Department of Rural Water Supply (DRWS)
Ministry of Water (MoW)
The United Republic of Tanzania

The Study on Rural Water Supply in Mwanza and Mara Regions in the United Republic of Tanzania

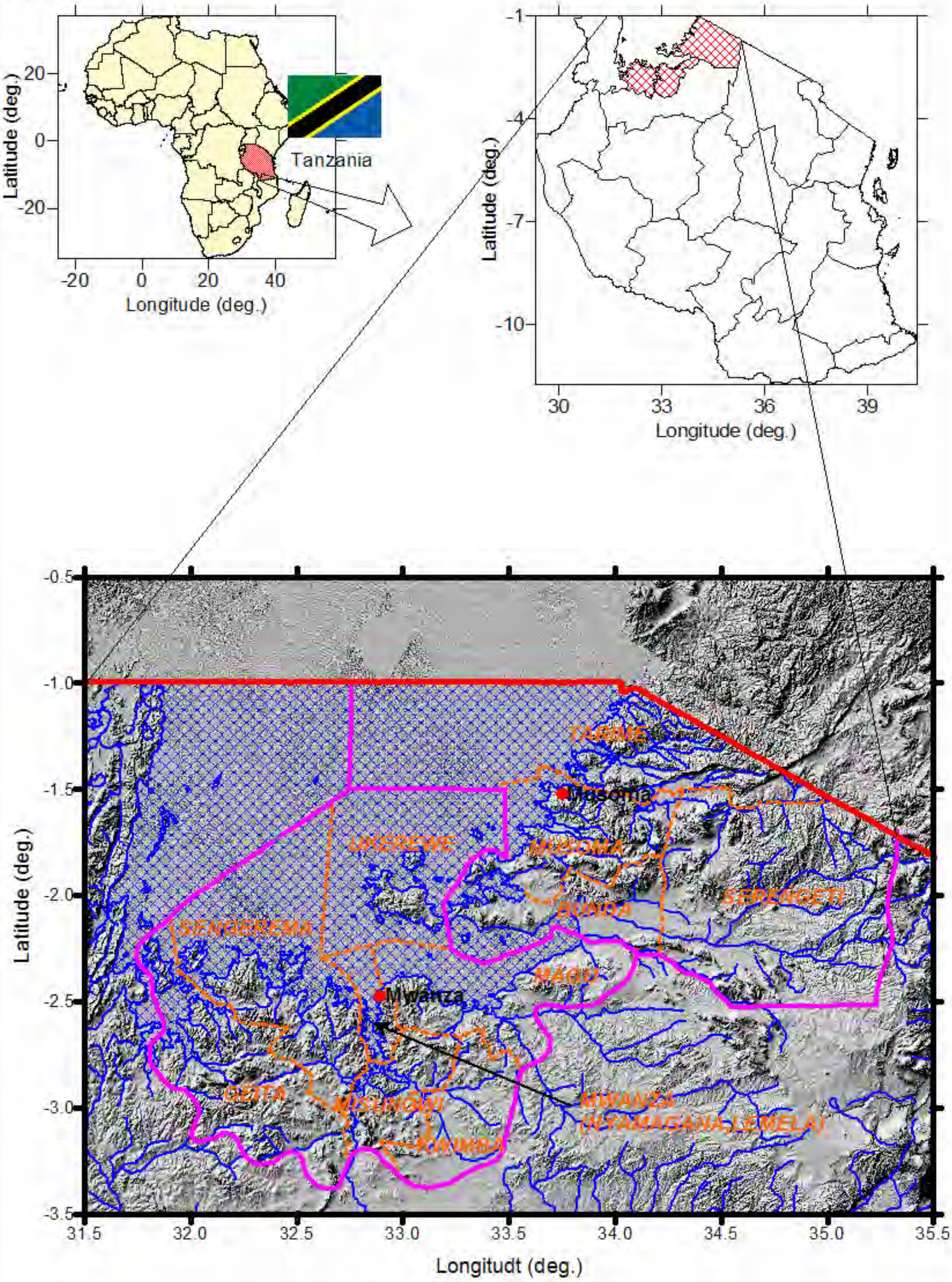
Final Report
SUPPORTING REPORT

September 2006

JAPAN INTERNATIONAL COOPERATION AGENCY

KOKUSAI KOGYO CO., LTD.

In this report, the project cost is estimated using the May 2006 price and at an exchange rate of 1 US$= 114.58 Japanese Yen = 1181 Tanzania Shilling.



Location Map

CONTENTS

List of Tables

List of Figures

Abbreviations

ATP:	Affordability To Pay
AfDB:	African Development Bank
AFD:	Agence Française de Développement
BWO:	Basin Water Office
CBOs:	Community Based Organization
CIDA:	Canadian International Development Organization
COWSOs:	Community Owned Water Supply Organizations
CDO:	Community Development Officer
DC:	District Commissioner
DC:	District Council
DED:	District Executive Director
DDCA:	Drilling & Dam Construction Agency
DRWS:	Department of Rural Water Supply
DPO:	District Planning Officer
DWD:	District Water Department
DWE:	District Water Engineer
DWP:	Domestic Water Points
DWST:	District Water and Sanitation Team
DWT:	District Water Technician
EC:	Electric Conductivity
EIA:	Environmental Impact Assessment
ESAs:	External Support Agencies
EU:	European Union
FGD:	Focus Groups Discussion
FSPs:	Facilitation Service Providers
TSPs:	Technical Service Providers
GDP:	Gross Domestic Product
GEF:	Global Environmental Facility
GIS:	Geographic Information System
GNP:	Gross National Product
GOT:	Government of Tanzania
GTZ:	Deutsche Gesellschaft fur Technische Zusammenarbeit
HESAWA:	Health through Sanitation and Water
IEE:	Initial Environmental Examination
IFAD:	International Fund for Agricultural Development
IDA:	International Development Association
IWSs:	Improved Water Sources
JICA:	Japan International Cooperation Agency
LGRP:	Local Government Reform Policy
LVBWO:	Lake Victoria Basin Water Office
LVEMP:	Lake Victoria Environmental Management Project
MDGs:	Millennium Development Goals
M/M:	Minutes of Meeting
MOF:	Ministry of Finance
MOL:	Ministry of Land
MoW:	Ministry of Water
NEMC:	National Environmental Management Council
NGO:	Non-Governmental Organization

NAWAPO:	National Water Policy
NWSDP:	National Water Sector Development Policy
O&M:	Operation and Maintenance
PRA:	Participatory Rural Appraisal
PRSP:	Poverty Reduction Strategy Paper
RF:	Registration Form
PHAST:	Participatory Health and Sanitation Transformation
PMO-RALG:	Prime Minister's Office, Regional Administration and Local Government
RAS:	Regional Administrative Secretariat
RRA:	Rapid Rural Appraisal
RWSD:	Rural Water Supply Division
RWSSP:	Rural Water Supply and Sanitation Program
SIDA:	Swedish International Development Cooperation Agency
SC:	Specific Capacity
SR:	Scoping Report
SWAP:	Sector Wide Approach to Planning
SWL:	Static Water Level
TBA:	Traditional Birth Attendant
TOR:	Terms of Reference
Tsh/TSH:	Tanzanian Shillings
TWSs:	Traditional Water Sources
UFW:	Unaccounted for Water
UNICEF:	United Nations International Children's Fund
VES:	Vertical Electric Sounding
VEO:	Village Executive Officer
VF:	Village Fundis (Artisans)
VHC:	Village Hesawa Committee
VHV:	Village Health Volunteer
VWC:	Village Water Committee
WB:	World Bank
WEO:	Ward Executive Officer
WRI:	Water Resources Institutes
WSS:	Water Supply System
WSSAs:	Water Supply and Sanitation Authorities
WSSMC:	Water Supply System Management Centre
WTP:	Willingness To Pay
WUA:	Water User Association
WUG:	Water User Group

Chapter 1

Meteorology and Hydrology

1 Meteorology and Hydrology

1.1 Meteorology in the Study Area

Meteorological and hydrogeological study was carried out to clarify the potential use of water sources such as surface water and groundwater. The meteorological analysis was carried out by using existing data such as rainfall, evaporation, temperature and humidity. Annual average rainfall in Mwanza and Mara Regions is 946 mm, average evaporation is about 1,800mm and average temperature is about 24.5 degree Celsius. The characteristic of those parameters will be mentioned in this chapter.

1.1.1 Meteorological Stations in the Study Area

There are 76 meteorological stations in the study area, 48 in the Mwanza region, 24 in the Mara region and 4 in the Shinyanga region. Rainfall was measured at every station, evaporation was measured at 5 stations, and temperature was measured at 2 stations in and around the study area.

Eighteen stations which are shown in Figure 1.1-1 were selected as representative meteorological stations out of all the meteorological stations around the study area for meteorological analysis. Rainfall, evaporation and temperature data were collected from the Tanzania Meteorological Agency and Lake Victoria Basin Water Office (hereinafter referred to as LVBWO).

1.1.2 Rainfall

Monthly rainfall data for 35 years (from 1970 to 2004) at each meteorological station were reviewed. The characteristics of annual and monthly rainfall are shown in Table 1.1-1.

Availability of the data at each station was insufficient due to the missing data. Most of the rainfall data from the period of 1980 to 1989 is available. However, other than the period from 1980 to 1989, frequency of missing data will be apparent. The detailed information of rainfall at each station and calculated results of probable rainfall are shown in Appendix 2 Table 5.

Table 1.1-1: Average Monthly and Annual Rainfall (Unit: mm)

Region	Station Code	Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mara	9133000	Musoma Airport	58.76	67.17	123.32	180.91	113.79	27.78	16.41	14.54	26.47	62.16	96.69	87.77	875.76
	9133002	Shirati Mission	78.66	62.26	118.29	200.75	119.83	29.33	32.16	26.08	29.80	63.73	108.08	75.49	944.46
	9133007	Kiabakari Prison	93.41	90.99	160.55	198.88	126.30	22.93	14.80	14.37	29.33	80.48	137.99	114.93	1084.95
	9133013	Bwayi Primary School	56.39	52.66	102.42	142.43	76.83	12.10	6.02	13.13	16.66	32.76	56.35	55.18	622.91
	9134033	Mugumu Primary School	105.21	100.08	140.81	150.62	121.05	51.12	34.29	59.56	61.53	77.99	114.92	121.49	1138.66
	9234005	Seronera	105.29	97.76	141.28	143.44	85.00	39.39	10.86	21.43	36.27	47.89	93.78	86.04	908.42
Mwanza	9132002	Ukerewe	156.83	117.76	193.30	234.35	113.20	41.84	34.75	53.95	80.09	125.21	174.06	187.68	1513.03
	9232009	Mwanza Airport	114.80	103.71	144.29	171.73	72.17	18.43	11.51	22.36	23.07	83.60	154.41	147.78	1067.86
	9232027	Kahunda	104.70	97.82	145.21	174.77	86.17	9.55	9.12	20.50	68.29	121.33	184.17	141.31	1162.93
	9232028	Nyehunge Primary School	97.13	89.76	127.09	152.33	82.67	18.56	7.84	12.93	31.71	85.52	124.54	131.21	961.31
	9232029	Buslwangiri Primary School	109.62	74.04	108.38	121.16	70.29	7.68	3.97	14.93	28.12	65.19	109.12	103.34	815.84
	9233001	Sumve T.T.C.	109.20	97.82	148.58	164.75	73.55	6.43	8.75	10.39	13.24	74.19	110.61	137.54	955.05
	9233005	Ngudu	93.11	95.09	140.96	136.81	57.80	16.11	4.12	5.91	16.56	61.63	130.34	126.32	884.75
	9233031	Nyanguge Primary School	67.39	56.27	99.45	116.91	49.95	19.81	3.87	8.05	13.55	46.30	102.19	109.17	692.90
	9233035	Mwanangwa Primary School	93.27	67.19	104.91	131.33	51.73	6.14	1.99	2.21	15.49	54.41	113.38	103.78	745.83
	9332011	Kharumwa Primary School	104.37	104.80	127.23	108.54	55.35	11.49	4.72	2.28	24.97	61.26	143.78	137.33	886.13
	9333058	Buhingo Parish	101.32	82.80	150.82	139.68	52.86	3.98	3.90	4.45	18.68	72.28	118.00	119.49	868.26
Shinyanga	9333005	Masuwa	117.68	99.94	149.12	131.52	52.38	6.37	1.70	5.87	8.06	42.14	122.10	163.83	901
		Average	98.17	86.55	134.78	155.61	81.16	19.39	11.71	17.39	30.10	69.89	121.92	119.43	946.10

The maximum annual rainfall is 2,080 mm at Seronera in 1992, and the minimum annual rainfall is 358 mm at Bwayi Primary School in 1984. The average annual rainfall from total data in the study area is 946 mm. The distribution of the average annual rainfall (isohyets) is shown in Figure 1.1-2. There is a tendency for higher rainfall at Lake Victoria and its shore areas (Ukerewe, Sengerema) and north-east Mara Region (Tarime, Serengeti), lower in the west of Mara Region (Part of Bunda and Musoma) and Central plane of Mwanza (Mwanza, Misungwi, Kwimba and Geita).

The maximum average monthly rainfall is 234.35 mm at Ukerewe in April, and the minimum average monthly rainfall is 1.7 mm at Masuwa in July. The fluctuation of the average monthly rainfall is shown in Figure 1.1-3. The values of average monthly rainfall differ greatly at each station. However, the period of the dry season, which is from June to September, and the rainy season, which is from November to April, are the same at each station.

1.1.3 Evaporation

Evaporation was measured at five stations, but data is available at only two stations (Mwanza A.P. and Musoma A.P.) due to a large amount of missing data. The fluctuation of the average monthly evaporation for 20 years (from 1985 to 2004) is shown in Figure 1.1-4 and the list of monthly evaporation is shown in Appendix 2 Table 8. The average monthly evaporation tends to decrease from November to May and increase during June to October which is in reverse proportion to monthly average of rainfall.

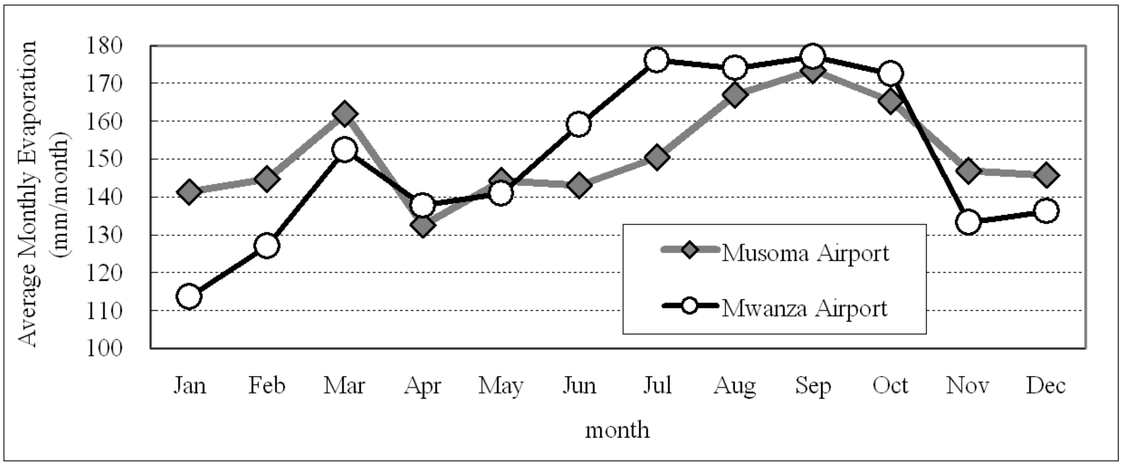


Figure 1.1-4: Average Monthly Evaporation (mm/month, 1985-2004)

The maximum annual evaporation is 2,058 mm at Musoma in 1984 and 2,057 mm at Mwanza in 1999. The minimum annual evaporation is 1,662 mm at Musoma in 1991 and 1,703 mm at Mwanza in 1994. These values of evaporation are more than the values of annual rainfall in the study area. The average annual evaporation is 1,817 mm at Musoma A.P. and 1,800 mm at Mwanza A.P. The maximum average monthly evaporation is 173.4 mm at Musoma in September and 177.0 mm at Mwanza in September. The minimum average monthly evaporation is 132.6 mm at Musoma in April and 113.7 mm at Mwanza in January.

The value of evaporation is measured by pan, and this method is not indicating representative area and surface structure. Therefore, Thornthwaite method has been used for the estimation of the evapotranspiration by the area for the hydrologic calculation.

1.1.4 Temperature and Humidity

Temperature was measured at only two stations (Mwanza A.P. and Musoma A.P.). The average monthly temperature (maximum, minimum and average) for 35 years (from 1970 to 2004) shown in Figure 1.1-5 and Appendix 2 Table 6.

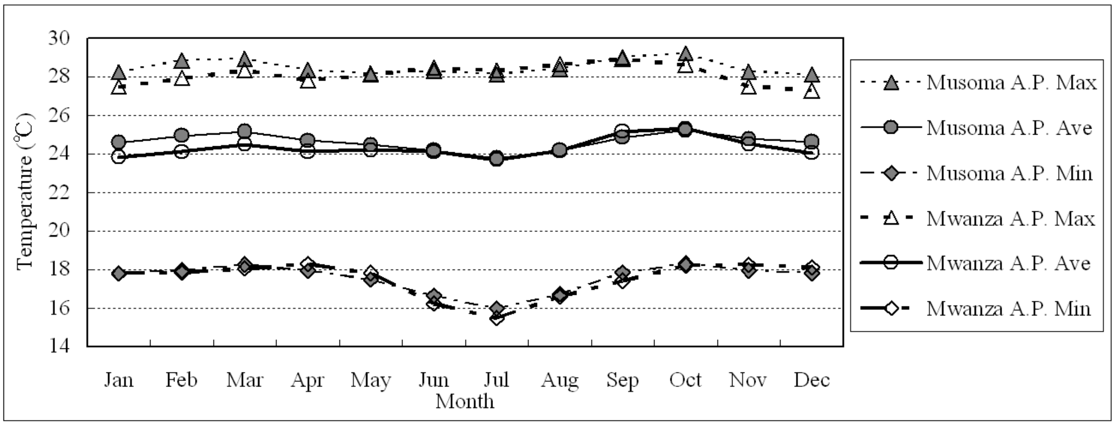


Figure 1.1-5: Average Monthly Temperature (℃, maximum and minimum, 1970-2004)

The maximum monthly temperature is 31.1 degree Celsius at Musoma in September 1997 and 32.1 degree Celsius at Mwanza in September 1997. The minimum monthly temperature is 14.6 degree Celsius at Musoma in July 1999 and 11.6 degree Celsius at Mwanza in July 1998. The fluctuation of monthly temperature is high in the rainy season and low in the dry season. The average monthly temperature is about 0.5 to 1 degree higher in Musoma than in Mwanza.

The maximum average monthly humidity is 84 % in Musoma in April 1985, February 1996 and January 2000, and 91% in Mwanza in February 1996. The minimum average monthly humidity is 46% in Musoma in August 1992 and June 1993, and 37% in Mwanza in July1989. The fluctuation of average monthly humidity tends to increase in the rainy season (55 to 80%) and decrease in the dry season (45 to 70%).

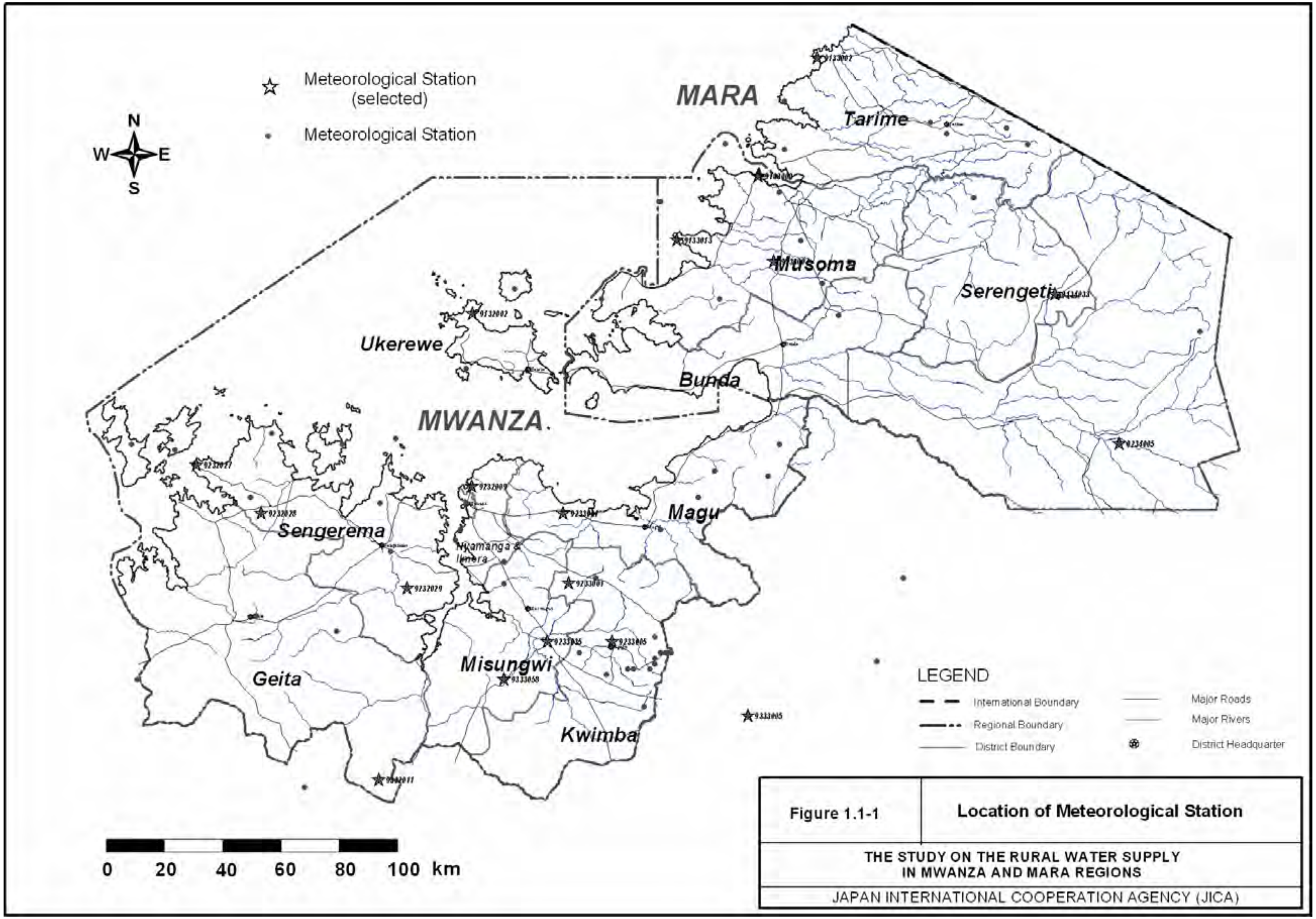


Figure 1.1-1 Location of Meteorological Station

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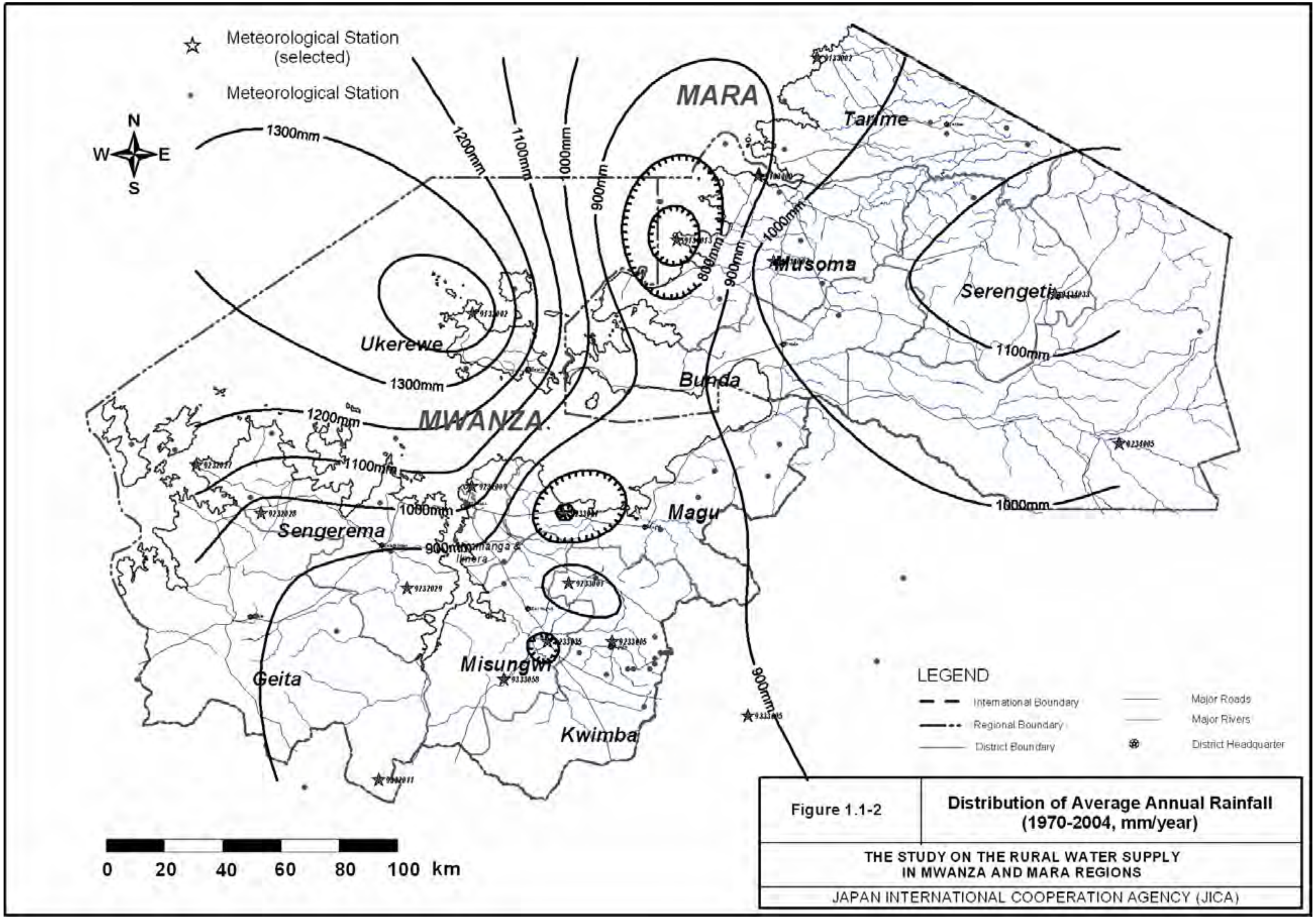

Figure 1.1-2 Distribution of Average Annual Rainfall (1970-2004, mm/year)

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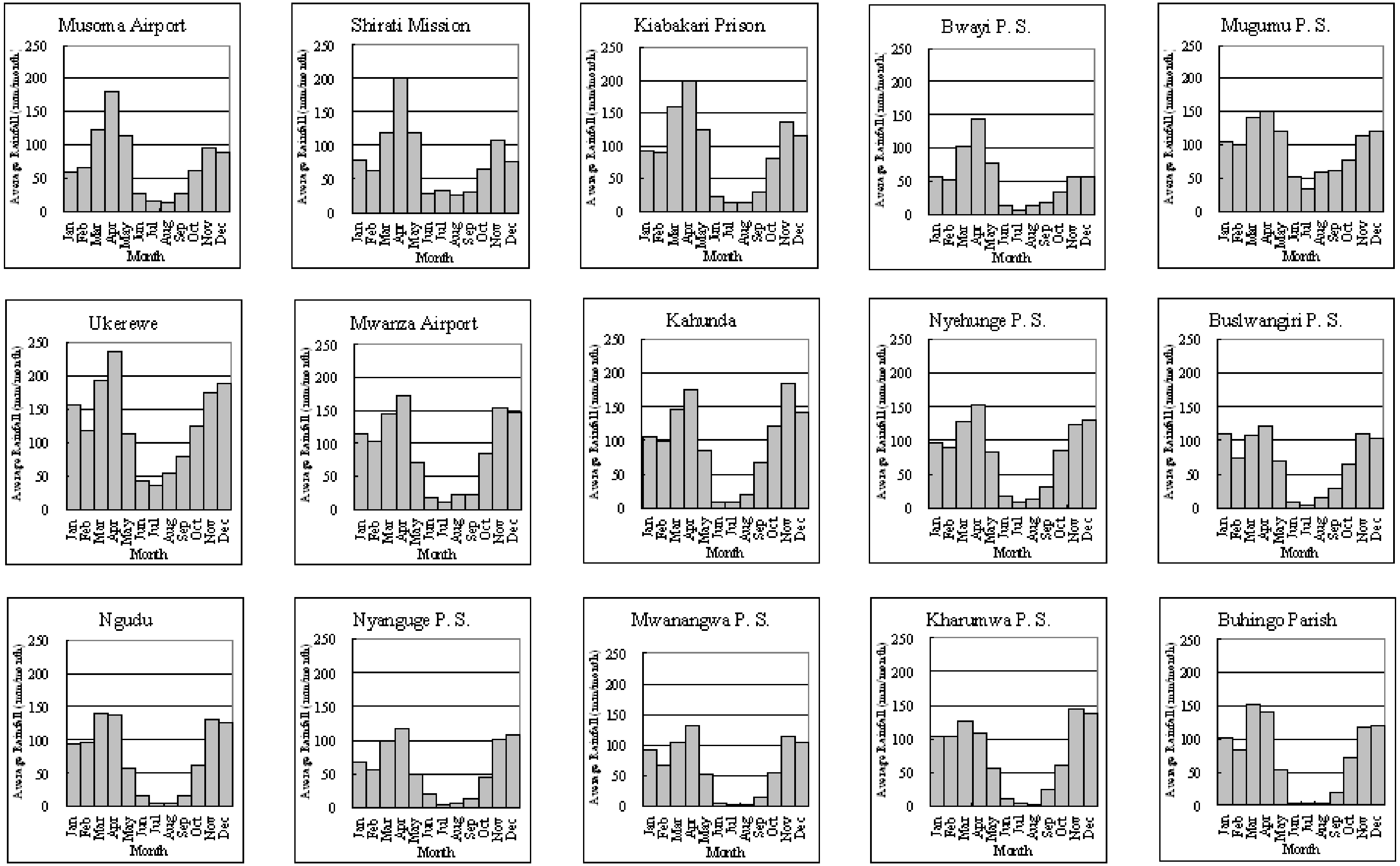

Figure 1.1-3: Average Monthly Rainfall (mm/month, 1970-2004)

1.2 Hydrology in the Study Area

The characteristics of the river basins were arranged from the topographic map of the study area and its surroundings. Furthermore, the discharge by basin was calculated based on data from water level and discharge observation stations. The results of the river discharge calculations were used as verification data for the water balance estimation. Also, the water level fluctuations in Lake Victoria were reviewed from existing data to understand the hydrological feature of Lake Victoria.

1.2.1 River System in the Study Area

The river system in the study area is shown in Figure 1.2-1. Almost all rivers and streams flow into Lake Victoria, except in the southwest area of the Mwanza region. Divisional river basins and its catchment area are shown in Figure 1.2-2. Watersheds of the river basin are located out of the study area, especially the Mara River, which flows down from Kenya across the eastern international boundary. River basins are defined into twelve areas in reference with LVEMP (2002) reports to ensure the consistency of the results of analyses.

However, the definition of river basin in this study is classified as a smaller area than that of LVEMP (2002), due to the necessity of adopting a small river basin which has different meteorological features for water balance calculation.

Lake Victoria gathers water from the rivers of Tanzania, Kenya and Uganda, and flows down into the Nile River around Jinja in Uganda. The main rivers in the study area are the Mori river, Mara river, Suguti river, Grumeti river, Mbalageti river, Duma river, Simiyu river, Magogo river, Moame river and Isanga river in order from north side. Especially, Mara river, Grumeti river, Duma river, Simiyu river and Isanga river have long streams with many tributaries. The flow directions of the main rivers are from east to west in north-east area, from south-east to north-west in central area and from south to north in western area.

1.2.2 Hydrological Observation Stations and River Water Level

Hydrological observation stations were established at 15 places (8 places in Mara region, 7 places in Mwanza region) in the seven river basins in the study area, and managed by LVBWO. However, water levels are currently monitored at only seven stations (4 stations in Mara region, 3 stations in Mwanza region). Their locations are shown in Figure 1.2-1.

Water levels were measured daily at each station, and measurements of discharge were conducted at some stations at a specific time. Water levels and discharge data at each station were obtained from LVBWO. Analyzable data was obtained at nine stations, of which only five are still carrying out observations.

1.2.3 Correlation between River Water Level and River Discharge

In order to calculate the river discharge from the river water level, rating curves were drawn from existing observation data. The correlation between the river water level and the river discharge has almost a good correlation as shown in Appendix 2-1 Figure 4, 5. However three stations (Mara River at Kirumi, Magogo River at Ngudu and Moame River at Moame/Magogo confluence) have no measured river discharge data. Under the present observation network, the full understanding of the hydrological situation in all of the study areas is difficult.

The fluctuations of river discharge by calculation are shown in Figure 1.2-3 and Figure 1.2-4. Mara and Simiyu rivers are perennial streams in the study area, but most of the rivers dry up in the dry season.

1.2.4 Water Level of Lake Victoria

Lake Victoria which is located towards the north of the study area has an area of 69,490 km^2, maximum water depth of 82m and average water depth of 40m.

It is an international lake which shares its border with Tanzania, Kenya and Uganda. All of the river discharge in the study area inflows into Lake Victoria. The total volume of stored water in Lake Victoria is always affected by precipitation from the surrounding rivers flowing into the lake, evaporation and the artificial consumption and discharge of the shore side cities and villages.

The present water level of Lake Victoria is about 1,134m above sea level, and fluctuation of water level from 1965 to 2004 is shown in Figure 1.2-5. These results indicate the trend of a decrease in water level from 1,136m to 1,134m during past 40 years (1965- 2004).

According to the LVEMP data, potential sum of 33m^3/s inflow is calculated to the water balance of the Lake. This inflow will raise the water level of 0.015m of the Lake which the value is considerably low compare to the annual fluctuation. Presumably, the water level of the Lake Victoria is strongly controlled by evaporation, rainfall and inflow from the tributary from the surrounding catchment.

The conspicuous trend of a change of water level is not explained by the observation data of rainfall and evaporation. Increase of inflow to the Nile, increase of artificial utilization of the water from lakes and long-term climatic changes are supposed as the reasons for the decrease in the water level of Lake Victoria. However, it is difficult to conclude a reason for the water level change as the hydrogeological data and exploitation from the lake is not known in Kenya and Uganda.

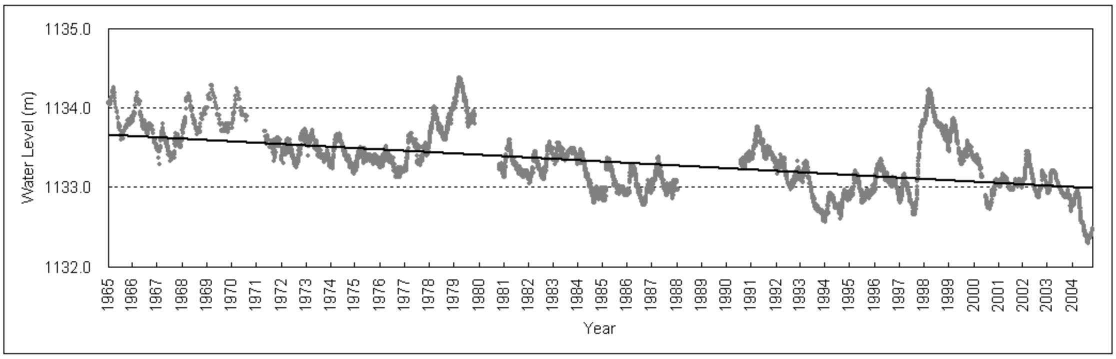

Figure 1.2-5: Water level of Lake Victoria at Mwanza Port (1965-2004)

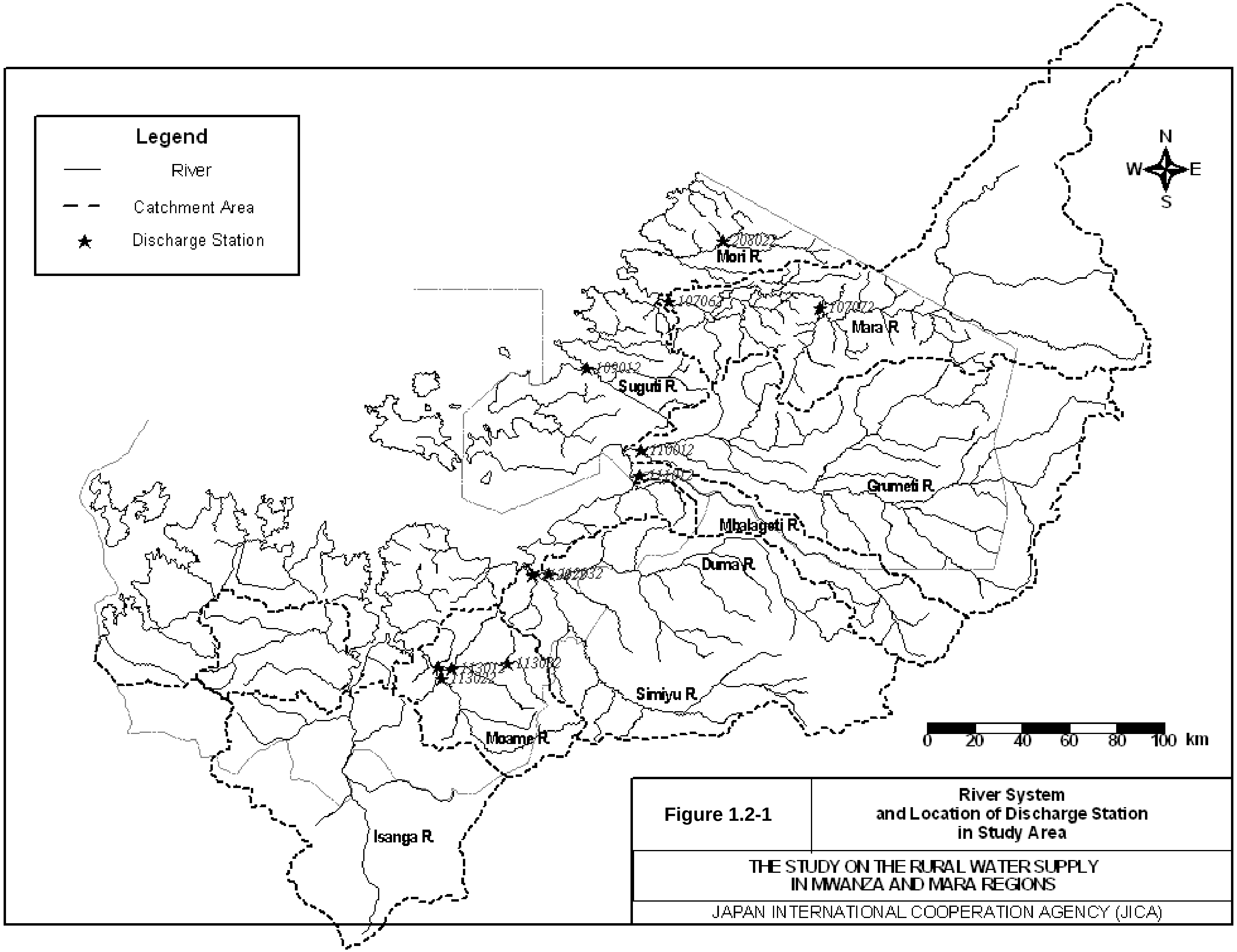

Figure 1.2-1	**River System and Location of Discharge Station in Study Area**
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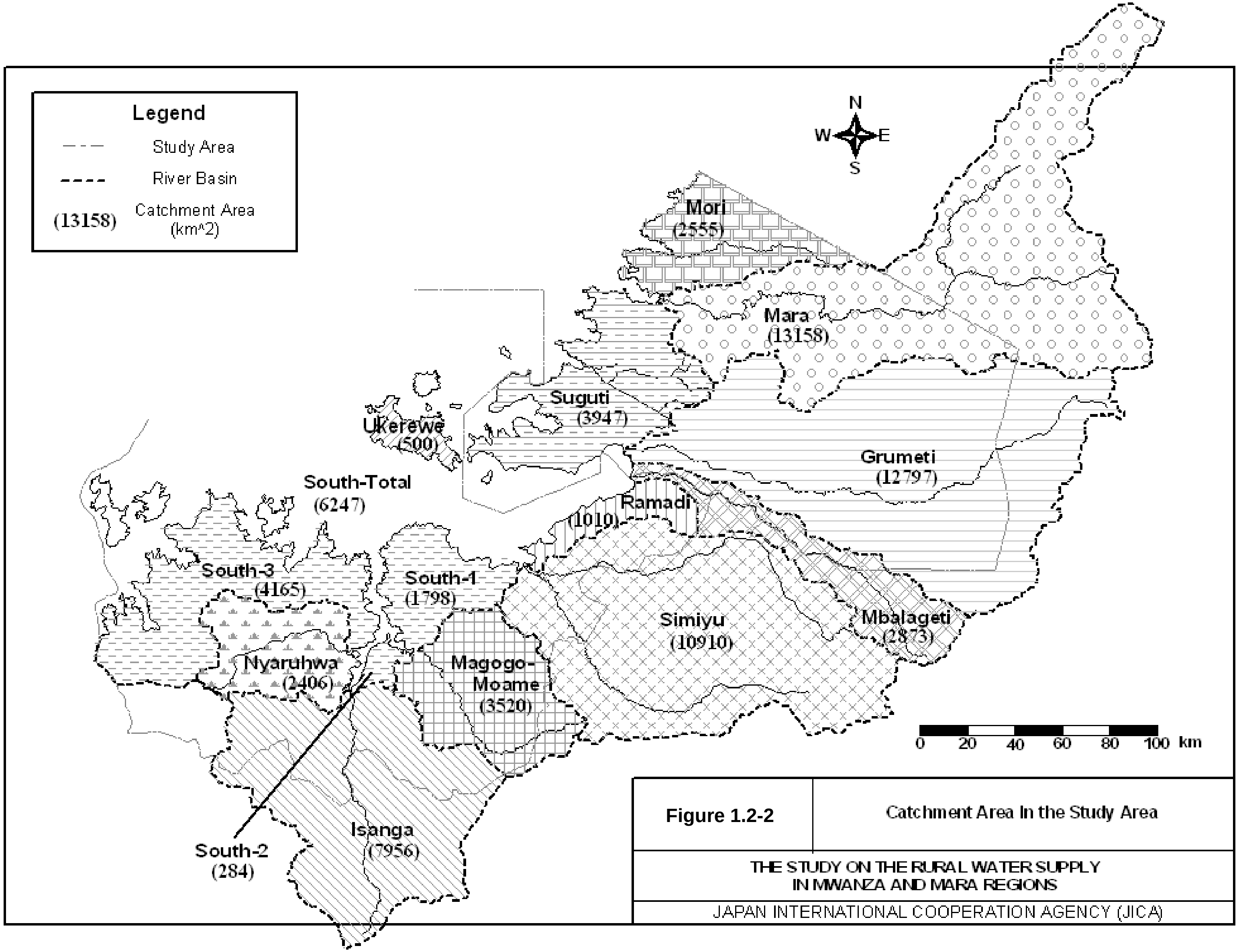
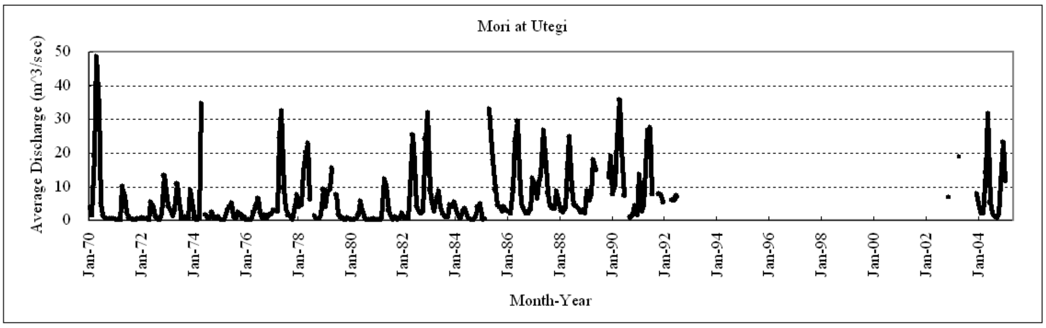
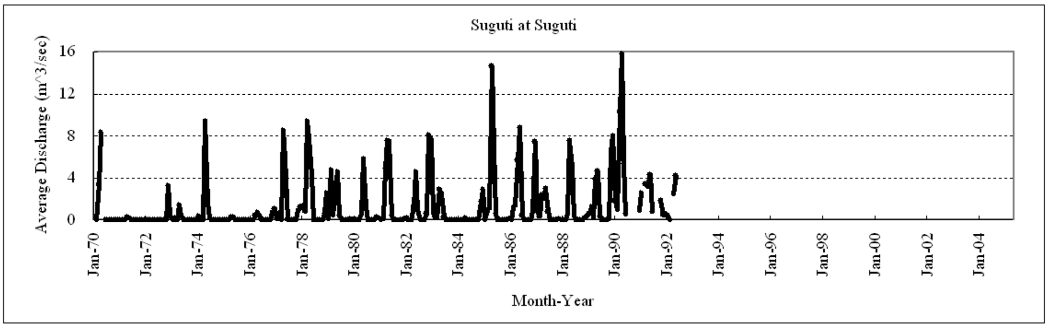
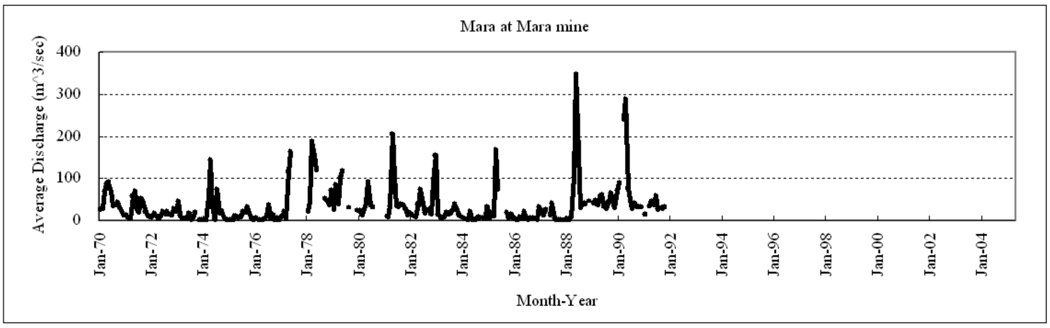
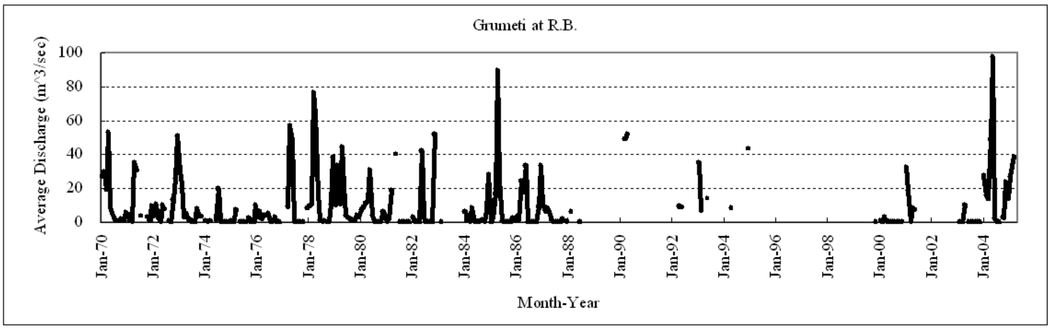


Figure 1.2-2 Catchment Area In the Study Area









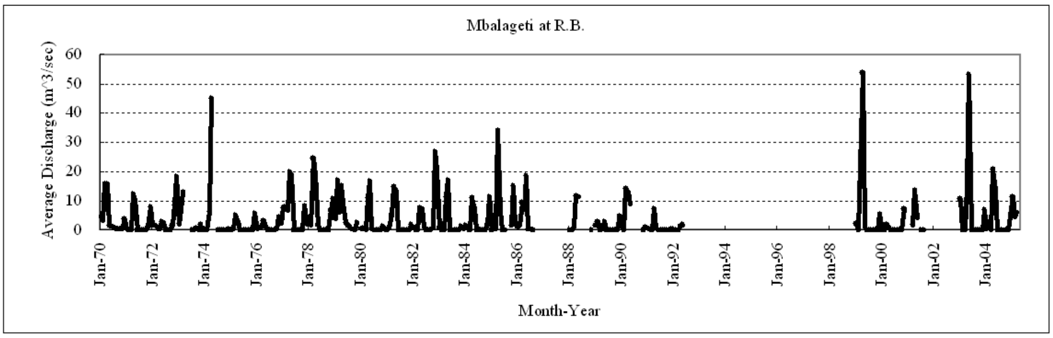
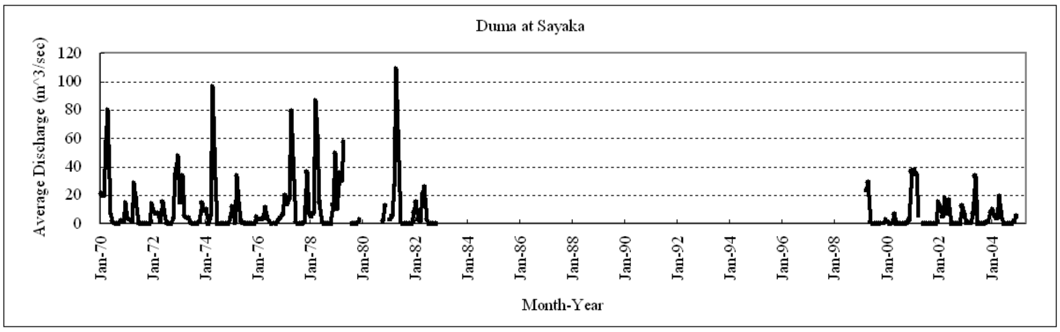
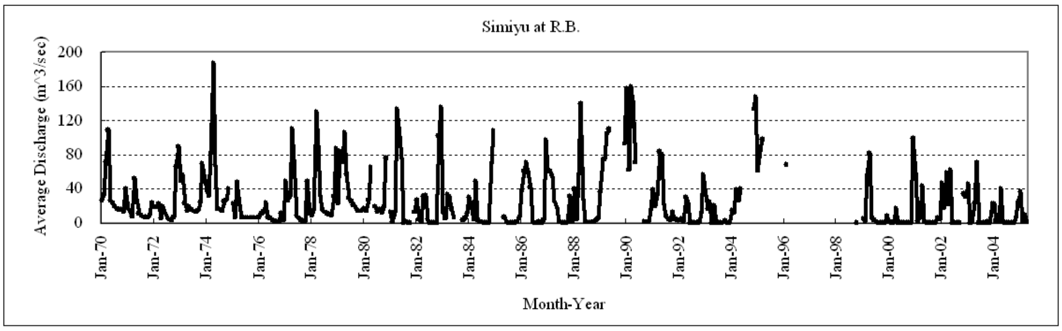
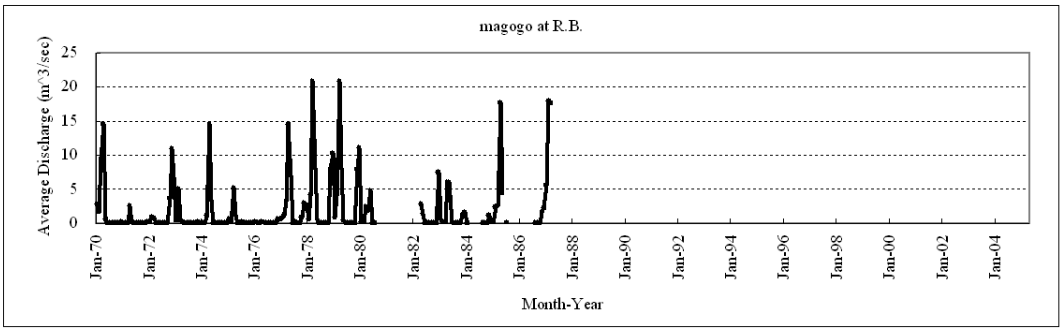


Figure 1.2-3: Calculated River Discharge (1)







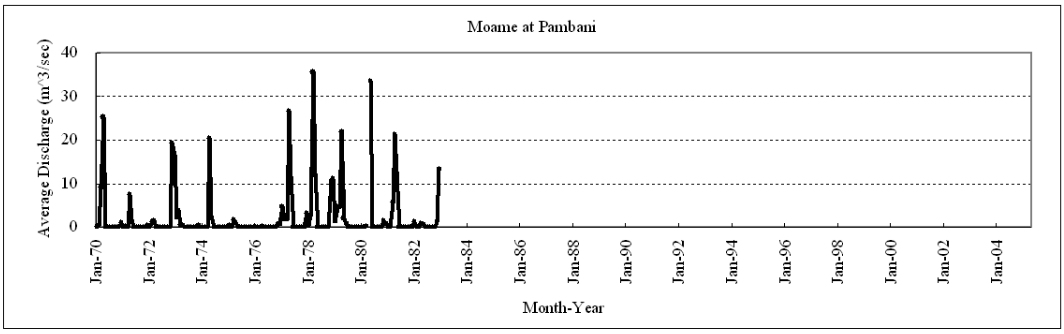


Figure 1.2-4: Calculated River Discharge (2)

1.3 River Discharge Measurement

The hydrologic characteristics of all the basins are not fully understood because some of the basins have no station for river discharge (water gauge). And hydrologic characteristics are able to change under different geomorphologic and geologic conditions even in the same basin. In order to understand the situations of the river discharge in the study area, river discharge measurements at new measuring points has been conducted to complement the existing river discharge stations.

a. Places and periods of River Discharge Measurement

Ten points were selected to obtain the river discharge measurement of both upstream and downstream including existing stations in the same river. The criteria for selecting 10 new points (5 in Mara region, 3 in Mwanza region and 2 in Shinyanga region) from the 19 candidate points (7 in Mara region, 9 in Mwanza region and 3 in Shinyanga region) was based on favorable conditions of the points for conducting accurate river discharge measurement. Selection of new points for the non-gauging river had taken more consideration than the other basin which has an existing gauge for river discharge. Unfortunately, the new point for river discharge measurement was not selected in the western part of the study area because the main river of this area dried up in May 2005. Table 1.3-1 and Figure 1.3-1 show the locations of those points for discharge measurement in and around the Study Area.

Table 1.3-1: River Discharge Measuring Points

No.	River Basin	River	Region	District	Place	Latitude (UTM)	Longitude (UTM)	Catchment Area (km2)
Dc-1	Mori	Mori	Mara	Tarime	Utegi	9856404	631745	827
Dc-2	Suguti	Suguti	Mara	Musoma	Suguti	9803333	574048	1052
Dc-3	Suguti	Suguti	Mara	Musoma	Mwanza-Musoma R.B.	9790582	593398	340
Dc-4	Grumeti	Grumeti	Mara	Serengeti	Fort Ikoma	9768472	682604	3041
Dc-5	Mbalageti	Mbalageti	Mara	Bunda	Mwanza-Musoma R.B.	9757621	596369	2828
Dc-6	Simiyu	Duma	Shinyanga	Baridai	Baridai-Ramadi R.B.	9718047	609076	2445
Dc-7	Simiyu	Simiyu	Shinyanga	Baridai	Malita	9659796	597519	3045
Dc-8	Simiyu	Simiyu	Mwanza	Magu	Lumeji	9707045	560147	4924
Dc-9	Magogo-Moane	Moame	Mwanza	Misungwi	Pambani	9671730	512360	1678
Dc-10	South Shore	Nyamkama	Mwanza	Mwanza	Mwanza-Shinyanga R.B.	9696158	503424	55

b. Methodology of River Discharge Measurement

The river discharges were calculated based on river flow velocities and cross-section areas both measured on site. River flow velocities were measured by following a current meter method. The respective cross-sectional areas of flows were determined on the basis of the measured river depths and widths. To ensure accuracy, two readings were carried out at each velocity measuring point. All measurements and calculations were done in accordance with “the Manual for River Works in Japan”.

The types of current meters used are as follows:

- OTT type which are C31 (10.002) OTT Universal Current Meter (OTT Hydrometrie, OTT Messtechnik GMBH & Co. KG, Munich, Germany)
- OTT C 2 Small Current Meter (OTT Hydrometrie, OTT Messtechnik GMBH & Co. KG, Munich, Germany) were used for the river velocity measurements.

- C31 (10.002) OTT Universal Current Meter was used for the river velocity measurements in principle.

OTT C 2 Current Meter was used where water level (minimum depth of water 4 cm) was low and flow velocity was between 2.5 m/sec. and 5 m/sec. For counting the impulses of water current meters during the measuring periods, A Z 30 Counter (OTT Hydrometrie, OTT Messtechnik GMBH & Co. KG, Munich, Germany) was used.

c. Result of River Discharge Measurement

A summary of description of river discharge measuring point, methods and instruments used and calculated values of river discharges are shown in Table 1.3-2. Works of measurements for the rainy season had carried out from 24^{th} to 27^{th} of May 2005 and from 28^{th} to 31^{st} of September 2005 for dry season. Some points were not measurable due to dry up or no flow of the rivers.

Table 1.3-2: Result of River Discharge Measurement

Station Number	River	Place	Date	Starting Time	Finishing Time	Duration (min)	Width of the river (m)	Measured interval (m)	Number of measuring points	Mean velocity (m/sec)	Area (m²)	Discharge (m³/sec)		
												1st measurement	2nd measurement	Mean
Dc-1	Mori	Utegi	24 May 05	11:30	12:22	52	12.8	1 - 2	13	0.18	5.888	1.06	1.064	1.062
Dc-2	Suguti	Suguti	24 May 05	16:35	17:20	45	13.75	1 - 2	11	0.150 ± 0.000	3.818	0.572	0.572	0.572
Dc-3	Suguti	Mwanza - Musoma R.B.	24 May 05	14:30	15:05	35	7.5	1	9	0.072	1.505	0.109	0.108	0.1085
Dc-4	Grumeti	Fort Ikoma	25 May 05	13:10	13:56	46	9.7	0.5 - 1	12	0.342	1.325	0.455	0.451	0.453
Dc-5	Mbalageti	Mwanza - Musoma R.B.	25 May 05	18:00	18:34	34	2.25	0.2	12	0.155 ± 0.003	0.171	0.028	0.025	0.0265
Dc-6	Duma	Baridai - Ramadi R.B.	26 May 05	13:00	13:40	40	24.5	2	14	0.725	14.255	10.339		10.339
Dc-7	Simiyu	Malita	26 May 05	15:30	16:15	30	5.25	0.5	12	0.198 ± 0.004	0.737	0.143	0.149	0.146
Dc-8	Simiyu	Lumeji	27 May 05	10:20	11:12	52	23.1 (large part) 2.35 (small part)	2 0.5	13 6	0.149 ± 0.003	17.564	2.664	2.563	2.6135
Dc-9	Moame	Pambani	27 May 05	14:30	15:10	40	5.1	0.5	10	0.017 ± 0.000	0.363	0.006	0.006	0.006
Dc-10	Nyamkama	Mwanza - Shinyanga R.B.	27 May 05	18:20	18:42	22	0.6	0.1	7	0.200 ± 0.000	0.035	0.007	0.007	0.007

The measured hours were different in each measuring point depending on the scale of the river. The widths of river are from 0.6m (Dc-10, Nyamkama river, Mwanza-Shinyanga R.B.) as the narrowest while 25.5m (Dc-6, Duma river, Baridai-Ramadi R.B.) as the widest. The measured interval and number of measuring point at one measuring line were adjusted according to river flow velocities and cross-section areas. The measured intervals were from 0.1m to 2m, and numbers of measuring point were from 6 to 14. The river discharges, which were calculated by measured velocity and measured area of section, were from 0.006 m³/sec (Dc-9, Moame river, Pambani) to 10.339 m³/sec (Dc-6, Duma river, Baridai-Ramadi R.B.).

The ratio of runoff in each point of river discharge measurement was calculated by the above-mentioned formula on the basis of river discharge data at each point. Ratio of runoff at each river discharge points is shown in Table 1.3-3.

$$Rr = D / A$$

Rr : Ratio of Runoff (mm/month)
D : River Discharge (mm^3/month)
A : Catchment Area (mm^2)

Table 1.3-3: Ratio of Runoff at the River Discharge Measuring Points

No.	River Basin	River	Place	Date of Measurement	River Discharge		Catchment Area		Ratio of Runoff
					(m^3/sec)	(mm^3/month)	(km^2)	(mm^2)	(mm/month)
Dc-1	Mori	Mori	Utegi	24-May-05	1.062	2.7527E+15	827	8.26929E+14	3.3288
Dc-2	Suguti	Suguti	Suguti	24-May-05	0.572	1.48262E+15	1052	1.05175E+15	1.4097
Dc-3	Suguti	Suguti	Mwanza-Musoma R.B.	24-May-05	0.109	2.82528E+14	340	3.39725E+14	0.8316
Dc-4	Grumeti	Grumeti	Fort Ikoma	25-May-05	0.453	1.17418E+15	3041	3.04086E+15	0.3861
Dc-5	Mbalageti	Mbalageti	Mwanza-Musoma R.B.	25-May-05	0.0265	6.8688E+13	2828	2.82847E+15	0.0243
Dc-6	Simiyu	Duma	Baridai-Ramadi R.B.	26-May-05	10.339	2.67987E+16	2445	2.44547E+15	10.9585
Dc-7	Simiyu	Simiyu	Malita	26-May-05	0.146	3.78432E+14	3045	3.04509E+15	0.1243
Dc-8	Simiyu	Simiyu	Lumeji	27-May-05	2.614	6.77549E+15	4924	4.92427E+15	1.3759
Dc-9	Magogo-Moane	Moame	Pambani	27-May-05	0.006	1.5552E+13	1678	1.67798E+15	0.0093
Dc-10	South Shore	Nyamkama	Mwanza-Shinyanga R.B.	27-May-05	0.007	1.8144E+13	55	5.54602E+13	0.3272

Calculated ratios of runoff ranges from 0.0093 mm/month (Dc-9, Moame river, Pambani) to 10.9585 mm/month (Dc-6, Duma river, Baridai-Ramadi R.B.).

In general, infiltration of rainfall is larger in the area which has a small ratio of runoff and less in the area which has a large ratio of runoff.

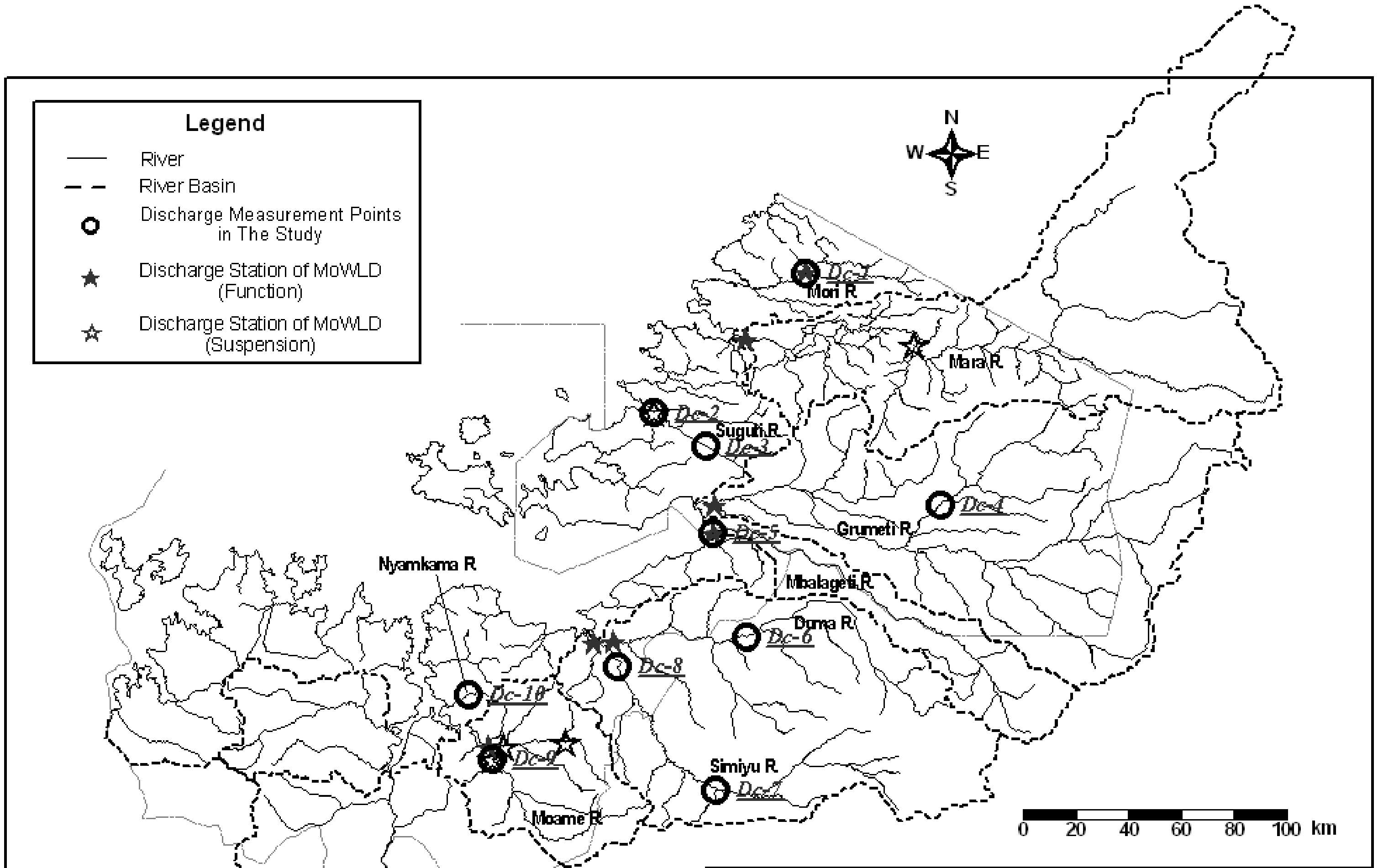


Figure 1.3-1	Location of River Discharge Measurement
THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

1.4 Water Balance Analysis

In order to examine the potential of development for surface water and groundwater, water balance analysis was carried out by two methods which are macro water balance analysis and calculation by applying the Tank Model.

1.4.1 Macro Water Balance Analysis

Monthly recharge to groundwater of each river basin was estimated based on calculation of hydrological and meteorological observation data. The rainfall (P) in the river basin was divided into three components (river discharge (D), potential evapotranspiration (E) and recharge to groundwater (R)) as referred to as the following formula.

$$P = D + E + R$$

Recharge to groundwater per unit area was calculated by the input of each parameter per unit area following the above formula. All parameters are indicated by per unit area to compare the potential recharge to groundwater among river basins.

a. Rainfall in River Basin

The monthly rainfall in each river basin was calculated using the observation data for 35years (from 1970 to 2004) which was arranged in Chapter 1.2. However, some observation stations have a lot of missing data so it was necessary to supplement this missing data to calculate the monthly rainfall. The missing data was supplemented by the following methods.

- The supplementary data were calculated with a correlation coefficient which was taken from the correlation with the reference station.
- Observation stations in Mwanza Region made reference to observation data from Mwanza airport, which has had no missing data for 35 years.
- Observation stations in Mara Region made reference to observation data from Musoma airport, which has had few missing data for 35 years.
- The station of Musoma airport made reference to observation data from Mwanza airport.

The rainfall in each river basin was calculated by the Thiessen Method, which is shown in the Appendix 2-2 Figure 1, based on the supplemented observation data at each station. The Thiessen Method was widely used for hydrological analysis because there is very little individual variation in this method.

The fluctuation of average monthly rainfall in river basin is shown in Figure 1.4-1. The maximum average monthly rainfall is 234.35 mm in the Ukerewe basin in April, and the minimum average monthly rainfall is 2.89 mm in the Isanga basin in August. The maximum average annual rainfall is 1512.44 mm in the Ukerewe basin, and the minimum average annual rainfall is 867.61 mm in the Magogo-Moame basin.

b. Ratio of Runoff in River Basin

The average monthly runoff ratio in each river basin was calculated based on the arranged river discharge data for 35 years (from 1970 to 2004) in each basin, which is explained in Chapter 1.2. However, as the observation stations for river discharge are established in only seven basins in the study area, it was necessary to supplement the river discharge data in the other five basins. Furthermore, it was also necessary to supplement missing data because all the observation stations have a lot of missing data, even in basins where a gauge has been established. The missing data was supplemented by the following methods.

- The data was supplemented for the ungauged five basins without river discharge stations by using the observation data in adjacent basins that have few missing data and similar geomorphologic and geologic conditions. Supplementary data on river discharges were calculated by the ratio of the catchment area and the rainfall in each basin.
- The observation data of the Simiyu basin are used as supplementary data, because granite is mainly distributed in both the Simiyu basin and the five ungauged basins.
- The data for the seven basins with river discharge stations was supplemented by using a correlation coefficient with the rainfall and river discharge in each respective basin.

The fluctuation of the average monthly runoff ratio in the river basin is shown in Figure 1.4-2, and a list of the average monthly runoff ratios in the river basins is shown in the Appendix 2-2 Table 2. The maximum average monthly runoff ratio is 56.94 mm in the Mori basin in April and the minimum average monthly runoff ratio is 0 (zero) mm in the Magogo-Moame basin from July to October. The maximum average annual runoff ratio is 237.11 mm in the Mori basin, and the minimum average annual runoff ratio is 23.14 mm in the Grumeti basin. The values of average monthly runoff ratio vary greatly at each station and in each month.

Furthermore, the monthly average river discharges in each basin were calculated and are shown in the Appendix 2-2 Table 3. The annual average river discharge into Lake Victoria from the entire basin area is 149.39 m^3/sec.

c. Potential Evapotranspiration

Based on the existing measured temperature data, the average monthly potential evapotranspiration was calculated in accordance with the following formula (Thornthwaite, 1948). The result of the calculation is shown in the Appendix 2-2 Table 5, 6. The average monthly temperature at Musoma Airport was used for the calculation in the four basins of East Shore, Mara, Grumeti and Mbalageti, and accordingly, the average monthly temperature at Mwanza Airport was used for the calculation in the four basins of Simiyu, Magogo-Moame, Isanga and South Shore. The calculated values of potential evapotranspiration were lower at about 70% of the observed evaporation indicated in the Appendix 2-1 Table 8.

$$E_t = 1.6 \times \left(\frac{10T}{I} \right)^{a}$$

$$I = \sum_{i=1}^{12} \left(\frac{T_i}{5} \right)^{1.514}$$

a : $(492390 + 17920\,I - 77.1\,I^2 + 0.675\,I^3) \times 10^{-6}$
E_t : Potential Evapotranspiration (cm/month)
T : Average monthly Temperature (℃)

d. Potential recharge to groundwater

The potential recharge to groundwater per unit area in each basin, which is a sum of the above-mentioned calculations, is shown in Table 1.4-1, and the percentage recharge to groundwater against the rainfall in each basin is shown in Table 1.4-2. The potential recharge to groundwater in each basin is shown in Table 1.4-3. Furthermore, the potential recharge to groundwater per unit area in each district is shown in Table 1.4-4, while the percentage recharge to groundwater against the rainfall in each district is shown in Table 1.4-5. The potential recharge to groundwater in each District is shown in Table 1.4-6.

According to the calculation results, the potential recharge to groundwater in every river basin becomes zero (0) during the season when rainfall decreases (February and from June to September). The annual average potential recharge to groundwater in the total basin area is 45.84 m^3/sec, and the annual potential recharge to groundwater per unit area in the total basin area is 154.54 mm.

The maximum annual potential recharge to groundwater per unit area is 491.95 mm in the Ukerewe basin while the minimum annual potential recharge to groundwater per unit area is 116.04 mm in the Mori basin. The maximum annual percentage recharge to groundwater is 32.38 % in the Ukerewe basin while the minimum annual percentage recharge to groundwater is 12.03 % in the Mori basin.

In the case of district unit, the maximum annual potential recharge to groundwater per unit area is 491.95 mm in Ukerewe while the minimum annual potential recharge to groundwater per unit area is 132.62 mm in Sengerema. The maximum annual percentage recharge to groundwater is 32.38 % in Ukerewe while the minimum annual percentage recharge to groundwater is 13.71 % in Tarime.

1.4.2 Analysis of Water Balance by Tank Model

The potential recharge to groundwater is greatly influenced by the conditions of surface geology and the infiltration capacity of soil. In order to reflect the natural characteristics in the study area accurately to the potential recharge to groundwater, analysis of water balance was carried out according to the Tank Model method.

The Tank Model method, one of the water balance models, was proposed by Sugawara (1972), and it is usually composed of two or three tanks. Each tank conceptually expresses the reservoir of the surface system, the soil system and the aquifer system. The structure of each tank has an outlet on the side and on the bottom. This model reproduces the fluctuation of river discharge by rainfall, and simulates recharge to groundwater and the fluctuation of groundwater level. This model is widely used in Japan due to little input data and easy operation.

a. Construction of Tank Model

The concept of the Tank Model, which has three tanks for the surface system, the soil system and the shallow aquifer system, is shown in Figure 1.4-3. The output data of river discharge and recharge to groundwater was computed by inputting data on the rainfall and potential evapotranspiration in each river basin as explained in the previous paragraph and then calculated with the adjusted tank parameters. Ideally all data should be calculated on a daily basis. However, daily rainfall data was unavailable for most of the metrological stations; therefore, computation of the Tank Model was carried out monthly as a unit.

For verification of the computation results, a comparison was made between the observed river discharge and computed river discharge, which was calculated in Chapter 1.3. Thus, for relevance of the model, the duration of verification was set as 35 years from 1970 to 2004, and the points of verification were set at the river discharge station. In order to complement unavailable observed data, the river water level was calculated by using a complemented runoff ratio and catchment area based on the observation data in an adjacent basin, and the points of verification were set at the mouth of the basin.

b. Verification of the Computed Results

The computation by Tank Model was repeated while adjusting the parameters until it was decided that there was a good agreement between the observed river discharge and the computed results. Verification of the computer results was visually done by using graphs that indicated the correlation between the observed river discharge and the computed results, shown in the Appendix 2-2 Figure 2-5. In the setting of each parameter, infiltration which is caused by the surface geology in each basin was considered for adjusting the parameter.

The consistency of the computed results in each river basin and the fixed parameters are shown in Table 1.4-7 The comparison between the actual observed river discharge and the river discharge computed by the Tank Model has good correspondence in the long term. However, some of the computed results indicate a lower value when the actual observed river discharge shows a sharp rise. The computed river discharge is shown in the Appendix 2-2 Table 4, and the annual average river discharge is 130.87 m^3/sec.

In reference to the fixed parameters, the features of each river basin are estimated as follows:

- Mori at Utegi: The infiltration of rain is fast. The recharge to groundwater is limited; however, the base flow as spring is high.
- Mara at Mara mine: The infiltration of rain is fast. The storage in the soil system is comparatively high, and the recharge to groundwater is also high.
- Grumeti at R.B.: The infiltration of rain is fast, however, the runoff into river is low. The storage in the soil system is comparatively high, and the recharge to groundwater is also high.
- Mbalageti at R.B.: The infiltration of rain is fast. The storage in the soil system is low; however the recharge to groundwater is high.
- Suguti at Suguti: The infiltration of rain is comparatively fast. The storage in the soil system is low; however, the recharge to groundwater is high.
- Ukerewe basin: The infiltration of rain is fast. The storage in the soil system is low, the storage in the aquifer system is also low. The recharge to groundwater is comparatively high.
- Ramadi basin: The infiltration of rain is slightly slow. The storage in the soil system is low, and the storage in the aquifer system is also low. The recharge to groundwater is comparatively high, the base flow as spring is also high.
- Simiyu at R.B.: The storage in the surface and soil system is low; and, the storage in the aquifer system is also low. The recharge to groundwater is high, and the base flow as spring is also high.
- Magogo at R.B.: The infiltration of rain is comparatively fast; however, the storage in the aquifer system is low.
- Moame at Pambani: The infiltration of rain is comparatively fast; however, the storage in the soil and aquifer system is low.
- South shore basin: The storage in the surface and soil system is high; however, the storage in the soil and aquifer system is low. The recharge to groundwater is slightly low.
- Nyaruhwa basin: The infiltration of rain is slightly slow. The storage in the soil system is low, and the storage in the aquifer system is also low.

- Isanga basin: The infiltration of rain is slightly slow. The storage in the soil system is high; however, the storage in the aquifer system is low.

c. Computed Potential Recharge to Groundwater

The potential recharge to groundwater per unit area, computed according to the Tank Model, is shown in Table 1.4-8, and the percentage recharge to groundwater against the rainfall in each basin is shown in Table 1.4-9. The potential recharge to groundwater in each basin is shown in Table 1.4-10. Furthermore, the potential recharge to groundwater per unit area in each district is shown in Table 1.4-11, and the percentage recharge to groundwater against the rainfall in each district is shown in Table 1.4-12. The potential recharge to groundwater in each district is shown in Table 1.4-13.

The comparison by river basin indicated that the computed potential recharge to the groundwater is generally low throughout the year, especially in the dry season. In comparison with each basin, the recharge to groundwater in the Ukerewe basin, which has a large amount of rainfall, is also high. The recharge to groundwater in the Mara and Mbalageti basin is slightly high compared with other basins, on the contrary, it is low in the Mori and Nyaruhwa basin. The difference in the computed recharge to groundwater in each basin seems to be influenced by rainfall and the distribution of surface geology.

The annual average potential recharge to groundwater in the total basin area is 40.60 m^3/sec, and the annual potential recharge to groundwater per unit area in the total basin area is 151.89 mm. These computed results are slightly low compared with the calculation of the observation data.

The maximum annual potential recharge to groundwater per unit area is 535.08 mm in the Ukerewe basin while the minimum annual potential recharge to groundwater per unit area is 109.15 mm in the Mori basin. The maximum annual percentage recharge to groundwater is 35.38 % in the Ukerewe basin while the minimum annual percentage recharge to groundwater is 11.31 % in the Mori basin.

In the case of each district unit, the maximum annual potential recharge to groundwater per unit area is 535.08 mm in Ukerewe while the minimum annual potential recharge to groundwater per unit area is 129.71 mm in Geita. The maximum annual percentage recharge to groundwater is 35.38 % in Ukerewe while the minimum annual percentage recharge to groundwater is 12.88 % in Tarime.

1.4.3 Evaluation for the result of Analysis

a. Comparison between Two Types of Method

In comparison with calculation of observation data and computation by the Tank Model, the following points of common and difference are recognized.

- The estimated recharge to groundwater does not greatly differ in every area.
- The estimated recharge to groundwater has the trend of a similar fluctuation pattern in every area.
- The recharge to groundwater by calculation of observation data frequently becomes zero (0) in dry season; however by Tank Model it was estimated to have a few values even in dry season.
- The average recharges to groundwater in the total area by Tank Model are estimated less than it was by calculation of observation data.

The outline of hydrologic feature in the study area seems to have probably reappeared in either method of estimation.

b. Adaptability and Limitation of Water Balance Analysis and Future Subjects

The water balance analysis in Lake Victoria and its soundings (Tanzania, Uganda and Kenya) was carried out with the Rainfall-Runoff model (LVEMP, 2002). The model skillfully reproduced the fluctuation in the water level of Lake Victoria; however, the following points were recommended.

- Gauging stations for the ungauged catchment in the south part of the lake (Isanga, South shore etc.) should be established as soon as possible.
- In general, the rating curve should be updated for all rivers.
- More effort should be put into capacity building in terms of data arrangement, processing and analysis and modeling.

Regarding the evaluation of recharge to groundwater conducted in this study, the following problems need to be solved as the condition of basic data.

- The distribution of rainfall stations is not uniform and missing data exists in some areas. The deliberate establishment of observation stations and appropriate management are required.
- Tank Model computation was not carried out on a daily basis as the daily rainfall data was not sufficient.
- River discharge stations are limited, and the results of the estimations in ungauged basins are used only as a reference.
- Some of the data on river discharge could not be used for hydrologic analysis because appropriate rating curves were not sufficient due to the lack of data in the study area.
- The accuracy for verification of the computed results is not sufficient because monitoring data on shallow groundwater level is not available. Continuous monitoring data on groundwater level in shallow aquifers will be required for a more quantitative understanding of the runoff into rivers and the recharge to groundwater in deep aquifers.
- A data management system (monitoring method, data keeping and data arrangement) and the collection of new data (e.g. establishment of the new stations) will be required for a more accurate evaluation of recharge to groundwater.

Reference

Lake Victoria Environmental Management Project (LVEMP), 2002: Integrated Water Quality / Limnology Study for Lake Victoria, Final Report, Part Ⅱ: Technical Report.

Table 1.4-1: Average Monthly Potential Recharge to Groundwater per unit area in River Basin (mm/month, 1970-2004)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mori	5.21	9.36	36.06	42.03	1.81	0.00	1.69	0.00	0.00	3.71	13.58	2.58	116.04
Mara	14.32	18.65	34.17	35.78	14.91	1.33	0.63	0.83	1.85	7.00	25.82	31.76	187.07
Grumeti	17.17	16.32	31.29	40.70	11.98	1.32	0.00	0.00	0.00	3.90	23.19	15.50	161.36
Mbalageti	20.32	16.11	35.04	42.56	14.44	2.92	0.00	0.00	0.00	5.29	21.23	9.27	167.16
Suguti	4.15	4.59	36.74	60.25	10.20	0.00	0.00	0.00	0.00	2.01	8.71	9.18	135.83
Ukerewe	61.85	27.57	83.37	101.74	16.72	5.88	3.13	5.30	11.29	30.59	70.46	74.04	491.95
Ramadi	7.57	6.20	36.83	47.35	6.45	0.00	0.00	0.00	0.00	4.54	23.03	17.41	149.39
Simiyu	19.16	11.29	34.88	27.11	1.09	0.00	0.00	0.00	0.00	2.78	21.96	32.57	150.83
Magogo-Moame	16.23	10.20	32.26	28.50	1.52	0.13	1.79	0.82	0.00	4.00	24.67	29.62	149.75
South shore	12.14	8.47	26.68	29.02	2.64	0.00	0.00	0.00	0.00	5.82	27.29	23.56	135.62
Nyaruhwa	17.74	5.81	18.01	28.26	7.76	0.00	0.00	0.00	0.00	5.17	22.69	19.74	125.19
Isanga	14.08	13.07	28.60	12.54	0.29	0.00	0.00	0.00	0.00	5.04	36.95	26.73	137.31
Total Area	15.19	13.15	32.38	33.93	7.45	0.68	0.30	0.24	0.44	4.83	24.61	23.68	156.89

Table 1.4-2: Average Monthly Percentage Recharge to Groundwater in River Basin (%, 1970-2004)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mori	3.05	4.28	13.38	17.49	1.25	0.00	1.39	0.00	0.00	2.09	5.69	1.17	12.03
Mara	8.18	10.87	15.70	17.79	8.85	1.10	0.54	0.68	1.12	4.13	12.60	13.29	16.56
Grumeti	10.11	10.15	15.84	21.44	6.51	1.03	0.00	0.00	0.00	2.14	10.88	8.34	16.10
Mbalageti	11.62	8.92	16.09	19.52	7.46	1.83	0.00	0.00	0.00	2.57	9.58	5.88	17.44
Suguti	2.68	2.56	15.08	29.04	6.03	0.00	0.00	0.00	0.00	1.36	5.44	5.95	14.91
Ukerewe	26.63	17.36	31.14	36.71	8.39	3.32	2.29	2.73	5.86	14.84	25.71	31.39	32.38
Ramadi	5.24	4.04	15.28	24.03	3.53	0.00	0.00	0.00	0.00	2.71	12.92	9.55	16.17
Simiyu	11.70	8.54	18.52	14.70	0.84	0.00	0.00	0.00	0.00	1.67	11.54	17.35	16.57
Magogo-Moame	9.42	7.76	17.91	15.81	0.99	0.12	1.20	0.66	0.00	2.39	14.25	16.53	16.71
South shore	7.99	6.02	14.45	15.11	1.69	0.00	0.00	0.00	0.00	3.47	13.62	13.56	14.51
Nyaruhwa	11.41	4.39	9.98	15.85	4.64	0.00	0.00	0.00	0.00	2.70	10.66	10.63	14.51
Isanga	8.93	7.38	15.64	7.73	0.26	0.00	0.00	0.00	0.00	3.14	18.51	16.73	15.44
Total Area	9.08	8.25	15.97	17.33	4.31	0.52	0.24	0.19	0.26	2.79	12.21	12.39	

Table 1.4-3: Average Monthly Potential Recharge to Groundwater in River Basin (m^3/sec, 1970-2004)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Mori	4.97	9.89	34.40	41.43	1.73	0.00	1.61	0.00	0.00	3.54	13.39	2.46	9.45
Mara	70.33	101.44	167.86	181.65	73.26	6.75	3.10	4.09	9.41	34.37	131.09	156.04	78.28
Grumeti	82.01	86.32	149.48	200.93	57.24	6.53	0.00	0.00	0.00	18.61	114.50	74.07	65.81
Mbalageti	21.79	19.12	37.58	47.17	15.49	3.23	0.00	0.00	0.00	5.67	23.53	9.94	15.29
Suguti	6.11	7.49	54.14	91.74	15.04	0.00	0.00	0.00	0.00	2.96	13.27	13.53	17.02
Ukerewe	11.54	5.70	15.56	19.62	3.12	1.13	0.58	0.99	2.18	5.71	13.59	13.82	7.79
Ramadi	2.86	2.59	13.89	18.45	2.43	0.00	0.00	0.00	0.00	1.71	8.97	6.56	4.79
Simiyu	78.03	50.91	142.06	114.12	4.44	0.00	0.00	0.00	0.00	11.34	92.42	132.67	52.16
Magogo-Moame	21.33	14.85	42.39	38.70	1.99	0.18	2.36	1.08	0.00	5.26	33.50	38.93	16.71
South shore	28.31	21.88	62.23	69.96	6.16	0.00	0.00	0.00	0.00	13.58	65.77	54.96	26.90
Nyaruhwa	15.94	5.78	16.18	26.23	6.97	0.00	0.00	0.00	0.00	4.64	21.06	17.73	9.54
Isanga	41.83	42.99	84.94	38.50	0.87	0.00	0.00	0.00	0.00	14.96	113.43	79.40	34.74
Total Area	385.05	368.96	820.71	888.50	188.73	17.83	7.66	6.17	11.58	122.35	644.51	600.11	338.51

Table 1.4-4: Average Monthly Potential Recharge to Groundwater per unit area in District (mm/month, 1970-2004)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Tarime	8.59	12.81	35.36	39.71	6.67	0.49	1.30	0.31	0.69	4.93	18.13	13.41	142.40
Musoma	6.41	7.70	36.16	54.84	11.23	0.30	0.14	0.18	0.40	3.10	12.50	14.12	147.08
Serengeti	16.59	16.88	32.14	39.56	12.80	1.39	0.16	0.21	0.46	4.71	23.76	19.26	167.91
Bunda	11.57	11.10	34.05	49.51	11.41	0.86	0.01	0.01	0.02	3.20	16.61	12.38	150.72
Ukerewe	61.85	27.57	83.37	101.74	16.72	5.88	3.13	5.30	11.29	30.59	70.46	74.04	491.95
Magu	12.85	8.04	39.48	47.75	2.47	0.00	0.00	0.00	0.00	2.91	22.72	21.09	157.32
Kwimba	16.18	11.04	31.78	24.54	1.17	0.08	1.05	0.48	0.00	4.06	27.10	29.38	146.86
Missungwi	14.46	10.53	29.63	24.11	1.49	0.06	0.77	0.36	0.00	4.81	28.91	27.08	142.20
Ilemela-Nyamang	12.14	8.47	26.68	29.02	2.64	0.00	0.00	0.00	0.00	5.82	27.29	23.56	135.62
Sengerema	13.75	7.71	24.18	28.80	4.11	0.00	0.00	0.00	0.00	5.63	25.96	22.46	132.62
Geita	14.40	9.13	24.73	23.64	3.41	0.00	0.00	0.00	0.00	5.38	28.96	23.43	133.08
Total Area	14.10	12.01	32.36	37.78	7.47	0.61	0.36	0.23	0.37	4.78	23.71	20.75	154.54

Table 1.4-5: Average Monthly Percentage Recharge to Groundwater in District (%, 1970-2004)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tarime	4.95	6.72	14.24	17.61	4.07	0.41	1.08	0.25	0.42	2.85	8.26	5.67	13.71
Musoma	3.91	4.40	15.22	26.56	6.64	0.24	0.12	0.15	0.24	1.96	7.02	7.56	15.27
Serengeti	9.69	10.28	15.82	20.46	7.12	1.08	0.13	0.17	0.28	2.65	11.26	9.46	16.26
Bunda	6.89	6.68	15.52	24.63	6.40	0.63	0.01	0.01	0.01	1.85	8.37	7.14	15.68
Ukerewe	26.63	17.36	31.14	36.71	8.39	3.32	2.29	2.73	5.86	14.84	25.71	31.39	32.38
Magu	7.50	5.40	14.54	16.51	1.14	0.00	0.00	0.00	0.00	1.63	9.79	11.05	14.33
Kwimba	9.68	7.78	17.44	13.72	0.80	0.07	0.70	0.38	0.00	2.45	14.77	16.68	16.36
Missungwi	8.87	7.16	16.28	13.31	0.98	0.05	0.52	0.28	0.00	2.91	15.29	15.74	15.72
Ilemela-Nyamang	7.99	6.02	14.45	15.11	1.69	0.00	0.00	0.00	0.00	3.47	13.62	13.56	14.51
Sengerema	8.97	5.55	13.16	15.32	2.54	0.00	0.00	0.00	0.00	3.25	12.77	12.72	14.51
Geita	9.29	5.97	13.51	13.02	2.11	0.00	0.00	0.00	0.00	3.14	14.28	13.69	14.80
Total Area	8.38	7.48	15.32	18.44	4.27	0.46	0.28	0.17	0.21	2.74	11.53	11.00	

Table 1.4-6: Average Monthly Potential Recharge to Groundwater in District (m^3/sec, 1970-2004)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Tarime	13.03	21.51	53.64	62.25	10.12	0.77	1.97	0.47	1.08	7.48	28.41	20.35	18.42
Musoma	8.09	10.75	45.60	71.46	14.17	0.38	0.17	0.23	0.53	3.91	16.29	17.81	15.78
Serengeti	70.77	79.76	137.13	174.41	54.60	6.11	0.66	0.88	2.01	20.11	104.77	82.18	61.12
Bunda	12.75	13.54	37.53	56.38	12.58	0.98	0.01	0.01	0.02	3.53	18.91	13.65	14.16
Ukerewe	11.54	5.70	15.56	19.62	3.12	1.13	0.58	0.99	2.18	5.71	13.59	13.82	7.79
Magu	15.64	10.83	48.06	60.06	3.01	0.00	0.00	0.00	0.00	3.55	28.57	25.68	16.28
Kwimba	21.26	16.06	41.76	33.32	1.54	0.11	1.37	0.63	0.00	5.33	36.80	38.60	16.40
Missungwi	12.63	10.18	25.89	21.77	1.30	0.05	0.68	0.31	0.00	4.21	26.10	23.66	10.57
Ilemela-Nyamang	2.46	1.90	5.40	6.07	0.53	0.00	0.00	0.00	0.00	1.18	5.71	4.77	2.34
Sengerema	14.96	9.28	26.31	32.38	4.48	0.00	0.00	0.00	0.00	6.13	29.19	24.44	12.26
Geita	28.68	20.14	49.27	48.68	6.80	0.00	0.00	0.00	0.00	10.73	59.62	46.68	22.55
Total Area	211.80	199.65	486.14	586.41	112.24	9.54	5.44	3.52	5.81	71.84	367.96	311.62	197.67

Table 1.4-7: Determined Parameter of Tank Model

	Parameter	Mori at Utegi	Mara at Mara	Grumeti at R.B.	Mbalageti at R.B.	Suguti at Suguti	Ukerewe	Ramadi	Simiyu at R.B.	Magogo at R.B.	Moame at Pambani	South shore	Nyaruhwa	Isanga
TANK1														
F11	height of infiltration (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	coefficient of infiltration	0.85	0.90	0.95	0.90	0.80	0.95	0.75	0.65	0.80	0.80	0.60	0.75	0.75
F12	height of outlet (mm)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	5.00	5.00	5.00	1.00	10.00	10.00
	coefficient of outlet	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.10	0.05	0.05	0.05
	water depth (mm)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
TANK2														
F21	height of infiltration (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	coefficient of infiltration	0.40	0.50	0.50	0.90	0.80	0.95	0.80	0.70	0.75	0.85	0.90	0.80	0.60
F22	height of outlet (mm)	0.50	0.50	10.00	10.00	10.00	10.00	10.00	10.00	1.00	1.00	5.00	0.05	10.00
	coefficient of outlet	0.30	0.10	0.05	0.05	0.05	0.05	0.10	0.05	0.05	0.05	0.05	0.10	0.10
	water depth (mm)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
TANK3														
F31	height of infiltration (mm)	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	5.00
	coefficient of infiltration	0.10	0.20	0.40	0.40	0.30	0.30	0.20	0.20	0.50	0.40	0.30	0.40	0.40
F32	height of outlet (mm)	0.00	1.00	1.00	1.00	1.00	1.00	2.00	0.00	0.00	1.00	0.00	0.00	5.00
	coefficient of outlet	0.10	0.20	0.40	0.10	0.20	0.40	0.20	0.20	0.10	0.10	0.30	0.30	0.30
F33	height of outlet (mm)	0.50	20.00	20.00	10.00	10.00	5.00	10.00	10.00	10.00	10.00	5.00	1.00	10.00
	coefficient of outlet	0.50	0.15	0.05	0.20	0.15	0.15	0.50	0.40	0.30	0.30	0.30	0.30	0.20
	water depth (mm)	20.00	20.00	20.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

Table 1.4-8: Average Monthly Potential Recharge to Groundwater per unit area (mm/month, 1970-2004,conmuted by Tank Model)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mori at Utegi	4.33	5.67	18.72	35.97	18.85	5.72	2.43	0.79	0.30	1.84	7.99	6.55	109.15
Mara at Mara mine	15.36	15.87	24.52	33.12	24.79	10.86	4.71	2.64	2.08	4.50	15.06	21.88	175.40
Grumeti at R.B.	14.43	14.82	22.98	32.59	21.27	10.49	4.93	2.38	1.18	2.51	12.76	13.83	154.19
Mbalageti at R.B.	17.56	15.35	33.15	45.26	16.73	3.77	0.26	0.03	0.00	4.29	20.53	11.56	168.49
Suguti at Suguti	5.06	4.19	26.59	53.76	21.08	3.51	0.69	0.14	0.03	1.40	6.88	9.56	132.90
Ukerewe	60.38	31.23	87.90	116.65	27.38	6.77	2.99	7.49	11.84	30.16	72.65	79.63	535.08
Ramadi	9.72	7.33	29.09	49.66	15.77	2.15	0.43	0.09	0.02	2.86	18.03	19.15	154.30
Simiyu at R.B.	20.18	15.07	26.38	31.03	11.23	3.08	0.92	0.28	0.08	1.33	12.86	25.79	148.23
Magogo at R.B.	16.82	11.31	25.52	34.61	8.49	1.81	1.47	0.97	0.20	2.44	17.77	27.22	148.61
Moame at Pambani	15.09	10.05	27.02	35.06	4.99	0.63	1.30	0.83	0.08	2.73	19.74	27.93	145.45
South shore	13.27	10.67	22.06	33.51	8.35	0.53	0.05	0.01	0.00	3.29	18.88	23.34	133.95
Nyaruhwa	16.24	8.87	17.60	25.78	8.85	0.89	0.09	0.01	0.00	3.57	17.66	20.14	119.70
Isanga	17.87	14.87	22.67	19.48	7.54	2.67	1.05	0.42	0.17	2.45	20.13	24.47	133.79
Total Area	15.40	13.30	24.77	33.65	15.92	5.66	2.36	1.19	0.76	3.02	15.51	20.34	151.89

Table 1.4-9: Average Monthly Percentage Recharge to Groundwater (%, 1970-2004,conmuted by Tank Model)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mori at Utegi	5.47	8.42	13.39	18.76	16.00	18.58	9.06	3.19	1.01	2.74	7.27	8.16	9.34
Mara at Mara mine	14.95	16.33	17.16	21.42	20.61	22.43	14.39	4.79	3.59	5.79	13.07	17.52	14.34
Grumeti at R.B.	13.62	15.30	16.03	21.41	21.25	24.40	25.82	7.28	3.60	3.99	11.77	13.20	14.81
Mbalageti at R.B.	16.69	16.11	22.97	29.03	18.17	9.82	2.13	0.13	0.01	7.52	19.17	12.06	12.82
Suguti at Suguti	6.63	5.73	19.43	29.90	20.39	17.36	4.76	0.94	0.11	2.24	6.55	9.76	10.31
Ukerewe	38.50	26.52	45.47	49.78	24.18	16.42	8.61	13.89	14.78	24.09	41.74	42.43	28.72
Ramadi	12.11	9.86	21.53	29.53	17.19	10.24	3.77	0.78	0.07	4.33	14.45	16.69	11.68
Simiyu at R.B.	18.61	15.91	18.40	22.61	17.71	17.76	18.48	2.77	0.49	2.74	11.03	18.95	13.44
Magogo at R.B.	16.86	12.86	18.44	24.90	14.96	18.63	37.77	17.55	1.29	3.99	14.51	21.32	14.59
Moame at Pambani	15.13	11.43	19.53	25.23	8.80	6.47	33.47	14.95	0.55	4.47	16.12	21.89	12.75
South shore	13.30	12.45	17.30	22.63	11.30	3.59	0.74	0.04	0.00	4.12	14.45	18.39	9.89
Nyaruhwa	15.40	11.15	15.25	19.40	11.68	7.68	1.73	0.08	0.01	4.93	15.16	17.80	10.18
Isanga	17.03	15.42	17.04	16.89	13.51	28.40	27.55	14.50	0.74	3.75	14.59	18.49	15.37
Total Area	14.69	14.16	17.44	22.30	17.26	17.97	15.82	5.01	1.73	4.34	12.94	16.43	

Table 1.4-10: Average Monthly Potential Recharge to Groundwater in River Basin (m^3/sec, 1970-2004,conmuted by Tank Model)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Mori at Utegi	1.34	1.94	5.78	11.47	5.82	1.82	0.75	0.24	0.09	0.57	2.55	2.02	2.87
Mara at Mara mine	75.02	85.82	119.79	167.20	121.10	54.82	23.03	12.89	10.52	21.99	76.02	0.00	64.02
Grumeti at R.B.	68.48	77.86	109.07	159.83	100.94	51.46	23.39	11.29	5.77	11.92	62.56	65.65	62.35
Mbalageti at R.B.	18.55	17.94	35.01	49.39	17.67	4.11	0.28	0.03	0.00	4.53	22.40	12.21	15.18
Suguti at Suguti	1.99	1.82	10.44	21.81	8.28	1.42	0.27	0.05	0.01	0.55	2.79	3.75	4.43
Ukerewe	11.27	6.45	16.40	22.49	5.11	1.31	0.56	1.40	2.28	5.63	14.01	14.86	8.48
Ramadi	3.67	3.06	10.97	19.35	5.95	0.84	0.16	0.03	0.01	1.08	7.02	7.22	4.95
Simiyu at R.B.	81.14	67.10	106.08	128.94	45.14	12.78	3.69	1.11	0.34	5.36	53.42	103.69	50.73
Magogo at R.B.	7.92	5.89	12.01	16.83	3.99	0.88	0.69	0.46	0.10	1.15	8.64	12.81	5.95
Moame at Pambani	9.45	6.97	16.92	22.69	3.13	0.41	0.82	0.52	0.05	1.71	12.78	17.50	7.75
South shore	30.94	27.55	51.46	80.77	19.47	1.28	0.12	0.01	0.00	7.67	45.50	54.45	26.60
Nyaruhwa	14.59	8.82	15.81	23.93	7.95	0.82	0.08	0.01	0.00	3.21	16.39	18.09	9.14
Isanga	53.08	48.90	67.33	59.81	22.39	8.20	3.12	1.25	0.52	7.27	61.79	72.69	33.86
Total Area	376.08	358.19	571.29	773.03	361.11	138.33	56.22	29.05	19.60	72.07	383.32	382.92	293.43

Table 1.4-11: Average Monthly Potential Recharge to Groundwater in District (mm/month, 1970-2004,computed by Tank Model)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Tarime	8.42	9.45	20.87	34.91	21.06	7.63	3.28	1.48	0.96	2.83	10.61	12.24	133.74
Musoma	7.34	6.78	26.13	49.18	21.89	5.14	1.59	0.69	0.48	2.08	8.68	12.26	142.23
Serengeti	14.78	15.10	23.76	33.22	21.96	10.32	4.70	2.35	1.35	3.07	13.63	15.73	159.96
Bunda	10.51	10.13	25.41	43.04	20.87	6.85	2.67	1.20	0.58	2.18	10.77	11.84	146.06
Ukerewe	60.38	31.23	87.90	116.65	27.38	6.77	2.99	7.49	11.84	30.16	72.65	79.63	535.08
Magu	13.78	10.26	30.17	53.86	10.41	1.46	0.38	0.11	0.03	1.53	15.27	19.27	156.53
Kwimba	16.59	12.04	25.83	30.71	6.70	1.52	1.16	0.63	0.10	2.43	18.64	26.70	143.06
Missungwi	15.36	11.60	24.37	30.19	6.67	1.18	0.88	0.48	0.08	2.81	19.61	25.64	138.86
Ilemela-Nyamang	13.27	10.67	22.06	33.51	8.35	0.53	0.05	0.01	0.00	3.29	18.88	23.34	133.95
Sengerema	14.12	10.15	20.78	31.28	8.49	0.63	0.06	0.01	0.00	3.37	18.53	22.42	129.85
Geita	15.58	11.45	20.94	26.85	8.24	1.31	0.38	0.14	0.05	3.11	18.91	22.76	129.71
Total Area	13.92	11.90	24.71	36.78	15.71	5.27	2.27	1.17	0.74	3.07	15.48	18.94	149.94

Table 1.4-12: Average Monthly Percentage Recharge to Groundwater in District (%, 1970-2004, computed by Tank Model)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tarime	8.99	11.36	14.79	19.74	17.71	20.01	11.04	3.78	1.97	3.87	9.42	11.63	12.88
Musoma	8.47	8.08	18.92	28.01	20.44	18.49	6.95	1.80	0.88	3.02	7.99	11.46	14.80
Serengeti	14.07	15.58	16.58	21.71	20.98	23.35	22.09	6.39	3.46	4.57	12.38	14.22	15.50
Bunda	10.75	11.10	18.11	25.80	20.62	20.09	14.42	3.86	1.76	3.51	10.04	11.63	15.21
Ukerewe	38.50	26.52	45.47	49.78	24.18	16.42	8.61	13.89	14.78	24.09	41.74	42.43	35.38
Magu	13.64	11.73	18.89	27.25	14.41	9.36	7.55	1.10	0.19	2.59	12.06	15.04	14.42
Kwimba	16.15	13.14	18.72	22.80	11.46	13.49	29.11	12.57	0.57	4.00	14.87	20.55	16.32
Missungwi	15.15	12.85	18.19	22.12	10.85	11.89	22.49	10.58	0.45	4.16	15.21	19.93	15.61
Ilemela-Nyamang	13.30	12.45	17.30	22.63	11.30	3.59	0.74	0.04	0.00	4.12	14.45	18.39	14.27
Sengerema	13.91	12.08	16.71	21.70	11.41	4.77	1.03	0.05	0.00	4.35	14.66	18.22	14.11
Geita	15.09	13.00	16.61	19.89	12.11	12.56	9.42	4.58	0.23	4.24	14.70	18.25	14.40
Total Area	13.39	12.93	17.30	23.01	16.68	16.28	13.95	4.66	1.69	4.26	12.79	15.66	

Table 1.4-13: Average Monthly Potential Recharge to Groundwater in District (m^3/sec, 1970-2004,conmuted by Tank Model)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
Tarime	12.77	15.88	31.67	54.72	31.94	11.95	4.98	2.24	1.50	4.29	16.64	18.57	17.26
Musoma	9.26	9.46	32.95	64.08	27.60	6.70	2.00	0.87	0.63	2.63	11.32	15.46	15.25
Serengeti	63.06	71.32	101.36	146.44	93.70	45.51	20.04	10.04	5.97	13.10	60.07	67.10	58.14
Bunda	11.58	12.36	28.01	49.02	23.00	7.80	2.94	1.32	0.66	2.40	12.27	13.05	13.70
Ukerewe	11.27	6.45	16.40	22.49	5.11	1.31	0.56	1.40	2.28	5.63	14.01	14.86	8.48
Magu	16.77	13.83	36.72	67.74	12.67	1.84	0.46	0.13	0.04	1.87	19.21	23.45	16.23
Kwimba	21.79	17.52	33.94	41.70	8.80	2.07	1.53	0.82	0.14	3.20	25.31	35.08	15.99
Missungwi	13.42	11.22	21.30	27.26	5.83	1.07	0.76	0.42	0.08	2.45	17.70	22.41	10.33
Ilemela-Nyamang	2.69	2.39	4.47	7.01	1.69	0.11	0.01	0.00	0.00	0.67	3.95	4.73	2.31
Sengerema	15.36	12.23	22.60	35.17	9.24	0.71	0.07	0.01	0.00	3.67	20.83	24.39	12.02
Geita	31.04	25.27	41.72	55.27	16.42	2.69	0.75	0.27	0.11	6.19	38.93	45.34	22.00
Total Area	209.02	197.92	371.12	570.90	236.00	81.76	34.09	17.52	11.41	46.09	240.23	284.44	191.71

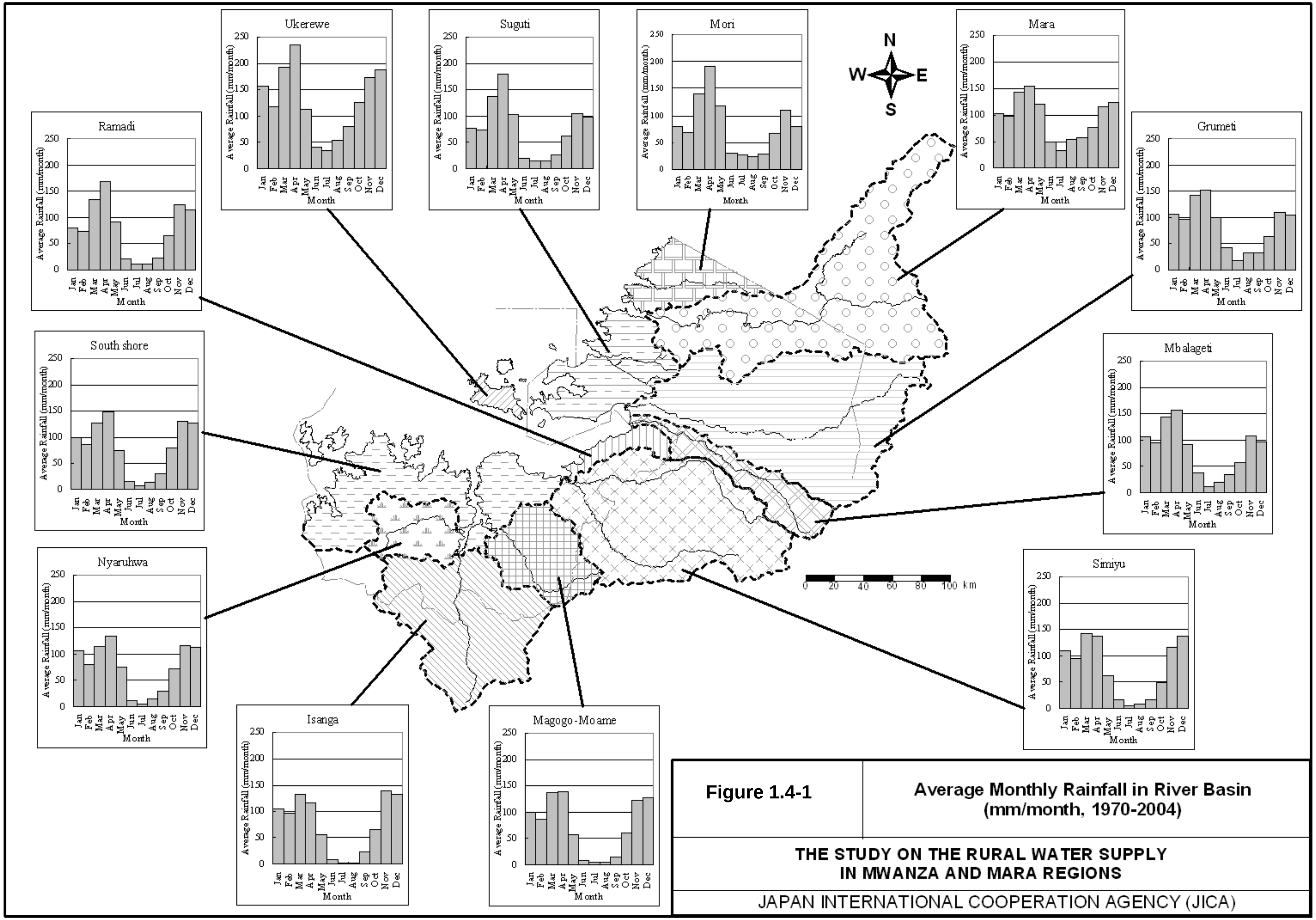


Figure 1.4-1	**Average Monthly Rainfall in River Basin (mm/month, 1970-2004)**

THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

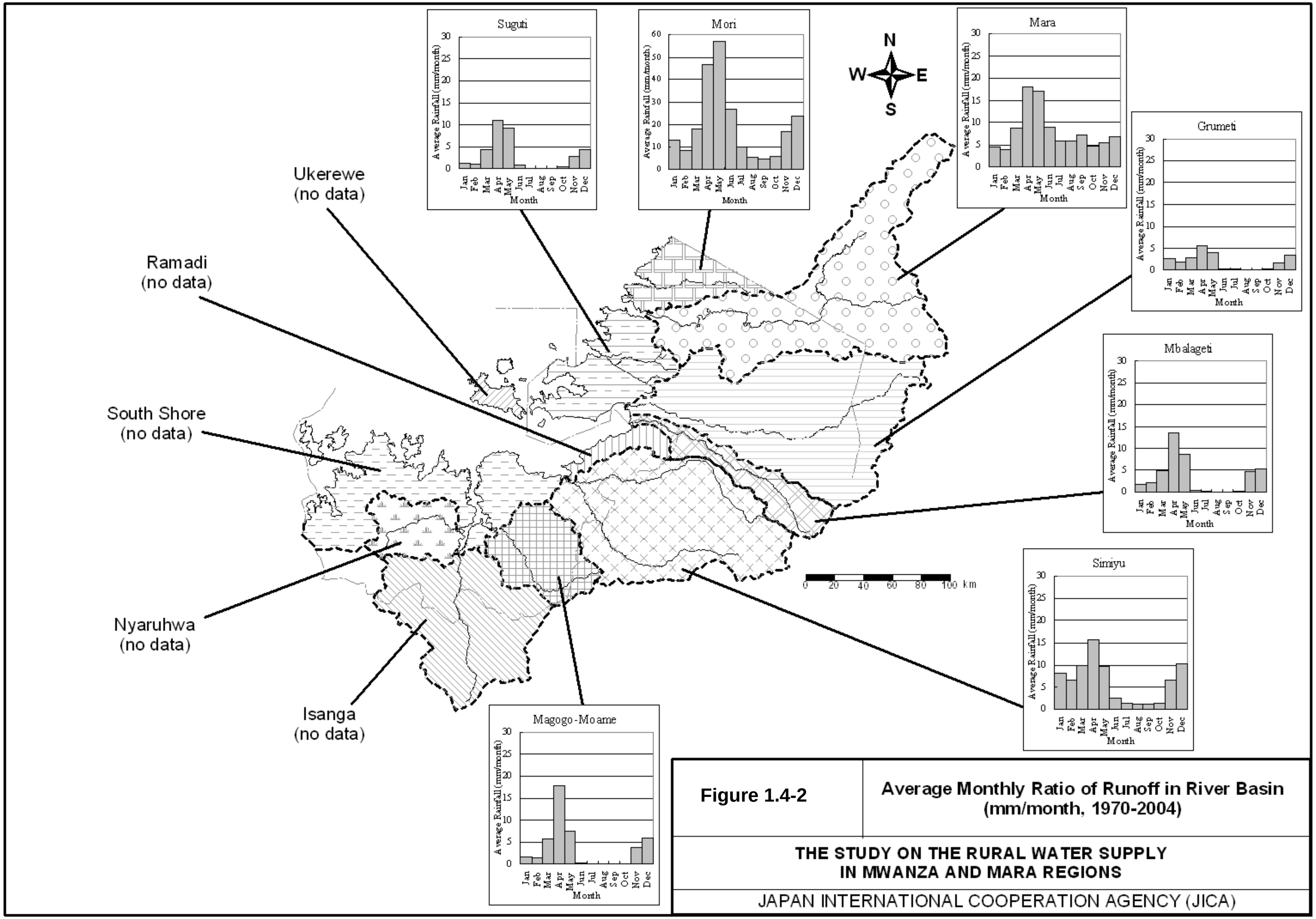


Figure 1.4-2 Average Monthly Ratio of Runoff in River Basin (mm/month, 1970-2004)

THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS

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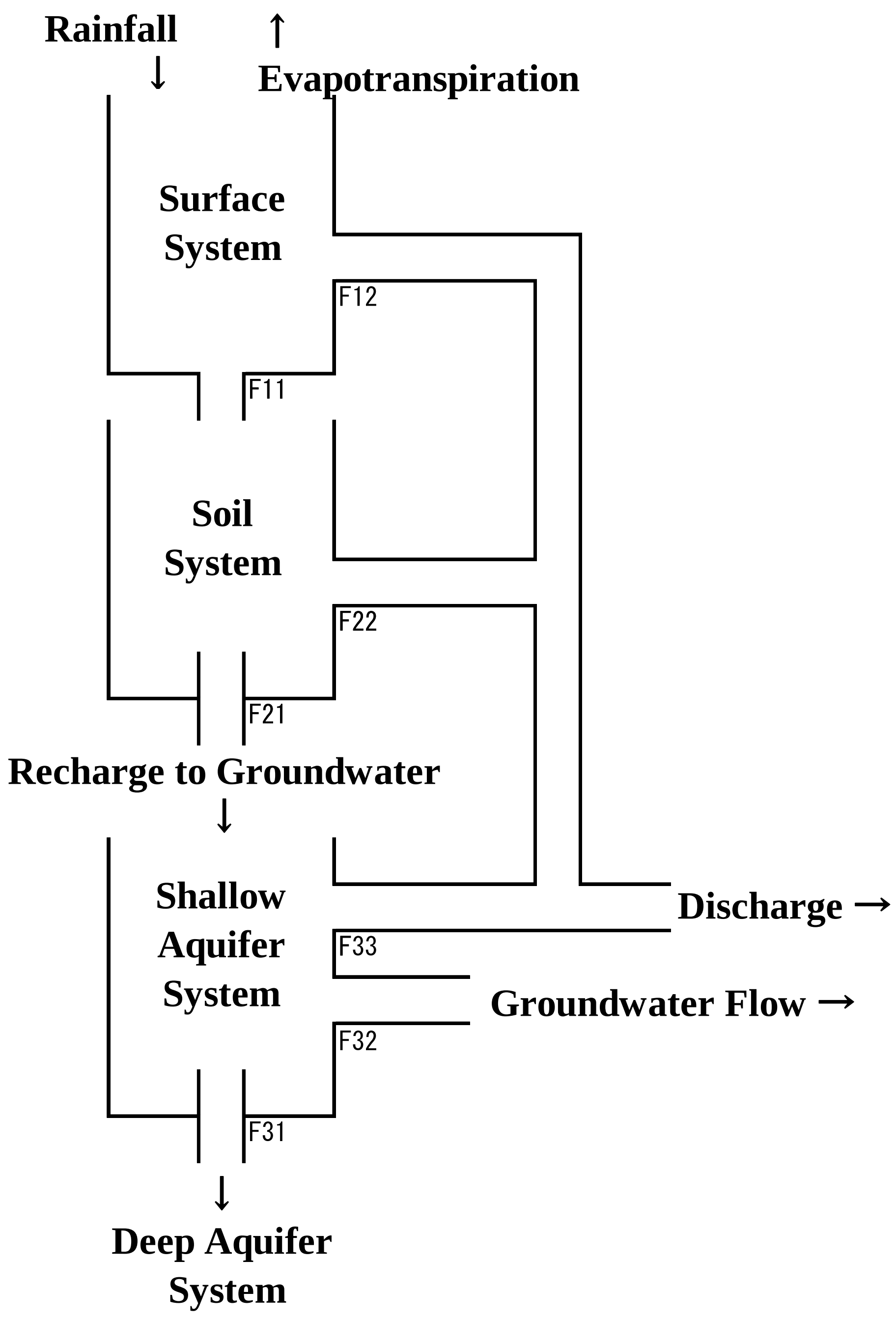


Figure 1.4-3: Structure of Tank Model

Chapter 2

Topography and Geology

2 Topography and Geology

2.1 Topography

2.1.1 General

The geomorphology of the study area is featured by flatland with some hills and terrain which project the geologic character of the area. The land is bordered on the north (Mwanza region) and west (Mara region) by Lake Victoria, which is one of the largest freshwater lakes in the world.

The Mwanza region is mostly occupied by low-lying land and rolling hills from the north to east end and particularly in the south-western area, the region is composed of comparatively higher ridges and deep, wide valleys. The typical topographical feature of the flatland in the area is the so called "monadnock" or "inselberg", which is characteristic of an arid to semiarid landscape in the latest stage of the erosion circle.

The lake shore is composed of relatively undulating ridges and hills, and the region is divided into west and east portions by the Mwanza Gulf – Smith Sound which cuts deeply into the mainland.

The Mara region is characterized by sharp valleys and rolling hills with some terraces bounded by structural lineaments. Wide valleys are developed along the major rivers of Mara, the Grumeti and Mori. Cliffs can be found along the large fault structure.

The altitude is lowest at Lake Victoria (1,134m) and the highest portion is some 1400m above sea level.

Most of the land area is cultivated. Dams can often be found in areas used for agriculture and grazing. The shaded surface map created from satellite radar is presented in エラー! 参照元が見つかりません。Figure 2.1-1. The contour map with the river and stream systems is shown in Figure 2.1-2 エラー! 参照元が見つかりません。.

The geomorphologic interpretation was made based on the following maps:

- Topographical Map (Scale 1:250,000) Series Y503 – Edition 2-TSD (Surveys and Mapping Division, Ministry of Lands, Housing and Urban Development, Tanzania, 1980): 7 sheets
- Topographical Map (Scale 1:50,000) Series Y742 Edition 2-TSD (Surveys and Mapping Division, Ministry of Lands, Housing and Urban Development, Tanzania, 1976): 104 sheets (11 sheets are missing in the Surveys and Mapping Division because the original copies were lent to Kenya).

2.1.2 Satellite Image Interpretation

A satellite image was downloaded from the USGS (United States Geological Survey). The image presented in Figure 2.1-3 エラー! 参照元が見つかりません。 (at the end of this chapter) is composed from various images, to optimize the quality of the image.

The downloaded Landsat data sets are from the Global Land Cover Facility (GLCF).

Figure 2.1-4 presents the location of the downloaded data sets of the image, and the respective specification of data is shown in Table 2.1-1.

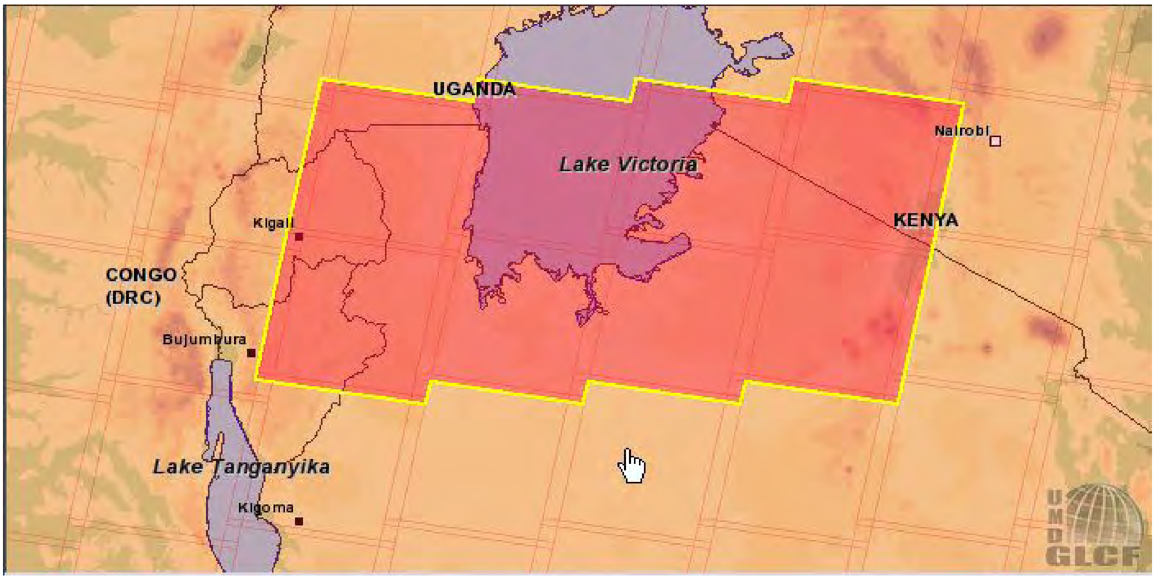


Figure 2.1-4: Location of Downloaded Landsat Image

Table 2.1-1: Specification of Landsat Data

ID	WRS: Path/Row	Acq.Date	Dateset	Producer	Attr.	Type
037-443	2: 172/061	1999-07-08	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF
037-444	2: 172/062	2002-02-22	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF
037-589	2: 171/061	2000-07-19	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF
037-590	2: 171/062	2000-05-16	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF
037-664	2: 169/061	2000-01-27	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF
037-665	2: 169/062	2000-02-12	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF
037-740	2: 170/061	2001-05-12	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF
037-741	2: 170/062	2001-05-12	ETM+	EarthSat	Ortho, GeoCover	GeoTIFF

Not only the band combination of R=1,G=2,B=3 (1,2,3) but also (4,3,2), (3,4,2) and (7,5,4) were used for the interpretation.

The downloaded data sets were combined to observe surface phenomena such as lineaments and other characteristic geological geomorphology at a relatively larger scale compared to the aerial photograph interpretation.

Western Mwanza, Geita and Sengerema Districts have relatively clear continuous lineament in an ENE-WSW direction, and other fragmented small lineament trends in a NNW – SSE direction. Western Mwanza, Mwanza, Magu and Misungwi Districts have NNW – SSE lineaments, as well as a trend in an ENE – WSW direction.

The strong sharp edge of the fault line trends ENE-WSW at the boundary of the Tarime and Musoma or Serengeti District. Capes extended in a northwestern direction in western Mara feature the trend of NW-SE and E-W lineaments abundant in the Musoma and Bunda Districts. Small fragmented stream systems have developed on the mountainous side of Serengeti, and the main lineament direction is NE-NW.

2.1.3 Aerial Photograph Interpretation

The aerial photographs were obtained from the Surveys and Mapping Division, Ministry of Lands, Tanzania. The main source is on a scale of 1:40,000 and was taken in the 1950s. The following shows the photograph sets prepared. The total number of photos was 916 sheets.

- Mara: Runs 1-16, Rolls 2,3,6,7, and 9
- Geita: Runs 5 (A-C), 6(A-B), 7(A-C), 8(A-D), 9(A-D), 10(A-C), 11(A-B), 12(A-B), 13(A-C), 14(A-C), and 15(A-B)

The partition numbers (of topographic map on the scale of 1:50,000) 19,20,21,22, 23 (upper half), 24 and 25 (western half) were not developed as these areas are not necessary for the interpretation. The neglected sheets are mostly lake water areas or lowland areas where the lineament has obviously not developed.

Some areas could not be interpreted due to unusual photo order (i.e. duplications in the different photo numbers, the direction of the aerial photographs were not straight to the direction of the run and roll number). In addition, the orientation map could not be obtained as it was restricted by the government. In these areas, the local lineament was interpreted using a topographical map (1:50,000), geological map (1:200,000) and satellite image.

The result of the interpretation was projected onto a 1:50,000 scale map.

In general, clear lineaments are observed in the mountainous areas in Geita, Sengerema, Misungwi, Mwanza, the north western area of Magu and northern Kwimba in the Mwanza region. In the Mara region, lineaments are widely observed, except for the flat terrace formed in the surroundings of major rivers.

The lineaments were classified into the following categories:

- Clear lineament
- Relatively clear lineament
- Other minor lineament (not obvious but readable, rounded or not long (less than 5km))

Lineaments were observed in the whole region, except the lowland and flat areas, as most of the area is covered by plutonic rocks. The direction of the major lineaments tends to be as follows by respective area.

- The major trend of lineaments in Geita, Sengerema, Ukerewe, West of Misungwi and Mwanza rural area is in a WNW-ESE direction, intersected by several lineaments in a NNE-SSW direction. Some of the lineaments are also confirmed in the NNW-SSE direction. The area is basically segmented into small fragments of rock mass.
- Low lying hills and flatland are abundant in the area of Kwimba, and part of Magu. Strong lineaments cannot be seen, but lineaments in a WE-SW, WNW-ESE direction have developed. Lineaments in a NNE-SSW and WNW-ESE direction intersect in the north-eastern part of Magu.
- South of Bunda is the flatland of the river terrace. Major lineaments in a NW-SE direction can be found at the boundary with Musoma District.
- The major trend of lineaments in the Musoma, Tarime and Serengeti areas is in NW-SE, NE-SW and EW directions, but there is high irregularity of the lineaments in the area. They also intersect each other, and are fragmented. The large fault structure is well identified by aerial photograph at the boundary of Tarime, Serengeti, and Musoma.

A lineament map on the scale of 1:50,000 is under preparation due to some missing parts of the topographical maps which are to be interpreted. The major lineaments in the area are presented in Figure 2.1-5.

Figure 2.1-6 shows the lineament density. The figure indicates the number of major (clear) lineaments in the area of 4 sq. km.

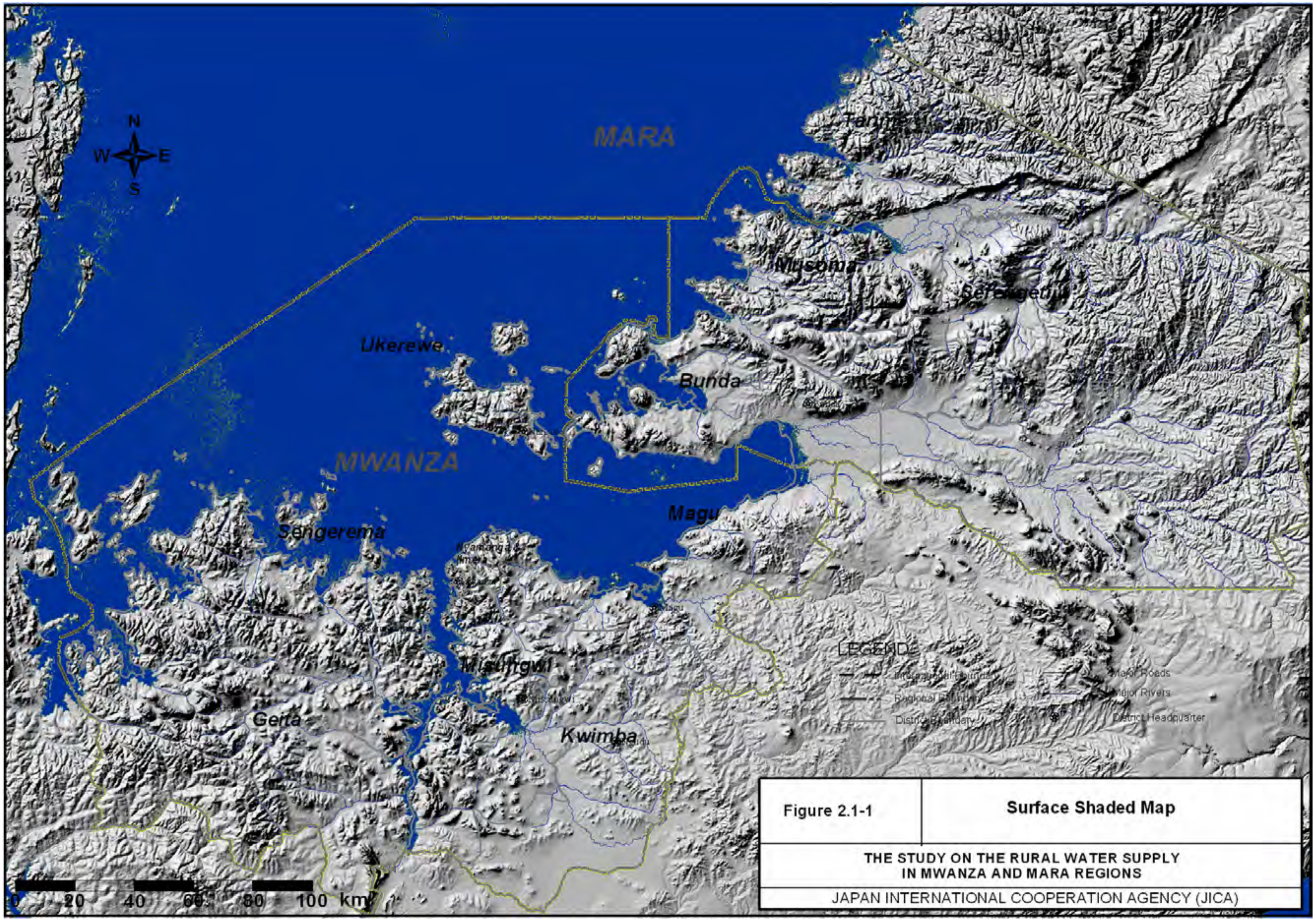
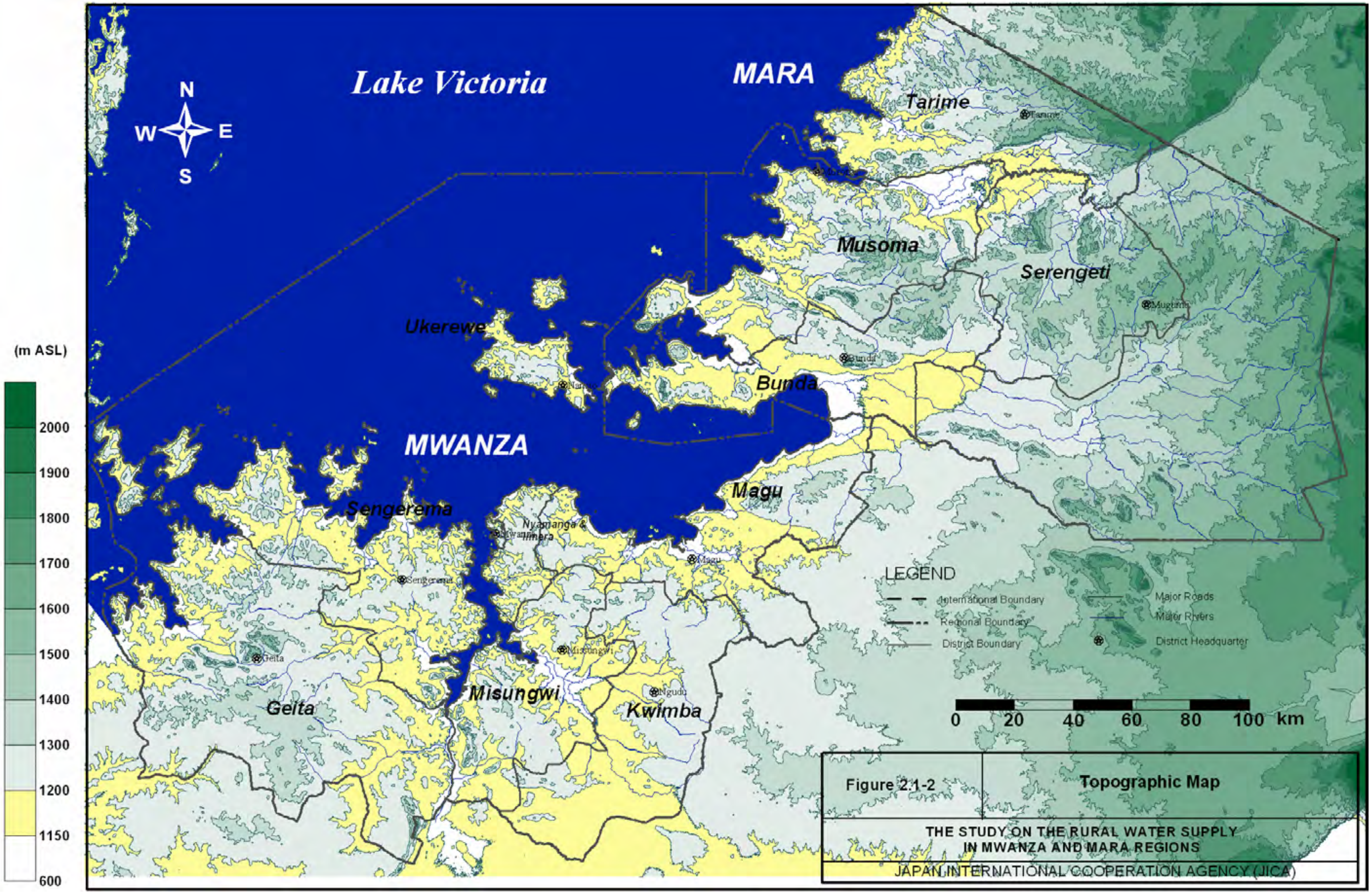


Figure 2.1-1 Surface Shaded Map

THE STUDY ON THE RURAL WATER SUPPLY
IN MWANZA AND MARA REGIONS

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)


Lake Victoria
MARA
N
W
E
S
Tarime
Musoma
Serengeti
Ukerewe
Bunda
MWANZA
Magu
Sengerema
Nyamanga & Ilimera
Misungwi
Geita
Kwimba
(m ASL)
2000
1900
1800
1700
1600
1500
1400
1300
1200
1150
600
LEGEND
International Boundary
Regional Boundary
District Boundary
Major Roads
Major Rivers
District Headquarter
0 20 40 60 80 100 km
Figure 2.1-2
Topographic Map
THE STUDY ON THE RURAL WATER SUPPLY
IN MWANZA AND MARA REGIONS
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

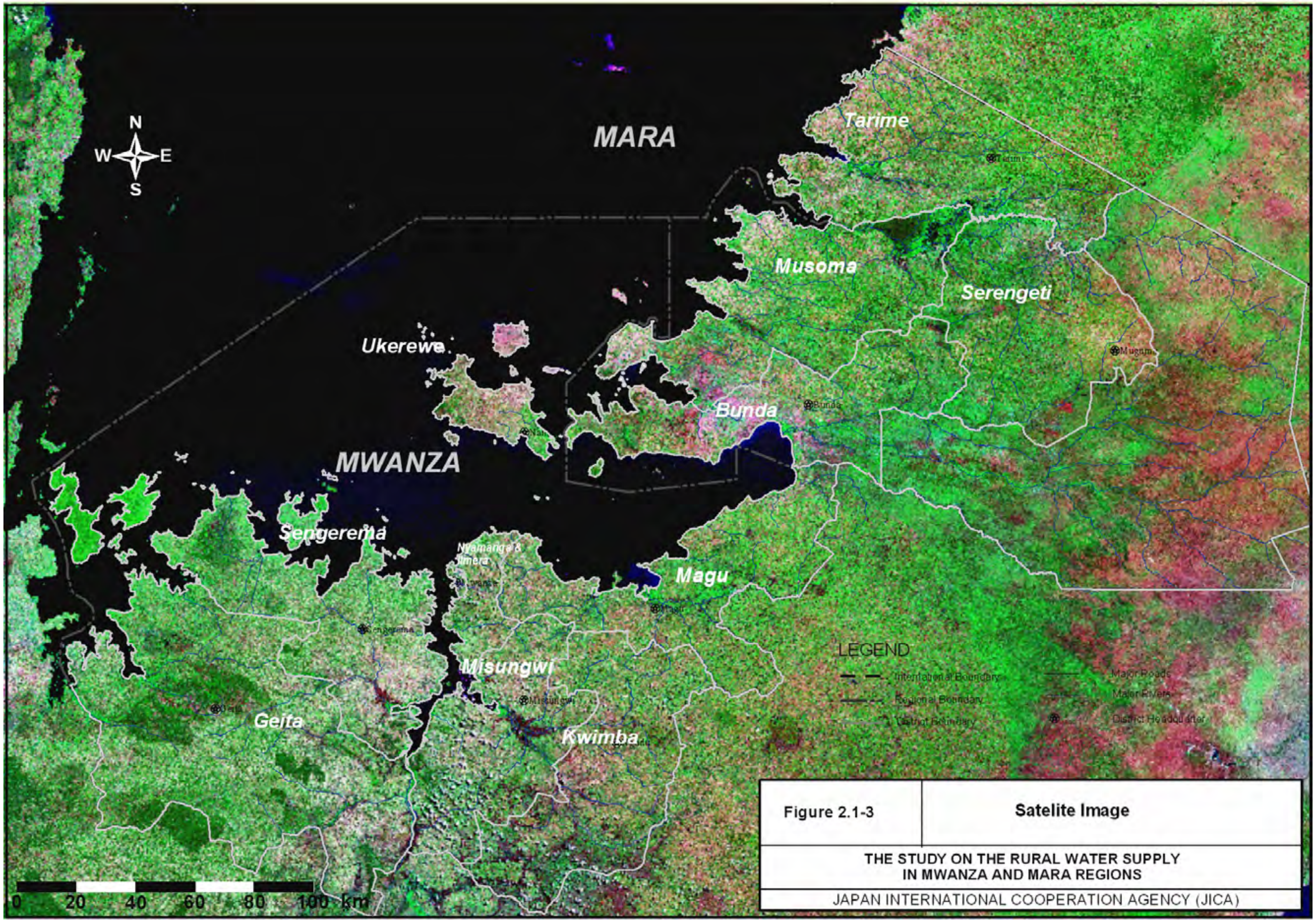


Figure 2.1-3	Satelite Image
THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

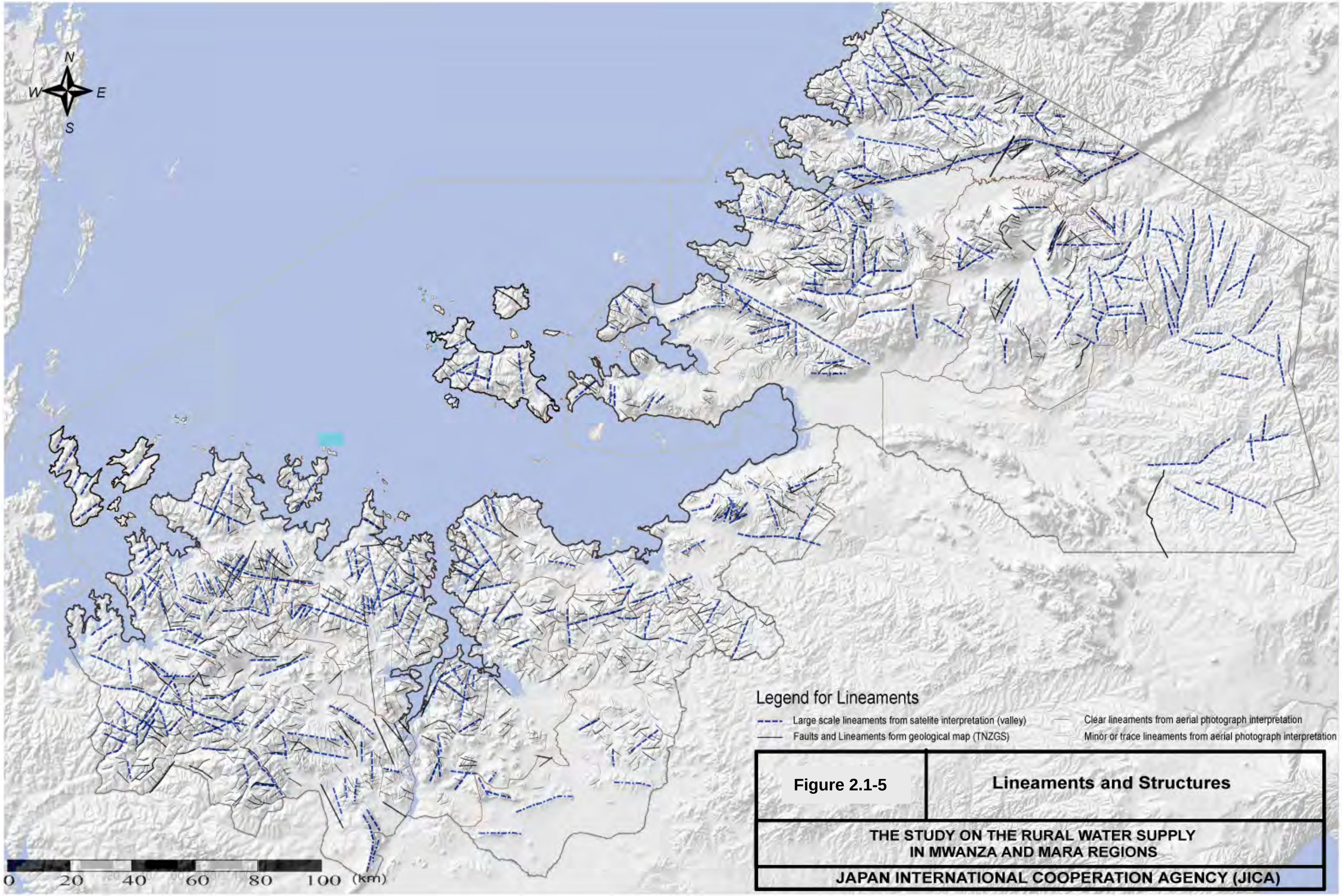


Figure 2.1-5 Lineaments and Structures

THE STUDY ON THE RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

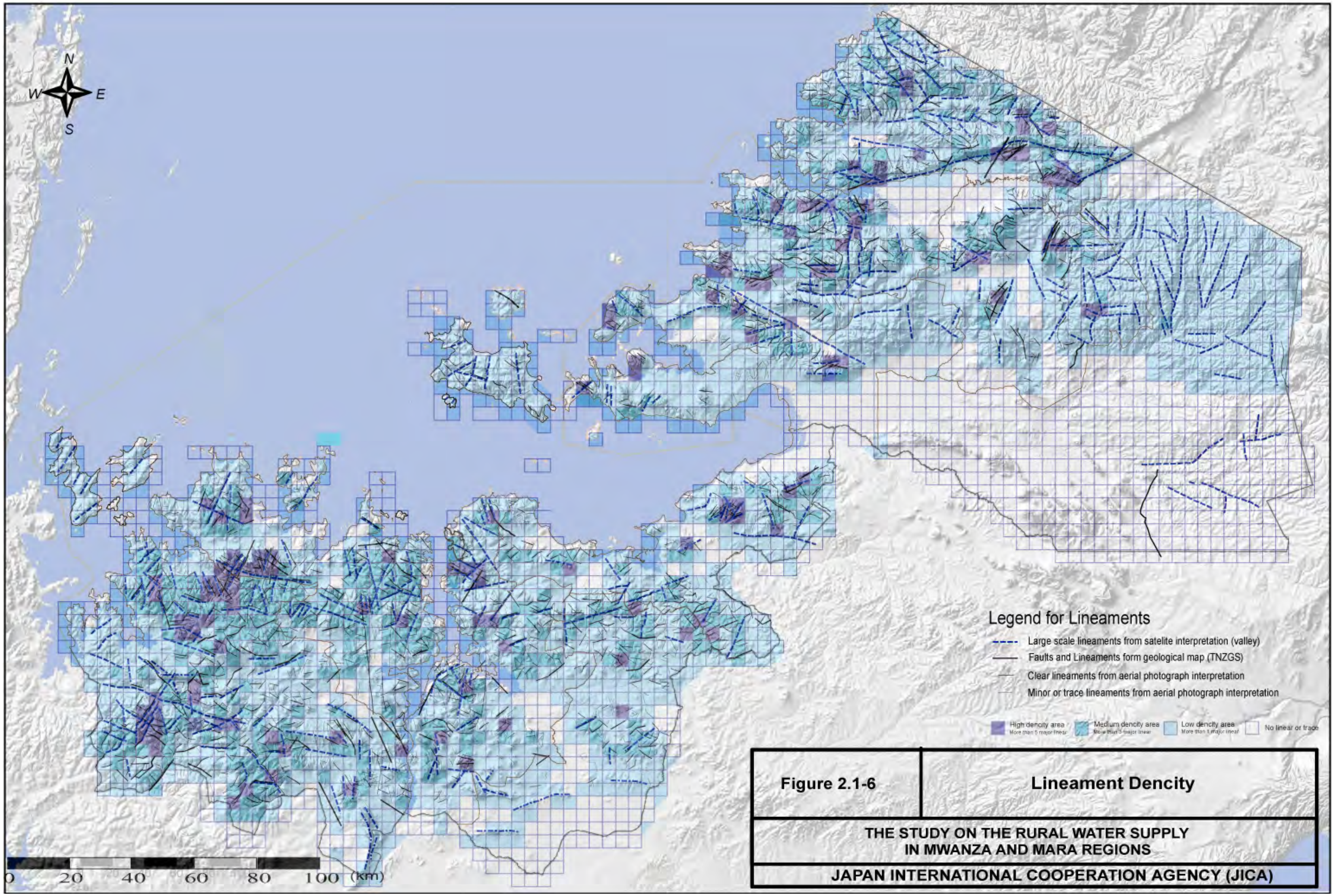


Figure 2.1-6	Lineament Dencity

THE STUDY ON THE RURAL WATER SUPPLY
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