MINISTRY OF WATER AND ENVIRONMENT
THE REPUBLIC OF UGANDA
DIRECTORATE OF WATER RESOURCES
MANAGEMENT (DWRM) &
DIRECTORATE OF WATER DEVELOPMENT (DWD)

THE DEVELOPMENT STUDY ON WATER RESOURCES DEVELOPMENT AND MANAGEMENT FOR LAKE KYOGA BASIN IN THE REPUBLIC OF UGANDA

FINAL REPORT

MAIN REPORT

March 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

OYO INTERNATIONAL CORPORATION
IN ASSOCIATION WITH
TOKYO ENGINEERING CONSULTANTS Co., Ltd.
AND
ORIENTAL CONSULTANTS Co., Ltd.

GED
JR
11-054

MINISTRY OF WATER AND ENVIRONMENT
THE REPUBLIC OF UGANDA
DIRECTORATE OF WATER RESOURCES
MANAGEMENT (DWRM) &
DIRECTORATE OF WATER DEVELOPMENT (DWD)

THE DEVELOPMENT STUDY
ON
WATER RESOURCES DEVELOPMENT AND
MANAGEMENT FOR LAKE KYOGA BASIN
IN
THE REPUBLIC OF UGANDA

FINAL REPORT
MAIN REPORT

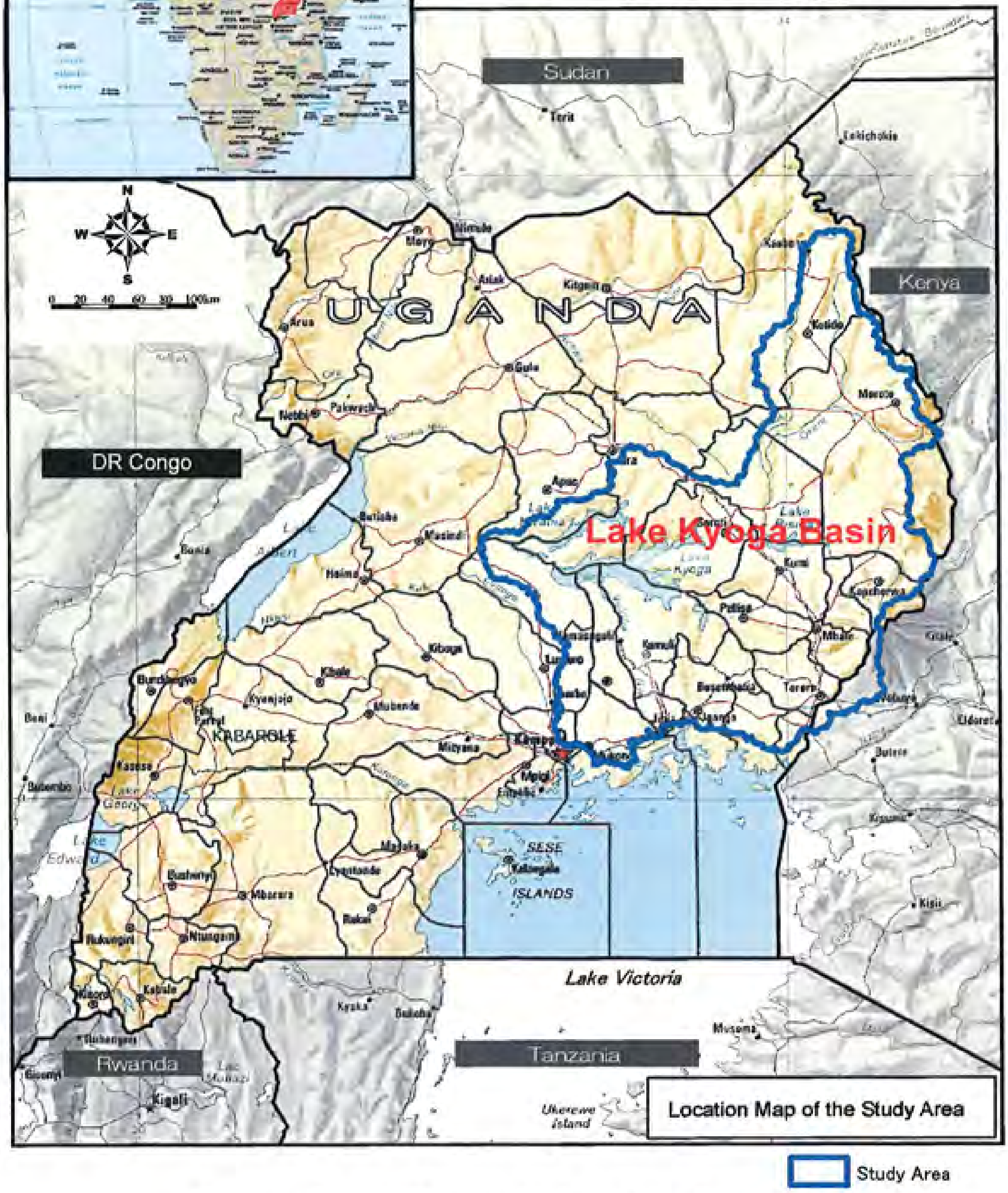
March 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

**OYO INTERNATIONAL CORPORATION
IN ASSOCIATION WITH
TOKYO ENGINEERING CONSULTANTS Co., Ltd.
AND
ORIENTAL CONSULTANTS Co., Ltd.**

Exchange rate on Mar. 2011 is US$1.00 = Uganda Shilling UGS 2,335.14
= Japanese Yen ¥81.73

The Development Study on Water Resources Development and Management for Lake Kyoga Basin in the Republic of Uganda



Location Map of the Study Area

Photo Album (1)

River gauging station
(Sironko District) [June 2009]

Gauging station near outlet of Lake Kyoga
(Masindi Port) [May 2009]

Meteorological equipment in DWRM

(Entebbe) [June 2009]

Okok River at about 5km west from Katakwi. Almost no flow around outlet of Okere and Okok sub-basin.
(Katakwi District) [June 2009]

Wetland covered by overgrowth papyrus
(Mpologoma River in Namutumba District) [June 2009]

Photo Album (2)

Water hyacinth is choking of river flow
(Soroti District) [June 2009]

Livelihood of villagers around Lake Kyoga
(Soroti District) [June 2009]

Ferry boat near outlet of Lake Kyoga
(Nakasongola District) [June 2009]

Deforestation of forest reserve area near Mbale City
(Mbale District) [June 2009]

Intake facility for Soroti Municipality from Awoja River
(Sotori District) [June 2009]

Reservoir tank of water for Soroti Municipality
(Soroti District) [June 2009]

Photo Album (3)

Transmission pipes to Soroti, Amuria and Kaberamaido
(Soroti District) [June 2009]

Intake Facility in Manafwa River for Mbale Municipality
(Mble District) [July 2009]

Long Line of jerry cans for fetching water
(Bumana RGC, Iganga District) [Feb. 2010]

Crowded people around water point
(Busesa RGC, Iganga District) [Feb. 2010]

Upstream of Manafwa River originated from Mt. Elgon
(Bududa District) [Nov. 2009]

Higher turbidity in mid-stream of Manafwa River due to soil erosion
(Manafwa District) [Nov. 2009]

Photo Album (4)

Protected spring in mountainous area
(Manafwa District) [June 2009]

Children fetching water from water pond
(Tirinyi RGC, Pallisa District) [Feb. 2010]

Hand dugwell
(IgangaDistrict) [Feb. 2010]

Plenty spring water flowing
(Pallisa District) [Sep. 2010]

Rain water storage tank
(Soroti District) [Nov. 2009]

Intake facility of gravity scheme
(Sironko District) [Nov. 2009]

Photo Album (5)

Intake facility of irrigation water supply system for Doho Rice Scheme blocked partially by Sedimentation.
(Butaleja District) [Aug. 2010]

Irrigated farm of Doho Rice Scheme

(Butaleja District) [Aug. 2010]

Simple weir in Mpolongoma sub-basin lead to irrigation water conflict..
(Butaleja District) [July 2009]

Small scaled irrigation system using spring water.

(Mbale District) [June 2009]

Valley dam losing storage capacity due to collapse of the left bank.
(Katakwi District) [June 2009]

Photo Album (6)

Cotton factory using shallow groundwater for cleaning

(Iganga District) [Feb. 2010]

Simple bridge of trunk road. Sometimes being under water in rainy season.
(Bugiri District) [June2009]

Sediment disaster site near Mbale
(Mbale District) [June 2009]

Exposed drainage pipe of simple bridge due to erosion in rainy season
(Mbale District) [June 2009]

Cultivated land of mountainous slopes
(Bududa District) [June 2009]

Terrace fields over slopes after deforestation.
(Bukwa District) [June 2009]

Photo Album (7)

Solar powered water supply system
(Nsozibili, Jinja District) [Aug. 2010]

Water source for Serere Water Supply System
(Soroti District) [Aug. 2010]

Interview survey to TSU4, UO, WSDF
(Mbale District) [Aug. 2010]

Repair works of handpump
(Soroti District) [Jul. 2009]

RGC of Category IV (more than 5,000 people) Commercial facility is facing the trunk road.

(Kadama RGC, PallisaDistrict) [Feb. 2010]

Photo Album (8)

RGC of Category IV (more than 5,000 people) Commercial facility concentrates in market along main road.
(Namungalwe RGC, Iganga District) [Feb. 2010]

RGC of Category III (3,000 to 5,000 people). Commercial facility concentrates along main road.
(Nambale RGC, Iganga District) [Feb. 2010]

RGC of Category III (3,000 to 5,000 people). Few people in daytime because of fisherman town facing Lake Kyoga
(Kagwara Port RGC, Soroti District) [Feb. 2010]

Photo Album (9)

RGC of Category II-2 (2,000 to 3,000 people) keeping away from trunk road.
Commercial facility is small scale yet.
(Kameke RGC, Pallisa District) [Feb. 2010]

RGC of Category II-2 (2,000 to 3,000 people) located secondary road to Pallisa Town .
Commercial facility is small scale yet.
(Buseta RGC, Pallisa District) [Feb. 2010]

RGC of Category II-1 (1,000 to 2,000 people) keeping away from Trunk Road.
Commercial facility is small scale yet.
(Ikumbya RGC, Iganga District) [Feb. 2010]

Photo Album (10)

RGC of Category II-1 (1,000 to 2,000 people) at Intersection of roads connecting small towns.
Commercial facility is small scale yet
(Naigobya RGC, Iganga District) [Feb. 2010]

RGC of Category II-1 (1,000 to 2,000 people) keeping away from trunk road.
Commercial facility is small scale yet.
(Kidetok RGC, Soroti District) [Feb. 2010]

2nd Seminar
(Kampala) [May 2009]

Technology transfer of water balance simulation
to C/P. (Entebbe) [Dec. 2009]

TABLE OF CONTENTS

FINAL REPORT
MAIN REPORT

PHOTO ALBUM
TABLE OF CONTENTS
LIST OF TABLES
LIST OF FIGURES
ABBREVIATIONS

CHAPTER 1 INTRODUCTION ······ 1-1
1.1 Background of the Study ······ 1-1
1.2 Objectives of the Study ······ 1-2
1.3 Study Area ······ 1-2
1.4 Implementation of the Study ······ 1-2
1.5 Study Schedule ······ 1-5
1.6 Composition of the Reports ······ 1-5

CHAPTER 2 NATURAL CONDITIONS ······ 2-1
2.1 Definition of Lake Kyoga Basin ······ 2-1
2.2 Meteorology and Hydrology ······ 2-1
2.2.1 Meteorology and Climate ······ 2-1
2.2.2 Hydrology ······ 2-2
2.2.3 Climate Change Projection in IPCC Fourth Assessment Report ······ 2-7
2.3 Geomorphology and geology ······ 2-9
2.3.1 Geomorphology ······ 2-9
2.3.2 Geology ······ 2-13
2.3.3 Geomorphology and Geology around Mt. Elgon ······ 2-16
2.4 Water Quality ······ 2-17
2.4.1 Water Quality Standard ······ 2-17
2.4.2 Field Survey for Water Quality ······ 2-17
2.4.3 Analysis of the Existing Water Quality Data ······ 2-19
2.5 Hydrogeology ······ 2-22
2.5.1 Hydrogeological Analysis ······ 2-22
2.5.2 Results of Hydrogeological Analysis ······ 2-23
2.5.3 Direction of Groundwater Flow ······ 2-28

2.5.4 Hydrogeological Condition by Geological Unit 2-29

CHAPTER 3 SOCIO-ECONOMIC CONDITIONS 3-1
3.1 Socio-economic Condition of Uganda 3-1
3.1.1 Ethnic, Language and Religion 3-1
3.1.2 System of the Government 3-1
3.1.3 Socio-Economy 3-2
3.2 Socioeconomic Conditions of Lake Kyoga Basin 3-3
3.2.1 General Conditions 3-3
3.2.2 Socio-Economic Survey 3-5
3.3 Political, Legal and Organizational Frameworks 3-11
3.3.1 Policy and Legal Frameworks 3-11
3.3.2 Organizational Framework 3-12
3.4 Present Situation of Water and Sanitation 3-19
3.4.1 General 3-19
3.4.2 Sector Objectives 3-19
3.4.3 Present Situation of Water Supply 3-20
3.4.4 Sanitation 3-34
3.5 Flood, Sediment Disaster and Drought 3-35
3.5.1 Present Condition on Deforestation and Forest Degradation 3-36
3.5.2 Present Condition on Flood and Sediment Disaster 3-37
3.6 Environmental and Social Considerations 3-38
3.6.1 Legal System Concerning Environment and Social Consideration 3-38
3.6.2 EIA Scheme 3-38

CHAPTER 4 WATER RESOURCES POTENTIAL EVALUATION 4-1
4.1 Water Balance Analysis for Water Resource Evaluation 4-1
4.1.1 Estimation of Precipitation 4-1
4.1.2 Estimation of Evapotranspiration 4-1
4.1.3 Estimation of Runoff Ratio 4-2
4.1.4 Estimation of Infiltration (Groundwater Recharge) 4-2
4.2 Potential Evaluation of Surface Water Resources 4-3
4.2.1 Building up Simulation Model 4-3
4.2.2 Simulation Results 4-4
4.3 Groundwater Potential Evaluation 4-6
4.3.1 Indices for Groundwater Potential Evaluation 4-6

4.3.2 Potential Evaluation for Groundwater Development ······ 4-9
4.3.3 Exploitable Water Resources ······ 4-9

CHAPTER 5 ISSUES ON WATER RESOURCES DEVELOPMENT AND MANAGEMENT ······ 5-1
5.1 IWRM and Water Resources Development Plan ······ 5-1
5.2 Surface Water Resources Development and Management ······ 5-3
5.3 Groundwater Resources Development and Management ······ 5-4
5.4 Conservation of Water Environment ······ 5-6
5.4.1 Water Quality ······ 5-6
5.4.2 Necessity of Ambient Water Quality Standards and Water Quality Monitoring ·· 5-6
5.5 Water Balance of Supply and Demand ······ 5-7
5.5.1 Future Water Demand ······ 5-7
5.5.2 Water Balance of Supply and Demand ······ 5-11
5.6 Plateaued Coverage Rate of Rural Water Supply ······ 5-17

CHAPTER 6 BASIC PLAN ON WATER RESOURCES DEVELOPMENT AND MANAGEMENT ······ 6-1
6.1 Approaches to IWRM ······ 6-1
6.2 Major Issues on Water Resources Development and Management in Lake Kyoga Basin ······ 6-1
6.3 Basic Course for the Basic Plan ······ 6-2
6.4 Basic Plan on Water Resources Development and Management ······ 6-6
6.4.1 Comprehensive Water Resources Management ······ 6-6
6.4.2 Effective, Stable and Equitable Water Supply ······ 6-11
6.4.3 Prevention of Flood and Sediments Disaster to Protect Lives and Properties ···· 6-17
6.4.4 Conservation Plan of Water Environment ······ 6-23
6.4.5 Information System for Water Resources Development and Management ······ 6-26
6.4.6 Total Schedule of the Basic Plan ······ 6-27
6.5 Priority of the Basic Plan on Water Resources Development and Management ······ 6-30
6.6 Outline Schedule and Approximate Cost of Water Supply Plan ······ 6-30
6.6.1 Outline Schedule ······ 6-30
6.6.2 Method for Cost Estimate ······ 6-30
6.6.3 Result of Cost Estimation ······ 6-30
6.7 Evaluation of the Basic Plan on Water Resources Development Management ······ 6-32
6.7.1 Technical Evaluation ······ 6-32
6.7.2 Economical and Financial Evaluation ······ 6-32

6.7.3 Evaluation on Social Environmental Consideration ··· 6-34

CHAPTER 7 MASTER PLAN OF RURAL WATER SUPPLY IN PRIORITY DISTRICTS ··· 7-1

7.1 Selection of Priority Districts ··· 7-1

7.1.1 Water Source for Rural Water Supply ··· 7-1

7.1.2 Districts to be Considered for the Selection ··· 7-2

7.1.3 Prioritization Criteria ··· 7-3

7.1.4 Evaluation Methods and Prioritization ··· 7-4

7.1.5 Selection of Priority Districts ··· 7-5

7.2 Inventory Survey for Water Supply Situations in Sub-counties and RGCs in Selected Priority Districts ··· 7-6

7.2.1 WATSUP Survey ··· 7-6

7.2.2 Rural Growth Center Survey ··· 7-8

7.3 Rural Water Supply Master Plan ··· 7-10

7.3.1 Present Situation of Rural Water Supply ··· 7-10

7.3.2 Basic Conditions of Master Plan ··· 7-18

7.3.3 Water Demand ··· 7-19

7.3.4 Water Supply Plan ··· 7-20

7.3.5 Water Supply Facilities ··· 7-23

7.3.6 Management Plan of Water Supply Systems ··· 7-29

7.3.7 Project Cost Estimate ··· 7-33

7.4 Economic and Financial Evaluation of Master Plan ··· 7-38

7.4.1 Evaluation Method ··· 7-38

7.4.2 Economic Evaluation of Total Master Plan ··· 7-38

7.4.3 Financial Evaluation of O&M Stage ··· 7-39

7.5 Initial Environmental Evaluation ··· 7-41

7.5.1 Construction Period ··· 7-41

7.5.2 Operation Period ··· 7-42

7.5.3 Conclusion ··· 7-42

CHAPTER 8 SELECTION OF PRIORITY PROJECT ··· 8-1

8.1 Basic Concept of Selection ··· 8-1

8.2 Prioritization of Project Works ··· 8-1

8.3 Selection of Priority Project ··· 8-3

CHAPTER 9 CONCLUSION AND RECOMMENDATIONS ······ 9-1
9.1 Conclusion ······ 9-1
9.2 Recommendations ······ 9-3

List of Tables

Table 1-1 Member Lists of the JICA Study Team and Counterpart Team 1-3
Table 1-2 Compositions of the Reports 1-5

Table 2-1 Characteristics of Climatological Zones in Lake Kyoga Basin 2-1
Table 2-2 Outline of Sub-basins in Lake Kyoga Basin... 2-3
Table 2-3 Current Conditions of Existing Gauging Stations 2-4
Table 2-4 Land Cover in Whole of Uganda and Lake Kyoga Basin 2-12
Table 2-5 Stratigraphy of Lake Kyoga Basin 2-14
Table 2-6 Drinking Water Standards 2-17
Table 2-7 Water Quality Items in the Study 2-18
Table 2-8 Results of Water Quality Surveyk 2-21
Table 2-9 Drilling Depth, Static Water Level, Well Yield and Depth to Bedrock of each Geological Unit 2-22

Table 3-1 Economic Indices and General Information of Uganda 3-3
Table 3-2 Engagement in Economic Activities 3-6
Table 3-3 Average Wealth Indicators per Household.. 3-7
Table 3-4 Water Collection and Consumption 3-9
Table 3-5 Key Policies and Legal Framework... 3-11
Table 3-6 Large Scale Water Supply Systems in Lake Kyoga Basin 3-20
Table 3-7 Water Supply Systems for Small Towns in Lake Kyoga Basin (2007 - 2008) 3-21
Table 3-8 Definition of Main Improved Water Supplies.. 3-22
Table 3-9 Ratio of Water Sources for Each District 3-23
Table 3-10 Population Served and Coverage of District 3-27
Table 3-11 Functionality of Deep Borehole and Shallow Well 3-29
Table 3-12 Cultivated Lands in Lake Kyoga Basin 3-29
Table 3-13 Potential Areas for Irrigation in Lake Kyoga Basin 3-30
Table 3-14 Irrigation Water Requirements for Doho and Lwoba Schemes................................ 3-31
Table 3-15 Number of Livestock in Kyoga Basin 3-32
Table 3-16 Fish Pond and Production in Lake Kyoga Basin 3-33
Table 3-17 Present Situation of Sewerage System in Urban Areas of Lake Kyoga Basin 3-34
Table 3-18 Latrine Coverage of Districts in Lake Kyoga Basin (2008) 3-35
Table 3-19 Statue, Regulation and Guideline on EIA and Water Resources.............................. 3-38

Table 4-1	List of Used Monitoring Data	4-1
Table 4-2	Runoff Characteristic of Each Sub-Basin	4-4
Table 4-3	Water Resources of each Sub-basin in 1/10 Drought Year	4-5
Table 4-4	Potential Evaluation Scores of Each Index for Groundwater Development	4-9
Table 5-1	Issues on the Related Sector to Water Resources Development and Management	5-2
Table 5-2	Short History on Uganda's Water Resources Management	5-3
Table 5-3	Present and Future Population in Lake Kyoga Basin	5-7
Table 5-4	Area and Population Density in Each Sub-basin	5-8
Table 5-5	Present and Future Water Demand for Sub-basins	5-8
Table 5-6	Present and Future Water Demand for Sectors	5-9
Table 5-7	Targets of Urban and Rural Water Supply	5-9
Table 5-8	Target Indices for Irrigation Requirement	5-10
Table 5-9	Target Indices for Livestock Requirement	5-10
Table 5-10	Target Indices for Fish Production	5-11
Table 5-11	Estimated Water Shortage in Five Sub-basins	5-13
Table 5-12	Evaluation of Water Balance in Each Sector	5-17
Table 6-1	Full Picture of Water Resources Development and Management Plan	6-4
Table 6-2	River Discharge Monitoring Plan	6-7
Table 6-3	Lake Water Level Monitoring Plan	6-8
Table 6-4	Rainfall Monitoring Stations	6-8
Table 6-5	Expansion Plan of Water Supply System for Small Towns in Lake Kyoga Basin	6-14
Table 6-6	Present and Future Techno logy Mix of SIP	6-15
Table 6-7	Rural Water Supply Coverage of each Sub-basin	6-15
Table 6-8	Number of Facilities to be Constructed in 2008 to 2035	6-16
Table 6-9	List of Disaster Information	6-21
Table 6-10	Outline of Early Warning System for Flood and Sediments Disaster	6-22
Table 6-11	Ambient Water Quality Standards for River, Lake and Swamp	6-24
Table 6-12	Ambient Water Quality Standards for Human Health	6-24
Table 6-13	List of Water Quality Monitoring Point	6-24
Table 6-14	Ambient Standard Class of each Sub-basin	6-25
Table 6-15	Construction Schedule of Sewerage System	6-26
Table 6-16	Schedule of the Basic Plan on Water Resources Development and Management for Lake Kyoga Basin	6-29

Table 6-16 Summary of Estimated Project Costs 6-30
Table 6-17 Priority Evaluation of Basic Plan on Water Resources Development and Management for Lake Kyoga Basin 6-31
Table 6-18 Economic Evaluation of Rural Water Supply Plan 6-33

Table 7-1 Candidate Districts for Selection of Priority Districts 7-2
Table 7-2 Evaluation of Priority District by Social Condition 7-3
Table 7-3 Evaluation of Priority District by Natural Condition 7-4
Table 7-4 Survey Contents of WATSUP Survey 7-6
Table 7-5 List RGCs for RGC Survey 7-9
Table 7-6 Ratio of Water Sources in Priority Districts 7-11
Table 7-7 Present Population of Rural Areas in Priority Districts (2010) 7-11
Table 7-8 Present Water Demand of Rural Areas in Priority Districts (2010) 7-12
Table 7-9 List RGCs for Master Planning 7-13
Table 7-10 Result of Test Borehole Drilling 7-16
Table 7-11 Comparison between Water Demand and Available Groundwater Amount 7-17
Table 7-12 Target Value of Master Plan 7-18
Table 7-13 Future Rural Water Demands of Priority Districts 7-20
Table 7-14 Summary of Water Supply Facilities Proposed for Master Plan 7-21
Table 7-15 RGCs and Implementation Term 7-23
Table 7-16 RGCs Selected for Representing Category 7-25
Table 7-17 Categories of RGCs and Water Supply Facilities to be Applied 7-26
Table 7-18 Comparison of Power Sources for Piped Water Supply Systems 7-28
Table 7-19 Water Supply System and O&M Organization 7-30
Table 7-20 Workshops and Trainings 7-33
Table 7-21 Summary of Estimated Project Costs 7-34
Table 7-22 Project Cost for Selected RGCs Representing Categories 7-35
Table 7-23 Operation and Maintenance Cost for Piped Water Supply Facility 7-36
Table 7-24 Cost and Benefit 7-39
Table 7-25 Calculation and Evaluation Result 7-39
Table 7-26 Calculation and Evaluation Result (1) 7-40
Table 7-27 Calculation and Evaluation Result (2) 7-40
Table 7-28 Calculation and Evaluation Result (3) 7-41
Table 7-29 Result of Scoping (Water Supply Facilities: Level 2 Class) 7-44

Table 8-1 Works Proposed for Short Term Plan 8-1

Table 8-2	Parameters Applied for Prioritization	8-2
Table 8-3	Results of Prioritization of Piped Water Supply Systems	8-4
Table 8-4	Prioritization of RGCs of Short Term Plan for Urgent Implementation	8-5

List of Figures

Figure 1-1 Eight Basins in Uganda .... 1 - 1
Figure 1-2 Location of the Study Area .... 1 - 2
Figure 1-3 Organizations for Implementation of the Study .... 1 - 3
Figure 1-4 Related Districts of Lake Kyoga Basin and Insecure Districts .... 1 - 4
Figure 1-5 Total Schedule of the Study .... 1 - 5

Figure 2-1 Climatological Zoning of Uganda 2-1
Figure 2-2 Mean Monthly Rainfall 2-1
Figure 2-3 Mean Max. and Min. Temperature 2-2
Figure 2-4 Daily Mean Sunshine Hours 2-2
Figure 2-5 Daily Mean Evaporation 2-2
Figure 2-6 River Network, Sub-basins and River Gauging Stations 2-3
Figure 2-7 Main Rivers and Gauging Stations 2-5
Figure 2-8 Runoff Characteristics of Downstream of Akweng, and Okok River 2-6
Figure 2-9 Runoff Characteristics of Middlestream of Mpologoma and Awoja River 2-6
Figure 2-10 Main Lakes in Lake Kyoga Basin 2-7
Figure 2-11 Water Level Changes of Lake Kyoga and Lake Victoria 2-7
Figure 2-12 Temperature and Precipitation Changes shown in IPCC Report 2-8
Figure 2-13 Geomorphology of Uganda 2-9
Figure 2-14 Geomorphology of Lake Kyoga Basin 2-10
Figure 2-15 Shaded Relief Image 2-11
Figure 2-16 Elevation Classification Map 2-11
Figure 2-17 Slope Classification Map 2-11
Figure 2-18 Land Cover of Lake Kyoga Basin 2-12
Figure 2-19 VSW Index Image in January 2003 2-13
Figure 2-20 Faults and Lineaments in Lake Kyoga Basin 2-14
Figure 2-21 Geological Map of Lake Kyoga Basin 2-15
Figure 2-22 Geology in and around Mt. Elgon Area 2-16
Figure 2-23 Geological and Geomorphologic Feature around Mt. Elgon 2-16
Figure 2-24 Toppling Type of Collapse 2-16
Figure 2-25 Location of Water Sampling Points 2-18
Figure 2-26 Drilling Depth Distribution 2-23
Figure 2-27 Static Water Level Distribution 2-24

Figure 2-28 Well Yield Distribution 2-25
Figure 2-29 Total Dissolved Solid Distribution 2-26
Figure 2-30 Piper Diagram (Okure Sub-Basin) 2-27
Figure 2-31 Direction of Groundwater Flow 2-28

Figure 3-1 Ugandan Main Race Distribution 3-1
Figure 3-2 Population Density in the Lake Kyoga Basin by Sub-County 3-4
Figure 3-3 Location of Target Villages for Socio-Economic Survey 3-5
Figure 3-4 Average Household Size 3-6
Figure 3-5 Ethnic Variations of the Village Leaders 3-6
Figure 3-6 Ratio of Cultivated Area by Crops 3-7
Figure 3-7 Ratio of Main Water Source in Surveyed Villages 3-8
Figure 3-8 Ratio of Main Water Source Facillity in Surveyed Villages 3-8
Figure 3-9 Time Spent on Collecting Water 3-9
Figure 3-10 Occurrences of Reported Cases of Waterborne Diseases (a) (Village Survey) 3-9
Figure 3-11 Occurrences of Reported Cases of Waterborne Diseases (b) (Household Survey) 3-10
Figure 3-12 Needs for Development in the Surveyed Villages 3-10
Figure 3-13 Institutional Setting for Water and Environment Sector in Uganda 3-12
Figure 3-14 Organization of Ministry of Water and Environment 3-13
Figure 3-15 Water Supply System of Large Town 3-21
Figure 3-16 Typical Spring Water Supply Facility 3-24
Figure 3-17 Typical Groundwater Supply Facility (Hand Pump) 3-24
Figure 3-18 Typical Piped Water Supply Facility (Groundwater) 3-25
Figure 3-19 Rainwater Harvesting Facility 3-26
Figure 3-20 Typical Gravity Flow System 3-26
Figure 3-21 Equity of Access to Safe Water for Each District 3-28
Figure 3-22 Locations of Existing and Planned Hydropower Stations 3-33
Figure 3-23 Sediments Disaster Frequency 3-35
Figure 3-24 Flood Frequency 3-35
Figure 3-25 Drought Frequency 3-36
Figure 3-26 Heavily Deforested & Forest Degraded Area in and around Mt. Elgon 3-36
Figure 3-27 Flood and Sediments Disaster Prone Area in and around Mt. Elgon 3-37
Figure 3-28 EIA Process Flow in Uganda 3-40

Figure 4-1 Estimated Annual Precipitation 4-1

Figure 4-2 Estimated Evapotranspiration ... 4-1
Figure 4-3 Estimated Runoff Ratio ... 4-2
Figure 4-4 Estimated Annual Infiltration ... 4-2
Figure 4-5 Flow Chart of Calibration Work ... 4-3
Figure 4-6 Simulated Monthly Surface Water Resources in 1/10 Drought Year ... 4-6
Figure 4-7 Distribution of Each Index for Groundwater Potential Evaluation ... 4-8
Figure 4-8 Groundwater Development Potential ... 4-9
Figure 4-9 Estimated Exploitable Surface Water Volume in each Sub-basin ... 4-10
Figure 4-10 Exploitable Groundwater Volume in each Sub-basin in Drought Year ... 4-10

Figure 5-1 Two Concepts for Water Resources Development and Management ... 5-1
Figure 5-2 Present and Future Population in Lake Kyoga Basin ... 5-7
Figure 5-3 Present and Future Water Demand in Lake Kyoga Basin by Sector ... 5-9
Figure 5-4 Present and Future Water Demand in Lake Kyoga Basin by Sub-basin ... 5-9
Figure 5-5 Water Balance of Supply and Demand in Lake Kyoga Basin ... 5-11
Figure 5-6 Typical Crop Calendar of Pallisa and Bugiri District ... 5-12
Figure 5-7 Trend of Water Demand and Exploitable Water Resources (1) ... 5-14
Figure 5-8 Trend of Water Demand and Exploitable Water Resources (2) ... 5-15
Figure 5-9 Trend of Water Demand and Exploitable Water Resources (3) ... 5-16
Figure 5-10 Coverage Rate of Rural Water Supply in Uganda ... 5-17

Figure 6-1 Distribution of Sub-basins and Related Districts ... 6-5
Figure 6-2 Surface Water Monitoring Plan ... 6-7
Figure 6-3 Location of Groundwater Monitoring Stations ... 6-8
Figure 6-4 Rainfall Monitoring Plan ... 6-9
Figure 6-5 Expansion Plan of Urban Water Supply System for Large Towns and Peri-urban Areas (NWSC) ... 6-14
Figure 6-6 Population Served by Water Supply System for Small Towns in each Sub-basin ... 6-15
Figure 6-7 Present and Future Population Served by Each Technology in Lake Kyoga Basin ... 6-16
Figure 6-8 Present and Future Technology Mix ... 6-16
Figure 6-9 Distribution of Existing Surface Water Storage Facilities ... 6-17
Figure 6-10 Flow Chart of Stabilization Process ... 6-25
Figure 6-11 Outline of Information Sharing System ... 6-27
Figure 6-12 Transition of Real Economic Growth Rate (%) ... 6-32
Figure 6-13 Transition of Inflation Rate (%) ... 6-32
Figure 6-14 Transition of Year on Year of Inflation Rate ... 6-33

Figure 6-15 Transition of Budget for Water and Sanitation Sector 6-34

Figure 7-1 Districts to Which Entrance is Limited by JICA 7-1
Figure 7-2 Selection of Priority District for Master Plan of Rural Water Supply 7-5
Figure 7-3 Position of Water Sources in Soroti District.. 7-7
Figure 7-4 Position of Water Sources in Iganga District 7-7
Figure 7-5 Position of Water Sources in Pallisa District.. 7-7
Figure 7-6 Example of RGC Survey Result Map... 7-10
Figure 7-7 Former and Present Administrative Units 7-10
Figure 7-8 Coverage of RGCs and Other Rural Areas in Priority Districts 7-13
Figure 7-9 Groundwater Yield Distribution in the Priority Districts 7-15
Figure 7-10 Success Rate of Wells by Subcounty 7-16
Figure 7-11 Present and Future Rural Population of Priority Districts 7-19
Figure 7-12 Improvement of Sub-county-wise Coverage in Priority Districts 7-22
Figure 7-13 Location and Implementation Term of RGC.. 7-23
Figure 7-14 Typical Borehole Structure with Hand Pump for Rural Water Supply 7-24
Figure 7-15 Distribution by Population Scale of RGCs.. 7-25
Figure 7-16 Flow Chart of Piped Water Supply Syatem.. 7-26
Figure 7-17 Proposed Plan of Transmission from NWSC and Other RGCs................................ 7-27
Figure 7-18 Example of Preliminary Design of Water Supply System for Selected RGC 7-29
Figure 7-19 Proposed O & M Organization for RGCs of Categories II - IV 7-32
Figure 7-20 Operation and Maintenance Costs of Piped Water Supply Facilities and Population of RGC.. 7-37

Figure 8-1 Scoring for Prioritization... 8-2
Figure 8-2 Location of Priority Projects 8-6

ABBREVIATION

ADB	African Development Bank
ADC	Austrian Development Cooperation
ASL	Above Sea Level
AVNIR	Advanced Visible and New Infrared Radiometer
BADEA	Arab Bank for Economic Development in Africa
BH	Borehole
BHN	Basic Human Needs
BOD	Biochemical Oxygen Demand
B/C	Benefit by Cost
CBMS	Community Based Management System
CBO	Community Based Organization
CFR	Central Forest Reserve
CMO	Catchment Management Organization
COD	Chemical Oxygen Demand
C/P	Counterpart
CRED	Centre for Research on the Epidemiology of Disasters
DANIDA	Danish International Development Agency
DEA	Directorate of Environmental Affairs
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DO	Dissolved Oxygen
DWD	Directorate of Water Development
DWO	District Water Office
DWRM	Directorate of Water Resources Management
DWSCC	District Water and Sanitation Coordination Committee
EA	Environmental Audit
EC	Electric Conductivity (mS/m)
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EIS	Environmental Impact Statement
EM-DAT	Emergency Events Database
ETM	Enhanced Thematic Mapper
EU	European Union
FAO	Food and Agriculture Organization

FIEFOC	Farm Income Enhancement and Forestry Conservation Project
FIRR	Financial Internal Rate of Return
GDP	Gross Domestic Product
GFS	Gravity Flow Scheme
GIS	Geographic Information System
GoU	Government of Uganda
GPS	Global Positioning System
HH	Household
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IRR	Internal Rate of Return
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
ITCZ	Inter-Tropical Convergence Zone
JFP	Joint Partnership Fund
JICA	Japan International Cooperation Agency
JSR	Joint Sector Review
JTR	Joint Technical Review
LANDSAT	Land sensing Satellite
LC	Local Council
LFR	Local Forest Reserve
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MAC	Maximum Allowable Concentration
MCM	Million Cubic Meter
MDG	Millennium Development Goals
MERECP	Mount Elgon Ecosystem Conservation Programme
MoEMD	Ministry of Energy and Mineral Development
MoES	Ministry of Education and Sports
MoFA	Ministry of Foreign Affair
MFPED	Ministry of Finance Planning and Economic Development
MGLSD	Ministry of Gender, Labour and Social Development
MoH	Ministry of Health
MoLG	Ministry of Local Government
MoWLE	Ministry of Water, Land and Environment
MoWE	Ministry of Water and Environment
MoWT	Ministry of Works and Transport

MoTTI	Ministry of Tourism, Trade and Industry
NAADS	National Agricultural Advisory Services
NASA	National Aeronautics and Space Administration
NDP	National Development Plan
NEMA	National Environment Management Authority
NFA	National Forestry Authority
NGO	Non Government Organization
NGWDB	National Groundwater DataBase
NPV	Net Present Value
NSWG	National Sanitation Working Group
NWSC	National Water and Sewerage Corporation
OFDA	Office of U.S. Foreign Disaster Assistance
O&M	Operation & Maintenance
PCA	Principle Component Analysis
PEAP	Poverty Eradication Action Plan
RGC	Rural Growth Center
RWS	Rural Water Supply
RWSS	Rural Water Supply and Sanitation
SIDA	Swedish International Development Cooperation Agency
SRTM	Shuttle Rader Topography Mission
SS	Suspended Solids
SSIP	Strategic Sector Investment Plan
SWAP	Sector Wide Approach
TDS	Total Dissolved Solid
TLU	Tropical Livestock Unit
TM	Thematic Mapper
TNTC	Too Numerous To Count
TOR	Terms of Reference
TSU	Technical Support Unit
UBoS	Uganda Bureau of Statistics
UFW	Unaccounted For Water
UGX	Ugandan Shilling
UK	United Kingdom
ULGA	Uganda Local Governments Association
UNICEF	United Nations Children’s Fund
UNITAR	United Nations Institute for Training and Research

UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNOSAT	UNITAR Operational Satellite Applications Programme
UNRA	Uganda National Road Authority
UO	Umbrella Organization
USA	United States of America
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UWA	Uganda Wildlife Association
UWA-FACE	UWA-Forest Absorption Carbon-dioxide Emission
UWASNET	Uganda Water and Sanitation NGO Network
UWSS	Urban Water Supply and Sanitation
VAT	Value Added TAX
VSW	Vegetation-Soil-Water
WATSUP	Water Atlas Up-date Project
WESWG	Water and Environment Sector Working Group
WfP	Water for Production
WFP	World Food Programme
WGS	World Geodetic System
WHO	World Health Organization
WMO	World Meteorological Organization
WMZ	Water Management Zone
WPC	Water Policy Committee
WRM	Water Resources Management
WRMD	Water Resources Management Department
WSDF	Water and Sanitation Development Facility
WSC	Water and Sanitation Committee
WSSB	Water Supply and Sanitation Board
WSSWG	Water and Sanitation Sector Working Group
WUC	Water User Committee

Chapter 1
Introduction

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Uganda is an agricultural country with 40% of GDP or 80% of total export covered by agricultural products. Approximately 70% of rural people who constitute 86% of total population are engaged in agricultural activities, rural areas therefore play very important roles for sustainable economic development in Uganda. It is important to take measures against poverty reduction in rural areas in which 96% of poverty people live. The national development plan (NDP April 2010), which incorporates "PEAP" (Poverty Eradication Action Plan 1997 to 2008) and intertwines sustainable economic growth with poverty eradication, aims to reduce absolute poverty to less than 24.5 % of total population by the year of 2015. NDP sets target for water and sanitation sector as below.

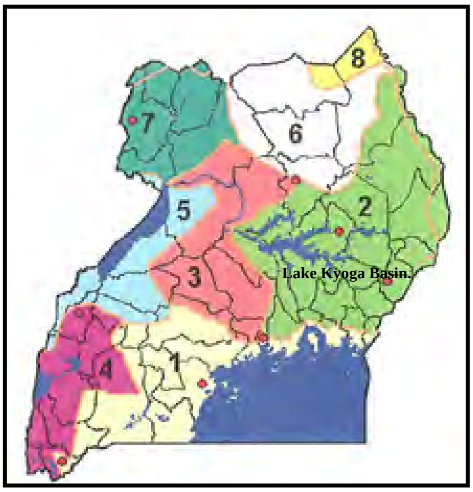
- By the year of 2015, 100 % of population in urban area can access to the safe water within 0.2 km and sanitation facilities.
- By the year of 2015, 77% and 90% of population in rural area can access to the safe water within 1.0 km and sanitation facilities, respectively.

The study area, Lake Kyoga Basin (hereinafter referred as to "the Basin") having approximately 58,000 km^2 equals to 25% of the area of Uganda, is one of the largest catchment areas among eight basins in the whole country. (refer to Figure 1-1) Approximately 9.3 million people (2008 estimated) are living in the Basin whose major industry is agriculture, which is composed chiefly of livestock farming mainly cattle and cash crop growing of cotton or coffee.

The Basin is considerably blessed with water resources, namely rivers, lakes and groundwater with an annual precipitation of more than 1,200mm. However, safe water supply coverage in the rural areas is approximately 57% on an average in comparison with a national coverage of 63% and besides Kaabong, Kotido, Abim and Bugiri districts have less than 40%.

On the other hand, here is serious surface erosion in the mountainous areas of the basin, which leads to soil erosion and stream capture resulting into heavy damage to agriculture and the daily life of the people. This means that not only "water resources utilization" but also "prevention of flood and sediments disaster" have been recognized as critical issues.

Under these circumstances, the Government of the Republic of Uganda and the Government of Japan agreed



No.	Basin	Area (km^2)
1	Lake Victoria Basin	59,858
2	Lake Kyoga Basin	57,669
3	Kyoga-Nile Basin	26,796
4	Lake Edward-George Basin	18,624
5	Lake Albert Basin	18,223
6	Aswa Basin	26,868
7	Albert Nile Basin	20,004
8	Kidepo Basin	3,129

(Source: NORPLAN (2005) "Water Resources Management Sub-sector Reform Study")

Figure 1-1 Eight Basins in Uganda

in August 2008 to conduct "The Development Study on Water Resources Development and Management for Lake Kyoga Basin in the Republic of Uganda" (hereinafter referred to as "the Study") in order to formulate "The Basic Plan on Water Resource Development and Management" for sustainable and effective water resources management, and "The Master Plan for Rural Water Supply" to accelerate actual construction of water supply facilities in the rural areas in the Basin.

1.2 Objectives of the Study

The objectives of the Study are

- To formulate a basic plan on water resources development and management for the Basin
- To formulate a master plan for rural water supply in priority areas
- To transfer technology and knowledge to the counterpart personnel through their direct participation into the Study.

1.3 Study Area

The study area is whole Lake Kyoga Basin, which covers approximately 58,000 km^2 in the eastern part of Uganda. The number of the related districts in the Basin is 38 as shown in Figure 1-4 (July 2009).

However, there were off-limit areas for the security reasons to the Study Team in the northern part of the Basin (refer to Figure 1-4). Therefore, such areas were included in the "Basic Plan on Water Resources Development and Management" but excluded in the "Master Plan for Rural Water Supply".

1.4 Implementation of the Study

Directorate of Water Resources Management (DWRM) and Directorate of Water Development (DWD) acted as the counterpart agency to the JICA Study Team and provide the counterpart team with the necessary staff. Ministry of Water and Environment (MoWE) organized a joint steering committee, which included delegates from JICA Study Team and other appropriate related organizations under the Co-chairmanship of DWRM and DWD. The members of JICA Study Team and Counterpart Team are listed as shown in Table 1-1.

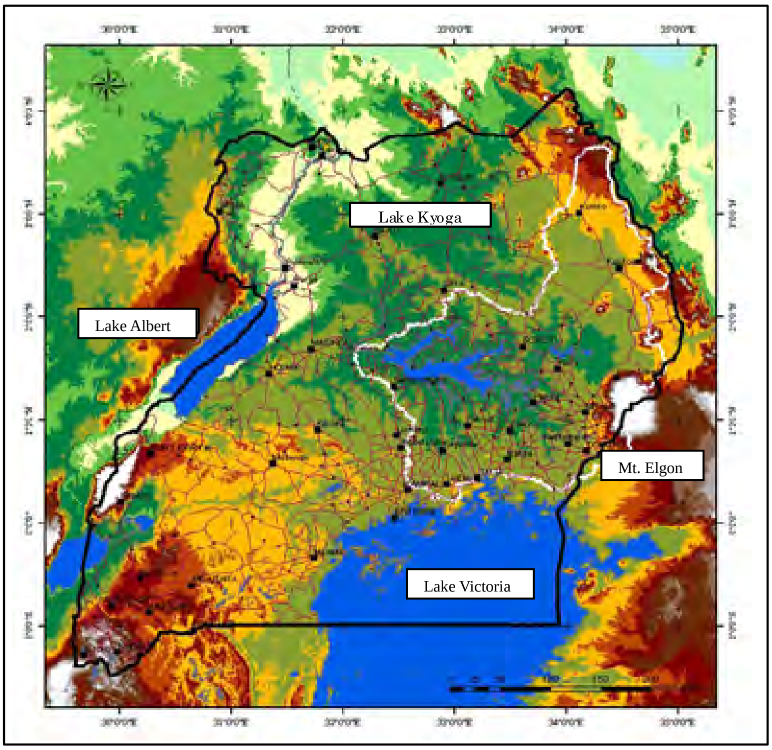


Figure 1-2 Location of the Study Area

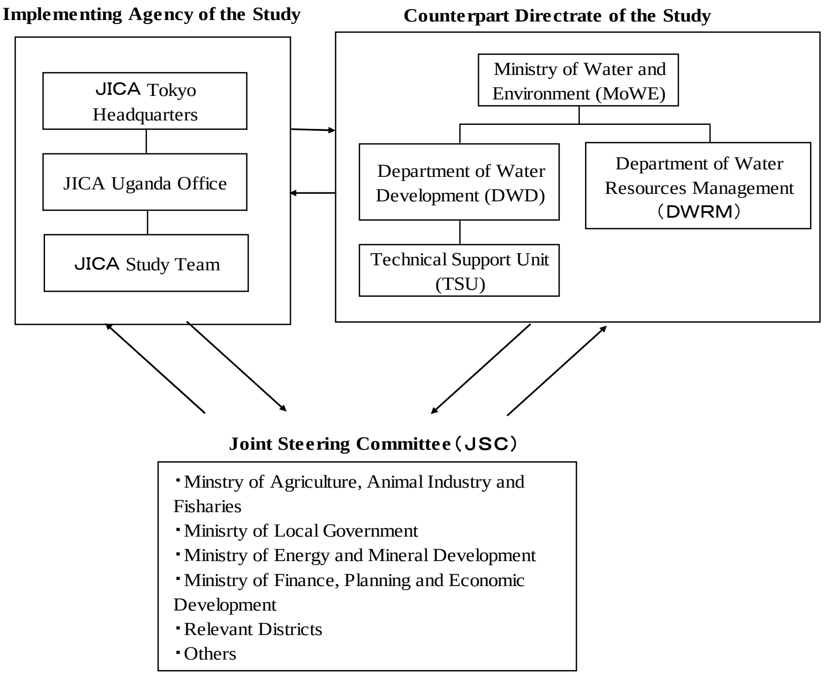


Figure 1-3 Organizations for Implementation of the Study

Table 1-1 Member Lists of the JICA Study Team and Counterpart Team

No	Assignment Title	JICA Study Team	Counterpart Study Team
1	Team Leader / Water Resource Management	Mr. Norifumi YAMAMOTO	Mr. Twinomujuni Jackson (DWRM)
2	Deputy Team Leader / Water Supply Planning	Mr. Soichiro YUMOTO	Eng. Ahmed Sentumbwe (DWD)
3	Meteorology / Hydrology	Mr. Ichiro TANAKA	Mr. Maximo Twinomuhangi (DWRM)
4	Hydrogeology (1)	Mr. Shinichi ISEKI	Ms. Eva Lwanga (DWRM)
5	Hydrogeology(2) / Test Drilling Survey	Mr. Iwao HAMADA	Mr. Erisa Kyeyune (DWD)
6	Basin Management / Flood Control Planning	Mr. Kenji MORITA	Mr. Benjamin Sekamuli (DWRM)
7	Remote Sensing / GIS	Mr. Soichiro KAGEYAMA	Mr. Maximo Twinomuhangi (DWRM) Mr. Benjamin Sekamuli (DWRM)
8	Water Balance Analysis / Simulation	Mr. Toru YORITATE	Mr. Tom Kanyike (DWRM)
9	Water Quality / Environmental and Social Consideratio	Mr. Rikichi ANDO	Mr. Simon Etimu (DWRM)
10	Socio-economy / Financial & Project Evaluation	Dr. Reza MAHABUB Dr. Kazuki NAKAMURA	Mr. Collins Amanya (DWD)
11	Facility Planning / Cost Estimation	Mr. Matasaburo TSUKUDA	Mr. Felix Twinomucunguzi (DWD)
12	Organization Operation & Maintenance	Mr. Terutoshi OZAWA	Eng. Ahmed Sentumbwe (DWD)
13	Coordinator	Mr. Kenji AKAMATSU	–

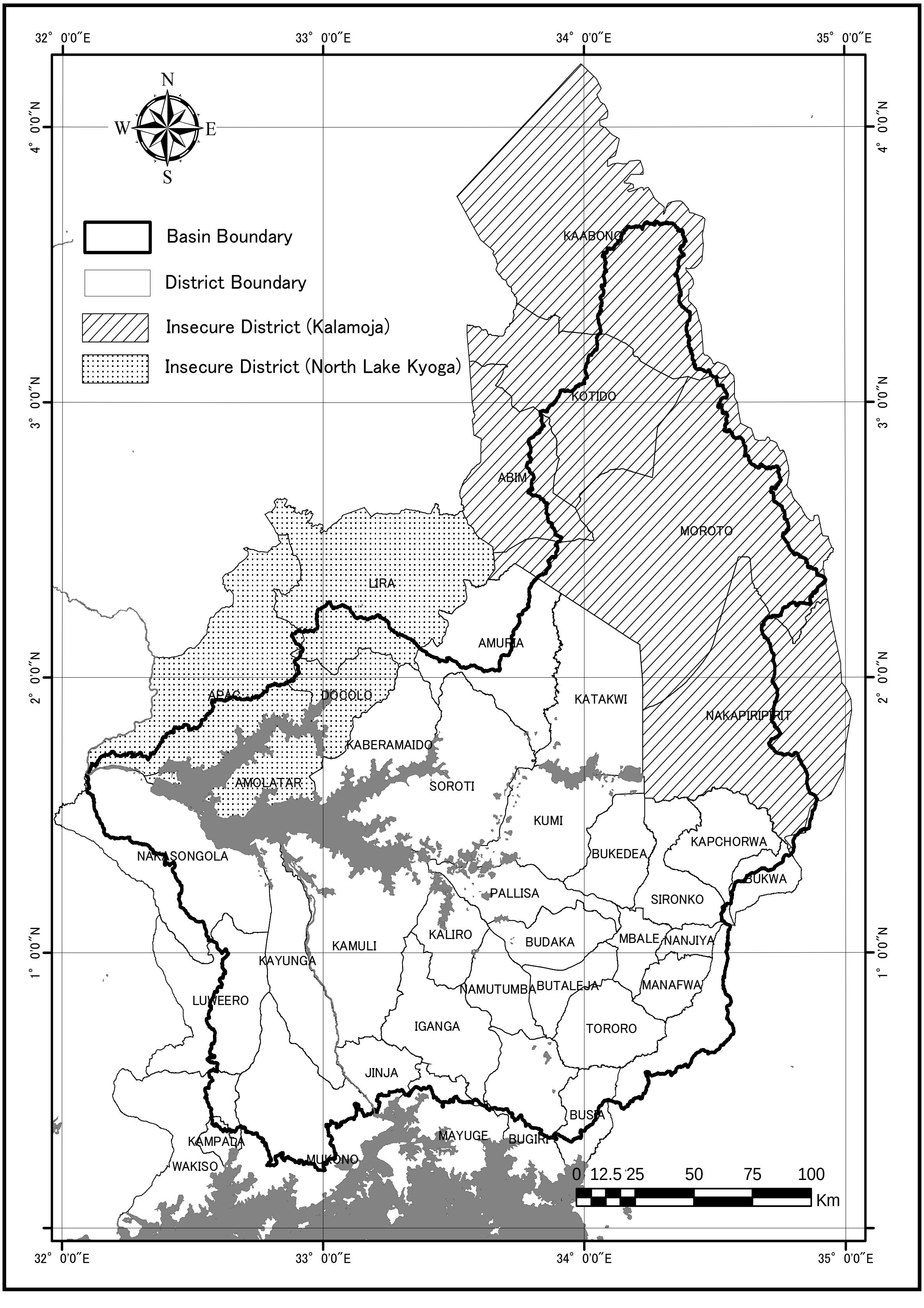


Figure 1-4 Related Districts of Lake Kyoga Basin and Insecure Districts

1.5 Study Schedule

The Study was scheduled to be completed in a period of approximately 25 months between March 2009 and March 2011 through nine stages of work as below.

- 1st Work in **Uganda** (Apr. 2009 - Jul. 2009)
- 1st Work in Japan (Jul. 2009)
- 2nd Work in **Uganda** (Aug. 2009)
- 3rd Work in **Uganda** (Oct. 2009 - Mar. 2010)
- 2nd Work in Japan (Mar. 2010 - May 2010)
- 4th Work in **Uganda** (Aug. 2010 - Oct .2010)
- 3rd Work in Japan (Nov. 2010 - Jan. 2011)
- 5th Work in **Uganda** (Jan. 2011)
- 4th Work in Japan (Mar. 2011)

Total schedule of the Study is shown in Figure 1-5.

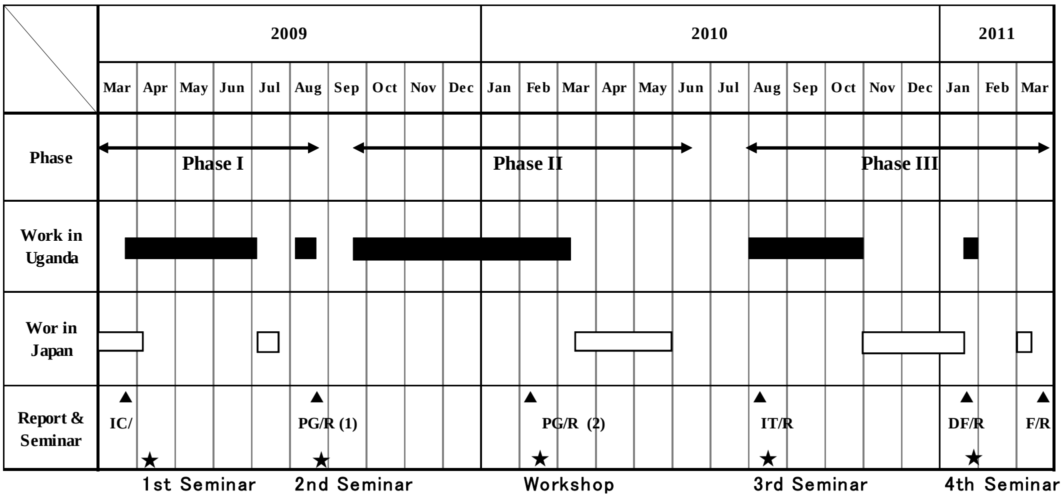


Figure 1-5 Total Schedule of the Study

1.6 Composition of the Reports

In the course of the Study, the Study Team prepared and submitted the following reports to the Government of Uganda. This report is the Final Report, which includes all contents of during Phase-I to III.

Table 1-2 Compositions of the Reports

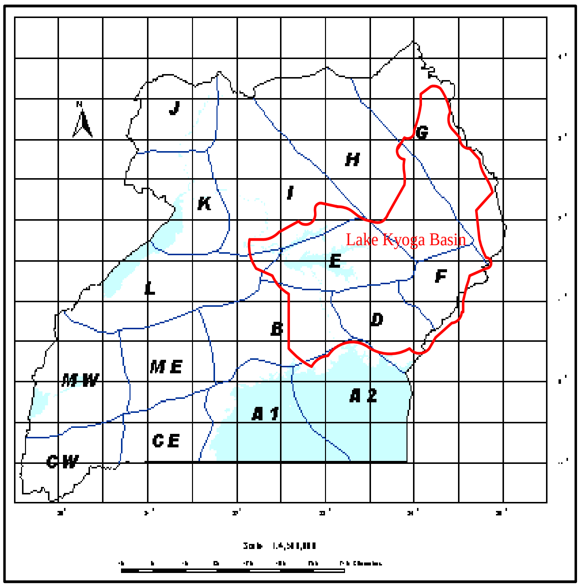
	Name of Report	Quantity	Submission Timing
1	Inception Report	20 Copies	April 2009
2	Progress Report (1)	20 Copies	August 2009
3	Progress Report (2)	20 Copies	February 2010
4	Interim Report	20 Copies	August 2010
5	Draft Final Report	20 Copies	January 2011
6	Final Report (Summary, Main, Supporting, Data Book, CD-ROM)	20 Sets	March 2011

Chapter 2
Natural Conditions

CHAPTER 2 NATURAL CONDITIONS

2.1 Definition of Lake Kyoga Basin

Satellite image data by the land observation satellite (LANDSAT) of NASA was adopted to capture land surface conditions of Lake Kyoga Basin. At the beginning of the Study, the Basin and sub-basin boundaries were redefined precisely with DEM (Digital Elevation Model) data by SRTM (Shuttle Radar Topographic Mission) as illustrated in Figure 2-6. The total area of the Basin is calculated to approximately 58,230 km^2 by DEM data. Ninety eight percent (98%) of the Basin: 57,080 km is in Ugandan side and two percent (2%): 1,150 km^2 is Kenyan side.



(Source：Hydroclimatic Study Report, 2001, DWRM)

Figure 2-1 Climatological Zoning of Uganda

2.2 Meteorology and Hydrology

2.2.1 Meteorology and Climate

(1) Climate Zone

DWRM classified the climate zones of the Basin as shown in Figure 2-1. Table 2-1 shows the characteristics of the climate zones of the Basin mentioned in the "Hydroclimatic Study (2001)".

Table 2-1 Characteristics of Climatological Zones in Lake Kyoga Basin

Zone	Annual rainfall (mm)	Main Rainy Season	Main Dry Season	Excess Months
A2	1,443	2 rainy seasons	2 dry seasons	2 months
B	1,250	2 rainy seasons	2 dry seasons	2 months
D	1,316	2 rainy seasons	2 dry seasons	3 months
E	1,215	1 rainy seasons	1 dry season	3 months
F	1,328	1 rainy seasons	1 dry season	8 months
G	745	I rainy season with 2 peaks	1 dry season	Over 10 months
H	1,197	I rainy season with 2 peaks	1 dry season	Over 10 months
I	1,340	I rainy season with 2 peaks	1 dry season	Over 10 months
L	1,270	2 rainy seasons	1 dry season	5 months

Note：Excess Months means number of months in a year while monthly evaporation is larger than monthly rainfall

(2) Meteorology

1) Rainfall

Mean annual rainfall varies 989 mm (Kakooge) to 2,477 mm (Buginyanya) spatially and the average is 1,466 mm in the Basin. The rainy season Basin experiences typically two annual rainfall maximum between March to May and September to November.

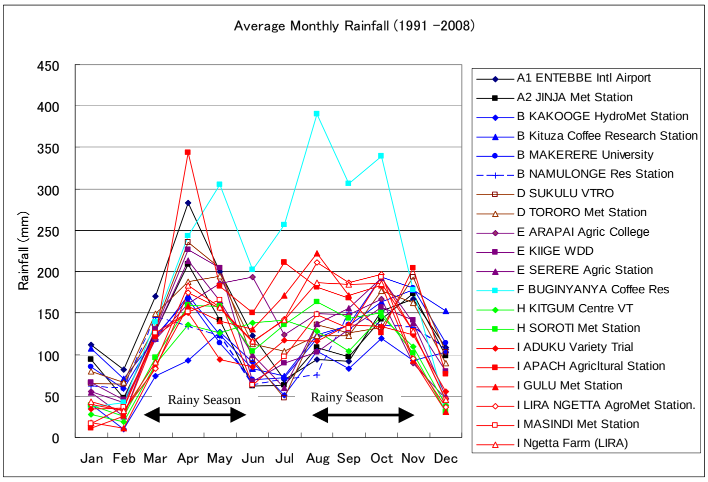


Figure 2-2 Mean Monthly Rainfall

2) Air Temperature

Air temperature of the several stations in the Basin and the surrounding areas was analyzed as shown in Figure 2-3. This figure presents mean maximum and minimum temperature for each month at the stations. Annual variation and difference of maximum temperature among the stations are bigger than those of minimum temperature. The temperatures are higher on January and February and lower on June or July.

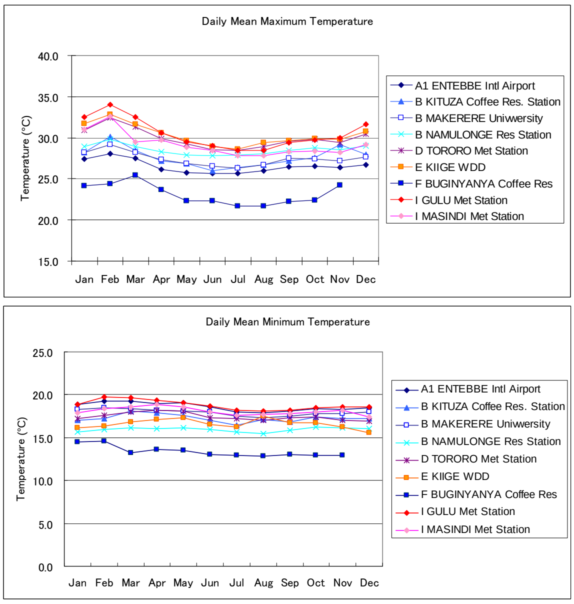


Figure 2-3 Mean Max. and Min. Temperature

3) Sunshine Hours

As shown in Figure 2-4, annual variation patterns of sunshine hours among the stations are the longest in January and the shortest in April, July or October. Daily mean sunshine hour a year is 6.8 hours in the Basin.

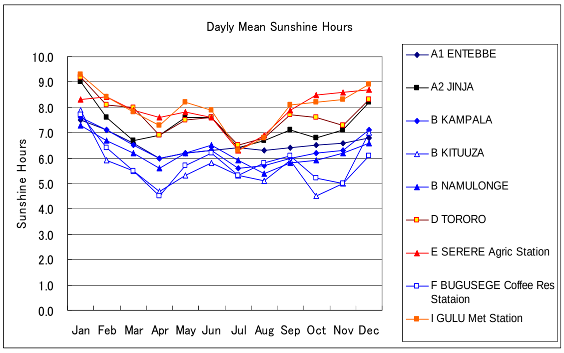


Figure 2-4 Daily Mean Sunshine Hours

4) Pan Evaporation

Many stations show their highest value in February, and a few in January or December as shown in Figure 2-5. The annual mean pan evaporation is 1,751 mm. The value exceeds annual mean rainfall in the study area. The highest value was recorded at Nakapiripirit station in January. The record of Nakapiripirit station shows more remarkable seasonal change than those of the other stations.

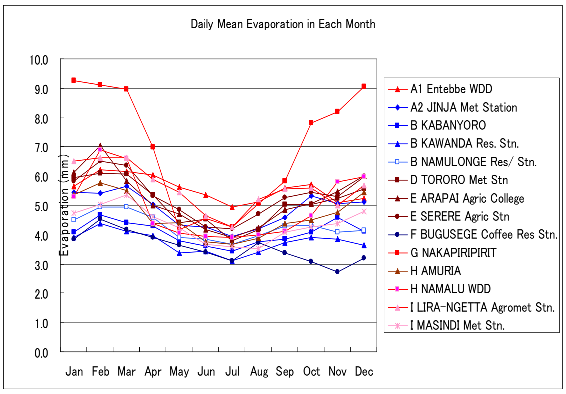


Figure 2-5 Daily Mean Evaporation

2.2.2 Hydrology

(1) River Network and Gauging Stations

1) Sub Basins in Lake Kyoga Basin

A river network and sub-basins (river catchments) were generated newly by using DEM data as illustrated in Figure 2-6. The area and name of each sub-basin are shown in Table 2-2. The sub-basins are named after main rivers in each sub-basin.

2) Monitoring Network of River Discharge

There are some gauging stations located at unsuitable points for monitoring total river discharge of each river. This is mainly due to the geomorphologic characteristics of Lake Kyoga Basin. The results of the site survey for checking their effectiveness is summarized in Table 2-3.

Table 2-2 Outline of Sub-basins in Lake Kyoga Basin

No	Name of Sub-basin	Land Area (km2)	Water Area (km2)	Total Area (km2)
1	Okok	5,512	0	5,512
2	Okere	8,199	8	8,207
3	Awoja	10,717	270	10,987
4	Lwere	1,618	58	1,676
5	Akweng	2,504	343	2,847
6	Abalang	2,908	386	3,294
7	Kyoga Lakeside Zone	5,206	2,173	7,379
8	Mpologoma	7,862	1,127	8,989
9	Lumbuye	1,478	42	1,520
10	Victoria Nile	3,456	126	3,582
11	Sezibwa	4,225	20	4,245
	Total	53,685	4,553	58,238

Source: JICA Study Team

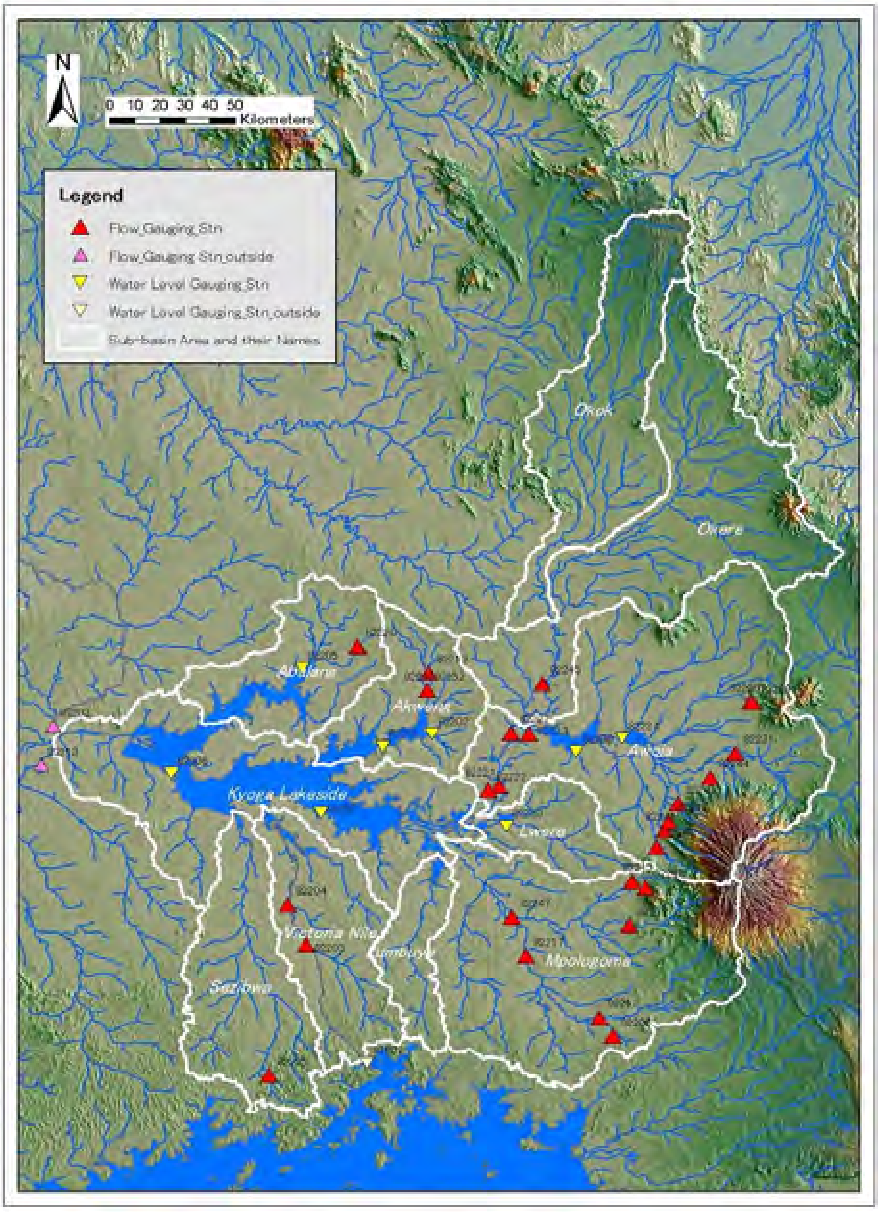


Figure 2-6 River Network, Sub-basins and River Gauging Stations

Table 2-3 Current Conditions of Existing Gauging Stations

Sub-Basin	Station Name	Station ID	Characteristics of River Gauging Stations								Current Observation Status	Proposed Future Situation
			Linearity	Cross Section	Bed Slope	Obstacle	Overflow	Single course	Back Water	Wetland		
Okere	R.Akokorio at Soroti-Katakwi Road	82245	×	×	-	-	-	×	-	×	Cessation	Not use
Awoja	R. Agu at Kumi- Serere Road	82221	-	×	-	×	×	-	×	×	Operating	Not use due to Back water
Awoja	R. Abuket at Kumi - Serere Road	82222	Curve	-	-	-	×	-	-	-	Operating	Not use: it cannot measure total
Awoja	R. Kapiri at Kumi - Soroti Road	82227	Pond	×	-	×	×	-	×	-	Operating	Not use due to Back water.
Awoja	R. Kelim (Greek) at Mbale - Moroto Road	82231	-	-	-	-	×	-	-	-	Operating	Use
Awoja	R. Sironko at Mbale - Moroto Road	82240	Curve	-	-	-	×	-	-	-	Operating	Use
Awoja	R. Simu at Mbale - Moroto Road	82241	-	-	-	-	×	-	-	-	Cessation	Not use
Awoja	R. Sipi at Mbale - Moroto Road	82243	-	-	-	-	-	-	-	-	Cessation	Not use
Abalang	R. Enget at Bata- Dokolo Road	82220	Curve	×	-		×	-	-	×	Operating	Not use due to unsuitable location.
Mpologoma	R. Manafwa at Mbale - Tororo Road	82212	Curve	-	-	-	-	-	-	-	Operating	Use
Mpologoma	R. Mpologoma at Budumba	82217	-	×		×	×	-	-	×	Operating	Use after Rehabilitation
Mplolgoma	R. Malaba at Jinja - Tororo Road	82218	-	×	-	×	×	-	-	-	Operating	Use after Rehabilitation
Mpologoma	R. Namatsyo at Busamaga	82247	×	×	-	×	×	×	-	×	Cessation	Not use
Victoria Nile	R. Victoria Nile at Mbulamuti	82203	-	-	-	-	-	-	-	-	Operating	Use
Sezibwa	R. Sezibwa at Falls	82225	Curve	-	-	-	×	-	-	-	Operating	Looking for another suitable point at the
Outside	R. Kyoga Nile at Masindi Port	83203	-	-	-	-	-	-	-	-	Operating	Use

Note:"×"points out that the station has a disadvantage corresponded to the item.

The survey result pointed that some existing gauging stations have following disadvantages

- The rivers ordinarily have no embankments so that some gauging stations located in lower land cannot measure discharges during high water and flooding.
- Some gauging stations installed at wide wetland do not measure total river discharge because there are number of river channels without gauges.
- Some gauging stations have effect of backwater so that the water level of down stream affects the discharge. This means that rating curve method cannot apply to such stations.
- Some gauging stations are installed at bent sides of rivers.
- Gauging stations with growing grass around the riverfront may have different quantity of river discharge for same river water level.

It is strongly recommended to review install points and observation method of monitoring river discharge and their distribution.

(2) River Flow Regime

1) Longitudinal Profile of the Rivers

The rivers run from northern part and eastern part of the Basin such as Awoja, Okok and Mpologoma rivers have mountainous area in the upstream and their gradients change to steep slope quickly in the upstream, especially in Awoja and Mpologoma rivers of which gradients in the upstream are more than 1/20. Their rivers' sections until upstream border of wetland have gentle slope of about 1/4,000 to 1/2,500.

2) River Flow Regime

The results of flow regime analysis are summarized as follows.

- In the northern area of the Basin, it has annual average discharge, but no low[1] and drought water discharge[2]. It is difficult to use surface water stably.
- In the southern area of the study area, it has some low and drought water discharges
- The stations near Mt. Elgon, they have small discharge, but sometimes has high water condition (flooding), but the stations far from Mt. Elgon have stable discharge.
- In Awoja sub-basin located at north of Mt. Elgon, the gauging station has low water discharge, but no drought discharge.
- In Mpologoma sub-basin located at southwest of Mt. Elgon, the flow regimes are more stable than the other sub-basin, and it has low and drought water discharges.
- The flow regime of a gauging station with wider catchment is getting more stable than others having smaller catchments.

3) Runoff Characteristic of Major Sub-Basin

Catchment area of river gauging stations: 82252 (R. Akweng) and 82245 (R. Okok) is quite different but they are located at downstream as shown in Figure 2-7. On the other hand, 82218 (R. Mpologoma) and 82231 (R. Awoja) are located at middle stream which their upstream have mountainous area. Based on a relationship between rainfall and runoff as presented in Figure 2-8 and 9, the runoff characteristics of the Basin is summarized below.

- Runoff ratio tends to increase gradually from February-March to December-January. In other words, runoff ratio is low in early part of the year (except January).
- The peak of Monthly Runoff appears lately than the peak of Monthly Rainfall. It is noticeable in the stations (82252 and 82245) located in downstream part of the rivers. Time lag of the peaks becomes large when catchment area is large. Time lag of Station 82252 with catchment area of 700.7km^2 is about one month but time lag of Station 82245 with catchment

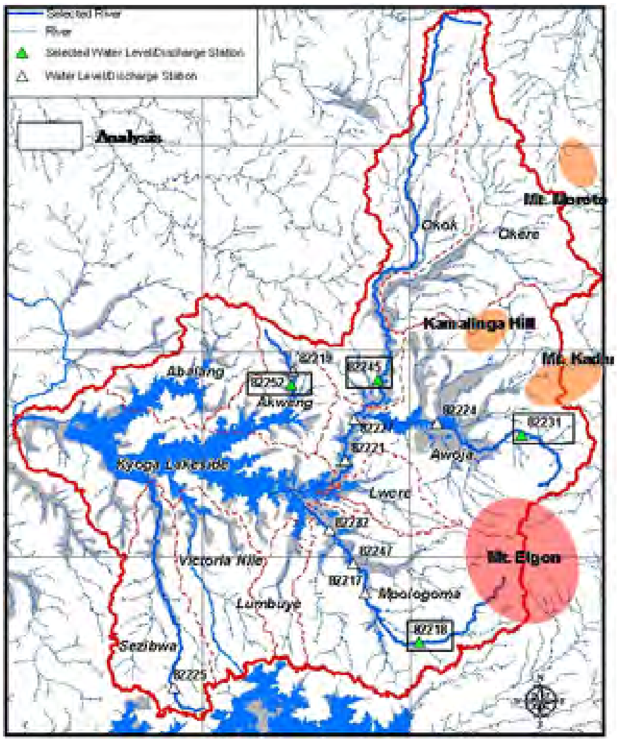


Figure 2-7 Main Rivers and Gauging Stations

---

[1] Low water discharge: 275th discharge from the greatest daily discharge.
[2] Drought water discharge: 355th discharge from the greatest daily discharge.

area of 12,653.0 km^2 is about three months. It is considered that wetland highly influences the time lag of the peaks, which become noticeable in downstream part.

- Regardless of catchment area, both Monthly Runoff and runoff ratio of middle part of the rivers with mountainous area in the upstream are higher than those of downstream.
- Monthly Runoff and runoff ratio of stations located in downstream part have no big differences in case that their catchment areas are quite different.

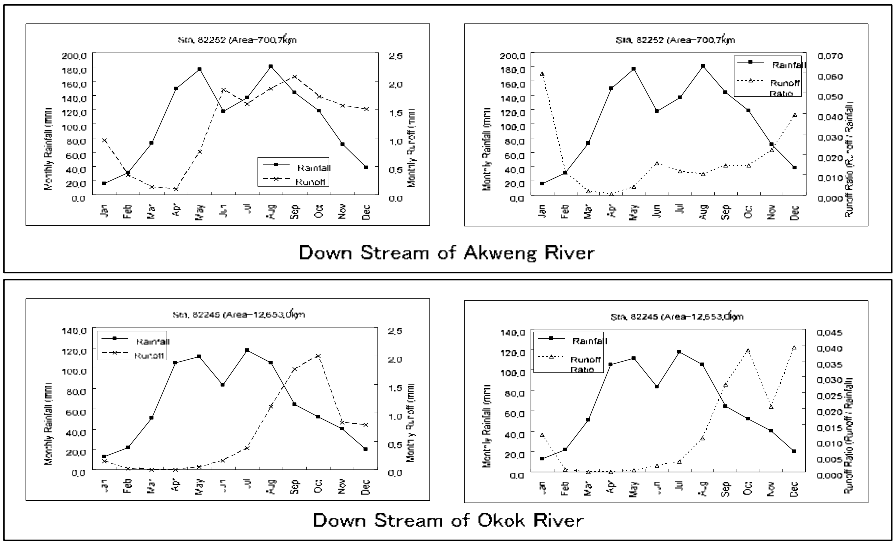


Figure 2-8 Runoff Characteristics of Downstream of Akweng and Okok River

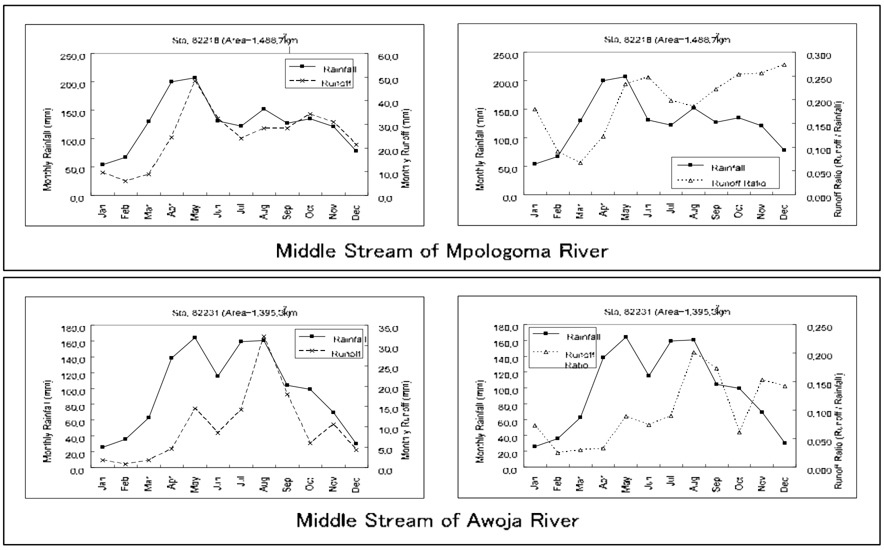


Figure 2-9 Runoff Characteristics of Middlestream of Mpologoma and Awoja River

(3) Lake Water Level Change

Lake Kyoga Basin has many lakes such as Lake Kyoga, Lake Kwania, Lake Bisina and Lake Opeta as shown in Figure 2-10, and their water level observations have been done. However, most of them have stopped their observation by the beginning of 1980s. Only one gauging stations at Bugondo Pier in Lake Kyoga has been working by now.

The lake water level changes of Lake Victoria and Lake Kyoga are summarized in Figure 2-11. This means that the lake hydrology is governed by the discharge from the Victoria Nile. In rough order of magnitude, the variations between high and low lake water levels can be seen to vary 0.5-1.0 m from year to year between extreme events. The 1962-1964 floods and the 1997-1998 floods added 1-2 m to these levels. It is said that the causes are record rainfalls in the years.

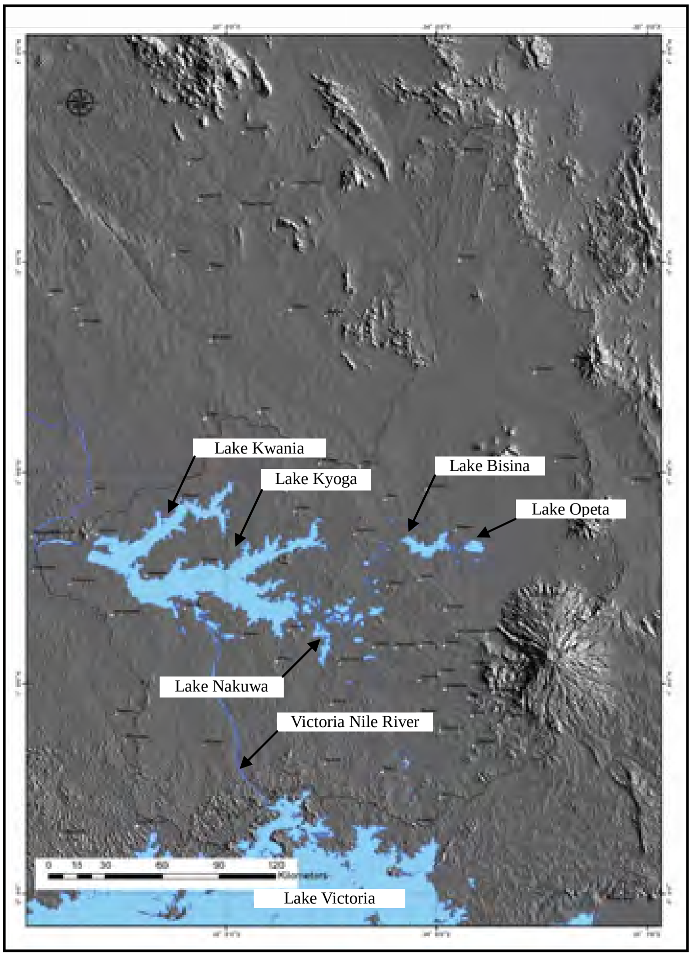


Figure 2-10 Main Lakes in Lake Kyoga Basin

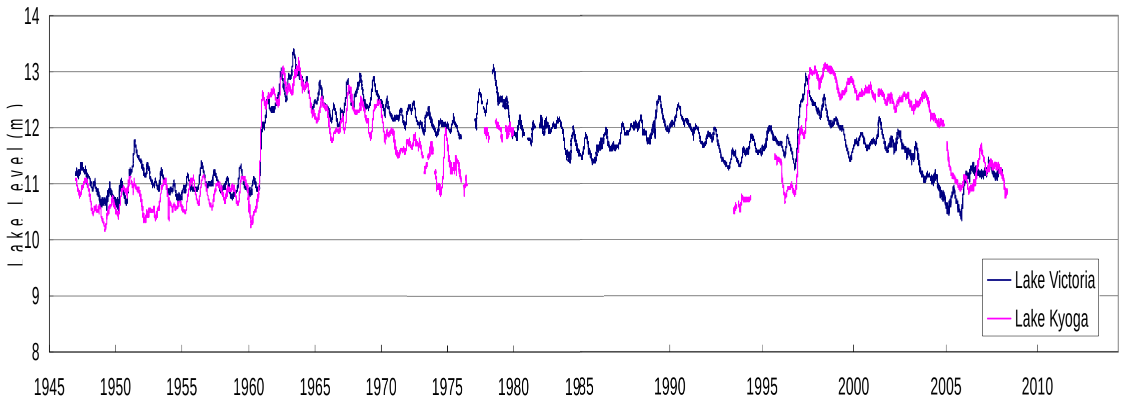
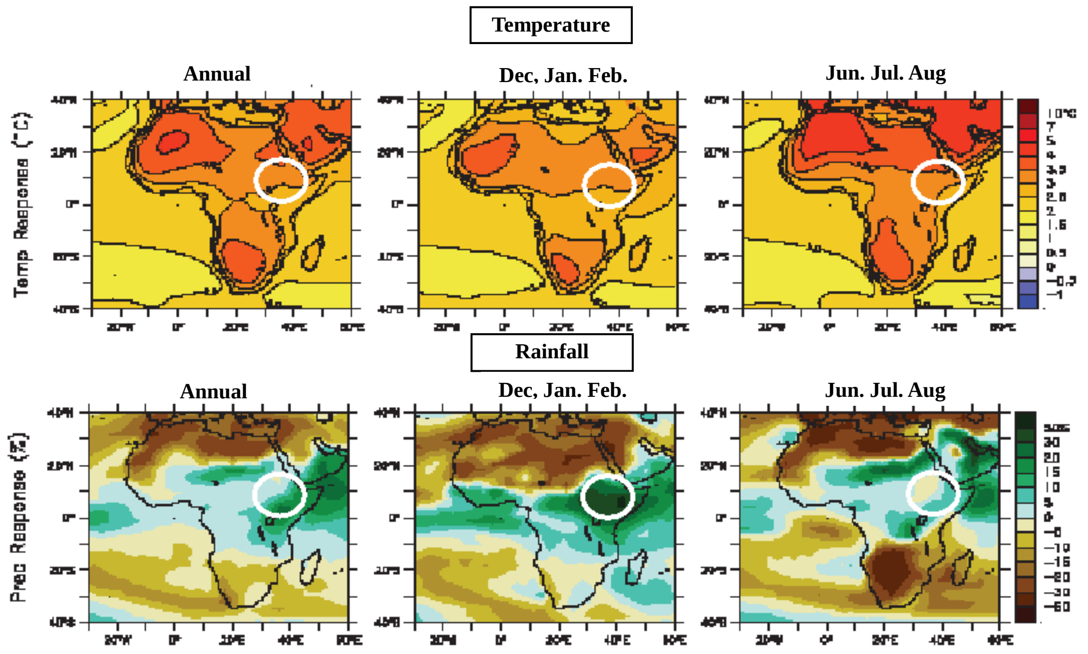


Figure 2-11 Water Level Changes of Lake Kyoga and Lake Victoria

2.2.3 Climate Change Projection in IPCC Fourth Assessment Report

According to IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report, temperature of Africa will increase; however, annual rainfall around Uganda is likely to increase in the 21st century. (refer to Figure 2-12)



source：IPCC Fourth Assessment Report WG1 Page 869

Figure 2-12 Temperature and Precipitation Changes shown in IPCC Report

(1) Climate Change Prediction by the Government of Uganda

The government of Uganda issued “Climate Change: Uganda National Adaptation Programmes of Action (2006)”. The report studied rainfall data from 1943 to 1999. The key points stated are summarized below.

- There is increasing variability in most regions of Uganda other than the central region; however, rainfall variability does not show any significant trends.
- On the other hand there is clear increase of frequency of droughts in recent years,
- Although it is predicted (IPCC Assessment Reports 1995/2001) that precipitation will increase in some areas of East Africa as a result of climate change, evapotranspiration will also increase due to a rise in temperatures thus reducing the benefit of the increase.

(2) Rainfall Variability Based on Existing Rainfall Data

Twelve reliable rainfall stations, which they covered the whole Kyoga Basin and had long-term data, were selected and analyzed their deviations from each average annual rainfall. This is because that simple deviation has no tendency like a random walk. The results are summarised below.

- Sometimes flooding and droughts happens at the same time in the wide area of Lake Kyoga basin. For example, annual rainfall in 2003 showed following result;

  High-water flow: Lira, Soroti, (Masindi), Mpigi, Mukono, (Entebbe)*

  Drought-water flow: (Kitugum), (Gulu), Apach, Kamuli, Tororo

(* Parenthetic station means that the station is located outside of Lake Kyoga basin.)

- Droughts continued more than ten years at some rainfall stations, on the other hands, rainfall harvest also continued more than ten years at other rainfall stations. However, those stations also have experienced opposite rainfall phenomenon in the past. For example, Jinja station has experienced rain harvest during recent ten years, and experienced poor rainfall before 1960.

These tendencies above mentioned have continued to recent years. Therefore, it is hard to conclude that the climate change will result in increase of drought.

2.3 Geomorphology and Geology

2.3.1 Geomorphology

(1) Geomorphology of Uganda

Uganda faces to Lake Victoria in the south and is surrounded by rises of the Great Rift Valleys in the east and west. Huge plain, which is lying between the rises, is tilting towards to the north gradually, and the River Nile, which is flowing down from Lake Victoria as a water source, is flowing to the Republic of Sudan via Lake Kyoga. Boundary with Kenya is the west rim of the Eastern Rift Valley (Gregory Rift Valley). Mt. Elgon (4,321m, the highest peak of Uganda) is dominated at the south end of the boundary. Western boundary faces to the Democratic Republic of Congo, and Western Rift Valley (Albertine Rift Valley) is consisted the boundary. In the rift valley, Rwenzori Mountains (5,109m, the highest peak is in Congo) pushed up by crustal movement are dominated, and Lake Albert and Lake Edward are in the bottom of the valley. Virungas Mountains (4,507m, the highest peak is in Rwanda)

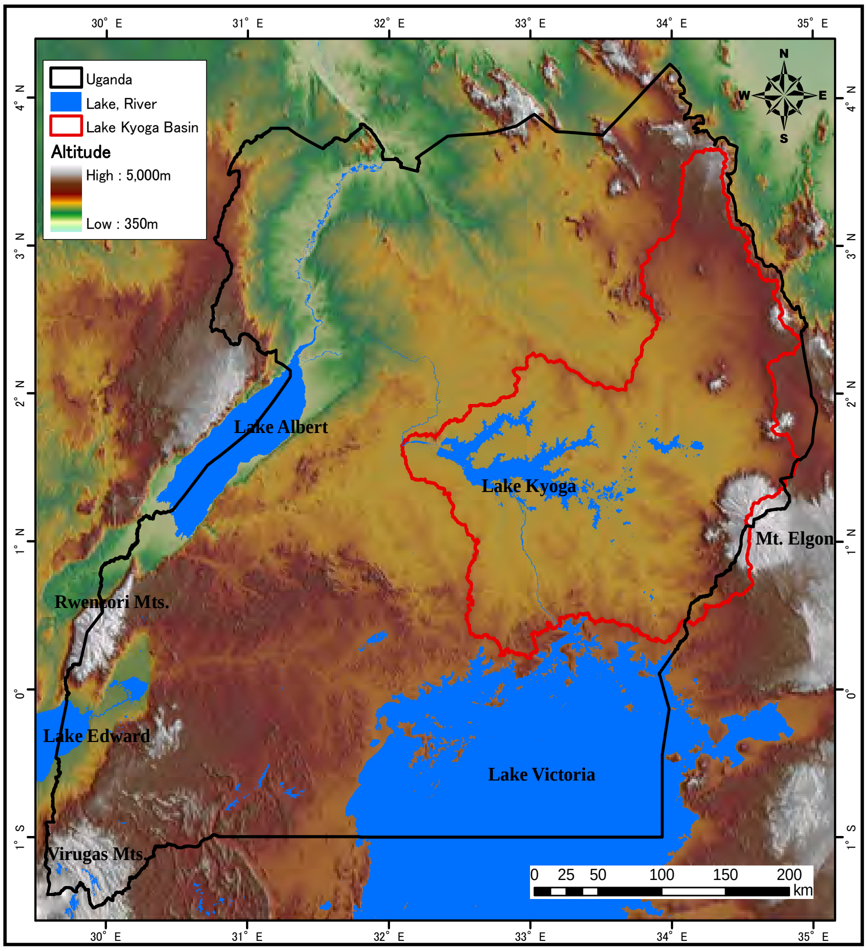


Figure 2-13 Geomorphology of Uganda

are at the south-western boundary between Uganda, Rwanda and Congo. Lake Victoria formed by the activity of Eastern and Western Rift Valleys is the largest lake in the Africa (the third largest in the world). Intermediated area between the rift valleys is forming a peneplain which has gentle topographic change with the elevation between 1,000 to 1,200m. The elevation is decreasing from southern east to northern west gradually. Lake Kyoga whose elevation of lake water is 1,034m is located in the middle of the peneplain. The water from Lake Victoria whose elevation of lake water is 1,034m is flowing down into Lake Kyoga, and flowing out to Lake Albert whose elevation of lake water is 615m from Lake Kyoga.

(2) Geomorphologic Characteristics of Lake Kyoga Basin

Lake Kyoga Basin is located in the eastern part of Uganda and consists of peneplanes, hills and mountains as presented in Figure 2-14. Its altitude ranges from 1,030m at the exit of Lake Kyoga to 4,321m at the peak of Mt. Elgon. Topography of the Basin is roughly tilted from the east to the west. Most of the rivers in the Basin have swamps because of its gentle slope. Lake Kyoga, whose water area is 1,720 Km^2, is very shallow: approximately maximum 6m depth.

Mt. Elgen is the one of the oldest volcano in East Africa, the area of skirts of the mountain is 3,500km^2. And along the east rim of Lake Kyoga Basin, some volcanoes are ranging from south to north, Mt. Kadam (3,068m), Mt. Napak (2,537m), Mt. Motoro (3,084m), etc. The boundary of the Basin from Moroto to Kitido is overlapping the rim of Eastern Rift Valley, and the national boundary is also taking along this.

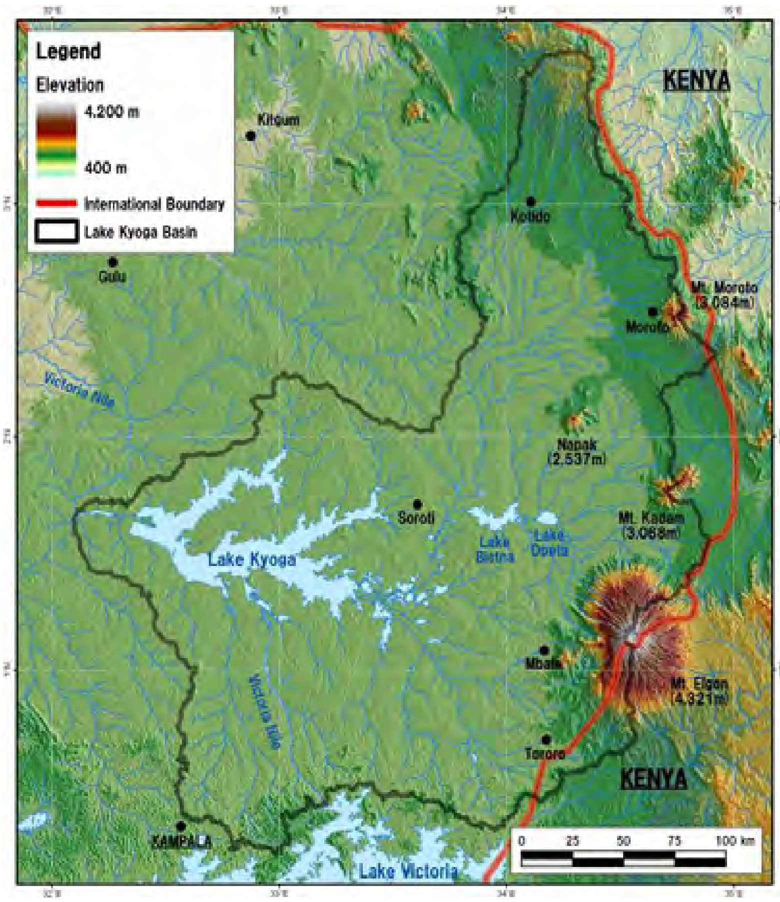


Figure 2-14 Geomorphology of Lake Kyoga Basin

The clear lineament structures: Aswa Shear Belt, which is extended from the northwestern part to the central part of the processed image, could be clearly extracted as shown in Figure 2-15. Concerning the surface textures of plane which assume a dominant position in the study area, the northern part with smooth textures differs from the southern west part with well-developed granular textures. These differences are concerning to the geology and surface soil.

The Basin is classified into three categories by elevation classification (refer to Figure 2-17): plain area whose elevation ranges from 900 to 1,150m in light brown color, hilly area from 1,150 to 1,600m in light green color , and mountainous area higher than 1,600m in blue to dark blue color.

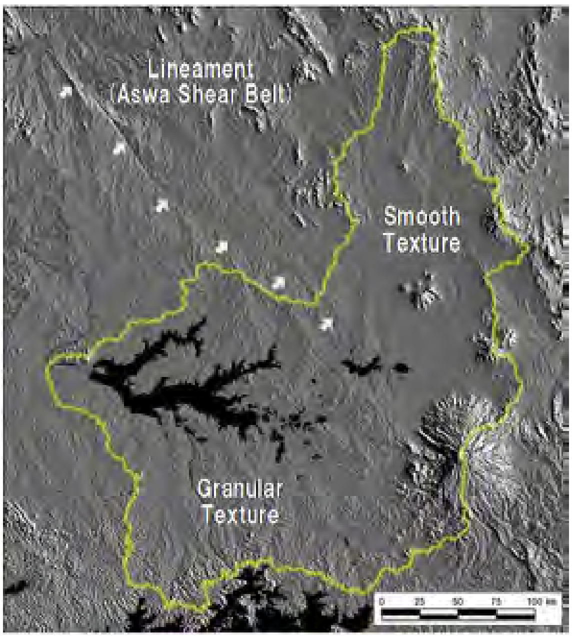


Figure 2-15 Shaded Relief Image

Slope degree of the plain is gentler than three degree shown as light yellow color in Figure 2-17 and hilly terrain is three to ten degree. The latter forms a dividing ridge between the Lake Kyoga Basin and the Lake Victoria Basin. Its geology is Precambrian metamorphic rocks composing mainly phylites, schists and metavolcanics.

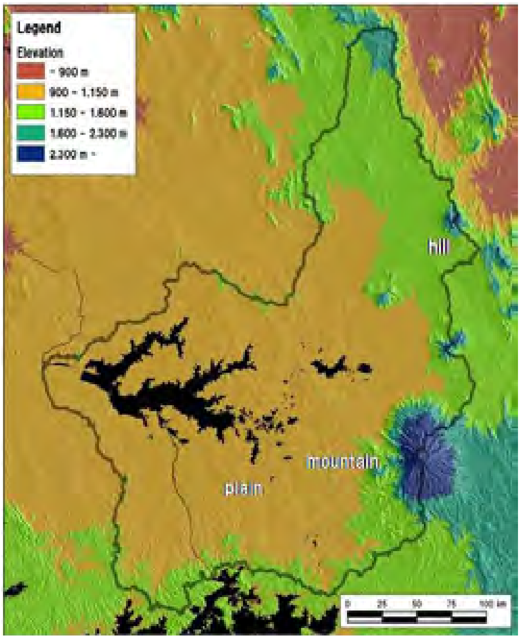


Figure 2-17 Elevation Classification Map

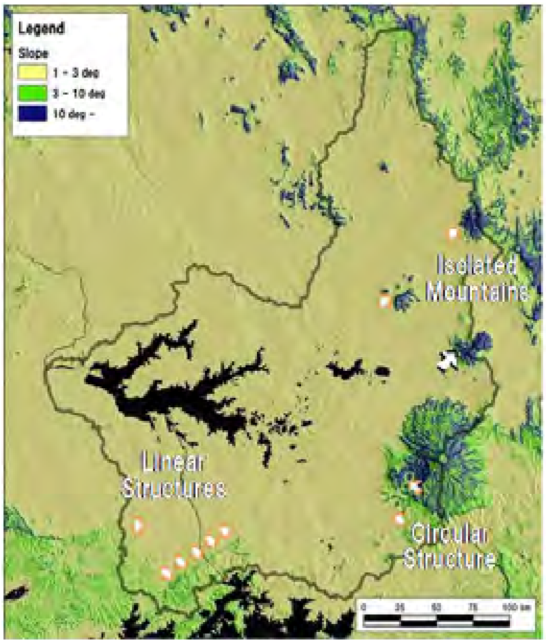


Figure 2-16 Slope Classification Map

The mountainous areas, whose slope degree is more than ten, are mainly distributed in the eastern and northern part of the Basin. In the eastern part of the Basin, there are isolated mountains composed of Tertiary volcanic rocks and associated sediments. Mt. Elgon forms the typical shape of strato-volcano with circular foots and slopes. On the other hand, the mountainous area located in the northern part runs from north to south and is mainly composed of Precambrian banded gneisses. These mountains have relatively gentle slope (3 to 10 degrees) and form the northern dividing ridge of Lake Kyoga Basin.

(3) Land Cover of Lake Kyoga Basin

Land cover of Lake Kyoga Basin is shown in Figure 2-18 and Table 2-4. Sum of forests and woodlands is 8.5% as one third of the value of Whole Uganda, and grassland and small-scale farmland are 28.5% and 45.8% respectively, which are about 8% higher than the values of Whole Uganda. As shown in Figure 2-18, central part of the Lake Kyoga Basin is widely covered by small-scale farmland and most part of Karamoja region is covered by grassland. Forests spread only in some parts of vicinity of the Basin boundary of northern, eastern and southern parts, and around Lake Kyoga in western part of the Basin.

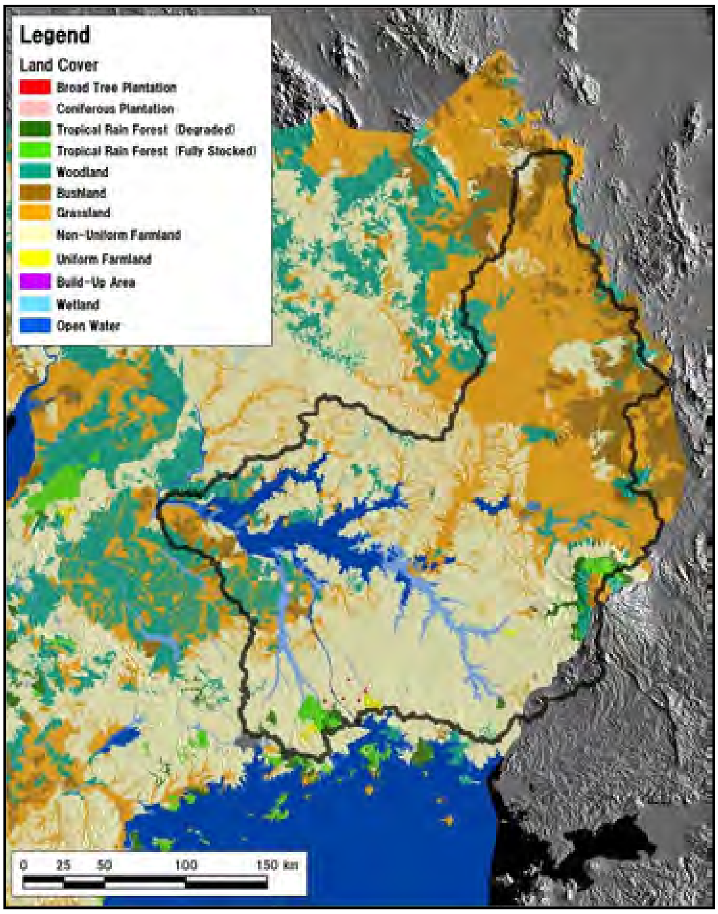


Figure 2-18 Land Cover of Lake Kyoga Basin

Vegetation – soil – water index (hereafter VSW index) is an advanced technique to calculate the ratio between vegetation, soil, and water. The VSW index image processed from satellite image, acquired in January of 2003, is shown in Figure 2-19. Concerning the northern part, although the field survey could not be carried out due to the security reason, the result of VSW Index suggests that the ground surface of this part is dry conditions; dried soils, exposed basement rocks, sparse trees and low vegetation, and distribution of vegetated area is limited to the area near the foot of isolated high mountain and along the rivers.

Table 2-4 Land Cover in Whole of Uganda and Lake Kyoga Basin

No.	Land Cover	Uganda i)		Lake Kyoga Basin ii)	
		Area (km^2)	Percentage	Area (km^2)	Percentage
1	Broadleaved Tree Plantation or Woodlot	35.2	0.0	28.7	0.1
2	Coniferous Plantation	162.2	0.1	24	0.0
3	Tropical High Forest (Fully Stocked)	7,263.70	3.0	497.3	0.9
4	Tropical High Forest (Degraded / Encroached)	2,239.10	0.9	435.7	0.8
5	Woodland	38,417.20	15.9	3,817.60	6.7
6	Bushland	12,550.60	5.2	4,263.40	7.5
7	Grassland	49,455.80	20.5	16,293.70	28.5
8	Wetland	3,866.70	1.6	2,126.10	3.7
9	Small-Scale (Non-Uniform) Farmland	89,495.00	37.0	26,161.60	45.8
10	Uniform or Large-Scale Farmland	346.6	0.1	179.6	0.3
11	Build-Up Area	262.2	0.1	56.2	0.1
12	Open Water	37,503.70	15.5	3,220.40	5.6
	Total	241,598.30	100.0	57,104.50	100

Source: i) GIS data of National Biomass Study (1996), Forest Department, ii) JICA Study Team