NILE TRANSBOUNDARY ENVIRONMENTAL ACTION PROJECT

Training Modules and Materials, Identification of key Parameters, and Design of Water Quality Assurance Program for Uganda

By Prof. John Okedi
P.O. Box 9592
KAMPALA
Tel; 256-077-2-462-855
E-Mail; johnokedi@yahoo.com

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TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

AMCOW -African Ministerial Council on Water
AMREF -African Medical Relief Fund
AQA -Analytical Quality Assurance
AWF -African Water Facility
AWI -Analytical Work Instructions
B.F.A -Bachelor of Fisheries and Aquaculture
BMU -Beach Management Unit
BOD -Biological Oxygen Demand
CBCL -Century Bottling Company Limited
CBO -Community Based Organisation
Cr -Cromomium
DWD -Directorate of Water Development
EAC -East African Community
EHD -Environmental Health Department
EQC -External Quality Control
EU -European Union
GIS -Geographic Information System
GWP -Global Water Partnership
IQC -Internal Quality Control
KCCL -Kasese Cobalt Company Limited
LVB -Lake Victoria Basin
LVBC -Lake Victoria Basin Commission
LVEMP -Lake Victoria Environment Management Project
M.SC. -Master of Science
Mn -Manganese
MUK -Makerere University Kampala
N -Nitrogen
N/R -Natural Resources
NBI -Nile Basin Initiative
NBS -Net Basin Supply
NEMA -National Environment Management Authority
NGO -Non Governmental Organisation
NRM -Natural Resources Management
NTEP -Nile Transboundary Environmental Action Project
NWQMS -National Water Quality Management System
NWSC -National Water and Sewerage Corporation
P -Phosphorus
Ph.D. -Doctor of Philosophy
PHD -Public Health Department
QA -Quality Assurance
QAO -Quality Assurance Officer
SANAS -South African National Accreditation System
TDA -Total Dissolved Solids
TN -Total Nitrogen
TP -Total Phosphorus
TSS -Total Soluble Solids
WHO -World Health Organisation
WID -Wetland Inspection Department
WRAP -Water Resources Assessment Project
WRMD -Water Resources Management Department
Zn -Zinc

NILE TRANSBOUNDARY ENVIRONMENTAL ACTION PROJECT
THE BASIN WIDE WATER QUALITY MONITORING COMPONENT

Executive summary

Fresh water in streams, rivers, wetlands, lakes and under ground sources are very important resources for human and livestock livelihood. Cultural, political, socio-economic and industrial development of communities and urban settings has been mainly related to availability and acceptability of freshwater in these systems. However, information on fresh water availability, quantity and quality for various uses, conflict resolution and information management is vital for sustainable management of the resources at local, national, trans-boundary and regional levels. Therefore, there is need for proper planning and implementation of management programs through application of professional skills, building adequate capacity both in facilities and human resources for comprehensive monitoring of quantity and quality variables, use of quality assurance system for generation of accurate and reliable scientific data and appropriate information management system.

The major findings of this report focus on availability, in Uganda, of capacity and training institutions for water quality monitoring and management, presence of programs for monitoring water quality at different levels by various institutions, identification of laboratories and key water quality monitoring parameters of national, cross-boarder, trans-boundary and basin wide importance, and design of an implementable quality assurance system to be applied by the laboratories.

The present situational analysis showed that there is inadequate capacity in Uganda to carry out comprehensive water quality monitoring at national and trans-boundary levels, and the available training institutions run courses that are tailored for their academic programs, specific in scope and are narrow in practicability. Institutions that implemented LVEMP phase I and others involved in water and environmental management have carried out some capacity building for their staff but for academic and particular institutional requirements. This study has, therefore, designed training modules for water resources management for Universities, Technical Tertiary Institutions, Secondary Schools and Community levels.
A number of government institutions and NGOs were found to be involved in water quality monitoring programs but their purpose of monitoring was geared towards specific responsibilities like quality compliance to set standards, regulatory, process control and others, therefore parameters considered were limited to the institutional needs. It was also evident that there are a number of government and private institutional laboratories in Uganda, which carry out water quality monitoring and analysis but their analytical procedures are not harmonized, programs are diverse and most of them have no quality assurance systems in place.

This report recommends parameters for water quality monitoring for national and trans-boundary levels and laboratories that can be used for this purpose. Implementable water quality monitoring programs at various levels have been suggested and a comprehensive quality assurance system leading to accreditation of the laboratories is presented.

TRAINING MODULES, KEY PARAMETERS AND QUALITY ASSURANCE SYSTEM FOR WATER QUALITY MONITORING

1.0 Introduction

The water quality monitoring component is initiating a basin wide dialogue on water quality management in a bid to improve the understanding of trans-boundary water quality issues, build capacities for monitoring water quality, promote sharing of information on key water quality parameters and enhance trans-boundary cooperation between states in the Nile Basin.
Trans-boundary cooperation is important for exchange of experiences on water quality management and regulatory issues to facilitate improved decision making by the resource users and the governments. The project component aims at establishing increased regional trans-boundary water quality assessment, collaborative action, raise awareness and basin-wise dialogue among relevant stakeholders so as to develop a common vision and goal for water quality management for the whole River Nile Basin.

Rivers and lakes are very important freshwater resource for people because, in the past, cultural, socio-economic and political development was mainly related to the availability and distribution of freshwater in river and lake systems. An evaluation of surface water available for trans-boundary, regional or national exploitation can be based on the total river discharge or lake water balance for various uses, which may include but not limited to the following drinking and commercial water supply sources, agricultural irrigation, industrial and municipal waste disposal, transportation, fisheries, boating, recreation and aesthetics. Therefore, upstream extraction or use of water in a river/lake system should be done in ways that do not negatively affect the water quality or quantity for the downstream or other users. Rational use of river/lake water has over the past been an issue of crucial political negotiations at various levels. By virtue of its intricacies, managers of river/lake waters require quality scientific data and information on the water they control.

Like all fresh water systems, river/lake quality data has to be interpreted within the context of basic understanding of the fluvial, limnological and the river/lake basin processes which control the underlying characteristics of the river/lake system. Likewise, the selection of sampling methods, variable parameters to be measured and the design of the monitoring network has to be based on knowledge of fluvial/limnological processes and the water use requirements.

1.1 Rationale for the study

River Nile Basin consists of the Nile River, lakes, streams and wetland ecosystems with the following significance;

- Global, regional and national importance;
- Essential for human survival;
- Provide services in:

    - Drinking, livestock and commercial water supply;
    - Agriculture and irrigation and tourism;
    - Industrial and municipal waste disposal;
    - Transportation, fisheries, boating, recreation;
    - Climate modulation;
    - Ecosystem maintenance and aesthetics.

Uganda, by virtue of its location, virtually lies within the Nile Basin, downstream of 5 countries and upstream of 2 countries, and all its water resources are shared with the neighbouring countries. Therefore, the water resources of Uganda are bound by a number of agreements and conventions on international waters of which some are ratified and others are not. The country is richly endowed with freshwater resources, which include open waters like Lakes Victoria, Kyoga, Albert, George, Edward and various other smaller lakes; and rivers like the Nile, Katonga, Kagera, Kafu, Aswa, Sezibwa, Sio, Malaba etc; and also in groundwater aquifers. Of the country's surface area of approximately 241,500 Km^2, 15% is freshwater while 12% is permanent and seasonal wetlands, and receives annual rainfall in the range of 500 – 2500 mm.

The quality of water received in Uganda is greatly impacted by the activities of the four upstream countries. The current trans-boundary water quality issues include sedimentation, agro-chemicals pollution, toxic heavy metals, micro-biological contamination, eutrophication and atmospheric deposition. These aspects of water quality pollution are expected to increase both qualitatively and quantitatively and get more complex as the population within the Nile Basin increases, and developmental activities like urbanization, industrialization, agricultural modernization, mining take place coupled with environmental degradation and climate change. Uganda, because of its sensitive location in the basin, ought to appropriately mobilize its resources and actively participate in the trans-boundary water resources and environmental pollution management issues. Water quality must gain importance from local, national, regional to international levels for balanced sustainable development. Uganda already participates in a number of activities through the Protocol for Sustainable Development of Lake Victoria, the Lake Victoria Basin Commission (LVBC), East African Community (EAC), Global Water Partnership (GWP), African Water Facility (AWF), African Ministers Council on Water (AMCOW) and Nile Basin Initiative (*National Water Quality Management Strategy, September 2006*).

There is therefore a need for a network of river and lake monitoring stations to:

- Establish short and long term fluctuations in water quantity, quality and climate characteristics in the River Nile Basin;
- Determine water quality criteria needed for optimization and maintenance of water uses;
- Determine impacts of water use, demographic changes and management interventions on water quality and quantity.

1.2 Objectives

This study was meant to address three main objectives which include:

i) Designing and developing training modules targeted for institutions, schools and local communities as assessed from the national needs;

ii) Identification, characterization and recommending key water quality monitoring parameters of cross-border, trans-boundary and basin-wide importance; and

iii) Designing a Quality Assurance program to be applied both at the national and trans-boundary levels.

1.3 Methodology for the study

The status of water resources management, monitoring, and training levels and facilities in water and environmental sector in the Uganda part of the Nile Basin were assessed through

1.3.1 Direct interviews with key personnel from

The status of water resources management, monitoring, and training levels and facilities in water and environmental sector in the Uganda part of the Nile Basin were assessed through direct interviews with key personnel from relevant government departments and parastatals like Directorate of Water Development (DWD), Water Resources Management Department (WRMD), National Water and Sewerage Corporation (NWSC), Wetlands Inspection Division (WID), Public Health Department (PHD) and National Environment Management Authority (NEMA). Institutions dealing with water and environmental issues were also visited and they included the following; Makerere University Kampala - Department of Civil Engineering, Institute of Environment and Natural Resources, Institute of Public Health, Kyambogo University – Department of Civil and Building Engineering, and other institutions of higher learning.

1.3.2 Literature Review

Documents and publications from the above departments and institutions were accessed and reviewed including reports from the National Water Quality Management Strategy, LVEMP and others. Information was also obtained from members of the Water Quality Task Force of the Nile Trans-boundary Environmental Action Project.

2.0 KEY FINDINGS

Key findings of this study relate to Water Quality Monitoring Institutions and Facilities; and the nature of the transboundary parameters which are commonly tested. Analysis of the present water quality monitoring programs has shown both strengths and deficiencies in the national monitoring system for achieving the strategic objectives and international targets of the National Water Quality Management Strategy as shown below.

2.1 Current Water Quality Monitoring Networks

2.1.1 Water Resources Assessment Project (WRAP) Net work

There are functional water quality monitoring networks and infrastructure, with the first national water quality monitoring network was established under Water Resources Assessment Project (WRAP) between the years 1996 and 2000. This network operates with three main objectives as follows:

i. The National Water Quality Monitoring Network

This is for the assessment of the impacts of point and non-point pollution sources on selected receiving water bodies.

ii. The National Water and Sewerage Corporation (NWSC) operational monitoring network

The purpose of this network is to monitor water quality for assessment of performance and providing back-up for water treatment and supply facilities. The NWSC carries operational monitoring, for process control and supplies, covers more than 800 points and 98 other points for sewage influents and effluents in 22 towns.

iii. The Water Resources Quality Monitoring Network

This is for assessment of water quality trends of major surface water bodies and ground water sources.

The three monitoring networks include a total of 119 monitoring stations (*see Appendix 1 Hydrological Tree for Uganda, Appendix 2 and Appendix 3 showing National Basic and Specific Monitoring Stations – adopted from 1st Regional water quality training workshop for NTEAP, Courtesy of WRMD - Entebbe*) and sampling is carried out at different frequencies for different parameters (as shown in Appendix 4, Appendix 5 and Appendix 6). The network was designed and is being reviewed to provide an integrated water resources issue-based approach, which when coupled with the database will support the foundation for efficient water quality management.

2.2 Water Quality Monitoring under the Water Quality and Ecosystem Management Component of the LVEMP-1

The water quality and Ecosystems Management Component of LVEMP-1 made considerable progress towards understanding Lake Victoria's water quality and its ecosystem as well as effects of resource utilization and exploitation on the lake and its catchment. The component was able to collect considerable amount of data and information. Further, the LVEMP played a major role in establishing monitoring stations for assessment of water quality, hydro-meteorological conditions, non-point pollution loading from agricultural lands and point source loading from iindustrial and municipal wastes. The project also established baseline hydraulic conditions, sedimentation rates, eutrophication and levels of pesticides and agrochemical contamination in the water bodies. These aspects are, therefore, described here in response to the TOR of this study requiring elucidation of current and ongoing efforts on water quality monitoring. The LVEMP contributed immensely in this and laid a firm basis for future monitoring of the quality and conditions of Uganda's water systems. Its experiences and lessons learnt are therefore useful and should be built on in the planning of future activities in this area. Hence, the following high lights LVEMP contributions and positive achievements upon which future work could be expanded.

2.2.1 Objectives of the Water Quality and Ecosystem Management Component

The specific objectives of the component were:

- To provide detailed and usable information on the characteristics of the waters of Lake Victoria;
- To establish and operationalise integrated water quality monitoring network so as to generate information on the physical status, chemical characteristics and biological composition of the lake;
- To develop and operationalise a water quality management model to be used as a planning tool in the management of Lake Victoria and its ecosystem;
- To develop and continuously update the mass water balance of Lake Victoria;
- To contribute on the social benefits which the community can accrue as a result of accessing lake water of good quality;
- Identify the impacts of deteriorating water quality on the beneficial uses of Lake Victoria;
- To develop, enforce and regularize water quality standards and monitor compliance;
- Determine historical trends and future projections;
- Build human capacity;
- Define the current baseline condition under LVEMP- I tenure; and
- Recommend future actions for the LVEMP-2 phase.

2.2.2 Summary of Findings

Lake Monitoring

- ➢ A number of sampling networks for littoral, pelagic and urban monitoring stations were established;
- ➢ Trends in physical and chemical parameters were monitored; and
- ➢ Lake wide cruises were under taken.

Hydro-Meteorological Conditions

- o Uganda's land catchment annual rainfall contribution to Lake Victoria is approx. 312 Million m^3/s;
- o Mean annual rainfall over the Ugandan side is about 2020 mm and this forms 35.2% of the mean annual lake rainfall;
- o No significant trends in rainfall were observed over the period of study;
- o Evaporation was less than rainfall by a factor of 0.66;
- o Lake levels in relation to the Nile outflow show that there has been a close relationship between the levels and amount of water released through the Owen Falls Dam;
- o Limited rains on the lake in recent years contributed to falling of lake levels;
- o Increased outflows at the Owen Falls dam for power generation contributed to a further fall in lake levels by about 0.34 m from the year 2001–2004; and
- o Full understanding of this scenario needs understanding net basin supply (NBS) and outflow data from the rest of the basin.

Non-Point Pollution Loading

- ➢ TSS and TN concentrations were river-dependent;

- River Bukora had significantly higher concentrations compared to River Katonga ($P<0.01$);
- TP concentrations were similar in Katonga and Bukora, and increased linearly with time ($p=0.05$);
- The concentration of TSS fluctuated, the peak was in the year 2000 for Bukora and 2001 for Katonga ($p<0.05$); and
- The sub-catchments loaded 2.1 t/day of TN and 0.3 t/day of TP, confirming small contribution compared to atmospheric deposition, which loaded 26.4 t/day of TN and 5.6 t/day for TP from the wet deposition.

Industrial and Municipal Effluents Management

- Pollution hotspots were identified;
- Fishing villages contribute significantly to Lake Victoria pollution;
- Factories in Kampala, Jinja and Entebbe with threat to lake pollution identified;
- It was established that about 14.17 tons of BOD, 2.91 tons of N and 1.93 tons of P / day is discharged into Lake Victoria from urban centers;
- 2.96 tons of BOD, 0.37 tons of N and 0.19 tons of P / day is discharged from 124 fishing villages;
- Industrial loads was estimated to be 2.51 tons of BOD, 0.34 tons N and 0.11 tons P per day;
- Use of natural and constructed wetlands showed a significant role in pollution reduction; and
- Pollution management strategies and sanitation improvement is proposed.

Hydraulic conditions

- Data on temperature, water velocities, oxygen concentration and secchi depths were studied from 1999 to 2005;
- The temperature distribution profiles on the eastern part of the lake showed similar patterns to historical observations;
- Water column temperatures and stratification are very prominent in the months of February, March and April;
- The western part of Lake Victoria is much influenced by winds hence more mixing and cooling patterns;
- The eastern part of Lake Victoria is much more influenced by thermal stratification patterns and therefore mixing is mainly due to density currents; and
- The eastern part of Lake Victoria experiences higher water temperatures throughout the year due to a lower rate of light penetration and weaker mixing.

Sedimentation

- Sedimentation rates were highest at littoral compared to pelagic stations;
- The composition of the settling material is highly organic and of algal origin;
- Inshore sediment cores had lower annual sediment burial rates than deep offshore;
- Only 10-15% of trapped carbon and nitrogen is permanently buried on an annual basis in contrast to 40% of phosphorus;
- The trapped amounts of biogenic silicon is insufficient to account for recent historic rates of burial;
- This is consistent with the depletion of soluble reactive Si in the lake as a consequence of P enrichment, causing eutrophication;

- Sediment cores indicate that increased loading of P began prior to 1940 and continues to the present;
- The increased loading of P has depleted dissolved Si in the lake's mixed layer and oxygen in the deeper waters;
- The created nitrogen demand can only be met through nitrogen fixation creating conditions where cyanobacteria now dominate; and
- Restoration of ecological conditions characteristic of the first half of the last century will require reductions in P loading.

Eutrophication of Lake Victoria

- Lake Victoria has clearly shown signs of eutrophication since the late 1980s;
- Phosphorus concentrations have risen by a factor of 2 to 3;
- High nutrient concentrations support elevated algal primary production and algal biomass have risen by a factor of 2 and 6 to 8 respectively;
- Average algal primary production has increased 2-fold and supports a 4 – to 5 – fold increase in yield compared to 1950s;
- Estimated abundance indicated higher densities of organisms and diversity indices around littoral compared to pelagic habitats, these trends are explained by a more productive inshore that receives nutrients;
- Vertical distribution of zooplankton is related to profiles of temperature and dissolved oxygen;
- In shallow littoral habitats, there was no development of thermocline and oxycline;
- In contrast, the vertical distribution at deeper pelagic stations indicated concentration of organisms in mid-to-surface water layers due to development of low dissolved oxygen conditions;
- The frequent encounter of these organisms is an indicator of the deteriorating water quality of the lake basin; and
- Adverse eutrophication effects include harmful algal blooms associated with fish kills; and reduction in lake transparency; changes in algal and invertebrates communities, loss of desirable fish species and seasonal bottom water oxygen depletion (anoxia).

Pesticides, agrochemicals and heavy metals

- Use of agricultural chemicals in the catchment has increased in recent years;
- Studies under LVEMP and other international investigators have revealed gross abuse and misuse of agricultural chemicals in Uganda;
- Many restricted chemicals are being used by untrained persons while adulteration of some is common;
- A number of banned organochlorinated pesticides (e.g. DDT, endosulfan, dieldrin and lindane) were detected in air showing that they may still be in use;
- However, these pesticides were not detected in sediments, water or fish tissue;
- Studies also showed that herbicides Touch Down (48% Glyophosate trimesium) and Gasepax (2,4-D and Ametryne) used in sugarcane cultivation pose no environmental threat in runoff water, soil and fish, four months after field application;
- Elevated metal concentrations (Mn, Zn and Cr) detected in some rivers were, related to industrial activities or runoff from urban areas;
- High Total Hg concentrations were higher in recently deposited lake sediments than older ones, indicating increased environmental degradation;

- Nevertheless, Hg concentrations in sediment, water and fish from Lake Victoria were below the WHO and international environmental guidelines; and
- Results call for more stringent measures to control the types of agricultural chemicals used in the catchment coupled with massive sensitisation of communities on safe handling and use of agrochemicals.

Water and Health

- Studies indicated that the shore waters were highly contaminated;
- Riparian communities sourced their water for domestic use mainly from the lake;
- Seasonal variation in coliform counts correlates positively with waterborne disease incidences that were higher in the wet season;
- The most prevalent diseases in the landing sites were malaria, dysentery, diarrhea and bilharzias;
- Cases of cholera, skin-related infections and influenza, where also observed;
- Fishers vulnerability to water-related diseases was further aggravated by inaccessibility to both health facilities and personnel;
- There was a significant difference in disease cases between those who used latrines regularly and those who did not use latrines;
- Other potential health risks in the communities arose from frequent algal blooms
- Cyanobacteria (potentially toxic to humans and animals) impaired ecological and aesthetic values of the lake;
- Algal blooms caused unpleasant odours and tastes in domestic water supplies, clogged filters on pumps and machinery, increased chlorine demand, requiring a more complex and expensive treatment process , and ultimately raised tariffs;
- Use of Ecosan toilets constructed by LVEMP in the riparian communities was estimated to be less than 50% on average, because of user fee and socio-cultural factors;
- People disposed their wastes in nearby bushes or in polythene bags, contaminating water sources with fecal material and leading to waterborne diseases; and
- Findings suggest that water quality and sanitation improvements, in association with hygiene behaviour change can have significant effects on population and health by reducing a variety of waterborne and water-related diseases.

2.3 Government Institutional and Private Sector Laboratories

Water quality testing capacity exists both in government institutions and private sector laboratories. All these institutions support data generation in their different capabilities and contribute to water quality management information. Other institutions that carry out water quality monitoring are FIRRI with 8 points for water quality assessment for fisheries. Public Health Department of Ministry of health has surveillance programs for drinking water quality in a number of towns. There are also some undocumented monitoring programs under private sector, local government and NGOs.

The present laboratories include the following:

Government Institutional Laboratories

- Water Quality and Pollution Control Laboratory, WRMD – Entebbe
- Rural Water and Sanitation (RUWASA) Laboratory, DWD – Mbale
- South Western Towns Laboratory, DWD – Kabale
- Government Analytical Laboratories, Kampala – Wandegeya
- Uganda National Bureau of Standards Laboratory, Kampala – Nakawa
- National Water and Sewerage Corporation (NWSC) – Central Laboratory, Kampala – Bugolobi
- Makerere University Kampala (MUK) – Departmental Laboratories
- Fisheries Resources Research Institute (FIRRI)Laboratory – Jinja

Private Laboratories

- Chemiphar Laboratory, Kampala – Kansanga
- Century Bottling Company Limited (CBCL), Kampala & Mbarara
- Kasese Cobalt Company Limited (KCCL), Kasese
- Kilembe Mines, Kasese
- Uganda Breweries Ltd, Kampala – Port Bell
- Mineral Water Bottling Companies; Rwenzori, Aqua Coolers, Blue Wave, etc.
- Mukwano Industries, Kampala.

2.4 Current Training Facilities in Water Monitoring and Environment Management

2.4.1 Technical and informal training available in Uganda

Available training programs are geared towards capacity building of departmental staff to handle internal responsibilities. In the Universities, the training is aimed at addressing academic requirements and specific departmental responsibilities since these institutions have tight academic programs. Hence the training is limited in scope. Some of the training undertaken was done by the following institutions and departments.

- The WID provided a few short community awareness programs on ‘wise-use’ of wetland resources and scantly touched on water uses and pollution.

- DWD once conducted training of some district and urban engineers/water officers in water quality monitoring;

- NWSC carried out training of a few industrialists, under LVEMP – Industrial and Municipal Waste Management Component. The training specifically addressed industrial effluents quality monitoring and has not been sustainable after the end of the first phase of the LVEMP.

- PHD trained Public Health Inspectors to carry out water quality analysis of drinking water sources, however, the objective of the monitoring was tailored for public health monitoring in relation to water sources as such parameters tested were limited to pH, electrical conductivity, total suspended solids, turbidity, colour and faecal coliforms.

- District local government staff have received training in water quality monitoring through water quality division, NWSC, AMREF, Ministry of Health – Environmental Health Division (EHD).

- The Current National Training Facilities in Uganda are shown in **Table 1** below.

Table 1: Current National Training Facilities in Uganda

Name of institution	**Courses offered** (Course units)	**Course duration** (Years)	**Capacity** (Trainees No./Yr)
Makerere University Department of Civil Engineering	-Water Resources Engineering -Environmental Engineering and Public Health -Engineering Hydrology	4	20
Makerere University Institute of Environment and Natural Resources	-Environmental Impact Assessment -Integrated Water Resources Management.	3	30
Makerere University Institute of Public Health	-Public health & sanitation -Drinking water quality -Water Diseases	3	60
Kyambogo University Department of Civil and Building Engineering	-Water Resources Engineering -Hydrology and Hydrogeology -Hydraulics	3	30

2.4.2 Training in Water Monitoring and Environment Management

2.4.2.1 National Training Programs

Assessment indicated presence of both technical and informal training in Uganda. However, the study showed that training in water and environment monitoring and management was available only in universities and technical institutes and the course modules/units were limited in scope to academic levels of the courses. The courses do not address issues concerning practical water resources and quality management like water quality monitoring and assessment for various objectives, management of shared water resources and conflict resolution and water pollution control. With their present course modules and schedules, training institutions were found to be lacking the capacity to offer water quality training on full time or part time basis because of their tight academic programs. Whereas government departments and parastatals like DWD, WRMD, NWSC, WID, PHD and NEMA had programs for water quality monitoring, each of them had specific objectives, which addressed issues within their responsibilities e.g. regulatory, compliance and process control. The aspect of training in all these institutions was geared towards capacity building of their staff to handle internal responsibilities other than management of the water resources and the environment. A few community awareness programs made by WID mainly addressed 'wise-use' of the wetland resources and scantly touched on water uses and pollution. However, these were carried out under time bound projects and were not sustainable after THE end of project periods. DWD once held a training of some district and urban engineers/water officers in water quality monitoring. However, the monitoring currently done only looks at a few water quality parameters for drinking and domestic uses e.g. pH, electrical conductivity, total dissolved solids, turbidity and faecal coliforms. NWSC carried out training of a few industrialists, under the Lake Victoria Environmental Management Project (LVEMP) – Industrial and Municipal Waste Management Component. The training specifically addressed industrial effluents quality monitoring and has not been sustainable after the end of the first phase of the LVEMP. PHD trained Public Health Inspectors in carrying out water quality analysis of drinking water sources, however, the objective of the monitoring was tailored for public health monitoring in relation to water sources as such parameters tested were limited to pH, electrical conductivity, total suspended solids, turbidity, colour and faecal coliforms. District local government staff have received training in water quality monitoring through water quality division, NWSC, AMREF, Ministry of Health – Environmental Health Division (EHD).

Generally, the status of training in water and environment monitoring in the country is aimed at addressing academic requirements and specific departmental responsibilities. It is therefore, deficient in both human resource capacity and facilities as such requires to be developed so as to address a wide spectrum of objectives concerning water quality monitoring and resource management, water pollution control, shared water resources management and conflict resolution, trans-boundary basin water quality management, and community awareness & participation in water resources management. Training needs to be designed to address and benefit various levels of stakeholders in the country, which mainly include communities, schools and institutions. It is important to train communities and teach school children basics about water and environment management because they are the major direct users of water resources and yet are not aware of the impacts of their activities on the resources and the environment in general. Community pathways of water pollution and environmental degradation are diffuse in nature and therefore difficult to mitigate. Whereas it is equally important to train stakeholders like industrialists and municipal authorities, their pathways of pollution can easily be tracked and appropriate mitigation measures adopted because they are point sources. Training of the latter may equally be simpler because it can be specifically designed to address point sources of pollution, whose quality and quantity of pollutants are known. Training at higher institutions of learning is important in grooming technocrats and managers in the fields of water resources utilization and environmental pollution control and management. The technocrats are mainly responsible for the aspects of planning, rational utilization, monitoring, management of the water resources and the environment, and appropriately advise the policy makers. Uganda has inadequate capacity in terms of technical professionals and facilities to sufficiently undertake quality monitoring and assessment of Nile Basin programs. This is because a good percentage of the few professionals available are engaged in government departments and other non governmental organizations (NGOs) programs leaving mainly fresh university graduates who still need specific training and experience in water quality management.

2.2.4.2 Training through the Capacity Building Component of the LVEMP-1

i. Objectives of the Program were:

- to strengthen the human resource capability and capacity of various participating components and strengthen facilities for training and analysis in 3 national universities in the region;
- to provide solutions to environmental problems through research; and
- to develop and conduct short courses for training of component staff.

ii. Implementing Universities

Moi University in Kenya;
Makerere University in Uganda; and
Dar es Salaam University in Tanzania.

iii. Formal Training Sponsored by LVEMP- 1 for Uganda

These included the following:

Ph.D.	Masters	Bachelors	Diplomas	Short courses	Total
14	20	0	18	1108	**1160**

The Capacity Building Component of the LVEMP-1 Project has had the following specific impacts.

- Facilitated students to deal with and answer some questions concerning fisheries management and conservation;
- Generated baseline data necessary for future research and accumulated information to help guide planning and activities necessary for rational management, wise use, and management;
- Created opportunities for experimenting and piloting conservation and development activities in order to test and harmonize scientific ideas and concepts as well as improving existing legislation, monitoring, mitigation, enforcement and strengthening service delivery mechanisms;
- Awareness creation through meetings, seminars, radio spots and talk shows, billboard and posters which led to formation of several community based organizations (CBOs) exclusively focusing on the conservation of Lake Victoria;
- Many policy makers and the public are now aware of the need to protect Lake Victoria as a resource. The resources of the LVB are now better known and can be prioritized for protection and some districts within the LVB have used the information gathered for production of their district development plans;
- There has been knowledge upgrading through various courses which has led to supportive staff having broadened and strengthened their grip on technical knowledge in various aspects on the lake environmental conservation and natural resources management;
- Publications and scientific reports from LVEMP-I research work by thesis and other forms indicate increased human capacity at the highest technical and professional levels. A number of posters, brochures, research reports and theses/dissertations, seminar proceedings and journal publications were produced through LVEMP I.

The following illustrate Lessons Learnt from the LVEMP Capacity Building program specific to Uganda

a) *New courses*

Before the intervention of LVEMP, there was only one M.Sc. course in fisheries. As a result other components sent their students abroad for other better courses in fisheries because the Zoology dept could not handle them. Therefore LVEMP could target or orientate its funding in the next phase at introducing those courses that the components had to look for from other countries, into the zoology dept of Makerere University. This would reduce the cost that the component incurred and as a result may have more students trained. The cost of one student abroad could cater for two or more students within the country. At the same time, this would benefit the dept and the university as a whole both financially (e.g. from school fees payment) and also technically (more lecturers and trained personnel in the Department).

b) *Local and International Academic Linkages*

The Zoology Department had a student (Gladys Bwanika) who did her course in Makerere but only went to the outside university for sample testing. This reduced the cost of her having to have studied abroad full time. Honorary lecturers acting as supervisors and also their hosting institutions providing facilities otherwise unavailable to the home institution facilitated this. Therefore this method is encouraged for replication in future programmes.

c) *Private Sector Linkages*

The public Private partnerships and linkages were realized. Through LVEMP, the linkage between the academic world and the private sector was established. The zoology dept was able to link up with the private sector under the LVEMP intervention. The dept offered lab services to the private sector at a fee and so was able to realize income but also provide the otherwise equally required service to the private sector. It was realized that there is a very high demand for fish fries by the private sector hence need for training in their handling.

d) *Knowledge upgrade*

The introduction of the new B.Sc. course in fisheries and aquaculture has attracted more students thn can be handled. This is a sign that program could target more modern courses in fisheries.

e) *Marketing*

In the past, Makerere University used to advertise its intake through the print media and those would reach a limited number of the public. However, under LVEMP intervention, the Department used radio spot messages in both English and local languages which attracted so many students in the Department. Therefore, the lesson is that there is need to change the advertising methods in the academic world. Another lesson is that this type of advert was pro-poor because most poor people and remote areas in the country do not have access to the print media but have access to radios.

f) *Publications:*

Several publications, research papers and conference presentations were produced during the LVEMP I. The project supported the production of one book on “*introduction of aquatic science in lower secondary schools*” that has created positive impacts and generated interests on the aquatic science amongst younger science based students.

g) Level of training success:

More success was realized at training M.Sc. than Ph.D. students. This was because M.Sc. Were junior employees while most Ph.D. students were senior employees of their Respective components and had therefore more responsibilities than M.Sc. Students.

h) Short-term in-service training

The potential for training using workshops and seminars is high for personnel in the fisheries sector fields. These include private managers in fisheries and fish processing.

i) Multiplier effect

Training resulted into several areas. These included introduction of a new BFA course in Fisheries and aquaculture and writing of teaching manuals and research publications.

j) Building institutional capacity:

The institutional support provided by the project to department of Zoology has enhanced its capacity to admit and train more undergraduates and postgraduates in areas relevant to Lake Victoria Management. For instance the component benefited from refurbished and well equipped laboratory and aquarium, internet services and vehicle as well as other consumable items. It is necessary that continued efforts and financial assistance be provided to maintain such expensive and valuable facilities. This development have enabled the department to advertise and admit more self sponsored students and generate good income from their fees.

2.5 Deficiencies of the present water quality monitoring system

i. The water quality monitoring objectives are not fully integrated with the environmental aspects of the National Water Policy, Regional Policies or other related policies and environmental responsibilities. Water quality data are not applied by water managers as performance indicators in addressing, national and international environmental concerns.

ii. The present water quality monitoring programs have been designed independent of each other thus creating a major deficiency in identification of overlaps and/or essential gaps that may exist within logical boundaries that could be defined by water management regions, gazettements, municipalities or land use. There is inadequate coordination between monitoring programs, which creates deficiency in planning, optimizing funding, materials and human resources for implementation.

iii. There is inadequate and insufficient information base because of the very low performance of the current water quality monitoring program. This is because of lack of integrated planning coupled with deficiencies in institutional capacities in terms of financial, technical and human resources.

iv. There is hardly any water quality monitoring programs at decentralized district level. A majority of the approx. 22 million persons in the rural areas depend on water sources whose quality is neither controlled nor monitored (*NWQMS, Sept 2006*).

v. There is insufficient awareness among the stakeholders on water quality monitoring and their roles in the management of the water resources. Priority is often given to infrastructural development of water supply facilities but minor consideration is given to water quality issues and pollution control and management.

vi. There is no harmonized or standard protocols right from water sampling, analysis up to data processing, and this has contributed to unreliable data. Professional, skilled and experienced manpower and analytical services are centered around the capital far away from where services are needed. There are hardly any local programs in place to address immediate water quality issues.

vii. There is poor information exchange and dissemination in water quality aspects among specialists, institutions and stakeholders resulting in poor coordination of programs and utilization of resources.

Programs should therefore be designed and implemented to address water resources management and quality monitoring issues from community, district, schools and institutional levels. The training modules which have been designed in this study will address the capacity building deficiencies of the current programs.

3.0 PROPOSED TRAINING MODULES

3.1 Introduction

Rivers and lakes are very important freshwater resources for the socio-economic development of the people. The country is richly endowed with freshwater resources, which include open waters like Lakes Victoria, Kyoga, Albert, George, Edward and various other smaller lakes; rivers like the Nile, Katonga, Kagera, Kafu, Aswa, Sezibwa, Sio, Malaba and groundwater aquifers. Of the country's surface area of approximately 241,500 km^2, 15% is open waters while 12% is permanent and seasonal wetlands. The country receives annual rainfall of 500–2500 mm annually.

Good clean freshwater provide services for drinking, livestock and commercial water supply; agriculture and irrigation; tourism; industrial and municipal waste disposal; transportation, fisheries, boating, recreation; climate modulation; ecosystem maintenance and aesthetics. All the water resources of Uganda fall within the Nile Basin. The water resources of Uganda are, therefore, bound by a number of agreements and conventions on international waters some of which are ratified and others are not.

The quality of waters received in Uganda is greatly impacted on by activities in the four upstream countries as well as activities within Uganda itself. The current trans-boundary water quality issues include sedimentation, agro-chemicals pollution, toxic heavy metals, micro-biological contamination, eutrophication and atmospheric deposition. These aspects of water quality pollution are expected to increase both qualitatively and quantitatively and get more complex with increasing populations, urbanization, industrialization, agricultural modernization, mining and social activities.

There is therefore a need for a network of river and lake monitoring stations to:

- establish short and long term fluctuations in water quantity, quality and climate characteristics;
- determine water quality criteria needed for optimization and maintenance of water uses;
- determine impacts of water use, demographic changes and other socio-economic and industrial uses.

To undertake the above monitoring activities, it is necessary to have properly trained man power at national, district and community level. This man power also needs to be adequately equipped and facilitated to carry out the monitoring. The following training modules are therefore proposed for several categories of stakeholders:

Universities,
Technical Institutions and Colleges of higher learning,
District Technical staff
Communities including Sub county chiefs, Local Council Chairmen and Secretaries for Environment, NGOs and CBOs.

3.2 Objectives

The Objectives of the training program / modules are:

- to create awareness of the importance of freshwater resources in the country and within the region and the need to keep these resources in good quality;

- to train high caliber professional staff at universities to undertake water quality evaluation, interpretation of water quality, its pollution levels, policies, laws, regulations and standards on water quality;

- to train middle level caliber of technicians in technical institutes and colleges to conduct field water monitoring, water sample collection, analysis of water quality characteristics and contaminant levels;

- to train various categories of stakeholders at district level to monitor the quality of water and levels of pollution;

- to create an array of concerned and capable stakeholders at community level to be field scouts to undertake preliminary observation and reporting of water quality, pollution and contaminant risks in rivers and lakes;

- to identify key water quality parameters of cross-border and trans-boundary significance to be monitored;

- to design a Quality Assurance Program to be applied both at the national and trans-boundary levels.

3.3 Justification for the Training Program

Water quality testing and monitoring capacity exists both in government institutions and in some private sector laboratories but sustained professional training in water quality monitoring is lacking or inadequate. Training in water and environment monitoring and management is available only in universities with courses being limited in scope to academics. In departments and other institutions, training has been aimed at addressing specific departmental responsibilities since these institutions have tight academic programs. Hence, their courses do not address practical issues in water resources management and monitoring, water quality and quantity monitoring and assessment, management of shared water resources, national policy, legal and institutional setting, regional and international obligations, conflict resolution and water pollution control. These institutions lack capacity to offer water quality training on full time basis.

3.4 PROPOSED TRAINING MODULE FOR UNIVERSITIES

Basic Entry Requirements- University Entry Requirements with ‘A’ Level Science Subjects in Biology, Chemistry, Physics, Geography
Basic Course Units – 3, one each in First Year, Second Year and Third Year
Expected Award- B.Sc. Degree;
B.Sc. Forestry;
B.Sc. Natural Resource Management;
B.Sc. in Wildlife;
B.Sc. Fisheries;
B.Sc. Engineering.

Topic/Course Unit	Course Content	Academic Year	Course Work - Duration	Field Work- Duration
1. Basic Natural Resource amd Data Management	1. Introduction to Basic N/R of Africa, East Africa and Uganda; 2. Introduction to Basic N/R Management; 3. Introduction to Water Resources of the region- value and uses, extent, resources, threats; 4. Eco-toxicology 5. Biological water quality monitoring 6. Limnology 7. Introduction to Environment Management 8. Introduction to Water Resources Management; 9. Introduction to Environment Impact Assessment and Audits- Principles. 10. Data management and reporting of results	1st Year	4 Weeks in Second Semester	2 Weeks in Second Semester
2. Basic Pollution Control and Management	1. Impacts of various industrial effluents on water; 2. Impacts of domestic wastes on water; 3. Solid waste management 4. Impacts of agricultural practices on water quality; 5. Public health and sanitation;	2nd Year	6 Weeks in Second Semester	2 Weeks in Second Semester

	6. Water quality analysis procedures 7. Water flow measurements; 8. Ugandan Natural Resource Management Policies, Laws and Institutions; 9. Ugandan Pollution Control Legislation; 10. Regional and International Conventions and Protocols for Environment Management and Transboundary Waters; 11. Dams, Reservoirs and Lake water quality management; 12. River basin and catchment management; 13. Rural water supply and sanitation. 14. Environmental standards, Guidelines and Regulations			
3. Basic Hydrology and Sanitation	1. Hydrology, 2. Hydrogeology, ground water, 3. Hydraulics, 4. Water treatment and Supply; 5. Wastewater treatment, collection and disposal; 6. Sanitation and drainage. 7. Sediment monitoring 8. Water quality management; 9. Public health and sanitation; 10. Sanitation and drainage; 11. Dams, Reservoirs, Lake and River water quality Management.	3rd Year	6 Weeks in First Semester	2 Weeks in First Semester

Required Training Materials

These include the following:

Well equipped water Laboratory,
Field water testing kits,
Water flow meters,
Cooled sample carriers,
Computers with Modeling and GIS packages,
Water engineering workshop,
Adequately stocked departmental libraries and
4 WD Field Vehicles.

3.5 TRAINING MODULE FOR TECHNICAL INSTITUTES AND COLLEGES OF HIGHER LEARNING

Basic Entry Requirements- 'A' Level Science Subjects in Biology, Chemistry, Physics, Geography
Basic Course Units – 3, one each in First Year, Second Year and Third Year
Expected Award- Diplomas in Forestry, Natural Resource Management, Wildlife Management, Fisheries, Health and Engineering.

Topic/Course Unit	Course Content	Academic Year	Course Work - Duration	Field Work- Duration
1. Basic Natural Resource and Data Management	1. Introduction to Basic N/R of Africa, East Africa and Uganda; 2. Introduction to Basic N/R Management; 3. Introduction to Water Resources of the region- value and uses, extent, resources, threats; 4. Eco-toxicology 5. Biological water quality monitoring 6. Limnology; 7. Introduction to Environment Management 8. Introduction to Water Resources Management; 9. Introduction to Environment Impact Assessment and Audits- Principles. 10. Data management and reporting of results	1st Year	4 Weeks in Second Semester	2 Weeks in Second Semester
2. Basic Pollution Control and Management	1. Impacts of various industrial effluents on water; 2. Impacts of domestic wastes on water; 3. Solid waste management 4. Impacts of agricultural practices on water quality; 5. Public health and sanitation; 6. Water quality analysis procedures 7. Water flow measurements; 8. Ugandan Natural Resource Management Policies, Laws and Institutions; 9. Ugandan Pollution Control Legislation; 10. Regional and International Conventions and Protocols for Environment Management and Transboundary Waters; 11. Dams, Reservoirs and Lake water quality management; 12. River basin and catchment management; 13. Rural water supply and sanitation. 14. Environmental standards, Guidelines and Regulations	2nd Year	6 Weeks in Second Semester	2 Weeks in Second Semester
3. Basic Hydrology and	1. Hydrology, 2. Hydrogeology, ground water, 3. Hydraulics,	3rd Year	6 Weeks in First Semeste	2 Weeks in First Semeste

Sanitation	4. Water treatment and Supply; 5. Wastewater treatment, collection and disposal; 6. Water quality management; 7. Sediment monitoring 8. Public health & sanitation; 9. Dams, Reservoirs, Lake and River water quality management; 10. Sanitation and drainage.		r	r

Required Training Materials

These include the following:

Well equipped water Laboratory,
Field water testing kits,
Water flow meters,
Cooled sample carriers,
Computers with Modeling and GIS packages,
Water engineering workshop,
Adequately stocked departmental libraries and
4 WD Field Vehicles.

3.6 TRAINING MODULE FOR ADVANCED LEVEL SCHOOLS

NEW ‘A’ LEVEL COURSE WHICH COULD BE CALLED “ WATER RESOURCES MANAGEMENT”

Basic Entry Requirements- ‘O’ Level Subjects Qualifying for ‘A’ Lev el

Expected Award- ‘A’ Level Certificate

Topic	Course Content	Academic Year	Course Work - Duration	Field Work- Duration
1. Basic Natural Resource and Data Management	1. Introduction to Basic N/R of Africa, East Africa and Uganda; 2. Introduction to Basic N/R Management; 3. Introduction to Water Resources of the region- value and uses, extent, resources, threats; 5. Introduction to Environment Management 6. Introduction to Water Resources Management; 7. Data management and reporting of results	Senior 5	4 Weeks	1 Week
2. Basic Pollution Control and Management	1. Impacts of various industrial effluents on water; 2. Impacts of domestic wastes on water; 3. Solid waste management 4. Impacts of agricultural practices on water quality; 5. Public health and sanitation; 6. Water flow measurements; 7. Water quality and basic quality parameters; 8. Biological water quality monitoring 9. Water quality analysis and testing procedures; 10. Interpretation of water quality test results; 11. Ugandan Natural Resource Management Policies, Laws and Institutions; 12. Ugandan Pollution Control Legislation; 13. Regional and International Conventions and Protocols for Environment Management and Transboundary Waters.	Senior 6	6 Weeks	2 Weeks

Required Training Materials

These include the following:
Well equipped water Laboratory,
Field water testing kits,
Water flow meters,
Cooled sample carriers,
Computers with Modeling and GIS packages,
Adequately stocked departmental libraries and
School Bus

3.7 TRAINING MODULE FOR ORDINARY LEVEL SCHOOLS

NEW ‘O’ LEVEL COURSE WHICH COULD BE CALLED ‘’ WATER RESOURCES MANAGEMENT”

Basic Entry Requirements- ‘P7’ Passes which qualify students to ’O’ Level

Expected Award- ’O’ Level Certificate

Topic	Course Content	Academic Year	Course Work - Duration	Field Work- Duration
1. Introduction to Basic Natural Resource and Data Management	1. Introduction to Basic N/R of Africa, East Africa and Uganda; 2. Introduction to Basic N/R Management; 3. Introduction to Water Resources of the region- value and uses, extent, resources, threats; 5. Introduction to Environment Management 6. Introduction to Water Resources Management; 7. Data management and reporting of results	Senior 3	4 Weeks	1 Week
2. Introduction to Basic Pollution Control and Management	1. Impacts of various industrial effluents on water; 2. Impacts of domestic wastes on water; 3. Impacts of agricultural practices on water quality; 4. Public health and sanitation; 5. Solid waste management 6. Water quality and basic quality parameters; 7. Water quality analysis and testing procedures; 8. Interpretation of water quality test results; 9. Simple water flow measurements; 10. Ugandan Natural Resource Management Policies, Laws and Institutions; 11. Ugandan Pollution Control Legislation; 12. Regional and International Conventions and Protocols for Environment Management and Transboundary Waters.	Senior 4	6 Weeks	2 Weeks

Required Training Materials
These include the following:
Well equipped water Laboratory,
Field water testing kits,
Water flow meters,
Cooled sample carriers,
Computers with Modeling and GIS packages,
Adequately stocked departmental libraries and School Bus

3.8 TRAINING MODULE FOR COMMUNITIES

NAME OF COURSE - WATER RESOURCES MANAGEMENT

Basic Entry Requirements- 'O' Level Passes

Expected Award- Certificate of Attendance

Topic	Course Content	Course Duration In Minutes
1. Introduction to Natural Resources	1. Natural Resources of Uganda…………………………………... 2. Forest Resources……………………………………………….. 3. Fisheries resources……………………………………………... 4. Wildlife resources and National Parks…………………………… 5. Mineral resources……………………………………………….	30 30 30 30 30
2. Introduction to Water Resources	1. Lakes, Rivers and Wetlands of Uganda…………………………. 2. Types of water sources………………………………………. 3. Water uses…………………………………………………….	30 30 30
3. Introduction to Environment Management	1. The hydrological cycle…………………………………………… 2. Water – sheds and Basins………………………………………… 3. Life in water……………………………………………………. 4. Ugandan Natural Resource Management………………………… Policies, Laws and Institutions………………………………….. 5. Legislation and policies on water 6. Community, legislation and legal actions………………………… 7. Introduction to Environment Impact Assessment for Activities with potential Impacts on water bodies…………………………. 8. Women and water source management …………………………. 9. Field work Organization, Recording, and Reporting…………….	30 30 30 30 30 30 30 60 30 30
4. Introduction to Basic Pollution Control and Management	1. Introduction to water pollution…………………………………… 2. Sources of pollution………………………………………………. 3. Types of pollution………………………………………………… 4. Pollution control……………………………………………….. 5. Soild waste management 6. Impacts of various industrial effluents on water…………………. 7. Impacts of domestic wastes on water…………………………….. 8. Impacts of agricultural practices on water quality……………….. 9. Water, Public health and sanitation……………………………… 10. Water quality and basic water quality parameters………………..	30 30 30 30 30 30 30 30 30 30

5. Field Work	11. Biological indicators of water pollution 12. Ugandan Pollution Control Legislation…………………………. 13. Regional and International Conventions and Protocols for Environment Management and Transboundary Waters…………………………………………… 14. Role of communities in management of water bodies and facilities………..………………………………………………… Visit to neighbouring sites of water pollution concern	30 30 5 Hours
	TOTAL DURATION OF COURSE	**3 DAYS**

Required Training Materials:
Transport and Stationary

4.0 WATER QUALITY ASSURANCE

Quality assurance (QA) refers to a wide range of practices applied to ensure that laboratory analytical results are reliable. Reliability of data for water quality monitoring programs depends on close adherence to the full range of the operating procedures for sampling, sample storage, preservation, analysis and reporting of results. Therefore, Quality Assurance may be defined as a system of documentation and cross referencing management procedures of a laboratory. QA aims at having clear and concise records of all procedures which have bearing on the quality of data so as to ensure that quality is maintained through monitoring of these procedures.

Laboratory analytical quality assurance (AQA) should start with the examination and documentation of all aspects of its management. This calls for clear identification of lines of responsibility and communication, description and documentation of all procedures and documentation of analytical instructions and instrumental checks. There should be specific control and assessment procedures designed to monitor quantitatively the accuracy and precision of specific tests. AQA should be based on a system of traceability and feedback. Traceability enables all steps in a procedure to be checked, whenever possible, by referring to documented results, calibrations, standards, calculations, etc. Feedback is the mechanism through which problems or omissions in the system can be brought to the attention of the laboratory management. Should standards in the laboratory fall below acceptable limits then procedures should ensure that this is easily recognized and corrected. Clear and documented criteria for recognition and correction of poor performance and responsibilities for corrective action have to be identified and their procedures established.

QA is basically a management system which deals with the general running of a laboratory but does not necessarily focus on individual analysis. QA achieves its objectives through establishment of protocols and quality criteria for all aspects of laboratory work and providing a framework for effective internal quality control (IQC) and external quality control (EQC) programs.

4.1 Implementation of Quality Assurance

A well implemented AQA demonstrates the standard to which the laboratory is working and ensures that this standard is effectively monitored and provides means for the correction of any deviations from the standard. The sole objective of QA system, therefore, is to ensure efficient and effective functioning of the laboratory. There are evident benefits that can be realized from an effectively implemented QA system, which include increased reliability of analytical results because any sources of analytical problems can be quickly identified and corrected, clear understanding and adherence to responsibilities and assignments by staff, easier human resource management through clear lines of communication, and prompt identification of developing problems with equipment through planned and documented calibration, maintenance and record keeping. An implementable QA program has in place documented procedures for the following aspects; Management, use of available laboratory facilities, training of staff, maintenance and calibration of equipment, sampling and transportation, analytical work instructions, sample receipt/storage/disposal and reporting of results.

4.2 Laboratory Management

Comprehensive management documents, which describe in detail management structure of a laboratory is one of the most vital components of the QA program. Management documents should specify the role of QA in the laboratory and clearly define individual roles and activities. Within the structure each member of staff should be able to locate their own job description, responsibilities and relationship with other staff members. The documents should also identify the records of routine operations that should be kept to ensure that a logical and coherent system of record keeping is established. This documentation should be put together as a single Quality Manual, which will be use as a reference text for the QA program.

Proper implementation and management of QA requires appointment of a Quality Assurance Officer (QAO) to liaise with management and his duties should be clearly defined in the management documents. In order for the role of QAO to be effective he/she should be free from management interference yet remain answerable to management for carrying out the assigned duties. Therefore, it is more convenient for the QAO to be in a middle management position so as to allow for effective communication with laboratory section heads. The QAO is responsible for regular inspection of all aspects of the system; checking facilities, procedures, data archives, staff compliance, ensures reporting of inspections, audits and recommending improvements to management.

4.3 Laboratory Facilities

Management policy should ensure that laboratory facilities are available prior to commencement of serious analytical work. Essential resources like space, staff, equipment and water & electricity supplies need to be sufficiently available for work of a given volume to be done. Laboratory should be appropriately lit, clean and tidy with enough space for equipment and working environment without risk to personnel or to the analytical samples, and should have sufficient space for storage of apparatus, samples, chemicals and consumables. If facilities restrict the efficient running of the laboratory then appropriate measures should be taken to ensure that this is not cause of non-compliance with the QA system.

4.4 Training of Laboratory Staff

The quality of analytical data produced by a water quality laboratory or monitoring program depends on the quality of work done by the staff. It is, therefore, important that laboratory staff are adequately trained for the tasks that they are to perform. Consequently, laboratories and monitoring agencies usually develop training programs designed to address their needs. The scope of training programs depends of the academic level, previous training & staff experience, range of activities to be handled in the field and in the laboratory and whether the monitoring program is to be done at national or regional laboratories.

Training should be continuing process, therefore, a basic framework of courses, should be developed, for all levels of staff, which should be followed by short courses, seminars and workshops. Training should be documented so that management and other personnel can verify that staff are competent to perform the duties assigned to them. The level of training required for each procedure should be clearly defined to ensure that staff ability and training match procedural requirements. Laboratory criteria for training standards should be clearly documented and should reflect the external criteria which apply i.e.

Criteria for the correct levels of training or competence for particular procedures and job roles are usually specified by national and international agencies, and occasionally by professional associations.

4.5 Sampling

Sampling procedures should be carefully documented, clearly giving details of precautions to be taken while sampling and the sampling strategies to be applied. It is important to ensure that all relevant information pertaining to the sample, e.g. where, when, how and under what conditions it was taken, should be clearly recorded on site during sampling by the person carrying out the sampling. QA of sampling can be achieved through the following:

- Strictly adhering to sampling procedures
- Ensuring that all equipment is in good working state and clean
- Recording all conditions which applied at the time of sampling
- Taking strict precautions to avoid sample contamination
- Ensuring that all sample bottles are clearly marked and their lids tightly closed before packing in the transportation container to avoid mixing them up
- Sample bottles are carefully packed in the transportation container to avoid breakage
- Ensuring that transportation container is sturdy, insulated plastic which protects samples from sunlight and should maintain more or less constant temperature

These simple procedures should ensure that the quality of samples matches the quality of analysis.

4.6 Analytical work instructions

Analytical work instructions (AWI), also known as analytical methods, provide the core of the performance of a laboratory or a monitoring program. Analytical work instructions are documents describing in detail all analysis methods used by a laboratory. AWI employed by a laboratory may include standard, non-standard and laboratory developed methods, and they should meet the requirements of the laboratory or monitoring program. The choice of methods of analysis is critical for ensuring that analytical results meet the laboratory's requirements because different methods have different precisions and sensitivities and are susceptible to potential interferences. Therefore, any analytical method should be properly validated before it is adopted and put into routine use by the laboratory. Method validation can be performed using the following experiments:

- Linearity: Determine calibration points and draw a linear response curve. If the curve is not linear then there is need to investigate linear transformation of the data
- Limit of detection: Determine the lowest concentration of variable that can be distinguished from zero with 95% confidence
- Precision: Perform coefficients of variation within day and between days at three concentration levels
- Accuracy: Analysis of reference materials with known concentration (certified reference materials) of the variable or by comparison of analyses with existing methods in other laboratories.

Internal Quality Control (IQC)

This comprises operational techniques that should be used by the laboratory analysts for continuous assessment of the quality of results of each analytical method. It mainly focuses on monitoring precision but to a lesser extent accuracy and emphasizes quantification of the two. IQC should focus on individual methods and test their performance against mathematically derived quality criteria.

A summary of the IQC program recommended by the GEMS/Water (*GEMS/WATER Operational Guide*) is given below.

For each variable:

i) Analyze five standard solutions at six different known concentrations over a working range to develop a calibration curve or, when a calibration curve already exists, analyze two standard solutions at different known concentrations over the working range to validate the existing calibration curve.
ii) Analyze one method blank per set of 20 samples.
iii) Analyze one field blank per set of samples.
iv) Analyze one duplicate of a sample chosen at random from each set of up to 20 samples, and interpret using the upper concentration method.
v) Analyze one specimen that has been spiked with a known amount of the variable as a recovery check. The specimen should have a matrix similar to those of the samples being processed.

Corrective action must be taken if any of the quality control procedures indicates that a method is out of control or that there is a problem. The major checks to carry out include calculations and records, standard solutions, reagents, equipment and quality control materials.

External Quality Control (EQC)

This is a way of establishing the accuracy of analytical methods through comparing of results of analyses carried out in one laboratory with the results obtained by others participating in the same analysis of the same test material. This is usually achieved by one laboratory, the reference laboratory, sending out sets of samples of known and unknown concentrations of variables to all the participating laboratories. Each participant analyses the samples for requested variables and reports the results to the reference laboratory. The overall objective of EQC is to assess the accuracy of analytical results measured in participating laboratories and to improve inter-laboratory comparability.

The EQC reports should clearly indicate whether performance is satisfactory or not; and if not two check actions must be done:

i) The defective analysis should be examined to determine cause of poor performance and the problem rectified.
ii) The IQC program that allowed the deterioration to progress without check should be closely investigated to establish source of inadequacies and the defects corrected.

4.7 Sample receipt, storage and disposal

It is important to ensure that handling of samples through the laboratory quality system is fully documented because proper storage of samples prior to analysis is as important as proper sampling. Therefore, procedures for sample handling should ensure that the sample is not compromised and minimize its deterioration. The condition of a sample, its storage location and analyses required should be recorded. Sub-sampling or splitting of a sample for different storage conditions and/or pretreatment to enhance stability should be recorded and the samples clearly and uniquely labeled to ensure that no confusion may occur about the source and identity of any sample.

The arrangements for sample disposal are equally important and should be done when the sample exceeds its stable storage time. Special analysis like for regulatory or legal purposes require safe storage of a substantial aliquot of sample, for a given time, to allow for re-examination if need arises.

4.8 Reporting of results

Interpretation and reporting of analysis results is the ultimate goal of the laboratory or a monitoring program. It is therefore, crucial that a lot of emphasis is put into ensuring and ascertaining that data generated is suitable for use in an assessment. The initial step in this process is examining of data to determine whether the results are good enough for reporting. This should be done at various stages in the QA system and no data should be reported from analyses that do not pass the internal and/or external quality control checks.

When data has been checked and is ready for reporting, it is important to ensure that it is reported accurately and in away that enables interpretation. All the information that may be vital for data interpretation, like nature of the sample or method of analysis, should be available to the reporting analyst. Reports should be made according to set procedure and should accurately reflect findings of the study including reference to all calibration, quality control data and any problems encountered in the course of the study. All reports should be closely checked and counter signed by more than one person but automatic signing of reports with minimal checking must be avoided.

4.9 Equipment maintenance and calibration

All equipment should be regularly maintained in accordance with documented procedures of the laboratory and as may be out lined in the manufacturers' users manual.
The laboratory should apply standards which are within recommended limits for the care of particular type of equipment. Care and cleaning of equipment is very important in ensuring quality. Frequent checks on the reliability of equipment should be performed, and this includes calibration checks on all relevant equipment depending on the stability of the equipment in concern. Equipment calibration and maintenance records should be kept to allow for monitoring of the repair status of each of the apparatus. This reduces the chances of malfunctioning equipment to be used for analysis, which would lead to poor analytical results, and it also allows for prompt diagnosis and correction of any problems.

4.10 Checking compliance with the quality assurance system

In order to maintain the quality assurance it is necessary to check periodically each area of the laboratory for compliance with the to QA systems. This involves auditing of the component parts to asses whether they continue to meet the original set criteria. As with any other aspect of quality assurance the procedures to be adopted for checking compliance should be formally documented. Reports on the audits should be made available to management, and to the individuals responsible for the work. Deviations from required standards must be corrected immediately. The audit should be extensive and systematic so as to test every part of the system. These audits are better done with prior knowledge of the implementers so as to give them chance double check areas of possible non-compliance. The audit should be independent, hence the need for quality assurance officer who reports directly to the highest level of management.

5. 0 CONCLUDING REMARKS

i. Government departments and parastatals e.g. DWD, WRMD, NWSC, WID, PHD and NEMA had programs for water quality monitoring, but each with specific objectives within their responsibilities like regulation, compliance and process control;

ii. The monitoring currently by DWD looks only at a few water quality parameters for drinking and domestic uses e.g. pH, electrical conductivity, TDS, turbidity and faecal coliforms;

iii. Generally, the training in water resource management and monitoring in Uganda is insufficient in both human resource capacity and facilities;

iv. There is inadequate capacity in terms of technical professionals and facilities to undertake full time water quality monitoring and assessment of Nile Basin programs as many of the few professionals available are engaged in other departmental activities;.

v. Training requires to be developed so as to address a wide spectrum of objectives concerning water quality monitoring and resources management, water pollution control, shared water resources management, conflict management, trans-boundary basin water quality management and community awareness and participation in water resources management;

vi. Training needs to be designed to address and benefit various levels of stakeholders in the country, which include communities, schools, institutions and local authorities, NGOs, CBOs, Government departments and parastatals;

vii. It is important to train communities and teach school children basics about water and environment management because they are the major direct users of water resources and yet are not aware of the impacts of their activities on the resources and the environment in general;

viii. Training of communities is important and should be designed to address point sources of pollution;

ix. Training at higher institutions of learning is equally important for grooming technocrats and managers in the fields of water resources and environmental management and pollution control.

x. There is need to strengthen and institutionalize national and regional water quality management in curricula of higher learning

x. There are large investments in infrastructure for water and wastewater treatment systems and facilities, which is addressing the issues of safe water supply and disposal of wastewater with environmentally friendly quality. Uganda government is in the process of investing in multi-purpose bulk water supplies which involve inter-basin water transfers to areas with water scarcity (NWQMS, Sept 2006).

xi. There is an established National Water Quality Database, which is undergoing improvement so as to ensure availability of scientific and management information on water and environment national and for regional and international collaboration.

xii. There is need for a national and regional water quality assurance program

xiii. Water quality monitoring procedures need to be harmonized at the sub-regional and regional levels.

6.0 REFERENCES

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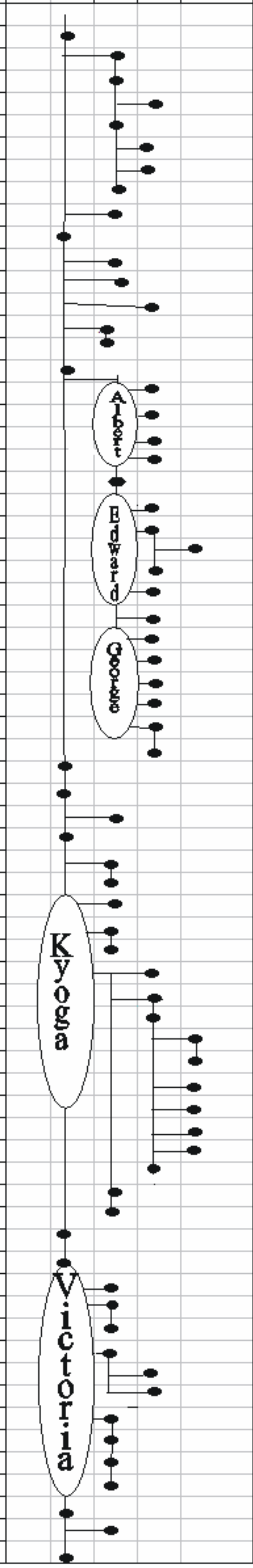
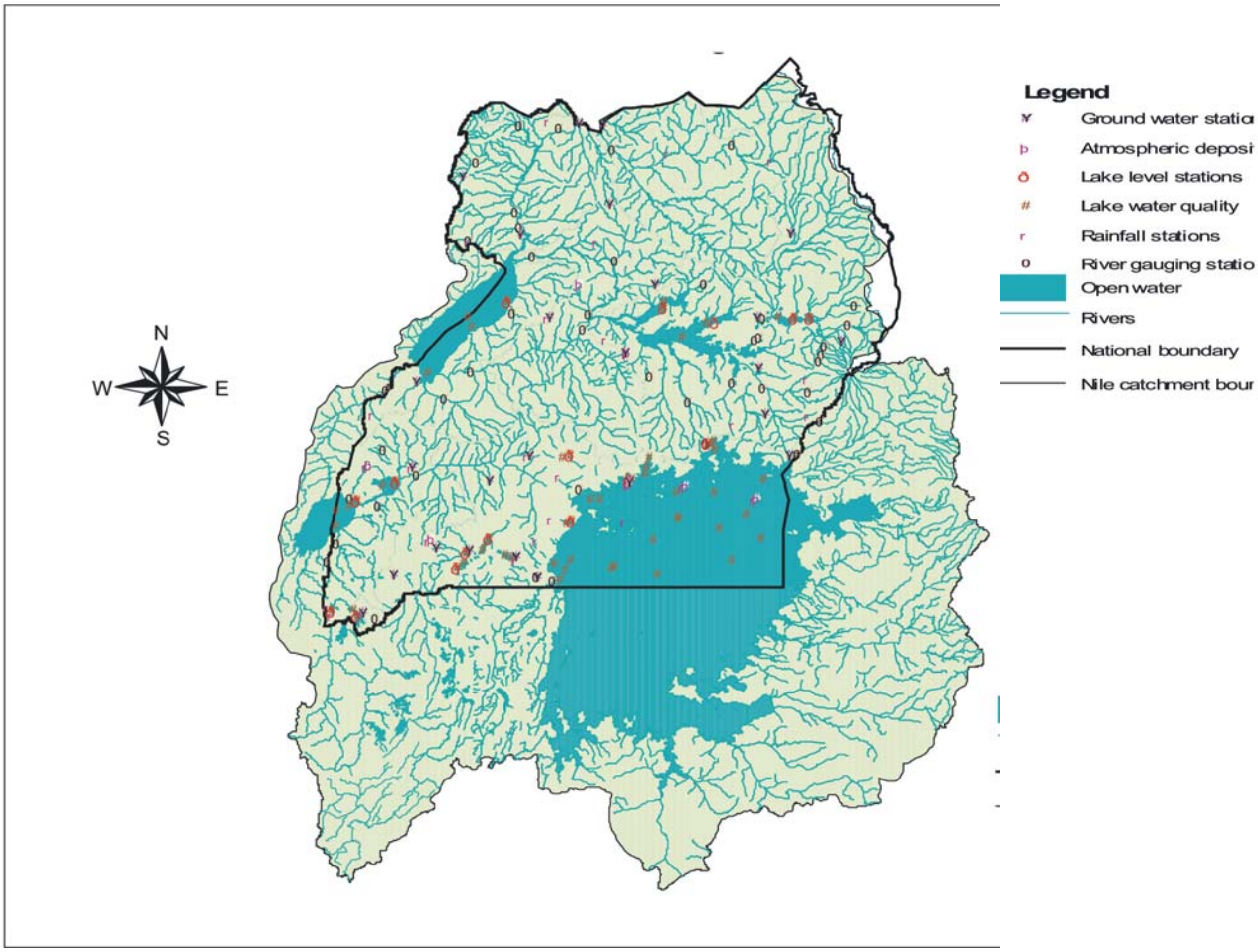
APPENDIX 1: HYDROLOGICAL TREE FOR UGANDA

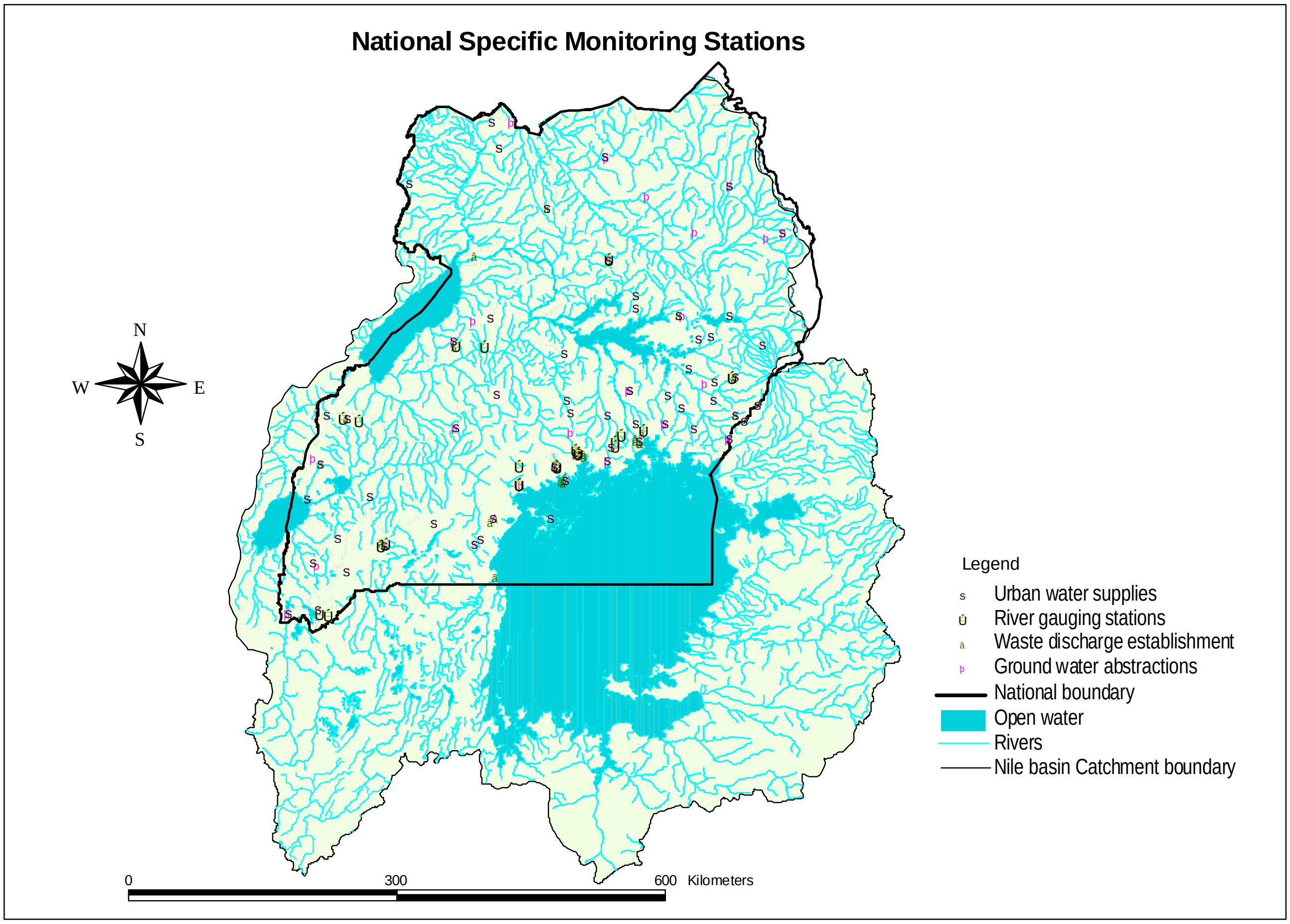


	1	2	3	4	Order	STN-NO	LAKE / RIVER	LAT	LONG	Area of st. km²	∑ Area km²	Δ Area km²
						Reference stations						
					1	82xxx	Sum of discharge from Uganda			0	528,636	25,173
1					2	862xx	Aswa sudan border	3.5200	32.2000	25,327	503,463	25,327
2					2	862xx	Aswa at Atiak	3.3300	32.3104	24,899	478,135	24,899
3					3	1`	R. Pager	3.3800	33.4500	6,160	453,236	6,160
4					2	86201	R. Aswa1	2.5833	32.9333	12,236	447,075	12,236
5					3	86213	R. Agago	2.8333	32.9667	4,488	434,839	4,488
6					3	822xx	R. Moroto at Aloi Rd	2.3700	33.2200	#REF!	#REF!	#REF!
7					2	86202	R. Aswa at Agago	2.9500	32.5833	4,959	430,351	4,959
8					2	87207	R. Ayugi	3.3500	32.0500	1,051	425,392	1,051
9					1	87217/221	R.Albert Nile At Laropi	3.5300	31.8000	424,341	424,341	9,038
10					2	87205	R. Kochi	3.5667	31.4333	827	415,303	827
11					2	87208	R.Oru at Arua- Yumbe Road	3.3000	31.1200	1,267	414,477	525
12					3	87206	R.Anyau (Amau)	3.2400	31.1200	742	413,951	742
13					2	87212	R.Ora at Inde-Pakwach Road	2.7167	31.4000	2,718	413,210	2,172
14					3	87218	R.Nyagak at Nyapea	2.4400	30.9500	546	411,038	546
15					1	87222	R.Albert Nile at Panyango	2.6000	31.4300	410,492	410,492	21,045
16					3	85217	R.Waki II	1.7085	31.3777	463	389,447	463
17					3	85214	R. Wambabya	1.5500	31.1100	780	388,984	780
18					3	85212	R.Nkusi	1.1400	31.0200	1,823	388,203	1,823
19					3	85211	R.Muzizi	0.8700	30.7300	2,624	386,380	2,624
20					2	85205	R. Semiliki	0.9500	30.1830	33,682	383,757	23,018
21					3	84228	R Nyamugasani	-0.1200	29.8330	548	360,739	548
22					3	84264	R Ntungwe	-0.5800	29.7200	2,796	360,190	518
23					4	84270	R.Chiruruma	-0.8600	29.7200	178	359,673	178
24					4	84267	R.Mitano	-0.6833	29.7833	2,101	359,495	2,101
25					3	842xx	R. Kaku	-1.1900	29.6005	1,144	357,394	1,144
26					3	84227	R. Chambura	-0.2200	30.1100	664	356,250	664
27					3	84224	R. Rukoki	-0.9000	31.6000	39	355,586	39
28					3	84222	R. Mobuku	0.2700	30.1200	278	355,547	278
29					3	84221	R. Ruimi	0.3800	30.2100	286	355,269	286
30					3	84223	R. Sebwe	0.2600	30.1100	72	354,983	72
31					3	84215	R.Mpanga Ibanda- Kiburara	0.1000	30.4600	4,836	354,911	4,504
32					4	84212	R.Mpanga at Kampala-F/Port	0.6400	30.4000	332	350,407	332
33					1	83209	R.Kyoga Nile at Paraa	2.2800	31.5600	350,075	350,075	3,067
34					1	83206	R. Nile Kamdini			347,008	347,008	5,595
35					2	83212	R.Tochi II at Gulu-Atura Road	2.2400	32.3400	2,248	341,413	2,248
36					1	83203	R.Kyoga Nile at Masindi Port	1.6800	32.0900	339,165	339,165	24,661
37					2	83213	R.Kafu at Kampala-Gulu Road	1.5400	32.0400	16,006	314,505	13,719
38					3	83218	R. Mayanja	0.6753	32.1697	2,287	300,785	2,287
39					2	82220	R. Enget at Bata-Dokolo Road	2.0200	33.2200	100	298,499	100
40					2	82255	R. Sezibwa at kayunga	0.5650	32.8000	3,272	298,398	3,102
41					3	82225	R. Sezibwa at falls	0.3800	32.8700	170	295,296	170
42					2	82253	R. Lumbuye at Kaliro Rd	1.0200	33.4500	1,128	295,126	1,128
43/44					2	82221/22	R. Agu / R. Abuket	1.4685	33.6999	24,549	293,998	664
45					3	82227	R. Kapiri at Kumi-Soroti Road	1.6000	33.7300	23,885	293,334	9,216
46					4	82245	R. Akokorio	1.8600	33.8600	12,715	284,118	12,553
47					5	82239	R. Longiro at bridge on Lira rd	2.9873	34.1000	162	271,566	162
48					4	82228	R. Namalu at Mbale-Moroto R	1.7900	34.5900	39	271,403	39
49					4	82240	R. Sironko	1.2362	34.2570	263	271,365	263
50					4	82241	R. Simu at Mbale-Moroto Road	1.3000	34.2900	178	271,102	178
51					4	82243	R. Sipi at Mbale-Moroto Road	1.3833	34.3000	85	270,924	85
52					4	82231	R. Kelim	1.5980	34.5439	1,391	270,839	1,391
53					2	82254	R. Mpologoma at Tirinyi	0.9700	33.7300	5,922	269,449	3,279
57					3	(82218)	R. Malaba at Kenya border	0.5900	34.0500	1,490	265,017	1,490
58					1	82203	R.Nile, Mbulamuti	0.8354	33.0279	263,527	263,527	579
59					1	81302	L.Victoria at Jinja	0.4167	33.2167	262,948	262,948	183,195
60					2	81269	R. Sio at Lukali	0.2400	34.0000	1,438	79,753	1,438
61					2	81268	Nakivubo Channel II	0.3200	32.5900	39	78,315	39
62					2	81267	Nakivubo Channel I			31	78,276	31
63					2	81259	R.Katonga	-0.0900	31.9500	14,051	78,245	10,768
64					3	81260	Kibimba at Kino Hydrology	0.1887	31.6907	2,263	67,477	2,263
65					3	81216	Kakinga (Index Catchment)	0.1173	31.0520	1,020	65,213	1,020
66					2	81270	R. Bukora	-0.8500	31.4833	7,401	64,194	603
67					3	81233	R. Kibale	-0.6000	31.5300	6,798	63,591	4,720
68					3	81224	R.Ruizi at Mbarara WW	-0.6150	30.6400	2,078	58,871	93
69					3	81272	Ruizi New Water works	-0.6173	30.6172	1,985	58,778	1,985
70					1	81222	R.Kagera at Lake Victoria	-0.9400	31.7500	56,793	56,793	2,108
71					2	81248	R.Nyakizumba	-1.1900	30.1800	425	54,685	425
					1	81222	R.Kagera, Kyaka Ferry, Tz	-0.9400	31.7500	54,261	54,261	54,261

APPENDIX 2: MAP OF UGANDA SHOWING NATIONAL BASIC MONITORING STATIONS



APPENDIX 3: MAP OF UGANDA SHOWING NATIONAL SPECIFIC MONITORING STATIONS



Appendix 4: Field Programs for monitoring various parameters

No	Field Programmes WR Issues	FP1- Surface Water	FP2 – Ground water	FP3 - Lakes	FP4 - Atmospheric deposition
1	Neighbouring Countries	Y	NA	Y	NA
2	Impact Demand of Abstraction	Y	Y	Y	NA
3	Pathogenic Contamination	Y	Y	Y	NA
4	Inadequate Water Quality	Y	Y	Y	NA
5	Ecosystem and Fisheries	Y	NA	Y	NA
6	Pesticide Pollution	NA	NA	NA	NA
7	Eutrophication	Y	NA	Y	Y
8	Other Chemical Pollution	NA	NA	NA	NA
9	LongTermClimaticChange	Y	Y	NA	Y
10	AtmosphericDeposition	NA	NA	Y	Y
11	SuspendedSolids/Erosion	Y	NA	Y	NA
12	SeasonalVariations	Y	Y	Y	Y
13	IntensiveRainsandFloods	Y	NA	Y	Y
14	DemandForHydropower	Y	NA	NA	NA
15	Nitrate Pollution	NA	Y	NA	NA
16	Poor Water Quality - Natural Conditions	Y	Y	Y	NA
17	State of Water Resources	Y	Y	Y	Y
18	Recreation and Tourism	Y	NA	Y	NA

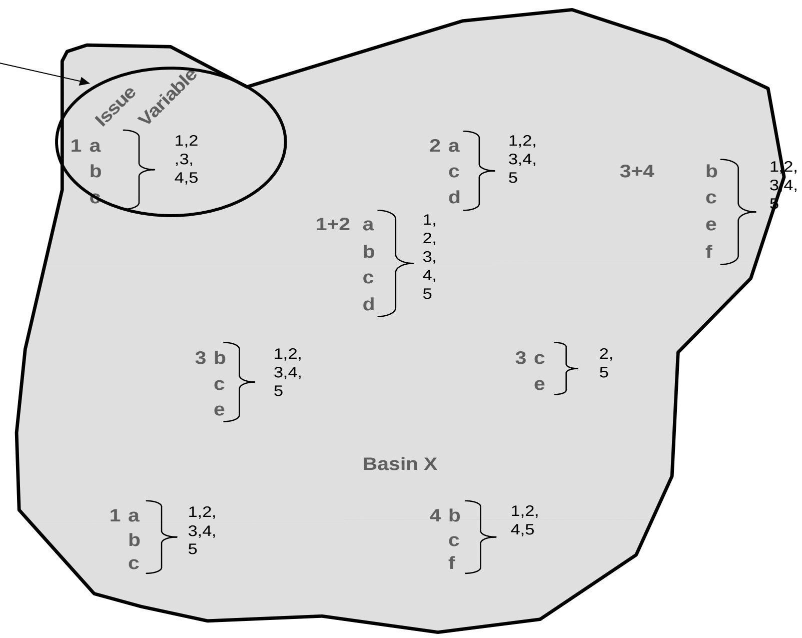
Key: Y = Yes
NA = Not Applicable

No	Field Programs	Water Monitoring Variables		Frequency/Yr	Remarks
		Field Measurements	Laboratory Measrements		
1	FP1 - Surface water	pH, EC, Turbidity, Total Coliform, Faecal Coliforms, Sechi depth,CO_2,DO, Alkalinity, Temperature	Colour, TDS, TSS,LOI, COD, BOD, TN, TP, Si, Chla, Fe, SO4, F, NO3, Cl, NO_2,NH_4, HCO_3,Na,K,Ca,Mg,CO_3, Anionic surfactants, Phenols, Oil and Grease	12	
2	FP2 - Groundwater	Temperature, pH, EC, Turbidity, Alkalinity, Total coliforms, Faecal coliforms, CO_2	Colour, TDS, Fe, CO_3,HCO_3,Na,K, Ca,Mg,SO_4, F, NO_3, NO_2, Cl	4	
3	FP3 - Lakes	pH, EC,DO,Sechi depth, Temperature	TSS, LOI, Chl a,Si,NH_4, NO3, NO2, PO4, TN, TP	4	
4	FP4 - Atmospheric deposition		TN, TP	12	
5	FP5 - Sediment screening		As, Cd, Cr, Cu, Co, Ni, Pb, Al, Zn,Mn, Fe, Hg, Se, Ta, Li, B, Be, Mo, Se, U, V, Ag, S, CN,Aldrin, Atrazine, Azinphos methyl, carbon tetrachloride, chloroform, cyfluthrin, DDT, 1,2 - Dichloroethane, dichor	1	
6	FP6 - Assessments				

Appendix 5: Monitoring Parameters for different water sources

Water resources issues	Activities addressing the issues	Variables to be monitored	Divisions
1	a	1,2,3	MA, WRA, WQ
	b	1,4	WRA, WQ, REG
	c	2,5	REG
2	a	1,2,3	MA, WRA, WQ
	c	2,5	REG
	d	1,4,5	WQ, REG
3	c	2,5	REG
	e	2	MA, WRA
4	b	1,4	WRA, WQ, REG
	c	2,5	REG
	f	1,4	MA, WRA
.	.	.	.
.	.	.	.
.	.	.	.

Water monitoring network (numbers refere to issues, their rel activities and variables monitored at the station



Key: REG = Regulation; WRA = Water Resources Assessment; WQ = Water Quality; MA = Management Assessment

Appendix 6: Monitoring Net work and frequencies