reliable water resources management decisions are not possible due to the inadequate data background,

- in the dry areas rivers are seasonal, and surface storage resevoirs dry out in many cases which increases the strain on the very few remaining sources of water.

- no quantitative information on the extent and effects of rosion and sedimentation exists.

Based on the above tentative conclusions the following action areas have been identified:

- review and rehabilitate the hydrometric network and resume comprehensive flow measurements programmes to recalibrate rating curves,

- strengthen the data processing capabilities of DWD through supply of technical assistance and necessary soft- and hardware, ensuring immediate and well qualified processing, quality checking and computer storage of currently collected as well as historical data,

- transfer of hydrometeorological data from TECCONILE to Ministry of National Resources (DWD),

- prepare hydrological yearbook,

- improve the design basis for small scale dams and valley tanks, water conservation measures, etc.

- undertake detailed water balance studies including evaporation and ground water recharge processes, including evaluation of the effects on the water resources of land use.

- strengthening DWD's capabilities for undertaking such water balance studies through supply of technical assistance, training and the necessary hydrological tools,

- monitoring and mapping of the extent, causes and effect of soil erosion and sedimentation,

- investigation of the detailed hydrological effects of wetlands and their possible exploitation for irrigated agriculture.

The first two points are included in the projects identified as part of the Water Action Plan work (see WAP.Doc.002, "Rehabilitation of water resources monitoring and assessment services in Uganda").

3 SURFACE WATER QUALITY

3.1 Approach to assessment

The objective for the rapid assessment of surface water quality is to provide an evaluation of the present quality of Uganda's surface waters on a broad national scale. Furthermore, an evaluation of the main effects of natural factors and manmade developments on the water quality shall serve to identify main issues to address within the use and protection of the Ugandan water resources.

A substantial amount of data is needed for a direct assessment of surface water quality. An evaluation of most water quality parameters requires data series covering seasonal variations measured at certain frequencies, and spatial differences measured in a strategically planned network of sampling stations. Such a data framework does not exist regarding the quality of Ugandan surface waters. The available data are extremely scattered both in time and space, implying that:

- many water bodies are not covered by any water quality measurements
- a number of essential water quality parameters have never been measured
- when data exist, they typically derive from single surveys covering a short period and/or restricted areas, generally made for special purposes (basic research, sewerage planning, water supply planning etc.)

Furthermore, the period of civil unrest in the country has resulted in an almost total lack of recent water quality data. This implies that changes or developments during the last 15 years have not been detected. Moreover, old data for certain parameters may be of doubtful value due to inadequate analytical methods used at that time.

In the following rapid assessment of Ugandan surface water quality, the existing data have been included to the extent it can be used for generalization, but it has been necessary to base most conclusions on collected information about current and foreseen sector activities combined with specific and general information about their impacts on the water quality. For this reason the chapter includes a review of current activities within the various sectors which have potential impacts on the aquatic environment.

3.2 Impact from natural factors

The quantitative chemical relationship between land and water in tropical Africa is complex and not fully understood. The following section, therefore, concentrates on a brief description of the major water quality characteristics as caused by natural processes.

The general variability of water quality in inland fresh water systems is basically governed by the following natural factors (i.e. without human impacts):

- occurrence of soluble or easily weathered minerals in the soils, thickness of weathered soils, organic soil cover etc.
- precipitation/river run-off ratio
- occurrence of peat bogs/wetlands retaining inorganic nutrients and releasing organic/humic substances
- ambient temperature
- internal chemical and biological processes

The natural chemical composition of the Ugandan surface waters generally reflects the characteristics seen for many African lakes and rivers (Viner, 1971) i.e. high ratios of:

$$(HCO_3^- + CO_3^{--})/(Cl^- + SO_4^{--})$$

$$Cl^-/SO_4$$

$$Mg^{++}/Ca^{++}$$

The inorganic constituents are derived from a very old eroded peneplain composed largely of metamorphosed precambrian rock.

3.2.1. Soil

A high insolation combined with high precipitation have produced mature soils (ferrulites) which are characteristic for almost the whole area. They are extremely weathered and leached, markedly lacking soluble ions, and are often found as laterites composed of iron and aluminium hydroxides, or of kaolinite impregnated with these hydroxides. Outcrops of later deposits, notably volcanic, are associated with the areas of tectonic disturbances of the western limb of East African Rift giving rise to somewhat higher natural concentrations of minerals in rivers and lakes in this area.

Due to the rainfall variations over the year, a marked seasonality exists in the mineral contents of the waters, reflecting the variations of precipitation induced runoff.

Another water quality aspect of the rivers is the load of suspended solids deriving from erosional processes in the catchment areas. The amount of data available on (natural) sediment transports in the Ugandan rivers are few, but the monitoring programme executed under the HYDROMET project in the late seventies, indicated generally low sediment loadings for the rivers in the project area. Annex 12 "Land and Water Management Study" in WAP.Doc.012 gives an assessment of the erosion/sedimentation situation and the impact on water resources.

3.2.2. Nutrients from plants and soils

A major factor governing the water quality of the Ugandan rivers and lakes is the washout of plant nutrients. As the growth of phytoplankton, macro algae or higher plants is the key process determining the ecosystem balance (trophic level) and thereby the balance of many water characteristics, the importance of the abundance of the nutrients is obvious.

The formation and leaching of nitrogen compounds from the soils depends on a number of factors of which the rainfall is the most important, but also the particular soil type and the vegetation cover play significant roles. A deeper discussion of the mechanisms is beyond the scope of this report. However, the general weathered nature of the Ugandan soils implies relatively low concentrations of nutrients in the receiving surface waters.

As both organic content, soil fertility and annual mean rainfall increase from the northeast to the southwest of Uganda, relatively higher amounts of nutrients should be expected to be washed out in the south Ugandan soils compared to the Northwest Region. This pattern is indicated in Table 3.1 showing the chemical composition of selected Ugandan rivers (Viner, 1971). Though the table reflects a single survey, it illustrates the ranges and variability of the major chemical constituents in the rivers. The figures shown reflect the early rainy season when the nutrient levels would be expected to be highest.

Table 3.1 - River water composition in Uganda

		Cond. umho	HCO3 mg/l	SO4 mg/l	Cl mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	SiO mg/l	Fe ug/l	Mn ug/l	PO4 ug/l	NH3N ug/l	NO3 ug/l
Mount Elgon	MIN	88	48	3.9	0.4	7.7	2.8	4.8	3.2	15	7	6	100	<5	0
9 rivers	MAX	365	220	18.2	4.2	44.5	10.9	18.4	7.4	36.2	350	26	314	<5	860
Wooded savan-	**AVG**	**156**	**87**	**8.1**	**2.2**	**15.9**	**4.5**	**9.6**	**4.2**	**21.8**	**100**	**20**	**160**	**<5**	**288**
na/forest	RAT		5.6	0.5	0.1	2.0	0.3	0.6	0.3	1.4	6.4	1.3	10		14
Karamoja	MIN	42	19	4.1	0.7	3.4	1.4	1.8	4.2	6.9	9	0.2	35	<5	50
4 rivers	MAX	130	76	6.2	2.1	14.3	3.2	7.4	6.5	12.9	19	2.5	940	<5	500
	AVG	**82**	**48**	**4.7**	**1.3**	**8.4**	**2.4**	**4.1**	**5**	**18.6**	**17**	**1.1**	**248**	**<5**	**204**
	RAT		5.9	0.6	0.2	1.0	0.3	0.5	0.6	1.0	2.1	0.1	30		25
Papyrus swamps	MIN	45	0	10.7	1.6	1.5	1.5	4.1	1.6	2	20	10	5.8	<5	0
11 rivers	MAX	210	40	71.5	7.5	9.7	7.3	14.5	10.9	33.5	7200	800	40.6	<5	425
	AVG	**114**	**10**	**32.5**	**4**	**4.7**	**3.5**	**9.6**	**3.8**	**18.1**	**1970**	**370**	**13.2**	**<5**	**15.4**
	RAT		0.9	2.8	0.4	0.4	0.3	0.8	0.3	1.5	173	33	2.2		1.4
Semliki river	MIN	480	300	74	40.1	11	35	70.1	50.2	9.1	54	53	105		22
4 stations	MAX	640	353	120	47.1	12.1	44.6	92	72	16.2	104	85	148		126
Lake supply	**AVG**	**565**	**323**	**95.7**	**44.2**	**11.3**	**38.5**	**79.6**	**60.2**	**12.9**	**85**	**67**	**127**		**57.7**
	RAT		5.5	1.7	0.8	0.2	0.7	1.4	1.1	0.2	1.5	1.2	2.3		1.0
Semliki trib.	MIN	56	24	6.6	0.9	3.8	2.3	3.9	1.7	13.2	94	74	68	<5	50
6 rivers	MAX	142	43	30.6	4.7	7.7	3.8	15	4.2	30	220	120	202	55	470
Moist savanna	**AVG**	**85**	**34**	**15.6**	**2.3**	**5.2**	**2.9**	**8.3**	**3.12**	**20.3**	**172**	**91.7**	**137**	**11.8**	**290**
	RAT		4.0	1.8	0.3	0.6	0.3	1.0	0.4	2.4	20	12	16		34
Ituri Forest	MIN	136	75	20.3	4.1	11.7	4.8	11	2.3	45.2	59	24	202	68	432
3 rivers	MAX	215	124	34.5	6.4	21.4	10	18.6	3.3	49.5	71	63	253	136	550
	AVG	**180**	**97**	**28**	**5.5**	**15.4**	**7.2**	**15.2**	**1.8**	**47.5**	**68.3**	**48.7**	**230**	**97.7**	**477**
	RAT		5.4	1.6	0.3	0.9	0.4	0.8	0.2	2.6	3.8	2.7	13	5.4	26
Kigezi highl.	MIN	52	6.1	6.7	1.6	1.8	1.8	3.1	1.8	5.2	25.5	0	21.4		0
18 rivers	MAX	472	330	84	35.5	55.8	24.4	75.5	4.9	29.5	3170	642	740		1050
For./sav. mos.	**AVG**	**107**	**47.3**	**19.6**	**8.3**	**8.6**	**5.25**	**11**	**3.14**	**16.2**	**960**	**113**	**184**		**416**
	RAT		4.4	1.8	0.8	0.9	0.5	1.0	0.3	1.5	90	11	17		39
Ruwenzori	MIN	34	13.2	5.5	0.3	1.1	0.9	2.8		7.1		14	2.5		0
7 rivers	MAX	420	270	46	13.1	57	12.9	29		30.8		385	215		2390
Bogs/forest	AVG	270	78.5	20	4.7	15.6	5	12.3		16.4		123	78.8		533
	RAT		2.9	7.4	0.2	0.6	0.2	0.5		0.6		4.6	2.9		20

RAT: Ratio to conductivity. Source: Viner, 1971.

Regarding nitrogen distribution it is concluded that the soils from the Savanna Region most readily leaches nitrogen, but that the higher rainfall over the mountains compensates for a lower nitrogen proportion in the total nitrogen runoff from the forests (Viner, 1971).

The figures also show generally low ratios of inorganic nitrogen/inorganic phosphorus (in the order of 2-4) indicating nitrogen as the potential limiting factor for aquatic production. This is in concordance with the general opinion among many limnologists, that the availability of nitrogen is the limiting factor for the aquatic plant production in the Ugandan water systems.

3.2.3. Swamps and wetlands

The survey illustrates clearly the special water quality conditions characterizing rivers that pass through the swamps. The marked differences between these rivers and those that bypass wetlands are the low concentrations of inorganic nitrogen and phosphorus found in the swamps.

The ability of swamps to retain nutrients by sedimentation, plant uptake and denitrification is well known. The extensive distribution of swamps in Uganda makes them an important factor governing the supplies of nutrients in the waterbodies downstream the swamps.

Another prominent feature of the swamps is the release of organic/humic substances as well as iron and manganese. Similar conditions are also found for water running through peat bogs such as those found in the Rwenzori mountains.

3.2.4. Lake water

A distinction can be made between the streams and rivers which are fed by the catchment runoff and the Equatorial Lake system and its connecting rivers which receive main water quantities from the dominantly rainfed Victoria Lake. Being relatively stagnant the lakes act as traps for organic material that is both externally and internally produced. This results in a build up of sediments which, for Lake Victoria, approximates 3 mm/y (Hecky, 1993).

The outlets of the lakes under natural conditions would be expected to contain less nutrients and organic material than rivers directly fed by catchment runoff. The main river stretches connecting the lakes will therefore reflect the lake water characteristics and act as diluters regarding dissolved and suspended material entering from their possible tributaries. An example of this is seen in the Table 3.1 where the Semliki river (draining Lake George) shows much less inorganic nitrogen and phosphorus than its tributary streams.

The water quality of the lakes themselves depends partly on the external input of minerals and nutrients from tributaries and rain water. A major factor influencing quality is the internal recycling of these chemical compounds from demineralized organic matter precipitated to the depths of the lakes. This recycling is due to the relative shallow nature of Ugandan lakes, which allows for at least seasonal vertical mixing of the water column. However, as the total natural input of nutrients and organics to the lakes is relatively low, the productivity of these lakes must be considered low. Surveys covering the annual cycle of phytoplankton productivity in Lake Victoria in the sixties support this statement.

As mentioned above, there are geological aspects that affects the conditions in the Lake George area which, due to the younger volcanic deposits as well as the forested vegetation here, provide this lake with significantly higher loads of minerals than do the others. This load results in a relatively high level of primary production. The Lake George system, however, exerts little influence on the main drainage system of Uganda.

3.2.5. General assessment

Summarizing, the general surface water quality as governed by natural factors depends on the input of minerals and suspended matter mainly from rain induced soil leaching and the atmospheric contribution of especially nitrogen to the rainfed Victoria Lake. The generally weathered nature of the Ugandan soils and the retaining effect of extensive swamp areas implies therefore a basic state of low productivity. Combined with an apparently low load of suspended solids as well as a balanced composition of major ions, this leads to generally excellent water quality in the natural state.

3.3 Impacts from human activities

This section briefly describes the sector activities which are considered most important with respect to their possible impact on the water quality of the surface water resources. For each relevant sector current activities are evaluated and the significance of possible impacts tentatively discussed. Additionally, possible developments and their foreseen implications for the future surface water quality are discussed.

3.3.1 Mining

Formerly, the mining activities in Uganda contributed significantly to the economy of the country. Thus, commercial scale mining in Uganda started in 1907, and exploitation has been made (at different scales) of a range of minerals such as: tin, wolfram, copper, limestone, gold, gypsum, asbestos, mica, columbite, tantalite, quarts, kaoline and lead.

The most notable mining activities were the Kilembe Copper Mines, established in 1956 in the foot hills of Mount Rwenzori, and the Tororo and Hima cement factories exploiting limestone as a raw material.

The Kilembe mines produced 15,4 mill. tons of copper ore (1.9% copper) from its start to its closure in 1977. The raw material was processed on site into concentrates (27% copper) which were transported to the refining industry in Jinja. A byproduct from the activity containing cobalt-ferrous pyrite (1,4% cobalt) was stockpiled at Kasese. Today no activity occurs at the mines.

Small scale gold mining is currently going on (licensed as well as unauthorized) in the Moyo, Mubende, Karamoja and Kikagati Districts. Good estimates of the number of gold miners cannot be obtained due to the unknown number of unauthorized miners, but an estimated total of approximately 200 was given by Geological Survey and Mining Department (GSMD). The mining methods used are usually simple (pan washing techniques), but contradictory information has been received regarding possible use of mercury for gold recovery (GSMD, NEAP, 1993).

Tin and wolfram is exploited at small scale from old mines in the Mbarara District (Kikagati near the border to Tanzania) and at Mt. Kafunzo near Kabale in Kabale District.

The most important impact on the water resources from mining activities is the contamination by minerals (including toxic heavy metals) of surface and/or groundwaters due to:

- process and drain water from the mines,
- weathering of dumped or stocked byproducts and wastes.

Furthermore, discharged process water may be chemically altered due to high concentrations of strong acids such as sulphuric acid, resulting in a lowered pH of the receiving water body.

In the present situation, the above information indicates that general mining activities in the country are low and as such do not threaten the general quality of the Ugandan surface or ground waters. However, the possibility for local problems still exists. The environmental impact from the former activities in Kilembe/Kasese mines is discussed in Subsection 3.4.2.

The development perspective for Ugandan mining industry includes the possible commercial exploitation of a range of minerals of which the most promising, according to GSMD, are: the rehabilitation of the Kilembe mines, the recovery of cobalt from the stockpiled pyrite in Kasese, tin and wolfram in Mbarara/Kabale Districts, copper, chrome, gold and marble in the Karamoja District, iron/phosphate in Tororo rock and iron around Muko in Kisoro District (see Fig 3.1).

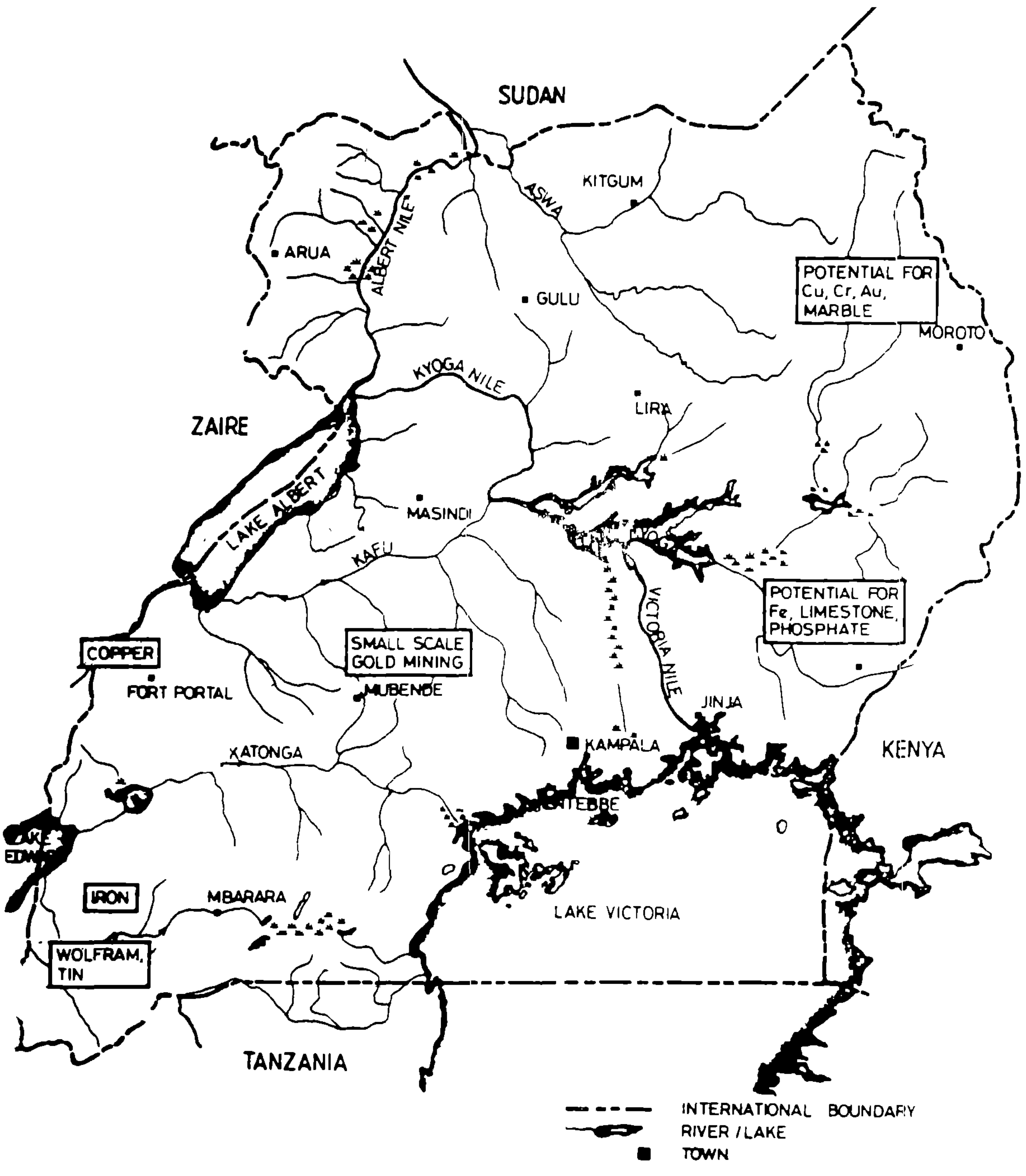

Figure 3.1 - Location of mining areas

The Government of Uganda is currently encouraging investors for the rehabilitation of the mining industries, and a Mineral Investment Promotion Project (UNDP) has been launched under the Geological Survey and Mines Department.

3.3.2 Petroleum exploitation

The existence of mineral oil in Uganda has been known since the beginning of the century due to oil seepage phenomena observed in the Western Rift Valley at Lake Albert. Attempts to explore the oil were initiated in 1917 by test drilling in Kibiro 1925. In 1925 the geology of the area was surveyed with the aim to exploit the oil. With the existing technology at that time, the exploitation of the oil was not possible. It was not until the 1980's that a determined effort was made by the Government of Uganda and the World Bank. This effort led to the Petroleum Exploration and Production Act (1985) as well as a number of geophysical surveys. In 1991 a Production Sharing Agreement was made between the Government of Uganda and Petrofina of Belgium giving the company exploration rights in Laropi-Pakwach, Lake Albert and Lake Edward basins.

This exploration is actively going on, and according to the Petroleum Exploration and Production Department (PEPD) additional surveying is ongoing in the Kyoga and Karamoja areas.

The water quality impacts from oil production concentrate on oil pollution of surface/ground waters due to:

- leaching from the production sites
- discharging of process water containing oil
- deposition of drilling mud (especially if oil based mud is used)
- accidental oil spills

Another possible water quality problem connected to the production of oil can arise from the disposal of saline brines produced with the oil from the production wells. The induced increase of salinity of receiving waters can make these unsuitable for other use.

Until now, the activities are at the stage of exploration and even though test drilling may induce some local pollution problems, currently pollution by hydrocarbons is definitely not a national scale issue. However, with the prospect of initiating oil production within a timescale of 5-10 years from now (PEPD), substantial water quality impacts must be foreseen in certain areas if no proper management is implemented.

3.3.3 Manufacturing industries

The level of industrial activity in Uganda has been severely diminished since the sixties due to the period of civil unrest in the country. Today there are only 5000 factories registered in the country, among which many produce below capacity.

The current activities concentrate on manufacturing goods using raw materials from agriculture, livestock and forestry with the aim to satisfy domestic requirements such as textiles, soap, and beverages. Furthermore, primary processing (pre-cleaning, grading and packaging) of agricultural products for export, such as coffee, cotton, tea, and beans takes place.

The major activities consist of manufacturing of textiles and garments, leather, sugar, foods, soft drinks and flour milling. These activities are concentrated in southern Uganda, particularly Kampala and Jinja, at the shores of Lake Victoria and Victoria Nile. The major industries relevant in this context and their location are shown in Table 3.2.

Breweries and soft drink industries

There are two breweries located at the shores of Lake Victoria: Uganda Breweries Ltd located at Luzira and the Nile Breweries Ltd located at Njeru. There are also ten soft drink factories producing soft drinks and fruit juice, these are concentrated in Kampala, Jinja and Masaka.

The water quality impacts from the breweries are mainly related to the discharge of waste water containing organic solids and solubles such as yeast, alcohol and barley which reduce oxygen content and increase available nutrients which contributes to eutrophication in the receiving water. For the soft drink industries, the wastes mainly contain sugar and fruit residues. Furthermore, the use of caustic soda for cleaning bottles raise the pH in the effluents affecting the water quality locally around the discharge point.

Together the two breweries produce 5000 m3 of waste per day which is discharged into Lake Victoria/Victoria Nile untreated. With measured BOD_5 values of 3500 mg/l (NEAP, 1993) this is resulting in a total discharge of 17.5 tonnes BOD_5 per day.

Table 3.2 - Major Ugandan industries

TYPE OF INDUSTRY	NAME	LOCATION
Breweries	Uganda Breweries Ltd Nile Breweries Ltd.	Luzira Njeru
Soft drinks	Masaka Bottling Co. Masaka Food Processors Pop Soda Bottling Co. Lake Victoria Bottling Kampala Bottlers Uganda Mineral Water Co. Century Bottling Co. Allison Company Crystal Springs Jubilee Ice and Soda Plant	Masaka Masaka Masaka Kampala Kampala Kampala Kampala Jinja Jinja Jinja
Sugar	Kakira Sugar Works Sugar Corporation of Uganda Ltd.	Kakira Lugazi
Plant oil and soap	22 registered companies	Spread over the country
Meat and fish industry	Municipal abattoirs Uganda Meat Packers Uganda Meat Packers Uganda Fisheries Enterprise Gomba Factory Victoria Fresh Foods	Most urban centres Kampala Soroti Jinja Jinja Kampala
Dairy industry	Milk collecting centres Milk packaging plant	Spread over the country Kampala
Textile industries	United Garments Industries Ltd. National Enterprise Corporation (NEC) Uganda Blanket Manufactures Nyanza Textile Industries Mulco Textiles Ltd. Uganda Bags and Hessian Mills African Textile Mills Uganda Spinning Mills	Kampala Kawempe/Kampala Kampala Njeru/Jinja Jinja (closed 1990) Tororo Mbale Lira (closed)
Leather Tanning	-	Jinja
Paper	-	Jinja
Rolling mill	-	Jinja

Source: NEAP, 1993

This is a considerable load of organics which, depending on the water exchange, is likely to affect the water quality markedly due to oxygen depletion near the discharge point. Thus, fish kills have also been reported in the vicinity of the breweries. The wastes from the soft drink industries have somewhat lower concentrations of biodegradable organic matter resulting in BOD_5 values around 450 mg/l, but no estimates of total loads have been obtained.

Sugar industries

Currently, two sugar refining factories are operational in Uganda namely Kakira Sugar Works and the Sugar Corporation of Uganda Ltd (SCOUL Lugazi). A third (the Kinyara Factory) has been closed since 1985 but may be rehabilitated.

As for the breweries, the main impact from the sugar industry derives from the loading of the receiving water by organic wastes resulting in excessive oxygen demand and contribution to eutrophication processes. The organic wastes contain cane wash, cellulose matter, cane juice and molasses waste. Indications of very high BOD_5 values are cited (NEAP, 1993): 130,000 mg/l and 224,000 mg/l for Lugazi and Kakira, respectively. With a reported daily amount of wastes around 500 m3, these figures give rise to estimated amounts of 65 tonnes BOD_5 released per day to the river Musambya (Lugazi) and 112 tonnes to the river Kiko (Kakira).

Plant oil and soap industries

A total of 22 factories are currently registered within the field of processing oil containing seeds (cotton seeds, sunflower seeds, ground nuts, sesame etc.) into edible or industrial oil products. A part of these products are further processed into soap. The oil and soap industries are spread throughout the country, typically located in the areas of raw material production. As for other industries, plant oil and soap production have been operating at a very low level in the period from the 1970's to 1987, but production is increasing again.

The processes include mechanical crushing of seeds to press out oil, neutralizing the acids in extracted oil using sodium hydroxide, scrubbing the oil using water to remove impurities, bleaching/decolorising the oil using activated carbon. The manufacturing of soap involves further adding of sodium hydroxide.

The wastes from this type of production contain high amounts of dissolved and suspended organic material, and consequently affect the receiving water body by increased oxygen demand and eutrophication. Furthermore, the wastes often contains sodium hydroxide which increases the pH. Levels of suspended solids of 1000 mg/l and BOD_5 of 25,000 - 30,000 mg/l have been measured from these industries' effluent. A survey of the major oil processing industries revealed that no waste water treatment occurred and often the wastes were discharged to the public oxidation ponds (NEAP, 1993). Though no quantification of the actual amounts of these wastes have been obtained, this type of waste water is likely to affect the recipient markedly within certain distances from the outlet.

Meat and fish industries
Except for the abattoirs which are located in most urban centres throughout the country, the major meat and fish processing industries are concentrated in Kampala and Jinja. These industries are slaughterhouses, and factories involved in cleaning, smoking and packing fish. The wastes consequently contain high amounts of organic material deriving from blood, meat, fat, grease and intestines. Thus, measured values of BOD_5 ranging from 2000 to 3000 mg/l have been found for the effluents from abattoirs. Some of the factories also discharge salt and chlorine.

The wastes are generally discharged through the public sewers without any treatment, but no quantity estimates of effluents have been obtained. It is, however, well known that untreated waste water from this type of industry may create severe local effects on the receiving water bodies.

Dairy industries
One major milk packaging factory is located in the Kampala industrial area. This factory uses around 250 m3 of water per day for cleaning and washing. The wastes contain mostly milk from spillage and washouts, and BOD_5 of 2,500 mg/l has been estimated for the effluent which is lead to the Bugolobi treatment plant through the public sewer. Additionally, a number of milk collecting centres are located around the country, but no quantification of effluents has been obtained.

Leather tanning
There is one significant factory located at the shores of Lake Victoria in Jinja. The leather tanning process involves a variety of chemicals which characterize the waste effluents such as: arsenic, DDT, zinc chloride and various dichlorobenzenes, chlorine and sodium fluoride, caustic soda, sodium sulphide, sulphuric acid, hydrochloric acid and chromium. Such a mixture of toxic chemicals will, if discharged in significant amounts, cause various lethal or chronic effects on the flora and fauna in the receiving water. These chemicals can also render the water unsuitable for water supply or other utilization. The waste from this factory constitutes 430 m3/day (with a BOD_5 of 700 mg/l) which is discharged to Lake Victoria. However, the concentrations of the various chemical constituents are not known, and thus the significance of this pollution source cannot be assessed.

Textile industries
The number of textile manufacturing industries in Uganda totals eight, of which three are located in Kampala, two in Jinja and one in Tororo, Mbale and Lira. The latter, however, is now closed. In general activities in the textile industry have been low.

The wastes contain various chemicals used mainly for the dying and printing processes: caustic soda, hydrogen peroxide, sodium silicate, dyes (mostly azo, diazo- and phenolic compounds). Other chemicals in this process include solvents for the dyes such as aromatic hydrocarbons (benzol, toluol, xylol, naphthas and aromatic amines) and solvents used for cleaning machinery. The effluents also contain metallic ions and the organic content results in a BOD_5 of 1200 mg/l. Many of these chemicals are toxic or carcinogenic and will, when discharged in significant quantities, severely affect the water quality of the receiving water body. A total effluent quantity from the textile industries is estimated at 20,000 m3/day (NEAP, 1993), However, no concrete information on the concentrations of the various chemical constituents has been found for the tanning industry.

Other major industries

Paper industry is also present in Uganda. The number of employees in this industry was 640 in 1991 and an installed capacity of 2,690 tonnes is present. However, the production was only 346 tonnes in 1991 (Background to the budget, 1992) but on an upward trend. Wastewater from such industries are normally rich in fibres and various chemicals used for purposes such as bleaching.

Steel industry (steel ingots and corrugated iron sheets) has an installed capacity of 42,000 tonnes/year and a present (1991) production of 2,296 tonnes on an increasing trend. The environmental problems related to this type of industry are mainly due to the slag produced during the iron refining processes. Thus, slag deposits contain a variety of metals, including cadmium and chromium, which are washed out by rainwater.

No information on composition and quantities of wastes from the paper and steel industries has been obtained.

Semi-industrial activities

In addition to the major current industrial activities as mentioned above, there are a number of semi-industrial activities which may affect the water quality in the vicinity of their location or in the recipients for the urban sewerage systems. Among these are:

- Battery manufacturing and repair (producing acidic wastes containing lead)
- Garages (discharging oil products)
- Gas stations (leaching oil products)
- Petroleum storage facilities (spillage and leakage of oil products)

Presently, the significance of these pollution sources may be considered low due to the generally low economic activity in the country. However, with continued economic growth, water quality impacts from these activities will be an issue for action.

3.3.4 Summary - mining and industrial sectors

The mining activities in Uganda must be considered low and therefore the impact on water quality from this sector is presently not an issue at a national scale. However, at least one example of local pollution from (former) mining activities exists due to acid drainage from Kilembe mines and leakage from the cobalt stockpile in Kasese (see Subsection 3.3.1).

Uganda possess considerable exploitable mineral resources and investments in this sector are encouraged. Without proper management such a development will effect the quality of the water resources (at least locally) by chemical pollutants such as toxic heavy metals, influencing possible water use for other sectors in the impacted areas.

Exploration of petroleum reserves is on going in Western Uganda. Depending on the outcome from this exploration, Uganda may initiate land based petroleum production within a timescale of 5-10 years. A management strategy for the environmental aspects of such production is needed as well, to avoid possible severe impacts from hydrocarbon pollution in the water resources in these areas.

Regarding the industries of Uganda, the level of activities is considered low. Consequently, the main water pollution problems are confined to local areas. At present these are the Jinja and Kampala areas, but single industries located in the countryside are likely to significantly affect streams or rivers receiving the wastes.

The main pollution problems connected to Ugandan industries are organic wastes from sources such as breweries, abattoirs, other meat and fish industry and sugar industry etc. (the latter discharging extremely high loads). However, a few industries produce chemical hazardous wastes which are likely to seriously affect water quality seriously at the local level. Examples of sources of hazardous waste being textile, paper and tanning industries.

The effects of an organic waste outfall on the river water quality are exemplified in Fig 3.2. At a distance from the outlet the critical point, or minimum oxygen content, occurs. This is the point where supply of oxygen due to reaeration just balances the use of oxygen due to the degradation processes. Depending on the volume and BOD concentration of the load the degradation of organic material may result in total oxygen depletion incurring kills of fish and other organisms in the river. The degradation further releases nutrients and other minerals formerly bound in the organic material which increases the concentrations of these compounds downstream. Fig 3.2 includes a depiction of this phenomena for nitrogen compounds found downstream of a wastewater outfall.

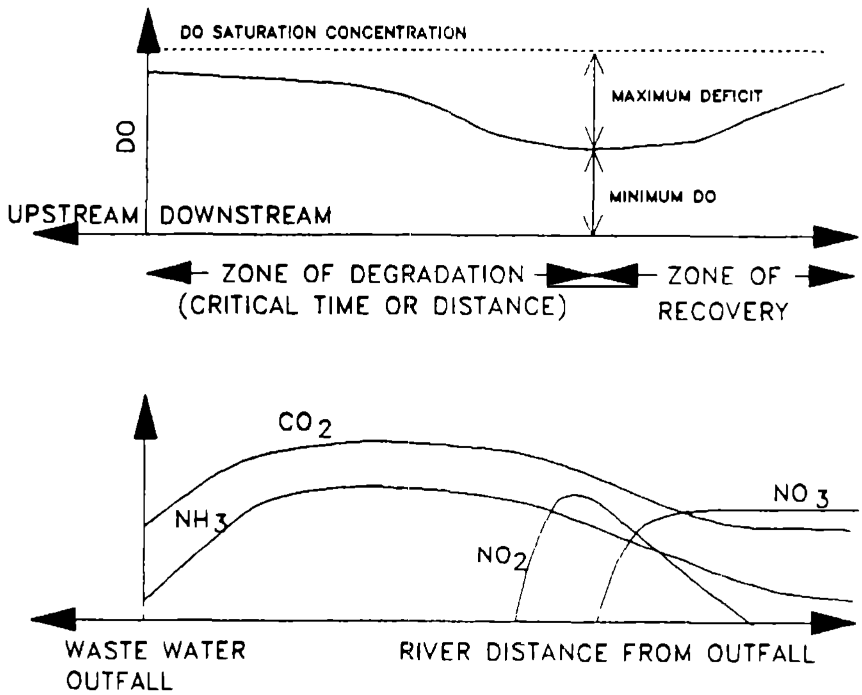

Figure 3.2 - Effects of an organic waste outfall on the river water quality
(DO = dissolved oxygen)

3.3.5 Agriculture

Agriculture is the most important economic sector in Uganda. The sector accounts for 59 percent of the GDP (1991) and over 90 percent of the exports. Food crops dominate the industry totalling 74 percent of agricultural GDP, leaving 16 percent for livestock, 2.5 percent for forestry, 3.9 percent for fishery and 3.9 percent for cash crops.

Agricultural output comes almost exclusively from about 2.5 million small holders, 80 percent of whom have less than 2 hectares of land. Only tea and sugar are grown on large estates which total only 40,000 hectares. The total cultivated area is estimated at 50,000 square km, which is about 30 percent of the estimated cultivable area. Figs 3.3 and 3.4 show the land-use distribution and the distribution of the cultivated land, respectively.

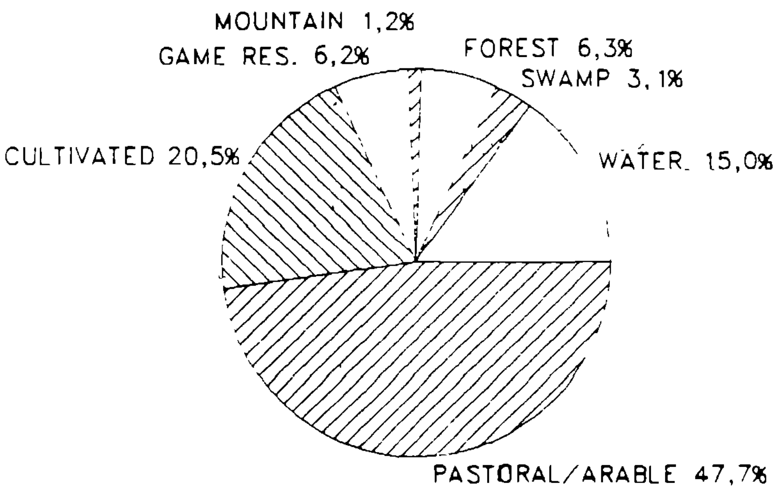

Figure 3.3 - Land-use estimates (Source: Survey and Mapping Department)

91.5 percent of the total area under cultivation in 1990 was used for food crops.(Fig 3.4). Excluding the estate crops, tea and sugar, the cash crops are coffee (250,000 ha), cocoa (10,000 ha), cotton (70,000 ha) and tobacco (4,000 ha).

The potential impacts from agricultural activities on water quality involve issues such as increased sediment loads to the rivers due to soil degradation, increased nutrient runoff due to application of fertilizers, and contamination by toxic chemicals used for control of weeds and insects.

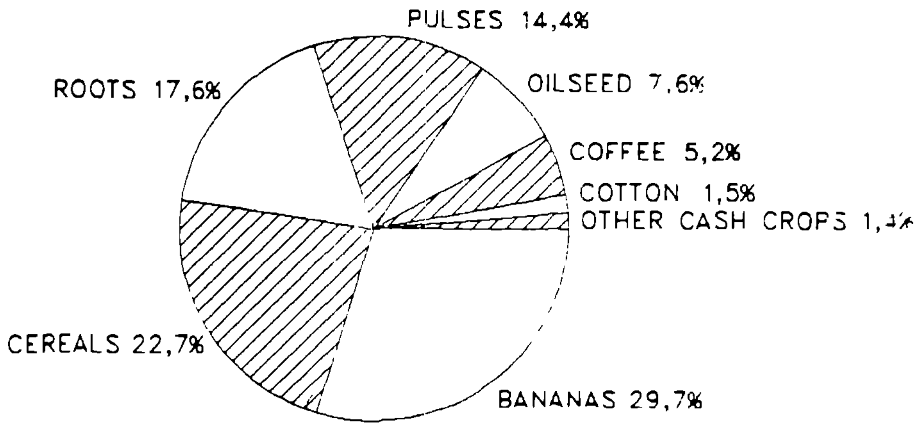

Figure 3.4 - Distribution of cultivated area, 1990

Soil erosion and sediment transport

As mentioned in Subsection 2.8.2, the extent of soil erosion as well as its relation to land-use practices in Uganda cannot be assessed in detail due to lack of quantitative data. However, Annex 12 "Land and Water Management Study" in WAP.Doc.012 gives an assessment based on field studies, literature and interviews.

Among relevant possible impacts related to water quality and ecology from sediment transport are:

- excessive turbidity of drinking water supplies
- destruction of the substrate for bottom-living fish
- destruction or alteration of the benthos that forms the source of food for many fish species

- exposing of anoxic sediment layers

- increase of turbidity resulting in irritation or clogging of fish gills, interfering with visual feeding,

- inhibition of plant photosynthesis.

Fertilizers

Nutrients such as nitrogen and phosphorus are essential for the growth of all plants. Discharge of nutrients into the rivers might be beneficial to the growth of algae and weeds and thus to other aquatic biota as well as for irrigation purposes. High concentrations of nutrients from excess fertilizer run-off from cropped areas into lakes and rivers might result in dense growth of algae and weeds, which are considered a component of eutrophication.

In Uganda the use of artificial fertilizers has been very low up to now. Thus, the total imports of agrochemicals for 1990 and 1991 were as low as 4,120 and 1,166 metric tons, respectively (Bank of Uganda, 1992). The reason is that fertilizer use is mainly confined to the estate crops such as tea, sugar and tobacco which presently count for a very small proportion of the cultivated area. The application of fertilizers for food crops is virtually non-existant. Consequently, leaching of fertilizer nutrients to the Ugandan freshwater systems cannot be considered a significant threat to the general water quality at present.

The prospects for use of fertilizers in the short term continues to lie with the estate crops, since the food production is not expected to increase in productivity due to a combination of high prices for fertilizers and the current reasonable food balance in the country (Bank of Uganda, 1992). However, fertilizer use is predicted to continue for high-value export- or import-substitute-crops, such as sugar, tea and tobacco. Growth in these exports will stimulate demand for agrochemicals (World Bank, 1993).

Crop protection

In Uganda agro-pesticides are used in order to increase agricultural production - especially for cash crops such as sugar, tea, coffee, cotton and tobacco.

Organochlorines were formerly used for insect control. They are insoluble in water but highly soluble in fat. Due to their persistence, organochlorines may be effective even 10 years after application and they tend to have a bioconcentration trend in the food chain.

DDT is the most well known of all organochlorine biocides. Since it was synthesized in 1874, DDT has been widely used as an insecticide. It was primarily used in residential areas. Due to its effectiveness and low price, DDT was also applied in agriculture particularly in Uganda against seedling and foliage pests in cotton and boll worm. This chemical's ecological effect, however, has resulted a ban of its use in many countries. Today the use of DDT in Uganda has virtually been replaced by thiodan, permethrin and cypermethrin (since 1982).

Against the banana weevil and the banana nematode *Radopholus similis*, Dieldrin and Furadan have been used, and in the coffee plantations Fenitrothion is used against foliage pests while "Round Up" (a glyphosate) is used against weeds.

Table 3.3 - Import of agrochemicals 1990-1991

	1990		1991	
	Quantity (l)	Value (US $)	Quantity (l)	Value (US $)
Pesticides	363,220	2,603,110	508,970	5,117,178
Herbicides	41,460	450,223	169,110	2,390,652
Total	404,680	3,053,333	44,010	7,507,830

Source: Bank of Uganda, 1992

Neither detailed estimates of the amount of biocides used in agriculture in Uganda, nor data on their accumulation in the environment exists. The lack of control and monitoring of biocides makes such estimates difficult. However, statistics on import exist (Table 3.3), and information on the distribution of land-use practices illustrates where the potential of contamination by these chemicals is located (see Fig 3.5). The value of chemical imports for crop protection increased from US$ 3.1 million in 1990 to US$ 7.5 million in 1991 (Table 3.3). Most of the increase was due to increased herbicide application in the tea and sugar estates, arising mainly from expansion in area and a manual labour shortage in this sub-sector (Bank of Uganda, 1992).

		Cond. umho	HCO3 mg/l	SO4 mg/l	Cl mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	SiO mg/l	Fe ug/l	Mn ug/l	PO4 ug/l	NH3N ug/l	NO3 ug/l
Mount Elgon	MIN	88	48	3.9	0.4	7.7	2.8	4.8	3.2	15	7	6	100	<5	0
9 rivers	MAX	365	220	18.2	4.2	44.5	10.9	18.4	7.4	36.2	350	26	314	<5	860
Wooded savan-	AVG	156	87	8.1	2.2	15.9	4 5	9.6	4.2	21.8	100	20	160	<5	288
na/forest	RAT		5.6	0.5	0.1	2.0	0.3	0.6	0.3	1.4	6.4	1.3	10		14
Karamoja	MIN	42	19	4.1	0.7	3.4	1.4	1.8	4.2	6.9	9	0.2	35	<5	50
4 rivers	MAX	130	76	6.2	2.1	14.3	3.2	7.4	6.5	12.9	19	2.5	940	<5	500
	AVG	82	48	4 7	1.3	8 4	2.4	4 1	5	18 6	17	1.1	248	<5	204
	RAT		5.9	0.6	0.2	1.0	0.3	0.5	0.6	1.0	2.1	0.1	30		25
Papyrus swamps	MIN	45	0	10.7	1.6	1.5	1.5	4.1	1.6	2	20	10	5.8	<5	0
11 rivers	MAX	210	40	71.5	7.5	9.7	7.3	14.5	10.9	33.5	7200	800	40.6	<5	425
	AVG	114	10	32.5	4	4 7	3 5	9.6	3.8	18.1	1970	370	13.2	<5	15.4
	RAT		0.9	2.8	0.4	0.4	0.3	0.8	0.3	1.5	173	33	2.2		1.4
Semliki river	MIN	480	300	74	40.1	11	35	70.1	50.2	9.1	54	53	105		22
4 stations	MAX	640	353	120	47.1	12.1	44.6	92	72	16.2	104	85	148		126
Lake supply	AVG	565	323	95.7	44 2	11 3	38.5	79 6	60.2	12.9	85	67	127		57.7
	RAT		5.5	1.7	0.8	0.2	0.7	1.4	1.1	0.2	1.5	1 2	2.3		1.0
Semliki trib.	MIN	56	24	6.6	0.9	3.8	2.3	3.9	1.7	13.2	94	74	68	<5	50
6 rivers	MAX	142	43	30.6	4.7	7.7	3.8	15	4.2	30	220	120	202	55	470
Moist savanna	AVG	85	34	15 6	2 3	5.2	2 9	8.3	3 12	20 3	172	91 7	137	11 8	290
	RAT		4.0	1.8	0.3	0.6	0.3	1.0	0.4	2.4	20	12	16		34
Ituri Forest	MIN	136	75	20.3	4.1	11.7	4.8	11	2.3	45.2	59	24	202	68	432
3 rivers	MAX	215	124	34.5	6.4	21.4	10	18.6	3.3	49.5	71	63	253	136	550
	AVG	180	97	28	5 5	15 4	7 2	15.2	1 8	47 5	68.3	48.7	230	97 7	477
	RAT		5.4	1.6	0.3	0.9	0.4	0.8	0.2	2.6	3.8	2.7	13	5.4	26
Kigezi highl.	MIN	52	6.1	6.7	1.6	1.8	1.8	3.1	1.8	5.2	25.5	0	21.4		0
18 rivers	MAX	472	330	84	35.5	55.8	24.4	75.5	4.9	29.5	3170	642	740		1050
For./sav. mos.	AVG	107	47 3	19.6	8.3	8.6	5.25	11	3.14	16.2	960	113	184		416
	RAT		4.4	1.8	0.8	0.9	0.5	1.0	0.3	1.5	90	11	17		39
Ruwenzori	MIN	34	13.2	5.5	0.3	1.1	0.9	2.8		7.1		14	2.5		0
7 rivers	MAX	420	270	46	13.1	57	12.9	29		30.8		385	215		2390
Bogs/forest	AVG	270	78.5	20	4.7	15.6	5	12.3		16.4		123	78.8		533
	RAT		2.9	7.4	0.2	0.6	0.2	0.5		0.6		4.6	2.9		20

RAT: Ratio to conductivity. Source: Viner, 1971.

Figure 3.5 - Areas with high production of pesticide dependent crops

Livestock protection

Another field of application of insecticides is the protection against tics in livestock. In the past, this protection was dominated by organochlorines (toxaphene and lindane) but as in other cases these have given way to organophosphate and synthetic pyrethroids such as deltamethrin (Decatix) and cypermethrin (Fendona). These chemicals are mainly used in cattle dips, and are generally disposed of directly into the river/stream systems or through seep pits.

Vector control

Aside from strict agricultural application, biocides are used in the control of vectors, such as mosquitoes, tse-tse flies, black flies and snails. These vectors can be the carriers of diseases such as malaria, sleeping sickness, river blindness and. Those of major concern are the tse-tse flies and mosquitoes. Before 1960 DDT was the main pesticide used against these vectors. However, owing to the insects subsequent resistance, DDT has been largely replaced by Dieldrin, which is still used but on restricted basis. It is used for ground spraying and selective treatment of tree trunks (landing sites for flies) and fly traps. Its use was highest from 1962 to 1988, but has now decreased owing to a ban on its manufacture and use in Europe and the USA. However, stocks of this pesticide do exist in the country, having been imported with the intent to be used on the tse-tse fly through aerial spraying (a practice that has been discontinued).

Dieldrin has largely been replaced for aerial spraying by thiodan (endosulfan). In 1990, 130,000 litres of thiodan were sprayed over 1,100 km2 of land in Iganga District. This was the third area in Busoga Region to be sprayed with this chemical. The first campaign (1988) covered 600 km2 and the second covered 925 km2. Further aerial spraying campaigns are planned for the West Nile Region of northern Uganda aimed at controlling the sleeping sickness epidemic that broke out in these areas between 1985 and 1990.

Assessment - threats from pesticides

Considering the current agricultural structure in the country, with the majority of land being used for traditional food crop farming as well as a general shift towards use of more biodegradable and less harmful chemicals, the present use of pesticides for crop protection and vector control is not likely to be a major quality issue for Ugandan surface waters as a whole. There are, however, several reasons why local contaminations by these chemicals may occur:

- accumulation of persistent organochlorines/residues due to former use of hazardous chemicals, namely DDT

- continued use of organochlorines due to old stocks

- improper application practices due to low education level of farmers

- geographical concentration of high yielding cash crops depending on use of pesticides

- the locally intensive spraying of pesticides necessary for an effective vector control

3.3.6 Sewage and solid wastes

Sewage
The situation in Uganda is characterized by extensive use of simple sanitation techniques. The vast majority of the population in towns rely on traditional pit latrines. A few towns have bucket systems and in the core areas of many towns septic tanks are used. In total, only thirteen towns or cities have installed waterborne sanitation systems, and these are only covering the core areas of the towns, thus serving a minor part of the urban population. The waterborne sewerage systems pose potential threats to the surface waters, since the sewage (with or without treatment) is ultimately discharged into streams, rivers or lakes.

The impacts from discharged domestic wastes on the quality of the receiving waters are:

- contamination with pathogenic bacteria, viruses and parasites

- organic loading resulting in oxygen depletion

- nutrient loading contributing to eutrophication

- contamination with chemicals used in the households

Among the towns and cities which have water borne sewerage systems the following types of sewage treatment are provided:

- large septic tanks

- sedimentation (mechanical treatment)

- traditional trickling filter plants providing mechanical and biological treatment

- stabilization ponds

Surveys of the sanitation situation (Cowiconsult/NCG/Habitat, 1993 and Gauff /Parkman, 1989) revealed that the general state of the sewage treatment facilities was very poor. Table 3.4 summarizes this status.

As seen from the table, the general state of sewage treatment in Ugandan towns has been considered poor or non-existing. This implies that for a number of towns the raw sewage is discharged into small rivers or streams untreated.

Having far the largest population, the discharge of sewage from Kampala needs special attention. Here, the central part of the city is served by sewers. Thus, the sewage treatment plant at Bugolobi is fed by four main sewers. Over 150 km of lateral sewers discharge into these main sewers. In addition, the sewerage system has three sewage pumping stations which lift sewage from the low lying areas to the plant. The general conditions of the sewers are, however, poor and it has been estimated that only 50 % of the sewage ever reach the treatment plant (NEAP, 1993). The remainder is expected to find its way to the Nakivubu channel, which was originally constructed as a storm water channel, and is thus lead untreated to the Nakivubu swamp which drains into Murchison Bay of Lake Victoria.

Table - 3.4 Towns with waterborne sewerage systems

Town	Population		Treatment		Amount m3/day	Receiving water
	Total	Served	Type	State		
Kampala	775,000	15%	S,F,D	Poor	20,000	Swamp -> Lake Victoria
Jinja	61,000	-	P	Poor	7,650	River Nile
Entebbe	42,000	-	P	Rehab.	835	Lake Victoria
Mbale	54,000	-	P P	-	2,910	River Namatala River Doko
Tororo	27,000	-	P	Poor	800	River Luruluro
Masaka	49,000	-	S,A	Inadeq.	460	Swamp -> River Kamamba
Mbarara	40,000	-		Rehab.	-	River Ruizi
Fort Portal	32,000	-	SE,F	Poor	-	River Mpanga
Lira	27,000	-	P P		900	River Okole
Gulu	43,000	10-15%	P	Not func.	200	River Pece
Iganga	20,000	10%	S,F	Not func.	-	River Walugogo
Kabale	28,000	4%	F,SE	Not func.		
Soroti	41,000	20%	P,F	Poor		

A: Activated storage
D: Sludge digestors
F: Trickling filters
P: Oxidation ponds
S: Sedimentation
SE: Septic tanks

The sewage treatment plant for Kampala is located at Bugolobi in the industrial area. This plant was constructed in the 1940's, expanded in the late 1950's and again in 1969/70. Rehabilitation work on the plant was carried out in 1986/87 under World Bank funding. It is a conventional mechanical plant, depending on electricity supply. The plant process consists of screening removal, grit removal, primary sedimentation, biofiltration, secondary sedimentation and aerobic sludge digestion. The plant treats both domestic and industrial sewage, and the effluents are led to the Nakivubu Channel.

The fact that the sewage from Kampala city flows through the Nakivubu swamp, results in a reduction of polluting elements before it finally enters the open water of Murchison Bay. This is due to sedimentation of organics, uptake of nutrients by the swamp vegetation and denitrification within the swamp. Thus, the effluents from the swamp contain relatively low concentrations of BOD_5, nitrates and phosphorus (Taylor, 1991). Therefore, the water quality in the Murchison Bay is still acceptable for the drinking water intake which is located here. However, the steady supply of nutrients to the bay results in algae blooms.

The sewage from Masaka town also passes a wetland, reducing the pollutants of the final effluent, before it reaches the Kamamba river. However, in this case the wetland is also used for horticulture farming and the raw sewage creates health risks to the local farmers. The role of wetlands as purifiers is discussed further in Subsection 3.4.1.

Due to the low coverage of sewers in Ugandan towns, non-connected wastes, such as household water containing organic matter, are left on the ground or in surface runoff channels. During rainfall these wastes are flushed with the runoff to the receiving waters. In some low lying areas high water levels may be flooding inhabited areas bringing wastes in suspension and creating health hazards due to bacterial contamination.

Solid waste

The domestic solid waste contains all types of waste from the households, including organic debris from food preparation as well as plastic, glass, metal, batteries and medicine.

The impacts of the solid waste on the surface water quality derive mainly from rain induced washout of bacteria, organic matter, and hazardous chemicals from urban dump sites located near the water bodies. The leakage from such sites may, if drained to streams or lakes, create local water quality constraints to other water use, mainly due to health hazards.

In Uganda such local water quality problems are likely to exist around the bigger towns and cities, where the waste is concentrated in dump sites. Especially Kampala, in which the population produces 2,800 m3 of wastes per day (equal to 0,004 m3/day per capita), needs attention. Here, a waste collection system exists and about 50% of the household wastes are (or have been) disposed on the three available dump sites - Wakaliga, Lugogo and Port Bell. Moreover, the dump sites in Kampala receive solid wastes from the industries.

Assessment of threats to water quality

The general low service regarding sanitation, i.e. limited coverage of water borne sewerage systems in the Ugandan urban centres, implies that the surface waters of Uganda can not be considered severely impacted by sewage currently. Assuming that a maximum of 15% of the population is served by public sewers in the towns where such are installed, a total of less than 200,000 people contribute to direct faecal pollution of surface waters. Half of these are concentrated in Kampala which, due to the Nakivubu swamp, possess a quite efficient natural sedimentation area which also act as tertiary filter for the wastes.

However, local contamination problems exist in streams and rivers receiving more or less untreated waste waters from a number of towns where sewage collection systems are installed. Furthermore, it shall be noted that waterborne sanitation is likely to develop rapidly in major urban centres (due to public health aspects) if general economic growth takes place in the coming years. For Kampala and other cities a significantly better sanitation service will imply increasing water quality problems in the receiving waters if no effective treatment systems follow the service development. The use of swamps as purifiers for sewage from cities such as Kampala will become inadequate as the sanitation service level and coverage increases significantly (see Subsection 3.4.1).

Surface water quality problems due to pollution from waste dump sites are similarly not considered a general problem in Uganda. As for the sewage, centralized collection systems are not common in Ugandan towns. Therefore, pollution of surface waters from this source is likely to be restricted to local areas (e.g. Kampala). An economic development of the country will, however, similarly increase the amounts of dumped wastes, and attention should be paid to the design and location of future landfills to avoid serious water pollution problems. Another consideration is the content of hazardous compounds in solid wastes, which tends to increase with increasing living standard among the population due to higher consumption of sophisticated products. This would ultimately result in an increase in the hazardous effects of this pollution if appropriate treatment measures were not implemented.

3.4 Assessment of present water quality problems

3.4.1 Key elements of the Ugandan surface water system

Lake Victoria

The size and hydrology of Lake Victoria makes this lake the most important water body governing the water quality of the White Nile system. With its dominating outflow to the Upper Nile system compared to other contributions, the quality of the Victoria Nile, Lake Kyoga, Kyoga Nile and Albert Nile is to a great extent similar to that of Lake Victoria. The lake itself also plays a large role in the economic development of the riparian states due to its many possibilities for exploitation such as fishery, water supply and transport.

In recent years, Lake Victoria has given cause for concern due to several indications of radical changes in the lake ecology. The most apparent change has been the introduction of non-indigenous fish species, specifically the predatory Nile Perch (Lates Niloticus and the herbivorous Oreochromis Niloticus). These species, which were introduced in the late fifties and early sixties, have increased the catch from the lake, but at the same time their dominance have resulted in an exclusion of a large number of indigneous species on which they feed.

There is furthermore strong indications that the nutrient chemistry and the phytoplankton biomass and composition have changed during the same period in which the changes in fish stock took place (Hecky & Bugenyi, 1992). In particular, the silicate concentrations have fallen by an order of magnitude and the accumulation of total nitrogen in the sediments has increased. The phytoplankton biomass has increased. Also chlorophyll-a levels have increased from 1-5 ug/l in the sixties to 13-71 ug/l in the late eighties. Analyses of species composition in sedimented phytoplankton have shown that the former abundant diatom Melosira has become extinct from the recent sediment layers (i.e. the last 20-30 years) and blooms of blue-green algae have now increased in frequency.

Moreover, there are strong indications that events of oxygen depletion are more pronounced, resulting in anaerobic conditions in the deeper parts of the lake. This phenomena has not been observed formerly.

These changes are similar to those normally seen for lakes that are subject to increased eutrophication. Lake Victoria receives nutrients from rainfall and from rivers discharging into it (mainly Nzoia, Kagera and Mara) and it has been suggested that increased nutrient loadings - primarily nitrogen - from these sources are responsible for the ecological changes in the lake.

Organic pollution of the rivers and rainwater uptake of nitrogen from bushfire smoke have been mentioned as possible major sources of origin. However, the lack of regular monitoring of chemical composition of the sources prevents verification of these hypotheses. Another possible factor causing the observed changes is the introduction of the Nile Perch. The rapid stock increase of this species have reduced the stocks of especially phytoplankton feeding fish (e.g Cichlides) thereby reducing their former grazing effect on phytoplankton.

Theoretically, both increased nutrient loadings and the introduction and dominance of the Nile Perch could explain the observed changes in the lake ecosystem. The possibility exists, that both factors have interacted and given the observed changes.

The abovementioned trends towards eutrophied conditions may seriously affect the present important exploitation of the lake fishery potential. A resulting increase in oxygen demand in the deeper parts will decrease the volume habitable for fish and anaerobic conditions will kill the bottom fauna which is the food source for a number of fish species.

The role of wetlands
The wetlands in Uganda covers large areas (approx. 3.2 % of the total area) and therefore they play a major role in determining the quality of many rivers by retaining particulate material, nutrients and several toxic polluting compounds. This purification potential has been used all over the world in small scale treatment of organic wastes, mainly of human origin. In Uganda it has been believed that the Nakivubu swamp up to now has had a purification effect on a major part of the discharges from Kampala. However, the purification capacity of similar swamps have been found to have a limited capacity if overloaded.

The nutrients and other pollutants retained are stored in the sediment and peat deposits build up in the swamps. An effective removal of phosphorus is normally depending on chemical binding in calcium and iron complexes and the capacity therefore depends on the content of these elements. The nitrogen is the only element that can be ultimately removed by the swamp itself. This is due to the bacterial denitrification process which release the nitrogen to the atmosphere as gaseous nitrogen. Only a part of the nutrients taken up by the papyrus is retained in the dead organic material forming peat deposits. The rest is released by bacterial degradation of the dead papyrus.

The continuous deposition of peat and sediments, as well as the availability of chemical binding of compounds, obviously sets a limits for the retention capacity of the swamp. High loadings of waste water will in the end surpass the retention capacity and even affect the swamp itself to a degree where the purification effect decreases or stops. The result is increased discharge of pollutants to the receiving water.

Many of the retaining processes are reversible. When not overloaded and loads are not decreasing, the retaining effect will continue maintaining a high production of organic material and sedimentation rate with a chemical equilibrium retaining the pollutants in the swamp. If the pollution discharge is reduced the production of organic material in the swamp may decrease. The ongoing bacterial degradation of the organic material stored in the swamp may then surpass the production. As a consequence, the compounds stored in the swamp are released affecting the receiving water for years after the pollution discharge to the swamp was reduced. Such phenomena has been observed e.g. in European swamps.

It can be concluded that "swamp treatment" of sewage cannot be recommended for treatment of unlimited loadings of sewage. In the case of the discharges from Kampala the capacity On the other hand, many small towns can, to a large extent, benefit from this type of inexpensive and sustainable sewage treatment provided that the loadings are small compared to the swamp capacity and that no other important uses of the swamps are affected.

3.4.2 Localized major quality problems

This section covers significant local, existing or potential, water quality problems. The major interest in this respect are the two population centres Kampala and Jinja where most industry is located. Furthermore, the pollution from the Kilembe mines is believed to pose a local threat to health and to the aquatic ecology.

Murchison Bay
The Murchison Bay receives effluent from the highest density of industries in Uganda namely the "Industrial Areas" of Kampala:

- the central industrial area
- Nakawa/Ntinda industrial area
- Port Bell industrial area
- Kawempe industrial area
- Masaka Road industrial area.

These areas contain over 500 factories from which effluents are discharged into the public sewer or the storm water channel (the Nakivubu channel) and thereby lead to Inner Murchison Bay. The major factories discharging into this bay include:

- 4 soft drinks factories
- 2 textile industries
- 2 abattoirs and meat processing industries
- 3 oil and soap industries
- more than 24 engineering workshops and garages
- 1 brewery
- 1 distillery

of these industries can be made. The fact that several industries are discharging toxic chemicals, which can be concentrated in the food chain, further emphasizes the need of such data.

Water hyacinth
The water hyacinth was discovered for the first time in Ugandan waters in 1989 in Lake Kyoga. It is a free floating water weed originating from South America, and due to prolific growth the water hyacinth covers many square kilometers of lakes and rivers. The species has been introduced to waterways throughout the world, particularly in the tropical and subtropical areas, where it has caused severe problems and immense economic difficulties during the last century. Many African countries have been infested, particularily during the last decade.

The water hyacinth is characterised by the ability to grow and multiply increasingly fast with increasing nutrient availability.

Since the time of its discovery in Uganda, the plant has spread to the adjacent parts of the Nile system, and is now found in abundance in Lake Victoria and the Victoria Nile. The proliferation of the weed has become serious and creates problems such as hampered navigation affecting transport and fisheries, blocking of the Owen Falls power plant intake. Moreover, dense mats of the weed deplete the oxygen content of the waters due to shading of the oxygen producing phytoplankton, resulting in fish migrations or even killing of fish and bottom fauna.

In natural waterways the plants exploit steady supplies of nutrients from sewage discharges and agricultural activities due to runoff of fertilizers and the leaching from soils. Consequently the plants are often found spreading from areas near such nutrient sources.

In spite of many scientific and practical efforts, man has not yet succeeded in effective control of this species. The efforts have mainly concentrated on mechanical, chemical or biological means, but the economic or environmental implications of these methods have generally been too costly. The reason for unsuccessful attempts to provide efficient control measures against this increasing problem should be investigated despite inadequate understanding of the growth dynamics and spreading strategies of the opportunistic weeds and their relations to the surrounding environmental factors - including impact from human activities.

Given such knowledge, management of the influencing factors or direct measures against the weed at the right time and place would improve the success of its control. It is, however, well known that nutrient availability predominantly determines the growth rate

- 1 metal enamel factory

- 1 leather tanning factory

The characteristics of the resulting effluent were discussed in the sections above. About 12,000 m3/day of wastewater from these industries has been estimated to lead to Nakivubo swamp or directly to the lake (NEAP, 1993). Even though these figures are uncertain, the organic substances and chemical wastes together with the high load of sewage to the same area are considered a severe threat to the water quality of the bay. Although the swamp may retain a part of the organic substances in the present situation, there is no evidence of the fate of many industrial chemicals, and the retaining capacity of the swamp is unknown. The fact that the Inner Murchison Bay is the source of water supply for Kampala, makes it highly necessary to introduce measures to more accurately assess the impact of this pollution source and thereby make it possible to reduce it in a prioritized manner. These measures must furthermore be considered a prerequisite for further economic and social development of Kampala, since highly increased water quality problems in the bay can be foreseen to follow such developments.

Victoria Nile - Jinja
This area receives waste from a number of industries located at the banks of the Victoria Nile, among these are:

- Nile Breweries

- Nyanza textile industry

- Papco paper industry

- Mulco textile industry

- Mulbox paper industry.

Together they discharge over 13,000 m^3/day of untreated industrial waste into the Nile downstream from Owen Falls Dam (estimated by NEAP, 1993). To this figure should be added 7,000 m3/day of domestic sewage which is also discharged into the Nile. At Jinja the flow of the Nile is currently about 1,000 m3/sec resulting in a dilution ratio of the above mentioned effluents of approximately 1:4,300. This high dilution diminish the effects of organic pollution considerably. It should, however, be stressed that neither precise estimates of the quantities of the effluents nor accurate determinations of the chemical composition exist. Such data must be provided before a proper assessment of the water quality impact due to general economic growth in the country if no adequate management tools are implemented.

Tentatively, the major surface water quality issues can be summarized as follows:

- eutrophication phenomena of Lake Victoria
- organic and chemical pollution of Lake Victoria from Kampala localized in the Murchison Bay
- organic and chemical pollution of the Victoria Nile from Jinja/Njeru
- proliferation of water hyacinths in the Lake Victoria and the Victoria Nile system
- Pollution by toxic metals and other hazardous chemicals from the Kilembe mines.

In addition to these significant issues, local water quality problems are likely to occur scattered around the country due to:

- organic pollution from sewage outlets
- organic pollution from food processing industries (mainly abattoirs)
- chemical pollution from textile and other industries
- pesticide contamination from crop protection, tic-control and vector control.

Such local water degradation may pose serious problems when population downstream from the discharge points use river water for water supply. For instance, this is the case in Fort Portal where the public sewerage system discharges upstream of the town.

Another aspect is the rather diffuse application of pesticides for various purposes. It is unknown to what extent for example the less degradable organochlorines (e.g. DDT) have been accumulating in the surface water systems.

of the water hyacinth, and any surplus of nutrient scompounds can therefore be foreseen to increase the biomass of the weed in infected water bodies.

The presence of water hyacinth in Ugandan waters has already reached a level where severe local impacts on the exploitation of the water resources occurs, implying that the effects of localized nutrient sources get much more apparent and costly than might be experienced without the weed. Consequently, regulation measures in connection with these sources becomes more important.

Kilembe mines
Although the Kilembe mines closed operations 16 years ago, the mine is still open even though it is not producing. In order to keep the mine ready for investors, it is drained of water in all levels, giving a constant flow of drainage water to the Nyamwamba river which discharges into Lake George. The drainage water is highly contaminated by copper sulphate (blue colour), and the water flow rates are considerable, i.e. 30 m3/h.

The old cobalt stockpile is leaching sulphuric acid (from pyrite), cobalt and other trace elements.

The considerable and long term discharge of copper sulphate (highly toxic to vegetation) and heavy metals to the Nyamwamba river has, beyond a doubt, seriously affected the water- and sediment quality of the river. This is confirmed by a sampling survey made by the Centre for Research in Aquatic Biology where high concentrations of heavy metals and lack of algae growth were observed in the river. As to what extent Lake Edward has been affected by this pollution is not clear due to lack of data.

3.5 Tentative conclusions and action areas

Based on assessment of basic physical and chemical properties, the Ugandan surface waters must be considered as high quality resources in their natural state. Due to lack of sufficient monitoring data for the surface waters, no direct assessment can be made as to what extent various human activities have had an impact on the water quality during the last decades. The human activities which have impact potentials on the water quality are, however, generally in an early stage of development and should therefore not be expected to threaten the surface water quality at a broad national scale.

However, the activities of the various economic sectors in Uganda show almost no attempt to protect the water resources which they are utilising. The implication is that local deterioration of water quality occurs, affecting other users of the waters. A further implication of this practice will be a rapidly increasing frequency of water quality problems

4 GROUNDWATER QUANTITIES

4.1 Approach to assessment

The assessment of groundwater resources available for sustainable abstraction focuses on the following two considerations:

- is it physically possible to extract the required amount of groundwater from the aquifers ?

- can recharge take place to an extent where full replenishment of the aquifers occur under the given specific hydrometeorlogical and hydrogeological conditions ?

The assessment needs to be made from the perspective of the potential use of groundwater. Groundwater (from boreholes, dug wells and springs) is presently the major source of domestic water supply with the great majority of boreholes, wells and springs constructed for rural water supply. The rates of extraction are comparatively low and most boreholes are fitted with handpumps with capacities between 600 l/hour and 1200 l/hour depending on pumping heads. The future use of groundwater will most likely continue to be handpump based rural water supply, and springs and small-scale piped water supply for rural towns and growth centres requiring abstraction rates in the interval of approximately 0.5-10 m^3/h.

With these considerations and framework the following assessment has been made. The assessment is based on available information at the DWD, a current groundwater research project in Mbarara and Apac districts (IDRC, 1989 & 1994), past and ongoing rural water supply projects and planning programmes, as well as data from similar geologic and climatic settings in Kenya, Zimbabwe, Malawi and Sri Lanka.

4.2 Hydrogeology and aquifers

4.2.1 Occurrence of aquifers

Aquifers are water bearing formations with hydraulic characteristics which allow water to be extracted in significant amounts. The occurrence of aquifers is closely related to the geological characteristics of a given area. The productive aquifers in Uganda are mainly found in in-situ weathered bedrock and regolith overlying a crystalline basement rocks, and in faults and fractures in the basement. The characteristics of this aquifer is described in Subsection 4.2.2. and a simplified geologic map of Uganda is given in Fig 4.1 overleaf.

Finally, there may be an increasing load of sediment in rivers in certain areas due to erosion induced by land use practices.

It is obvious that even though the country possesses a relatively sound surface water environment, there are many activities in the various sectors which create conflicts between water users (including the natural environment) owing to water quality impacts. To be able to manage such conflicts, an effective collection, processing and distribution of information about the quality aspects of the surface water resources is a prerequisite. Based on the above, the following action areas have been identified:

- water quality modelling for Lake Victoria in order to identify the reasons for the rapid development in the eutrophication and to devise the proper interventions. The model should also be capable of simulating effects in local water bodies like Murchison Bay. A project to this effect has been identified during the Water Action Plan work. (Reference WAP.Doc.004, "Regional Water Quality Management in the Upper Nile Basin").

- identification, characterization and quantification of major pollution sources at sensitive water bodies

- environmental impact assessments of sector activities

- monitoring, control and regulation of significant polluting discharges

- establishment of surface water quality monitoring programmes to detect long term trends or shifts in essential parameters (early warning)

- establishment of databases, processing, reporting and dissemination routines for water quality information

The water quality action areas relating to the institutional and management aspects (follow-up on the water resource statute through preparation of regulations, discharge permits, capacity building, creation of cross-sectoral cooperative bodies at appropriate levels, sensitizing etc.) are described in WAP.Doc.008 "Institutional and Management Aspects".

Aquifers in volcanic formations are found at Mount Elgon on the eastern border and at Mfumbira in the South-West. The areal extent of volcanic rocks is limited and they are characteristically forming high relief topography where groundwater development primarily is in the form of springs.

The aquifers of Uganda are highly variable in terms of hydraulic characteristics but they can all be regarded as having only limited areal extent. Although the Rift Valley sedimentary aquifers are found in both Uganda and Sudan, the possibility of any hydraulic connection across the border due to the localized nature of the aquifers is low. The yields, which may be comparatively high in the local context are insignificant in a regional context and it is therefore not conceivable that an international issue should evolve over the exploitation of these aquifers.

4.2.2 Crystalline rock aquifers

The aquifers in the crystalline rock and the overlying regolith are interconnected. Aquifer characteristics are controlled by fractures and the effective porosity in each material respectively. Fig 4.2 shows a typical profile of a subsurface section including the two interconnected aquifers.

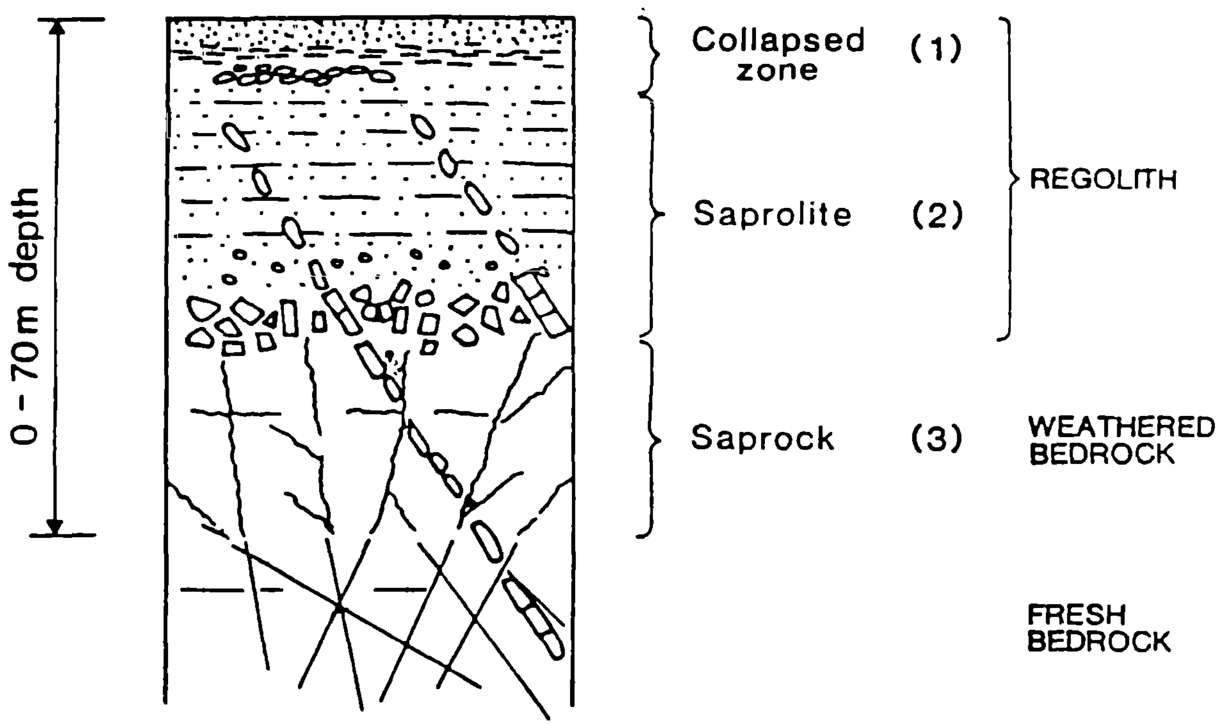

Figure 4.2 - Typical in-situ weathered regolith profile and underlying crystalline bedrock

The basement rocks, which covers more than 90% of Uganda, is dominated by Precambrian gneiss, the Precambrian cover zone, and major intrusive bodies.

Other aquifers are present in the Western Rift Valley sediments in a zone around Lake Edward and northwards from Lake Albert. They are sedimentary alluvial infills of gravel, sand and clay. In the Northern part of the zone, these infills are predominantly sandy and provide comparatively good aquifers. However, these aquifers are often constrained by limited storage and erratic recharge.

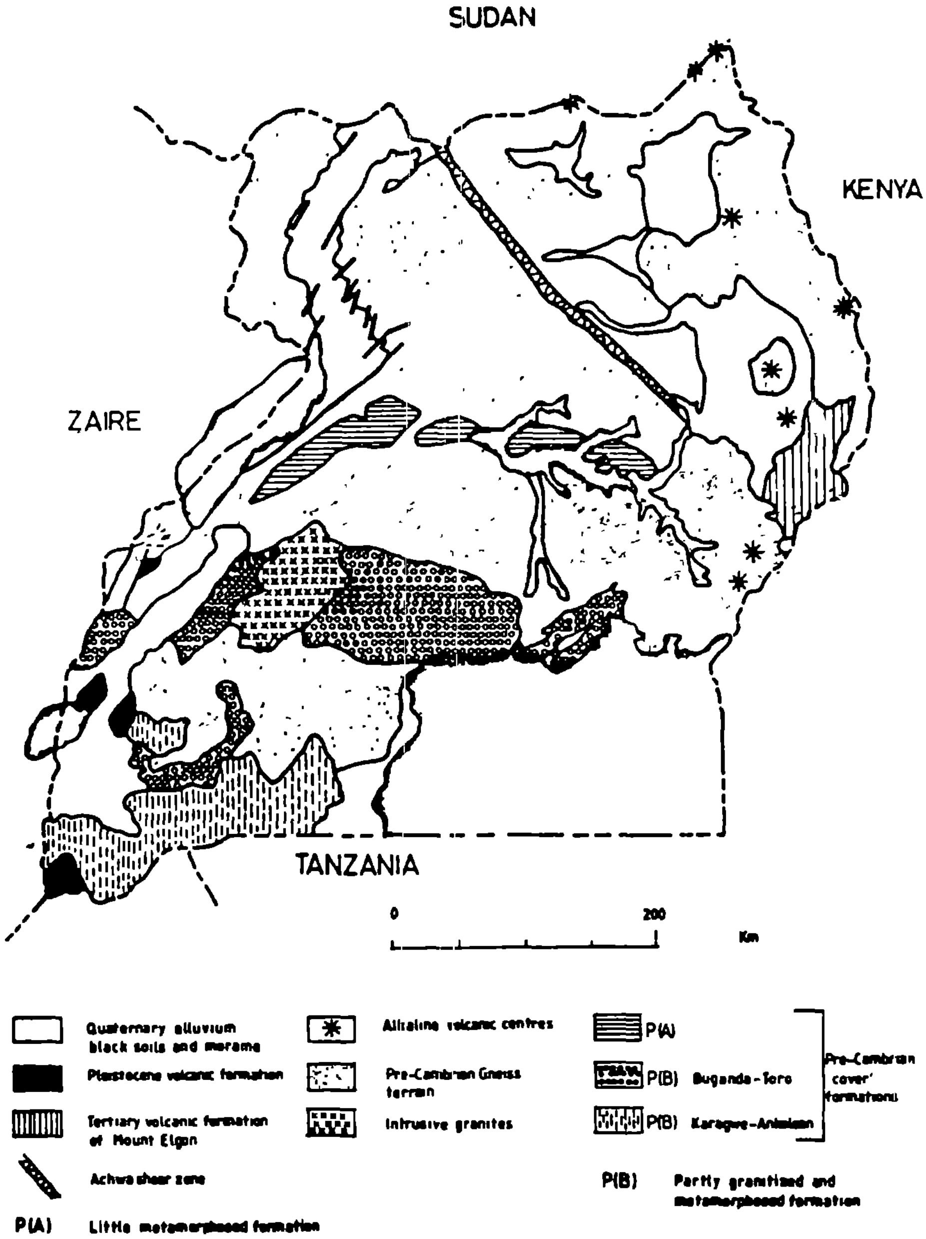

Figure 4.1 - Simplified geologic map

The yield is based on pumping tests, most often done by air-lift or sand-bucket. The results of such tests are not very precise and they give only rough indications of the long-term yield and of possible yield in cases where large draw-downs can be established.

It appears that the average yield is in the range of 1-4 m^3/hour with a tendancy for the higher values to be found in the Northern and Eastern parts of Uganda, while seemingly lower potentials are found in the Central and Western districts. It should however be noted that large variations occur locally and that such variations not will be reflected by averages. Further statistical parameters have to be taken into account in order to describe the situation in more detail.

Table 4.1 - Average hydrogeological parameters assessed district wise.

REGION	DISTRICT	YIELD (m^3/hour)	DRILLING DEPTH (m)	REGOLITH THICKNESS (m)	WATER LEVEL (mbgl)
Central	Kalangala	1.0	44.8	46.5	17.8
	Kiboga	1.1	74.0	26.5	36.0
	Luwero	1.7	59.1	33.9	20.1
	Masaka	1.1	101.0	44.0	34.8
	Mpigi	1.8	70.2	38.7	23.6
	Mubende	1.0	76.3	37.7	25.8
	Mukono	1.4	65.3	38.3	24.2
	Rakai	1.5	113.[illegible]	46.5	28.8
Western	Bundibugyo	---	---	---	---
	Bushenyi	1.3	80.0	---	15.0
	Hoima	2.9	63.0	34.5	17.0
	Kabale	1.8/2.2 (1)	63.7	46.5	28/10 (1)
	Kabarole	1.8/2.2 (1)	84.0	---	---
	Kasese	2.2	41.0	46.5	14.8
	Kibale	---	---	---	
	Kisoro	---	---	---	
	Masindi	3.1	73.0	42.0	26.0
	Mbarara	2.9	92.8	64.4	26.7
	Ntungamo	---	---	---	---
	Rukungiri	1.2	64.0	34.3	15.0
Northern	Apac	3.7	78.2	---	22.2
	Arua	3.1	68.4	17.8	12.4
	Gulu	3.7	83.0	19.0	15.0
	Kitgum	1.3	59.7	26.7	18.7
	Kotido	0.8	66.3	24.0	27.0
	Lira	3.4	97.4	---	15.0
	Moroto	1.4	79.4	38.7	24.1
	Moyo	3.1	75.4	16.9	13/10 (1)
	Nebbi	1.8	69.7	34.4	17.6
Eastern	Iganga	5.1	52.0	28.2	19.8
	Jinja	2.2	88.0	38.0	26.0
	Kamuli	1.5	103.0	48.5	28.6
	Kapchorwa	2.5	>90	38.7	>20
	Kumi	1.2	79.1	15.0	12.3
	Mbale	2.2	82.4	19.7	16.7
	Palissa	2.0	72.5	22.3	25.0
	Soroti	2.6	82.0	25.9	13.0
	Tororo	3.6	56.5	21.8	14.3

(1) Second figure valid for Rift Valley sediments

Source: WDD, 1993

The regolith overburden is clayey, especially in the upper levels where relatively low permeability is dominating. Higher permeability is likely to be found in the lower levels and in fractures of any residual hard bands, such as quartz veins. The overburden has a thickness of up to approximately 70m and is found consistantly over the bedrock, except in a few places where bedrock outcrops occur. Average overburden thickness is in the order of 30m.

The weathered bedrock has a more open structure than the fresh bedrock and can have a comparatively high permeability if the fractures have not been filled by clay. Fractures in this part of the profile are often horizontal exfoliation (pressure release) cracks with a high density of occurrence, whereas the deeper fractures and faults are related to tectonic movements. Such faults and fractures are usually steeply dipping and are often discernible from aerial photos and satellite imageries.

The hydraulic properties of the combined regolith-bedrock aquifer are best defined by transmissivity as determined from pump tests. Data from 53 pump tests carried out by RUWASA in subsurface areas of Eastern Uganda show average transmissivity values of 14 m^2/day. Such transmissivity values typically corresponds to draw-downs in the order of a few metres at pumping yields of 1 m^3/hour.

4.3 Groundwater development

The aquifers are developed by boreholes and dug wells. The boreholes have predominantly been constructed with a blank casing to the top of bedrock and an open hole completion. Depths have typically ranged between 60-90m. In unconsolidated formations, screens and gravel packing are used.

Boreholes with yields above 200-400 l/hour are considered successful and fitted with handpumps, although no clear definition of the term successful is given.

4.3.1 Deep well potential

The assessment of major groundwater development parameters given in Table 4.1 has been compiled by DWD staff and external consultants (WDD, 1993) based on borehole records and results from ongoing water supply development programmes. The data are from deep wells and concerns the primary aquifer.

4.3.2 Shallow well potential

The construction of protected shallow dug wells is a fairly recent development in Uganda. NGOs, and to some extent DWD, applies a dug well technique where cylindrical concrete rings (one meter diameter, 0.75 m length) are placed and moved into place by undercutting. The lower two rings are perforated and acts as a screen through which the shallow groundwater seeps into the well. The construction technique can generally be applied to depths of say 5-8 metres below ground level. Collection of construction and performance data has not been done to an extent allowing an assessment of the district potential based on actual shallow dug well yields. The RUWASA and WATERAID projects utilize augering by drilling rig as well as by handaugering tools for construction of shallow boreholes.

The development of shallow dug wells requires favourable conditions of high water levels and regolith permeability at shallow levels. As a working hypothesis, the regolith should be saturated at a level less than 5 mbgl. High water levels (saturated zones) may occur frequently at the margins of depressions and in valleys, where springs are also found. The permeability is generally highest where the bedrock is fairly coarse grained. The occurrence of hard laterite bands (hardpan) in the uppermost part of the regolith can be a constraint to the dug well development as these are not penetrable by hand tools. Further, water level variations over the year must be small. This is most likely to occur in areas with fairly even rainfall distribution over the year.

A relative assessment of the district potential for shallow dug wells has been attempted based on the factors mentioned above and present DWD experience on shallow well development. The result of the assessment is depicted in Fig 4.3 below.

4.3.3 Spring potential

There are an estimated 20,000 protected and unprotected springs in Uganda and they constitute an important water source for a large part of the population. Springs are mainly found in the South-Eastern part of the country close to Lake Victoria, in the mountainous parts of the Eastern Rift Valley, and in the West and South-West in the Rwenzori and Mfumbira mountain ranges.

Springs are most commonly developed in valley margins where comparatively less permeable strata intersect the lower parts of hill slopes. In order to have a perennial flow the springs must have a fairly large catchment and be located in areas with an annual rainfall adequate to maintain a minimum groundwater baseflow, (i.e. annual rainfall >700mm).

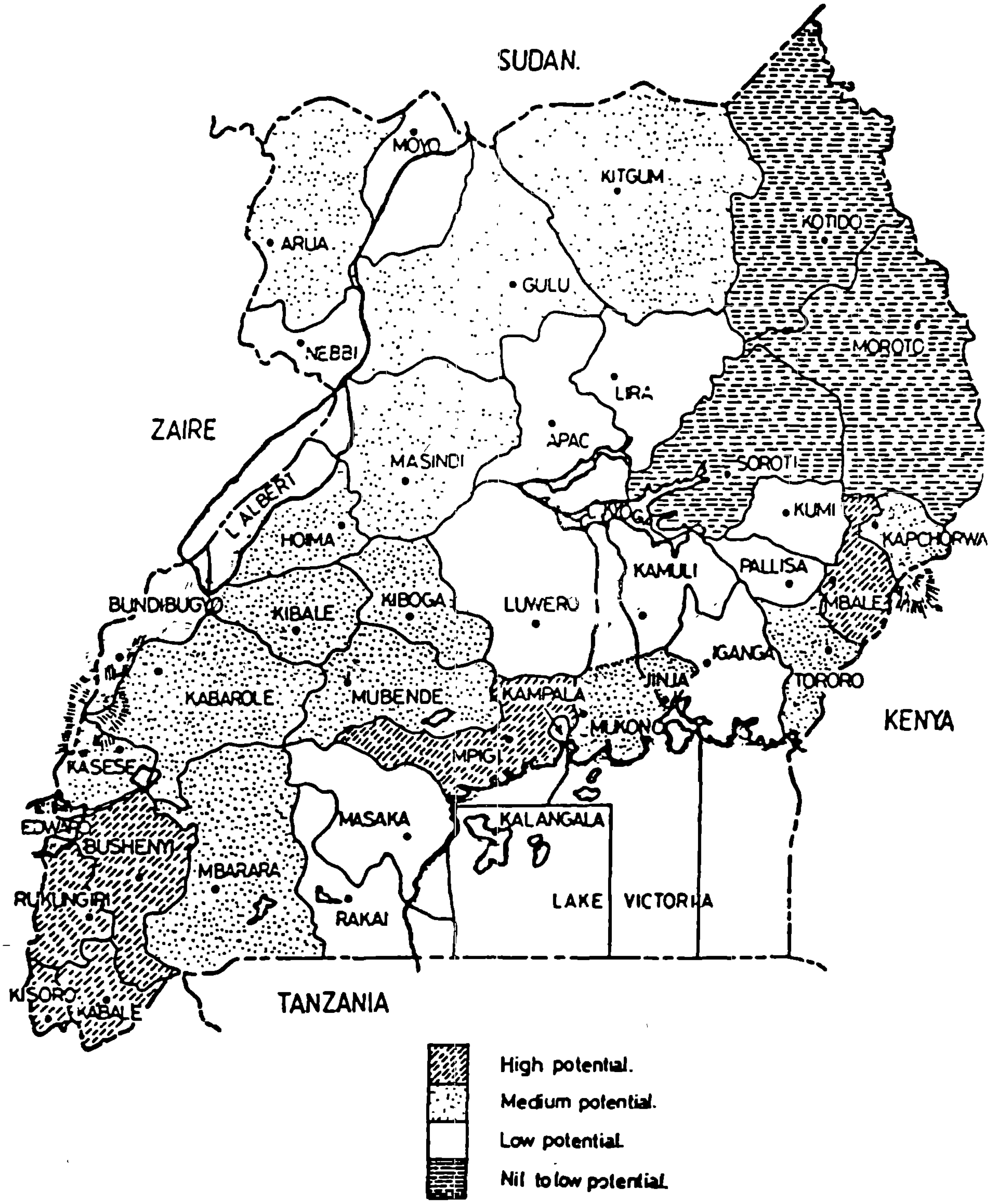

Figure 4.3 - Shallow well development potential based on DWD experience

Springs are developed and protected by clearing of the springs "eye" (or source) and construction of a chamber at the springs natural outlet. The chamber consists of highly permeable sand/gravel media retained behind a concrete or masonry wall which is pierced by the outlet pipe. The spring chamber is covered by an impermeable layer of clay, and the area is fenced off in order to avoid direct infiltration (and pollution) to the chamber.

Spring yields vary considerably but are most frequently found to be in the range of 0.3-2m^3/hour. There may be considerable yield variations over the year as shown by the fact that many springs are non-perennial.

4.4 Groundwater recharge

Groundwater recharge assessments are rather difficult to make and will always involve a large element of interpretation. Estimates can be made by a variety of techniques which all have constraints on accuracy and it is therefore important that different methods are used in establishing the magnitude of groundwater recharge.

Data from Uganda is presently very scarce but a number of rather detailed observations and calculations have been made in countries representing various tropical settings, and it is thus possible to arrive at an average order of magnitude for groundwater recharge.The aquifer under consideration is the combined saprolite-bedrock aquifer (without attempting to distinguish between the two formations as they are intimately connected with the saprolite constituting the storage capacity).

Calculations based on data from Meru District in Kenya (Ministry of Water Development, 1991) gives the following:

a) Measurements of minimum groundwater baseflow contributions to streams during three-month dry periods in low rainfall years have shown yields of 45mm correspon-ding to an annual baseflow (or recharge) of 180mm which again is estimated to increase by 25% during "normal" rainfall years giving an annual recharge of 225mm or more than 20% of the total annual rainfall of 1000mm. The measurements were made in a part of Meru District characterized by granitic basement rocks and thus similar to many parts of Uganda.

b) Static water level measurements for boreholes in the same part of Meru district show typical seasonal variations of 1-4 m over the rainy seasons from March to May and October to December respectively. If an effective porosity of 3% is assumed for the overburden, this corresponds to a recharge of 30-120mm per season or 60-240mm (6-24%) annually.

Detailed groundwater recharge assessments has furthermore been prepared for a district in the northern (inland) parts of Sri Lanka (NWS&DB 1993). Geologically the area is dominated by granitic basement with a typical ferralitic weathering profile of approximately 15m thick. The area is comparatively dry and characterized by low relief topography and a tropical climate with average annual rainfall of 1200mm. The area resembles central Uganda in many ways with the exception that there is only one infiltration period per year, i.e. October-December where many parts of Uganda have two (April-June and September-November). A computerized rainfall-runoff model was applied for a selected catchment in the area and the resulting calculated groundwater recharge was 120mm corresponding to 10% of the annual rainfall. These results were further supported by recharge assessments based on groundwater level monitoring which also indicated average annual recharge in the order of 10%.

An ongoing groundwater research programme (IDRC, 1994) has established recharge on the basis of soil moisture balance calculations in Aruca catchment in Apach district. Recharge calculations were made for two different periods (1954-1961 and 1988-1992) with significantly different vegetative cover resulting from 25% deforestation (in terms of area) from the first to the latter period of measurements. The most recent results indicated a recharge of 220mm per year or 16% of the total annual rainfall. This figure had doubled over the last 30 years from 110mm per year. Under the same research programme, Howard and Karundu (1992) have made a catchment water balance calculation for Nyabisheki catchment in South-West Uganda. The total annual rainfall in this area is as low as 750mm and the calculated minimum groundwater recharge is 17mm, or 2%.

Table 4.2 gives a summary of groundwater recharge rates and it is readily concluded from the results that the variation is considerable. This is believed to equally reflect the margins of error involved in this type of calculation as actual differences from one area to another. It is, however, possible to establish that the order of magnitude of variation is about 10% or 100mm (strongly dependant on the total annual rainfall), which in turn corresponds to an average groundwater recharge over the entire country of $20*10^9$ m^3 per year. If the total number of groundwater users is 16 million, and the individual consumption is set at 25 l/day, the present annual groundwater demand (for domestic purposes) is $150*10^6$ m^3 or 0.75% of the available resource. The figures show that even areas of low rainfall, and hence reduced recharge (say 1% or 10mm), can sustain groundwater abstraction for domestic water supply (7.5% of available resource) at an average population density.

The relationship between rainfall and groundwater baseflow (and thus recharge) is more or less linear and strongly dependant on the total rainfall as well as on the rainfall intensity. The dependence on intensity is clearly illustrated by the fact that recharge only occurs during the rainy/wet seasons (3-6 months per year) when the soils' field capacity has been reached and when the actual evapotranspiration is exceeded by precipitation.

However, even when considering such variations in rainfall intensity at different locations, it is possible to establish a rough correlation between total annual precipitation and groundwater recharge. This is illustrated in Fig 4.4 below where baseflow data from Malawi and Zimbabwe (Farquharson, F.A.K. & Bullock, A., 1992) have been combined with the results from Uganda, Kenya and Sri Lanka presented above. The linearity is clearly seen in the fact that minimum recharge approaches zero at annual rainfall of around 700mm. The minimum recharge at a mean rainfall of 1000mm is 100mm and thus 10% whereas this recharge increases to 300mm or 24% at 1250mm rainfall.

Table 4.2 - Summary of groundwater infiltration rates for selected catchments at annual rainfall in the range of 700-1500mm

Area Method of calculation	Meru District, Kenya	Selected catchments, Malawi	Selected catchments, Zimbabwe	A'pura District, Sri Lanka	Selected catchments, Uganda
Groundwater level measurements %	6-24	---	---	10	---
Baseflow / Water balance %	>20	14-30	2-7	10	2
Soil Moisture Balance %	---	---	---	---	16
Annual precipitation (mm)	1100	900-1500	700-900	1200	750-1400

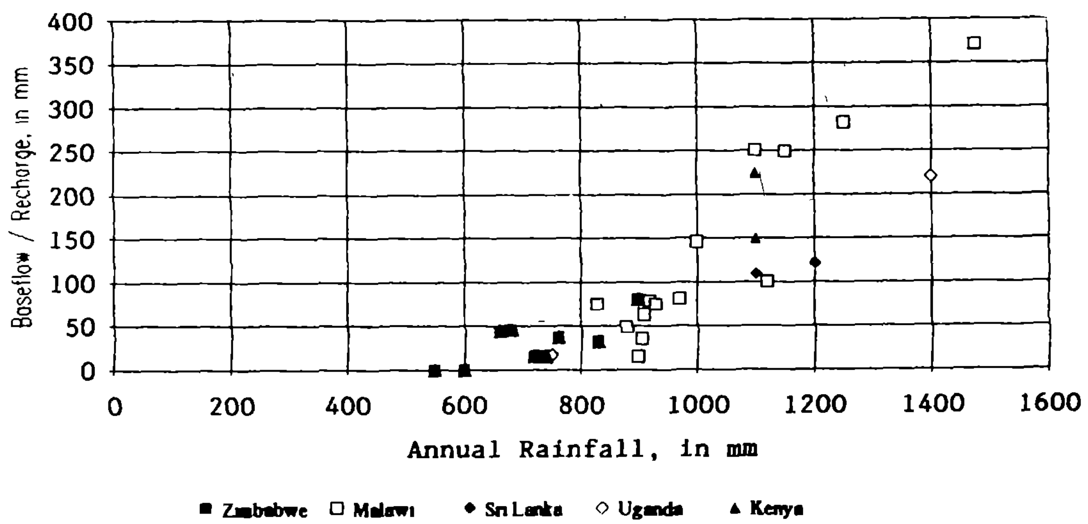

Figure 4.5 - Baseflow/recharge and annual rainfall for selected catchments in Malawi, Zimbabwe, Uganda, Kenya and Sri Lanka

4.5 Constraints in groundwater development

From the above recharge estimates it appears that the available groundwater resource, in general, is more than adequate to meet the demands for domestic consumption. The major constraint to groundwater development is thus local geologic conditions which may prevent abstraction by means of wells and boreholes. One such area is North Kamuli along the Southern shores of Lake Kyoga where widespread layers of ancient lake sediment has proven to be virtually impervious resulting in little or no infiltration in localized areas. Geophysical surveys and drilling campaigns will inevitably experience severe difficulties in under such conditions, and the result will be failure rates as high as 50%, such as it has been experienced by RUWASA in the aforementioned area.

In Luwero and Moroto districts rapid yield decline has been experienced for a large number of deep boreholes. A study revealed that the decline in yields was due to silting partly because of collapse of uncased overburden sections and partly because of improper sealing the borehole. It was concluded that poor construction methods were the main reasons for these problems.

Isolated cases of borehole and deep well failure are reported from all over Uganda. Drillers report that such failures are mainly due to corrosion of old steel casing pipes. In the case where new boreholes fail due to other than hydrogeological reasons, they are usually caused by casing collapse in thick sections of water saturated overburden or difficulties in establishing a proper seal at the interface between overburden and bedrock.

4.6 Conclusions and action areas

The general assessment of Uganda's groundwater resources in terms of quantities show that:

- aquifers are comparatively low yielding with a limited areal extent and poor hydraulic characteristics

- recharge estimates exist for only a few locations in Uganda but comparison to estimates from other countries with similar hydrogeological and hydrometeorlogical settings indicate average recharge in the order of 10% of the annual rainfall

- groundwater abstraction for domestic water supply in rural areas and in small towns and rural growth centres will on average account for less than 1% of the potentially available resource

- Pumped irrigation would only be feasible in very limited areas due to the poor hydraulic aquifer characteristics. Present livestock water demand (Appendix 6.4) is less than the domestic demand and can therefore be met by the groundwater resource in most areas

- borehole construction and completion methods are often deficient leading to frequent cases of well failure

- hydrogeologic and well data are generally not stored in a manner which makes such data readily available to potential users. This makes planning and dissemination of experience inadequate. RUWASA is the only project to maintain comprehensive computerized databases

- the shallow well potential is generally unknown due to poor reporting, but could be significant

- systematic monitoring of groundwater levels is not being carried out.

Based on the above conclusions the following action areas have been identified:

- further recharge investigations should be made in order to establish the more detailed groundwater resource available for availability use

- ongoing work on development of a groundwater data bank should be continued and the uniform reporting system which has been introduced must be made compulsory for all developers

- comprehensive groundwater level monitoring should be introduced in order to prepare accurate recharge assessments and to establish in detail the potential for shallow wells and boreholes.

5 GROUNDWATER QUALITY

5.1 Approach to assessment

The assessment of groundwater quality emphasized the following considerations:

- is the groundwater quality adequate for potential use ?
- is human impact placing constraints on the use and to what degree are the groundwater resources protected against such impact ?

The groundwater quality assessment needs to focus on the present and potential use which is expected to be rural and small urban water supply requiring drinking water quality sources.

At present, most analytical work on groundwater quality in Uganda is done under specific water supply implementation programmes. These programmes are predominantly for rural water supply with emphasis on a large number of point sources, and they therefore provide a comparatively wide geographical coverage, but only limited time series data which could give information on possible development trends in the groundwater quality. Water quality is generally tested after drilling has been completed and before the source is commissioned.

The DWD Laboratory has established standards and procedures for quality testing but these are only rarely followed in a systematic manner due to the many implementors/projects involved. Different methods of analysis, sampling and storage procedures are being followed and varying number of parameters are included in each test. This makes comparison of results difficult and the reported data for sensitive parameters (e.g. pH, CO_2 and Fe) are often unreliable. Together with deficiencies in area coverage, this unreliability means that a comprehensive picture of groundwater quality and possible variations between different hydrogeological zones is very difficult to establish.

However, some general characteristics emerge, and the following description is based on available information from the DWD Laboratory and different donor assisted projects (RUWASA, RTWSP and UNICEF/SWIP).

5.2 Impact from natural factors

The "natural" quality of groundwater is a result of the surrounding environment and is as such influenced by both atmospheric, surface and subsurface conditions. Formation of raindrops often takes place around condensation nuclei of HNO_2/HNO_3 in the atmosphere, where carbon dioxide is also taken up. At the ground surface and during infiltration through the soil, chemical processes involving decay of organic matter and release of CO_2 from microbial action takes place. Mineral decomposition will occur at deeper levels and in the aquifers, as a result of the long contact time between water and the surrounding rock, the groundwater will be enriched in elements characteristic of the geological environment. The combination of such processes and the chemical environment that the water is exposed to during the hydrological cycle determines the "natural" chemical composition of the groundwater.

5.2.1 Aggressiveness of groundwater

Aggressiveness is probably the most widespread groundwater quality problem. Groundwater from granitic and gneissic basement areas covering more than 90% of Uganda (see Chapter 4, Fig 4.1) is characterized by very low hardness values and consequently a reduced buffer capacity towards acids. When carbon dioxide from the atmosphere and the uppermost part of the soil profile is introduced to such water it will form carbonic acid (H_2CO_3), which in turn will lead to a significant lowering of pH and cause the water to become carbon dioxide aggressive.

Aggressive groundwater leads to rapid corrosion of steel casing and galvanized iron riser pipes in boreholes. This has been reported to be the cause of many borehole collapses where caving has occured due to corrosion and weakening of the casing. The effect of corroded riser pipes and pumping rods is failure of pumps to deliver according to capacity due to leakages, and an eventual complete breakdown. Excessive corrosion will often result in an unacceptably high content of iron in the water making the taste objectionable to the users and causing discoloration of clothes and utensils etc. In a corrosive environment, stainless steel (or PVC whenever the requirements to strength allows it) will have to be used for critical components which will increase costs considerably.

A complicating factor for the detection of corrosiveness is that analysis of chemical parameters in the carbon dioxide-bicarbonate-carbonate system must be carried out on site immediately after sampling. This is due to the rapid escape of carbon dioxide, which in turn will cause significant changes in the system's equilibrium. This has obvious implications for the sampling techniques to be applied, as water sampled from boreholes without prior pumping or water sampled during air-lift testing of boreholes is likely to yield values of carbon dioxide far lower than actually exist. It is worth mentioning that the same applies to testing for iron (if acid conservation of samples is not practised) due to the fact that the half-life of ferro-ions in an oxidizing environment is in the order of minutes.

5.2.2 Iron

The iron content of the groundwater in Uganda is frequently found to be above the WHO guideline value of 0.3 mg/l. The occurrence of high iron contents are related to aquifer mineral composition and the ability of groundwater to dissolve such substances as silicate minerals containing iron. As Previously mentioned, iron content may be a result of aggressive water corroding casing pipes, riser mains and pump rods.

An elevated iron content in itself does not have serious health implications for the user, but may make the water objectionable due to bitterness in taste and discoloration of clothes, utensils etc. Removal of excess iron is relatively easy at a water treatment plant, but is hardly feasible at village level although successful experiments and pilot iron-removal technology tests have been made in rural parts of India and Sri Lanka and at the DWD Laboratory in Entebbe.

An iron content up to 1 mg/l is generally acceptable and users in areas of water scarcity are often found to accept much higher levels (around 3 mg/l). In general, elevated iron content in Ugandan water supply is a minor consideration when faced with more serious and prevalent issues such as pathogen contamination.

5.2.3 Fluoride

Fluoride concentrations in drinking water above around 2 mg/l cause discoloration and mottling of teeth (dental fluorosis) and in severe cases (concentrations higher than 6-8 mg/l and long exposure) skeletal fluorosis. Fluoride occurrence in Uganda is of a local character with the highest incidence rates found in the Western Rift Valley and in the volcanic areas of Eastern Uganda. High fluoride concentrations are characteristic of these volcanic settings, and the problem is enhanced by the relatively high solubility of most fluoride minerals. Local variations can be considerable and experience shows significant variations in fluoride content of groundwater from boreholes within short distances.

Various methods of fluoride-removal techniques applicable to rural areas have been developed. The most simple method is based on contact between the fluoride rich water and a filter medium such as bone char, which has been tested on a pilot basis in countries including Tanzania and Sri Lanka. However, the cultural acceptability and operation of the methods under rural conditions may become limiting factors in its applicability. Other filter media such as crushed bricks and serpentine-marble are currently being tested in Sri Lanka. Tests with brick fragments (low temperature burnt clay) have shown a fluoride removal capacity in the order of 60% (from 4.1 mg/l to 1.7 mg/l) with a retention period of 3 hours.

5.2.4 Water with high chloride content

High chloride values are reported from a number of boreholes in the Eastern districts. Chloride contents up to several thousand mg/l are found in some locations and concentrations in excess of 500-700 mg/l make the water unacceptable for human consumption. The exact cause of the high chloride content is not known but it could be the result of conditions with low groundwater infiltration and high evapotranspiration which characteristically leads to the formation of brines. The volcanic rocks in the area may be another influencing factor.

5.2.5 Trace metals

A comprehensive study of trace metal contents in groundwater was carried out in Nyabisheki and Aroca catchments in Mbarara and Apach districts respectively (IDRC, 1994). The study included 158 groundwater samples analyzed for 24 different metals in addition to iron and manganese. With the exception of iron, manganese and aluminium, trace metal contents were generally very low and complied with WHO Guidelines for Drinking Water Quality. Manganese was only slightly above the recommended limit, whereas iron showed significant elevated levels and an average of 4 mg/l. Aluminium levels in regolith groundwater were found to be significantly higher (average up to 1.2 mg/l) than for the underlying bedrock. This may be indicative of secondary weathering of regolith clay minerals. Aluminium is widely used in water treatment and does not represent a health threat. It may, however, when combined with iron, intensify discoloration of the water. The WHO Guideline value for Al is 0.2mg/l.

5.3 Impact from human activities

The major impact on groundwater quality from human activities in Uganda relates to insufficient sanitary practices. Isolated impact from deposits of industrial or domestic waste could also affect the groundwater quality, but only at a localized level. The impact from unsanitary practices is seen in groundwater in the form of high bacteria counts and the occurrence of nitrate, the latter formed as a result of nitrification of ammonium.

5.3.1 Occurrence of bacteria and pathogens

Bacterial tests are extremely sensitive to conditions such as temperature. Bacteria constitute more than 30% of the wet volume of faeces and counts of 10 billion anaerobes and 0.1 billion aerobes per wet weight gram of faeces have been reported. The total coliform group includes four classifications of bacteria out of which one is faecal coliform (Escherichia

Coli). Several of the species can be found in unpolluted soil and water, thus high counts of total coliforms are not conclusive evidence of pollution. However, high total counts in combination with other indicative factors, such as possible pollution sources, will add to the evidence of contamination and thereby the risk of pathogens. Faecal coliforms are used as indicator organisms for the presence of pathagens from facal pollution sources. E. Coli is exclusively faecal and constitutes over 90% of the coliform flora of the human intestines. The presence of E. Coli at unacceptable levels indicates a probable health risk due to pathagen contant.

Significant contents of coliform bacteria have been reported in spring and borehole water (i.e. groundwater) from both the UNICEF supported SWIP project and the Danida supported RUWASA project. It is believed that some of these high coliform recordings are the result of contamination during sampling as well as inadequate sealing of boreholes and improper protection of springs. Human activities and livestock watering near the water points are, however, the most likely causes of contamination.

Another potential source of bacterial contamination of groundwater is the use of bacteria infested water for drilling operations and lack of sterilization of boreholes prior to water quality testing, handpump installation and handing over of water points to the communities. Groundwater sources, when properly developed, are likely to free of coliforms and pathogens.

It is obviously important to identify water sources which can remain free from contamination when properly managed. However, equal emphasis should be placed on water use practices after the collection of the water at the source as this is a far more common cause of bacterial contamination.

The possible impact of latrines on the groundwater quality is highly dependent on the level of the pit bottom relative to the groundwater table. Pit latrine depths are typically within the range of 5-13m with depths up to 16m being reported. If the pit bottom at all seasons of the year is above the water saturated soil zone (groundwater table), then bacteriological contamination is reduced to insignificant levels at a distance of one meterfrom the pit. Contamination could be present at distances of 10-15m or more from the pit if direct seepage into the saturated zone takes place. These figures are obviously dependent on local conditions such as soil permeability and groundwater flow rates.

In the Ugandan context, groundwater levels are fairly deep and soil permeability is quite low. If latrines are constructed at a reasonable distances from the water source and if the pit bottoms are kept clear of the aquifer, the risk of contamination will be negligible. UNICEF recommends pit depths of about 4 m and the Ugandan Public Health rules specify a minimum distance between water source and pit of 33m (100ft).

5.3.2 Occurrence of nitrate

Nitrate is formed in nature by oxidation of nitrogen, which is found in large quantities in fertilizer, human faeces and manure. Concentrations in groundwater of 10-20 mg/l NO_3 indicates a general contamination from fertilizers or human/livestock sources. The use of fertilizer is presently very limited in Uganda (ref Section 3.3) and nitrate concentrations in excess of 10 mg/l almost inevitably indicates human contamination. High nitrate values may have health implications especially for infants, where it may cause methenoglobinemia due to intestinal reduction of nitrate to nitrite. Nitrite binds to hemoglobin and thereby reduces the oxygen transport capacity of the blood.

5.4 Groundwater quality test results

The most consistent and comprehensive database on groundwater quality is established under the Danida assisted RUWASA project covering eight districts in Eastern Uganda. Results from water quality analyses of samples from 702 boreholes under this programme are summarized in Table 5.1, along with the WHO (1984) recommended guidelines for acceptance limits for drinking water supply. In principle, the DWI adhere to the WHO guidelines for water quality. It is realized though, that strict enforcement of these guidelines is not always applicable in Uganda, where the quality of alternative and often unprotected sources must be considered.

Table 5.1 - Water quality data from 702 RUWASA boreholes and WHO recommended maximum limits for drinking water

PARAMETER	MIN. VALUE	MAX. VALUE	AVERAGE	WHO 1984 GUIDELINES
pH	4.5	9.9	6.7	6.5-8.5
Conductivity, µS/cm	'0	13600	737	-
Total iron, mg/l $Fe^{2+}+Fe^{3+}$	0.01	6.3	0.8	0.3
Manganese, mg/l Mn^{2+}	0.004	1.2	0.07	0.1
Alkalinity, mg/l $CaCO_3$	8	1042	186.1	-
Hardness, mg/l $CaCO_3$	2.5	3976	229.8	500
Calcium, mg/l Ca^{2+}	0.4	2126	94.1	-
Magnesium, mg/l Mg^{2+}	9.8	451	22.1	-
Bicarbonate, mg/l HCO_3^-	18.6	1270	216.3	-
Carbon dioxide, mg/l CO_2	1.7	1298	165.6	-
Sodium, mg/l Na^+	0.04	1090	60.6	200
Potassium, mg/l K^+	1	30	5.1	-
Chloride, mg/l Cl^-	0.7	2153	73.4	250
Sulphate, mg/l SO_4^{2-}	0.01	2450	57.5	400
Phosphate, mg/l PO_4^{2-}	0.02	1.8	0.8	-
Nitrate, mg/l NO_3^-	0.0	101	3.7	10
Fluoride, mg/l F^-	-	5.5	0.8	1.5

Source: RUWASA

Table 5.2 - Average values for water quality parameters. RUWASA dug wells, protected springs and boreholes

PARAMETER	AVERAGE, DUG WELLS (n= 234)	AVERAGE, PRTEC.SP-RINGS (n = 280)	AVERAGE, BOREHOLES (n = 702)	WHO 1984 GUIDELINES
pH	6.8	5.8	6.7	6.5-8.5
Conductivity, µS/cm	390	113	737	-
Total iron, mg/l $Fe^{2+}+Fe^{3+}$	0.5	0.3	0.8	0.3
Manganese, mg/l Mn^{2+}	0.10	0.05	0.07	0.1
Alkalinity, mg/l $CaCO_3$		38.8	186.1	-
Hardness, mg/l $CaCO_3$	119 5	48.4	229.8	500
Calcium, mg/l Ca^{2+}	124.6	20.7	94.1	-
Magnesium, mg/l Mg^{2+}	41.0	5.2	22.1	-
Bicarbonate, mg/l HCO_3^-	9.1	51.1	216.3	-
Carbon dioxide, mg/l CO_2	140.5	126.5	165.6	-
Sodium, mg/l Na^+	97.5	6.4	60.6	200
Potassium, mg/l K^+	25.3	1.6	5.1	-
Chloride, mg/l Cl	5.6	9.3	73.4	250
Sulphate, mg/l SO_4^{2-}	22.1	12.8	57.5	400
Phosphate, mg/l PO_4^{2-}	27.8	0.4	0.8	-
Nitrate, mg/l NO_3^-	1.3	2.6	3.7	10
Fluoride, mg/l F^-	2.2	0.14	0.8	1.5
	0.7			
% waterpoints with E.coli count >0	34	13	5	0

Source: RUWASA

Typically, WHO guidelines are exceeded in the cases of Fe and pH, none of which involve a serious health threat to the consumers. In terms of bacteriological quality, a total of 86 borehole samples were analyzed for E.coli with 4 samples showing counts >1mg/1.

The results from approximately 100 deep boreholes drilled by UNICEF/SWIP during 1991, shows the following water quality values:

- pH — 6.8-8.1 (average 7.3)
- Total coliform — 0.4 per 100 ml
- Total iron — 0.0-0.2 mg/l

Average parameter values for different categories of waterpoints (dug wells, protected springs and boreholes) have been compiled in Table 5.2. Significant differences clearly emerge reflecting the variations in both construction mode and geological environment. From the table appears that boreholes show the lowest frequency of bacteriological (E.coli) contamination and dug wells the highest. This is clearly caused by the difficulties in construction and maintenance of proper sealing on large diameter dug wells, whereby seepage of surface water into the well may occur. Boreholes, on the other hand, are sealed with cement or bentonite and furthermore backfilled.

In terms of inorganic chemistry it is interesting to note that the conductivity values (and thus degree of mineralization) are significantly lower for springs than for dug wells which in turn are clearly lower than boreholes. This is explained by the fact that spring water trajectories have been intensively leached through many years of flow whereby the water in these aquifers shows relatively minor enrichment in inorganic substances. Spring water clearly shows the lowest pH values, which again demonstrates that the water, in spite of low pH, has caused limited decomposition of aquifer minerals.

Boreholes, on the other hand, clearly show the highest degree of mineralization with relative enrichment of nearly all tested elements. This is due to the ability of agressive groundwater to decompose the relatively fresh minerals in the bedrock fractures. Water from dug wells shows an intermediate enrichment in inorganic constituents, in accordance with the aquifers' geological setting.

The general picture described above does not apply to nitrate. This shows that other than geological factors influence the nitrate concentrations. The nitrate values are determined by the contents of the infiltrating water, which reflects the nitrate concentrations in the rainwater and the nitrate load produced by humans and livestock.

5.5 Tentative conclusions and action areas

From the above outline of Ugandan water quality issues, it appears that a major quality problem is related to the widespread corrosiveness of the groundwater. This problem has to be counteracted by selecting resistant borehole construction materials.

Another problem is the occurrence of groundwater with comparatively high iron contents, which presently cannot be reduced by methods appropriate for rural areas. In the case of a town water supply, however, the technology for removal or reduction is readily applicable.

Problems of a more localized nature are the occurrence of groundwater with high mineral content (in the areas near Lake Kyoga) and groundwater with high fluoride content in certain locations in the Rift Valley and in volcanic areas in the East. The groundwater quality in the Eastern area also has frequently high chloride contents.

Under the given hydrogeologic conditions (low groundwater tables and low permeability), the human impact on groundwater quality related to sanitary practices is unlikely to be significant if sound construction principles for latrines are followed in addition to appropriate (human/livestock) behaviour near water points.

Based on the above observations the following action areas have been identified:

- standardization of groundwater quality data generation and storage shall be enforced through requirements to all implementing organizations

- staff should be trained in appropriate standard practices for groundwater sampling, storage and analysis with particular focus on testing for carbon dioxide and fluoride

- water quality data should be included in a groundwater databank in a uniform format for accumulation of experience and planning

- research on fluoride and iron removal/reduction technology shall be followed closely with the intention of introducing such technology when extended pilot tests under rural conditions show positive results

The need for general institutional strengthening including the requirements to water quality testing capacities and capabilities is included in WAP Doc. 008 "Institutional and Management Aspects" as well as in the identified project "Rehabilitation of Water Resources Management and Assessment Services in Uganda" (WAP Doc. 002)

6 DEMANDS AND WATER RESOURCES DEVELOPMENT

6.1 National development framework

Developments on a national scale within the water resources related sectors are key considerations in assessment of the present and future requirements to water resources. Having assessed such requirements, it can then be considered to what degree such requirements can be met and the degree of water management required. The need for water management increases with scarcity of the resource in comparison with demand. The following description of the development context is based mainly on "Background to the Budget 1992/93" (Ministry of Finance and Economic Planning, 1992) and "Agricultural Sector Study", (World Bank, 1993)

6.1.1 Population

The population of Uganda was about 16 million in 1992. Annual growth in the period from the 1980 census was 2.5%, down from 2.8% in the period 1969-1980. Reasons behind this decline can be found in the economic and social difficulties the country has been subject to, increased mortality connected to civil unrest and emmigration.

With the prospects of a growing economy and improved social conditions the population, growth rate could be expected to increase. The apparently extensive propagation of AIDS in the country is, however, a factor with the potential for a serious, adverse impact. With a growth rate at the earlier level, 2.8% per annum, the population of Uganda would increase to 28 million in the year 2010.

The urbanization rate is presently 11%, one of the lowest in Africa. However, the Ugandan capital, Kampala, increased its population at a rate of 4.9% per annum in the period 1980-1991, wellover the average increase for the country. The predominantly rural Western Region nevertheless had a growth rate at the same level as the Central Region which includes Kampala.

There is currently a certain inter-regional migration, from the most densely populated areas to less developed regions with good agricultural potential.

6.1.2 Production and income

During a period starting in the early 1970's, Uganda was exposed to the effects of armed conflicts, with devastating social and economic costs. Development has now started to catch up, but the levels achieved in the late 1970's are not yet restored in many sectors. Income per capita, as calculated by the World Bank, is US$ 220 per year (in 1990), which is low even in the Sub-Sahara African context.

The growth in the gross domestic product (GDP) of the country improved significantly from 1987 onwards, exceeding 7% in the best years. In 1990/91 the growth slowed to 4.1%, mainly due to the prolonged drought in some parts of the country in the second half of the year. The growth of GDP is expected to recover from 1992/93 onwards, with annual rates of about 5%, depending mainly on the performance of the important food crop sector and on ample rainfalls. A government target is to maintain an annual GDP growth rate of at least 5%.

The agricultural sector accounts (in 1991) for about 60% of the country's GDP and for over 90% of the exports. Manufacturing, with 5% of GDP, is to a large degree related to processing of agricultural commodities. The electricity and water sector contributes 0.5% to the GDP.

Growth in the agricultural sector depends on the food crop sector which has developed steadily over the last years. Cash crops have stagnated in real terms due to fall in both coffee prices and shipments, while livestock, forestry and fishing all have made good contributions to growth. Agricultural production increased by 2.5%, industry by 14.1% and services by 6.3% in 1990/91.

6.1.3 Foreign trade

The value of Uganda's annual imports and foreign debt payments is much larger than the value of exports. Grants and loans from foreign sources cover the deficit. The trade balance improved in 1991. The effect resulted primarily from lower imports with a decline of 25%, while exports grew only by 0.7% in value terms.

In 1992, the Bank of Uganda introduced weekly foreign exchange auctions. The policy was intended to stimulate exports and defer imports by avoiding an overvalued exchange rate of the Ugandan Shilling. The Shilling has been continuously devaluated over the latest year years compared to the US dollar.

6.1.4 Public spending

The Government's budget is currently running at large deficits. The situation became particularly grave in 1991-92 with extensive loans from the Central Bank. The increased money supply contributed severely to the inflation rate which reached 66% by May 1992. Subsequent actions were taken to cut government spending and raise revenues by an increase in taxes. In recent years, the budget has relied heavily on donor import support funds to finance the large deficits. A Government target is to reduce the inflation rate to 10% by 1994/95.

6.1.5 Employment

The potential workforce in Uganda is estimated at 7 million with a majority of 80% engaged in agricultural activities. It is assumed that 115,000-120,000 new persons enter the labour market annually to look for work opportunities.

Employment opportunities have been falling over time with the marked decline in the private sector, while the public sector, to a large degree, has become an employer of last resort. Unemployment is rampant, especially when taking into account also the less discernible underemployment.

6.2 Sectoral requirements, impacts and trends

The different economic sectors have diverse requirements for water resources. These needs can be either consumptive or non-consumptive. The consumptive uses are for instance, water supply, while important non-consumptive uses are comprised of uses such as hydropower and fisheries. The following table very briefly summarizes some important aspects of these requirements in the Ugandan context while the assessment of the requirements is given in the following sections.

Table 6.1 - Sector requirements and major impacts on water resources

SECTOR	REQUIREMENTS TO WATER RESOURCES	MAJOR IMPACT ON WATER RESOURCES
WATER SUPPLY -rural domestic -urban -single industries	Water for consumptive use in drinking water quality for rural and urban supplies. A few industries may have lower quality requirements.	Consumptive use of groundwater and surface water entailing reduced flows in streams, lowering of groundwater table and possible depletion if recharge does not match demand.
AGRICULTURE AND FORESTRY -irrigation -livestock -deforestation -agrochemicals -soil erosion -wetland cultivation	Water with irrigation water quality for crop consumptive use. Water for livestock with low quality requirements.	Reduction in surface water flows. Deforestation affects surface runoff regime. Agrochemicals in larger amounts may affect surface water quality. Soil erosion entails siltation and in severe cases surface water runoff regime. Wetland cultivation may affect downstream water quality and change hydrological regimes.
HYDROPOWER -hydropower on the Nile -mini-hydro	Stream flows and stream gradients compatible with power generation requirements.	Non-consumptive use of river flows. Presently no storage on the Nile (within Uganda). River flows remain unchanged. Mini-hydro with storage reservoirs have equalizing effect on flows.
SEWERAGE & SANITATION -waterborne sewerage -industrial waste water -pit latrines	Water supply for water-flushed installations in urban areas and for industrial process use. Water availability for waterflushed latrines in rural areas and small towns.	Contamination of surface water recipients (incl. certain wetland areas). Risk of groundwater contamination from latrines in case of short distances to groundwater sources.
FISHERIES -commercial (lake/pond) -sports	Stable water quality and ecosystems suitable for fish stocks.	Overfishing will change ecological balance as will dominance of single species. Inland fish ponds may introduce unacceptable pollution in small streams.
NAVIGATION -lake transport	Lake water levels maintained within design intervals for ports and transport infrastructure. Water hyacinth occurrence kept at a level where it does not interfere with navigation.	No major impact
RECREATION AND TOURISM -wildlife -scenic beauty	Water for wildlife in park areas. Water falls and scenic spots to be conserved.	No major impact
HEALTH -water related diseases	Water for domestic use to be of drinking water quality. Breeding spots for mosquitoes to be controlled.	No major impact
ENVIRONMENT -conservation -biodiversity -sustainability	Minimize impact on water resources from human activities	No impact

6.3 Water supply

6.3.1 Domestic water supply

The situation within the domestic water supply in Uganda is characterized by a very low level of coverage by supplies of adequate water with acceptable quality both within rural and urban water supplies. The table below gives the approximate status in coverage and plans for increased coverage.

Table 6.2 - Present status and planned investment in water supply sector. Coverage is given as per cent of population served

DESCRIPTION	RURAL DOMESTIC SUPPLY	URBAN DOMESTIC SUPPLY
population (1992)	15 mill.	1.7 mill.
population ratio	90%	10%
service target	25 l/cap/d	50 l/cap/d
Coverage & annual level of investment		
1990	20%	40%
1992	26% /US$14m	60% /US$30m
1995	36% /US$30m	75% /US$40m
2000	75% /US$40m	100% /US$40m

Source: WDD, 1992

The above data shows the existing low water supply coverage and the distribution between investments in the rural and urban sub-sectors. The apparent bias in investments towards the urban sub-sector is attributed to the levels of service, technology and institutional requirements provided in the two sub-sectors. For example, while investment per capita in the rural areas may be as low as US$ 6 (spring protection), the corresponding figure in the urban sub-sector often exceeds US$ 120.

The urban water supply and sanitation sector is implemented by the National Water and Sewerage Corporation (NWSC) and DWD. The NWSC is responsible for supplying water to a population of approximately 1 million in Kampala, Entebbe, Jinja, Mbale, Tororo, Masaka and Mbarara urban centres. The average coverage in terms of persons served is 51% of the urban target population.

With the on-going rehabilitation and/or expansion under the Second Water Supply Project, NWSC intends to supply 76% of its target population.

Water supply to sixty small towns (with population exceeding 5,000 people) falls under the responsibility of DWD. The total population in these centres is estimated at 700,000 people and is expected to increase to 1 million by the year 2000. Of these centres, 25 have existing water supply systems which are in a very poor state of repair due to maintenance constraints; most often the population has to rely on unsafe water sources.

An umbrella programme, the Rural Towns Water and Sanitation Programme (RTWSP), has been instituted to coordinate all the urban water projects under DWD. The strategy of RTWSP follows a major shift in government policy towards decentralisation and represents a demand-driven participatory approach.

Beneficiaries, to be organised on the basis of management units, will determine the type of water supply and sanitation system they want and how to manage it, including operation, maintenance, repairs and revenue collection. The role of government or DWD will be that of a facilitator, providing construction financing guidelines, regulatory supervision and ensuring that communities receive good technical advice.

The towns have been grouped into implementable packages, preliminary technological options for serving the different towns have been formulated as well as policies and guidelines for implementing the programme. Implementation costs are estimated at US$ 120 million (Cowiconsult/NCG/Habitat, 1993).

DWD (1992) estimated the rural potable water supply coverage to be 26%. The level of investment required to raise the coverage to 100% is estimated to be US$ 351 million. The major rural water supply development programmes are RUWASA East Uganda Project (Danida financed), running up to year 2000 and covering eight districts, and SWIP (UNICEF/CIDA/SIDA) covering nine districts. Further programmes are the WATSAN, National Water and Sanitation Programme (UNICEF & various NGOs) covering nine districts, and the West Nile Rural Water Supply Programme (Italian funding and NGOs) covering two districts.

6.3.2 Industrial water supply

Uganda's industry is mainly engaged in processing of raw materials arising from agriculture, livestock and forestry with the aim to produce essential domestic requirements or preparing of agricultural outputs for export.

The major activities consist of manufacture of textiles and garments, leather, sugar, foods, soft drinks, beer and flour milling. These activities are concentrated in the south of Uganda particularly, Kampala and Jinja at the shores of Lake Victoria and Victoria Nile. Uganda had a strong industrial base in the 1960's but this was rapidly destroyed during the 1970's. To date there are only about 5000 registered factories, many of them producing below capacity. Industry in total contributes 5% of the GDP. Industries are generally connected to the urban water supply networks.

The estimates (Ministry of Finance and Economic Planning, 1992) of the development trends for industrial production vary between the different sectors from 2.8% to around 7%. As the production has been very low, such increases seem likely over the coming years. No attempt has been made here to estimate the water demand of the individual industries, but an allowance has been made in the demand figure for urban dwellers to include industrial demand.

A more detailed account of industries with significant wastewater production is given in Section 3.3, where water quality and pollution aspects have been considered.

6.3.3 Present and future rural and urban water demand

The present and future water demand for urban and rural domestic supplies have been calculated based on the population data and forecasts on district and catchment level presented in Appendix 6.1. The basic assumptions on unit water demands are very rough and are taken to be uniform for the whole country. However, for the purpose of a first estimate of a countrywide domestic demand the figures will give a good approximation. The assumptions are:

- present and future rural domestic demand 25 l/cap/day
- present and future urban domestic demand (incl. industry) 75 l/cap/day

The results of the water demand calculation for districts and the eight major catchments are given in Appendix 6.3. The calculations deal with both the present and future demand. The coverage has been taken as 100% and the figures thus give the upper limit of the demand. The results show that the upper limit (year 2010) of the urban demand is 100 mill. m3/year sec (or 3.2 m3/sec), while the corresponding rural demand (year 2010) is 230 mill. m3/year (or 7.3 m3/sec).

6.4 Agriculture

6.4.1 Livestock water demand

The structure of food demand is likely to change with the rise in income, with a shift away from root crops and starchy products like cassava and bananas, to livestock and dairy products. Government policy is aimed at reactivating the livestock industry after the heavy losses during the 1980's. The present stock is estimated at 4.5 million cattle, 1.2 million pigs and 5.5 million sheep and goats.

The rearing of livestock is aimed at self-sufficiency in meat and dairy products and at expansion of the leather industry for export. The number of livestock is expected to grow at an average rate of 5% annually (Ministry of Finance and Economic Planning, 1992). A distribution of livestock by district is given in Appendix 6.2.

Livestock water demand is a significant water use, especially in the semi-arid pastoral areas where surface water sources are scarce and where long dry seasons are experienced. The semi-nomadic pastoralists who inhabit these areas often encroach on the nature reserves, such as Lake Mburo National Park, and settled neighbouring communities in search of water and pasture.

In the past, 425 medium-sized dams and valley tanks, as well as several small valley tanks, were provided. Most of these have silted up due to lack of maintenance, poor animal watering methods and soil erosion as a result of overstocking. In 1989, under the direction of the President, it was planned to construct two valley tanks in each parish in Karamoja and later in the South-West. A total of 264 valley tanks are required in Karamoja. However, DWD and Karamoja Development Agency (KDA) expressed the need for a special study to assess the feasibility and requirements of the project. Ministry of Agriculture Animal Industry and Fishery (MAAIF) estimates the investment required for construction of 230 communal valley tanks and 135 private dams for ranches at US$ 6.8 million.

6.4.2 Present and future livestock demand

The livestock population and the projection is given in Appendix 6.2 on a district and catchment basis. The total present livestock herd is estimated to approximately 4.5 mill. cattle, 4.8 mill. goats and sheep and 1.2 mill. pigs. From the figures in Appendix 6.2 livestock demand has been estimated using the following assumptions:

- one livestock unit consumes 50 l/head/day
- cattle = 0.7 livestock equivalents
- pigs = 0.4 livestock equivalents
- goats/sheep = 0.15 livestock equivalents

Based on the projections and the above assumptions on consumption the figures in Appendix 6.4 were derived. In addition to the distribution of demand by district, the demand has been calculated for each of the eight major catchments of Uganda. These figures also appear in Appendix 6.4.The livestock equivalents are given along with the present and future water demands. It appears from Appendix 6.4 that the present (1989) livestock demand is approximately 81 mill. m3/year (or 2.6 m3/s), whereas the future (2010) demand amounts to 223 mill. m^3/year (or 7.1 m^3/s).

6.4.3 Irrigation

In recent years irrigation attracted increasing attention in Uganda. Today there exist plans to achieve higher agricultural production per unit area and improve food security through a more efficient use of land and water resources. Small-scale irrigation is planned to be supported by extension services and training as well as through planning and design.

The existing irrigated areas are predominantly located around Lake Kyoga and in the areas between Lake Kyoga and Mount Elgon. A total of 32,510 hectares of land is estimated as irrigated area in 1992. Current practices regarding water application indicate that a total oj about 206 mill. m3 of water is used annually for irrigation. Swamps presently provide the largest areas, with approximately 30,000 hectares of small scale irrigation in Tororo, Iganga and Pallisa Districts. For comparison, the swamp area of Uganda is estimated at 3 mill. hectares. Appendix 6.5 gives an overview of the present irrigation situation (1992) in regards to crops, areas under cultivation, and present water use.

An increasing interest in rice cultivation has been registered among the farmers. In areas surrounding the Doho rice scheme it was found that several hundred small scale farmers grow rice outside the regular scheme, with an approximate cultivated area of 1/2 hectare per farmer.

In Lake Victoria Crescent area many horticultural farmers have plans to start small scale irrigation. However, the general undulating topography precludes gravity irrigation in most areas. This necessitates pumping of irrigation water from lakes and streams. In several instances farmers have procured electrical pumps and use these whenever irrigation is needed.

The major sector projects include a Small Scale Irrigation Project financed by FAO with the objective to increase agricultural production per unit area and provide training and support to the farmers. Three pilot schemes for irrigated horticultural areas have been established in Mpigi and Luwero Districts. In Tororo and Iganga three pilot schemes were established for improved water management in areas of irrigated rice production. A special study of the wetland irrigation situation in Tororo District is given in Annex Report, Volume 1, WAP.Doc.010 Annex 8. Studies of both institutional and technical aspects of wetland irrigation have been reported.

The Olweny Swamp Rice Irrigation Project, financed by AfDB and IDA, comprises the development of 800 ha of the Olweny Swamp in Lira District for smallholder rice farming.

Six hundred smallholders are the beneficiaries with individual holdings of 1 ha. Inputs, credit, extension and other services are provided under the project.

6.4.4 Future irrigation demands

In 1992, the failure of the usually reliable first annual rainfall season upset the food security of the country by causing crop failures and decrease in livestock production. Out of the total 38 districts of Uganda, 15 districts experienced a long dry spell and food security problem reached crisis levels. The worst hit districts were Kasese, Kabale, Mbarara, Rakai, Bundibugyo, Masaka, Masindi, Mpigi, Mukono, Luwero, Moroto, Kumi, Soroti, Kotido and Rukungiri. Presently, 16 districts are declared famine stricken and it is feared that permanent climatic changes have taken place. (Ref. Appendix 2.6 "Trends and variations in hydrometeorological parameters.").

Since 1964 various irrigation potential estimates have been prepared. The most often quoted estimates were made during a consultancy in the 1960's (Halcrow, 1964). These estimates are summarized in Table 6.3. They are based on what is technically possible, and do not necessarily represent what is economically and socially feasible.

Table 6.3 - Regional assessment of irrigation potential in Uganda based on soil patterns, water reserves, possibilities for conservation and conveyance of water and agricultural considerations

LOCATION	POTENTIAL AREA (ha)	MAIN SOURCE OF WATER
Albert Nile Valley	22,000	Albert Nile, Anyaur River
Aswa River Catchment	3,600	Aringa & Pager Rivers
Karamoja & North East Teso	10,000	Okere, Namalu & Akororo Rivers
Lake Salisbury Area	11,200	Akororo River & Lake Salisbury
North Bugisu & Sebei	9,200	Siroko River & Mt.Elgon Streams
Lake Kyoga Basin	80,800	Victoria Nile, Lakes Kwania & Kyoga
South Busoga	22,000	Lake Victoria
Western Region, Rift Valley Plains	24,800	Rivers Sebwe, Mubuku & Nyamagasani, Lake George
Kibimba Valley & Lake Wamala Basin	1,200	Lake Wamala & Kibimbi River
Orichinga Valley & Koki Lakes Basin	2,000	Lakes Maburo & Nakivali
	186,800	

Source: Halcrow, 1964

At an average annual crop water requirement of 10,000 m3/ha (single crop) the potential irrigation area would represent a demand of 1868 mill. m3/year or 59 m3/s. The usual Ugandan practice of two growing seasons would double this demand.

During the water use study of the Upper Nile basin made by HYDROMET in 1977, potential irrigation schemes were identified in Uganda by the then Water Development Department in cooperation with Ministry of Agriculture, Animal Industries and Fisheries and an Egyptian irrigation expert. The exercise considered earlier studies and took into account only other estimates of potentials that were technically reliable possibilities. However, economic and social feasibility has not been included in the studies. The total potential area for irrigation was estimated at 247,000 ha corresponding to an approximate 2,500 million m3/year (or 78 m3/s) for a single irrigation season. The identified potential distributed by major catchments is given in Appendix 6.5.

In 1987, FAO estimated 410,000 ha to have a potential for irrigated agriculture. This corresponds roughly to 4,000 mill m3/year (or 126 m3/s) for a single season. Again, as with the 1964 estimates by Halcrow, the FAO estimates are based on technical considerations, rather than on the economic and social feasibility of large scale irrigation.

In 1993 the World Bank assessed that agricultural production increases could be brought about by expansion of the cultivated area rather than by intensified use applying irrigated agriculture. However, it was recommended to prepare feasibility studies of possible irrigation schemes and to follow the results of present efforts.

The development in irrigation requirements thus seems rather difficult to estimate, and social and economic aspects need to be given proper attention. The estimation is further complicated by the fact that smallholder rice schemes at swamp margins will probably not require more water for evapotranspiration than the cleared swamp vegetation. The reports on increased use of water for irrigation of vegetables and other garden crops at the individual homesteads is another factor which complicates the estimation.

However, even a rather limited irrigation development will require substantial water resources which can only be supplied from surface water and which may create competition with other users in areas of scarce water resources.

6.5 Hydropower

The majority of hydropower generation takes place at Owen Falls Dam at the Victoria Nile near Jinja. The present installed capacity is 180 MW. An extension programme intended for increases to 270 MW and 300 MW of generating capacity has been prepared. The identified hydropower potential on the Victoria Nile within the Ugandan territory totals 2700 MW, with the Murchison site having a potential of 600 MW and Bujagali site having a potential of 250 MW.

Rehabilitation of the Maziba Mini-Hydro Power Station has started. Other mini-stations are planned, for instance at Phaidha (3.0 MW), Ishasha (4.0 MW) and Bisheruka (10 MW).

Uganda has exported electricity to Kenya since 1955 and is extending the power grid to Tanzania. Under the Kagera Basin Organization, Uganda is expected to supply power to Rwanda, Burundi and Eastern Zaire. Total installed capacity in Uganda is presently 185 MW out of which 5 MW capacity comes from diesel powerplants and 180 MW from hydropower. Production was 781.5 million kWh of hydroelectricity and 1.2 million kWh from diesel in 1991.

Hydropower generation is a non-consumptive use. Presently, there is no artificial storage on the Upper Nile and river flows are kept unchanged as compared to the situation before the construction of the Owen Falls Dam. The mini-hydropower stations have small storage reservoirs and there is thus a slight tendency towards equalizing the natural river flows.

Hydropower generation can be expected to increase in step with the transboundary distribution of electricity, the increase in rural electrification and the increase in industrial and domestic demand. However, the impact on the water resource (Victoria Nile) is negligible.

6.6 Sewerage and sanitation

The sewerage and sanitation sector's impact on the water resources comes from the discharge of domestic and industrial sewage into the surface waters and from the possible impact of pit latrines on the groundwater. The development of such threats to the water quality will follow the general development in population and industrial activities. Details of considerations and descriptions of the sewerage and sanitation situation is given in Subsection 3.3.6, whereas Section 5.3 deals with the possibility of groundwater pollution from pit latrines.

6.7 Fisheries

The fisheries industry is increasing in importance with a total catch of 255,000 tonnes in 1991, a growth of 4% from 1990. The number of fish processing plants increased to seven and a significant part of the population is depending on this sector for their living. A catch of approximately 120,000 tonnes came from Lake Victoria, while the remaining catch was predominantly from Lake Kyoga and Lake Albert. In addition to the catch from lakes and rivers there are about 2,000 man-made ponds for fish farming in the country. Restrictions can be expected to be introduced to prevent overfishing of certain species, while fish-farming could expand significantly. A further growth of total catch at 4% per annum could be well feasible (Ministry of Finance and Economic Planning, 1992).

Fisheries interact with the water resources through a requirement for a certain quality of the habitat for the fish stocks and through the possible pollution of small streams if intensive aquaculture is practised. Key elements of the interaction of lake ecology and fish stocks are described in subsection 3.4.1.

6.8 Navigation

Uganda relies on transport routes through Kenya and Tanzania for shipment of her export goods. Part of these routes include transport on Lake Victoria to Kisumu and Mwanza, respectively. Ferry services exist to a certain extent on Lake Kyoga as well. The transport facilities include two ferry terminals on Lake Victoria including the recently completed Port Bell wagon ferry terminal. Three wagon ferries are part of the stock of the Uganda Railways Corporation. Passenger transport is also an important part of the navigation activities.

6.9 Tourism and wildlife

Uganda's policy in the tourism sector is to expand employment and incomes from tourism with the ultimate goal to increase incomes in foreign currency. This has become even more important with stagnation or decline in earnings from traditional export commodities, and the advantage of diversifying foreign trade.

Work has been concentrated on conservation and rehabilitation of facilities, with help from foreign technical assistance. Prospective investors have started to appear, and activity in this sector can be expected to grow steadily. The number of tourists arriving has increased from 25,000 in 1985 to 60,000 in 1991. An annual growth in the number of visitors of 10% could be realistic in the future (Ministry of Finance and Economic Planning, 1992).

Requirements in relation to water resources lies in the preservation of natural scenic spots, in particular water falls. Further, conflicts involving encroachment of cattle owners on wildlife parks due to scarcity of water has to be resolved.

6.10 Health

Economic recovery along with the restoration and rehabilitation of social services has started to reverse the negative trend of health care in Uganda. So far, however, only limited impact has been made on the high prevalence of preventable diseases. The water related diseases malaria and diarrhoea constitute about 30 % of the total number of patients registered by the Ministry of Health. Malaria alone accounts for over 22% and affects all age groups. Diarrhoea predominantly effects age groups under 4 in particular.

The relation of health to the water resources is through the water quality for drinking water, the pools where malaria mosquitoes can breed, the bilharzia occurrence in the lakes and streams, etc. The planning of water resources exploitation has to take into account such health aspects.

6.11 Environment

In a broad sense, environmental issues involve all aspects of human interaction with nature. The goal of environmental policies is generally to mitigate or minimize these impacts on nature. A relationship between the environment and water resources occurs in most aspects of water resource development projects. Environmental issues must be considered particularly in the planning stages of a water resources project, but also during design and implementation.

Considerations regarding water often resources exclusively focus on availability and/or suitability of the water for a specified use. However, long term sustainability of water resources in conjunction with the natural environment requires a more broad, holistic approach. Activities should be planned and managed according to at thorough knowledge of the significance of their impact on all aspects of the environment. These issues include biological, physical, chemical, ecological, socio-economic and health aspects of the environment. Required knowledge can be gained through Environmental Impact Assessments (EIA's) which serve to ensure that potential environmental problems are identified and mitigated at an early stage in the planning and execution of development projects.

Ugandan environmental issues are expected to be taken increasingly into consideration in step with rising awareness of environmental conservation and the formation of an environmental lobby. Thus, water resource planning must take these issues into account through a tight collaboration with the environmental protection authorities.

A detailed assessment of the Ugandan environmental situation is being prepared by the National Environment Action Plan (NEAP), and is beyond the scope of the Rapid Water

Resources Assessment. However, some important issues which relate to water planning are mentioned below.

6.11.1 Reduction of biodiversity

Biological diversity (biodiversity) is an expression covering the variability of life forms and it includes the diversity of genes, species and eco-systems or habitats. Reduction of the biodiversity is happening as a result of various human activities in all parts of the world through extinction of species belonging to all categories of life. This irreversible impact of development activities is of increasing concern because human life derives foods, medicines and other products from various natural components.

Uganda has the greatest diversity of animal and plant species in the continent corresponding to a high diversity of habitats ranging from grasslands to mountain forests, moist evergreen forests to swamps, and open water to semi deserts.

Biodiversity can be threatened through development of land use which reduces the extent of natural habitats for the various organisms. Water related examples of this are:

- draining and cultivation of wetlands which hold a specialised diversity of flora and fauna

- siltation of dams, rivers and lakes as a result of soil erosion due to agricultural practicies, overstocking, rangeland degradation, deforestation etc.

- intensive livestock watering in game areas may exclude the natural wildlife from its habitats

A most striking example of the threat to biodiversity in the Ugandan context is the ecological development of Lake Victoria during the last decades. Here, the fishery which was previously based on about 20 fish species, is now limited to 2-3 species, mainly the Nile Perch and Tilapia.

The stock of Cichlides has been significantly reduced and they are not observed today in the open water. To what extent the various species of Cichlids have become extinct or are surviving in the backwaters of the lake, is currently being investigated by researchers. These changes are connected with the introduction of the carnivorous Nile Perch. However, the catch of Nile Perch increased the fishery in the lake manyfold, at least for a period. The possible environmental cost of this measure could be the total extinction of a number of endemic fish species in the lake.

6.11.2 Introduction of exotic aquatic organisms

As mentioned the introduction of the Nile Perch to Lake Victoria has caused severe impacts on the lake ecosystem, including a possible ultimate reduction of the lake biodiversity. Such consequences are often experienced when non-native species are introduced by man. The competitive balance between the native species which have been build up during the evolutionary process are destroyed and monocultures of opportunistic species are thriving. The Ugandan lake system is facing a similar problem with the introduction of the South American water hyacinth. The lack of natural competitors in the Ugandan aquatic environment combined with an enormous growth potential of this weed (facilitated further by increased loads of organic and inorganic nutrients) results in a prolific creation of biomass leading to serious effects - ecological as well as economical.

These two examples illustrate clearly the environmental danger connected with the introduction of exotic species, and it is obvious that caution should be observed before e.g. biological methods are applied to control the water hyacinth problem.

6.11.3 Accumulation of hazardous compounds

Use of pesticides, dumping of solid waste, discharge of industrial waste water which contains toxic substances and accidental spill of chemicals during transportation, create a potential risk of polluting the environment by hazardous substances and contamination of groundwater and surface waters. Toxic substances that will accumulate in the environment, such as certain metals, pesticides and other organic substances resistant to bio-degradation, require particularly cautious regulation since their effect may be irreversible or present hazards to consumers of the water,i.e. for drinking or for aquatic organisms.

At present Uganda is not detrimentally impacted due to discharges of industrial waste products or agricultural chemicals. However, accumulation of toxic elements may occur locally due to i.a the former mining activities in Kilembe/Kasese where considerable amounts of toxic metals have been discharged to the Lake George/Lake Edward system. The extent of ecological consequences of these discharges is not known. Similarly, the former use of biologically persistent organochlorines (e.g. DDT) may have caused accumulation of these compounds locally.

In parallel to economic development, which inevitably will increase use of hazardous substances, the responsible environmental authorities has to establish management procedures aiming at protecting the environment against the spreading of these compounds.

6.11.4 Ecosystem balance

A sustainable development of the natural resources including the aquatic systems rely on the protection of the balance of the ecosystems. A stable ecosystem has a build-in buffer capacity to resist external impacts without detrimental consequences. As any human activities will affect the environment to certain degree, the environmental sustainable development lies i.a in a practice where the buffer capacities of the natural systems are not exceeded.

As mentioned above, introduction of exotic species can change the ecological structure (species composition) resulting in an unstable and unpredictable lake environment. Excessive organic pollution or nutrient discharges can do the same resulting in so-called eutrophic conditions of the water bodies. Eutrophication describes a situation where the natural productivity (algae) has been accelerated due to surplus of nutrients (mainly nitrogen and phosphorus) resulting in increased degradation of organic material and leading to decreased oxygen concentrations. In the case that the oxygen levels reach the minimum for heterotrophic organisms to live, the ecological structure will change rapidly towards an unstable system mainly governed by microorganisms which are not dependent on oxygen.

Indications of eutrophication have been observed in Lake Victoria, but the cause/effect relations still require investigation.

LIST OF LITERATURE

Acres (1990):
Proposed Extension to the Owen Falls Generating Station. Feasibility Study Report, Draft, Volume 3. Report to Uganda Electricity Board.

Atlas of Uganda (1965).

Bank of Uganda (1992):
Inputs in the Agricultural Sector.

Beshir, M.E. (1987):
On the history of planning the Jonglei Canal. Water Resources Development.

Biswas, A.K. (1992):
Water for the Third World Development, A perspective from the south. Water Resources Development.

Brown, J.A.H. et al. (1981):
A Mathematical Model of the Hydrologic Regime of the Upper Nile Basin. Journal of Hydrology, 51.

Carl Bro International et. al. (1990):
Rural Water and Sanitation East Uganda Project; Vol. 1: Plan of Operation.

Cowiconsult, NCG, Habitat (1993):
Small Towns Water and Sanitation Project. Institutional strengthening of WDD.

Danida (1992):
Uganda Action Plan for Water Resources Development and Management (Project Identification). Prepared by: Water Quality Institute, Centre for Development Research and Danish Hydraulic Institute, June 1992.

Danida (1993):
Project Document - Action Plan for Water Resources Development and Management (WAP).

FAO (1987):
Irrigation Potential in Uganda.

FAO (1992):
Water Resources Management Policy and Institutions in the Lake Victoria Region. Draft TCP Project Document.

FAO/IDEA Bologna (1991):
Workshop on Monitoring and Forecasting of River Basins for Agricultural Production.

Federal Environmental Protection Agency, Nigeria (1989):
National Policy on the Environment.

Fisher, F., IDIOM (1992):
Capacity Building concepts to Improve the Performance of HDR Institutions, professionals and programme activities.

Sir Alexander Gibb and Partners et. al. (1989):
Hydrogeological map of Uganda.

Sir Alexander Gibb and Partners et. al. (1989):
Hydrological map of Uganda.

Sir Alexander Gibb & Partners, British Geological Survey and Institute of Hydrology (1989):

Sub Saharan Africa Hydrological Assessment (IGADD Countries). Final Report. Introductory Volume and Country Report on Uganda.

Government of Uganda - Ministry of Water, Energy, Minerals and Environment Protection (1992):
Uganda Second Water Supply Project - Water Legislation Study. Prepared by: Mott MacDonald Water and Wastewater/Kabugo and Company.

Government of Uganda, Ministry of Water, Energy, Minerals and Environment Protection (1992):
Uganda Second Water Supply Project - Water Legislation Study.
Prepared by: Mott Mac Donald Water and Waste Water.

Sir William Halcrow (1964):
Agricultural Studies.

Kentucky, R.E. (1993):
The Eutrophication of Lake Victoria. Verh. Internat. Verein. Limnol - Peter Kilham Memorial Lecture.

Hecky, R.E. and F.W.B. Bugenyi (1992):
Hydrology and Chemistry of the African Great Lakes and Water Quality issues: Problems and Solutions. Mit. Internat. Verein. Limnol. 23, pp. 45-54.

Howell, P.P. & J.A. Allan (1990):
The Nile. Resource Evaluation, Resource Management, Hydropolitics and Legal Issues.

Hydromet (1992):
Hydromet Survey Project Proceedings. Regional Workshop on Evaluation of Hydromet Survey Project and future Co-operation among the Participating Countries.

Hydromet (1974):
Hydrometeorological Survey of the Catchments of Lakes Victoria, Kyoga and Albert. Hydromet project, Entebbe Uganda.

Hydromet Survey Project (1991):
Hydromet Project Evaluation and Recommendations (1967-1991).

Hydromet Survey Project (undated):
The Status of Water Quality Activities (Field Work and Mathematical Model).

Hydromet Technical Committee (1992):
Proposal for Further Co-operation of the Countries Sharing the Nile Basin. (Follow-up of the Hydromet Project).

I. Krüger Consult AS / Nordic Consulting Group & WDD (1991):
National Planning Strategy, Rural Water Supply Programme. Final Report.

Institute of Environment and Natural Resources, Makerere University (1992):
Environmental and Natural Resource Management Policy and Law.

Institute of Hydrology, Wallingford (IoH) (1985):
Further Review of the Hydrology of Lake Victoria.

Jørgensen, S.E. (1979):
Water Quality Model of the Upper Nile Lake System. Report No. 3.

Jørgensen, S.E. et al. (1982):
An Environmental Management Model of the Upper Nile Lake System. ISEM Journal, 4, Nos. 3-4.

Kahangire, P.O. (1993):
Water Resources Monitoring and Hydrological Data Availability in Uganda.

Kamugisha, J.R. & M. Ståhl (eds.) (1993):
Parks & People, Pastoralists and Wildlife. Proceedings from a seminar on environmental degradation in and around Lake Mbure National Park, Uganda.

Kitaka, G.E.B. (1969):
An Instance of Cyclonic Upwelling.

Kite, G.W. (1984):
Regulation of the White Nile. Hydrological Sciences.

Kuteesa, F. N. (undated):
Contribution to Topical Paper: Training Needs for Human Resource Development (Public Service). Task Force No. 2 under NEAP.

Sir Mott MacDonald & Partners Limited and Hidroprojecto Consultores de Hidraulica e Salubridade, S.A. (1990):
Sub Saharan Africa Hydrological Assessment (SADCC Countries). Regional Report. Draft.

Sir Mott MacDonald Water and Wastewater and Kabugo and Company, Advocates (1992):
Uganda Second Water Supply Project. Water Legislation Study. Draft Report.

Mageed, Y.A. (1985):
The Integrated River basin Development; The Challenges to the Nile Basin Countries. In Lunquist et. al.: Stragegies for River Basin Management.

Mageed, Y.A. (1991):
Feasibility Study on Cooperation for Nile Basin-wide Integrated Sustainable Development. Report for UNEP.

Ministry of Finance and Economic Planning (1992):
Background to the Budget 1992-1993.

Ministry of Water, Energy, Minerals and Environment Protection (1992):
Country Report on the Proposed UNEP Diagnostic Study of the Nile Basin.

Ministry of Water, Energy, Minerals and Environment Protection (1993):
National Environment Action Plan 1993,
- Draft Topic Paper on Energy and Climate Changes
- Draft Topic Paper on Water Resources and Aquatic Biodiversity
- Draft Topic Paper on Population, Health and Human Settlement
- Draft Topic Paper on Mining, Industry, Hazardous Materials and Toxic Chemicals
- Draft Topic Paper on Environment Information System
- Draft Topic Paper on Land Management: Agriculture, Livestock and Rangelands
- Draft Topic Paper on Environmental Education, Research and Human Resources Development

Ministry of Water Development, Republic of Kenya (1991):
MERU Water Resources Assessment Study. Prepared by: TNO-Institute of Applied Geoscience, Delft, Netherlands.

NEAP Task Force (undated):
Environment Education, Research and Human Resource Development. Report No. 2.

Nemec, J. et al. (1992):
Proposal for Further Co-operation of the Countries Sharing the Basin of the Nile.

Piper, B.S. et. al. (1986):
The Water Balance of Lake Victoria. Hydrological Sciences.

Republic of Uganda (MWMD + NWSC) & Gauff/Parkman JV. (1989):
Seven Towns Water Supply and Sewerage Expansion Project - Water Quality Studies.

Republic of Uganda, WHO/UNDP (1971):
Master Plans for Water Supply and Sewerage for the Greater Kampala and Jinja Areas (Special Studies - Lake Investigations)

Republic of Uganda/Commision of the European Communities DG VIII (1989):
Review of Kampala Water Supply Scheme (Draft Report).

Rijks, D.A. et al. (1970):
Potential Evaporation in Uganda. For The Republic of Uganda, Ministry of Mineral and Water Resources, Water Development Department.

Shahin, Mamdouh (1985):
Hydrology of the Nile Basin. Developments in Water science. Elsevier.

Smith, S.E. (1990):
The Blue nile: Potential for Conflicts and Alternatives for Meeting future Demands. Water International.

Ssenfuma, N.S. (1992):
Hydromet Survey Project (short description).

Taylor, A.R.D. (1991):
National Wetlands Conservation and Management Programme. Report on the Status of the Nakivubo and Luzira Swamps, Kampala.

TECCONILE (1993):
TECCONILE (January 1993 - December 1995).

Twongo T., F.W.B. Bugenyi, & F. Wanda (1992):
The Potential for Further Proliferation of Water Hyacinth in Lakes Victoria and Kyoga and some Urgent Aspects for Research. CIFA subcommitee for management and development of the fisheries of Lake Victoria, 10-13 Feb. 1992, Jinja, Uganda.

UN/FAO (1991):
The Water Hyacinth in Uganda - Ecology, Distribution, Problems and Strategies for Control. Proceedings of a National Workshop 22-23 October 1991.

UNDP (1989):
Nile River Basin Fact-Finding Mission, Draft Summary of the Mission's Report.

UNDP (1990):
Rehabilitation and Strengthening of the Water Resources Monitoring and Assessment Services. Project Document.

UNDP (1990):
National Water Resources Master Plan. Project Document.

UNDP, WMO (1974):
Hydrometeorological Survey of the Catchments of Lakes Victoria, Kyoga ad Albert.

UNDP/World Bank (1990):
Organization and Management Study of Water Development Department (Working Document). Prepared by: Carl Bro International.

UNEP (undated):
Wetlands. Strategic Resources Planning in Uganda, Vol. IX

UNEP (1992):
Final Report of the Meeting of the Panel of Government-Nominated Experts of the Nile Basin.

UNEP (1992):
Country Report on the Proposed UNEP Diagnostic Study of the Nile Basin.

UNICEF/SWIP (1992):
District Water Development Plan, Masaka District. 3 Volumes.

UNICEF/SWIP (undated):
Setting up of Basic Potable Water Quality Control System within the South-west Integrated Programme. Draft.

Viner, A.B. (1971):
The Supply of Minerals to Tropical Rivers and Lakes.

WDD (1992):
Water Supply and Sanitation Sector. On-going and Planned Projects and Funding Requirements.

WHO/WMO/UNESCO/UNEP (1992):
GEMS/WATER, Report of a workshop on water quality monitoring and assessment 23 March - 3 April 1992, Arusha, Tanzania.

Wittingham, D. & E. McClelland (1992):
Opportunities for Regional and International Cooperation in the Nile Basin,
Water International, 17, pp. 144-154.

WMO (1981):
Hydrometerological Survey of the Catchments of Lakes Victoria, Kyoga and Mobuto Sese Seko. Draft: Project Findings and Recommendations.

WMO (1991):
Information Needs for Water Quality Assessment and Management. Report of a WMO/WHO/UNEP Expert Consultation.

Smith, S.E. (1990):
The Blue nile: Potential for Conflicts and Alternatives for Meeting future Demands. Water International.

Ssenfuma, N.S. (1992):
Hydromet Survey Project (short description).

Taylor, A.R.D. (1991):
National Wetlands Conservation and Management Programme. Report on the Status of the Nakivubo and Luzira Swamps, Kampala.

TECCONILE (1993):
TECCONILE (January 1993 - December 1995).

Twongo T., F.W.B. Bugenyi, & F. Wanda (1992):
The Potential for Further Proliferation of Water Hyacinth in Lakes Victoria and Kyoga and some Urgent Aspects for Research. CIFA subcommitee for management and development of the fisheries of Lake Victoria, 10-13 Feb. 1992, Jinja, Uganda.

UN/FAO (1991):
The Water Hyacinth in Uganda - Ecology, Distribution, Problems and Strategies for Control. Proceedings of a National Workshop 22-23 October 1991.

UNDP (1989):
Nile River Basin Fact-Finding Mission, Draft Summary of the Mission's Report.

UNDP (1990):
Rehabilitation and Strengthening of the Water Resources Monitoring and Assessment Services. Project Document.

UNDP (1990):
National Water Resources Master Plan. Project Document.

UNDP, WMO (1974):
Hydrometeorological Survey of the Catchments of Lakes Victoria, Kyoga ad Albert.

UNDP/World Bank (1990):
Organization and Management Study of Water Development Department (Working Document). Prepared by: Carl Bro International.

UNEP (undated):
Wetlands. Strategic Resorces Planning in Uganda, Vol. IX

UNEP (1992):
Final Report of the Meeting of the Panel of Government-Nominated Experts of the Nile Basin.

UNEP (1992):
Country Report on the Proposed UNEP Diagnostic Study of the Nile Basin.

UNICEF/SWIP (1992):
District Water Development Plan, Masaka District. 3 Volumes.

UNICEF/SWIP (undated):
Setting up of Basic Potable Water Quality Control System within the South-west Integrated Programme. Draft.

Viner, A.B. (1971):
The Supply of Minerals to Tropical Rivers and Lakes.

WDD (1992):
Water Supply and Sanitation Sector. On-going and Planned Projects and Funding Requirements.

WHO/WMO/UNESCO/UNEP (1992):
GEMS/WATER, Report of a workshop on water quality monitoring and assessment 23 March - 3 April 1992, Arusha, Tanzania.

Wittingham, D. & E. McClelland (1992):
Opportunities for Regional and International Cooperation in the Nile Basin,
Water International, 17, pp. 144-154.

WMO (1981):
Hydrometerological Survey of the Catchments of Lakes Victoria, Kyoga and Mobuto Sese Seko. Draft: Project Findings and Recommendations.

WMO (1991):
Information Needs for Water Quality Assessment and Management. Report of a WMO/WHO/UNEP Expert Consultation.

World Bank (1991):
Southern Africa Regional Water Management Programme. Overall Terms of Reference, Project AF6IN.

World Bank (1992):
District Management Study, Uganda. Report No. 10695-UG.

World Bank (1992):
Kenya/Tanzania/Uganda Environmental Management of Lake Victoria - Criterion Reference Sheet a.o. (GEF).

World Bank (1993):
Agricultural Sector Memorandum, Uganda. Report No.10715-UG.

APPENDIX 1.1

WATER ACTION PLAN DOCUMENTS

UGANDA WATER ACTION PLAN (WAP)		
DOCUMENT	TITLE	DATE
001	WATER ACTION PLAN PHASE I - PROJECT DOCUMENT Description of the background and requirements to the work in WAP Phase I including budget.	Jan 1993
002	REHABILITATION OF WATER RESOURCES MONITORING AND ASSESSMENT SERVICES IN UGANDA - PROJECT IDENTIFICATION REPORT Background and proposal for a water resources monitoring project including budget	Feb 1994
003	REGIONAL WATER QUALITY MANAGEMENT IN THE UPPER NILE BASIN - PROJECT IDENTIFICATION REPORT Background and proposal for a water quality management project including budget	Feb 1994
004	WATER ACTION PLAN PHASE II - PROJECT DOCUMENT Description of the background and requirements to the work in WAP Phase II including budget.	Oct 1993
005	WATER ACTION PLAN - MAIN REPORT Synthesis of the key points of the Water Action Plan comprising the water resources management framework, the action programme and guidance for the implementation and monitoring of the plan	Jul 1994
006	WATER RESOURCES POLICY Policy document defining a water resources policy with associated management strategies. Outline of areas for further policy development and actions. Preliminary discussion draft of a water supply and sanitation policy	Jul 1994
007	RAPID WATER RESOURCES ASSESSMENT An assessment of the surface water and groundwater resources occurrence in time and place and a tentative estimate of the water requirements and water resources development trends	Jul 1994
008	INSTITUTIONAL AND MANAGEMENT ASPECTS An assessment of water resources management functions, structures and tools Proposals for a future management strategy and corresponding capacity building	Jul 1994
009	INTERNATIONAL ASPECTS An assessment of the international aspects and implications of Uganda's position in the Upper Nile Basin in relation to water resources	Jul 1994
010	ANNEX REPORT - VOLUME 1 - DISTRICT STUDIES Collation of district studies for Arua, Mbale, Mbarara, Moroto, Mukono and special studies for Hoima, Kabale and Tororo	Jul 1994
011	ANNEX REPORT - VOLUME 2 - GROUNDWATER DATABASE Groundwater database development description, specification and manual	Jul 1994
012	ANNEX REPORT - VOLUME 3 - MANAGEMENT ASPECTS Background for preparation of regulations supporting the Water Resource Statute, guidelines for district water resources management and management procedures for issuing of permits	Jul 1994
013	ANNEX REPORT - VOLUME 4 - PROJECTS AND ACTIONS Description of water resources development plans and projects giving guidelines for prioritization, impact assessments, updating and coordination Catalogue of water resources related projects and actions	Jul 1994
014	WATER ACTION PLAN - EXECUTIVE SUMMARY A concise short version of the set of strategies, actions and guidelines constituting the Water Action Plan also giving a key to the documentation	Jul 1994

APPENDIX 2.1

LOCATION AND LENGTH OF RECORDS OF SELECTED FLOW STATION

Location and Length of Record of Selected Flow Stations														
Stations Representing Ugandan Catchments														
Ser No	Station No	Station Name	Basin No	Long °	'	"		Lat °	'	"		Catchment (km2)	Period Start	End
1	81316	R Kakinga	1	31	3	9	E	0	7	15	N	996	1968	1978
2	81324	R Ruizi at Mbarara	1	30	39	0	E	0	37	0	S	2070	1954	1979
3	81333	R Kibale at Kalungi	1	31	21	0	E	0	46	0	S	4715	1960	1980
4	81359	R Katonga	1	31	56	0	E	0	7	0	S	13930	1956	1980
5	82313	R Namatala at Mbale - Soroti Road	2	34	11	0	E	1	7	0	N	152	1948	1992
6	82318	R Malaba	2	34	3	0	E	0	35	0	N	1458	1956	1980
7	82320	R Enget at Bata - Dokolo Road	2	33	11	0	E	2	0	0	N	100	1970	1979
8	82322	R Abuket	2	33	40	0	E	1	27	0	N	25395	1948	1979
9	82325	R Sezibwa at falls	2	32	52	0	E	0	22	0	N	175	1960	1975
10	82345	R Akokorio at Soroti - Katakwi Road	2	33	51	0	E	1	52	0	N	14335	1969	1973
11	83311	R Tochi I	3	32	24	0	E	2	33	0	N	671	1950	1984
12	83313	R Kafu at Kampala - Gulu Road	3	32	3	0	E	1	33	0	N	15492	1952	1991
13	84324	R Rukoki at Kasese - Fort Portal Rd	4	30	7	0	E	0	11	0	N	156	1954	1984
14	84328	R Nyamugasani	4	29	50	0	E	0	7	0	S	507	1954	1979
15	85311	R Musizi	5	30	44	0	E	0	52	0	N	2603	1956	1980
16	85312	R Nkussi	5	31	0	0	E	0	57	0	N	1815	1956	1980
17	85314	R Wambabya at Buseruka	5	31	8	0	E	1	30	30	N	737	1967	1978
18	85317	R Waki II at Biiso at Hoima Road	5	31	22	0	E	1	43	0	N	475	1967	1979
19	86302	R Aswa II	6	32	35	0	E	2	57	0	N	5015	1949	1982
20	86312	R Pager at Kitgum at Kitgum Matidi	6	33	4	0	E	3	15	0	N	6140	1959	1981
21	87305	R Kochi at Yumbe at Moyo Road	7	31	26	0	E	3	34	0	N	838	1955	1978
22	87307	R Ayugi at Atiak - Laropi Road	7	32	2	0	E	3	21	0	N	1066	1955	1987
23	87308	R Oru at Arua - Yumbe Road	7	31	8	0	E	3	16	0	N	431	1955	1978
24	87312	R Ora at Inde - Pakwach Rd	7	31	24	0	E	2	43	0	N	2775	1956	1984
25	81319	R Katonga at Bugomola	1	31	0	0	E	0	13	0	N	3870	1970	1978
26	81328	R Mpamujugu at Rail Bridge	1	31	58	0	E	0	26	0	N	271	1970	1980
27	81348	R Nyakizumba at Maziba	1	30	5	0	E	1	19	0	S	820	1956	1993
28	81349	R Kiruruma N at Kab-Kis Rd	1	29	59	0	E	1	15	0	S	161	1955	1992
29	81350	R Kiruruma S at Kitumba	1	30	0	0	E	1	17	0	S	390	1956	1964
30	81358	R Bukora at Katera	1	31	36	0	E	0	54	0	N	5000	1964	1979
31	82312	R Manafwa at Mbale-Tororo Rd	2	34	10	0	E	0	56	0	N	494	1948	1993

Location and Length of Records of Selected Flow Stations

Stations Representing Ugandan Catchments

Ser No	Station No	Station Name	Basin No	Long °	'	"		Lat °	'	"		Catchment (km2)	Period Start	End
32	82326	R Kami at Tororo-Busia Rd	2	34	6	0	E	0	31	0	N	92	1957	1979
33	82331	R Kehiri at Mbale-Moroto Rd	2	34	33	0	E	1	36	0	N	1400	1957	1979
34	82340	R Siroko	2	34	15	0	E	1	14	0	N	265	1953	1980
35	82341	R Simu	2	34	17	0	E	1	18	0	N	165	1953	1980
36	82342	R Muyembe at Mbale-Moroto Rd	2	34	18	0	E	1	20	0	N	136	1952	1980
37	82343	R Mpanga	4	30	24	0	E	0	30	0	N	401	1954	1981
38	84317	R Hima at F/P-Kasese Rd	4	30	10	0	E	0	17	0	N	86	1968	1982
39	84318	R Kanyampara at Equator Rd												
40	84322	R Mubuku at F/P - Kasese Rd	4	30	7	0	E	0	16	0	N	256	1954	1971
41	84325	R Kamulikwenzi at F/P-Kasese Rd	4	30	6	0	E	0	10	0	N	181	1954	1975
42	84327	R Chambura at Kichwamba	4	30	6	0	E	0	12	0	N	660	1954	1980
43	84365	R Ishasha at Katunguru	4	29	37	0	E	0	45	0	S	772	1958	1968
44	84366	R Rushaye at Kabale-Rwensama Rd	4	29	47	0	E	0	35	0	S	228	1959	1982
45	84367	R Mitano	4	29	48	0	E	0	41	0	S	1746	1958	1985
46	84372	R Ibalya	4	29	45	0	E	0	49	0	S	119	1964	1982
47	85318	R Waki I at Siba Forest	5	31	22	0	E	1	40	0	N	238	1970	1978
48	85318	R Siba at Masindi-Butiaba Rd	5	31	29	0	E	1	38	0	N	83	1968	1983
49	86301	R Aswa I at Paranga	6	32	56	0	E	2	35	0	N	2690	1049	1982
50	86313	R Agago at Kitgum - Lira Rd	6	32	58	0	E	2	50	0	N	4490	1963	1981
51	87301	R Nyarwedo at Angal-Okullo Rd	7	31	8	0	E	2	30	0	N	259	1955	1979
52	87302	R Ala at Arua-Mutir Rd	7	31	4	0	E	2	54	0	N	306	1965	1978
53	87306	R Ora at Okello	7	31	9	0	E	2	40	0	N	1750	1962	1979
54	87318	R Anyau at Arua-Yumbe Rd	7	31	7	0	e	3	15	0	N	749	1963	1978
55	87318	R Nyagak at Nyapea	7	30	58	0	E	2	52	0	N	602	1967	1979

Stations on the Main Channels of the Nile

Ser No	Station No	Station Name	Basin No	Long °	'	"		Lat °	'	"		Catchment (km2)	Period Start	End
56	82303	R Victoria Nile at Mbulamuti	2	33	2	0	E	0	49	0	N	263000	1970	1992
57	83303	R Kyoga Nile Masindi	3	32	6	0	E	1	42	0	N	73161	1947	1978
58	85305	R Semiliki Bweramule	5	30	11	0	E	0	57	0	N	26223	1950	1978
59	87310	R Albert Nile at Pakwach	7	31	30	0	E	2	27	0	N		1955	1978
60	87317	R Albert Nile at Laropi	7	31	49	0	E	3	33	0	N		1958	1970
61	82304	R Victoria Nile at Namasagali	2	33	56	0	E	1	10	0	N		1953	1978
62	87322	R Albert Nile at Panyango	7	31	28	0	E	2	32	0	N		1969	1979

APPENDIX 2.2

ANNUAL WATER BALANCE FOR SELECTED CATCHMENTS

Annual Water Balance for Selected Catchments

Ser No	Station No	Station Name	Basin No	Catchment Area (km2)	Catchment Rainfall (mm)	Runoff			Evapotranspiration			
						(m3/s)	(mm)	%	Actual, Ea (mm)	Pot , E0 (mm)	Pot, Ep (mm)	Ea/Ep %
1	81316	R Kakınga (Index Catchment)	1	996	838	0 2	7	1	831	1700	1550	54
2	81319	R Katonga at Bugomola	1	3870	817	3 59	29	4	788	1600	1459	54
3	81324	R Ruızı at Mbarara	1	2070	1067	7 8	119	11	948	1450	1322	72
4	81328	R Mpamujugu at Raıl Brıdge	1	271	1146	2 44	284	25	862	1600	1459	59
5	81333	R Kıbale at Kalungı	1	4715	965	2 9	19	2	946	1450	1322	72
6	81348	R Nyakızumba at Mazıba	1	820	938	4 9	188	20	750	1350	1231	61
7	81349	R Kırwuma N at Kab Kıs Rd	1	161	1062	0 92	180	17	882	1400	1277	69
8	81350	R Kirwuma Sat Kıtumba	1	390	1000	5 17	418	42	582	1350	1231	47
9	81353	R Bukora at Katera	1	300	1000	2 63	276	28	724	1350	1231	59
10	81359	R Katonga	1	13930	914	2 7	6	1	908	1600	1459	62
11	82312	R Manafwa at Mbale-Tor Rd	2	494	1590	7 83	500	31	1090	1800	1641	66
12	82313	R Namatala at Mbale - Sorotı Rd	2	152	1320	2 7	566	43	754	1500	1368	55
13	82316	R Malaba	2	1458	1372	15 1	327	24	1045	2050	1868	56
14	82320	R Enget at Bata - Dokolo Road	2	100	1270	0 5	142	11	1128	1900	1732	65
15	82322	R Abuket	2	25395	991	2 7	3	0	988	2050	1868	53
16	82325	R Sezibwa at falls,	2	175	1397	2 1	386	28	1011	1700	1550	65
17	82331	R Kelım at Mbale-Moroto Rd	2	1400	1298	10 51	237	18	1061	1800	1641	65
18	82340	R Sıroko	2	265	1625	3 56	424	26	1201	1700	1550	78
19	82341	R Sımu	2	165	2000	3 74	715	36	1285	1700	1550	83
20	82342	R Muyembe at Mbale - Moroto Rd	2	136	1875	3 28	761	41	1114	1700	1550	72
21	82343	R Sıpı at Mbale-Moroto Rd	2	92	1777	3 65	1251	70	526	1800	1641	32
22	82345	R Akokorıo at Sorotı - Katakwı	2	14335	762	1 1	2	0	760	1900	1732	44
23	83311	R Tochı I	3	671	1524	2 9	137	9	1387	1800	1641	85
24	83313	R Kafu at Kampala - Gulu Road	3	15492	1118	18 0	37	3	1081	1600	1459	74
25	84312	R Hıma at F/P-Kasese Rd	4	86	1386	0 27	99	7	1287	1800	1641	78
26	84312	R Mpanga	4	301	1483	4 51	473	32	1010	1600	1459	69
27	84318	R Kanyampara at Equa-Rd	4	114	1500	1 65	456	30	1044	1800	1641	64
28	84322	R Mubuku at F/P - Kasese Rd	4	256	1695	9 56	1178	69	517	1600	1459	35
29	84324	R Rukokı at Kasese - Fort Rd	4	156	1346	5 7	1146	85	200	1200	1095	18
30	84325	R Kamulıkwenzı at F/P-Kasese Rd	4	181	1500	1 49	260	17	1240	1600	1459	85
31	84327	R Chambura at Kıchwamba	4	660	1531	8 05	385	25	1146	1800	1641	70
32	84328	R Nyamugasanı	4	507	1041	8 4	525	50	516	1200	1095	47
33	84365	R Ishasha at Katunguru	4	772	1470	9 86	403	27	1067	1800	1641	65
34	84366	R Rushaya at Kabale-Rwensema Rd	4	228	1156	1 42	196	17	960	1600	1459	66
35	84367	R Mıtana	4	1746	1175	14 23	257	22	918	1600	1459	63

Annual Water Balance for Selected Catchments												
Ser No	Station No	Station Name	Basin No	Catchment Area (km2)	Catchment Rainfall (mm)	Runoff (m3/s)	(mm)	%	Evapotranspiration Actual Ea (mm)	Pot E0 (mm)	Pot Ep (mm)	Ea/Ep %
36	84372	R Ibalya	4	119	1250	1 32	350	28	900	1400	1277	71
37	85311	R Musizi	5	2603	1219	4 9	60	5	1159	1650	1504	77
38	85312	R Nkussi	5	1815	1245	4 2	73	6	1172	1600	1459	80
39	85314	R Wambabya at Buseruka	5	808	1295	4 0	155	12	1140	1600	1459	78
40	85316	R Waki I at Siba Forest	5	238	1438	1 53	203	14	1235	1700	1550	80
41	85317	R Waki II at Biiso at Hoima Rd	5	523	1524	2 7	160	11	1364	1600	1459	94
42	85318	R Aswa I at Puranga	6	2690	1251	15 59	183	15	1068	2000	1823	59
43	86302	R Aswa II (	6	5015	1194	40 6	255	21	939	2000	1823	52
44	86312	R Pager at Kitgum	6	6140	940	4 9	25	3	915	2100	1914	48
45	86313	R Agago at Kitgum-Lira Rd	6	4490	1188	5 39	38	3	1150	2000	1823	63
46	87301	R Nyarwodo at Ang-Okullo Rd	7	259	1750	2 16	263	15	1487	1800	1641	91
47	87302	R Ala at Arua-Mutir Rd	7	306	1438	4 17	430	30	1008	1800	1641	61
48	87303	R Ora at Okollo	7	1750	1395	11 04	199	14	1196	1800	1641	73
49	87305	R Kochi at Yumbe at Moyo Road	7	838	1295	7 4	279	22	1016	1700	1550	66
50	87306	R Anau at Arua-Yumbe Rd	7	749	1471	6 44	271	18	1200	1800	1641	73
51	87307	R Ayugi at Atiak - Laropi Road	7	1066	1270	6 3	188	15	1082	1900	1732	63
52	87308	R Oru at Arua - Yumbe Road	7	431	1372	3 8	281	20	1091	1700	1550	70
53	87312	R Ora at Inde - Pakwach Rd	7	2775	1245	16 6	188	15	1057	1700	1550	68
54	87318	R Nyagak at Nyapea	7	602	1625	5 28	277	17	1348	1800	1641	82

APPENDIX 2.3

LOW FLOW ANALYSIS

Low Flow Analysis (Monthly Values)

Serial No.	St. No.	Station Name	Catchment Area (km2)	Average Driest Month No.	Average Driest Value (m3/s)	Min. Flow Recorded (m3/s)	1:5 Year Low Flow (m3/s)	1:5 Year Low Flow (1/s/km2)
1	81316	R. Kakinga	996	3	0	0	0	0.00
2	81319	R. Katonga at Bugomola	3870	4	3.288	0.11	0.543	0.14
3	81324	R. Ruizi at Mbarara	2070	8	2.869	0	1.563	0.76
4	81328	R. Mpamujugu at Rail Bridge	271	5	3.88	0	0.002	0.01
5	81333	R. Kibale at Kalungi.	4715	9	1.343	0	0.278	0.06
6	81348	R. Nyakizumba at Maziba	820	7	3.4	1.24	1.649	2.01
7	81349	R. Kiruruma N at Kab-Kis Rd	161	9	0.92	0.12	0.264	1.64
8	81350	R. Kiruruma S. at Kitumba	390	7	3.98	0.39	0.839	2.15
9	81358	R. Bukora at Katera	5000	1	2.75	0.69	0.677	0.14
10	81359	R. Katonga	13930	10	1.138	0	0.108	0.01
11	82312	R. Manafwa at Mbale-Tororo Rd	494	2	2.99	0.66	0.618	1.25
12	82313	R. Namatala at Mbale - Soroti Road.	152	2	1.38	0	0.322	2.12
13	82318	R. Malaba	1458	2	3.99	0.98	1.232	0.84
14	82320	R. Enget at Bata - Dokolo Road.	100	6	0.16	0	0.06	0.60
15	82322	R. Abuket	25395	4	0.7	0	0	0.00
16	82325	R. Sezibwa at falls.	175	2	1.46	0.34	0.58	3.31
17	82326	R. Kami at Tororo-Busia Rd	92	2	0.52	0.02	0.028	0.30
18	82331	R. Kelim at Mbale - Moroto Rd	1400	4	4.23	0	0	0.00
19	82340	R. Siroko	265	3	1.69	0	0	0.00
20	82341	R. Simu	165	3	1.2	0.35	0.356	2.16
21	82342	R. Muyembe at Mbale-Moroto Rd	136	3	1.05	0.2	0.033	0.24
22	82343	R. Sipi at Mbale-Moroto Rd	92	3	1.01	0	0	0.00
23	82345	R. Akokorio at Soroti - Katakwi Road	14335	3	0	0	0	0.00
24	83311	R. Tochi I	671	3	0.59	0	0.076	0.11
25	83313	R. Kafu at Kampala - Gulu Road.	15492	3	8.91	0	1.925	0.12
26	84312	R. Mpanga	401	2	1.97	0.68	0.689	1.72
27	84317	R. Hima at F/P-Kasese Rd	86	3	0.15	0	0	0.00
28	84318	R. Kanyambara at Equator Rd	114	2	1.28	0.57	0.506	4.44
29	84322	R. Mubuku at F/P-Kasese Rd	256	7	8.59	4.82	5.62	21.95
30	84324	R. Rukoki at Kasese - Fort Portal Rd.	156	1	3.44	0.17	1.539	9.87
31	84325	R. Kamulikwezi at F/P-Kasese Rd	181	3	1.14	0.02	0.001	0.01
32	84327	R. Chambura at Kichwamba	660	8	2.4	2.35	3.068	4.65
33	84328	R. Nyamugasani.	507	7	5.91	2.48	2.961	5.84
34	84365	R. Rushaya at Kabale-Rwenshama Rd	772	7	6.28	3.09	2.611	3.38
35	84366	R. Mitano	228	10	2.14	0	0	0.00

LIST OF CONTENTS

4 METEOROLOGICAL STUDIES

4.1 Data analysis

Rainfall data ranging from 1926-1993 for seven stations have been applied in the analysis. A substantial part of these data have been collected from the HYDROMET (TECCONILE) database in Nairobi.

The basin rainfall is characterized by a strong bimodal pattern in the southern part while this pattern is clearly weaker in the northern part. The rainfall data from the seven stations well distributed over the basin have been combined to give figures representing the average rainfall. The rainfall stations used in the analysis incorporated Masindi, Bulindi in the northern part, Kiboga and Nakasongola in the central part and Kawanda, Bukalasa and Bakijujula in the southern part.

The analysis has comprised calculation of annual and seasonal (March-May, September-November) standardized, normalized departures from the mean for the whole catchment. The standardized, normalized departure from the mean is calculated as the actual value subtracted the mean value. This value is then divided by the standard deviation.

4.2 Results and discussion

4.2.1 Presentation of main results

Results of the calculation of departures have been presented in Figs 4.1 and 4.2 below.

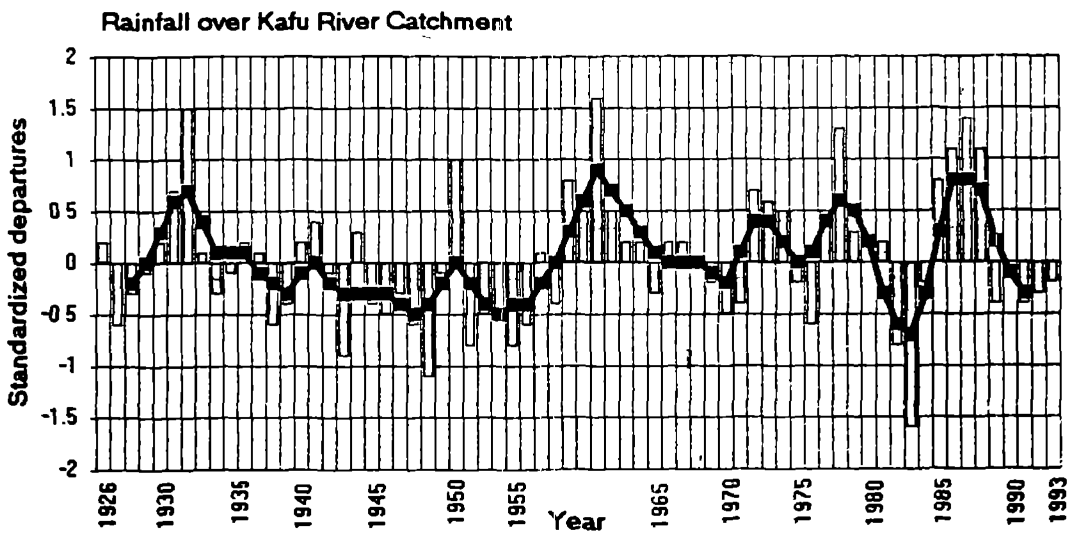

Figure 4.1 - Annual standardized, normalized departures from the mean for Kafu river basin. The curve shows the 5 year moving average

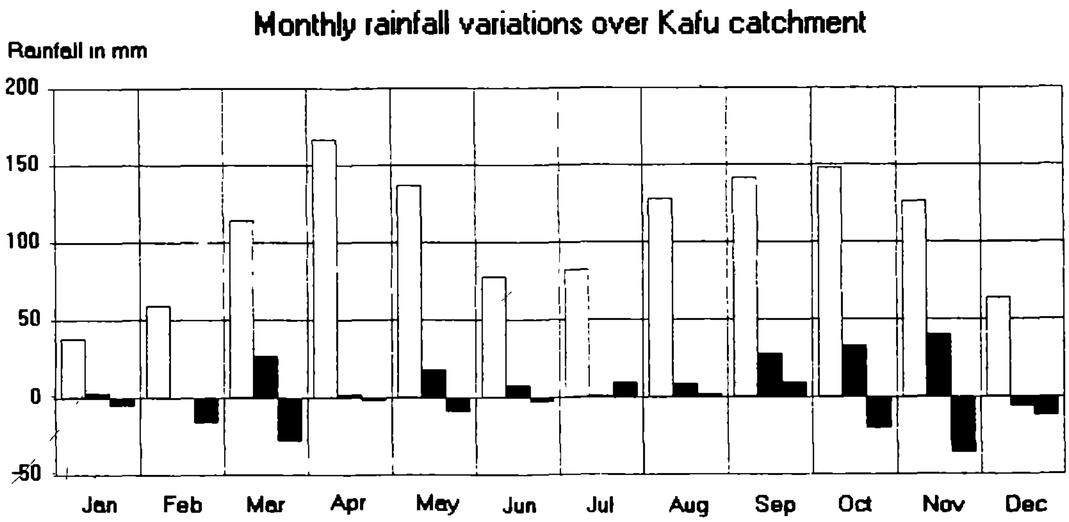

Figure 4.2 - Mean monthly rainfall and departures from the average during years of rainfall above average and during years of rainfall below average

4.2.2 Annual rainfall variability

The annual values (Fig 4.1) indicates a strong interannual rainfall variability with a tendency of years above average to be persisting for up to six years. The series from 1926 to 1993 clearly indicates repetitive phases of years with above average rainfall and below average rainfall. The longest period with rainfall below average was from 1938 to 1958. Within this period of 21 years there were only five years of above average rainfall, but the 5-year moving average remains below the mean for the full 21 years. The negative impact on water resources availability during this period has been much more severe than the accumulated effect of the recent below average rainfall lasting from 1989 to 1993.

However, the present perceived impact of the deficient rainfall is probably aggravated by the increased human and animal populations and the ensuing stress on areas of scarce water resources.

There is no evidence of trends in annual values towards permanently decreased rainfall and climate changes.

4.2.3 Monthly rainfall variability

During the years of above average rainfall (Fig 4.2) it appears that the highest rainfall occurs during the months of September to November with November receiving the largest amount. The season March to May also receives above average rainfall in particular during the month of March.

Table 5.1 - Hydrological statistics for River Kafu

	Long Term 1953-1983	Dry 1953-1959	Wet 1960-1971	Dry 1972-1983
Mean Annual Outflow (m3/s)	16.50	5.05	26.86	12.82
Mean Annual Rainfall (mm)	1147	1124	1255	1049
Max. Outflow (m3/s)	156.15	45.20	156.15	52.74
Min. Outflow (m3/s)	0.25	0.25	1.23	4.17

The recent low flow or drought 1990-1993 was a repetition of a historical pattern and much less serious than the low flow period 1953-1959. The minimum recorded flow (0.25 cumecs) occurred in that period (1953 - 1959) and the recorded cumulative deficit was 2.5 billion m3 over 7 years compared to cumulative deficit of 1.4 billion m3 over the recent 12 years period 1972-1983. The pattern of the moving 5-year mean flow departures and the long term rainfall pattern (re. Fig 4.1) suggests that the drought of long duration (1942-1959) is the worst recorded drought.

Apart from the cyclic pattern (Fig 5.1) there is no indication of an upward or downward trend to suggest an impact of change in climate or land-use.

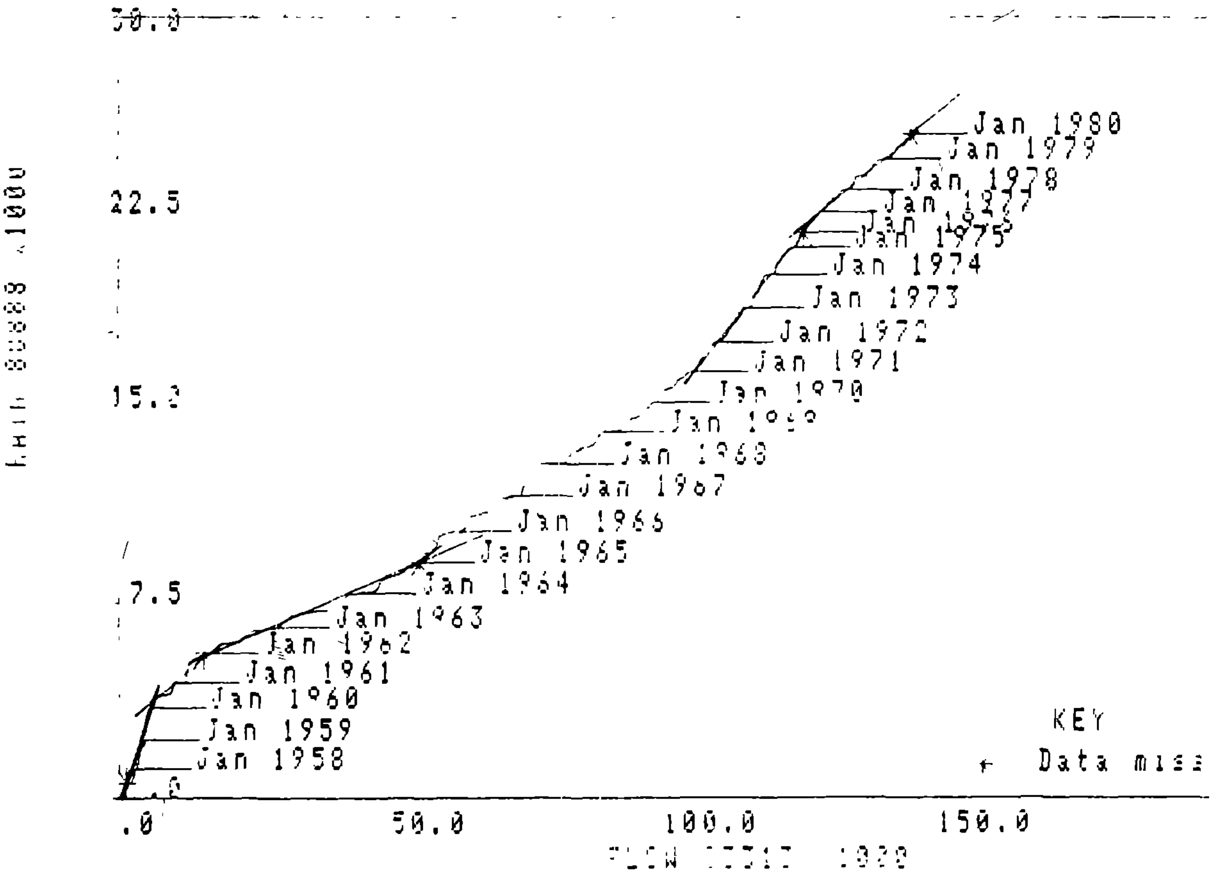

Figure 5.2 Double mass curve, River Kafu flow versus rainfall

The double mass curve (Fig 5.2) show several changes in slope. This is possible due to the different responses of the catchment over the wet and dry years. The changes in slope (1960, 1962, 1965, 1971, 1976) correspond to the transition between the dry and wet periods.

The mean normal rainfall departures and the moving 5-year anomalies plotted against the corresponding mean runoff are shown in Fig 5.3.

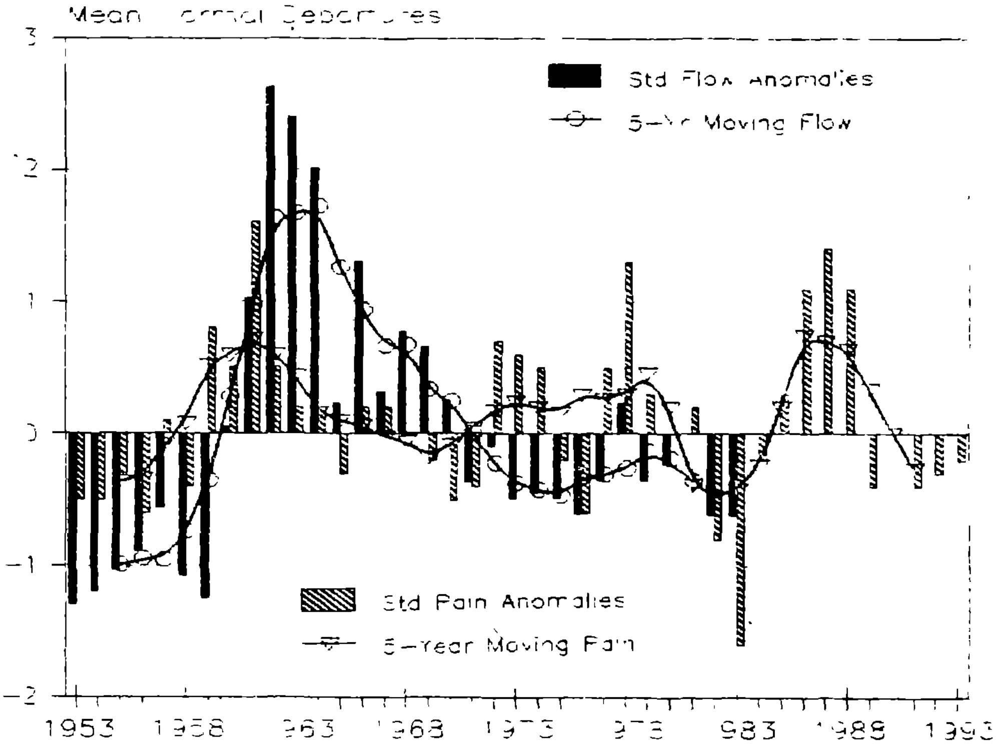

Figure 5.3 Mean normal rainfall, flow departures and 5-year moving averages

The above plot leads to the following observations:

- the cyclic pattern in rainfall and runoff are correlated with a significant delay lag. The lag is due to the large storage capacity in the catchment. The runoff is correlated to the rainfall and runoff in the previous years;

- the variation in runoff may be wholly explained by the variations in rainfall; the recent low flow period (1990 - 1994) may be explained by the recent drought or decline in rainfall;

- the variations in runoff are wider than the variations in rainfall and therefore the effect of decline or increase in rainfall on water resources is magnified. For example an increase in rainfall from 1124 mm to 1255 mm over the periods 1953-1959 to 1960-1971 caused an increase in runoff by more than 5 times. Similarly a decline in rainfall from 1255 mm to 1049 mm was followed by a decline in runoff by more than 2 times.

APPENDIX 6.1

POPULATION DATA AND FORECASTS

Livestock data and forecasts (Source: World Bank, 1993)

REGION	DISTRICT	LIVESTOCK NOS. 1989 (x 1000)			GROWTH % p.a.	LIVESTOCK NOS. 2010 (x 1000)		
		CATTLE	PIGS	GOATS/ SHEEP		CATTLE	PIGS	GOATS/ SHEEP
Central	Kalangala	5.0	1.8	4.7	8.2	26.0	9.4	24.7
	Kampala	187.6	67.7	177.9	7.1	792.0	285.8	751.2
	Kiboga	31.8	11.5	30.1	2.3	51.2	18.5	48.6
	Luwero	99.0	35.7	93.9	3.0	184.2	66.5	174.7
	Masaka	183.3	66.1	173.8	4.9	500.5	180.6	474.7
	Mpigi	206.5	74.5	195.9	5.2	598.7	216.0	567.9
	Mubende	109.7	39.6	104.0	4.9	299.5	108.1	284.1
	Mukono	184.1	66.4	174.6	4.5	464.0	167.4	440.1
	Rakai	80.6	29.1	76.4	5.2	233.6	84.3	221.5
Western	Bundibugyo	43.7	9.5	42.1	2.5	73.4	16.0	70.6
	Bushenyi	276.9	60.4	266.4	5.3	819.0	178.5	787.9
	Hoima	88.8	19.4	85.4	4.2	210.7	45.9	202.7
	Kabale	174.2	38.0	167.6	4.3	421.7	91.9	405.7
	Kabarole	325.9	71.1	313.6	5.5	1003.2	218.7	965.2
	Kasese	136.6	29.8	131.4	4.1	317.5	69.2	305.5
	Kibaale	98.5	21.5	94.7	5.6	309.1	67.4	297.4
	Kisoro	86.7	18.9	83.4	5.7	277.7	60.5	267.2
	Masindi	107.0	23.3	102.9	4.1	248.7	54.2	239.3
	Mbarara	363.2	79.2	349.5	5.0	1012.0	220.6	973.6
	Rukungiri	151.6	33.1	145.9	4.7	397.7	85.7	382.7
Northern	Apac	65.7	39.2	238.2	6.3	236.9	141.4	859.3
	Arua	69.7	41.6	253.0	5.2	202.2	120.7	733.5
	Gulu	46.3	27.6	168.0	4.7	121.5	72.5	440.7
	Kitgum	47.9	28.6	173.7	3.8	104.8	62.6	380.2
	Kotido	22.8	13.6	82.8	2.6	39.1	23.4	141.9
	Lira	74.2	44.3	269.1	5.3	219.5	131.0	795.9
	Moroto	23.5	14.0	85.1	2.6	40.2	24.0	145.8
	Moyo	24.4	14.6	88.5	7.4	109.3	65.3	396.4
	Nebbi	39.9	23.8	144.8	5.4	120.5	71.9	437.1
Eastern	Iganga	256.8	34.0	285.1	5.7	822.5	108.9	913.2
	Jinja	84.2	11.1	93.5	4.2	199.8	26.5	221.9
	Kamuli	133.4	17.7	148.1	5.1	379.2	50.2	421.0
	Kapchorwa	31.6	4.2	35.1	6.4	116.4	15.4	129.2
	Kumi	62.0	8.2	68.8	2.1	95.5	12.7	106.5
	Mbale	213.6	28.3	237.1	4.4	527.5	69.8	585.7
	Pallisa	89.7	11.9	99.5	5.1	254.8	33.7	282.9
	Soroti	122.1	16.2	135.6	1.3	160.1	21.2	177.8
	Tororo	157.0	20.8	174.3	5.0	473.3	57.9	485.5

DISTRICT	Livestock equ. 1989	Livestock equ. 2010	Water demand 1989	Water demand 2010
Kalangala	5	25	89	464
Kampala	185	781	3,370	14,254
Kiboga	31	50	558	914
Luwero	97	181	1,775	3,309
Masaka	180	493	3,293	8,999
Mpigi	203	590	3,706	10,768
Mubende	108	295	1,962	5,386
Mukono	181	458	3,309	8,351
Rakai	79	230	1,442	4,195
Bundibugyo	40	68	730	1,241
Bushenyi	257	763	4,692	13,917
Hoima	82	195	1,496	3,564
Kabale	162	392	2,957	7,151
Kabarole	303	934	5,527	17,046
Kasese	126	295	2,308	5,388
Kibaale	91	288	1,663	5,250
Kisoro	80	258	1,457	4,708
Masindi	99	231	1,814	4,217
Mbarara	338	942	6,169	17,198
Rukungiri	141	369	2,567	6,738
Apac	97	350	1,767	6,396
Arua	103	299	1,873	5,463
Gulu	68	180	1,245	3,276
Kitgum	70	155	1,278	2,821
Kotido	33	58	600	1,052
Lira	110	325	2,003	5,930
Moroto	34	59	629	1,083
Moyo	36	162	650	2,951
Nebbi	58	178	1,060	3,248
Iganga	236	756	4,299	13,789
Jinja	77	183	1,408	3,337
Kamuli	122	348	2,228	6,359
Kapchorwa	29	107	521	1,945
Kumi	57	87	1,037	1,591
Mbale	196	484	3,574	8,838
Pallisa	82	233	1,488	4,258
Soroti	112	147	2,045	2,682
Tororo	144	427	2,628	7,786
Sum	4,450	12,376	81,217	225,862

Livestock equivalents in thousands

Water demands in thous[illegible] m^3/year

APPENDIX 6 5

PRESENT AND POTENTIAL IRRIGATION WATER USE

IRRIGATION (POTENTIAL) WATER DEMANDS BY CATCHMENTS				
Basin Name	Scheme Name	Potential Area (Ha)	Ultimate Water Use (Mill m3/year)	Water Source
L. Victoria	Kibimba Valley	6012	60.12	L. Wamala
	Biluma	4273	42.73	L. Victoria
	Kityerera	9306	93.06	L. Victoria
	Idokwe Bay	4198	41.98	L. Victoria
	South Bukoli	9176	91.76	L. Victoria
	L. Mburo	462	4.62	L. Mburo
	Orichinga Valley	2082	20.82	L. Nakivali
Sub Total		35,509	355.09	
L. Kyoga	Kaabong	1892	18	R. Dopeth
	Moroto	1600	16.00	R. Matheniko
	Adip/Olweny	6039	60.39	L. Kyoga
	Bokora/Isuku	3764	37.64	R. Okere
	Akokoroi	14766	147.66	R. Okere
	Nabilatuk	1077	10.77	R. Beletur
	Kafu	7250	72.50	R. Kafu
	Akokoro	8200	82.00	Vic. Nile
	Nabiswera	3325	33.25	Vic. Nile
	Katinge	2685	26.85	L. Kyoga
	Okapel	1155	11.55	L. Kyoga
	Omunyal	7664	76.64	R. Omunyal
	Opurei	1426	14.26	L. Kyoga
	Kadunguhi	1300	13.00	L. Kyoga
	Agu/Kapiri Vall	11407	114.07	L. Bisina
	Komolo	53.92	53.92	R. Okore
	L. Salisbury N	4300	43.00	R. Bisina
	L. Salisbury S.	3026	30.26	L Bisina
	Namalu	895	8.95	R. Nakiriyonyet
	Nakasongola	7070	70 70	L. Kyoga
	Sezibwa	4762	47.62	R. Sezibwa
	Nakasongola	7616	76.16	Vic. Nile
	Byero	900	9.00	L. Kyoga
	Malima	1967	19.67	L. Kyoga
	Labori	2695	26.95	L. Kyoga
	Pigire	1581	15 81	L. Kyoga

SCHEME	DISTRICT	SOURCE	MAIN CROPS	PRESENT IRRIGATED AREA Hectares	PRESENT WATER USE per year mill. m3
MUBUKU	KASESE	Sebwe/Mub. Res.	R,V,A	550	4 81
KIBIMBA	IGANGA	Kibimba Res	Rice	700	8 40
DOHO	TORORO	Manafwa R	Rice	1,000	12 00
KIIGE	KAMULI	Nabigaga L.	Citrus	60	0.42
ONGOM	LIRA	Owemen/On Res	Citrus	40	0.28
ODINA	SOROTI	L. Kyoga	Citrus	-	-
LABORI	APAC	L. Kyoga	Vegetables	-	-
ATERA	APAC	L. Kyoga	Rice, Veget.	-	-
ACORO	KITGUM	Agoro R	Rice, Veget.	-	-
OLWENY	LIRA	L Kwania	Rice	-	-
SMALL SCALE RICE FARMERS	TORORO	Mpologoma,	Rice	15,000	90 00
		Lumbuka	Rice		
		Manafwa	Rice		
	IGANGA	R Mpologoma	Rice	10,000	60 00
		Kitumbezi	Rice		
		Naigombwa	Rice		
		Lumbuye	Rice		
	PALLISA	Mpologoma	Rice	5,000	30 00
NYAMUGAS.	KASESE	R Nyamugasani	V,C,S,M,R	10	0.76
KAKIRA	JINJA	L Victoria	Sugarcane	100	0 95
LUGAZI	MUKONO	R Sezibwa	Sugarcane	50	0 48
TOTAL				32,510	207 47

IRRIGATION (POTENTIAL) WATER DEMANDS BY CATCHMENTS				
Basin Name	Scheme Name	Potential Area (Ha)	Ultimate Water Use (Mill m3/year)	Water Source
	Nawaikoke	7014	70.14	L. Nakawa
	Lwere Valley	570	5.70	R. Lwere
	Siroko	1950	19.50	R. Simu
	Namatala	2349	23.49	R. Namatala
	Malaba	2178	21.78	R. Malaba
	Bugusu/Sebei	5713	57.13	R. Simu
	Atera	2806	28.06	Vic. Nile
	Doho	800	8.00	R. Manafwa
Sub Total		137,134	1371.34	
Kyoga Nile	Koli Valley	6742	67.42	Vic. Nile
	Arocha	5206	52.06	R. Arocha
	Aganga/Ibuje	6685	66.85	Vic. Nile
	Tochi Valley	6285	62.85	R. Tochi
Sub Total		24886	248.86	
Lks. Edward & George	Hima/Mubuku	4215	42.15	R. Mubuku
	Nyakatonzi	5250	52.50	R Nyamugasani
	Kihihi Flats	7067	70.67	R. Ishasha
Sub Total		16,532	165.32	
R. Aswa	Alinga	1500	15.00	R Pager
	Lakara	400	4.00	R. Kapeta
	Adilang	1200	12.00	R. Agago
	Labwor	900	9.00	R. Kadokadoi
	Katabok	417	4.17	R. Kadokadoi
Sub Total		4417	44.17	
Albert Nile	Laropi	858	8.50	Albert Nile
	Oya(Rhino Camp)	1350	13.50	Albert Nile
	Acha	1400	14.00	R. Acha
	Anyau	3128	31.28	R. Anyau
	Waki Swamp	5907	59.07	Albert Nile
	Lower Nyawa	2385	23.85	Albert Nile
	Ala	1048	10.48	R Ala
	Ora	4392	43.92	Albert Nile
	Oceke(Pakwaro)	956	9.56	Albert Nile
	Panyimur	4951	49 51	Albert Nile
	Ayila	1124	11.24	Albert Nile
Sub Total		27,499	274 99	
Kidepo Valley	Kitgum	1,249	12.49	R. Lanyag
GRAND TOTAL		247,226	2472.26	

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