CHAPTER 4 EXTENT OF FLOOD DAMAGE

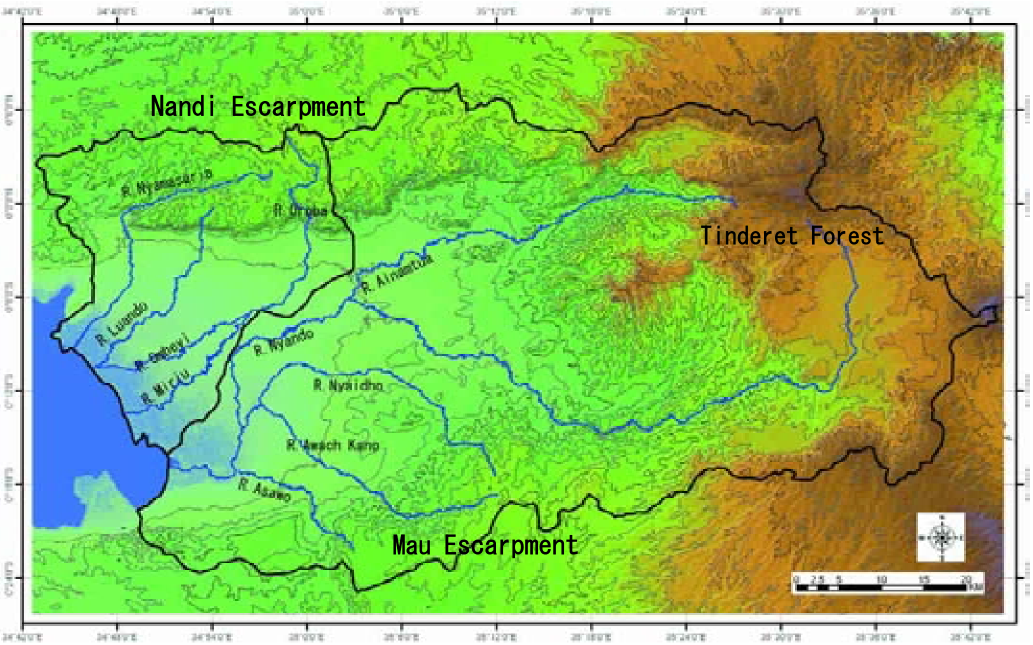
4.1 RIVER SYSTEM

4.1.1 River Basin of Nyando

Two major river systems, the Nyando and Nyamasaria river basins are situated in the Study Area. The Nyando and Nyamasaria river basins are surrounded by Nandi Escarpment in the north, Lake Victoria in the west, Mau Escarpment in the south and Tinderet forest in the east. The Nyando River pours into the Winam Gulf of Lake Victoria.

The catchment area of Nyando river basin is 3,618 km^2 including Awach Kano and Asawo rivers, and the length of the Nyando River is 153 km. The catchment area of Nyamasaria river basin is 890 km^2.

The Nyando and Nyamasaria rivers have fairly steep riverbed slopes. Figure 4.1.1 shows the river basins of the Nyando and Nyamasaria rivers.



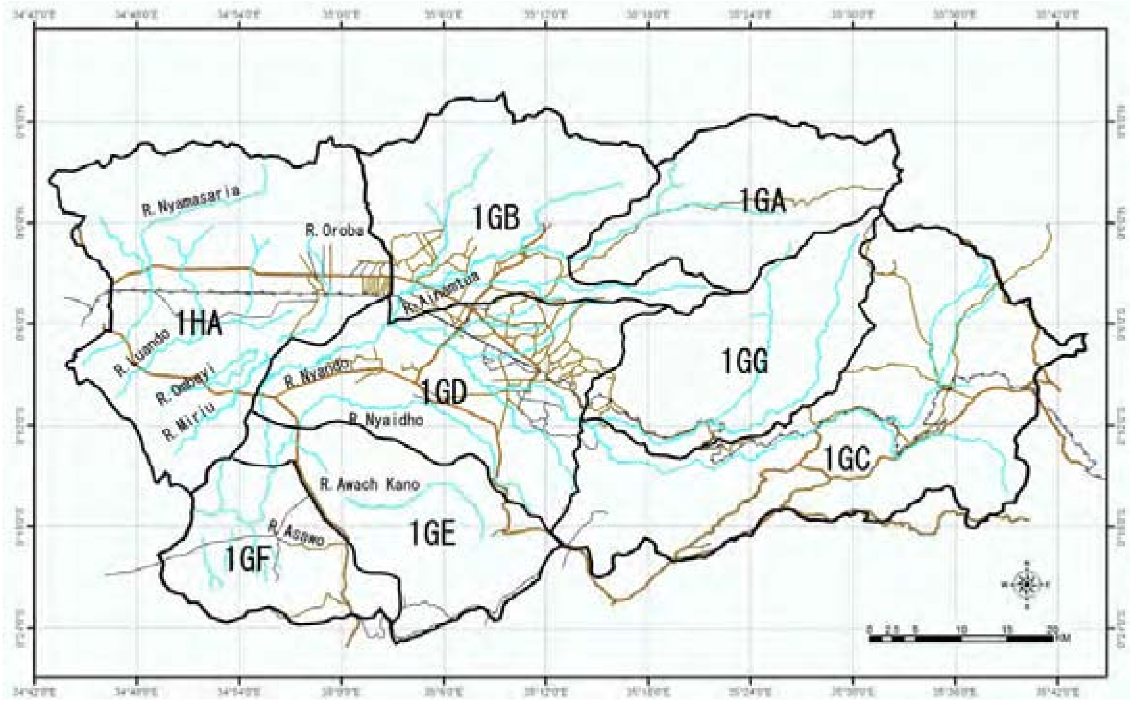
Source: JICA Study Team

Figure 4.1.1 Nyando River Basin

The major tributaries of the Nyando River are the Ainamutua and Pararget which join the right bank. Within the swamp area in the lower reaches, major tributaries are the Asawo and Awach Kano rivers which join the left bank. The Nyamasaria river basin flowing directly into Lake Victoria is composed of the Nyamasaria, Luando, and 2 distributaries, the Ombeyi and Miriu which are bifurcated from Oroba River.

4.1.2 Composition of Sub-Basin and Basin Areas

The sub-basin boundaries of the Nyando and Nyamasaria rivers are delineated in Figure 4.1.2. The Study Area is divided into seven sub-basins in the Nyando river basin and one sub-basin in the Nyamasaria river basin. The details are given in Table 4.1.1.



Source: JICA Study Team

Figure 4.1.2 Composition of Sub-Basins of Nyando and Nyamasaria Rivers

Table 4.1.1 Sub-Basin Name and Basin Area in Nyando River

No	Name of Sub-Basin	River Name	Sub-Basin Area (km^2)	Accumulative Area (km^2)
Nyando main river (from upper to lower)				
1031	1GC	Nyando	912	
1032	1GG	Pararget	374	1,286(after joining Pararget)
1033	1GA	Ainamutua	443	
1034	1GB	Ainamutua	518	
1037	1GD	Nyando incl Nyaidho	720	2,967
Nyando main and Awach Kano including Asawo rivers				
1035	1GE	Awach Kano	391	
1036	1GF	Asawo	260	3,618 (at river mouth)

Source: WRMA

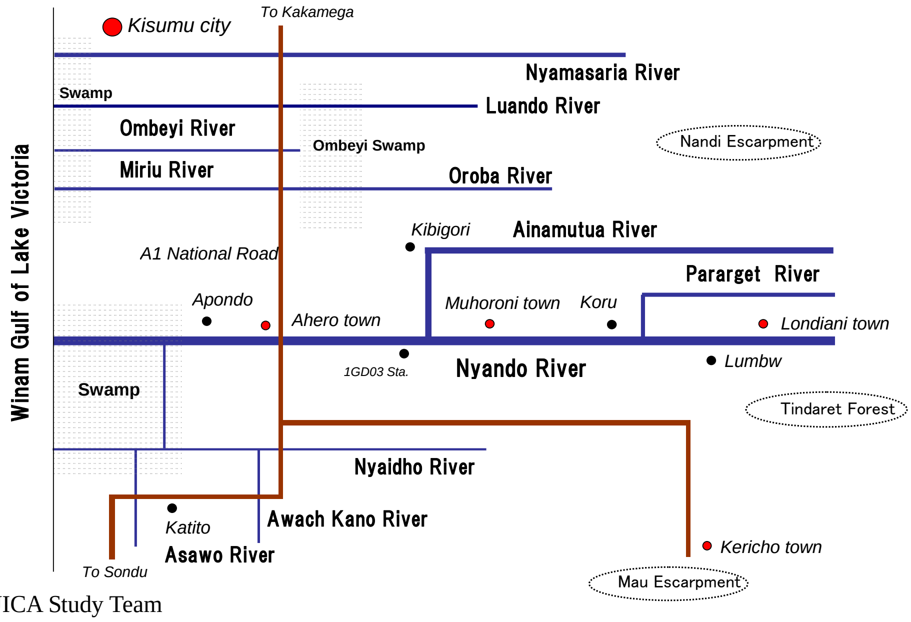
Table 4.1.2 Sub-Basin Name and Basin Area in Nyamasaria River

No	Name of Sub-Basin	River Name	Sub-Basin Area (km^2)	Accumulative Area (km^2)
1060	1HA	Nyamasaria	260	at A1 trunk road
		Luando	250	at A1 trunk road
		Ombeyi (upper basin:Oroba)	90	at A1 trunk road
		Miriu (upper basin: Oroba)	90	at A1 trunk road
		Others (swamp)	179	869 (at river mouth)

Source: WRMA Note: sub-basin area is estimated by JICA Study Team

4.1.3 River System

Figure 4.1.3 shows a schematic diagram of the river systems of the Nyando and Nyamasaria rivers.



Source: JICA Study Team

Figure 4.1.3 Schematic Diagram of River System of Nyando and Independent Rivers

(1) Nyando River

The Nyando River originates in Tinderet forest in the north-eastern corner of the basin where it has a ground elevation of El.1,700 m. Passing through the forest zone toward the south, the Nyando River flows down through the mountainous area and changes its flow direction to south-westerly at Londiani. The river flows down through the V-shape valley in the upper and middle reaches of the basin for approximately 50 km collecting several small tributaries. Near Koru at the right bank, the Nyando River joins the second largest tributary, the Pararget River. The total catchment area is around 1,286 km^2.

Source: JICA Study Team

Figure 4.1.4 River Channel at Lumbwa in Upper Nyando River

The Nyando River flows down further in a westerly direction for about 30 km passing through the middle basin towards a confluence with the largest tributary, the Ainamutua River which has a catchment area of 960 km^2 at the right bank. The river width in this reach of the Nyando River is 20-40 m with a riverbed slope of 1/45- 1/160 on the average. (Figure 4.1.5)

Source: JICA Study Team

Figure 4.1.5 Intake Weir at Muhoroni (left) and Billboard at Chemeli in Middle Nyando River

The Nyando River has a catchment area of 2,247 km^2 at the confluence with the Ainamutua River where it changes its flow direction to south-westerly and reaches Ahero after flowing for about 18 km. A key water level gauging station, 1GD03, is located at the left bank at this point (Ogira) as shown in Figure 4.1.6. The catchment area at 1GD03 is 2,625 km^2. After passing 1GD03 station, the river flows down an extensive flood plain, and also meanders because of the gentle riverbed slope. The meandering continues to Ahero Bridge as shown in Figure 4.1.6.

Source: JICA Study Team

Figure 4.1.6 1GD03 Water Gauging Station (left) and Ahero Bridge in Lower Nyando River

At Ahero, the river changes its flow direction to south and flows down through the low-lying area of the Kano Plain for about 10 km. In this reach, average river width and riverbed slope are around 50 m and 1/1,600, respectively. Figures 4.1.7 and 4.1.8 show the downstream stretches.

Source: JICA Study Team

Figure 4.1.7 River Channel at Apond in Lower Nyando River

Source: JICA Study Team

Figure 4.1.8 River Channel of Awach Kano (left) and Nyaidho downstream of A1 Trunk Road

After passing the 10 km point from Ahero Bridge, several tributaries, the Awach Kano and Asawo rivers and others, join at the left bank,. The Awach Kano basin is characterised as having a remarkably high sediment flow.

The catchment area of the Nyando at the river mouth is 3,618 km^2. The Nyando River finally pours into the Winam Gulf of Lake Victoria which has a total basin area of 197,500 km^2 with a lake surface area of 69,300 km^2.

(2) Nyamasaria River

The rivers of the Nyamasaria are the Nyamasaria, Luando and Oroba (with 2 distributaries, the Ombeyi and Miriu in the lower reaches). The river basin of the Nyamasaria River is categorised as a 1HA sub-basin having a total basin area of 870 km^2. The river length in this basin is fairly short at less than about 40 km and therefore, flood flow during the rainy season frequently manifests as flash flooding with high velocity.

The Nyamasaria flows down through steep mountains in a southerly direction and directly discharges into the Winam Gulf in Lake Victoria at the east side of Kisumu City. The Oroba

River flows down passing through a steep mountain area and reaches a swamp area called Ombeyi swamp.

The Luando, starts in the southern slopes of a hilly area of Nandi Escarpment and also reaches a swamp area. Figure 4.1.9 shows river conditions of the upper Nyamasaria and Oroba after passing through the mountains. Also Figure 4.1.10 shows the river channels in the lower reaches of Luando and Ombeyi rivers downstream of A1 trunk road.

Source: JICA Study Team

Figure 4.1.9 River Channel of Nyamasaria (left) and Oroba in Middle Reaches

Source: JICA Study Team

Figure 4.1.10 River Channel of Luando (left) and Ombeyi in Lower Reaches

After being temporarily retarded in the Ombeyi swamp (as illustrated in Figure 4.1.3), the flood water flows down towards Winam Gulf branching into Luando, Ombeyi and Miriu. However, during ordinary flow, it is observed that no water is flowing in the Ombeyi and Miriu due to blockage of the inlet to the swamp as shown in Figure 4.1.9.

Average river widths in the respective lower reaches of the rivers downstream of A1 trunk road are around 10 m in Nyamasaria and around 20 m in the others. Channel depth ranges from 4 m in Nyamasaria and 1.5 to 2 m in others.

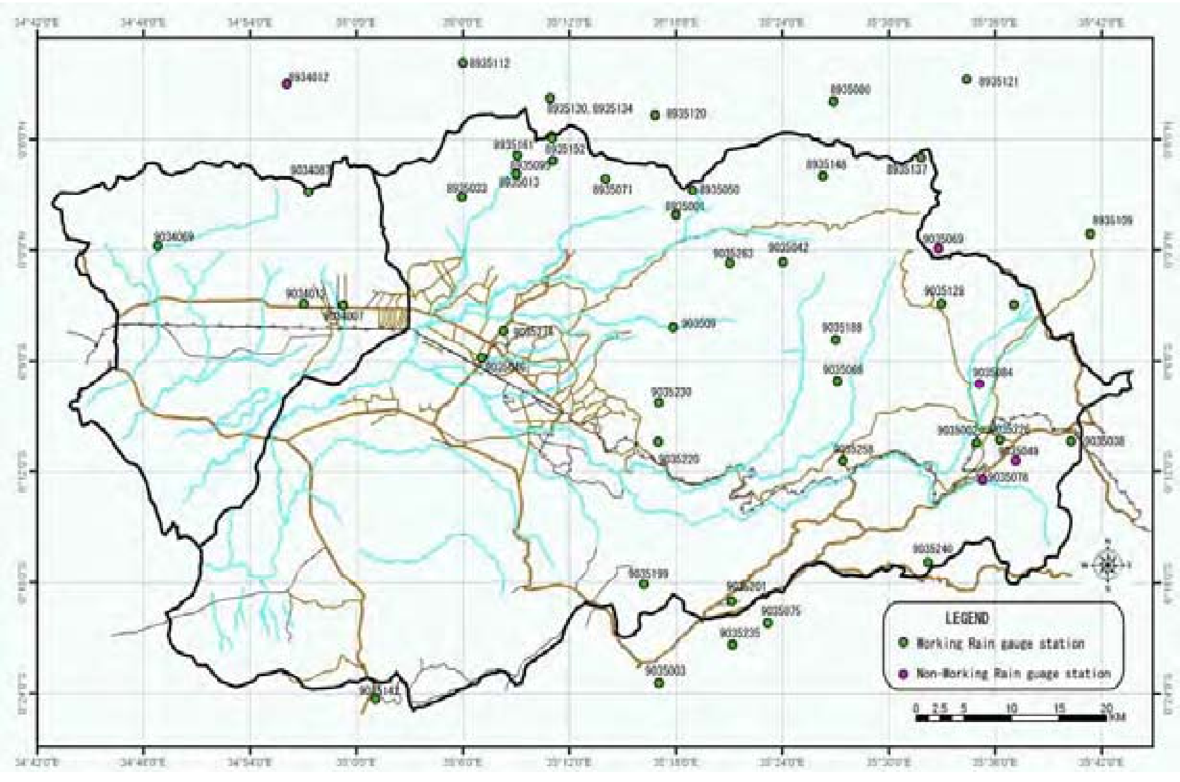
4.2 METEO-HYDROLOGICAL FEATURES OF THE NYANDO RIVER BASIN

4.2.1 Meteo-Hydrological Monitoring Network and Data Availability

In this section, meteorological and hydrological conditions in the Nyando river basin are described. Firstly, an inventory of the monitoring network and general conditions of the meteo-hydrology are shown and subsequently, chronological variation of rainfall and discharges, analysis of probable peak discharges by return period, etc., are explained.

(1) Meteorological Stations and Data Availability

There are a large number of rainfall observation stations in the Nyando river basin. There exist 40 working rainfall stations including adjacent ones. Figure 4.2.1 shows the locations of the working stations within the Nyando river basin.



Source: JICA Study Team, Data is provided by LVSWSB

Figure 4.2.1 Locations of Rainfall Observation Stations

The available records of rainfall data at each station are summarised in Table 4.2.1.

Table 4.2.1 Available Recorded Measurement Rainfall Data

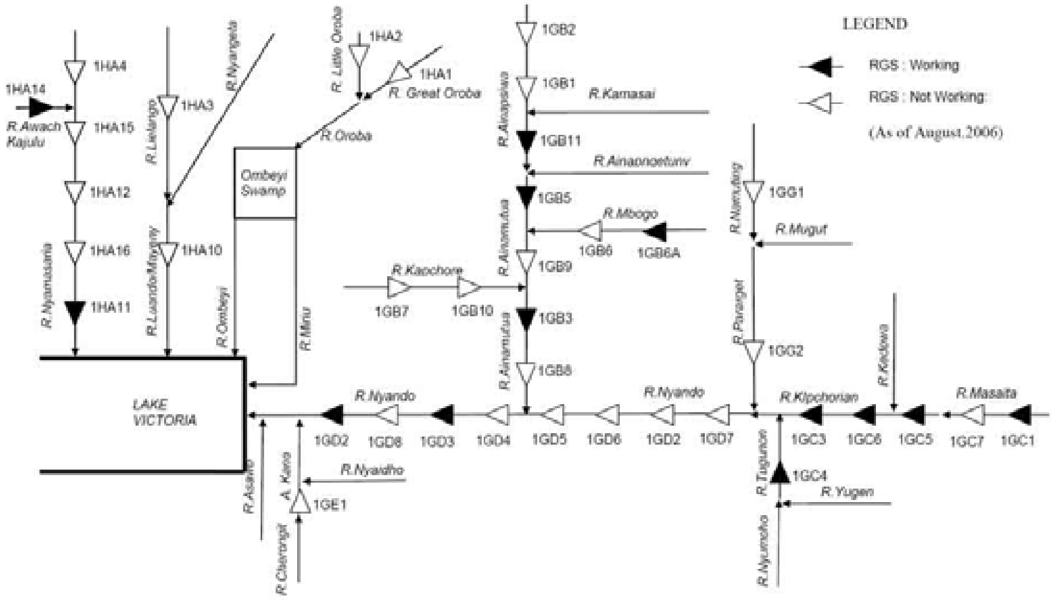
Station	No	Degrees	Minutes	Degrees	Minutes	Year opened	Year Closed	Drainage
Murogosi Estate, Turbo	8934012	0	40N	34	59E	1925	1964	1C
Kabagendui Kibet Farm	8935001	0	2N	35	18E	1920	----	1G
Hoey's Bridge, Brindley Park	8935005	0	47N	35	3E	1923	1965	1B
Nandi,Koisagat Tea Estate	8935013	0	5N	35	16E	1921	----	1G
Nandi Hills, Savani Estate	8935033	0	3N	35	6E	1929	----	1G
El Lahre S.F.T. Farm	8935042	0	52N	35	7E	1936	1973	1B
Kimugul Primary School	8935050	0	2N	35	20E	1937	----	1G
Siret Tea Co. Ltd.,Nandi	8935071	0	4N	35	14E	1944	----	1G
Nabkoi Forest Station	8935080	0	8N	35	28E	1947	----	1C
Narasha Forest Station	8935109	0	2N	35	41E	1950	----	2E
Nandi Forest Station	8935112	0	12N	35	4E	1950	----	1F
Kibabet Estate Ltd.	8935120	0	8N	35	17E	1952	----	1F
Kapsiwoni Nandi Tea Estate Ltd.	8935130	0	7N	35	11E	1954	----	1F
Kessup Forest Reserve,Elgeyo	8935134	0	39N	35	31E	1955	----	2C
Timboroa Forest Station	8935137	0	4N	35	32E	1954	----	2E
Tenges Intermediate School	8935142	0	20N	35	48E	----	----	2E
Kipkurere Forest Station	8935148	0	5N	35	25E	1959	----	1G
Nandi Hills Agricultural Office	8935152	0	7N	35	11E	1962	----	1F
Nandi Hills,Kibweri Tea Estate	8935161	0	5N	35	9E	1958	----	1G
Miwani Sugar Section II Office	9034007	0	3S	34	57E	1932	----	1G
Miwani Sugar Section I	9034012	0	3S	34	57E	1934	----	1H
Kibos National-Fibre Research Centre	9034081	0	04S	34	49E	1952	----	1H
Lambwe Forest Station	9034087	0	39S	34	21E	1958	----	1H
Londiani Forest Station	9035002	0	9S	35	36E	1908	----	1G
Kericho District Office	9035003	0	23S	35	17E	1904	----	1J
Mau Summit Station	9035038	0	10S	35	40E	1931	----	2E
Equator Barguat Estate	9035042	0	1S	35	24E	1932	----	1G
Chemelil Plantation	9035046	0	4S	35	9E	1932	----	1G
Londiani Braeside	9035049	0	11S	35	37E	1933	1981	1G
Kipkelion Moran Company Ltd.	9035068	0	08S	35	27E	1938	----	1G
C.D. Cullen, Equator	9035069	0	0S	35	33E	1938	1976	2E
Kaisugu House, Kericho	9035075	0	19S	35	22E	1939	----	1G
Hundreds Acres, Londiani	9035078	0	12S	35	35E	1939	1981	1G
Itiok Farm Co. Ltd., Londiani	9035084	0	07S	35	35E	1941	1977	1G
Sorget Forest Station	9035128	0	10S	35	35E	2001	----	1G
Nyabondo Water Supply	9035142	0	23S	35	01E	1954	----	1J
Makutano Forest Station, Londiani	9035155	0	03S	35	37E	1955	----	1G
Tinga Kipkelion Monastry	9035188	0	5S	35	27E	1959	----	1G
Ainamoi Chiefs Camp, Kericho	9035199	0	18S	35	16E	1960	----	1L
Kericho Laliat Farm, Ainamoi	9035200	0	16S	35	15E	1959	----	1L
Kapkorech Estate	9035201	0	19S	35	20E	1939	----	1G
Kenya Forestry College, Londiani	9035226	0	09S	35	35E	1957	----	1G
Coffee Board Sub-Station, Koru	9035230	0	08S	35	17E	1959	----	1G
Kericho Chagaik Estate	9035235	0	20S	35	20E	1954	----	IG
Keresoi Forest Station, Londiani	9035240	0	17S	35	32E	1961	----	1J
Kipkelion Water Supply	9035258	0	12S	35	28E	1961	----	1G
Chemelil Sugar Scheme	9035274	0	4S	35	8E	1970	----	1G

Source: JICA Study Team, values in database of LVSWSB

(2) Hydrological Stations and Data Availability

1) Water Level Gauging Stations and Data Availability

There exist water level stations at various locations on the main stream and several major tributaries. LVSWSB is responsible for water level, water quality and sediment measurements in the rivers flowing into Lake Victoria. However, the water level measurements has been terminated or abandoned at more than half of the stations due to financial constraints. The locations of stations within the Nyando river basin are illustrated in Figure 4.2.2. The availability of recorded data on water levels is summarised in the following Table 4.2.2.



Source: LVSWSB and WRMA

Figure 4.2.2 Schematic Diagram of Water Level Gauging Station

Table 4.2.2 Availability of Recorded Data on Water Levels

Code	River	Station Name (desceiption of location)	Coordinate Latitude	Coordinate Longitude	Catchment Area(km2)	Data Collection Period
1GB03	AINAMATUA	at Kibigori	S 0 04.553″	E 35 03.353″	1300	1968 – 1990
1GB05	AINAMATUA	at bridge after confluence	S 0 01.724″	E 35 10.452″	606	1965 – 1999
1GB06A	MBOGO	at Chem-Ker. Bridge	S 0 03.653″	E 35 08.866″	67	1973 – 1980
1GB10	KAPCHORE				158	
1GB11	AINAPSIWA	before meeting Ainopngetury	S 0 01.695″	E 35 10.478″	142	1965 – 1980
1GC01	MASAITA	at Londiani w/s dam	S 0 08.121″	E 35 36.109″	48	
1GC03	NYANDO (KIPCHORIAN)	at confl. with Kimoson	S 0 12.406″	E 35 27.708″	523	
1GC04	TUGUNON	at Tgunon Bridge	S 0 15.276″	E 35 24.914″	47	1965 – 1980
1GC05	NYANDO (KIPCHORIAN)	at Lambel Farm Bridge	S 0 11.822″	E 35 32.126″	251	1965 – 1980
1GC06	NYANDO (KIPCHORIAN)	at Kipkelion w/s	S 0 11.940″	E 35 28.355″	546	1967 – 1980
1GE01	CHERONGIT					
1GD02	NYANDO	at Ahero Bridge			1375	
1GD03	NYANDO		S 0 07.511″	E 35 00.061″	2625	1969 – 2004
1GD04	NYANDO				2520	1965 – 1980
1GD07	NYANDO		S 0 30'50″	E 35 09'50″	1419	1963 – 1994
1GG01	NAMUTING	(Pararget) at bridge	S 0 12.256″	E 35 20.844″	298	1965 – 1980
1GG02	NAMUTING				386	
1HA01	OROBA (GREAT)		S 0 03.306″	E 35 00.119″	62	
1HA02	OROBA (LITTLE)		S 0 03.257″	E 34 58.890″	10	
1HA11	OROBA (GREAT)				72	
1HA14	AWACH (Nyangori)		S 0 02.880″	E 34 48.340″	104	

Source: LVSWSB and WRMA

2) Water Level Measurement and Characteristics of Data

The water levels have been measured by means of reading water levels using staff gauges twice a day (morning and early evening) at stations in Kenya throughout the year without any additional measurements during flood. Hence, maximum water level or peak discharge of large-scale floods has not been measured at all stations. A rating curve between water level and discharge (H-Q curve) is available at almost all working stations by periodic reviewing of cross sectional changes due to erosion or sedimentation; however it has not been reviewed at some stations.

Also no data is available at 1 GD03 stations over a period of two years from 1998 to 1999 due to failure of the measuring equipment. In April 2000, automatic water level recording equipment of the water pressure type was installed at the key station of 1GD03 (Ogira site: basin area 2,625 km^2) in addition to the existing staff gauge, and the water levels have been automatically recorded every 15 minutes most of the time since. In the database at LVSWSB, water level records on an hourly basis and daily highest and lowest water levels have been stored. However, due to financial constraints, the measurements actually stopped over a period of several months in the dry season. From the above situation, it can be said that annual highest water level or peak discharge during flood has been recorded only at 1 GD03 stations since April 2000.

4.2.2 General Meteorological Features

(1) General Climactic Features

The climate in Kenya is controlled by the northward and southward movements of the Intertropical Convergence Zone (ITCZ). The influence of the ITCZ within Kenya is summarised in the following Table 4.2.3.

Table 4.2.3 Influence of ITCZ within Kenya

Months	Location/Position of ITCZ	Extent of Influence/Wind Direction/Monsoon
January to March	Southern most	not influenced (northeast monsoon)
April to June	Moving northwards	long duration rainfall (strong southeast wind and south monsoon)
July to October	Northern-most	slightly influenced (weak south monsoon)
November to December	Moving southwards	with short duration rainfall (weak northeast monsoon)

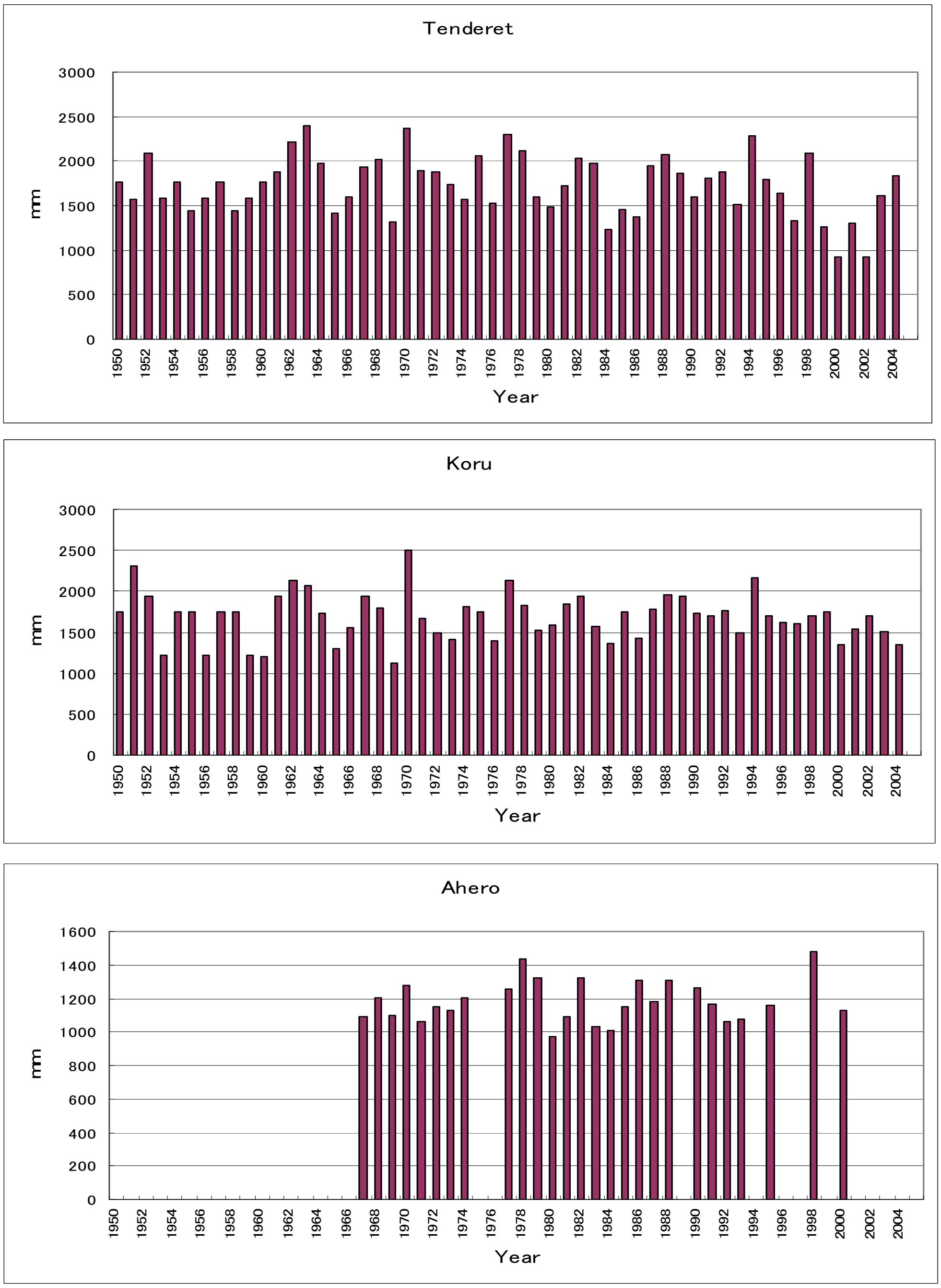
Source: 1992 National Water master Plan, JICA

The climate from April to June is strongly influenced by southeast wind and south monsoons with long duration rainfall and it is also influenced in November and December with short duration rainfall resulting from northwest monsoons. In August and September, the south monsoon is dominant, so the climate is slightly influenced with short duration rains. Therefore, the annual rainfall pattern is tri-modal with peaks in April to May, August to September and

November to December.

(2) Long-term Variation of Annual Rainfall

The annual rainfall varies from more than 2,500 mm in the upper basin to 1,000 mm near the lakeshore as shown in Figure 4.2.3 (showing upper to lower basin). No significant long-term trend can be recognised although large variations in annual rainfall amounts are repeatedly observed.



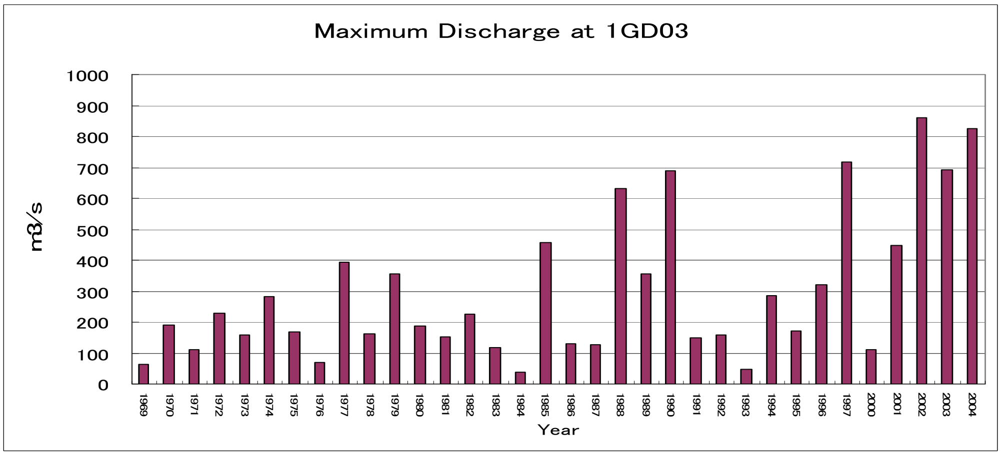
Source: JICA Study Team, values in database of LVSWSB

Figure 4.2.3 Annual Rainfall in Nyando River Basin

4.2.3 Hydrological Features of Nyando River Basin

(1) Annual Maximum Discharge

The 1GD3 water gauging station located at the uppermost point of Kano Plain has long-term data. A series of annual maximum discharges is reviewed by the respective H-Q curves. The variation in annual maximum discharges is illustrated in Figure 4.2.4. It is noted that the reported annual maximum discharges before 1997 are smaller than currently reported maximum discharges as the actual maximum water levels during floods before 1997 were not measured due to the manual reading system then in use.

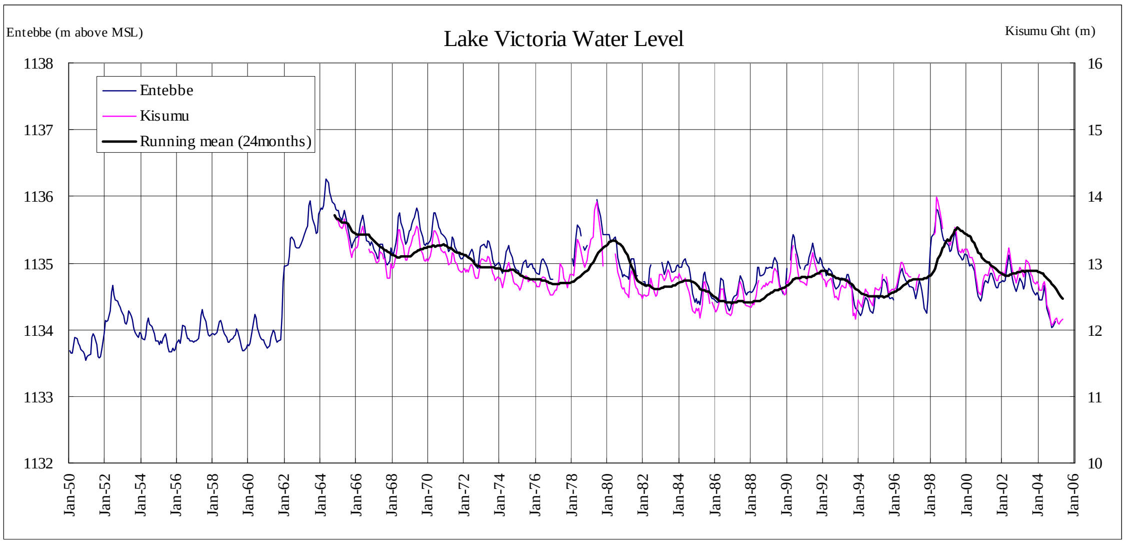


Source: JICA Study Team, values in database of LVSWSB

Figure 4.2.4 A Series of Annual Maximum Discharge Records at 1GD03 Station

(2) Chronological Change in Monthly Mean Water Levels in Lake Victoria

The lake water levels have been measured at Kisumu for the past five decades. The variation of monthly mean water level of the lake is illustrated in Figure 4.2.5.



Source: JICA Study Team, values in database of LVSWSB

Figure 4.2.5 Long-term Variation of Mean Water Levels of Lake Victoria

The lowest water level was recorded at El.1,133.19 m in 1923 and the lake water levels sharply rose in 1961 to 1962 because of widespread rain in and around Lake Victoria. The current lake water levels tend to drop and are at about 1,134 m in 2006.

If the water level drops to as low as it was in 1923, the lake water depth at Winam gulf into which the Nyando River pours, would be less than 2 m and serious navigation problems in the Nyando and related rivers could be experienced up to a distance of 30 km from the lakeshore. However, it can be said that such water level fall would be quite convenient in the lower Nyando and related rivers from a viewpoint of flood control and drainage.

(3) Sediment Discharge in Nyando River

Sediment transportation in the Nyando river basin was analysed in "the Pilot Study on Sedimentation and Sediment Characteristics on Nyando and Nzoia River Mouths and Winam Gulf of Lake Victoria", December 2005, Lake Victoria Environmental Management Project (LVEMP).

In that study, sampling of suspended solids load was made at several points in the Nyando River and annual sediment volume was estimated. According to the above Pilot Study, three study results on mean annual sediment volume transported by rivers flowing into Lake Victoria have been reported addressing suspended solids load. Out of those data, mean annual sediment volumes transported by rivers within Kenya are summarised in the following Table 4.2.4.

Table 4.2.4 Annual Sediment Volume to Lake Victoria

River	Catchment Area (km^2)	Mean Discharge (m^3/s)	LVEMP Result in 2005 (t/yr)	Okungu Result in 2002 (t/yr)	Pilot Study Result in 2005* (t/yr)
Nzoia	12,842	115	678,110	250,000	823,856 (probable) 2,236,714 (high probable)
Gucha-Migori	6,600	59	465,855	-	-
Nyando	3,652	18	23,144	160,000	415,975 (probable) 1,012,247 (high probable)
Yala	3,357	35	175,283	270,000	-
Sondu-Miriu	3,508	42	14,192	300,000	-
South Awach	3,156	6	29,826	-	-
North Awach	1,985	4	6,938	-	-
Sio	1,437	11	31,665	90,000	-

Source: Pilot Study on Sedimentation and Sediment Characteristics on Nyando and Nzoia River Mouths and Winam Gulf of Lake Victoria", December 2005, LVEMP.

Note: * probable=estimated lower value; high probable=estimated higher value.

In the above table, Nyando River includes the related Asawo and Awach Kano rivers. The volume estimated by the Pilot Study is high compared with the other 2 results although the value by LVEMP is quite small.

According to the above result, the specific sediment volume in the Nyando river basin is estimated at 6.4 t/km^2/yr (by LVEMP), 43.8 t/km^2/yr (by Okungu) and 114 to 277 t/km^2/yr (by the Pilot Study). In the Nyando river basin, it is supposed to be on an order of 200 to 300 t/km^2/year judging from river characteristics of the Nyando river basin.

4.2.4 Probability Analysis of Annual Maximum Discharges

(1) Review of Previous and Current Data

The 1GD3 water level gauging station is located at the upper point of the flood plain in the Nyando river basin after joining the largest tributary, the Ainamutua River. The flow at 1GD03 is completely confined by the hilly banks on both sides without any diffusion of flood flow.

By including the most recent data at the said stations from 2000 to 2004 with the previous recorded data, a probability analysis by return period of annual maximum flood discharges was made. However, the annual maximum discharges obtained before 1997 can not be used unadjusted in the probability analysis because of data characteristics as already explained in 4.2.1 (2).

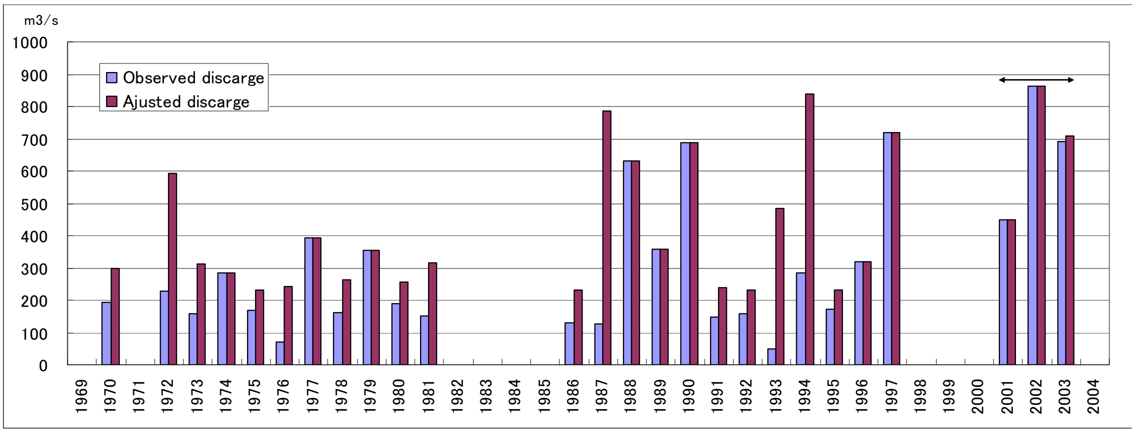
Therefore, the annual maximum discharges before 1997 were adjusted by means of an equation developed by correlation between flood peak discharges exceeding 400 m^3/s and basin mean rainfall amounts by using data in the period from 2001 to 2004 as explained below.

1) Correlation between flood peak discharges and basin mean rainfall amounts were checked for several cases,
2) Among those cases, the correlation coefficient is high (coefficient= 0.84) for the case between daily flood peak discharge and daily basin mean rainfall amount on the same date with the said flood peak discharge,
3) Based on this correlation, an equation to adjust annual maximum discharges obtained before 1997 was made as:

   Q= 16.405 * daily basin mean rainfall amount + 230.33,

4) By using the above equation, the annual maximum discharges obtained before 1997 were adjusted, and
5) As the result, the multiplying factor to adjust the annual maximum discharges before 1997 is 1.6 on average.

It should be noted that where the adjusted discharge was lower than the recorded data, the recorded value was adopted as the annual maximum discharge. The adjusted annual maximum discharges before 1997 are presented in Figure 4.2.6.

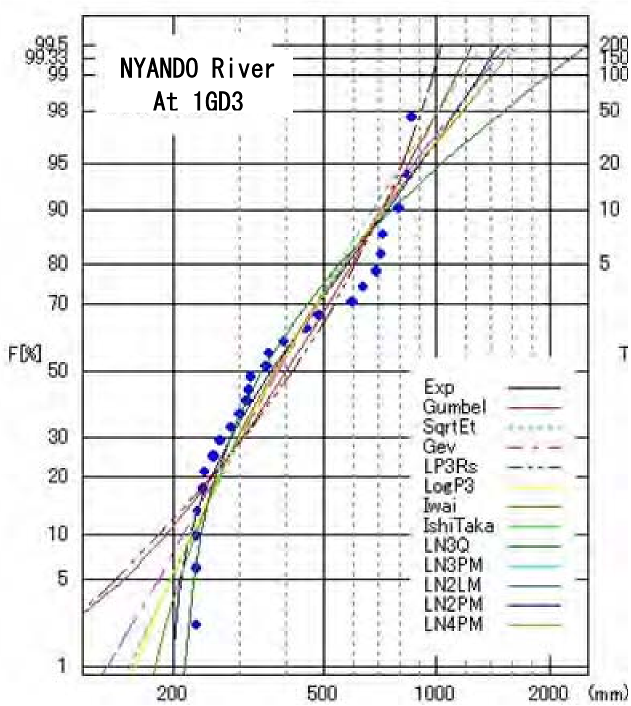


Source: JICA Study Team

Figure 4.2.6 Adjusted Annual Maximum Discharges

(2) Probable Discharges at 1GD03 Station

The probability analysis result for the reviewed data is illustrated in Figure 4.2.7 using several methods based on the adjusted annual maximum discharges.



Source: JICA Study Team

Figure 4.2.7 Probable Discharges by Return Period

From the above various probability analysis results, the estimated probable discharges obtained by the Gumbel method as employed in the previous studies are summarised in Table 4.2.5 compared with the previous values.

Table 4.2.5 Probable Discharges by Return Period

Return Period (yr)	2006 JICA Study (m^3/s)	2004 WMO (m^3/s)	1992 JICA Study (m^3/s)	1983 ItalConsult study (m^3/s)
2	400	-	-	
5	600	-	-	
10	730	863	437	550
25	890	1,044	564	650
50	1,010	1,178	659	750
100	1,130	1,310	752	850

Source: JICA Study Team

(3) Probable Discharges of Nyando Tributaries and Nyamasaria Rivers

There are no recorded data on water levels or discharge in the tributaries of Nyando and Nyamasaria rivers. On the other hand, in the 1992 Study on the National Water Master Plan (JICA), the design discharges were estimated by using an equation for estimation of probable discharges as shown below.

1) Equation for estimation of mean annual discharge: $q= 3.005 * A^{0.363}$

2) Equation for estimation of probable discharge Q= q* constant by return period.

The above 1) and 2) equations were developed based on the annual maximum discharges recorded twice a day, before installation of automatic gauges in 2000. In applying this curve, the same multiplying factor of 1.6 assumed in the former section 4.2.5 was used. The applied equation will be as follows;

1) $Q=3.005 * A^{0.363}$ * constant by return period * 1.6.

The following Table 4.2.6 summarises the estimated probable discharges by rivers.

Table 4.2.6 Design Discharges for Other Small Rivers

River/Basin Area at Base Point		Probable Discharge (m^3)			
	Return Period (yr)	5	10	20	25
	Constant by return period	1.47	1.84	2.17	2.3
Awach Kano (370 km^2)		60.5	75.7	89.3	94.6
Nyaidho (160 km^2)		44.6	55.8	65.8	89.8
Nyamasaria (260 km^2)		53.2	66.6	78.5	83.2
Luando (250 km^2)		52.4	65.6	77.4	82.1
Ombeyi+Miriu (180 km^2)		46.4	58.3	68.7	72.8

Source: JICA Study Team

4.2.5 Decreasing Effect of Peak Discharge through Dam Reservoirs

According to the previous reports, the following dam schemes have been recommended as prospective ones which need further study for future development.

1) Dam No. 05(Ainapngetuny river), Dams 07 or 11 (Nyando river) and 51(Kibos river): Pre-Investment Study by Italconsult, 1983.

2) Dam No. 07 (Nyando River, Muhoroni site): Investigation Report by Water Conservancy Team, 1990.

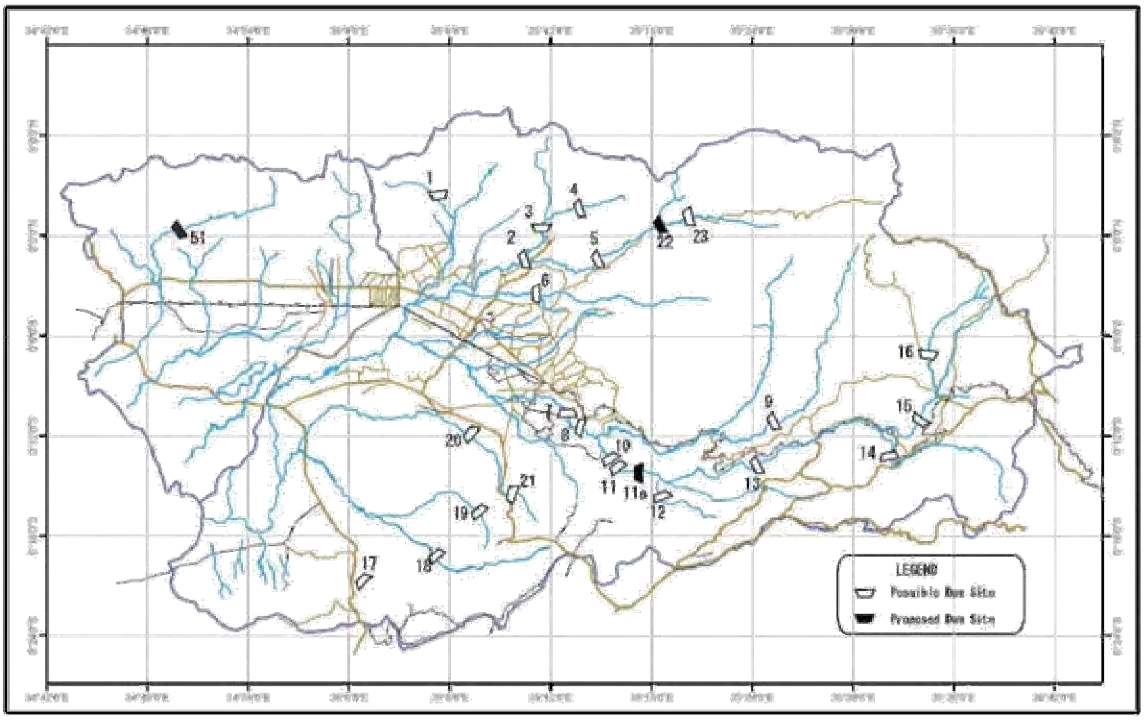
3) Dam No. 07 (Nyando river, Muhoroni site, Nyando dam): JICA Study, 1992.

4) Dam No. 03(Ainapngetuny river), Dams 08, 11 and 13 (Nyando river): MWRD Review, 2004.

Among the above candidate dam schemes at around 24 sites as shown in Figure 4.2.8, the three dam sites in the Nyando River, the Ainapngetuny River and the Kibos River are presently proposed as prospective ones.

In addition, a field survey was conducted to confirm more detailed features of the 3 proposed dams in view of location of dam axis and land use in proposed reservoir area. As the result, Dam No.51 in the Kibos, Dam No.22 in the Ainamutua and Dam No.11a were selected as the proposed ones in the master plan.

In order to check peak discharge reduction by the proposed dam reservoirs, storage area curves of each proposed dam are estimated based on the 1/50,000 topographic map are presented in Figure 4.2.9.



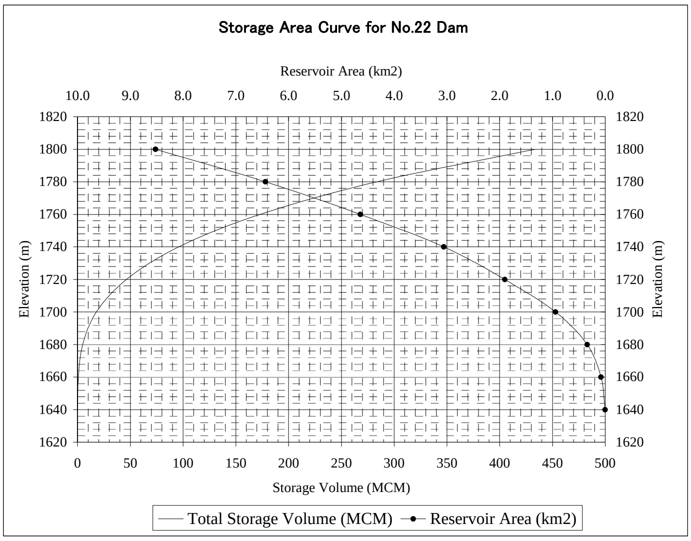
Source: JICA Study Team

Figure 4.2.8 Locations of proposed and Candidate Dam Sites

Dam No.	22
River Name	Ainapngetuny
River Bed Elevation	1640.0 El.m
Dam Height*1	80.0 m
Dam Crest Elevation	1720.0 El.m
Gross Storage Volume	0.0 MCM
Catchment Area	142 km2

Water Level (m)	Reservoir Area (km^2)	Increment Storage Volume (MCM)	Total Storage Volume (MCM)
1640.0	0.00	0.00	0.00
1660.0	0.08	0.80	0.80
1680.0	0.34	4.20	5.00
1700.0	0.94	12.80	17.80
1720.0	1.90	28.40	46.20
1740.0	3.06	49.60	95.80
1760.0	4.64	77.00	172.80
1780.0	6.44	110.80	283.60
1800.0	8.52	149.60	433.20
1820.0	10.83	193.50	626.70
1840.0	13.12	239.50	866.20

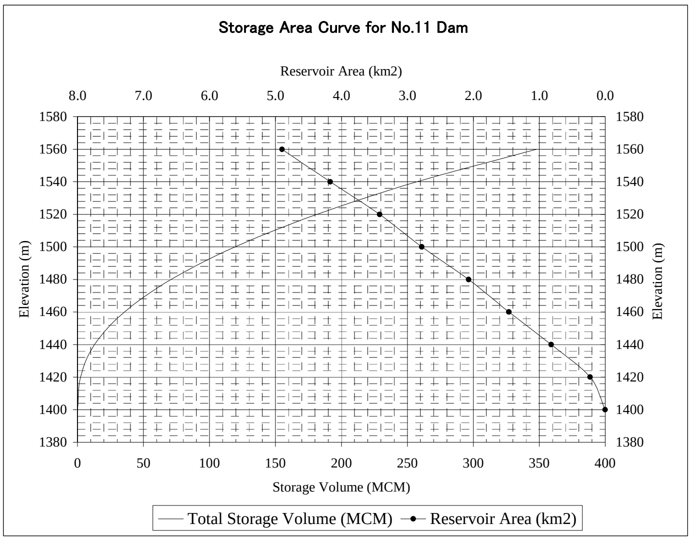
*1:source (NWMP1992 H.6-1)



Dam No.	11
River Name	Nyando
River Bed Elevation	1400.0 El.m
Dam Height*2	100.0 m
Dam Crest Elevation	1500.0 El.m
Gross Storage Volume	0.0 MCM
Catchment Area	729 km2

Water Level (m)	Reservoir Area (km^2)	Increment Storage Volume (MCM)	Total Storage Volume (MCM)
1400.0	0.00	0.00	0.00
1420.0	0.23	2.30	2.30
1440.0	0.82	10.50	12.80
1460.0	1.46	22.80	35.60
1480.0	2.07	35.30	70.90
1500.0	2.78	48.50	119.40
1520.0	3.42	62.00	181.40
1540.0	4.17	75.90	257.30
1560.0	4.90	90.70	348.00
1580.0	5.89	107.90	455.90
1600.0	6.94	128.30	584.20

*2:results of field survey



Dam No.	51
River Name	Kibos
River Bed Elevation	1440.0 El.m
Dam Height*1	97.0 m
Dam Crest Elevation	1537.0 El.m
Gross Storage Volume	0.0 MCM
Catchment Area	115 km2

Water Level (m)	Reservoir Area (km^2)	Increment Storage Volume (MCM)	Total Storage Volume (MCM)
1440.0	0.00	0.00	0.00
1460.0	0.02	0.20	0.20
1480.0	0.19	2.10	2.30
1500.0	0.90	10.90	13.20
1520.0	2.34	32.40	45.60
1540.0	4.43	67.70	113.30
1560.0	6.53	109.60	222.90
1580.0	8.82	153.50	376.40
1600.0	11.78	206.00	582.40
1620.0	15.60	273.80	856.20
1640.0	19.67	352.70	1208.90

*1:source (NWMP1992 H.6-1)

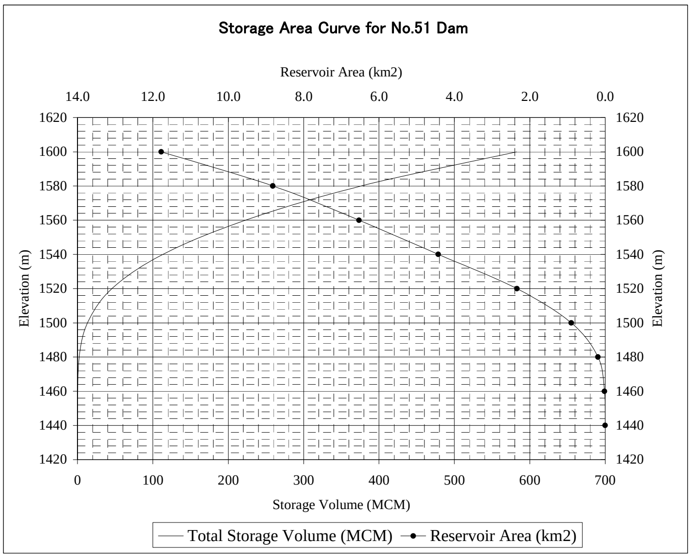


Figure 4.2.9 Storage Area Curve

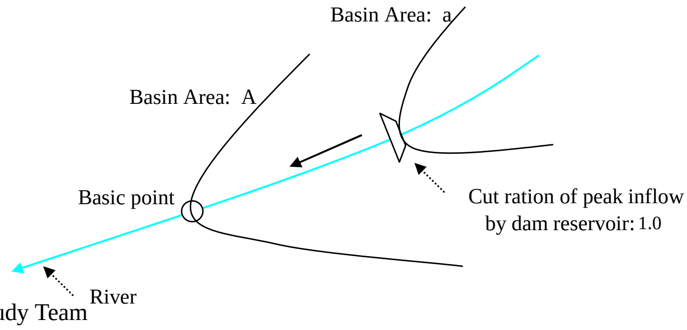
The reduction of peak discharge due to the dam reservoir for a 10-year probable flood is simply estimated at the basic point similar to the manner employed in the former section 4.2.4 (3) as follows.

1) Probable discharge Q1 (without dam): at 1GD03 in Nyando river and A1 trunk road in Nyamasaria river,

2) Probable discharge Q2 (with dam) at the above basic point: estimated by applying reduction ratio of peak discharge at dam site: r=1.0 and ratio of basin areas at basic point (A) and dam site (a).

3) The simple equation will be: Q2=Q1-Q1(a/A)r.

Figure 4.2.10 illustrates the locations of the basic point, dam site and basin areas.



Source: JICA Study Team

Figure 4.2.10 Explanation of Symbols in the Equation

According to this simple estimation, the reduction in the discharges at the respective basic points due to the dam reservoir would be as summarised in Table 4.2.7.

Table 4.2.7 Peak Discharge Reduction by Dam Reservoir

Item	Dam No.22 (upper Ainautua)	Dam No.11a (upper Nyando)	Dam No.51 (upper Nyamasaria)	Remarks
Probability scale (yr)	10	10	10	
Dam dimensions				
Basin area at dam site (a km^2)	142	729	115	
Dam height (m)	80*	100	97*	*1992 Study
Max. storage capacity (SV million m^3)	46.2	119.4	103.1	
Design Peak discharge at dam site (Qp m^3/s)	45	200	50	1992 Study refer to 4.2.4 (3)
Total Flood Volume (FV million m^3)	19.4	86.4	21.6	Qp*10days/2
Reduction ratio of peak inflow	1.0	1.0	1.0	FV/SV>1.0
Basin area at basic point (A km^2)	2,625	2,625	260	
Probable discharge at basic point without dam: (Q1 m^3/s)	730	730	70	Q1
Probable discharge at basic point with dam : (Q2 m^3/s)	700	530	39	Q2
Reduction (m^3/s)	30 (4 %)	200 (27%)	31 (44%)	Q1-Q2

Source: JICA Study Team

From the above preliminary review, it could be said that the three proposed dam reservoirs, dam No: 11a in the upper Nyando, dam No: 22 in the upper Ainamutua and dam No: 51 in the upper Nyamasaria are promising to reduce peaks of flood runoff by approximately 230 m^3/s in the whole Nyando river and by 39 m^3/s in the Nyamasaria river for a probable 10 yr flood, although this could differ depending on further study on locations and dam dimensions.

4.3 ASSESSMENT OF FLOOD DAMAGE

4.3.1 Major Floods in the Past

The climate in the Nyando river basin is controlled by the northward and southward movements of the Inter-tropical Convergence Zone (ITCZ). Above all, the climate from April to June is strongly influenced with the long duration rainfall brought by the southeast wind and south monsoon.

From such meteorological circumstance, the lower basin of the Nyando and Nyamasaria rivers has been suffering from serious flooding. According to the previous reports, major floods occurred in 1937, 1947, 1951, 1957-58, 1961, 1964, 1978, 1985 and 1988 in the period from the 1940s to the 1980s. In recent years, serious floods occurred in 1997-98, 2002, 2003 and 2004. Especially, the 1997-98 floods resulted from continuous rainfall that reached more than double the amount of a normal year. This was caused by the El Nino phenomena.

The types of floods causing damage in the lower basin are categorised into the three types; 1) flash floods in the Awach Kano and Nyamasaria rivers originating in Nandi and Mau Escarpments, 2) ordinary type in the Nyando main channel and 3) spot flooding or inundation by local torrential rain. However, the quantitative information such as depth, duration, evacuation conditions, emergency food and medical care extended, etc., is quite limited in the lower basin of Nyando and Nyamasaria Rivers.

4.3.2 Interview Survey on Flood Damage in Lower Nyando

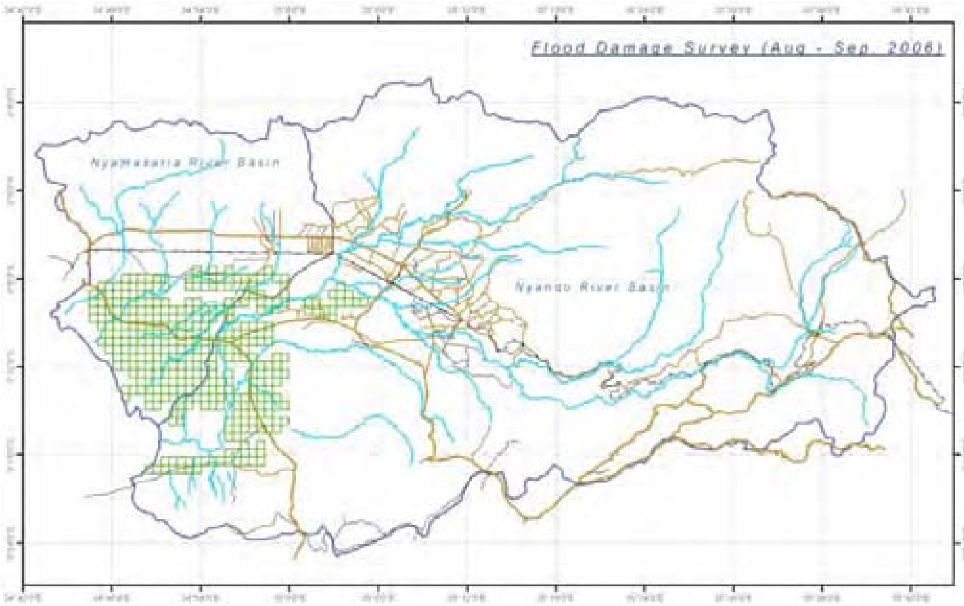
In order to supplement such quantitative information on flooding, a flood damage survey was conducted by the Study Team in August and September 2006.

The flood damage survey was made through an interview survey with questionnaires by employing assistant surveyors. The survey team was organised into six parties with 2 persons each and carried out the survey for about 3 weeks.

The sampling number totals to 350 spots which covered frequent inundation areas in the lower Nyando and Nyamasaria river basins. The following are major items in the questionnaire.

1) Inundation depth, duration, flow direction, etc., during the heaviest flood water level in the past and the annual average flood water level which occurs almost every year,
2) Availability of evacuation centres and resident behaviour,
3) Requests by residents for countermeasures, and
4) Others.

Figure 4.3.1 shows the survey area and interview spots by mesh in the lower Nyando and Nyamasaria river basins.



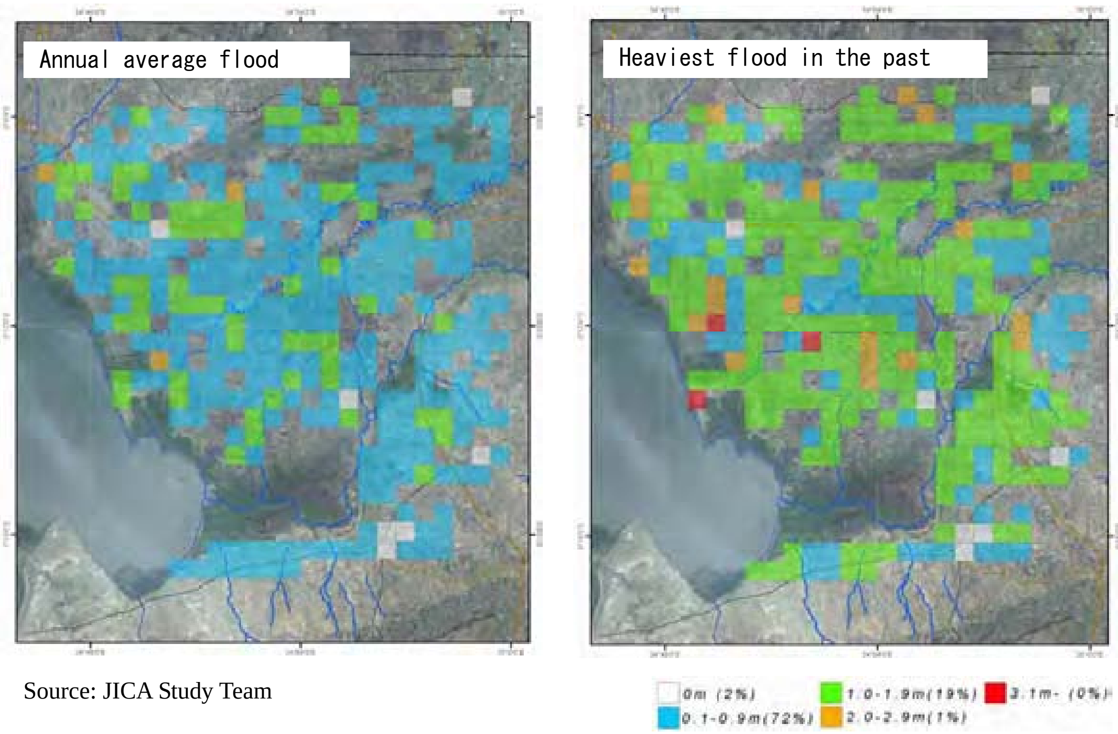
Source: JICA Study Team

Figure 4.3.1 Survey Area and Interview Sites in the Flood Damage Survey

4.3.3 Characteristics of Flooding and Evacuation Conditions

(1) Inundation Depths

Figure 4.3.2 presents inundation depths at 350 sampling spots for flood events of the annual average and the heaviest as obtained from the interview surveys.



Source: JICA Study Team

Figure 4.3.2 Inundation Depths by Mesh

The inundation depths in the survey area are summarised below.

1) Inundation depth ranges from 0.1 to more than 3 m,
2) Maximum inundation depth exceeding 3 m was observed at the three sampling spots in the lower basin of the Miriu River,
3) About 70% of the survey area was covered with inundation depths less than 1m (about 6%: no answer), and
4) About 20% of the survey area was covered with inundation depths more than 1 m.

(2) Flow Direction and Duration of Inundation/Flooding

Figures 4.3.3 and 4.3.4 show flow direction and duration of inundation periods on the average annual and the heaviest flood water levels obtained from the interview surveys. From the above figures, the following can be said.

1) Overflowing flood water exceeding channel flow capacity, especially in the Nyando, Luando, Oroba, Awach Kano and Nyaidho is subject to stagnation due to existence of the A1 trunk road,
2) A part of the overflowing flood water in the Nyando river influences the riparian areas of the Miriu and Ombeyi rivers by superimposing on the respective flood flows coming from the upper areas and local rainstorms therein,
3) From the above facts, duration of inundation in those areas continues over a long duration of more than a month, and
4) Velocity of river flow is fairly high in the rivers originating in the Nandi and Mau mountains areas (due to flash flooding).

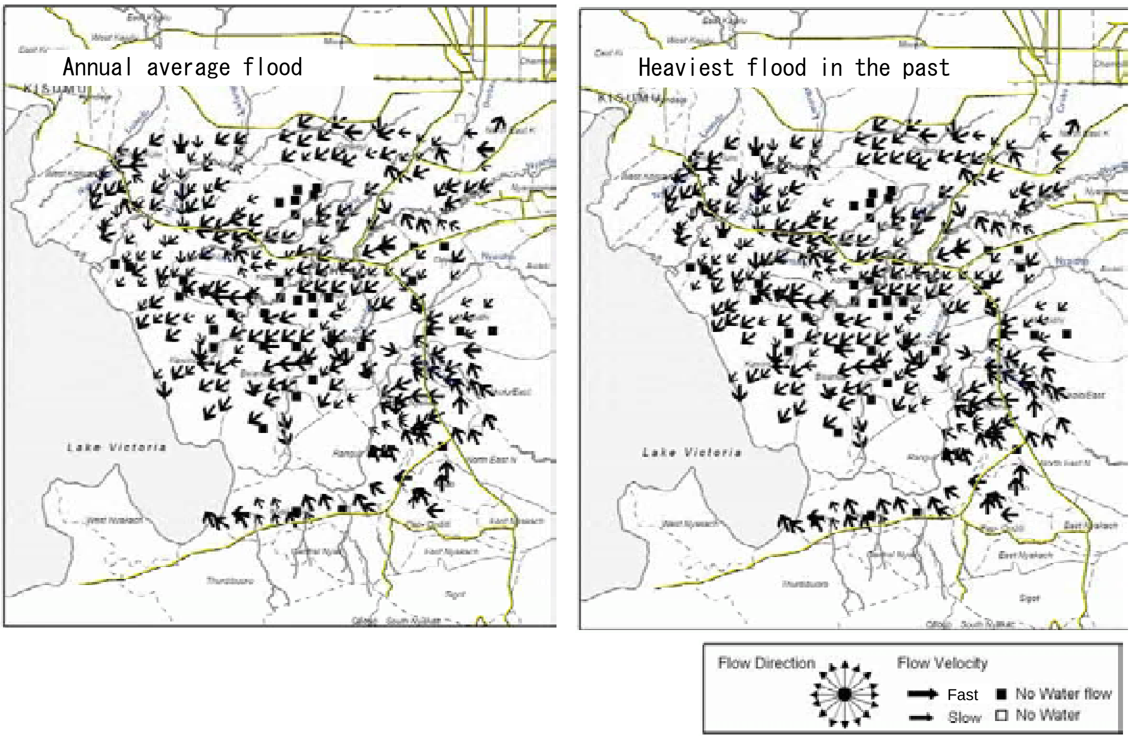
From such facts, it is supposed that the long period of stagnation results from a shortage of guide channels and culverts connecting to the existing main rivers besides the small rivers and ditches.

(3) Evacuation Ratio and Required Time to reach Evacuation Place

Figure 4.3.5 shows the evacuation ratio of the residents, the required time getting to the evacuation place and period that they stayed during the flood event of the heaviest water level. There exist around 135 evacuation centres in the lower Nyando and Nyamasaria rivers. From the above mentioned figures, the following can be said.

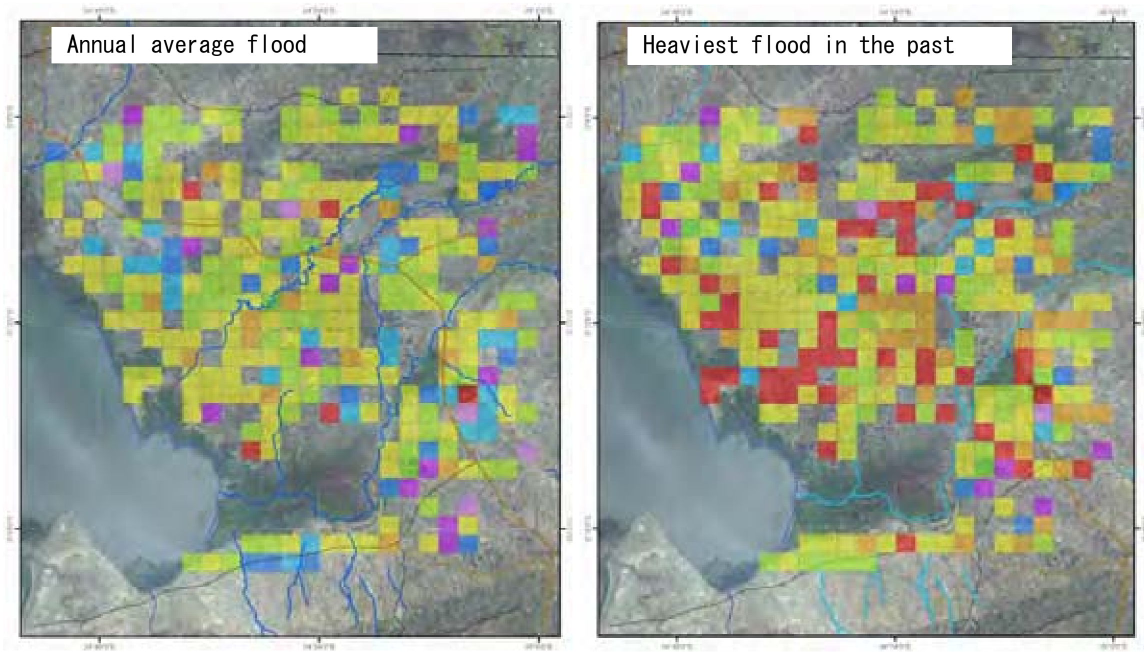
1) Evacuation ratio of the residents along the main river Nyando is remarkably high at 80 to 100%,
2) Maximum time getting to the evacuation place is more than 2 hours and average time is around 1hour,
3) High ratio is concentrated along the main river of the lower Nyando, and

4) Period of residence at the evacuation place is from a week to more than a month.



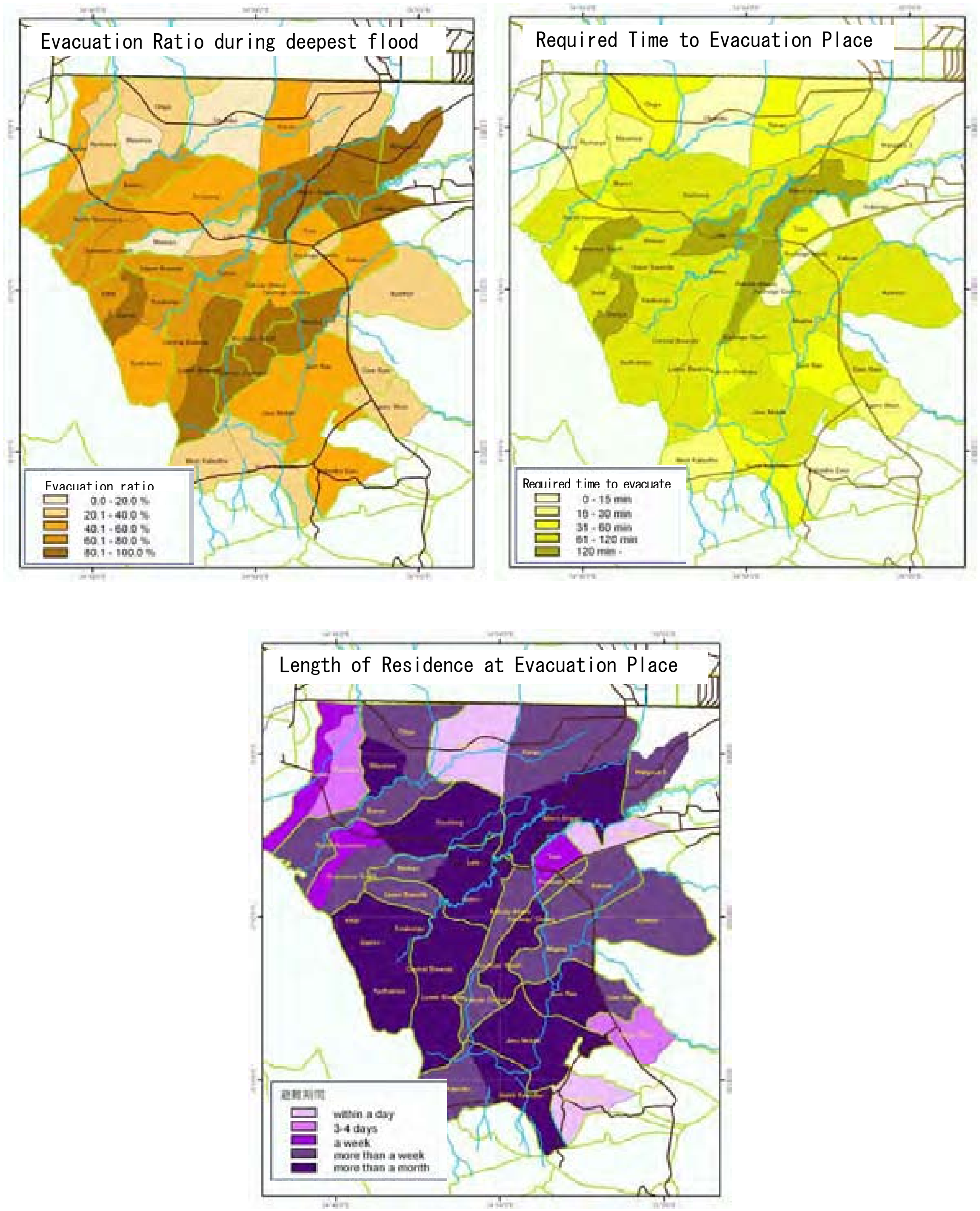
Source: JICA Study Team

Figure 4.3.3 Flow Direction of Heaviest and Annual Average Flood Events



Source: JICA Study Team

Figure 4.3.4 Duration of Inundation of Heaviest and Annual Average Flood Events



Source: JICA Study Team

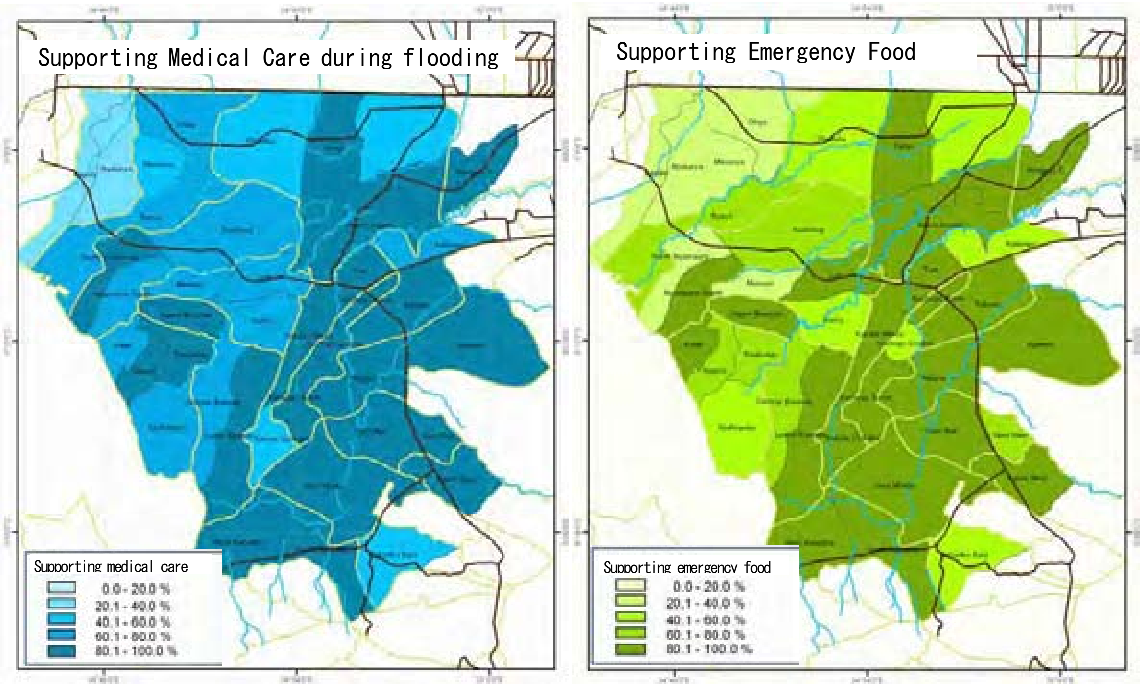
Figure 4.3.5 Evacuation Ratio, Required Travel Time and Residence Period in Evacuation

(4) Medical Care and Emergency Food during Flooding

Figure 4.3.6 shows the ratio of medical care and emergency food provided during flooding. For medical care and emergency food provided, the following can be said.

1) Rate of medical care provided during flooding is fairly high, especially in the riparian areas of the main Nyando river, and

2) Rate of emergency food provided is also fairly high at 80 to 100%, especially in the riparian areas of the main Nyando River.



Source: JICA Study Team

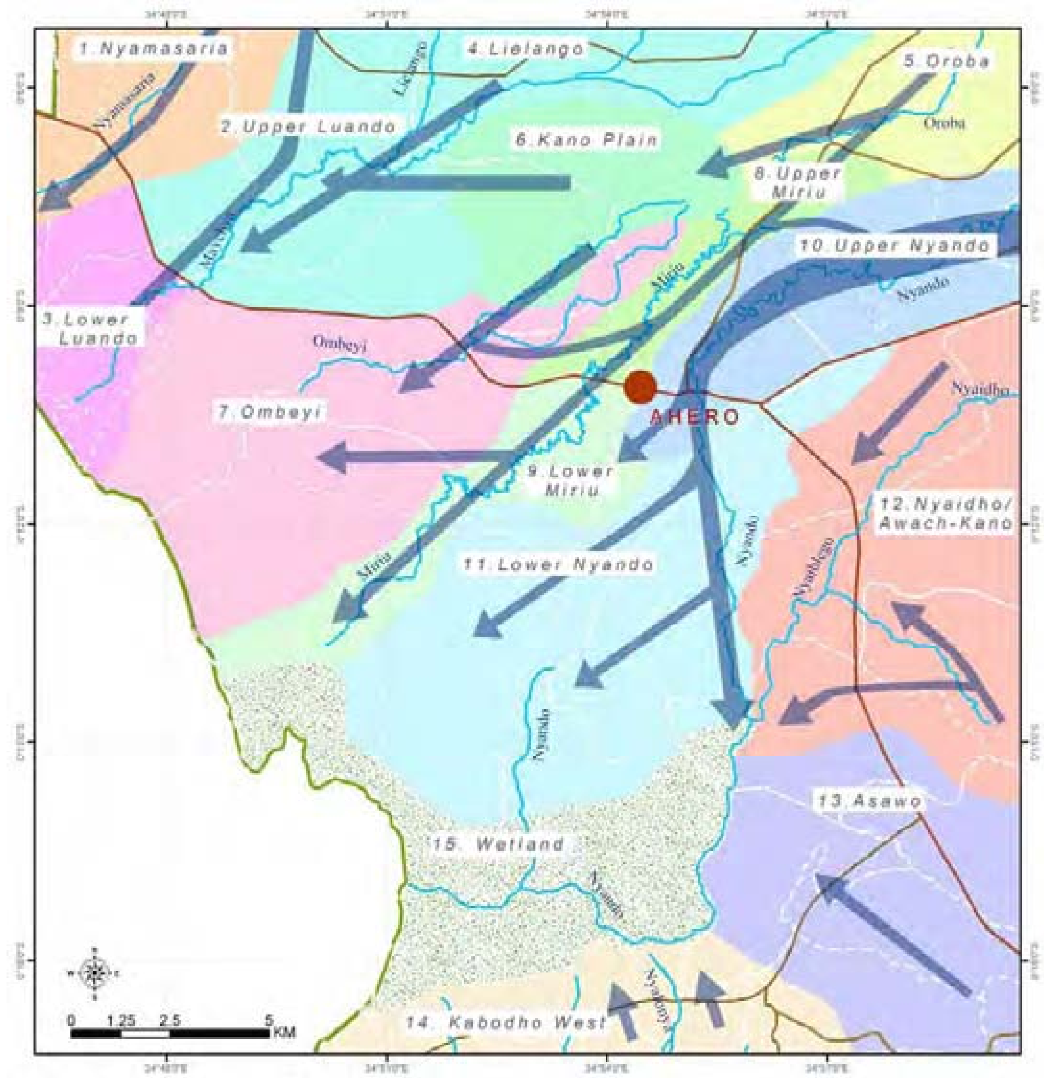
Figure 4.3.6 Medical Care and Emergency Food

4.3.4 Assessment of Flood Damage

(1) General Features of Floods in the Study Area

The lower basin of the Nyando and Nyamasaria rivers topographically extends over the low-lying areas along Lake Victoria. Rainfall amount and intensity during the rainy season, especially in the periods of April to May are heavy and high, respectively.

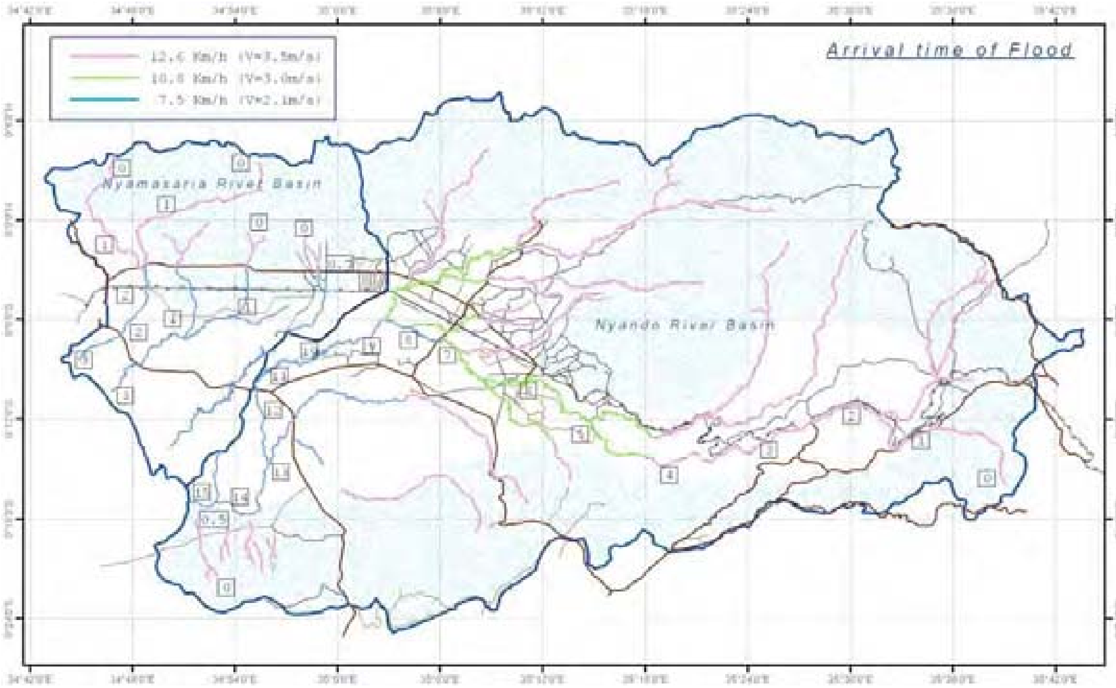
In the macro viewpoint, flood flow diagram as shown in Figure 4.3.7 was supposedly illustrated based on the flow direction data and results of interviews with residents. The figure shows that flood water exceeding channel capacity of the existing rivers is overflowing towards the low-lying areas.



Source: JICA Study Team

Figure 4.3.7 Macro Flow Direction in Lower Nyando River Basin

Figure 4.3.8 shows travel time of flood flows at various points estimated by assuming average velocity against riverbed gradient.



Source: JICA Study Team

Figure 4.3.8 Travel Time of Flood Flows at Various Points

From such information and data as in Figures 4.3.7 and 4.3.8, the general features of the meteo-hydrology in the basin can be summarised as below.

1) Large amount and intense rainfall,

2) Flood flow with high velocity,

3) Short travel time of flood flow after rainfalls,

   ・10 hours at Ahero in the Nyando main river,
   ・1 to 2 hours at A1 trunk road in the Awach Kano and Nyamasaria rivers,

4) Overflowing river water from the existing river channels especially Nyando, Oroba and Awach Kano,

5) Overflowing river water from Nyando and Oroba influences riparian areas of Miriu and Ombeyi rivers, and

6) Superimposition of local rainstorms and overflowing river water.

(2) Detail Features of Floods in the Respective Rivers

Followed by the above general overview, the following observations by the respective rivers are withdrawn from the hydrological viewpoint.

1) Nyando Main River

a) Short arrival time of flood flow at Ahero bridge (around 10 hours after rain falls),
b) Lack of prompt information on flooding (warning and evacuation),
c) Overflowing due to shortage of channel flow carrying capacity in the existing channels,
d) A part of the overflowing water influences the riparian areas of the Miriu and Ombeyi rivers by superimposing on the respective flood flow coming from upper areas and local rainstorms therein, and
e) On the upper side of A1 trunk road, overflowing water runs along the trunk road towards nearby Ombeyi river.

2) Awach Kano and Nyaidho Rivers

a) Flood type is categorised as flash floods,
b) Besides high velocity, there is a large amount of sediment flow,
c) Lack of prompt information on flooding (warning and evacuation),
d) Overflowing due to shortage of channel flow carrying capacity in the existing rivers mainly resulting from siltation,
e) Long stagnation due to shortage of drainage culvert capacity crossing under A1 trunk road, and
f) Submerged A1 trunk road around crossing point of Awach Kano river (over 3 km long),

3) Nyamasaria and Other Rivers

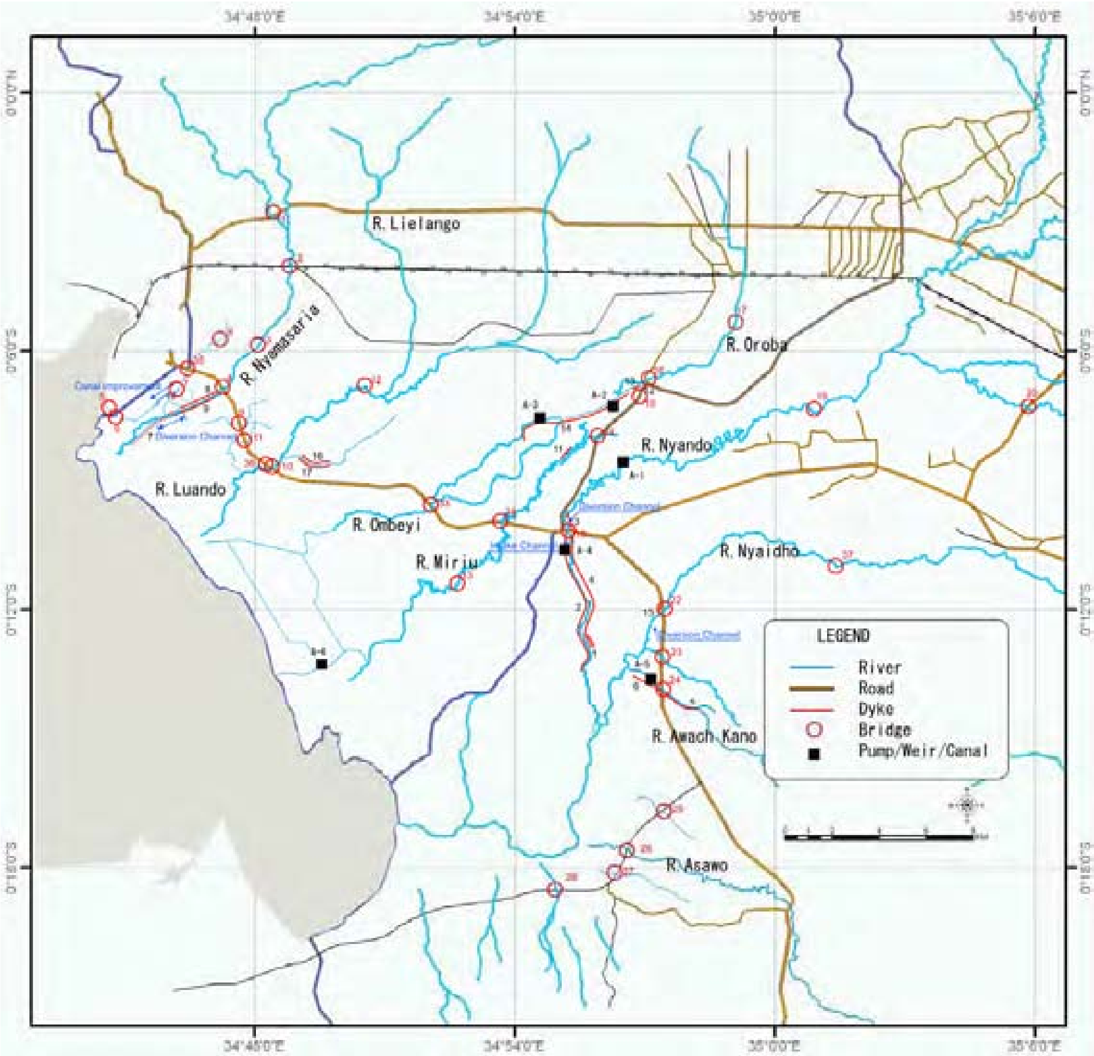
a) Flood type is also categorised as flash floods with high velocity,
b) Short arrival time of flood flow (around 1 to 2 hours at A1 trunk road point after rain falls),
c) Lack of prompt information on flooding (warning and evacuation),
d) Overflowing due to shortage of channel flow carrying capacity in rivers and ditches resulting from siltation,
e) Long stagnation due to shortage of drainage culvert capacity across A1 trunk road,
f) Overflowing from the Oroba River and Ombeyi swamp,
g) Lower area of the Ombeyi and Miriu rivers influences overflowing flood water coming from Nyando river and results in long stagnation, and
h) Submerged local roads from Ahero to Ombeyi and others are hindered as evacuation routes.

4.4 ASSESSMENT OF RIVER AND RELATED STRUCTURES

4.4.1 Inventory Study

Various water related structures such as flood dykes, intake weirs, pumping stations for water intake, bridges, etc., have been constructed in the lower catchment of the Nyando river basin. A survey was conducted by the Study Team to inventory river and related structures which exist in the Nyando and Nyamasaria rivers.

The inventory study was conducted through an interview survey by employing assistant surveyors. The survey team consisted of 3 parties with 2 persons each. The interview survey was carried out from 23 to 31 August 2006. Figure 4.4.1 presents locations of existing major rivers and related structures.



Source: JICA Study Team

Figure 4.4.1 Locations of Existing River and Related Structures in Lower Nyando River Basin

4.4.2 Existing River and Related Structures

(1) River Dykes

River dykes have been constructed in the lower catchment of the Nyando river basin for about 5 km on both banks and small-scale river dykes in the Awach Kano and Nyaidho. Features of such existing dykes are outlined in Table 4.4.1 and photographs of dykes in the lower reaches of Nyando river basin are shown in Figure 4.4.2.

Table 4.4.1 Existing Major Flood Dykes

River/Location	Construction Year	Dyke Dimensions		Remarks
		Dyke Length (m)	Dimensions of Dyke (m) (top width×height and shape)	
Nyando river				
Right bank: downstream of Ahero bridge	1984 to date	5,000	3 to 4.5×2 to 3.2, trapezoidal section with 1: 2 slope	Constructed by MWI. Dyke construction is ongoing as of August 2006
Left bank: downstream of Ahero bridge	1984 to date	6,000	3 to 4.5×2 to 3.2, trapezoidal section with 1: 2 slope	Constructed by MWI. Dyke construction is ongoing as of August 2006
Awach Kano river				
Left bank (up and downstream)	2004	5,000 in total	1.2 to 1.6 × 1.4, trapezoidal section with 1:1 slope	Constructed by CBO
Nyaidho river				
Right bank	2004	150	1×0.7, trapezoidal section with 1:1 slope	Constructed by MWI

Source: JICA Study Team

Source: JICA Study Team

Figure 4.4.2 Right Dyke (left picture) and Damaged Left Dyke due to Passage

In the lower end of the existing dyke on the right bank of Nyando River, the dyke construction is ongoing as of August 2006 by NWCPC under contract with MWI. The construction cost of ongoing works is around Ksh. 16 million. The budget for construction was financed by the constituency development fund (CDF).

On the other hand, small-scale river dykes (crest width: 1m, height: 1m) have been locally constructed at the respective sites in the Nyamasaria river basin. According to the inventory study, such dykes were constructed by CBO under finance from CDF. The Auji canal running along the Nyamasaria River was also recently improved with a trapezoidal section dyke for drainage improvement. This improvement work was carried out by MWI.

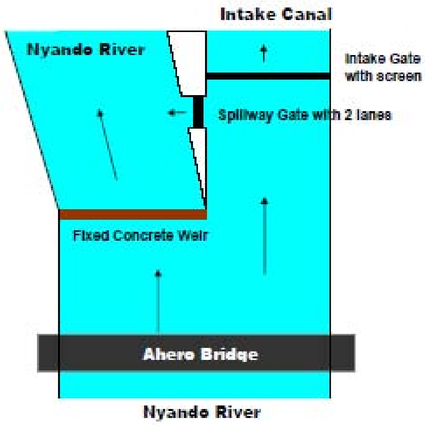
(2) Water Intake Structures

There exist two major irrigation schemes operated by NIB in the lower reaches of the Nyando river basin. One is the Kano Plain Ahero Pilot Rice Scheme and the other is West Kano Rice Irrigation Scheme.

The irrigation water at Ahero pilot scheme is taken by a pumping station installed at the riverbank of the Nyando River. As for the West Kano scheme, irrigation water is also taken by 2 pumping stations which were constructed near the shore of Lake Victoria. In the middle reaches of the Nyando river basin, there exist 3 pumping stations for the purpose of intake of water by private companies.

Aside from such large scale schemes, there are a number of rice fields and crop lands in the lower Nyando river basin which take irrigation water from neighbouring rivers or boreholes.

Among those, immediately downstream of Ahero bridge in the lower Nyando river basin, an intake weir which was built across the river channel exists for water intake to farmlands situated on the right bank of the Nyando River as illustrated in Figure 4.4.3.



Source: JICA Study Team

Figure 4.4.3 Intake Weir immediately downstream of Ahero Bridge in the Lower Nyando River

(3) Bridges

There are a number of bridges in the lower Nyando and independent rivers within the Kano Plain. In the centre of the subject areas, a trunk national road called A1 route is running from

Sondu to Kisumu to further northern regions of Kenya. Accordingly, there exist various bridges on the A1 route. The sub-structure type of large scale bridges is of abutments and piers; however others are of culvert type. The culvert type bridge is constructed mainly by using corrugated pipes. Among those, the Ahero Bridge across the Nyando River at Ahero town is a key infrastructure on the national trunk road of A1 route.

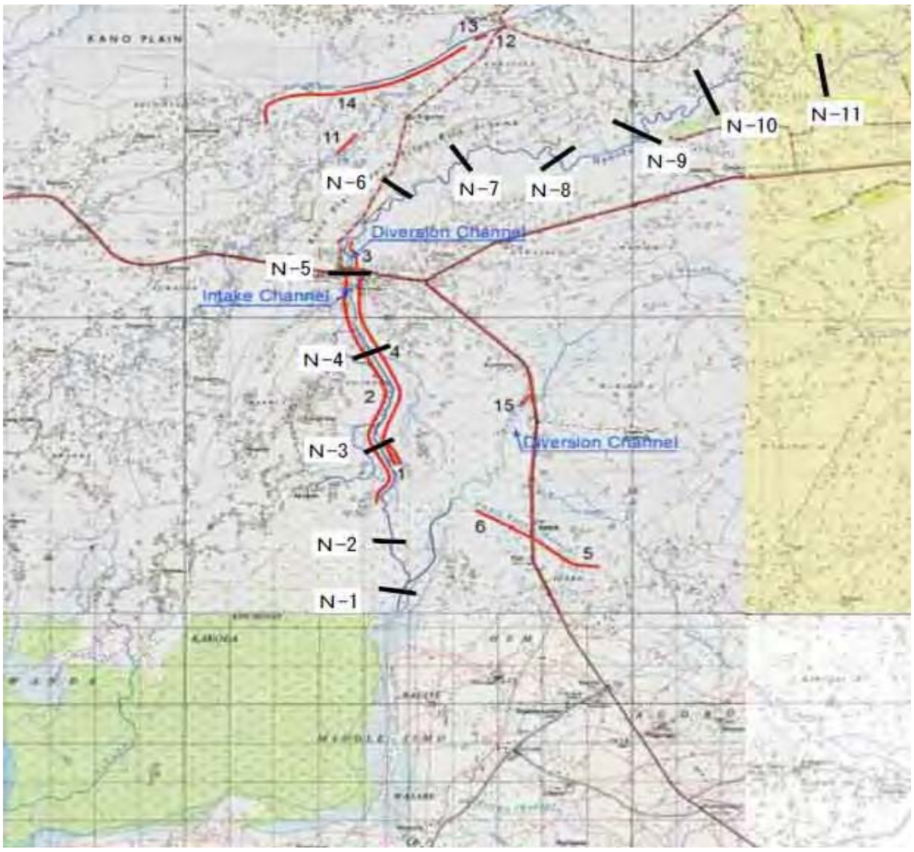
4.4.3 Carrying Capacity of Channel Flow in Lower Nyando River

(1) River Cross Section Survey

In order to determine the channel features and carrying capacity of channel flow, a river cross section survey was carried out by Photomap (Kenya) Limited, of which result can be utilised for planning use in the later stage,

Prior to the site survey, a surveying company was selected by lowest tender price among three candidate companies in Nairobi through local bidding procedures. The selected surveying company was Photomap (Kenya) Limited.

The cross section survey was thus conducted from 24 August to 8 September 2006. The locations of cross sections surveyed are presented in Figure 4.4.4.



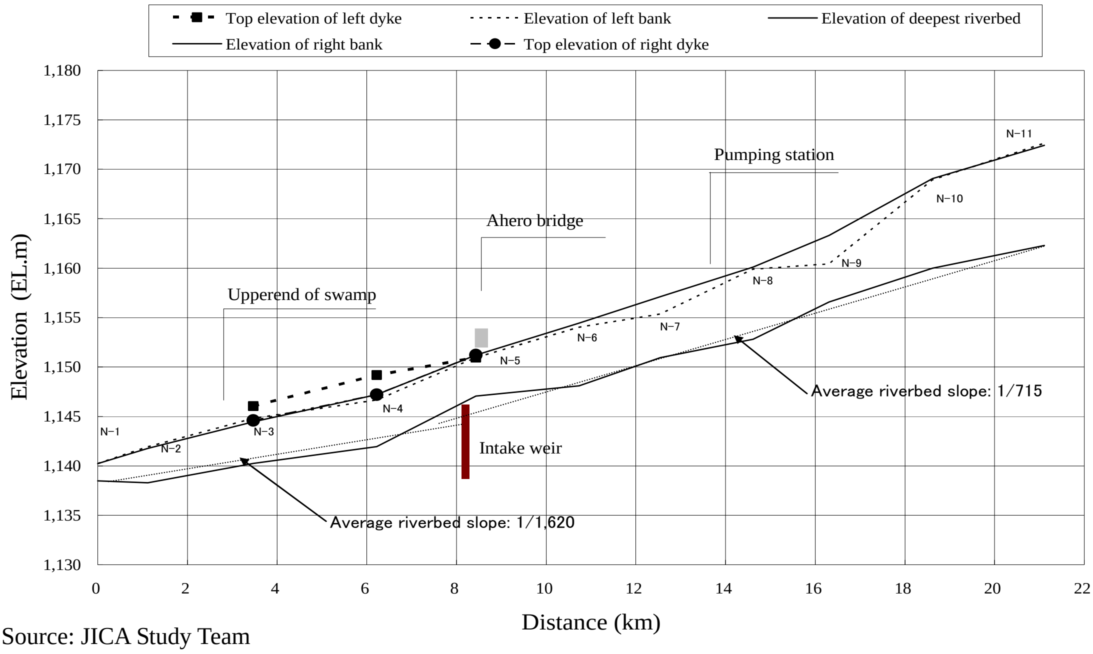
Source: JICA Study Team

Figure 4.4.4 Locations of Survey Cross Sections

The survey using a total station is outlined as follows.

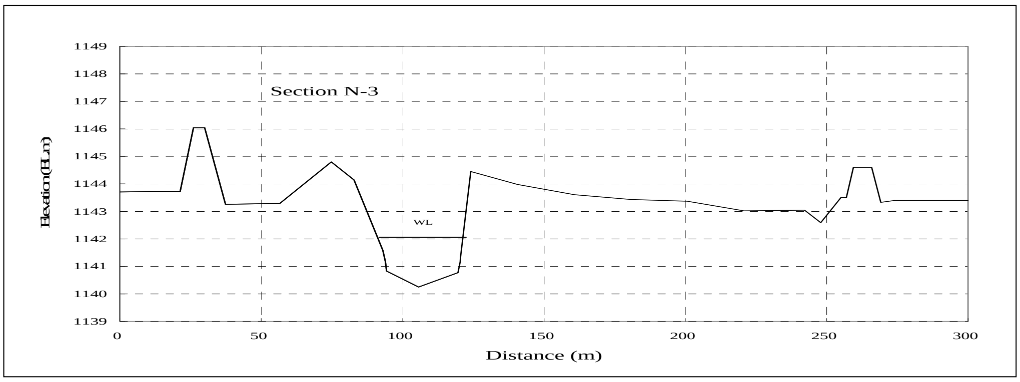
1) Stretch of cross section survey: about 21 km from the upper part of the swamp to upstream of Ahero Bridge
2) Base bench mark: bench mark installed at Chemilil railway station with elevation 1,227.798 m above mean sea level
3) Cross section interval: approximately 3 km
4) Width of cross section: about 250 m including river channel

Based on the cross sections surveyed, the longitudinal profile and channel cross sections were developed. The developed longitudinal profile is sketched in Figure 4.4.5 and representative cross section at N-3, in Figure 4.4.6.



Source: JICA Study Team

Figure 4.4.5 Longitudinal Profile of Existing Lower Nyando

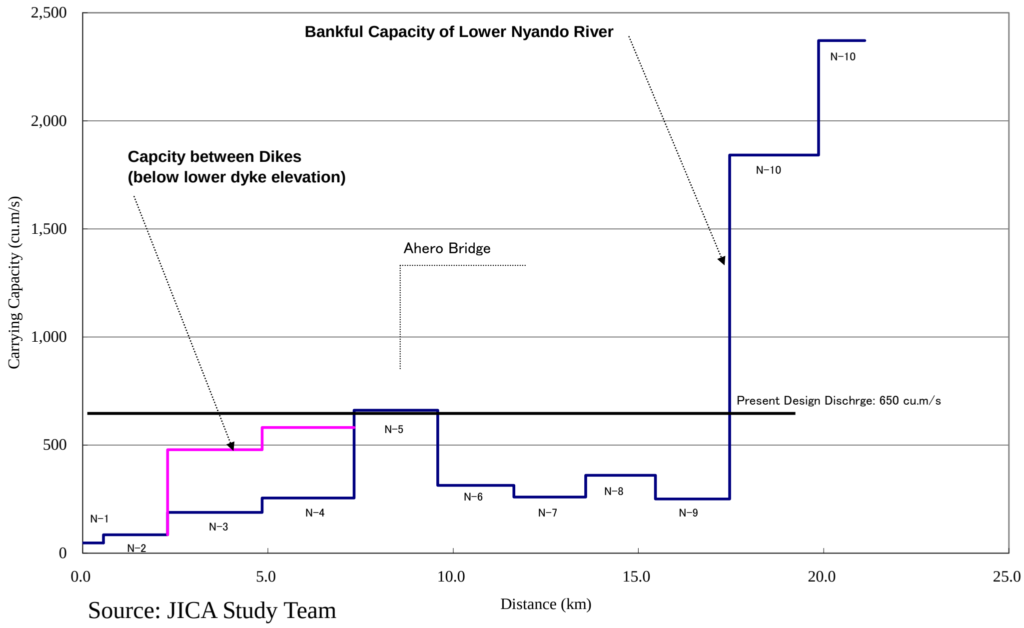


Source: JICA Study Team

Figure 4.4.6 Typical Cross Section of Nyando River at Section N-3

(2) Estimated Channel Flow Carrying Capacity in Lower Nyando River

Channel flow carrying capacities in the lower Nyando were estimated by a uniform flow method assuming a water surface gradient of 1/1,600 for the lower reaches from the intake weir downstream of Ahero Bridge and 1/700 for the upper reaches from the intake weir to the upper end and Manning's roughness coefficient of 0.03. Figure 4.4.7 illustrates the estimated full capacity ranges from 200 to 300 m^3/s. In the reaches improved by dyke construction downstream of Ahero Bridge, the capacity exceeds around 500 m^3/s; however this is still less than the 650 m^3/s of the current design discharge of the lower stretch of Nyando River.



Source: JICA Study Team

Figure 4.4.7 Channel Flow Carrying Capacity in Lower Nyando

(3) Estimated Channel Flow Carrying Capacity in Other Rivers

The channel flow carrying capacities in the lower reaches of small rivers are approximately estimated by the uniform flow method against the average dimensions of the cross sections measured at sites by the Study Team. The following Table 4.4.2 summarises the estimated capacities.

Table 4.4.2 Channel Flow Carrying Capacity in Other Rivers

River	Channel Dimensions			Average River Slope	Carrying Capacity (m^3/s)
	Top width (m)	Bottom width (m)	Depth (m)		
Awach Kano	20	15	2	1/1,600	40
Nyaidho	20	15	2	1/1,600	40
Nyamasaria	12	5	4	1/1,200	55
Luando	20	10	2	1/1,600	35
Ombeyi	20	7	1.5	1/1,600	20
Miriu	20	7	1.5	1/1,600	20

Source: JICA Study Team Note: Adopted Manning's roughness coefficient: 0.03

4.4.4 Assessment of River and Related Structures

Throughout the inventory study, flood damage survey, site reconnaissance and hydrological analysis made so far, it can be said that there exist some inappropriate or improper structural problems in addition to shortage of carrying capacity of channel flow in the respective rivers. In the following, the existing river and related structures are assessed judged from existing conditions and functions to be expected respectively.

(1) River Channel and Existing Dykes

A dyke is generally constructed using excavated earth. Therefore, earth dykes are subject to erosion and penetration by river water and can be easily damaged or destroyed. It is therefore important to consider that the earth dyke must be a tough structure with enough section or size and well compacted against flood water level and its duration. The following Figure 4.4.8 presents the existing condition of dykes and channels.

Dyke on Left Bank of Nyando

Dyke on Left Bank of Nyamasaria

River Channel of Lower Ombeyi

River Channel of Upper Miriu

Source: JICA Study Team

Figure 4.4.8 Present Condition of Dykes and Channels

In the lower basins of Nyando and Nyamasaria rivers, there exist major ditches running between the major rivers. Flow area of these ditches is quite small due to siltation. The problems involved and the countermeasures are summarised in Table 4.4.3.

Table 4.4.3 Problems of River Channels and Dykes and Countermeasures

River	Problem	Countermeasures
Nyando river	1.Dyke section (size) is not adequate and uneven 2.Extent of compaction is not adequate 3.Top elevation of dyke is uneven 4.Shortage of channel flow capacity	1.Construction of dykes 2.Heightening and strengthening of existing dykes 3.Construction of retarding pond along river upstream of Ahero bridge
Awach Kano and Nyaidho river	1.Dyke section is not adequate 2.Large amount of sediment flow 3.Siltation in channel 3.Shortage of flow area in culverts (except Nyaidho river) 4.Shortage of channel flow capacity	1.Desiltation 2.Construction of additional culverts and drainage channels along A1 trunk road
Nyamasaria rivers	1.Dyke section is not adequate 2.Siltation in channel 3.Shortage of culvert flow area at Miriu bridge 4.Shortage of channel flow capacity	1.Desiltation 2.Construction of additional culverts and drainage channels along A1 trunk road
Drainage ditches	1.Siltation	1.Desiltation

Source: JICA Study Team

(2) Bridges across Nyando and Nyamasaria Rivers

Figure 4.4.9 shows present conditions of culvert type bridges on the A1 trunk road in the Awach Kano and Miriu rivers. The flow area of bridge culverts is quite small even for the normal flow rates outside the rainy season from April to May.

Culvert under A1 Trunk Road (Awach Kano R.)

Culvert under A1 Trunk Road (Miriu R.)

Source: JICA Study Team

Figure 4.4.9 Present Condition of Culvert Type Bridges

Figure 4.4.10 shows the Nyamasaria Bridge over the Nyamasaria River on A1 trunk road. Downstream of the bridge, riverbed erosion is progressing. The length of the bridge apron seems to be too short to work as protection of the river bank and riverbed.

Downstream view

Upstream view

Source: JICA Study Team

Figure 4.4.10 Present Condition of Nyamasaria Bridge

In the same manner as above, the following bridges in Table 4.4.4 were assessed from the viewpoint of providing necessary area for the required flow carrying capacity and to maintain the transportation system in the region during flooding.

Table 4.4.4 Problems of Bridges and Countermeasures

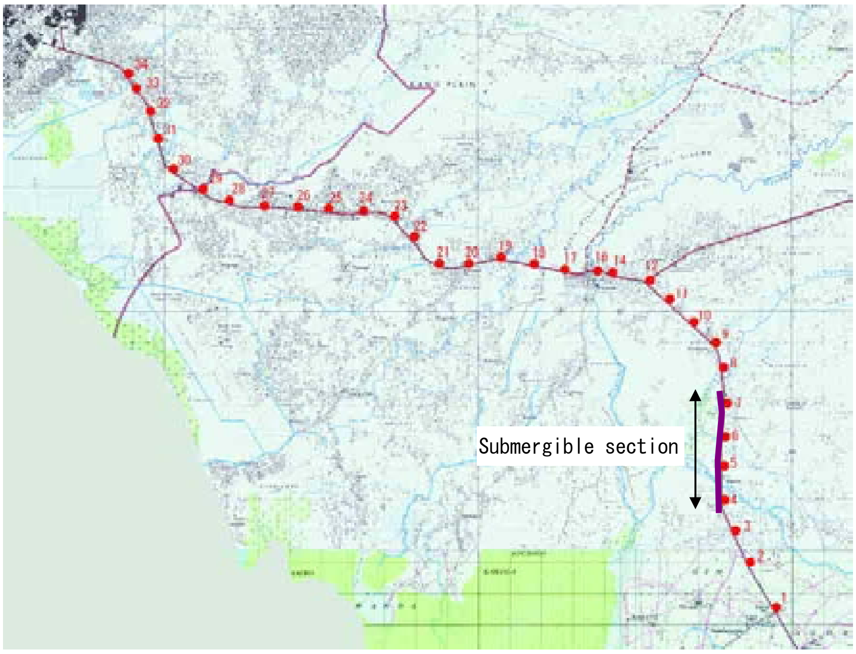
Location of Bridge	Problems	Countermeasures
Ahero bridge	1.Structural durability for the future	1.Reconstruction/strengtening
Awach Kano bridge 1 on A1 trunk road	1.Shortage of flow area in culvert 2.Shortage of number of culverts 3.Siltation 4.Trunk road: submerged frequently by flooding	1.Desiltation 2.Construction of additional culverts 3.Raising of road elevation
Awach Kano bridge 2 on A1 trunk road	1.Shortage of flow area in culvert 2.Shortage of number of culverts 3.Siltation 4.Trunk road: submerged frequently by flooding	1.Desiltation 2.Construction of additional culverts 3.Raising of road elevation
Nyamasaria bridge on A1 trunk road	1.Riverbed erosion (just downstream of bridge)	1.Protection of bridge apron 2.Raising of road elevation
Miriu bridge on A1 trunk road	1.Shortage of flow area 2.Siltation	1.Desiltation 2.Construction of additional culverts

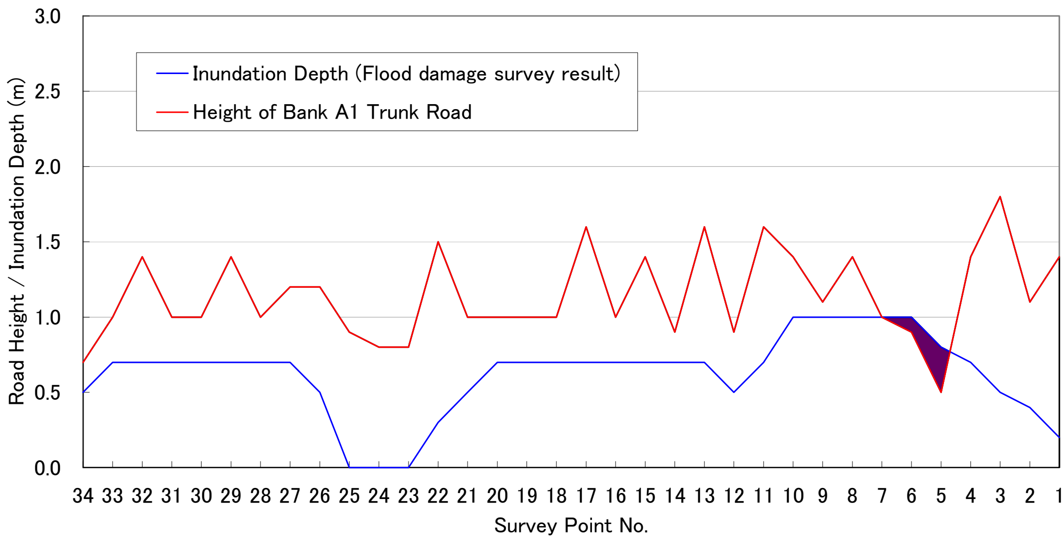
Source: JICA Study Team

(3) A1 Trunk Road

It is recognised that the top elevation of A1 trunk road around the crossing over the Awach Kano River is locally low compared with the flooding level or inundation depth throughout the surveys made so far. The flood water easily overtops the road surface and such situation results in frequent interruption of traffic during the rainy season. Figure 4.4.11 illustrates the longitudinal profile of A1 trunk road (direct road height) and inundation depth along the trunk road obtained from interview surveys.

Trunk Road submerged section





Source: JICA Study Team

Figure 4.4.11 Longitudinal Profile of A1 Trunk Road

Similarly, it is reported that the A1 trunk road around Nyamasaria Bridge was submerged in the 1998 flood. This matter will be overcome by means of de-siltation of the exiting channel around bridge site.

(4) Other Local Roads

According to the interview survey on flood damage and structures major local roads submerge frequently due to flood water in the rainy season. The main road in the inundation area is considerably important to maintain a safe evacuation route. From such viewpoint, it can be said that a fail safe concept is necessary in the severe inundation areas. The following Figure 4.4.12 shows one of the local roads that submerge in the rainy season.

Source: JICA Study Team

Figure 4.4.12 Condition of Local Road connecting Ombeyi and Chiga

4.4.5 Issues to be addressed in Structural Measures

It could be said that the lower areas of the Nyando and Nyamasaria rivers are at high risk of flooding. The main cause is insufficient and unsystematic structural measures addressing mitigation of damage which means resistance to flood. Secondarily, it is due to a social weakness in coping with flooding (lack of risk management and fail-safe concepts) from the viewpoint of preparedness that means resilience from damage.

From the viewpoint of the structural measures, the major issues to be addressed in the lower areas of Nyando and Nyamasaria river basins would be as follows;

(1) Nyando River

1) Shortage of channel flow carrying capacity,

2) Structural vulnerability of Ahero bridge for the coming several decades,

3) Lack of retarding ponds functioning as buffers against extraordinary flood events,

4) Lack of safe evacuation routes and places due to the lack of a fail safe concept in the existing infrastructure, especially local roads, and

5) Lack of systematic and periodic maintenance work.

(2) Awach Kano Basin

1) Shortage of channel flow carrying capacity in the respective lower reaches,

2) Lack of countermeasures against flash floods (against high velocity and large quantity of sediment flow),

3) Lack of drainage channels connecting the respective rivers along A1 trunk road so as to drain stagnant water extensively,

4) Shortage of flow area and number of drainage culverts across A1 trunk road,

5) Submerged A1 trunk road across the Awach Kano river, and

6) Lack of retarding ponds for buffers against extraordinary flood events, and

7) Lack of systematic and periodic maintenance work.

(3) Nyamasaria River Basin

1) Shortage of channel flow carrying capacity in the respective lower reaches including Oroba River,

2) Overflow from Ombeyi swamp,

3) Shortage of retarding ponds/basins in major rivers for buffers against extraordinary floods,

4) Lack of countermeasures against flash floods (against high velocity),

5) Lack of channel flow carrying capacity in major ditches,

6) Submerged local roads (especially Ahero to Ombeyi, along Ombeyi swamp and roads in the severe inundation areas to secure safe evacuation routes), and

7) Lack of systematic and periodic maintenance work.

4.5 ASSESSMENT OF EVACUATION CENTRES

4.5.1 Condition of Evacuation Centres

Approximately 150 facilities were listed as existing evacuation centres through the interview with chiefs, assistant chiefs and village elders in August 2006 as well as in the public hearings held in the flood prone areas in November 2006. All the facilities accessible by vehicle were visited by the study team members to confirm if they are really used as evacuation centres and to take GPS data. As a result, 136 facilities were identified as actual evacuation centres, and all 67 facilities that were listed in August, 33 in Kisumu District, and 34 in Nyando District, were interviewed about facility conditions and actual evacuation procedures.

Primary schools are most frequently used for evacuation centres and churches and markets are also used. Table 4.5.1 shows the distribution of facilities of each sub-location and each facility.

Of 67 facilities, 39 facilities are appointed as evacuation centres, mainly by Provincial Governments while 28 facilities are not appointed.

(1) Flood condition

The area where the facilities are used as evacuation centres is generally affected by flood water during the rainy season.

A total of 80% of 67 interviewed centres are situated in the villages where more than two thirds of the area is flooded. This condition is more often found in Nyando District, especially in Nyando Division where all centres are situated in villages where more than one third of the village area is flooded (Figure 4.5.1).

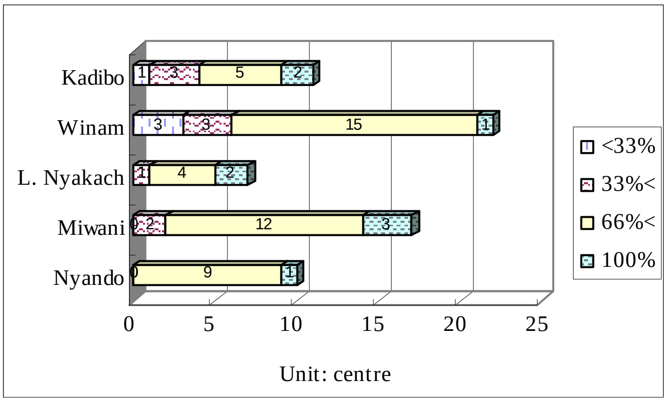


Figure 4.5.1 Degree of Flood Affects in the Area near the Centre

Source: Interview to Evacuation Centres, JICA Study Team 2006

Table 4.5.1 Facilities used as Evacuation Centres

Division	Location	Sub-location	Primary school	Church	Market	Medical institution	Administration office	secondary school	Others	Total
	Kisumu District									
Kadibo	Bwanda	Central Bwanda	1							1
	Bwanda	Upper Bwanda	2							2
	Kanyagwal	Anyuro	2							2
	Kanyagwal	Ogenya	1							1
	Katho	Kamayoga	1							1
	Katho	Kotieno	1		1					2
	Kawino North	Irrigation Scheme							1	1
	Kawino North	Kapiyo	1							1
	Kawino North	Kolal	2		1				1	4
	Kawino South	Kadibo	1							1
	Kawino South	Kwakungu	2	1						3
	Kawino South	n.d.		1	3					4
	Kawino South	Nduru	1							1
	Kochieng East	Kochieng	3							3
	Kochieng East	Okana	4							4
	Kochieng East	Rabuor (Kochieng)			1	1				2
	Kochieng West	Nyamware North	2							1
	Kochieng West	Nyamware	1					1		2
	Kombura	Lela	2	2	1			1		6
	Kombura	Masogo	3	1						4
	Kombura or Katho	Kamayoga	1							1
	Kombura or Katho	Kotieno	1							1
Winam	Central Kolwa	Kasule	3							3
	Central Kolwa	Kosule		1	1					2
	Central Kolwa	Mayenya	1							1
	Central Kolwa	n.d.		1						1
	Central Kolwa	Nyalunya	4							4
	East Kolwa	Buoye	5							5
	East Kolwa	Chiga	2							2
	East Kolwa	Mayenya	3		1					4
	West Kolwa	Nyalenda					1			1
	West Kolwa	Nyalenda A	1							1
	West Kolwa	Nyalenda B	1							1
	Nyando District									
Lower Nyakach	North Nyakach	Gem Rae	4	1						5
	Nyalunya	n.d.	2			1				3
	PapOnditi	n.d.	1		1					2
	Rangul	Jimo			1					1
	Rangul	Kasae/Wasare	1							1
	Rangul	n.d.	2							2
Miwani	North East Kano	Kabar West		1						1
	North East Kano	Wangaya 2	1							1
	Nyangoma	Kamswa South	3	1						4
	Nyangoma	n.d.	2	1	1					4
	Nyangoma	Wangaya 1	3	1						4
	Ombeyi	Irrigation Scheme	2				1			3
	Ombeyi	Kango	3	2						5
	Ombeyi	Kore		2					2	4
	Ombeyi	Obumba	2	1	1					4
	Ombeyi	Ramula		2						2
	Wawidhi	Ayweyo Luora	1							1
	Wawidhi	Red Cross			1					1
	Wawidhi	n.d.	1							1
Nyando	Awasi	Ayucha	1	1						2
	Awasi	Boder 1	1							1
	Kakola	Ahero				1				1
	Kakola	Kakola Ombaka	1							1
	Kakola	Ombaka	1							1
	Kakola	Tura					1			1
	Kochogo	Kochogo North	1							1
	Kochogo	Kochogo South	1							1
	Kochogo	n.d.	1	1						2
	Onjiko	Kakmie	1							1
n.d. (Nyando District)						1				1
		Total	89	21	14	3	3	2	4	136

Source: JICA Study Team, 2006

(2) Accessibility

Road conditions around the centres are difficult to assess. There is only foot access to 85 % of all centres in the rainy season. Only 6 centres in Winam Division are accessible by vehicle, while no centres are accessible by vehicle in divisions of Kadibo, Lower Nyakach and Miwani (Figure 4.5.2 on page 1). Many evacuation centres are at risk of inundation. Even though they are used as centres, more than 70% of them are partially (especially school grounds) flooded at the period of floods (Figure 4.5.3).

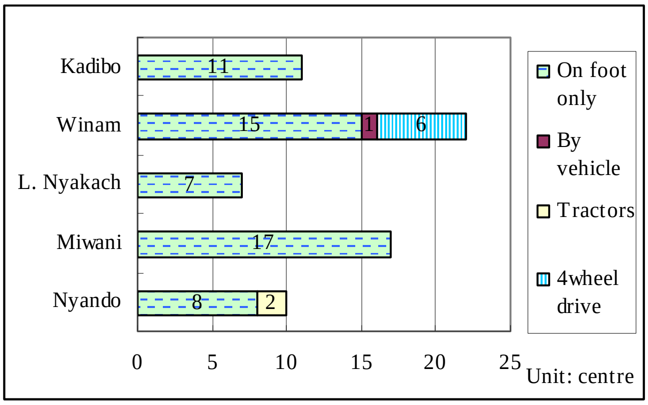


Figure 4.5.2 Accessibility in the Rainy Season

Source: Interview to Evacuation Centres, JICA Study Team 2006

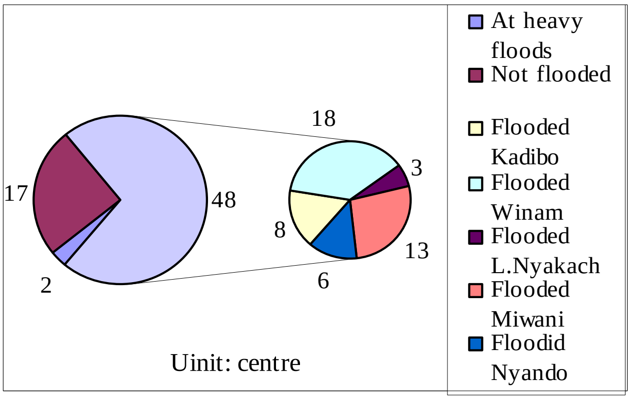


Figure 4.5.3 Inundation of Evacuation Centres

Source: Interview to Evacuation Centres, JICA Study Team 2006

(3) Space for refugees

Generally refugees from flood disasters stay in the classrooms in primary schools or on the floor of markets during their evacuation. Sufficiency of space depends on the scale of centres and the number of refugees, but the staff of 51 of the centres said the space is not adequate for evacuation use. It was also said that the existence of refugees and use of spaces interferes with the normal function of the facilities such as education programmes.

(4) Water

The most common water sources of the interviewed evacuation centres were boreholes in the centre or nearby. Piped water is not so common, while rain water caught by roof troughs and reserved in tanks is found in all five divisions in the flood prone areas and it

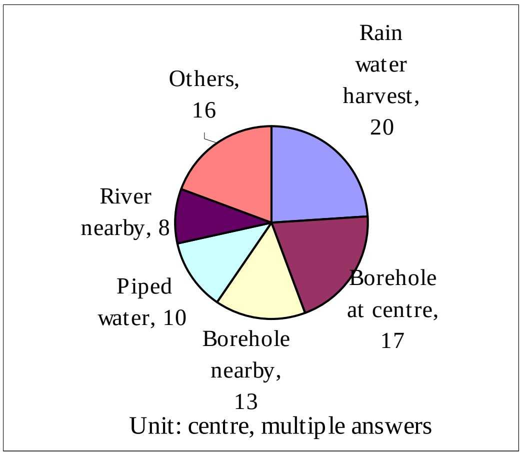


Figure 4.5.4 Water Sources for Evacuation Centres

Note: Multiple answers
Source: Interview of Evacuation Centres, JICA Study Team 2006

seems to be regarded as a supplementary water source in the entire flood prone area (Figure 4.5.4). Temporary ponds or water pans made by rain or flood water is also used in some centres.

Though the centres are situated in rather water-rich areas compared with other regions of Kenya, the volume of water of these sources is not sufficient in 47 centres. As for the quality of water, water is reported being good by the staff of 22 centres while it is reported being bad by staff of 17 centres.

(5) Toilets

Six evacuation centres situated in every division except Kadibo do not have toilets and 19 centres situated in each of five divisions have three or less toilets. As mentioned below, the insufficient number of toilets is one of the most serious problems which their staff and users suffer from. Most of these facilities are normally used as primary schools, so it influences not only the evacuees' condition but also education circumstances (Figure 4.5.5).

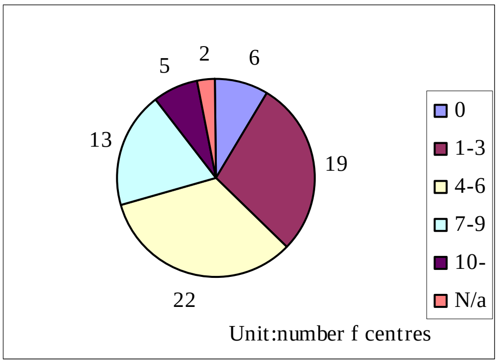


Figure 4.5.5 Number of Toilets

Source: Interview to Evacuation Centres, JICA Study Team 2006

Staff of 64 centres said that the current condition of toilets from the viewpoints of number and sanitary condition was neither sufficient nor appropriate.

(6) Disease

Insufficiency of space, water and toilets causes bad sanitary and health conditions in the centres. During the evacuation, outbreak of disease is not rare, though the statistical data is not recorded. According to the staff of the centres, the most frequent disease that attacks refugees is malaria; the diseases of digestive organs such as diarrhoea and cholera or typhoid come second; and the third are other diseases (Figure 4.5.6).

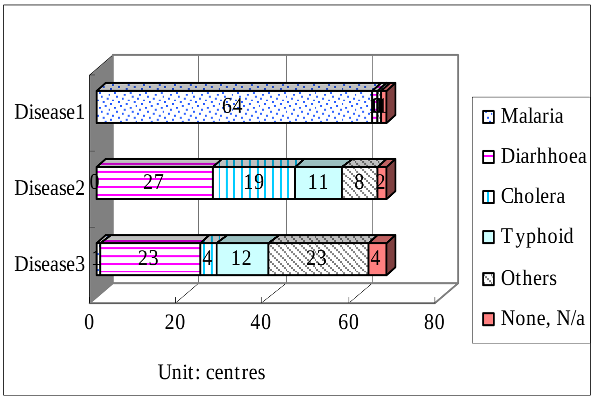


Figure 4.5.6 Diseases Frequently Occurring in the Evacuation Centres

Note: Source: Interview to Evacuation Centres, JICA Study Team 2006

After the refugees return to their home village, only eleven centres disinfect the rooms and facilities used by them. This is partly because of the lack or difficulty in getting disinfectant.

4.5.2 Characteristics of Evacuations

(1) Length of Stay

The length of a refugee's stay in an evacuation centre is 22 days on average with a 14 day median. In two evacuation centres in Lower Nyakach, people stayed for six months supposedly for waiting for the reconstruction or repair of their houses (Figure 4.5.7).

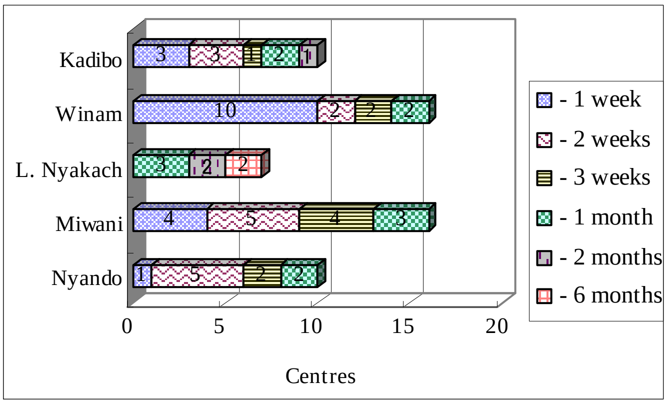


Figure 4.5.7 Length of Stay of Refugees

Note: Source: Interview to Evacuation Centres, JICA Study Team 2006

(2) Number of refugees

More than 70 families on average with a 30 family median come to a centre to stay. Eight centres hosted more than 100 families each. As a family is composed of four to five members on average, a median of more than 150 persons are estimated to stay in a centre. If considering the space of a standard primary school, this number is much too large and it is supposed to cause physical, health and psychological damages to both facilities and refugees (Figure 4.5.8).

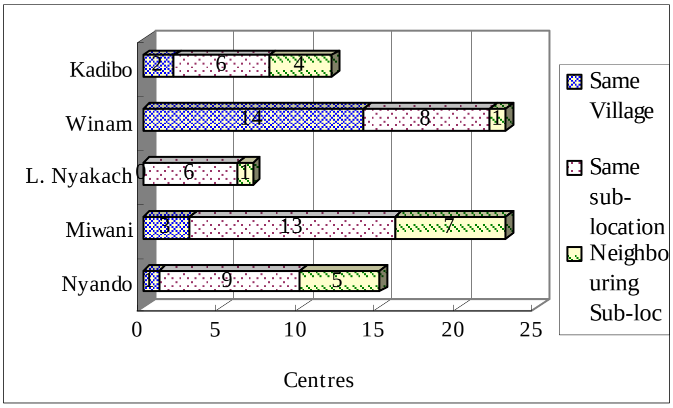


Figure 4.5.8 Number of Refugees

Note: Source: Interview to Evacuation Centres, JICA Study Team 2006

(3) Home village of refugees

Refugees coming to an evacuation centre live in the same sub-location and from the same village especially in case of Winam Division. Some people evacuate from neighbouring sub-locations, but not many people come from distant sub-locations. This means that they do not evacuate to distant areas in emergencies when the roads are bad. However, if the facilities nearby are

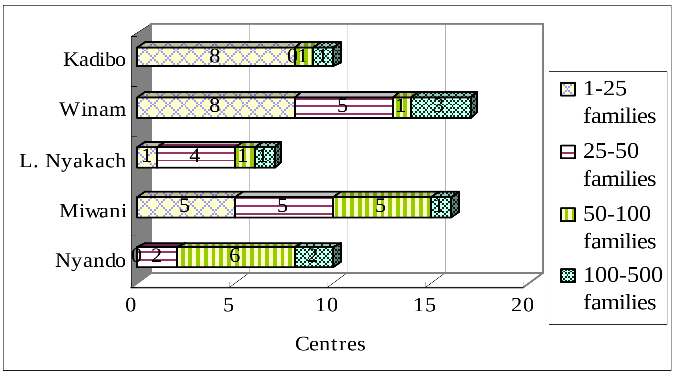


Figure 4.5.9 Home Village of Refugees

Note: Multiple answers
Source: Interview to Evacuation Centres, JICA Study Team 2006

scarce, they are forced to go to distant areas; this case is more frequent in Nyando District than in Kisumu District (Figure 4.5.9).

(4) Difference in characteristics of evacuations among divisions

In terms of period of stay and number of refugees, centres of Winam Division and those of Lower Nyakach Division show different aspects: shortest length of stay both on average and median and most people come from the same village in Winam Division; longest stay both on average and median and most people come from the same sub-location (not so much from neighbouring sub-locations and none from the same village) in Lower Nyakach Division.

It is supposed that the density in an evacuation centre is relatively high considering the flooded area in Winam Division and that the flooding period is no longer there than in other divisions.

4.5.3 Support of Refugees

(1) Assistance to refugees

The first role of the staff of the facilities used as evacuation centres is to inform the sub-location office or the disaster management committee of the appearance of refugees and their number and to demand their assistance. During the evacuation period, they give hospitality to refugees (19 centres) and counselling (17 centres) and health education (10 centres).

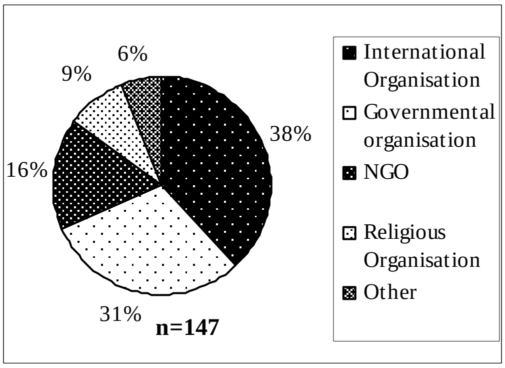


Figure 4.5.10 Supporting Organisations

Note: Multiple answers
Source: Interview to Evacuation Centres, JICA Study Team 2006

All evacuation centres except three (a primary school, a market, and a secondary school) receive assistance from supporting organisations and more than 50 centres are assisted by more than two organisations. As Figure 4.5.10 shows, mainly international organisations, governmental organisations, NGOs and religious organisations give assistance to refugees. The most important organisation is the Red Cross that supports 57 centres and this is followed by the District Headquarters that support 31 centres. World Vision is the NGO that gives assistance to the most centres.

(2) Prior stock for the flood period

It is noted that there are only three evacuation centres that store stocks for evacuation prior to the flood time; one of them is the Chief’s office of West Kolwa Location and the other two are primary schools in divisions of Kadibo and Winam.

4.5.4 Assessment of the Current State of Evacuation Centres

(1) Problems of the centres

Table 4.5.2 Important Problems of Evacuation Centres

Main problem 1	Number of Centres	Main problem 2	Number of Centres
Toilets	22	Water supply	21
Water supply	14	Toilets	19
Sanitary conditions	5	Space	4
Building of centre	4	Disease	3
Poor facilities	4	Others	15
Medical facilities	3	N/a	5
Others	15		

Source: JICA Study Team, 2006

The most serious problems that the centres face are insufficiency of toilets and water supply. Other problems such as space or quality of facilities are also claimed but they are not common problems. Table 4.5.2 shows the important problems reported by staff of the evacuation centres.

(2) Needs

Apart from the actual problems, several needs of the centres were reported by their staff. The first one is construction or extension of a building that can be used exclusively for evacuation so that the school or market can continue their normal functions. The second one is improvement of actual facilities such as classrooms, roofs or land elevation. Improvement of water supply and of health and sanitation condition/facilities come equal third, and construction of toilets are of fifth importance.

Materials and training for flood preparedness and skill of refugee management are not strongly considered to be necessary though a small number of centres mentioned.

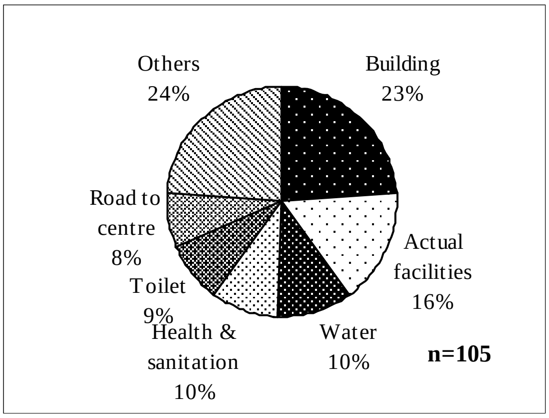


Figure 4.5.11 Needs of Evacuation Centres

Note: Multiple answers
Source: Interview to Evacuation Centres, JICA Study Team 2006

However, it must be noted that these needs posed by facilities used as evacuation centres are not only for better evacuation centres but also for better condition of their normal functions, especially school. Nevertheless, it can be summarised based on the results of the interviews that improvement of toilet and water conditions are urgently required issues for the existing evacuation centres.

4.6 FLOOD DISASTER MAPS

4.6.1 Necessity of Flood Disaster Map

The lower areas of the Nyando and Nyamasaria rivers are at high risk of flooding. The main cause is insufficient and unsystematic structural measures. However, the structural measures are not an all inclusive solution to the flooding problems; accordingly, the intended effects of the structural measures have limitations to mitigate flood damage. Secondarily, it is due to a social weakness in coping with flooding from the viewpoint of preparedness that could produce resilience from damage. In this sense, there is a necessity to have flood disaster map, which has been missed in the basin, designated to strengthen the social mitigation capacity (preparedness to flood hazard and resilience from damage) against flooding.

Various characteristics of the heaviest flood water level and average annual flood level which occurs almost every year were obtained from the interview survey results. By referring to such data, a flood disaster map showing the heaviest and annual average inundation areas jointly with information of inundation depth, major infrastructures including schools, hospitals, churches, evacuation centres, etc., has been produced. This disaster map will be a helpful tool to understand the extent of flood damage hazards and to keep up with succeeding actions of evacuation and relief activities. It will also be used for preparation of community flood hazard maps with more detailed information in a coming stage of this Study.

4.6.2 Data for Preparation of Flood Disaster Maps

(1) Data obtained from the Flood Damage Survey

The hydrological characteristics and information of inundation depth, duration, flow direction, etc., were clarified for flood events for the heaviest flood water levels in the past and for the flood event which occurs almost every year studied so far. Such data will be basic for preparation of detailed flood disaster maps.

(2) Data on Previous Inundation Maps

The following data was used as reference for preparation of the flood disaster map.

a) Inundation maps prepared in the 1983 Pre-investment Study for Water Management and Development and the 1992 Feasibility Study on Kano Plain Irrigation Project (refer to following Figure 4.6.1),
b) Inundation map prepared in the 1990 Study on the National Water Master Plan (following Figure 4.6.2), and
c) Inundation areas by means of MODIS Satellite Images photographed in 2003 and April 2004, Dartmouth Flood Observatory (ref. in the following Figure 4.6.2).

The following Figures 4.6.1 and 4.6.2 show illustrations of inundation areas which were prepared in the previous studies.

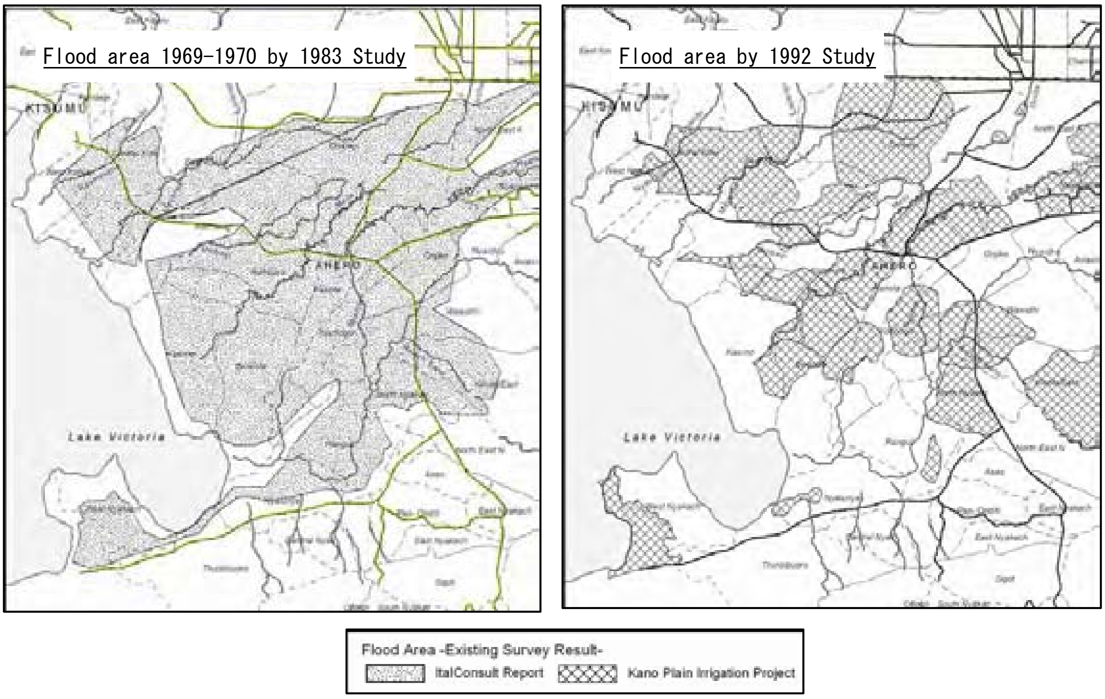


Figure 4.6.1 Inundation Maps prepared in the 1983 and 1992 Studies

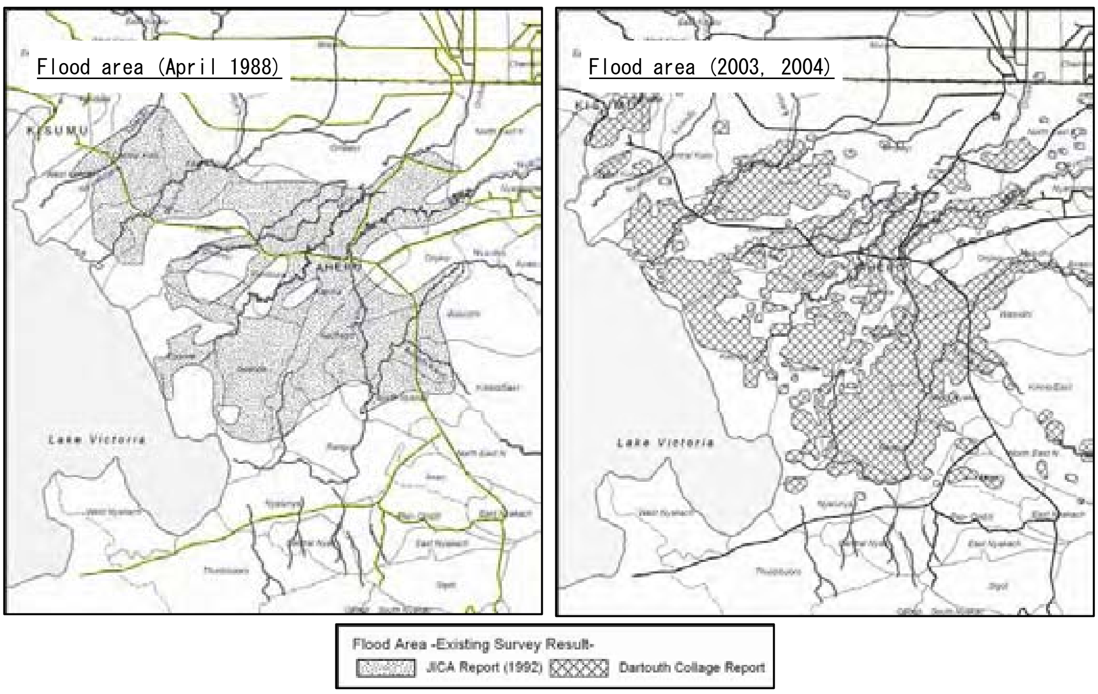


Figure 4.6.2 Inundation Maps prepared in 1992 Study and by means of MODIS Satellite Images

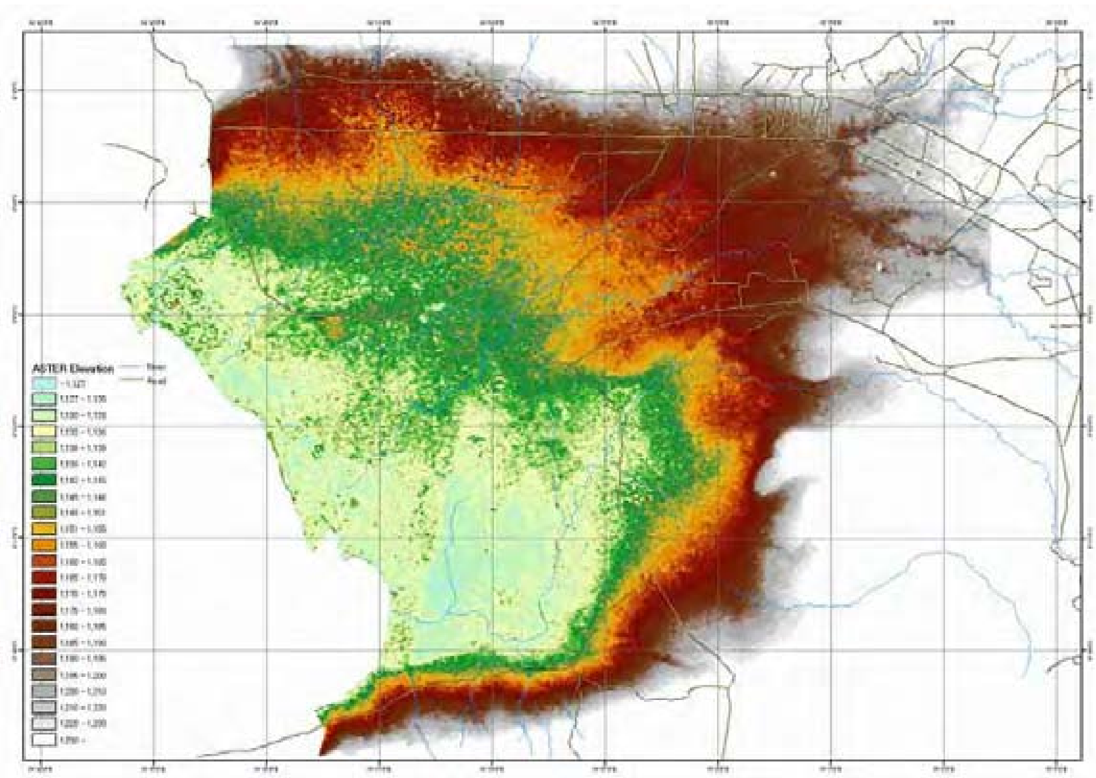
(3) Preparation of a Basic Topographic Map with Spot Elevations

The contour lines in the lower Nyando river basin indicated on existing available topographic maps (Map scale: 1/50,000. published for the Kenya Government by the French National Geographic Institute, 1997) are at 20 m intervals. Therefore, it is unfortunately impossible to read spot elevations.

Spot elevations were needed for preparation of the said map which shows inundation depths ranging from 0.5 to around 1.5 m.

To address this constraint the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) satellite image was employed to read spot elevations (average spot elevations in a 15 m square area).

Figure 4.6.3 shows the topographic map close spot elevations.



Source: ASTER satellite image in 2003 and 2004

Figure 4.6.3 Topographic Map

4.6.3 Flood Disaster Map

The flood disaster map for the lower Nyando River was thus prepared by using various data from the flood damage survey, previous studies and reports from the sites. The original map has been presented and subsequently discussed fully with participants in the public hearings held in three places, Rabuor, Ahero and Ombeyi in the subject area. The public hearings with participants in the respective divisions are outlined in Table 4.6.1 and Figure 4.6.4 shows pictures taken at the public hearings.

Table 4.6.1 Outline of Public Hearings

Date	Place	Target Division	No. of Participants
Nov. 7 (Tue) 9:00-11:00	Rabour	Winam, Kadonbo	100
Nov.08 (Wed) 9:00-11:00	Ahero	Nyando, lower Nyakach	100
Nov.09 (Thu) 9:00-11:00	Ombeyi	Miwani	50

Source: JICA Study Team

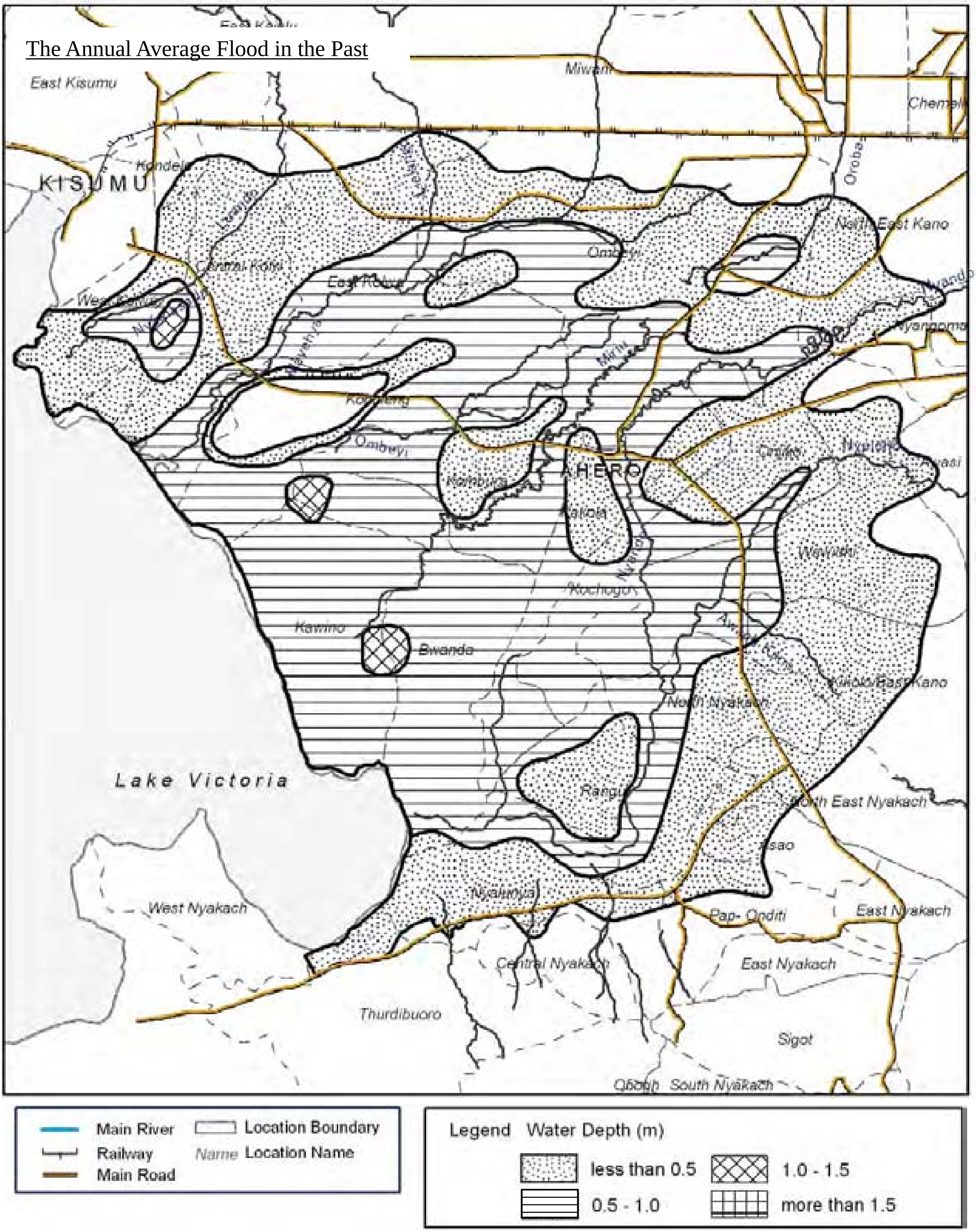
Source: JICA Study Team

Figure 4.6.4 Public Hearing at Rabour (November.07, 2006)

In the hearings, various valuable suggestions and opinions were raised and among those are the following.

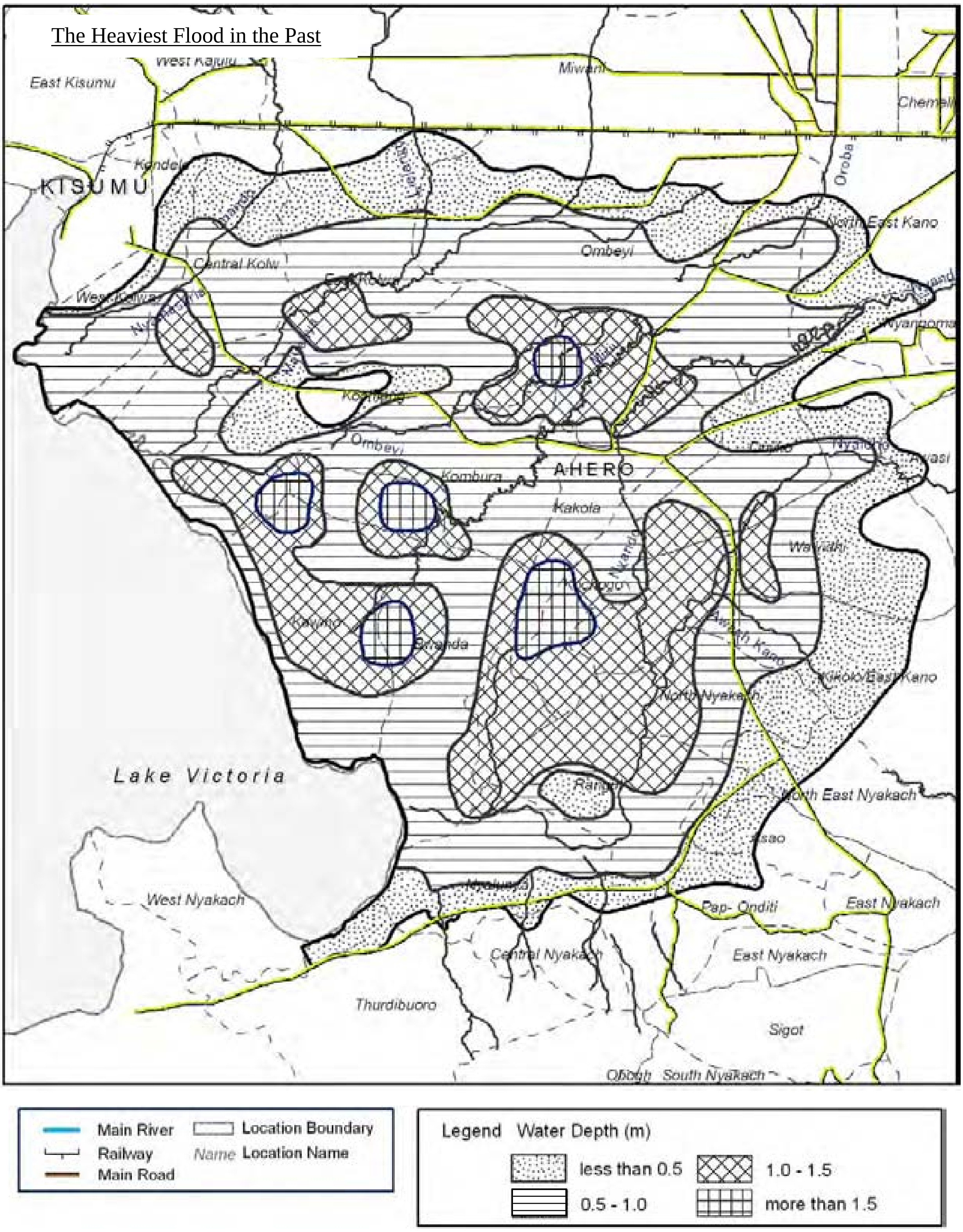
1) Naming of local ditches,
2) Clarification of boundaries (location and sub location),
3) Local flow direction,
4) Brief history of floods in the past,
5) Lack of drainage channels (as request), and
6) Others.

With due consideration of the suggestions and comments, the flood disaster map was considered as a draft. Also such comments were reflected again in the preparation of the detailed community hazard maps. The result is presented in Figure 4.6.5.



Source: JICA Study Team

Figure 4.6.5 Flood Disaster Map (1/2)



Source: JICA Study Team

Figure 4.6.5 Flood Disaster Map (2/2)