H. METEOROLOGY AND HYDROLOGY

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H.1 Meteorology

The study area is ASAL area with marked lowland, floor of Rift Valley. There are two peaks of rainfall in a year, April and August. The high rainfall occurs from the end of March to August, and it accounts about 70% of annual rainfall. August is highest rainfall month in a year, and then Marigat has 80-90 mm/month rainfall. The lowest rainfall occurs between December and February, and January is the driest month and it has about 30mm/month rainfall in Marigat.

The average rainfall in the study area is 900-600 mm/year. A rainfall in the western and eastern parts of the study area, Kimalel and Arabal Location, are the highest rainfall area and have about 800-900 mm/year rainfall, and their sea levels are EL. 1,300-1500m. The northern part of the Baringo Lake is about 600 mm/year rainfall, and other area is about 700 mm/year rainfall. The mean annual rainfall in the study area is estimated as 650mm/year. There are not so much changes in mean annual and monthly rainfall in long-term average. The highest and lowest rainfall peaks can be seen every 10-15 years cycle, and small peak of them occurs 3-4 years cycle.

The evaporation in the study area fluctuates from 1,800 to over 2,200 mm/year, which depend on elevation of the land. The mean annual evaporation in the study area is estimated as 2,020 mm/year. According to this high evaporation degree, water demand for domestic, livestock and irrigation is very high and supplement condition is inadequate. The temperature varies from 15°C to 35°C and it follows rainfall pattern. The temperature from June to October is relatively cool and from December to March is hot. The average of temperature is about 28 °C in a year.

H.2 Hydrology

A form of water resources in the study area is surface water and ground water. Conditions of surface water are river, lake, ground catchment and spring, and they are major water sources for domestic and livestock use in the study area. The ground water is available by using borehole and well, but its quality is not so good because of fluoride content. Fluoride compounds mainly come out from center of Rift Valley.

There are hot springs around Bogoria Lake at the floor of Rift Valley, and spring water of them includes fluoride. On the line area from Bogoria Lake to Kapedo through Baringo Lake, there are much springs and the main origin of this spring is considered as Mwanasis Peninsula area (Glover, 1972), where is western shore of the Bogoria Lake. From this reason, the water from Bogoria Lake, Loboi River, Baringo Lake and ground water around Baringo Lake (especially Loboi Plain) is not suitable for domestic or livestock use.

1) Surface Water

Rainfall in the study area has seasons, and about 3/4 of annual rainfall occurs from the end of March to August. The monthly rainfalls change very much from year to year, and it is unpredictable. This character of rainfall influences directly on surface water resource conditions, and

most rivers in the study area are seasonal rivers. The annual rainfall also changes from year to year and a ratio between maximum and minimum annual rainfall is about 3.6 in Marigat, highest is 964.6mm in 1987 and lowest is 265.8mm in 1984.

Considering the surface water resources, high evaporation is very much problem in the study area. A main water catchment lies in the high land, southern direction from the study area, and rainfall water becomes surface runoff and partly to ground water. These forms of water are lost by evaporation especially around Baringo Lake. Annual evaporation amount is more over 3 times bigger than annual rainfall in the study area, the former is 2,000-2,200mm/year and the latter is 650 mm/year.

The catchment of Baringo Lake covers the study area completely, and its area is about 6,670 sq.km. An area of Baringo Lake is 135-145 sq.km, and it depends on rainfall amount. The volume of the Lake water is estimated about 500-700 million cu.m. This fluctuation of water volume of Lake is a response to the hydrological conditions in the catchment area. During the rainy season, rivers in the Baringo Lake catchment area supply water about 250 million cu.m, and between 16 and 26 Mm^3 of water can be abstracted from Lake, but its use is limited because of its poor quality (MOWD, 1987).

People around Baringo Lake, southeastern and southwestern side, do not want to fetch water from Lake, and they try to fetch water from seasonal rivers in rainy season and then seasonal rivers can supply water for them. In the dry season, they can not fetch water from seasonal rivers, so they must use Lake water for domestic and livestock ues. Irrigation water can not be supplied from Lake. The discharge of two main perennial rivers in the study area, which drains into Baringo Lake, is estimated as follows.

Table H.1-1 Catchment area and discharge volume of main river

Name of River	Catchment	Catchment Area (sq. km)	Annual Discharge (million cu.m)
Perkera	Baringo Lake	1,310	160
Molo	Baringo Lake	2,145	110

Source: MOENR, 1987

There is another data of river discharges in the study area (refer to Table M.1-2) and they are calculated from monthly average discharges in several years. Many reports show different discharge values of rivers so basic data shall be collected and confirmed in the study area.

Table H.1-2 Discharge of Rivers in the Study Area

Name of Rivers	Discharge (million cu.m.)	Data Collection
Perkerra	139	1962-1989
Molo	52	1931-1989
Waseges	31	1973-1989
Ol Arabal	1	1979-1997
Others	5	Estimation from above data
Total	228 ≒ 230	

Data source: MOENR

All of irrigation schemes abstract water from rivers and an amount of water abstraction is increasing now. On the other hand, a runoff coefficient of rivers in the study area is estimated equal or less than 0.1, and this value shows almost all rainfall is not available to use and river water is limited.

The surface water resource in the study area is summarized as follows.

- Average annual rainfall is about 650mm
- Annual evaporation is about 2,000-2200, and it is 3 times higher than rainfall amount
- Baringo Lake is biggest water resource but not suitable for domestic and livestock use because of it quality
- There is no irrigation to abstract water from Baringo Lake
- Irrigation scheme abstract river water
- Runoff coefficient of main river is equal or less than 0.1
- Ground catchment cannot be used whole a year

2) Ground Water Resources

Ground water is closely related with geological condition and its aquifer in the study area is summarized as follows.

- Sedimentary deposits which include alluvial deposit and buried river channel
- Interface between successive lava flows, faulted and fractured zones
- Basement rock at fractured and weathered portion

Sedimentary deposit mainly occurred at Loboi Plain and floor of Rift Valley. The other area, surrounding Baringo Lake and Loboi Plain, is composed of volcanic and basement rock, but there are not so much number of suitable aquifer in the study area. The ground water yield in the study area is low.

The quality of the ground water affected from volcanic activity in the study area, and ground water at Loboi Plain includes fluoride and it exceeds drinking water standard in Kenya. The available water is located at a part of Mukutani, Arabal, a part of Marigat and Kimalel. The ground water

resource is also limited in the study area.

H.3 Water Resource Assessment

Water resource assessment is necessary to estimate water quantity for abstraction. Data for water resource assessment is not enough but some trial has been done.

1) Relationship between Rainfall and Discharge

Rainfall data and discharge data at some checking station is available and relationship between these data is shown in figure H.1-1 and H.1-2. Figure H.1-1 shows properties of Perkerra River and its rainfall weighted average is calculated as follows.

Weighted rainfall for Perkerra River = (Elbergon rainfall)×0.25+(Molo rainfall)×0.2+(Kabarnet rainfall)×0.05+(weighted rainfall at one month before)×0.35+(weighted rainfall at two month before)×0.15

Weighted rainfall for Molo River = (Eldama Ravine rainfall)×0.15+(Molo rainfall)×0.15 +(Kabarnet rainfall)×0.15+(Marigat rainfall)×0.05+(weighted rainfall at one month before)×0.3+(weighted rainfall at two month before)×0.2

More exact data collection and detail calculation is recommended.

2) Baringo Lake profile

By using area map, scale 1:50,000, relationship between water level of Baringo Lake and water surface area and water volume is calculated as Figure H-3.

3) Water Balance Simulation

Water balance simulation between Baringo Lake and water abstraction for irrigation is carried out in order to estimate limitation of water abstraction for irrigation and others, the results are shown in Table H.1-2 and H.1-3. Ground water in Table H.1-2 and H.1-3 means that water in Baringo Lake is considered to egress at its northern end by form of ground water run off and it emerges at Kapedo springs 110km from the north of Baringo Lake. For estimation for surface area of water in Baringo and water volume, Figure H.1-3 is used. Irrigation area in year 2020 is estimated as follows.

Mean discharge in Perkerra River from April to September:	25.3 million cu.m./month
-)Estimated water use for livestock and domestic use:	0.27 million cu.m./month
-)Water abstraction at Perkerra Irrigation Scheme Apr-Sep	3.55 million cu.m./month
Available water quantity in maximum	21.48 million cu.m./month

Irrigation hour in a day is usually 12 hours, so 21.48 million cu.m. is divided by 2 and can

get 10.74 million cu.m. It is 3.025 times as present irrigated area and 21.3 million cu.m. in Table H-3 is multiplied by 4.025 and can get 85.73 million cu.m. At year 2020, newly irrigated area is estimated as half of 4.025 because distance between intake and farmland becomes far and evaporation and infiltration will increase.

The result of simulation shows that water level in Baringo Lake goes down suddenly with water abstraction for irrigation and after that it gradually goes down according to water use for livestock and domestic use. So water level in Baringo Lake mainly depends on water abstraction for irrigation. Figure H.1-4 shows this relationship in the study area and Figure H.1-5 shows water drainage condition in the study area.

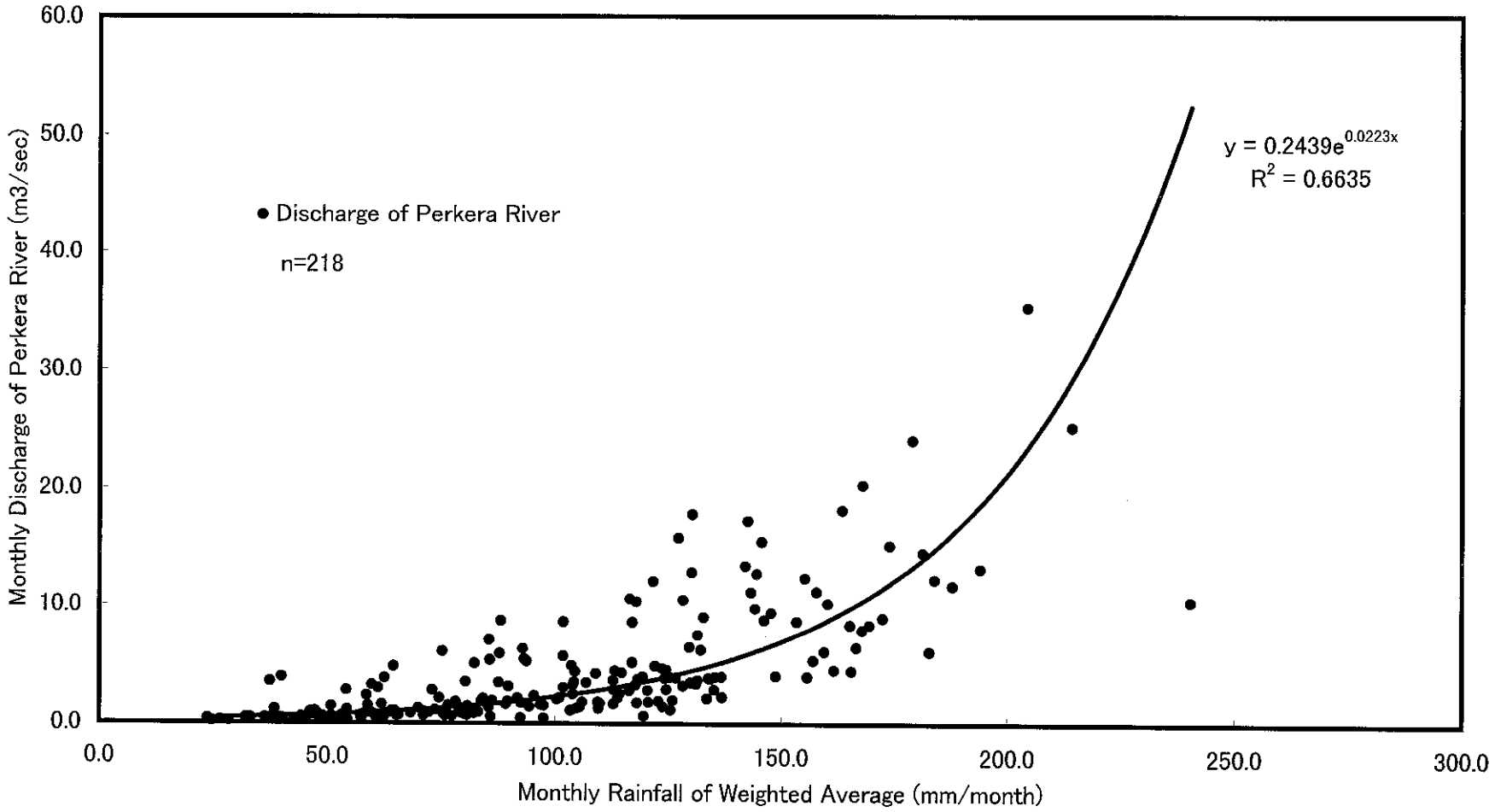

Figure H.1-1 The relationship between monthly weighted average rainfall and monthly discharge of Perkera River, the weighted average is calculated by rainfall of Eldama Ravin, Molo, Kabarnet and Marigat stations, data source is MoE&NR (1944-1988)

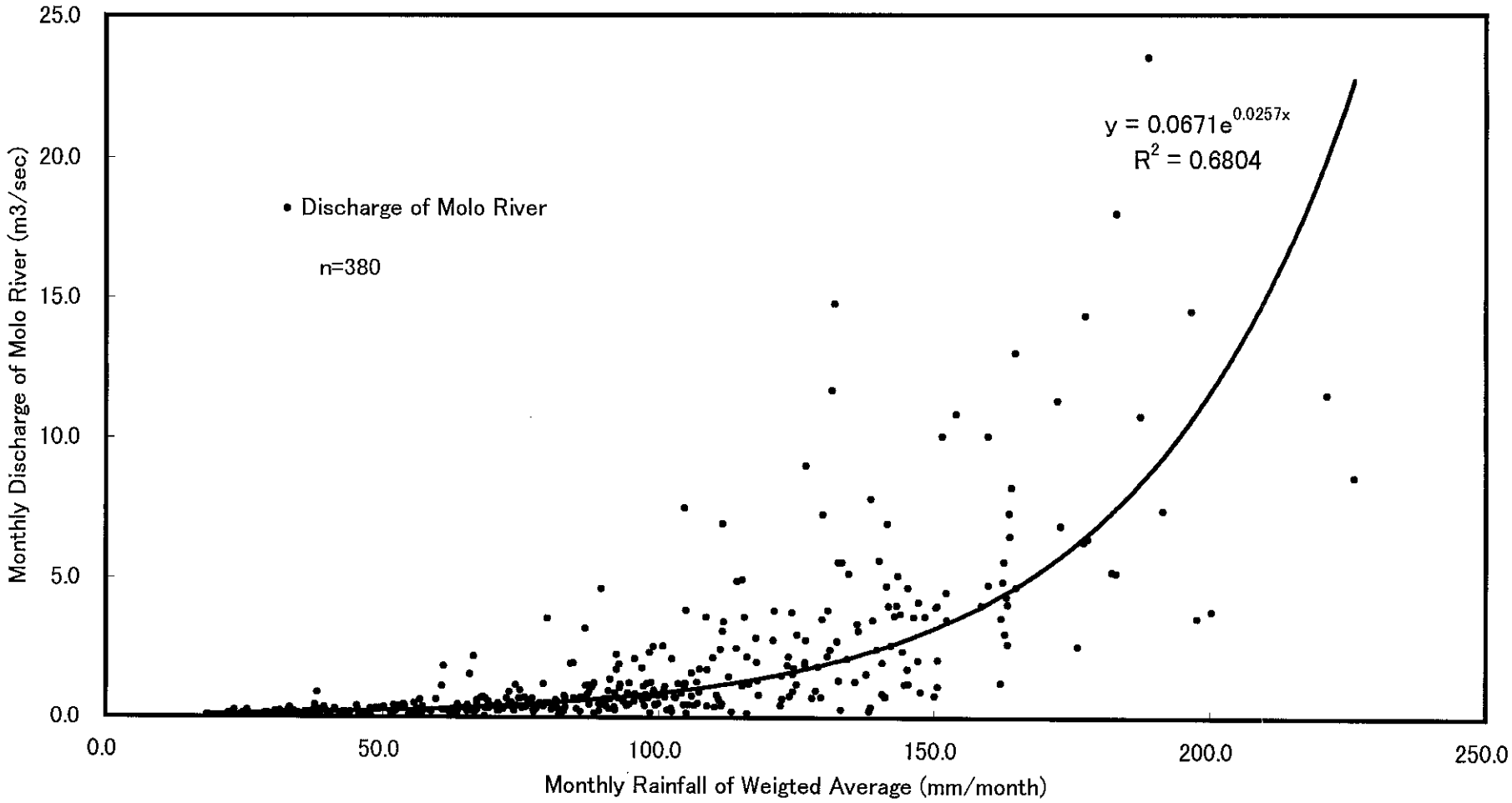

Figure H.1-2 The relationship between the monthly rainfall of weighted average and the monthly discharge of Molo River, the weighted average is calculated by the rainfall of Molo and Elburgon stations, data source is MoE&NR (1944-1988)

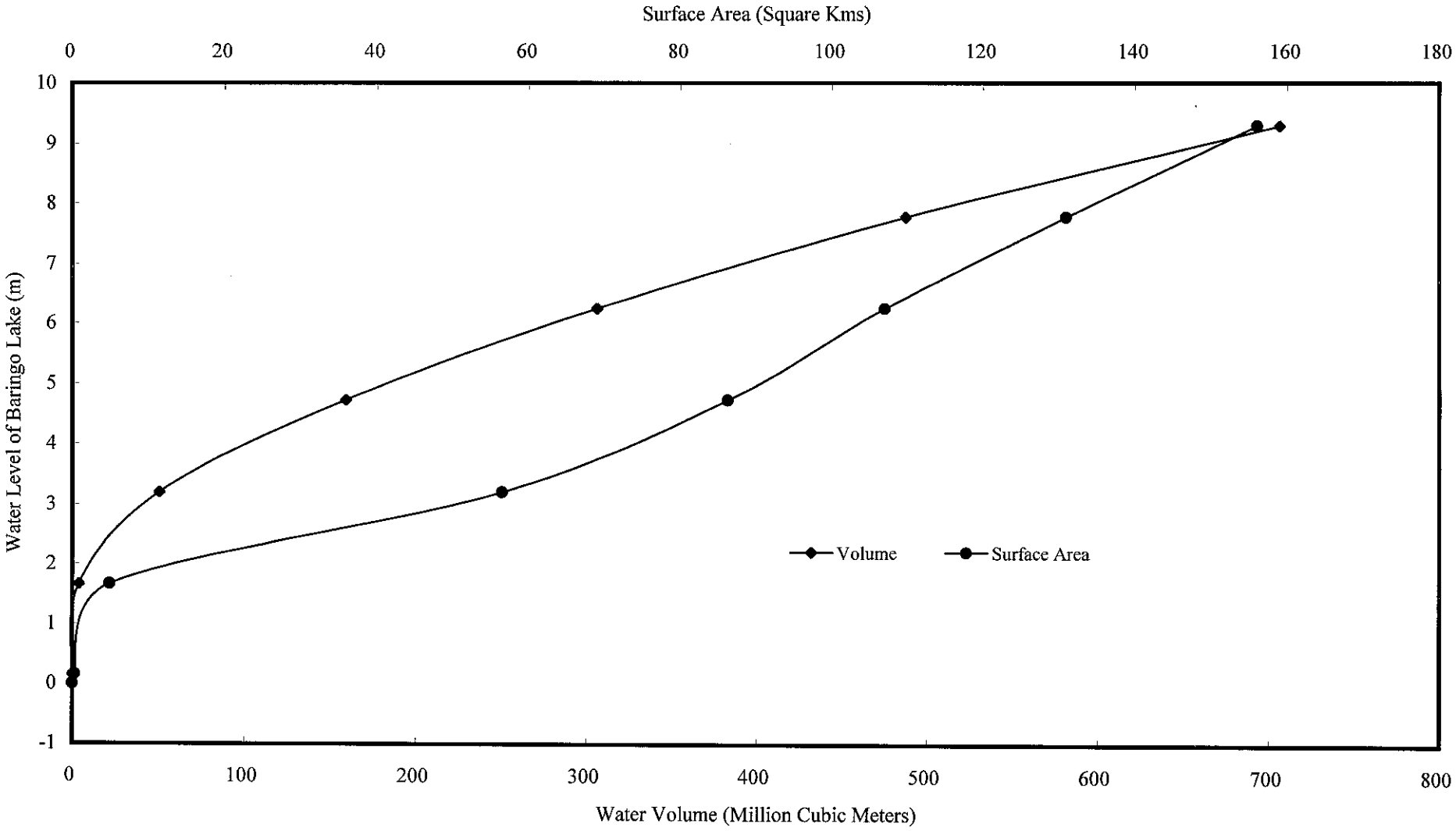

Figure H.1-3 Relationship between Water Level - Water surface Area and its Volume of Baringo Lake

Table H.1-3 Water balance simulation under irrigated area is increased condition

	①	②	③	④=②+③	⑤	⑥	⑦	⑧=⑦-⑤	⑨=①-④-⑥-⑧	⑩		
Year	Inflow	Irrigation	Dom+Live	Water use	Rain at Lake	Ground water	Evaporation	Rain+Evp	Balance	Cumulation	Water Depth	surface area of
	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(m)	(km2)
2,000	230	21.30	1.50	22.80	88.2	26.5	308.7	220.5	-39.8	590.2	8.5	147.0
2,001	230	23.36	1.58	24.94	85.8	26.5	300.3	214.5	-35.9	554.3	8.2	143.0
2,002	230	25.42	1.66	27.08	82.8	26.5	289.8	207.0	-30.6	523.7	8.0	138.0
2,003	230	27.49	1.74	29.22	81.0	26.5	283.5	204.0	-29.7	494.0	7.8	136.0
2,004	230	29.55	1.82	31.36	78.0	26.5	273.0	198.0	-25.9	468.1	7.6	132.0
2,005	230	31.61	1.92	33.53	76.2	26.5	266.7	193.5	-23.5	444.6	7.3	129.0
2,006	230	34.32	2.00	36.32	75.6	26.5	264.6	187.5	-20.3	424.3	7.2	125.0
2,007	230	37.02	2.08	39.11	75.0	26.5	262.5	185.4	-21.0	403.3	7.0	123.6
2,008	230	39.73	2.16	41.89	74.4	26.5	260.4	181.5	-19.9	383.4	6.8	121.0
2,009	230	42.43	2.24	44.68	73.8	26.5	258.3	177.0	-18.2	365.2	6.7	118.0
2,010	230	45.14	2.33	47.47	72.0	26.5	252.0	172.5	-16.5	348.7	6.5	115.0
2,011	230	49.20	2.42	51.61	72.0	26.5	252.0	170.4	-18.5	330.2	6.4	113.6
2,012	230	53.26	2.50	55.76	70.8	26.5	247.8	166.2	-18.5	311.7	6.2	110.8
2,013	230	57.32	2.59	59.90	70.2	26.5	245.7	160.5	-16.9	294.8	6.0	107.0
2,014	230	61.38	2.67	64.05	70.2	26.5	245.7	158.4	-18.9	275.9	5.9	105.6
2,015	230	65.44	2.76	68.19	70.2	26.5	245.7	154.5	-19.2	256.7	5.7	103.0
2,016	230	69.49	2.85	72.34	70.1	26.5	245.3	151.5	-20.3	236.4	5.5	101.0
2,017	230	73.55	2.93	76.48	68.4	26.5	239.4	148.5	-21.5	214.9	5.3	99.0
2,018	230	77.61	3.02	80.63	68.4	26.5	239.4	144.0	-21.1	193.8	5.1	96.0
2,019	230	81.67	3.10	84.77	67.8	26.5	237.3	137.4	-18.7	175.1	4.8	91.6
2,020	230	85.73	3.19	88.92	69.6	26.5	235.2	133.5	-18.9	156.2	4.6	89.0
2,021	230	85.73	3.28	89.01		26.5		128.4	-13.9	142.3	4.4	85.6
2,022	230	85.73	3.36	89.09		26.5		126.0	-11.6	130.7	4.2	84.0
2,023	230	85.73	3.45	89.18		26.5		120.0	-5.7	125.0	4.1	80.0
2,024	230	85.73	3.53	89.26		26.5		120.0	-5.8	119.2	4.0	80.0
2,025	230	85.73	3.62	89.35		26.5		118.5	-4.3	114.9	3.9	79.0
2,026	230	85.73	3.71	89.44		26.5		114.0	0.1	115.0	3.9	76.0
2,027	230	85.73	3.79	89.52		27.5		114.0	-1.0	114.0	3.9	76.0
2,028	230	85.73	3.88	89.61		28.5		114.0	-2.1	111.9	3.9	76.0
2,029	230	85.73	3.96	89.69		29.5		114.0	-3.2	108.7	3.8	76.0
2,030	230	85.73	4.05	89.78		30.5		112.5	-2.8	105.9	3.8	75.0

Table H.1-4 Water Balance simulation under no increase of irrigated area

	①	②	③	④=②+③	⑤	⑥	⑦	⑧=⑦-⑤	⑨=①-④-⑥-⑧	⑩		
Year	Inflow	Irrigation	Dom+Live	Water use	Rain at Lake	Ground water	Evaporation	Rain+Evp	Balance	Cumulation	Water Depth	surface area of water
	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(MMC/Year)	(m)	(km2)
2,000	230	21.30	1.50	22.80	88.2	26.5	308.7	220.5	-39.8	590.2	8.5	147.0
2,001	230	21.30	1.58	22.88	85.8	26.5	300.3	214.5	-33.9	556.3	8.2	143.0
2,002	230	21.30	1.66	22.96	82.8	26.5	289.8	207.0	-26.5	529.9	8.0	138.0
2,003	230	21.30	1.74	23.04	81.0	26.5	283.5	204.0	-23.5	506.4	7.8	136.0
2,004	230	21.30	1.82	23.12	78.0	26.5	273.0	199.5	-19.1	487.3	7.6	133.0
2,005	230	21.30	1.92	23.22	76.2	26.5	266.7	196.5	-16.2	471.1	7.5	131.0
2,006	230	21.30	2.00	23.30	75.6	26.5	264.6	193.2	-13.0	458.1	7.4	128.8
2,007	230	21.30	2.08	23.38	75.0	26.5	262.5	190.8	-10.7	447.4	7.3	127.2
2,008	230	21.30	2.16	23.46	74.4	26.5	260.4	188.4	-8.4	439.0	7.2	125.6
2,009	230	21.30	2.24	23.54	73.8	26.5	258.3	186.6	-6.6	432.4	7.1	124.4
2,010	230	21.30	2.33	23.63	72.0	26.5	252.0	184.8	-4.9	427.5	7.1	123.2
2,011	230	21.30	2.42	23.72	72.0	26.5	252.0	183.6	-3.8	423.7	7.0	122.4
2,012	230	21.30	2.50	23.80	70.8	26.5	247.8	182.3	-2.6	421.1	7.0	121.5
2,013	230	21.30	2.59	23.89	70.2	26.5	245.7	180.9	-1.3	419.8	7.0	120.6
2,014	230	21.30	2.67	23.97	70.2	26.5	245.7	180.2	-0.6	419.2	7.0	120.1
2,015	230	21.30	2.76	24.06	70.2	26.5	245.7	179.4	0.0	419.2	7.0	119.6
2,016	230	21.30	2.85	24.15	70.1	26.5	245.3	179.4	-0.0	419.2	7.0	119.6
2,017	230	21.30	2.93	24.23	68.4	26.5	239.4	179.4	-0.1	419.1	7.0	119.6
2,018	230	21.30	3.02	24.32	68.4	26.5	239.4	179.4	-0.2	418.9	7.0	119.6
2,019	230	21.30	3.10	24.40	67.8	26.5	237.3	179.4	-0.3	418.6	7.0	119.6
2,020	230	21.30	3.19	24.49	69.6	26.5	235.2	179.4	-0.4	418.2	7.0	119.6

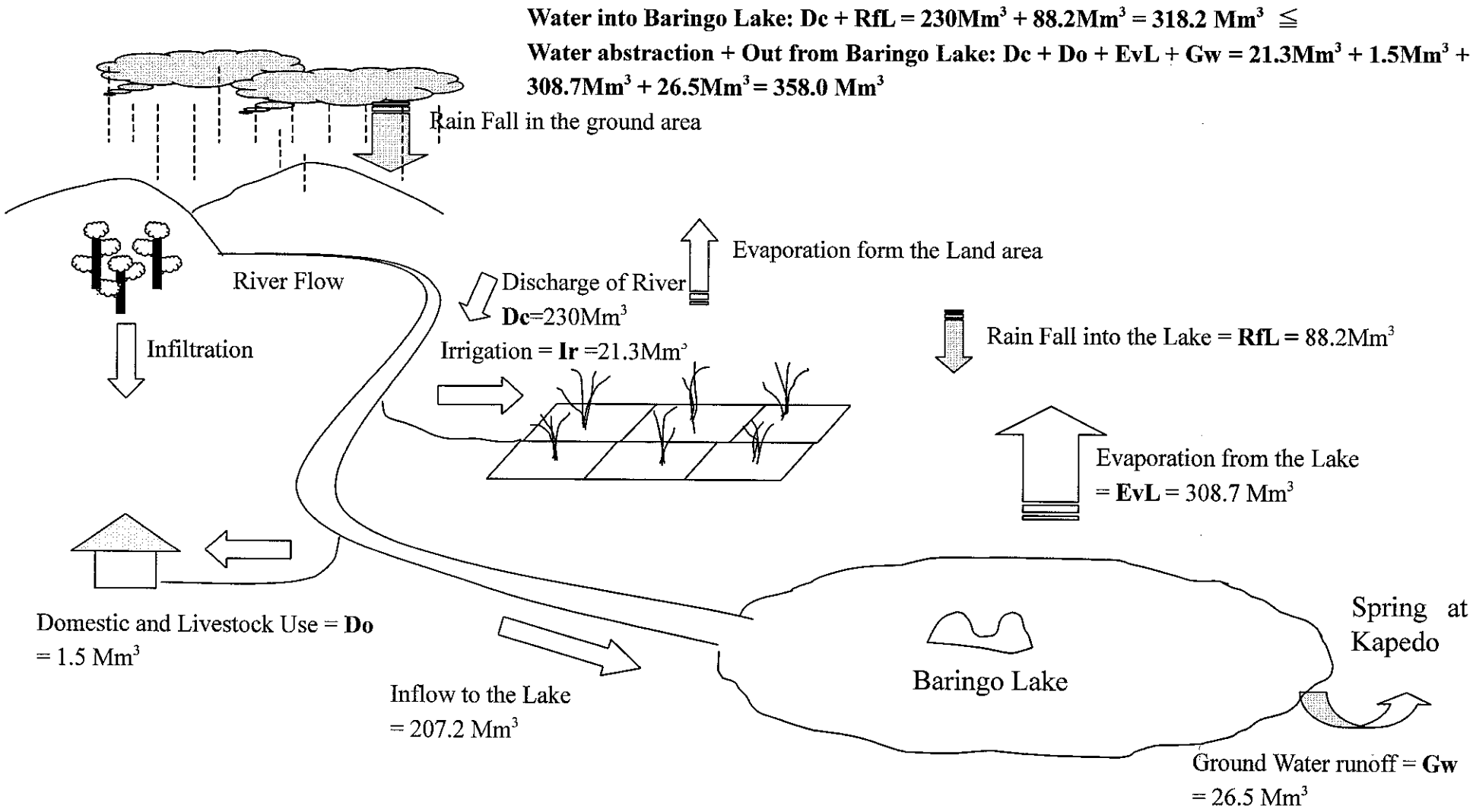

Figure H.1-4 The water balance model around Baringo Lake
(Source: JICA Study Team, Ministry of Environment and Natural Resources)

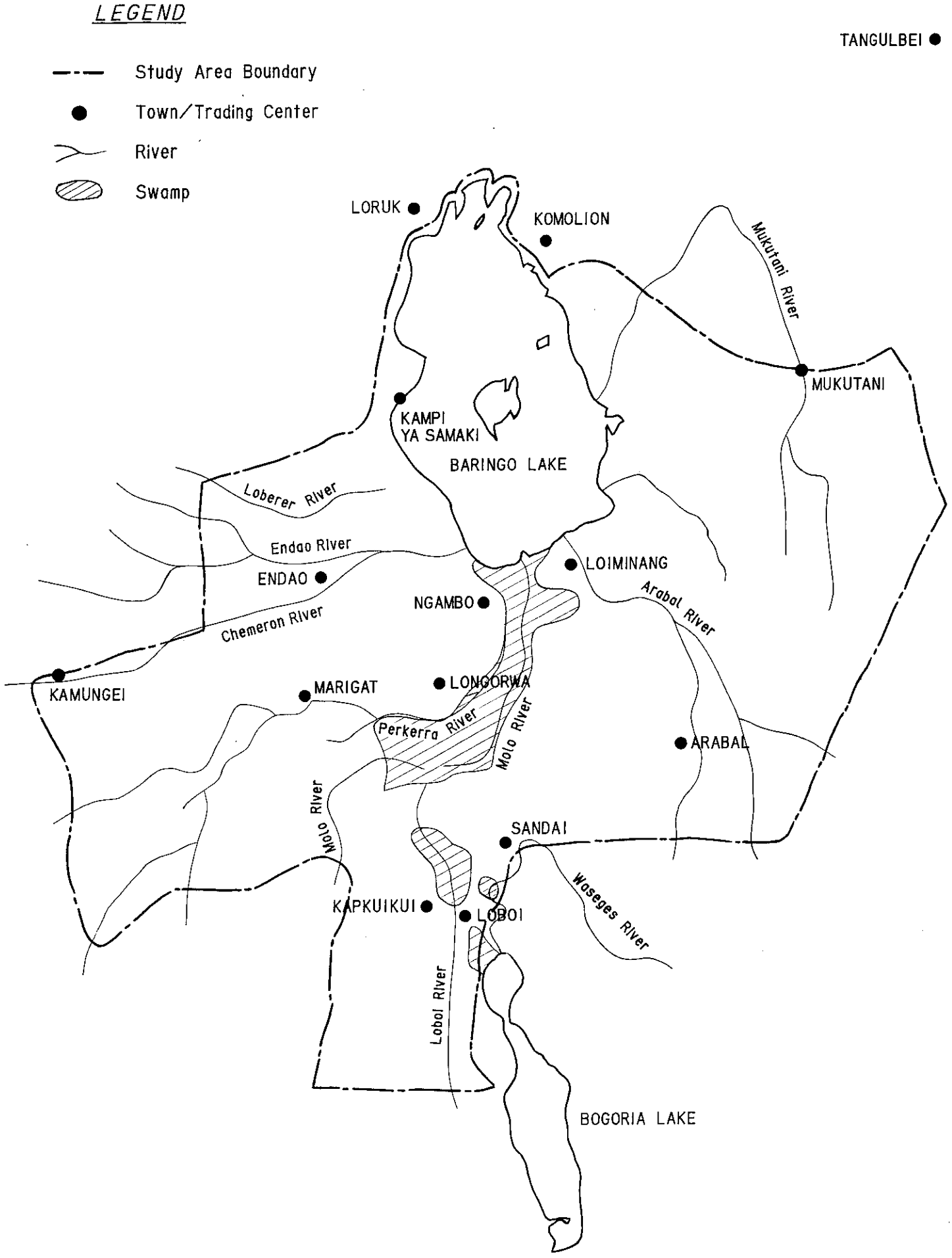

Figure H.1-5 Water Drainage Condition in the study area