Since the amount of water in the lakes (total volume of 690 million m3) is significant and stable compared to that of river water as mentioned in Section 2.4 of Appendix C, and that it only fluctuates slightly seasonally, it would be more beneficial to use as sources for urban water supply. Rwamagana Urban Water Supply uses lake water.

1.4 RAINWATER

For rainwater harvesting, the problem for providing a stable water supply during the dry season will continue to exist. Rain-water harvesting is a useful means to supplement domestic or drinking water sources for people living in the sparsely populated mountainous regions.

Due to the types of houses, few rainwater harvesting is used by the residents. Comparatively large-scale rain-water harvesting facilities using the strong roofs of hospitals and churches can be seen in the Study Area.

Based on the average monthly rainfall in Kibungo, the possible amount of rainwater harvesting is estimated as shown below.

Month	Monthly Rainfall (mm)	Roof System (Collecting Area 50m2) (Efficient 0.9)	Ground System (Collecting Area 2,500m2) (Efficient 0.4)
JAN.	84.5	123 l/day	2,730 l/day
FEB.	72.5	117	2,590
MAR.	152.3	221	4,910
APR.	160.9	241	5,360
MAY.	79.8	110	2,574
JUN.	10.5	16	350
JUL.	9.2	13	300
AUG.	20.6	30	660
SPT.	49.6	74	1,650
OCT.	78.3	114	2,530
NOV.	149.8	225	4,990
DEC.	80.3	117	2,590

According to the figures, it would be necessary to rely on other types of water sources during the three month period of June through August.

2. WATER QUALITY

2.1 GENERAL

Information on water qualities of water resources and served water is not sufficient in the Study Area, chiefly due to low interest in this matter. However, since water quality is an important element for rural water supply planning, consequently, sampling, field testing and detailed analyses in the laboratory of ELECTROGAZ were carried out. The results are summarized in Table K.1.

The water quality does not vary much in the different water-sources. The specific electric conductivity is mainly below 300 micro mhos/cm and pH values range from 7.0 to 8.1, which will be acceptable for drinking purposes.

The value of color (APHA) is under 50 in groundwater which has no constraint for drinking and more than 100 in surface water of both river and lake, which is required to be treated before the service of drinking water. Also, coliform organisms and total colonies contaminate the surface water and it is considered that surface water is not suitable for drinking purposes without treatment.

Surface water contamination is widely observed in the Study Area. It is estimated that rural waste water in the main cause of the wide contamination of surface water.

In addition, it should be note following problems of water quality for drinking purpose and a careful study of water quality should be required at the D/D and B/D stage.

- The surface water, such as lake water/river water, is heavily contaminated by domestic waste water from settlements.
- Also, the water quality of shallow groundwater closed to surface water; i.e. lake water, stream and swamp, are contaminated on items of turbidity, color, SS, Cl anion and Fe cation.

2.2 WATER QUALITY ANALYSES

The following water quality tests were conducted in the Study Area:

. Phase I analyses	:	Conducted during the Feasibility Study period in 1985
. Phase III	:	Conducted during 1989 and 1990
. Phase III field tests	:	Conducted during 1989
. Phase III jar tests	:	Conducted during 1990

2.3 DATA OF WATER QUALITY ANALYSES

(1) Phase I Water Quality Analysis

The results of the water quality analysis conducted for the 1985 Feasibility Study are as in Table K.2.

(2) Phase III Field Tests

The results of the field water quality tests conducted in 1989 to examine the water qualities in the Study Area are shown in Table K.3 and the sites to examine is given in Table K.4 and Fig K.2.

(3) Phase III Water Quality Analysis

By taking into account the results of the preliminary water quality tests, water samples for the Phase III water quality analysis were obtained at 19 locations as in Fig. K.3. Analysis of the water samples were entrusted to the Water Quality Analysis Laboratory of ELECTROGAZ in Kigali. The analysis results are shown in Table K.5.

(3) Jar Tests

To examine water treatment methods and the amount of chemicals to use, jar tests were made of the water sources in the System 1 adoption areas which were recommended in the basic plan. Water for Jar tests obtained July and August, 1990 in the Mugesera, Sake and Muhazi Lakes were conducted at the Water Quality Analysis Laboratory of ELECTROGAZ and in Japan. The test results are as in Table K.6.

2.4 CHARACTERISTICS OF WATER QUALITY IN THE STUDY AREA

From the results of the above tests, the water quality characteristics in the Study Area are clarified as follows:

(1) Surface Water

General characteristics
The Study Area is situated on 1,300 to 1,900 m high plateaus. Practically all of the Study Area is used as farming, cattle-breeding, and residential areas. Thus, the surface water (rivers and lakes) in the Study Area is contaminated by coliform bacteria and other types of bacteria because of the effects of domestic sewerage.

The comparison of river and lake water qualities is given below:

	Turbidity (NTU)	Hue (APHA)	pH	Electrical Conductivity (s/cm)	K MnO4 Consumption (mg/liter)
River Water	20	70	7.2	220	4.2
Lake Water	10	100	8.3	240	10.0

The difference between the river water qualities and the lake water qualities is believed to be attributable to the lake water being affected by decomposed plants, such as papyrus.

When the surface water is used as a source of drinking water, the problem is how to set up the improvement targets for the turbidity and hues.

Result of Jar Test
The purpose of jar tests is to determine the proper amounts of coagulant and alkali needed to treat water.

Water source qualities vary depending upon the amount of precipitation, the temperature, etc., and it is necessary to determine the proper amounts of chemical dosages and it may be required to change these dosages on a daily basis. The most economical water treatment management is to determine the amounts of chemical dosages based on the results of jar tests.

Following is a summary of the jar tests made for this Study:

Used water quality standard for jar tests (WHO standards)

Turbidity : 5 (No turbidity value in WHO standard)
Hue : 10 (WHO standard: 5 to 50)
PH : 0.7 (WHO standard: 6.5 to 9.2)
$KMnO_4$ Consumption:
Less than 10 ppm (WHO standard: less than 10 ppm)

i) Jar Test Results in Rwanda

- Muhazi Lake East
  By adding 60 ppm of coagulant $Al_2(SO_4)_3$ and 25 ppm of alkali $Ca(OH)_2$, turbidity 5.3, hue 3, PH 7.8, and $KMnO_4$ consumption 2.5 ppm were obtained.

  By adopting secondary rapid filtration treatment, it would be possible to meet the drinking water standard.

- Sake Lake
  By adding 80 ppm of coagulant $Al_2(SO_4)_3$ and 35 ppm of alkali $Ca(OH)_2$, turbidity 5, hue 3, PH 7.5, and $KMnO_4$ consumption 5 ppm were obtained. Using this dosage, the lake water will meet drinking water standards.

ii) Jar Test Results in Japan

By adding 70 ppm of coagulant $Al_2(SO_4)_3$ and 5 ppm of chloride NaOCl, turbidity 1, hue 10, PH 6.7 ere obtained. Floc diameters were 2 to 3 mm. Thus, it is expected that very effective sedimentation will be accomplished.

(2) Groundwater

Well
Because of the purification capabilities of nature, no coliform bacteria or other bacteria is contained in the groundwater in the Study Area. Thus, the water from the wells constructed by the Phase I project is used for drinking without any treatment. To further improve the qualities of the groundwater, its Ph value (light acidity) and excess Fe and Mn iron within water which is taken from shallow well close to stagnated surface water, will be problems.

Spring Water

The quality of spring water is believed to be good. However, the amount of water generally is small to develop.

In addition, from water quality point of view, it is considered that the water from springs having improper environment is contaminated with coliform bacteria and other bacteria that are influenced by domestic sewage. Thus, it is important to maintain a clean environment around the springs.

The characteristics of the water sources in the Study Area are summarized in the following Table:

Water Source	Characteristics	Problems Confronting the Water Supply Plan
Springs	. Water qualitites are good and distribution by gravity flow is possible because springs are located on relatively high locations. . Springs are used for the water sources of existing water supply facilities. . Water yield greatly varies according to the season. . Springs are unevenly distributed in certain areas.	. Large springs are already used for existing water supply facilities. Only a few unused large springs exist. . Therre is a possibility of developing new springs by constructing horizontal bore holes or collector wells, but, to do so, very accurate geological surveys and flow observations would be necessary.
Ground-water	. Water qualities are good and possible areas for shallow well construction eaxist in the Study Area. Development potential of groundwater is very good. . Existing wells have excess iron problems.	. A powered pump would be necessary to use groundwater for a large-scale water supply facility. . Possible pumping amount is limited. . To improve the water qualities, control of extraction of excess iron would be problems.
Surface Water	. Water of rivers and lakes is heavily contaminated. . Rivers having small catchment areas become dry during the dry season.	. To use surface water, installation of pumping stations and water treatment facilities are indispensable, and the facilities would require large amounts of operation and maintenance costs. Thus, the financial burden of the residents should be taken into consideration.
Rainwater Harvesting	. Water qualities are good and the water has a high potential for being used as drinking water sources for people living in sparsely populated mountainous area. . Other water sources are required during the dry season.	. Due to inadequate roof structures of residential houses, it would be difficult to install rainwater harvesting facilities.

Table K.1 Characteristics of Water Quality in the Study Area

Item	Unit	LAKE WATER			RIVER WATER			WELL WATER		
		Min	Max	Value Adopted	Min	Max	Value Adopted	Min	Max	Value Adopted
Turbidity	NTU	4.0	12.5	9.2	16.0	26.0	22.0	3.4	22.0	4.5
Colour	APHA	40	190	118	120	160	137	30	80	37
pH		7.0	8.5	8.1	7.0	7.5	7.2	6.5	7.5	7.0
Conductivity	mS/cm	104	480	293	198	240	219	38	240	240
T-Hardness	mg/lit	40	170	93	70	80	77	40	70	53
Free CO2	mg/lit	0.0	10.0	1.9	2.0	49.0	18.3	6.0	74.0	74.0
DO	mg/lit	2.0	5.0	3.9	1.0	4.0	2.7	3.0	3.0	3.0
KMnO4 Consumed	mg/lit	5.2	12.7	9.3	1.5	6.8	4.2	2.3	4.1	3.4
NH4-N	mg/lit	0.22	0.50	0.35	0.22	0.36	0.31	0.13	0.32	0.30
SS	mg/lit	4	18	10	16	30	21	0	8	2
ANION										
Cl	mg/lit	8.0	57.0	25.9	38.0	45.0	40.7	0.0	37.0	37.0
NO2	mg/lit	0.00	0.10	0.02	0.00	0.01	0.01	0.01	0.13	0.13
NO3	mg/lit	0.00	3.08	1.07	1.32	1.76	1.47	0.88	2.60	2.20
SO4	mg/lit	4.0	13.0	8.3	8.0	17.0	13.7	2.0	33.0	27.0
PO4	mg/lit	0.04	0.17	0.09	0.06	0.12	0.09	0.01	0.80	0.40
CACION										
Ca	mg/lit	40.0	130.0	78.6	50.0	70.0	63.3	10.0	70.0	40.0
Mg	mg/lit	0.0	40.0	11.4	0.0	30.0	13.3	0.0	70.0	20.0
Mn	mg/lit	0.0	0.2	0.1	0.03	0.2	0.1	0.01	0.06	0.04
Fe(III)	mg/lit	0.0	1.0	0.3	0.4	1.6	0.9	0.0	1.0	1.0
NH4	mg/lit	0.28	0.65	0.45	0.28	0.46	0.39	0.36	0.67	0.67
Coliform Organisms		++	++	++	++	++	++	-	-	-
Total Colinies		++	++	++	++	++	++	-	-	-

RESULTS OF WATER QUALITY TESTS(Phase I)

(Unit:ppm)

Water Source	NO2-N	NO3-N	NH4-N	Cl	Cr6+	Cu	Fe	Zn	pH	COD	CaCO3	C.B.	O.B.	Turv.
R.Nyakora	0	0	0.8	115	0	0	0	0	8.0	>20	255	++	++	>10
R.Kodilidimba	0	0	0	140	0	0	1.0	0	7.0	>20	150	++	-+	>10
R.Sendaya	0.05	2.0	0.5	100	0	0	0.5	0.5	7.0	>20	50	++	++	>10
Po.Rwinkavu	0	0	0	130	0	0	0	0	7.0	20	140	++	++	>10
R.Kadilidimba	0	0	0	150	0	0	0	0	7.5	5	150	++	-+	5
Kabilizi	0	0	0.4	50	0	0.5	0.5	0	7.0	>20	105	++	++	>10
Ruvuvu	0	0	0	110	0	0	0	0	8.0	>20	110	++	++	>10
Ka.Kayonza	0	0	0	80	0	0	0	0.5	6.0	15	150	-	+	0
Ka.Rutonde	0	0	0	140	0	0	0	0	5.5	5	100	-	+	0
Pub.Faucet	0	0	1.0	135	0	0	0.5	0	8.5	10	135	++	++	>10
T.W.Nyakora	0	0	0	75	0	0	0	0	7.0	0	125	-	-	0
T.W.Kabarondo	0	0	0	90	0	0	0.2	0	6.5	0	150	-	-	0
T.W.Rukirax.	0	0	0	75	0	0	0.2	0.5	6.0	0	50	-	-	0
T.W.Kigarama	0	0	0	85	0	0	0	0	6.0	0	45	-	-	0
T.W.Birenga	0	0	0	75	0	0.5	0.2	0	7.5	0	50	-	-	0

Note :C.B.=Colon Bactisille, O.B.=Other Bacteria
Source:Final Report of the Rural Water Supply Project in the Eastern Region(1985,JICA)

Results of Water Quarity Test-1(Lake)

(Unit : mg/liter)

Test Item		MUHAZI LAKE	MUGESERA LAKE	SAKE LAKE	NASHO LAKE	CYAMBWE LAKE	RWAMPANGA LAKE	Average	WHO STANDARD
Turbidity *1		4.0	12.5	12.5	7.1	10.0	6.5	8.7	-
Color *2		40.0	190.0	150.0	70.0	110.0	40.0	100.0	5-50
pH		8.5	8.0	8.5	8.3	8.3	8.0	8.3	6.5-9.2
Electrical Conductivity *3		480.0	186.0	240.0	300.0	114.0	104.0	237.3	-
Total Hardness		170.0	100.0	90.0	70.0	60.0	40.0	88.3	100-500
Total Alkalinity		0.2	0.0	0.4	1.3	1.0	0.0	0.5	-
Free CO2		0.0	1.0	0.0	0.0	0.0	2.0	0.5	-
Dissolved Oxygen		4.0	4.0	4.0	4.0	5.0	4.0	4.2	-
KMnO4 Consumed		7.1	11.1	11.5	9.1	8.5	12.7	10.0	10
NH4-N		0.25	0.42	0.50	0.24	0.42	0.22	0.34	-
Suspended Solids		8.0	16.0	4.0	8.0	10.0	4.0	8.3	-
(ANION)	Cl	57.0	34.0	13.0	17.0	8.0	15.0	24.0	200-600
	NO2	0.00	0.00	0.00	0.00	0.10	0.00	0.02	-
	NO3	0.90	0.00	0.90	0.00	3.10	2.60	1.30	40-80
	SO4	6.0	13.0	12.0	7.0	9.0	4.0	8.5	200-400
	PO4	0.11	0.07	0.08	0.17	0.04	0.12	0.10	-
(CATION)	Ca	130.0	90.0	80.0	70.0	50.0	40.0	76.7	75-200
	Mg	40.0	10.0	10.0	0.0	10.0	0.0	11.7	50-150
	Mn	0.00	0.10	0.20	0.00	0.10	0.00	0.10	0.1-0.5
	Fe(III)	0.0	1.0	0.2	0.1	0.2	0.2	0.3	0.3-1.0
NH4		0.32	0.54	0.65	0.30	0.54	0.28	0.44	-
Coliform		++	++	++	++	++	++	++	MPN 10
Total Colonies		++	++	++	++	++	++	++	-

Note-1) *1 : Unit is NIU *2 : Unit is APHA *3 : Unit is s/cm
Note-2) Coliform and Total Colonies are tested by simple test paper.

Results of Water Quarity Test-2(River and Others)

(Unit : mg/liter)

Test Item		RIVER				Artificial Lake		Rainwater	WHO
		KIBAYA RIVER	KIBILIZI RIVER	NYAGASENYI RIVER	Average	KADIGADIGA LAKE	GASHAKA LAKE	GAHINI	STANDARD
Turbidity *1		16.0	26.0	24.0	22.0	3.9	6.5	15.0	-
Color *2		160.0	130.0	120.0	136.7	30.0	70.0	180.0	5-50
pH		7.0	7.0	7.5	7.2	8.0	7.0	8.3	6.5-9.2
Electrical Conductivity *3		240.0	220.0	198.0	219.3	380.0	260.0	320.0	-
Total Hardness		80.0	80.0	70.0	76.7	130.0	100.0	120.0	100-500
Total Alkalinity		0.2	0.0	0.0	0.1	0.0	0.0	0.5	-
Free CO2		2.0	49.0	4.0	18.3	10.0	10.0	0.0	-
Dissolved Oxygen		4.0	1.0	3.0	2.7	3.0	2.0	4.0	-
KMnO4 Consumed		4.2	1.5	6.8	4.2	5.5	5.2	10.5	10
NH4-N		0.36	0.34	0.22	0.31	0.34	0.38	0.58	-
Suspended Solids		16.0	16.0	30.0	20.7	0.0	18.0	16.0	-
(ANION)	Cl	39.0	38.0	45.0	40.7	40.0	37.0	47.0	200-600
	NO2	0.00	0.00	0.00	0.00	0.00	0.00	0.10	-
	NO3	1.30	1.80	1.30	1.50	0.00	0.00	4.80	40-80
	SO4	8.0	17.0	16.0	13.7	3.0	7.0	12.0	200-400
	PO4	0.12	0.06	0.08	0.09	0.10	0.06	0.14	-
(CATION)	Ca	70.0	50.0	70.0	63.3	120.0	90.0	100.0	75-200
	Mg	10.0	30.0	0.0	13.3	10.0	10.0	20.0	50-150
	Mn	0.10	0.20	0.00	0.10	0.00	0.00	0.00	0.1-0.5
	Fe(III)	1.6	0.6	0.4	0.9	0.2	0.2	0.0	0.3-1.0
NH4		0.46	0.43	0.28	0.39	0.43	0.49	0.74	-
Coliform		++	++	++	++	++	++	++	MPN 10
Total Colonies		++	++	++	++	++	++	++	-

Note-1) *1 : Unit is NIU *2 : Unit is APHA *3 : Unit is s/cm

(continue)

Note-2) Coliform and Total Colonies are tested by simple test paper.

Results of Water Quarity Test-3(Well, Spring)

(Unit : mg/liter)

Test Item	Test Well No. 1	Test Well No. 2	Test Well No. 3	Test Well No. 4	Test Well No. 5	KANYAHI Spring	KIBILIZI Well	WHO STANDARD
Turbidity *1	10.0	0.9	22.0	100.0	22.0	5.6	3.4	-
Color *2	50.0	0.0	80.0	380.0	80.0	30.0	30.0	5-50
pH	5.2	5.1	5.5	6.0	6.0	6.5	7.5	6.5-9.2
Electrical Conductivity *3			110.0			38.0	240.0	-
Total Hardness	40.0	5.0	40.0	10.0	4.0	50.0	70.0	100-500
Total Alkalinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Free CO2	48.0		48.0	135.0	74.0	32.0	6.0	-
Dissolved Oxygen		3.0	3.0	1.0	2.0	3.0	3.0	-
KMnO4 Consumed	3.9		1.9	3.6	1.5	2.3	4.1	10
NH4-N	0.13	0.0	0.15	0.02	0.52	0.32	0.28	-
Suspended Solids	8.0	0.0	12.0	2.5	1.2	0.0	4.0	-
(ANION) Cl	0.0	0.0	0.0	26.0	0.0	17.0	37.0	200-600
NO2	0.00	0.00	0.00	0.10	0.10	0.00	0.00	-
NO3	2.20	2.20	1.30	2.20	2.60	2.20	0.90	40-80
SO4	27.0	27.0	23.0	33.0	22.0	2.0	3.0	200-400
PO4	0.01	0.02	0.04	0.8	0.4	0.11	0.03	-
(CATION) Ca	10.0	20.0	20.0	30.0	25.0	40.0	70.0	75-200
Mg	30.0	30.0	20.0	70.0	15.0	10.0	0.0	50-150
Mn	0.1		0.1	0.06	0.03	0.1	0.0	0.1-0.5
Fe(III)	0.8	0.4	0.2	25.0	1.0	0.0	0.3	0.3-1.0
NH4	0.66	0.09	0.19	0.02	0.67	0.41	0.36	-
Coliform								MPN 10
Total Colonies								-

Note-1) *1 : Unit is NTU *2 : Unit is APHA *3 : Unit is s/cm

RESULTS OF PRELIMINARY WATER QUALITY TESTS

No.	Location (Commune)	Kind of water	Temp. (C)	pH	Electrical Conductivety	Coliform Organisms	Total Colinies
1	R.Mwerera (Kayonza)	Stream	21.6	6.80	0.258ms/cm	++	++
2	R.Gashogo-shogo(Rukara)	Stream	21.1	7.35	0.272	++	None
3	Nyamugai (Rusumo)	Public Tap	24.5	6.07	0.190	++	++
4	R.Kibaya (Rukira)	Stream	-	-	-	++	++
5	R.Kibilizi (Rusumo)	Stream	18.8	7.40	0.216	++	++
6	R.Kibilizi (Rusumo)	Well	21.2	6.75	0.242	None	None
7	R.Nyagasenyi (Rusumo)	Stream	20.3	7.35	0.182	++	++
8	Kerembo (Mugesera)	Public Tap	24.0	5.59	0.095	None	++
9	Zaza (Mugesera)	Public Tap	24.1	5.57	0.095	++	None
10	R.Nukungu (Kigarama)	Stream	21.9	6.60	0.327	++	++
11	L.Mugesera (Rutonde)	Lake	27.5	7.12	0.302	++	++
12	R.Nyabishu-nzi(Rutonde)	Stream	25.5	7.01	0.539	++	++
13	L.Cyambwe (Rusumo)	Lake	-	-	-	++	++
14	L.Rwampanga (Rusumo)	Lake	-	-	-	++	++
15	L.Nasho (Rusumo)	Lake	-	-	-	++	++
16	Rukira (Rukira)	Spring	-	-	-	++	++
17	L.Sake (Sake)	Lake	-	-	-	++	++

Source : Study Team

Phase III Water Quality Analysis

No.	Sampling Point	Location	Type	Sampling Date	Test Number
1.	MUHAZI LAKE	MUHAZI	Lake	20/09/89	3895
2.	HADIGADIGA LAKE	RUIONDE	Lake	20/09/89	3896
3.	GAHINI HOSPITAL	RUKARA	Rainwater	20/09/89	3897
4.	GASHAKA LAKE	KAYONZA	Lake	20/09/89	3898
5.	CYAMBWE LAKE	RUSUMO	Lake	20/09/89	3899
6.	RWAMPANGA LAKE	RUSUMO	Lake	21/09/89	3900
7.	NASHO LAKE	RUKIRA	Lake	21/09/89	3901
8.	KANYAMI	RUKIRA	Spring	21/09/89	3902
9.	KIBAYA RIVER	RUKIRA	River	22/09/89	3903
10.	KIBILIZI RIVER	RUSUMO	River	22/09/89	3904
11.	KIBILIZI WELL	RUSUMO	Groundwater	22/09/89	3905
12.	NYAGASENYI RIVER	RUSUMO	River	22/09/89	3906
13.	SAKE LAKE	SAKE	Lake	22/09/89	3907
14.	MUGESERA LAKE	MUGESERA	Lake	22/09/89	3908
15.	Test Well No. 1	MUHAZI	Groundwater	03/03/90	3954
16.	Test Well No. 2	KAYONZA	Groundwater	03/03/90	3955
17.	Test Well No. 3	SAKE	Groundwater	06/03/90	3959
18.	Test Well No. 4	KIGARAMA	Groundwater	05/09/90	4026
19.	Test Well No. 5	RUSUMO	Groundwater	29/08/90	4025

Note : Site is as shown in following figure.

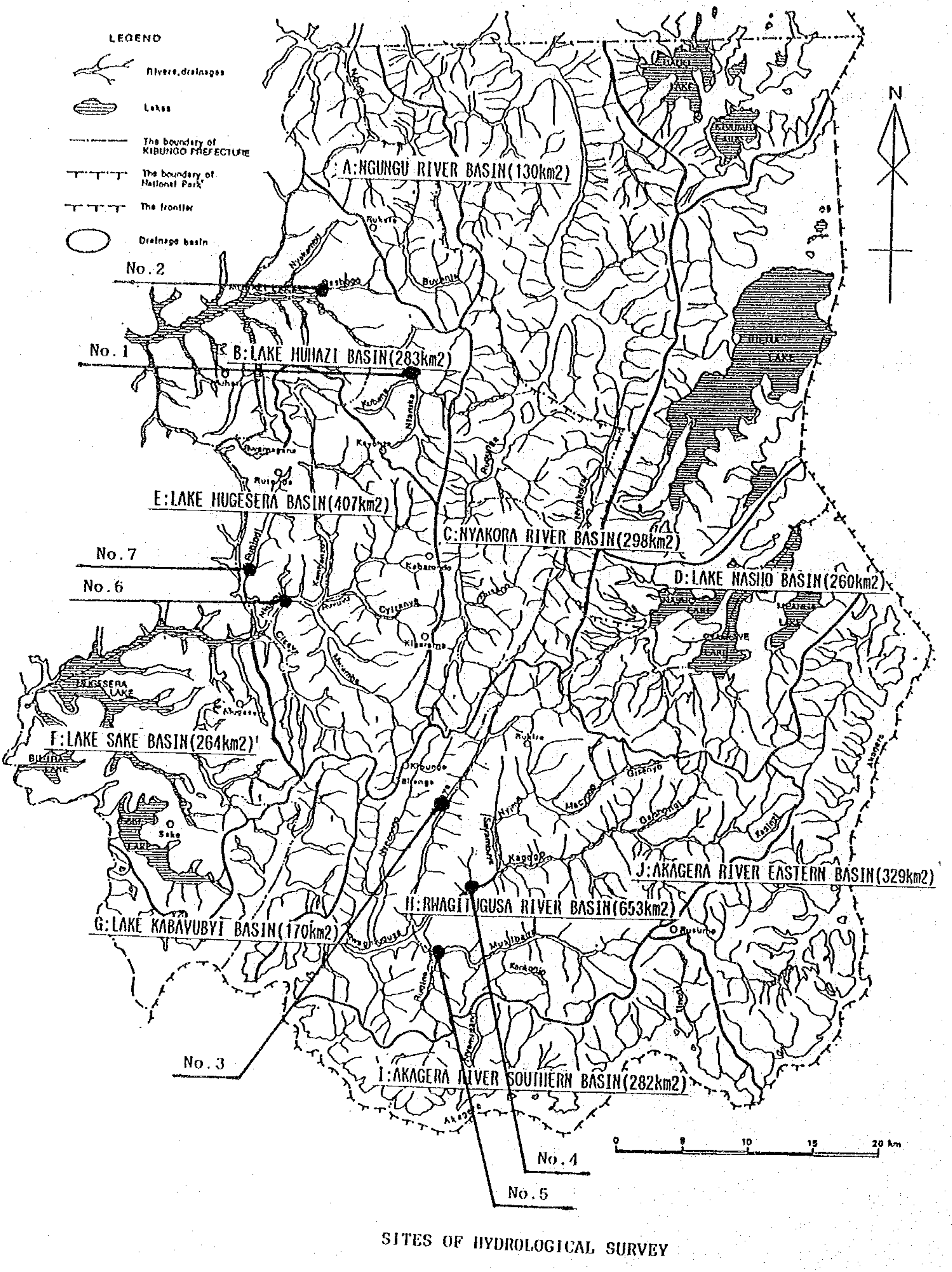
Phase III Jar Tests

Water Quality Analysis

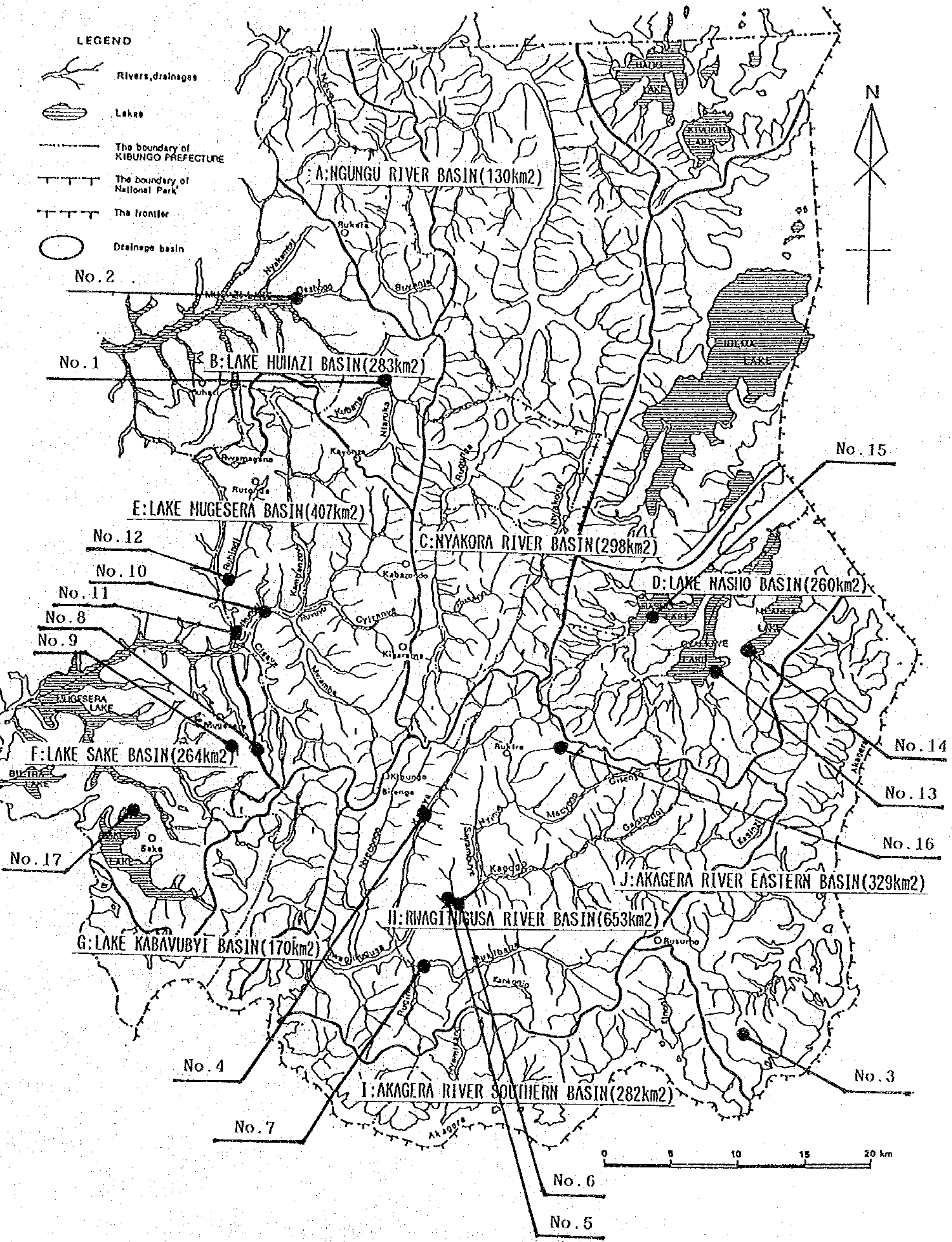
Test Item	Lake Water 30, Jul., 1990 Nontreated Water	Treated Water
Temparature(C)	28	
Turbidity *1	12	2
Color *2	90	25
pH	7.2	
Electrical Conductivity *3	227	
Total Hardness	54.4	
Ca-Hardness	28	
Mg-Hardness	26.4	
Total Alkalinit	59.0	
Free CO2		
Total -Fe	2.9	0.89
KMnO4 Consumed	44.8	44.3
NH4-N	0.02	
Suspended Solids		
(ANION) CI	32.5	
NO2-N	0.05	
NH4-N		
SO4	0.41	
SiO4	19.3	
(CATION) Ca		
Mg		
Mn	0.67	0.02
Fe(III)		
NH4		

Results of Treatment Test by ELECTROGAZ

Sampling Points	Dosage of Treatment Chemicals (mg/liter) Al2(SO4)2 / CA(OH)2	0 / 0	50 / 20	60 / 25	70 / 30	80 / 35	90 / 40	100 / 45
MUHAZI LAKE East	Color APHA	90		3.0				
	pH	8.0	7.5	7.8	8.0	8.0	8.0	8.0
	Turbidity NIU	20		5.3				
	KMnO4	10		2.5				
MUHAZI LAKE West	Color APHA	4.0						
	pH	8.5	8.0	8.3	8.0	8.3	8.0	8.5
	Turbidity NIU	7.5				4.9		
	KMnO4	6.0				1.8		
MUGESERA LAKE	Color APHA	200				0.5		
	pH	8.0	7.5	8.0	8.0	8.0	8.0	8.0
	Turbidity NIU	5.5				3.5		
	KMnO4	15.0				1.6		
SAKE LAKE	Color APHA	200					0.0	0.0
	pH	8.0	8.3	8.0	8.0	7.5	7.0	7.0
	Turbidity NIU	60.0					3.5	2.5
	KMnO4	14.0					1.7	1.5
MUHAZI LAKE RWAMAGANA Water Supply	Color APHA	4.0			2.0			
	pH	8.5	8.0	8.3	8.2	8.5	8.2	8.3
	Turbidity NIU	5.7			4.5			
	KMnO4	5.5			1.9			

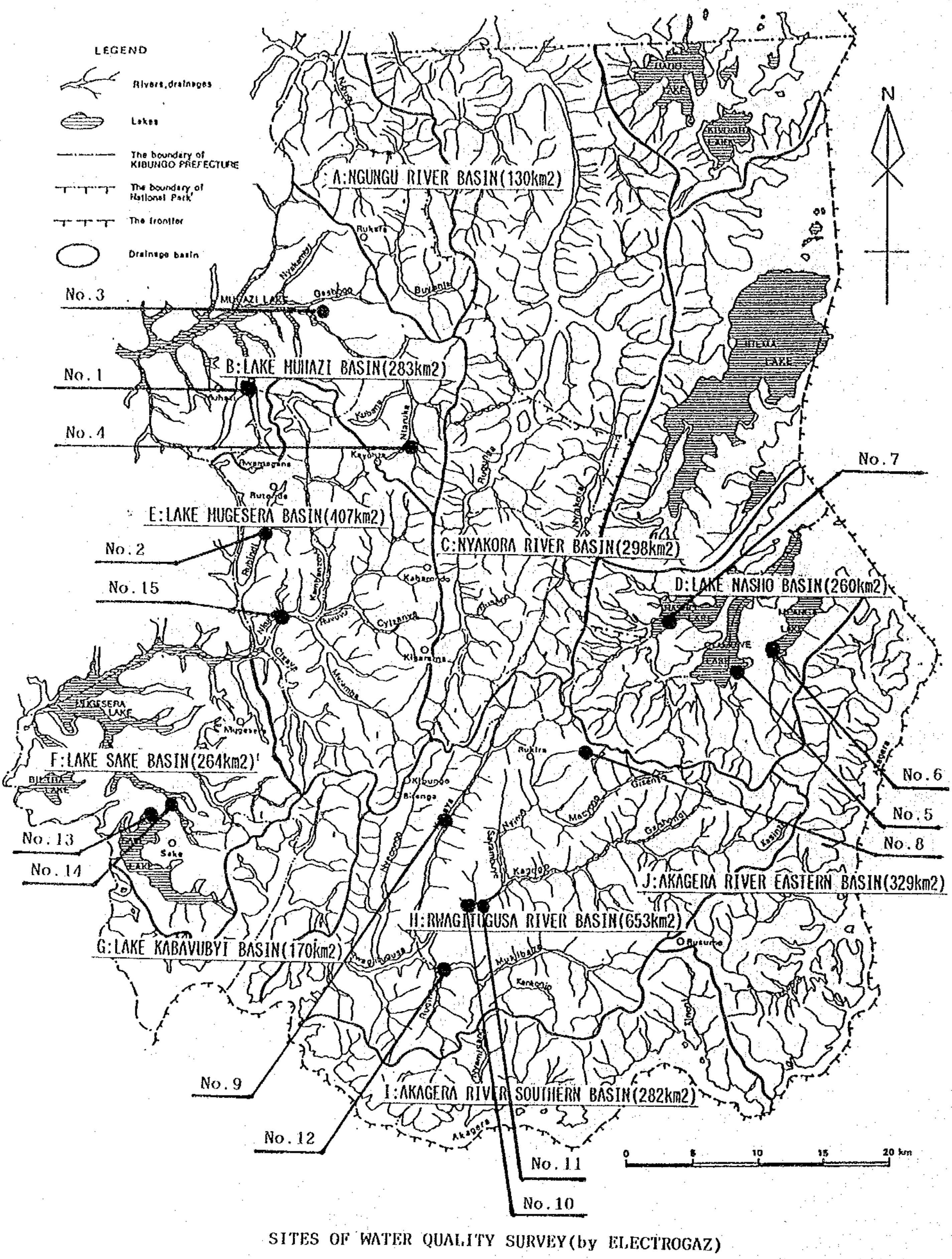


SITES OF HYDROLOGICAL SURVEY



SITES OF PRELIMINARY WATER QUALITY SURVEY(by STUDY TEAM)

Fig. K.3



SITES OF WATER QUALITY SURVEY(by ELECTROGAZ)

APPENDIX L

BASIC CONCEPT OF FORMULATION FOR BASIC PLAN

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BASIC CONCEPT OF FORMULATION FOR BASIC PLAN

1. PRESENT ENVIRONMENT FOR THE BASIC PLAN

In general, to prepare a development plan it is necessary at first to analyze present situation and to identify existing problems that need to be resolved and factors constraining development.

The formulation of the basic plan for the Phase III Project will follow the Phase I Project that was implemented with grant aid cooperation from the Government of Japan and the Phase II Project that is planned to be implemented with financial assistance from the Government of Japan.

The purpose of the Phase III Project is to supply domestic water to all residents in the Kibungo Prefecture. Thus, the Phase III Project Area includes the entire Kibungo Prefecture except for the areas covered by existing urban water supply systems in Rwamagana and Kibungo cities, and the Phase I and Phase II Project areas.

Under the Phase III Project, groundwater, springs, and surface water will be developed as water sources. The present environment of the Phase III Project Area is described in Appendices B through J.

The existing environment/problems and development constraints confronting the establishment of the Water Supply Project in the underdeveloped areas are clarified by dividing them into physical environment and economic and social environment.

By clarifying the environment in view of the formulation of the basic plan for the Phase III Project, the following problems can be pointed out:

1.1 PHYSICAL ENVIRONMENT

The physical environments may be classified into those items relating to water sources, and those relating to the Water Supply Plan.

(1) Items Relating to Water Sources

The precipitation in the Study Area is relatively high. The average annual rainfall here is approximately 1,000 mm while the land in most other African nations is arid.

Many lakes exist in the Study Area including Muhazi, Mugesera, and Sake Lakes. The potential for water resources development is not low.

Topography and Climate

i) However, the areas suitable for constructing shallow wells for domestic water supply, the best suited water resources for drinking purposes because of the their convenience, are limited to the narrow valleys and alluvial lands that are located some distance away from the villages.

ii) The areas suitable for construction of 150 m (approx.) deep wells are located in alternation of schist and hard rock formation areas. These areas have medium to large reliefs and are sparsely populated. The densely populated undulating areas that are composed of soft rock (mainly schist) have little potential for the development of the deep wells, from yield point of view.

iii) The Area's rainfall pattern can be described as having two dry seasons and two wet seasons a year. Precipitation during the four-month long dry season (May to September) is extremely small.

Construction

iv) Deep well construction in hard rock formation areas is considered to be unsuitable on account of costly and well experienced works for extremely hard rock.

Spring Water

v) There are many springs in the Study Area. But, in view of the area's hydrologic cycle, it is assumed that they don't yield water for a long period of time during the year on account of the small catchment areas. During the long dry season, the yield may be small.

vi) A spring water within the Study Area is a small amount and unsettled throughout year as a water sources of planning, except a few springs which are involved within existing water supply system, have a large amount of yield.

Water Quality

vii) Shallow groundwater contaminated is found on low lying land nearby water surface; i.e. lakes, streams and swamps.

viii) As domestic waste water from the villages located in high elevation areas flows in the lakes and rivers, the surface water is heavily contaminated.

Safe Groundwater Yield

ix) As a result of the Area's water balance simulation, it is estimated that the groundwater development potential is in the range of 100,000 to 300,000 m3/km2/year and 27,000 m3/km2 p.a. for sustainable groundwater development.

x) The safe yield for the Project is estimated as less than 102 m3/day for shallow well and 196 m3/day per a well (see Table J.5 of Appendix J). Thus, in view of the aquifers in the Area, a reasonable yield capacity of a well should be from 100 to 300 liter a minute.

(2) Items Related to the Preparation of the Water Supply Plan

Topography and Settlement Pattern

i) The entire Study Area has large reliefs. Water conveying structures, such as pipe lines, will therefore be subjected to large head differences.

ii) Valley lowlands have a high potential for the development of water resources, but villages are located in high elevation areas and on ridges. The installation of services areas and the arrangements of water conveying facilities should therefore be made by taking into account the elevation differences and the locations of large reliefs.

iii) Settlers are widely scatted in undulating to rolling lands and complicate arrangements of water conveying facilities would require planning.

For the present situation and development constraints, above the following subjects were considered:

- A careful examination of water supply conditions during dry seasons would be made.
- Priority given to shallow well construction in valley areas.
- The necessity of constructing deep wells in specific areas would be examined.
- In the case where groundwater is to be developed, it will be necessary to examine the possible groundwater yield and the safe pumping amount.
- In case of where surface water and shallow groundwater nearby water surface are to be developed, it will be required to examine the possible improvement/treatment scheme.
- In the case where shallow groundwater existed, it will be required to construct a well at those parts not close to water surface.
- Water supply facilities would be planned by taking into account the management and operation of the facilities having large head differences and include all safety measures.
- To set up the boundaries of the water service areas and the water supply service level, the distribution of the villages, the topography and the area boundaries would be carefully examined.

1.2 ECONOMIC AND SOCIAL ENVIRONMENT

The economic and social environment/constraints are clarified by classifying them into items concerning water supply facility construction and items related to the management, operation and maintenance of the facilities.

The present conditions of each Secteur, such as population, public services, activities and infrastructure, are summarized in Table L.1.

(1) Items Concerning Water Supply Facility Construction

<u>Topography</u>

i) Because of the characteristics of the area topography, the cost for constructing water supply facilities in the Study Area was considered to be relatively high.

Budget and Institution

ii) Due to the Government of Rwanda's insufficiency of budgetary funds for rural water supply systems and the insufficiency of qualified engineers, the promotion of water supply projects is constrained.

Infrastructure

iii) Infrastructure, such as roads and power supply facilities, in the Study Area are inadequate in comparison to those in other parts of the country. Thus, prior to the improvement of water supply facilities, an improvement of the infrastructure will be proposed. In particular, the access roads to water sources are in insufficient condition.

(2) Items Related to the Management, Operation and Maintenance of Water Supply Facilities

Operation/Management Cost

i) The costs for facility management, operation and maintenance would be considered to be high due to the characteristics of the area topography. Furthermore, low level technique would be required for the management, operation and maintenance works.

ii) To sustain facility management, operation and maintenance works, it would be necessary to adopt a water fee collecting system. But, as the financial capabilities of the residents are not high, it would impractical to adopt such a system for a rural water supply project.

Public Health

iii) Due to the insufficiency of public health and hygienic facility/education, it is considered the occurrence rates of diseases related to drinking water is high. The importance of public water supply facility maintenance work is not fully understood by the residents.

Institution

iv) The supporting system for water supply facility management, operation and maintenance works have not, as yet, been established.

v) Due to the unstable supply of fuel (gasoline and light oil), inadequate management and operating skills, insufficient budgetary funds, and the lack of spare parts, some existing water supply systems are not functioning. In particular, many of the systems using power generator operated pumps are inoperative.

In view of the above development constraints and measures, the examination of the basic policies for the Rural Water Supply Project and of the levels of Project facilities would take into account the following aspects:

- By referring to the size of existing water supply systems and the boundaries of their service areas, the sizes of newly proposed systems and their construction cost limits would be examined.

- For preparing the Project's implementation plan, the budgetary schedule for implementing the Project and for upgrading the technical levels would be taken into consideration.

- The water supply plan would be examined to determine if it conforms to the conditions of existing infrastructures and the future infrastructure development plan.

- The boundaries of water supply service areas would be examined by taking into account the operation and maintenance conditions of the facilities.

- Only after examining the management, operation and maintenance system (including water use fee collecting methods) of the facilities, the necessary continuously sustainable water supply system would be proposed.

- As for water supply recipient contributions, it would be necessary to examine the financial capabilities of the residents and the methods for collecting water use fees.

- To make a proposal for the management, operation, and maintenance system for a water supply facility, it is first necessary to establish a training program to upgrade technical levels, and to provide workers and residents with instructions and information concerning public health and hygiene in order to acquaint them with the need for public water facility maintenance work.

1.3 CLASSIFICATION OF THE DEVELOPMENT LEVEL WITHIN THE AREAS

1.3 CLASSIFICATION OF THE DEVELOPMENT LEVEL WITHIN THE AREAS

The development potentiality of the area is classified as in Table L.1 and Fig. L.1 based on the development level and existing facilities conditions of the area.

The classifications is based on population scale/density, facilities of public services, economic activities and infrastructure levels as follows:

- Vf: Farming village order
- Vs: Service village order
- LT: Locality town order
- D : District center
- H : Higher district center

The classifications will be taken into consideration of water supply development planning.

2. BASIC DEVELOPMENT POLICY

The service coverage rate of the water supply in the Study Area is low. Furthermore, the existing water supply facilities provide an unsuitable supply of water. Many residents use unsanitary water and must exert a great deal of energy to obtain it. However, as a result of water balance simulation, it was found that sufficient water resources exist in the Study Area.

The main objective of the Phase III Project is to provide the residents of Kibungo Prefecture with a safe and stable rural water supply.

2.1 BASIC POLICY OF THE DEVELOPMENT

By examining the Government of Rwanda's development policies, the intention of MINITRAPEE, and the present condition of the Study Area, it was apparent that the Rural Water Supply Project (Phase III) in the Eastern Region was based on the following development policy:

(1) To Promptly Provide Maximum Benefits to Residents Using a Limited Amount of Funds

For the residents to receive prompt benefits of a water supply within the limitation of appropriate grade of the Project's water supply systems.

The purpose of the water supply system is considered to improve sanitary conditions and eliminate to a great extent the arduous task of fetching the water (a task that is relegated the women and children).

(2) To Select the Most Appropriate Technology for the Area

By taking into consideration the present environment and development constraints in the Study Area (described in Section 1 of Appendix L), a plan should be made to determine what technology would be most appropriate for the Area. In particular, the following aspects should be considered:

- The highest priority should be given to such water distribution facilities requiring the easiest and most economical operation and maintenance work.

- High quality of water should be utilized to the greatest extent.

- The operation and maintenance of the water supply system will require cooperation from the residents.

- Step-by-step water supply development should be carried out in pace with the development of infrastructures.

(3) The Selection of Water Supply Areas by Taking into Account the Management, Operation and Maintenance of the Facilities

The water supply areas vary in size depending on the type of system to be adopted. For the smooth future introduction of the management, operation and maintenance system and the water fee collection system, the basic unit for a water supply area will be examined.

(4) To Establish a Water Supply Plan that Corresponds to the Financial Capabilities of Residents and the Infrastructure Conditions

The introduction of higher level of water supply methods and service standards should be examined based on the financial capabilities of area residents and the infrastructure conditions.

(5) Conformity with the Higher Level Development Plan and Related Projects

The Basic Plan for Rural Water Supply should be formulated in conformity with the higher level development plan, the Fourth Five-year Sectorial Development Strategies (1987-1991) of MINITRAPEE, as well as with the related projects presently being carried out in the Study Area.

(6) To Provide All Residents with a Constantly Supply of Safe and Sanitary Water by the Target Year.

To realize the President's promise to the people to give the highest priority to supply safe and stable drinking water to all residents of the Prefecture by the year 2000.

Thus, The Project's target year is 2000 on the basis of the national development policy.

3. DEFINITION OF THE PLANNING AREA

3.1 PROSPECTS OF EXISTING AND PROJECTED WATER SUPPLY SYSTEMS

Of the existing and projected water supply facilities, the following can satisfactorily meet present demands even though they may require reexamination in the future:

- wells bored with grant aid from Japan under Rural Water Supply Project, Phase I;
- water supply facilities covered by Phase II;
- the water supply facilities of Kibungo and Rwamagana cities which are managed and operated by ELECTROGAZ, and comparatively new water supply facilities located in Nyokibatika, Kirehe and Rukara; and
- water supply facilities that are being rehabilitated with financial assistance from IDA and facilities being improved under the Water Supply Facility Improvement Project in Kabarondo.

3.2 CLASSIFICATION OF EXISTING WATER SERVICE AREAS

In the Study Area, there are some existing water supply systems and on-going water supply projects by other official agency besides this Project (described in Appendix F). A few existing and planned systems which are considered to be able to satisfactorily meet water demand within the service areas, will be excluded from the Project Area of Phase III as a existing water service areas.

The conditions of the existing systems are discussed/evaluated in Appendix F. Based on the evaluation, the Study Area is divided into five zones to conform with other projects and avoid the redundant project as follows:

ZONE A:[Phase I Project Supply Area]

Phase I project which was formulated by Feasibility Study of 1985, has been executed under Japanese Grant Aid in 1986 and 1987. The project sites were divided into four service areas and main construction works of 71 manual pump wells, one piped water supply system with pump and three rain storage tanks were accomplished in 1989.

ZONE B:[Phase II Project Supply Area]

Phase II project also was formulated as groundwater development by F/S of 1985 and is planned to construct 114 wells through over eight service areas. Phase II project will be implemented by the Government of Rwanda.

ZONE C:[Existing Water Supply Area]

The area is served by the urban water supply facilities of Kibungo and Rwamagana Cities and the existing rural water supply facilities which are functional and not necessary to be rehabilitated at present.

ZONE D:[On-going Project Area]

11 existing water supply facilities are being rehabilitated with financial assistance from IDA (Refer to Section 7 of Appendix F). The Water Supply Facility Improvement Project in Kabarondo is on-going project under MINITRAPEE. This area is served by the above projects.

ZONE E:[Phase III Project Supply Area]

Zone E is the area excepted the above mentioned Zone A, B, C and D from the Study Area, and proposed the new water supply facilities by Phase III project.

The locations of the zones are shown in Fig. L.2 (except Zone E of Phase III Project Area) and the population/area of each Secteur by each zone is given in DATA BOOK.

The capacity in each system of zones A to D basically meet the water demand within the service area. However, in year 2000, it will be required to re-examine the system capacity and/or facilities for the areas served by the existing water supply systems because the future water demand will exceed the present system capacity.

Each water supply area is computed and the future population in each area is forecasted based on each Secteur's population density. It is estimated that 369,700 peoples will receive water supplies within Zone-E, in 2000.

Population and Area of Each Zone

Zone	Project	Area (km2)	Population (1988)	(2000)
Zone A	Phase I	183	34,200	51,600
Zone B	Phase II	373	56,500	85,200
Zone C	Existing	195	38,400	57,900
Zone D	On-going	222	59,000	89,100
Zone E	Phase III	1,694	244,900	369,700
	Total	2,667	433,000	653,500

The number of households and the water supply demand in areas not covered by the existing water supply systems (Zones A and C) and systems to be constructed under on-going projects deviate from those planned in Phase III Project. The reasons for the deviations are due to the differences in the planning policy for each project, each project's target year, the method used for calculating the design water supply amount, etc.

It would be difficult to rectify this problem in the Rural Water Supply Project (Phase III) in the Eastern Region. It is believed, however, that the deviations will be cleared up during the next stage.

3.3 THE PROJECT'S WATER SUPPLY AREA

The Project's water supply area (Zone E) is approximately 1,700 km2 and population served will be 369,700 peoples. This takes in entire Kibungo Prefecture except for those areas already having water supply systems (Zone A and C) and area where water supply plans have already been made (Zone B and D).

Since the existing water supply facilities such as;

Rusumo BGM,
Musaza Bas,
Kamushikuzi and
Sake

are not fully functional, these water supply areas are included in the Project Area (Zone E).

Prospects of existing and projected water supply systems in the Study Area is described in Appendix F.

4. SELECTION OF WATER SUPPLY SYSTEM OPTION

To select water supply system methods, the following water supply options are considered to be listed up, referring to the general options of water supply as in Table L.2.

4.1 EXAMINATION OF WATER SUPPLY SYSTEM POSSIBLE TO INSTALL

The possibilities for installing water supply system options A through I (see Table L.3) were examined from the viewpoint of;

1) natural conditions, such as water sources and topography,
2) water use, facility operation and management conditions and
3) economic aspects.

The examination results were as shown in Table L.4. Options A, B, D, E, F, and H can be selected as possible systems to be installed. However, Options A and H should be selected by taking into account the following points:

Option A: As most of the springs having large water yield amounts are already used for existing water supply systems, it would be more realistic to select Option A by combining it with Options D, E, or F.

Option H: Dry seasons in the Study Area continue for several months and it is difficult to secure sufficient amount of water. It would be appropriate to select Option H as a low priority system as the final selection choice.

4.2 OPTIONS FOR THE PHASE III PROJECT

By clarifying the examination results, the following four water supply systems are thought to be appropriate for installation in the Phase III Project because they are suitable for the area characteristics of Kibungo Prefecture and because they satisfy the basic policy of the Phase III Project:

System 1: Medium-scale piped water supply system, Option F plus Option A (use spring water within the capacities of available springs)
System 2: Small-scale piped water supply system, Option D or F plus Option A (use spring water with the capacities of available springs)
System 3: Shallow well with hand-pump system, Option B
System 4: Roof catchment system, Option H (to be selected as a final choice only in special cases)

5. THE CHOICE OF WATER SOURCES

5.1 GENERAL CONDITION

The annual precipitation in the Study Area is approximately 900 mm. In comparison with the arid neighboring African countries, the Study Area has a large amount of water resources.

The descriptions of water resource conditions in the Study Area are given in Appendix K. In view of the rural water supply, it would be advantageous to make the water source selection with priority given in the following order and by taking into account construction costs, reduction of costs for management, operations, and maintenance, and easy management and operation work:

1) Groundwater

According to the water balance simulation, the amount of groundwater flow resulting from groundwater nourishment and outflow is estimated to be approximately 200,000 m3/km2 p.a. It is believed that the groundwater is pumped up. Thus, from the viewpoint of groundwater preservation there will be no problems.

If the whole domestic water demand of Kibungo Prefecture relies on the groundwater source by the year 2000, about 5.3 m3/day/km2 of water must be pumped up.

i) Springs:
In general, spring water does not need to be treated except for a disinfection by chlorine. It can be distributed by gravity flow because most springs are located in high elevation areas. For these reasons, springs are the most desirable water sources. However, existing springs in the Study Area have already been developed and only a few will be available for Project use, except small springs which are considered to be unavailable for system design.

ii) Well:
Except for artisan wells, pumps are required to make use of groundwater. Since groundwater does not need to be treated, it is the most desirable water source as well as spring water.

However, in case of where shallow groundwater nearby water surface (area of "Sa") are to be developed, it will be required to examine the possible improvement and protection scheme.

2) Surface Water:

The water in the rivers and lakes in the Study Area is extremely contaminated by domestic sewerage and would require treatment before use. As the medium and small size rivers dry up during the dry season, lake water can be used at this stage because of the large amount and less fluctuation of lake water table.

3) Rainwater Harvesting:

Rainwater is a promising water source in mountainous areas where the previously described sources are not available. However, during the dry season an alternate water source must be provided. Rainwater on the roof of public facilities could be utilized as the supplemental water source.

The evaluations of water sources are outlined in Table L.5.

5.2 DEVELOPMENT PRIORITY OF WATER SOURCES

By taking into consideration the climate, topography, village distribution conditions, income of residents, existing water supply facilities, and the infrastructure in the Study area. In addition to the water source development potential, the water source development concept of the basic plan for the Phase III Project is as follows:

1) To give priority to the development of springs and groundwater that require minimum water treatment costs.

   - Springs are located in high elevation areas and the water can be distributed by gravity flow. Thus, springs having large water yield amounts are already being used as water sources. For future water source development, more reliance should be placed on groundwater.

   - As the locations and water yield mounts of small size springs are uncertain, they will be regarded as supplemental water sources without being developed for the Project.

2) To develop surface water in those areas where it would be difficult to develop springs or groundwater.

   - Surface water can be obtained from rivers or lakes. The contamination levels of river and lake water are about the same; therefore, lake water will be used because of its stable supply.

- To use lake water, a means must be devised to prevent the intrusion of decomposed aquatic plants and algae.

3) To install rainwater harvesting systems is sparsely populated hill area.

- To make the installation realistic, the supply amount should secure the resident's minimum necessary amount of water of 3 liters/person/day.

At this planning stage, the development potentiality of water resources for the water supply systems is presented in Table below taking into consideration of water quality, water quantity and water conveying system.

Water Resources	Water Quality	Water Quantity	Gravity Water Supply	Rank Out Development Potential
Spring	Good	Stable/ Unstable	Possible	1
Groundwater	Good	Stable	Impossible	1
Rainwater	Good	Unstable	Possible	2
Lake	Bad	Stable	Impossible	3
River	Bad	Unstable	Impossible	4

6. EXAMINATION OF SERVICE BLOCK

6.1 PRESENT CONDITION OF WATER SUPPLY SERVICE BLOCK

The water supply area should be classified into the following three groups; each group should have an appropriate water supply system:

a) Large Water Supply Area:
The area consists of from 5 to 8 Secteurs. The population served in the area ranges from 20,000 to 40,000.

b) Medium Water Supply Area:
This area basically comprises one Secteur. The population served in the area is from 2,000 to 10,000.

c) Small Water Supply Area:
Point water source such as a well or spring, etc. will supply residents living within a range of one kilometer from it in this area.

6.2 CONSIDERATION OF SERVICE BLOCK

The water supply system options proposed for the Phase III Project are as follows:

System 1: Large-scale piped system
System 2: Small-scale piped system
System 3: Shallow well with hand-pump
System 4: Roof catchment

Based on the present situations of water supply service block mentioned above, the service block sizes and boundaries of these systems are to be planned as follows:

(1) System 1
As a water treatment facility and a power operated pump are to be installed for this system, it will be necessary to set up a large service block to minimize the initial investment costs and running costs per recipient family.

On the other hand, if the service block is too large the water distribution piping network becomes very complicated and a high level of operation and maintenance techniques would be required.

By taking into account the topographic and population distribution conditions and the sizes of the existing water supply service blocks in the Study Area, the maximum boundary of the System 1's service block should be as follows:

Population: 20,000 to 40,000
Area : Approximately 50 km3

By taking into consideration the future operation and maintenance organization structure, one service block should not cover more than one commune.

(2) System 2
According to the capacity of an average well (deep well) the maximum service block of System 2 should be the area that can be covered by the water supply amount of 200 m3/day with two wells.

(3) System 3
The service block size for System 3 would be controlled by the shallow well capacity. In a sparsely populated area, the service block to be covered by one well should be approximately 4 km2 and that in dense population area should be covered less than 4 km2.

(4) System 4
Since a roof catchment facility will be installed per house, the service block (unit) for System 4 would be per household.

Condition of Service Block

Item	System-1	System-2	System-3	System-4
Object Area	High potential and Developed Area in Difficult Area of Introduction of Hand Pump	Developed Area in Difficult Area of Introduction of Hand Pump	Shallow Well Development Suitable Area	Mountainous Underpopulation Area
Area Scale	40km2	10～20km2	<4km2	-
Beneficial Population	20,000～40,000	4,000～8,000	<500	6～8/family

7. MODEL STUDY

7.1 GENERAL

The following model studies were conducted to obtain the basic data necessary for examining capital cost per capita and the selecting conditions for introducing Systems 1 or 2 in each water supply system service block.

(1) Model Study 1
By assuming the service area as being 40 km2 for the introduction of System 1, per capita capital cost and per household operation and maintenance cost were estimated for each case of the serving population of from 4,000 through 35,000 in increments of 1,000.

(2) Model Study 2
By assuming the serving population as being 20,000 for introducing System 1, the per capita capital cost and per household operation and maintenance cost were estimated for each case of the service area of 10 km2 through 50 km2 in 10 km2 increments.

(3) Model Study 3
By assuming the service area as being 10 km3 for introducing System 2, the per capita capital cost and per household operation and maintenance cost were estimated for each case of the serving population of from 1,000 through 7,000 in increments of 1,000.

7.2 RESULTS OF THE MODEL STUDIES

Per capita capital cost and per household operation and maintenance cost estimated in each Model Study are shown in Table L.6. The base conditions for the cost estimation and calculation form were as shown in Table L.7 and L.8.

(1) Definition of the Maximum Capital Cost and the Maximum Operation and Maintenance Cost

For introducing the high service levels System 1 and System 2, the maximum per capita capital cost and the maximum per household annual cost are to be set to prevent the Systems from being over-sized.

<u>Maximum Per Capita Capital Cost</u>
The maximum per capita capital cost as the bases for introducing System 1 or System 2 is to be US$150 by taking into consideration the actual cases in developing countries and the actual capital cost of System 3 introduced in sparsely populated area.

- Actual Cases in Developing Countries

According to the World Bank's report, the upper limit of per capita capital costs of rural water supply systems in developing countries is approximately US$100 (see the following table).

Community Water Supply Technology Costs (For a community of 400 people)

Technology	Low			High		
	Handpumps	*Standpipes*	*Yardtaps*	*Handpumps*	*Standpipes*	*Yardtaps*
Capital cost (US$)						
Wells[1]	4,000	2,000	2,500	10,000	5,000	6000
Pumps (hand/motor)	1,300	4,000	4,500	2,500	8,000	9000
Distribution[2]	none	4,500	16,000	none	10,000	30000
Sub-total	5,300	10,500	23,000	12,500	23,000	45000
Cost per capita	13.3	26.3	57.5	31.2	57.5	112.5
Annual cost (US$/year)						
Annualized capital[3]	700	1,500	3,200	1,400	3,000	6000
Maintenance	200	600	1,000	400	1,200	2000
Operation (fuel)	none	150	450	none	300	900
Sub-total (cash)	900	2,250	4,650	1,800	4,700	8900
Haul costs (labor)[4]	1,400	1,100	none	3,000	2,200	none
Total (including labor)	2,300	3,350	4,650	4,800	6,900	8900
Total annualized cost per capita						
Cash only	2.3	5.6	11.6	4.5	11.8	22.3
Cash + labor	5.8	8.4	11.6	12.0	17.3	22.3

SOURCE : COMMUNITY WATER SUPPLY BANK (World Bank)

- Actual Per Capita Capital Cost and Per Household Operation and Maintenance Cost in Sparsely Populated Areas

Actual per capita capital costs and per household operation and maintenance cost of System 3 in sparsely populated areas are as shown below:

Population Density	Per Capita Capital Cost	Per Household Operation and Maintenance Cost
40/km2	US$310	US$1.69/month
50/km2	US$250	US$1.37/month
100/km2	US$125	US$0.77/month

Maximum Running Cost per Household

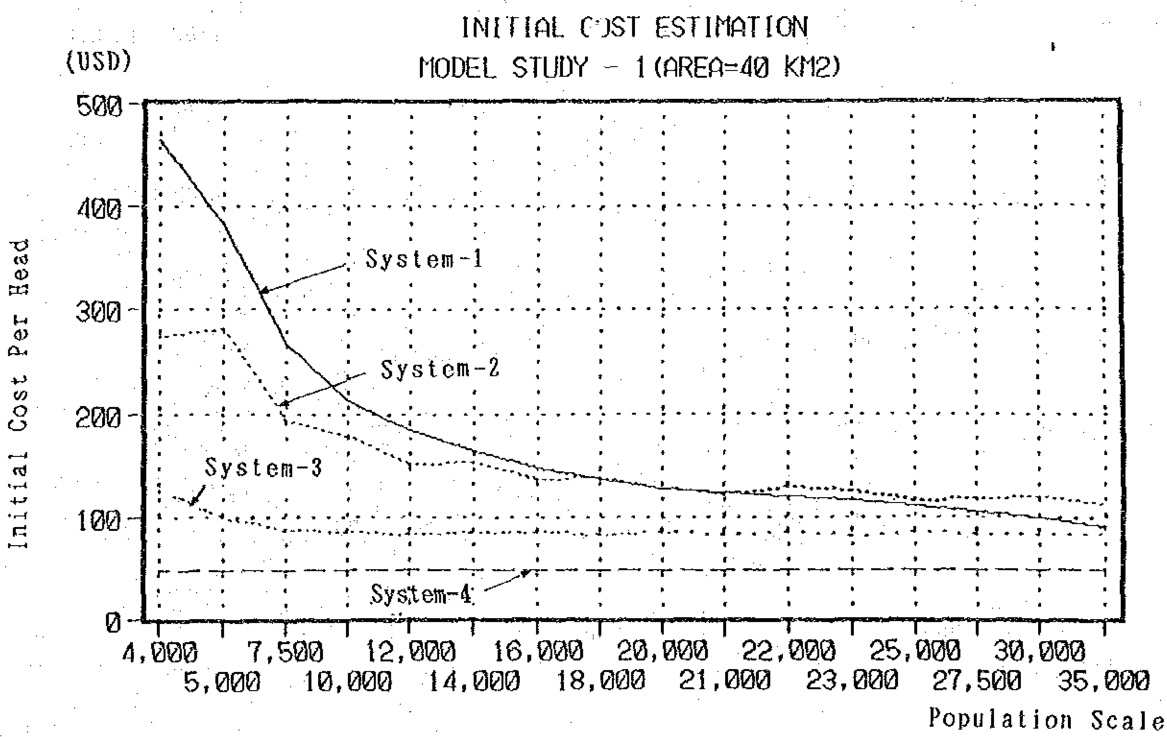
In developing countries, if the capital costs of water supply projects had to be paid (included in the water fees) by the water receiving residents, the projects could not be implemented because the residents would be unable to pay the costs because of their low incomes. For this reason, based on WHO's study results, the World Bank defines it to be appropriate that only the operation and maintenance costs of water supply facilities should be paid as water fees by the residents and that 10% of project construction costs be paid in the form of a labor service by the residents. Furthermore, it is defined that water fees should be less than 5% of household expenditures.

By adopting the World Bank's definition, it is believed to be appropriate that the per household operation and maintenance costs for the Phase III Project's facilities are to be less than 5% of the household expenditures, US$1.50 to 2.00/month/ household.

(2) Population Scale for System 1 Selection

In such areas where it would be difficult to construct shallow wells and where there are concentrated population distribution patterns within the areas, System 1 or System 2 will be installed. The population factor would be an important factor for the selecting conditions of System 1.

Per capita capital cost for different population scales was obtained in the Model Study 1 (a service area of 40 km2) as shown in the following Figure. When an area has a population of more than 21,000, the per capita capital cost of System 1 is less than for System 2. The cost is also less than the maximum per capita capital costs of US$150.



(3) Population Density for System 2 Selection

In addition to areas having difficulties in constructing shallow wells and have population concentrated regions within the areas, System 2 will also be installed in such areas where per capita capital cost of US$150 and the maximum per household running cost of US$2/month which are examined in Appendix P.

The population density of areas to suit installing System 2 was obtained as being more than 600/km2 by the Model Study.

Examination of the Capital Cost
As shown in the following Table, the capital cost for System 2 in an area having a population density of more than 600/km2 becomes less than the US$150 per capita.

MODEL STUDY - 3

Area = 10km2(constant) Unit : US$/capital

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
1,000	100	1,075.3	494.0	150.0	48.4
2,000	200	559.0	255.3	100.0	48.4
3,000	300	387.0	175.7	83.3	48.4
4,000	400	300.8	155.9	87.5	48.4
5,000	500	249.2	170.5	90.0	48.4
6,000	600	214.8	144.8	83.3	48.4
7,000	700	190.2	126.5	85.7	48.3

Examination of the Operation and Maintenance Cost
As shown in the following Table, when the areas' population density is more than 200/km2, the per household operation and maintenance cost becomes less than US$2/month.

MODEL STUDY - 3

Area = 10km2(constant) Unit : US$/month/family

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
1,000	100	6.92	2.90	0.90	0.12
2,000	200	4.24	1.92	0.65	0.12
3,000	300	3.34	1.60	0.57	0.12
4,000	400	2.90	1.43	0.59	0.12
5,000	500	2.63	1.56	0.60	0.12
6,000	600	2.45	1.46	0.57	0.12
7,000	700	2.32	1.38	0.58	0.12

(4) Extension of System 1 or System 2 to Shallow Well Suitable Areas

A condition to extend System 1 or System 2 (both having distribution pipelines) to the neighboring shallow well suitable areas is to be such that the cost to extend System 1 or System 2 are less than shallow well construction costs (including hand-pump installation costs) in the neighboring area.

Extending costs (to an area of 4 km2) = US$210,000 (costs for pipeline, public standpipe, and additional container installation).

Shallow well construction costs for an area of 4 km2 were estimated per different population density as shown in the following table.

Shallow well Construction Cost per 4 km2

(Unit : 1,000USD)

Population (pers./km2)	Classification Sa	Sb, Sc	Sd
250	100	120	120
300	100	120	180
375	150	180	180
400	150	180	240
500	200	240	300
600	200	240	300
700	250	300	300

Thus, System 1 or System 2 is to be installed in such areas whose shallow well construction costs exceed the extending costs for System 1 or System 2.

Sa Region : Areas having a population density of more than 700/km2

Sb and Sc Region: Areas having a population density of more than 500/km2

Sd Region : Areas having a population density of more than 400/km2

8. SYSTEM SELECTION PROCEDURES

8.1 BASIC CONCEPT FOR SYSTEM SELECTION

When a water supply system for a certain area is to be selected from water supply system options, the following basic concepts should be applied:

1) Priority should be given to System 3 (hand-pump installation) for the following reasons:

   - Its per capita capital cost and per household operation and maintenance cost are less than for other Systems.
   - It can be constructed by Rwandan themselves.
   - It can be operated and maintained by local residents.
   - Residents can participate in its construction and it can be managed by a residents' operation and maintenance organization.

2) In areas having difficulties in constructing System 3 (shallow wells with hand-pumps), the water supply systems should be planned as follows:

   a) In areas having population concentrated regions or public facility concentration regions, System 1 or System 2 should be installed by taking into consideration the balance with existing water supply systems in the surrounding areas. However, the new systems' per capita capital cost and per household operation and maintenance cost should not exceed the maximum per capita capital cost and the maximum per household operation and maintenance cost.

   As the results of Model Studies, the selection standards for System 1 and 2 are as follows:

   System 1: For an area having population concentrated regions and the number of residents to be provided with the water supply system are more than 21,000.

   System 2: For an area having population concentrated regions or having a population density of more than 600/km2.

For the appropriateness and evaluation of the system selection, the following two basic points should be taken into consideration:

- The maximum per capita capital cost of US$150
- The maximum per household operation and maintenance cost of US$2.00/month

b) In a sparsely populated hilly area, if the per capita capital cost and per household operation and maintenance cost are higher than the maximum values, it is recommended to install such a system even though the planning policies are not 100% satisfied.

System 4: Rainwater harvesting: Reduce the per capita supply amount (3 liters /person/day)

According to the basic frame of system selection, flow chart for system selection in the proposed service block is decided as shown in Fig. L.3.

8.2 EVALUATION CONDITION OF SELECTION PROCEDURES

(1) Selection of Shallow Well Development Area

According to the study results of groundwater development potential, the shallow well suitable areas were classified into the following four groups and the construction cost index and pumping amount for each group were set up as follows:

	Construction Cost Index	Pumping Amount
Sa	1.0	10 m3/day
Sb	1.25	10 m3/day
Sc	1.25	10 m3/day
Sd	1.0	8 m3/day

(2) Selection Conditions for System 1 and System 2

The operation and maintenance costs of System 1 and System 2 become less than US$2.00/household/ month when their population scales are as follows:

Over 18,000	:	System 1
Over 4,000	:	System 2

The capital costs of System 1 and System 2 become less than US$150/person when their population scales are as follows:

Over 21,000	:	System 1
Less than 21,000	:	System 2

As a result, System 1 is preferable when the population scale is over 21,000.

(3) Conditions of Pipeline Extension to Shallow Well Suitable Areas

As a result of Model Studies, pipeline extension should be selected when its construction costs become less than that of shallow well construction under the following population scales:

Sa	:	Over 700/km2
Sb and Sc	:	Over 500/km2
Sd	:	Over 400/km2

(4) Maximum Per Capita Capital Cost

As a result of Model Studies, the maximum per capita capital costs for water supply systems in the Study Area, other than shallow well suitable areas, are to be US$150.

The maximum operation and maintenance costs are to be US$2,00/household/month including system replacement cost and US$1.50/household/month excluding the system replacement cost.

8.3 SELECTION OF WATER SUPPLY SYSTEMS IN EACH SERVICE BLOCK

As a result of the discussion in Section 4.1 and 4.2, the following 4 systems would be adopted as a water supply system in Phase III Basic Plan.

System 1:	Large scale piped supply system
System 2:	Small scale piped supply system
System 3:	Shallow well + Handpump
System 4:	Rainwater harvesting

Fig. L.4 and Table L.9 show the adopted systems of service blocks in the Project Area, which are selected based on the system selection procedures presented in Section 8.2 above.

System	Number of Service Blocks	Service Area (km2)	%	Population served	%
1	2	94.0	5.6	55,800	15.0
2	8	102.2	6.0	51,000	13.8
3	477 W	1,009.9	59.6	215,400	58.2
4	8,351 F	487.0	28.8	47,700	12.9
Total	8,838	1,693.1	100.0	369,700	100.0

Note: W = wells, F = families

System 3 (Handpump) is basically adopted in the area where the shallow well development is suitable. In the area where is not suitable for System 3, System 1 and 2 are adopted in the population concentrated area while System 4 in the sparsely populated area.

The service area and population served of communes by each system are tabulated in Table M.1. It is standing out that the developed or improved comparatively, has a large population served.

		POPULATION(1988)			SERVICE					PUBLIC UTILITIES/INFRST.			ACTIVITIES		
		Area	Total	Density (/Km2)	Health	Education	Bus-Trans.	Admi.	Commerce	Water Supply	Elect.	Road	Indust. Develop.	Finance	OTHERS
[KIGARAMA]															
FUKWE	LT1	5.3	4,092	772.1		P	○			(P)	○	N		B	
GASETSA	Vf	23.7	2,653	111.9		P				W,P		L			
GASHANDA	Vs2	16.4	2,875	175.3		P	○			(W),(P)		N			
KABARE-1	Vs1	16.9	2,868	169.7	HC	P(2),S	○			P	○	IN,L			
KABARE-2	Vs2	72.4	5,130	70.9		P			M	W,(W)		L			
KABERANGWE	Vf	32.4	3,623	111.8		P(2)				W,P		C			
KANSANA	Vs2	19.3	3,646	188.9		P(2)	○			(P)	○	N			
REMERA	LT2	17.6	2,660	151.1		P	○	CC	S,WsM,M	P	○	IN,L			
RUBONA	Vf	23.7	5,814	245.3		P(2)				(W)		L			
RURENGE	Vf	21.9	2,442	111.5		P				W		L			
VUMWE	Vf	23.7	3,756	158.5		P				W	○	C			
-total-		273.3	39,559	144.7											
[RUKIRA]															
GASIRU	Vs2	29.4	4,197	142.8	DP		○		M	(P)	[○]	L			
GITUKU	Vs2	23.0	3,607	156.8		P	○		M	W,(W,P)	[○]	C			
GITWE	LT3	31.0	4,149	133.8		P,S	○			W,(W,P)	[○]	C	Rc		
MUBAGO	Vf	14.3	3,982	278.5		P				(W,P)	[○]				
MURAMA	LT1	10.8	3,582	331.7	NC,DP	P	○	CC	S	W,(P)	[○]	IN,N	Rc	B	
MUSHIKILI	Vf	53.8	3,605	67.0		P(2)				(W)					
NTARUKA	Vf	34.2	2,707	79.2		P(2)	○			(P)	[○]	C			
RUGARAMA	Vf	28.5	2,533	88.9		P	○			W,(W,P)	[○]	C			
RURAMA	LT1	13.5	3,725	275.9		P	○		WsM	(P)	[○]	N,C			
RURENGE	Vs2	14.7	3,883	264.1		P(2)	○		M	W,(P)	[○]	IN,N			
-total-		253.2	35,970	142.1											
[BIRENGA]															
BARE	LT3	31.4	3,178	101.2	NC,DP	P(2)	○		WsM	(W)	[○]	C		B	
BIRENGA	Vs2	27.7	3,237	116.9		P(2)	○			(W)	[○]	C			
GAHARA	Vs2	61.5	5,924	96.3	NC	P(3)			M(2)	(W)	[○]				
GAHULIRE	Vs1	11.4	3,107	272.5		P	○			(W),P	[○]	N,L	Rc		
GASHONGORA	Vf	32.4	4,581	141.4		P(2)				W,(W)					
KIBAYA	Vs1	7.0	2,566	366.6		P					[○]	IN,L			
KIBARA	Vf	13.0	2,615	201.2		P	○			W,(W)		L			
KIBIMBA	Vf	14.1	2,187	155.1		P	○			(W)	[○]	C			
KIBUNGO	H(D)	12.2	3,400	278.7	HP	P,S(2)	○	[CC,CH [PO,PG	S,WsM,M	P	○	IN,N,L	GS(4),Rc	B(2)	MC(3)
MATONGO	Vf	24.4	4,620	189.3		P				(W)		C			
NDAMIRA	Vs1	9.3	2,579	277.3			○				[○]	IN			
SAKARA	Vs1	19.2	5,419	282.2		P			M	W,(W)		L			
-total-		263.6	43,413	164.7											
[RUSUMO]															
GATORE	Vs2	60.7	7,731	127.4		P(3)	○			W,(W)	[○]	IN,N,L			
GISENYI	Vs2	38.3	3,661	95.6		P			M	(W,P)		L			
KANKOBWA	Vf	217.8	7,504	34.5		P(3)				P,(P)	[○]	L			
KIGARAMA	Vs2	110.4	7,911	71.7		P(3)	○		M	(W)	[○]	IN,L			
KIGINA	LT3	52.9	6,871	129.9	HC,NC	P(3)	○		S,WsM	P,(W)	[○]	IN,L		B	
KIREHE	LT3	41.2	6,375	154.7	NC,DP	P(3)	○	CC,CH	S	W,P,(P)	[○]	IN,L	GS		
MUSAZA	Vs2	70.5	8,212	116.5		P(2)			M	(W)	[○]	L			
NYABITARE	Vf	34.3	4,062	118.4		P(3)				(W,P)		C			
NYAMUGALI	Vs2	93.5	5,271	56.4		P(2)	○		M	(P)	[○]	IN,L			
NYARUBUYE	LT3	69.2	6,505	94.0	HC(2),NC	P(3)			WsM	(W,P)	[○]	C	Rc		
-total-		788.8	64,103	81.3											

(continue)

		POPULATION(1988)			SERVICE					PUBLIC UTILITIES/INFRST.			ACTIVITIES		
		Area	Total	Density (/Km2)	Health	Education	Bus-Trans.	Admi.	Commerce	Water Supply	Elect.	Road	Indust. Develop.	Finance	OTHERS
[SAKE]															
GITUZA	Vs2	12.0	3,260	271.7		P						N,L			
MABUGA-1	LT1	6.7	2,777	414.5			○	CC	S,WsM	(P)	○	N,L	Rc	B	
MABUGA-2	LT1	6.3	2,677	424.9	HC,NC,DP	P					○	N,L	Rc		
MBUYE	Vs2	17.2	3,577	208.0		P				(W)		L	Mn		
MURWA	Vs1	36.3	4,175	115.0	HC,NC	P			M	(W)		L			
NGOMA	Vs1	8.7	2,721	312.8		P	○		M	(W)	○	N,L			
NSHILI-1	Vs1	8.0	3,873	484.1			○			(P)	○	N,L			
NSHILI-2	Vs1	5.8	2,654	457.6		P				(P),(W)	○	L			
RUBAGO	Vs2	8.5	3,442	404.9		P						N,L			
RUKUMBERI	Vs2	16.0	3,886	242.9		P			M			C,L			
RUYEMA-1	LT1	2.8	2,145	766.1			○			(W)		N,L			
RUYEMA-2	Vs1	3.4	2,113	621.5		P	○			(W)	○	N,L			
SHOLI	Vf	14.4	3,541	245.9		P(2)						C,L			
-total-		146.1	40,841	279.5											
[KAYONZA]															
GASOGI	Vf	14.4	3,011	209.1		P	○				(○)	IN,L			
KAYONZA	LT1	12.9	3,523	273.1		P	○		S,WsM		(○)	IN,C,L	GS(2),Rc	B	
MBURABUTURO	Vf	9.6	2,223	231.6								L			
MUSUMBA	Vs2	19.3	2,660	137.8		P	○				(○)	IN,L			
NYAMIRAMA	LT1	18.8	3,776	200.9		P	○	CC			(○)	IN,L			
RUTARE	Vf	12.6	2,631	208.8		P									
RWINKWAVU	LT3	95.2	5,304	55.7	HP	F(6)	○		M	W	○	C,L	(GS),Mn	(B)	
SHYOGO	Vs1	7.2	2,825	392.4		P	○				(○)	IN,L			
-total-		190.0	25,953	136.6											
[RUTONDE]															
KADUHA	Vf	16.3	3,653	224.1		P(2)				W					
KIGABIRO	E	3.4	3,733	1097.9		P(3),S(2)	○	CC,CH,P	WsM	P	○	IN,C,L	GS,Rc	B	MC
NKUNGU	Vf	10.9	3,243	297.5		P				W		C,L			
NSHINDA	LT1	8.1	3,116	384.7		P	○		S	P	○	IN,C,L			
NYARUSANGE	LT1	10.5	3,524	335.6		P	○		S	P	○	IN,L	GS		
RUTONDE	Vs1	14.3	3,660	255.9		P				W	○	L		B	
RWERU	Vf	7.5	3,581	477.5								L			
RWIKUBO	D	10.7	3,390	316.8	HP,NC,HC	P,S(2)	○		S	P	○	IN,C,L	GS,Rc		
SOVU	Vf	12.0	3,124	260.3		P				P	○	C,L			
-total-		93.7	31,024	331.1											
[KABARONDO]															
BISENGA	Vs2	18.3	2,544	139.0		P				W				B	
CYINZOVU	Vs2	10.0	2,860	286.0		P	○			W,(P)	○	IN,L			
KABARONDO	LT2	13.8	2,433	176.3	HC	P	○	CC	S,WsM	W,(P)	○	IN,C,L	GS	B	
MURAMA	Vs2	19.4	1,616	83.3		P			M						
NKAMBA	Vs1	11.7	3,312	283.1		P				W	○	L		B	
RUBIRA	Vs2	6.2	2,594	418.4		P				(P)		L			
RUKIRA	Vf	5.5	2,146	390.2		P				W					
RUNDU	Vf	10.8	3,378	312.8						(P)		L			
RURAMIRA	Vs1	14.6	3,286	225.1		P			M	W	○	L			
RUSERA	Vs2	8.8	2,214	251.6			○				○	IN,L			
RUYONZA	Vf	7.8	2,548	326.7							○	L			
SHYANDA	Vf	33.4	3,044	91.1		P(2)				W					
-total-		160.3	31,975	199.5											

(continue)

Present Conditions of Population/Services and Facilities/Infrastructure of Each Secture and Its Spatial Type within the Area

	Type	POPULATION(1988)			SERVICE					PUBLIC UTILITIES/INFRST.			ACTIVITIES		OTHERS
		Area	Total	Density (/Km2)	Health	Education	Bus-Trans.	Admi.	Commerce	Water Supply	Elect.	Road	Indust. Develop.	Finance	
[RUKARA]															
GAHINI	LT1	26.2	5,698	217.5	HP	P(2), S(2)				P	(○)	IN, C, L	Rc		
KAWANGIRE	Vs2	17.3	3,930	227.2		P(2)			M		(○)	IN, C, L			
KIYENZI	Vs2	15.1	3,734	247.3		P(2)					(○)	IN, L			
NYAKABUNGO	Vf	30.8	3,010	97.7		P(2)						C, L			
NYAWERA	Vs2	43.1	4,279	99.3		P(2)			M			C, L			
RUKARA	LT2	45.9	6,856	149.4	HC, NC	P(3)		CC	S, WsM	P	(○)	C, L	Rc	B	
RWIMISHINYA	Vf	21.8	5,116	234.7		P(2)						L			
RYAMANYONI	Vs2	61.7	2,918	47.3		P(2)			M			C, L			
-total-		261.9	35,541	135.7											
[MUHAZI]															
GATI	Vf	10.7	3,865	361.2		P						L			
GISHALI	D	8.9	4,475	502.8	HP	P	○	CC	S, M	P	○	IN, C, L	Rc		
KABARE	Vs1	7.5	3,402	453.6		P(2)	○		M		○	IN, C, L			
KITAZIGURWA	Vs2	7.5	3,091	412.1		P	○					IN, L			
MUKARANGE	LT1	5.6	2,533	452.3	HC, NC	P(2), S	○				(○)	IN, L			
MUNYIGINYA	Vs1	5.8	2,874	495.5		P			M			L			
MURANBI	Vs2	10.7	3,630	339.3		P	○		M			IN, L			
NKOMANGWA	Vf	6.3	2,698	428.3		P						L			
NYAGATOVU	Vs1	8.6	2,663	309.7			○				(○)	IN, L			
NYARUBUYE	Vs2	6.0	3,250	541.7		P						L			
NYARUGARI	Vs1	5.9	2,754	466.8			○				○	IN, L	Rc		
RUHUNDA	Vf	8.1	3,243	400.4		P					○	C, L			
-total-		91.6	38,478	420.1											
[MUGESERA]															
CYIZIHIRA	Vf	8.3	3,230	389.2							○				
GATARE	Vf	13.8	3,316	240.3		P									
KAGASHI	Vf	18.3	3,951	215.9		P(2)									
KAREMBO	LT1	4.6	2,363	513.7			○		WsM	(P)	○	N, C, L		B	
KIBARE	Vs1	7.4	3,725	503.4		P				(P)		L			
KIBILIZI-1	Vf					P(2)						C, L			
KIBILIZI-2	Vf	17.4	5,680	326.4								C, L			
KIRAMBO	Vs2	9.0	2,757	306.3								N, L			
KUKABUYE	LT1	7.2	3,764	522.8				CC			○	L			
MATONGO	Vs2	4.4	2,866	651.4					M			L			
NGARA	Vs1	9.3	3,194	343.4		P	○		M			N, L			
NYANGE	Vs2	17.1	2,389	139.7	DP	P(2)			M			L			
SANGAZA	Vs2	13.8	3,223	233.6		P			M			L			
SHYWA	Vf	7.0	3,024	432.0		P						L			
ZAZA	D	6.5	2,646	407.1	HC, NC	P(2), S(3)	○		S	(P)	○	N, L	PF, Rc		
-total-		144.1	46,128	320.1											

Step	Type of Service	Water source	Quality protection	Water use LPCD[a]	Energy source	Operation and maintenance needs	Costs	General remarks
5	House Connections	Groundwater Surface water Spring	Good, no treatment May need treatment Good, no treatment	100 to 150	Gravity Electric Diesel	Well-trained operator; reliable fuel and chemical supplies; many spare parts; wastewater disposal	High capital and O&M costs, except for gravity schemes	Most desirable service level, but high resource needs
4	Yardtaps	Groundwater Surface water Spring	Good, no treatment May need treatment Good, no treatment	50 to 100	Gravity Electric Diesel	Well trained operator; reliable fuel and chemical supplies; many spare parts	High capital and O&M costs, except gravity schemes	Very good access to safe water; fuel and institutional support critical
3	Standpipes	Groundwater Surface water Spring	Good, no treatment May need treatment Good, no treatment	10 to 40	Gravity Electric Diesel Wind Solar	Well trained operator; reliable fuel and chemical supplies; many spare parts	Moderate capital and O&M costs, except gravity schemes; collection time	Good access to safe water; cost competitive with handpumps at high pumping lifts
2	Handpumps	Groundwater	Good, no treatment	10 to 40	Manual	Trained repairer; few spare parts	Low capital and O&M costs; collection time	Good access to safe water; sustainable by villagers
1	Improved traditional sources (partially protected)	Groundwater Surface water Spring Rainwater	Variable Poor Variable Good, if protected	10 to 40	Manual	General upkeep	Very low capital and O&M costs; collection time	Improvement if traditional source was badly contaminated
0	Traditional sources (unprotected)	Surface water Groundwater Spring Rainwater	Poor Poor Variable Variable	10 to 40	Manual	General upkeep	Low O&M costs (buckets, etc); collection time	Starting point for supply improvements

Steps within Phase III Planning (Steps 1 to 3)

Source : COMMUNITY WATER SUPPLY
(World Bank)

SYSTEMES D'ALIMENTATION EN EAU POTABLE ET LA ZONE DE DISTRIBUTION

Option	Method of Water Supply	Service Area
A	Small scale water distribution system of spring water by gravity	Available area of spring water
B	Shallow Tube-well with Hand-pump	*Available area of shallow well *Low population density
C	Tube-well with Power Pump (deep well) without distribution facilities	*Available area of deep well *Low population density
D	Small Scaled Water Distribution System with Electric Moter Pump using Groundwater	*Available area of groundwater development *Electric service area *High population density
E	Small Scaled Water Distribution System with Power Pump and Generator using Groundwater	*Available area of groundwater development *Non-electric service *High population density
F	Large Scaled Water Distribution System with Treatment Facilities using Surface Water(River,Lake)	*Non-available area of groundwater development *High population density *High residents income
G	Extension of Existing Urban Water Distribution System	*Rwamagana City *Kibungo City
H	Rain Storage by Roof Catchment	*Non-available area of groundwater development *Schools and hospitals *Low population density area in the mountains
I	Rain Storage by Slope Catchment	*Non-available area of groundwater development *Schools and hospital *Low population density area in the mountains

Source : by Study Team

	Option	Evaluation	Water Source and Topography	Water Use, Operation and Management	Economic Aspects
Ⓐ	Small-scale water distribution system of spring water by gravity flow	Suitable except securing of sufficient water amount. Prefer to combine with Option D, E, or F.	△Difficult to secure sufficient amount of water with new spring development. ◎No water quality problem exists.	◎No energy required for system operation. ○Local residents can operate and manage the system. ◎Easy to place residents into the management organization structure	◎Per capita capital cost is very low. ◎Operation and maintenance cost is low.
Ⓑ	Shallow tube-well with hand pump	Suitable	○No water quality problem exists if well sites are appropriately selected. △ May be possible to select well sites close to existing water sources. But, in lowlands, it is difficult to secure access roads.	Same as above	Same as above
C	Tube-well with power pump (deep well)	Unsuitable	△ Difficult to select well drilling sites.	△Electricity or fuel oil is needed to operate. △High levels of operation and maintenance skills are required. ×It is difficult to maintain by the management structure of the small number of residents. Convenient to obtain water	× Capital cost per capita is very high because this system does not have the water distribution sytem. × Operation and maintenance cost is very high.
Ⓓ or Ⓔ	Small-scale water distribution system with electric motor pump or generator operated power pump using groundwater	Suitable in population concentrated area if the operation and maintenance cost meets the requirements. If possible, use river water or groundwater with a shallow well.	○Difficult to select a deep well site. Difficult to secure sufficient amount of water with a shallow well. △ Difficult to install a pipeline because of variable topography.	△Electricity or fuel oil is needed to operate. △High levels of operation and maintenance skills are required. ○A certain number of population is needed to maintain the management structure. Convenient to obtain water.	○Capital cost becomes high if the area has less than a certain number of population. ○Operation and maintenance cost becomes high if the area has less than a certain number of population.
Ⓕ	Large-scale water distribu- system with treatment facilities using surface water (river or lake)	Same as above	○ Treatment facilities are required for obtaining good quality water. ◎ No problem exists for securing a large amount of water △ Special attention is needed to install a pipeline in an area having variable topography.	Same as above	Same as above
G	Extension of existing urban water distribution system	Unsuitable	Extension of existing urban water distribtuion systems in Kibungo and Rwamagana cities are being conducted. Thus, this option is not included in the Phase III Project.		
△H	Rainwater storage by roof catchment	Suitable only for special cases	△Difficult to obtain sufficient amount of water and maintain the water quality	◎Energy is not needed to operate. ◎Operation and maintenance work can be conducted by local residents. ×Inconvenient.	◎Capital cost is very low. ◎Operation and maintenance cost is very low.
I	Rainwater storage by slope catchment	Unsuitable	△Difficult to obtain sufficient amount of water and maintain the water quality. Lands are highly used and none is available for the slope catchment method.	Same as above	Same as above

Evaluation of Water Sources

Water Source	Quality	Amount	Remarks
Spring	Good	Unstable; varies according to season	. Springs having large amounts of yield are already used as the sources of existing water supply systems. . Horizontal test boring would be necessary for newly developing springs.
Ground-water	Good	Comparative-ly stable	. Other than the 72 well constructed under the Phase I Project, no wells exist in the Project Area. . In some areas, there are water quality problems such as excess iron.
River Water	Poor	Small rivers are unstable; their flow deviates. seasonally	. Since the rivers in the Project Area have small catchment areas, some of the rivers dry up during dry seasons. The upstream reaches of the rivers that are suitable for gravity flow intake dry up more frequently.
Lake Water	Poor		. Large amount is available. Easier to take than river water. . Have high turbidity and hue due to existing water grass and algae.
Rain-water	Good		. There are only several rainwater harvesting systems in Kibungo Prefecture. . Standard sizes of troughs and tanks are not available.

Resultss of Model Study

INITIAL PER CAPITA OF PROPOSED EACH WATER SUPPLY SYSTEM

MODEL STUDY - 1

Area = 40km2(constant) (Unit : US$)

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
4,000	100	465.8	274.6	125.0	48.4
5,000	125	381.2	281.5	100.0	48.4
7,500	188	268.4	193.2	86.7	48.4
10,000	250	212.0	178.2	85.0	48.3
12,000	300	183.8	151.3	83.3	48.4
14,000	350	163.6	152.9	85.7	48.3
16,000	400	148.5	135.9	84.4	48.3
18,000	450	136.7	138.9	83.3	48.3
20,000	500	127.3	126.6	85.0	48.3
21,000	525	123.3	121.4	83.3	48.3
22,000	550	119.6	129.9	84.1	48.3
23,000	575	116.3	125.0	82.0	48.3
25,000	625	110.4	116.3	84.0	48.3
27,500	688	104.3	117.9	83.6	48.3
30,000	750	99.1	119.2	83.3	48.3
35,000	875	91.1	112.8	82.9	48.3

MODEL STUDY - 2

Population = 20,000(CONSTANT)

Area(km2)	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
10	2,000	94.3	98.9	85.0	48.3
20	1,000	105.3	108.1	85.0	48.3
30	667	116.3	117.4	85.0	48.3
40	500	127.3	126.6	85.0	48.3
50	400	138.3	135.9	85.0	48.3

MODEL STUDY - 3

Area = 10km2(constant)

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
1,000	100	1,075.3	494.0	150.0	48.4
2,000	200	559.0	255.3	100.0	48.4
3,000	300	387.0	175.7	83.3	48.4
4,000	400	300.8	155.9	87.5	48.4
5,000	500	249.2	170.5	90.0	48.4
6,000	600	214.8	144.8	83.3	48.4
7,000	700	190.2	126.5	85.7	48.3

O/M COST(US$//month/fmly) OF PROPOSED EACH WATER SUPPLY SYSTEM

MODEL STUDY - 1

Area = 40km2(constant)

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
4,000	100	3.35	1.81	0.77	0.12
5,000	125	2.99	1.86	0.65	0.12
7,500	188	2.51	1.56	0.58	0.12
10,000	250	2.27	1.52	0.57	0.12
12,000	300	2.15	1.42	0.57	0.12
14,000	350	2.07	1.43	0.58	0.12
16,000	400	2.01	1.37	0.57	0.12
18,000	450	1.96	1.39	0.57	0.12
20,000	500	1.92	1.34	0.57	0.12
21,000	525	1.90	1.32	0.57	0.12
22,000	550	1.88	1.36	0.56	0.12
23,000	575	1.87	1.34	0.56	0.12
25,000	625	1.84	1.31	0.57	0.12
27,500	688	1.82	1.31	0.57	0.12
30,000	750	1.80	1.32	0.57	0.12
35,000	875	1.76	1.30	0.56	0.12

MODEL STUDY - 2

Population = 20,000(CONSTANT)

Area(km2)	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
10	2,000	1.82	1.27	0.57	0.12
20	1,000	1.86	1.29	0.57	0.12
30	667	1.89	1.32	0.57	0.12
40	500	1.92	1.34	0.57	0.12
50	400	1.95	1.37	0.57	0.12

MODEL STUDY - 3

Area = 10km2(constant)

Population	Dens.	Sys-1	Sys-2	Sys-3	Sys-4
1,000	100	6.92	2.90	0.90	0.12
2,000	200	4.24	1.92	0.65	0.12
3,000	300	3.34	1.60	0.57	0.12
4,000	400	2.90	1.43	0.59	0.12
5,000	500	2.63	1.56	0.60	0.12
6,000	600	2.45	1.46	0.57	0.12
7,000	700	2.32	1.38	0.58	0.12

Cost for Economical Analysis

Conditions of Model Study

Initial Cost

Item	System	unit	Cost(US$)	Note(Qnt'y etc.)
Electric Facility				
Electric & Instrument Equipments	1	ls	250,000	
	2	ls	65,000	
Power Trans. Line	1,2	m	80	Sys-1=2,000m, Sys-2=1,000m
Well Facilities				
Well Construction	2	well	55,000	D=60m
Well Construction	3	well	40,000	D=60m
Hand-pump Facilities	3	set	10,000	
Intake Facilities				
Under 600 m3/day(w-demand)	1	ls	70,000	
600 - 700 m3/day	1	ls	75,000	
700 - 800 m3/day	1	ls	80,000	
800 - 900 m3/day	1	ls	85,000	
900 - 1,000 m3/day	1	ls	90,000	
1,000 - 1,100 m3/day	1	ls	95,000	
1,100 - 1,200 m3/day	1	ls	100,000	
Treatment Plant	1	m3	1,100	
Transmission Pump				
Pump Station	1,2	ls	10,000	
Equipment & Facilities	1,2	m3	500	
Transmission Pipe	1,2	m	80	Sys-1=4,000m, Sys-2=1,000m
Reservoir Tank				
Strage Facilities	1,2	m3	500	V=WDx1.15/3
Preparatory Work	1,2	ls	2,500	
Distribution Pipe	1,2	m	35	Sys-1=(A/4)x1.2, Sys-1=A/4
Public Fauntains	1,2	ls	4,000	
Roof Catchment Facilities				
Catchment Facilities	4	House	250	
Strage Facilities	4	House	40	

O/M Cost

Item	System	unit	Cost(US$)	Note(Qnt'y etc.)
Power Cost	1,2	m3/m	4.50	
Machinary Parts		[5 % of machinary investment cost per year]		
Intake Facilities	1,2		15 % of "Initial Cost"	
Treatment Facilities	1,2		50 % of "Initial Cost"	
Transmission Facilities	1,2		40 % of "Initial Cost"	
Non-machinary Parts		[1 % of pipeline construction cost per year]		
Intake Facilities	1,2		15 % of "Initial Cost"	
Transmission Facilities	1,2		50 % of "Initial Cost"	
Distribution Facilities	1,2		55 % of "Initial Cost"	
Chemical Input	1	m3/m	2.00	
Wage	1,2	month	55.00	
Indirect Cost	1,2,3	pers/m	0.03	

(continue)

Sheet of Economical for Water Supply System Selection

Demography		Note
Population	20,000	
Area(km2)	40	
Total Households	3,334	6 pers./fmly
Density -persons/km2	500	
-households/km2	83.4	

Required Quantities

	Sys-1	Sys-2	Sys-3	Sys-4	
Water Demand	476.8	476.8	330.1		S-1,2:0.13 m3/d/f S-3:0.9 m3/d/f 10% of public use
Design Demand	548.3	548.3			Max. D = 115%
No. of Wells		5	34		
Pipe Line	24,000	20,000			
No. of W-points	10	10			
Strage Volume					

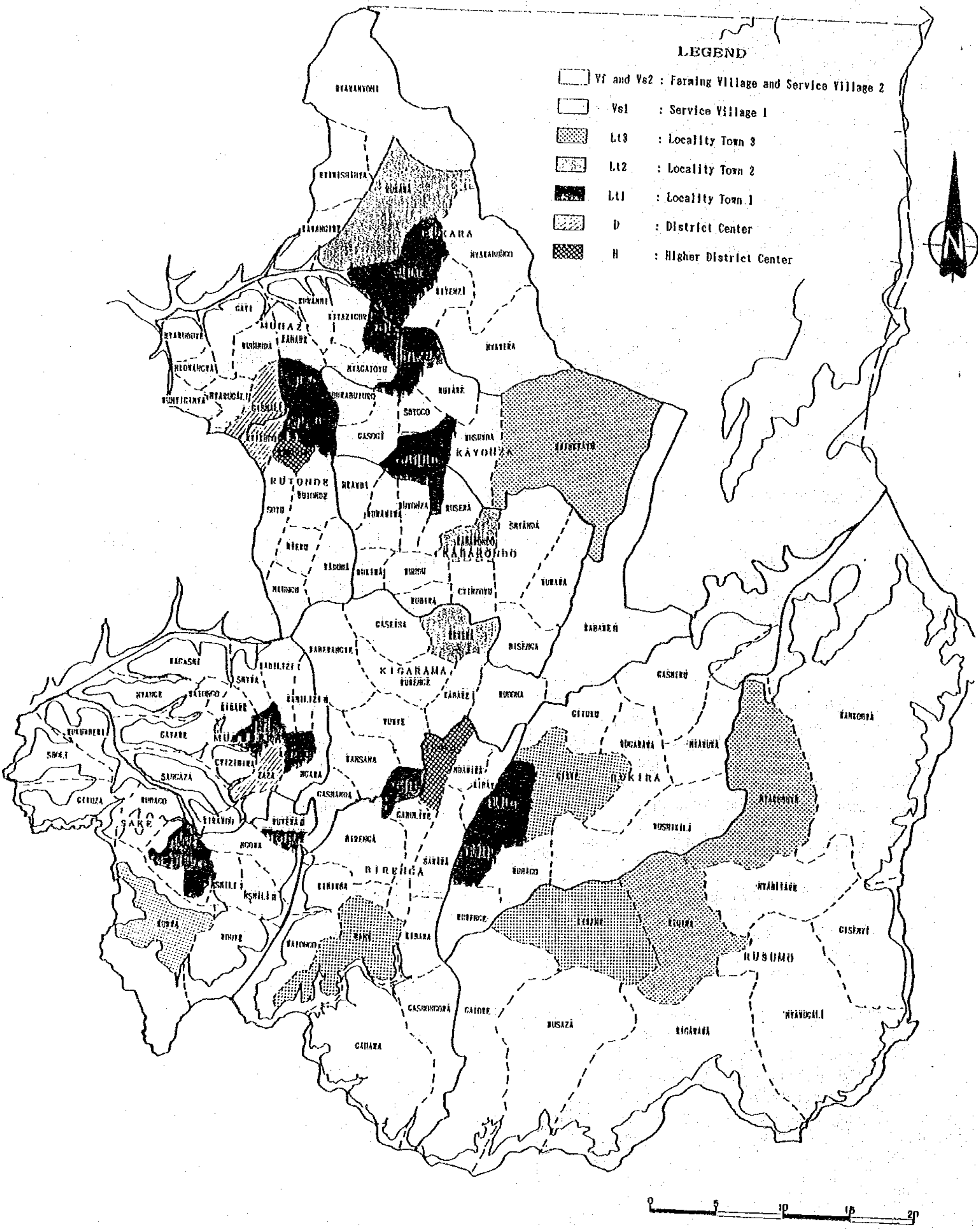
Initial Cost(1,000 US$)

	Sys-1	Sys-2	Sys-3	Sys-4
Electric Facility	410.0	725.0		
Well Facilities		275.0	1,700.0	
Intake Facilities	70.0			
Treatment Plant	524.4			
Transmission Pump	248.4	288.4		
Transmission Pipe	320.0	400.0		
Resouvoir Tank	93.9	103.9		
Distribution Pipe	840.0	700.0		
Public Fauntains	40.0	40.0		
Roof Cacthment				966.9
Total	2,546.7	2,532.3	1,700.0	966.9
Cost per Person(US$)	127.3	126.6	85.0	48.3

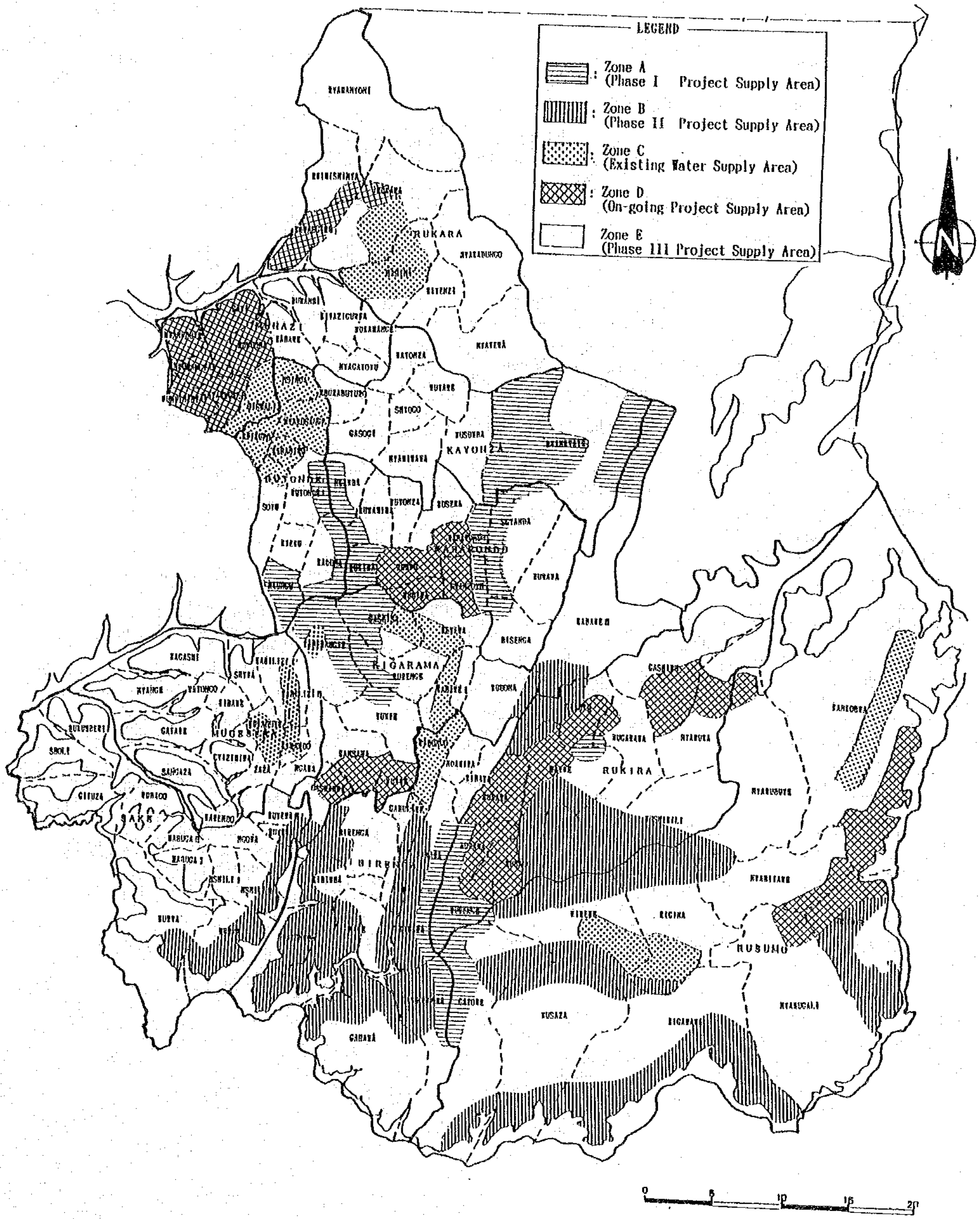
O/M Cost(1,000 US$/month)

	Sys-1	Sys-2	Sys-3	Sys-4
Total	6.39	4.47	1.92	0.40
Cost per Family(US$)	1.92	1.34	0.57	0.12
Power Cost	2.15	2.15		
Machinary Parts	2.08	1.15	1.42	
Non-machinary Parts	0.65	0.63		0.40
Chemical Input	0.95			
Wage	0.06	0.06		
Indirect Cost	0.50	0.50	0.50	

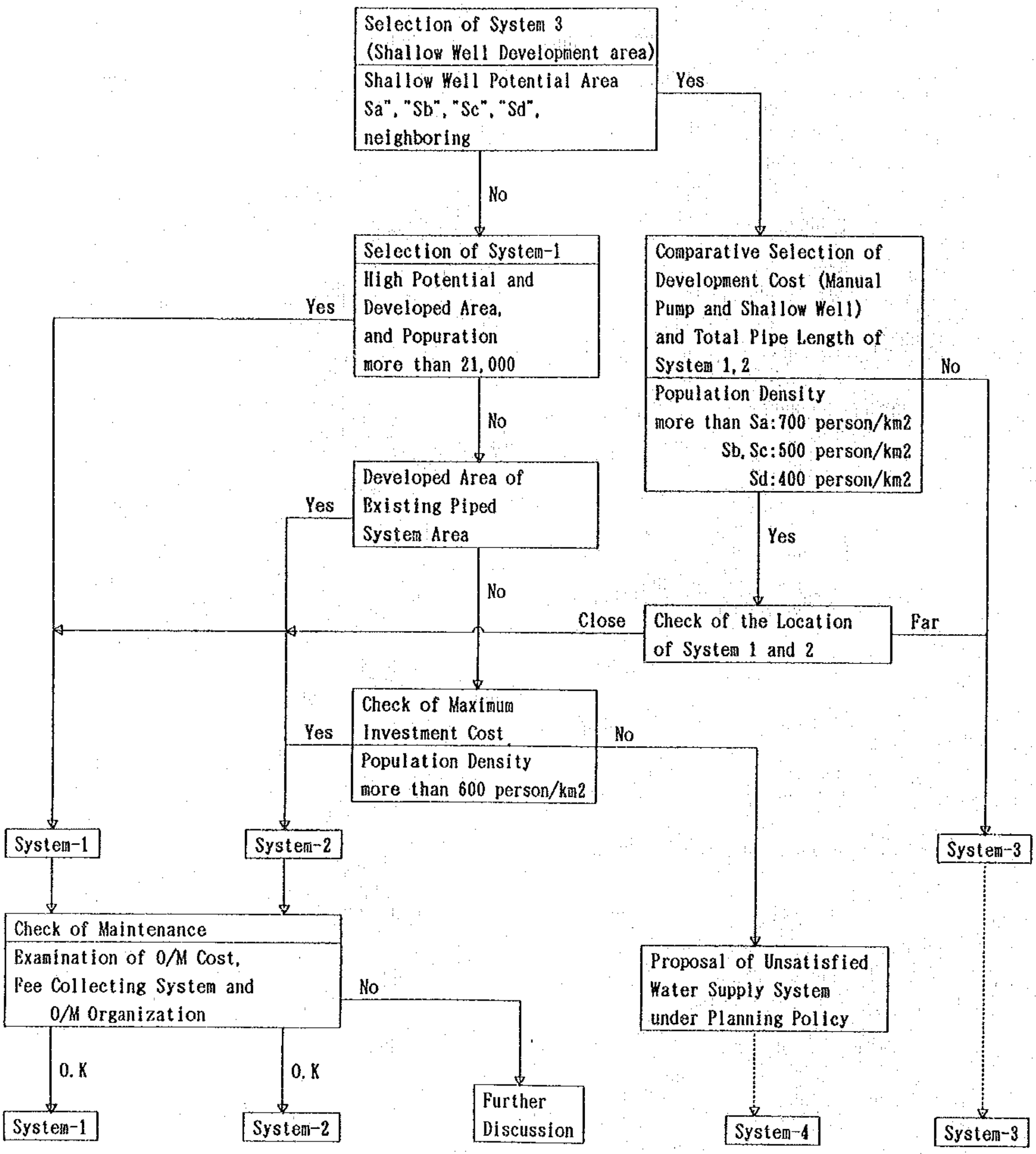
Fig. L.1

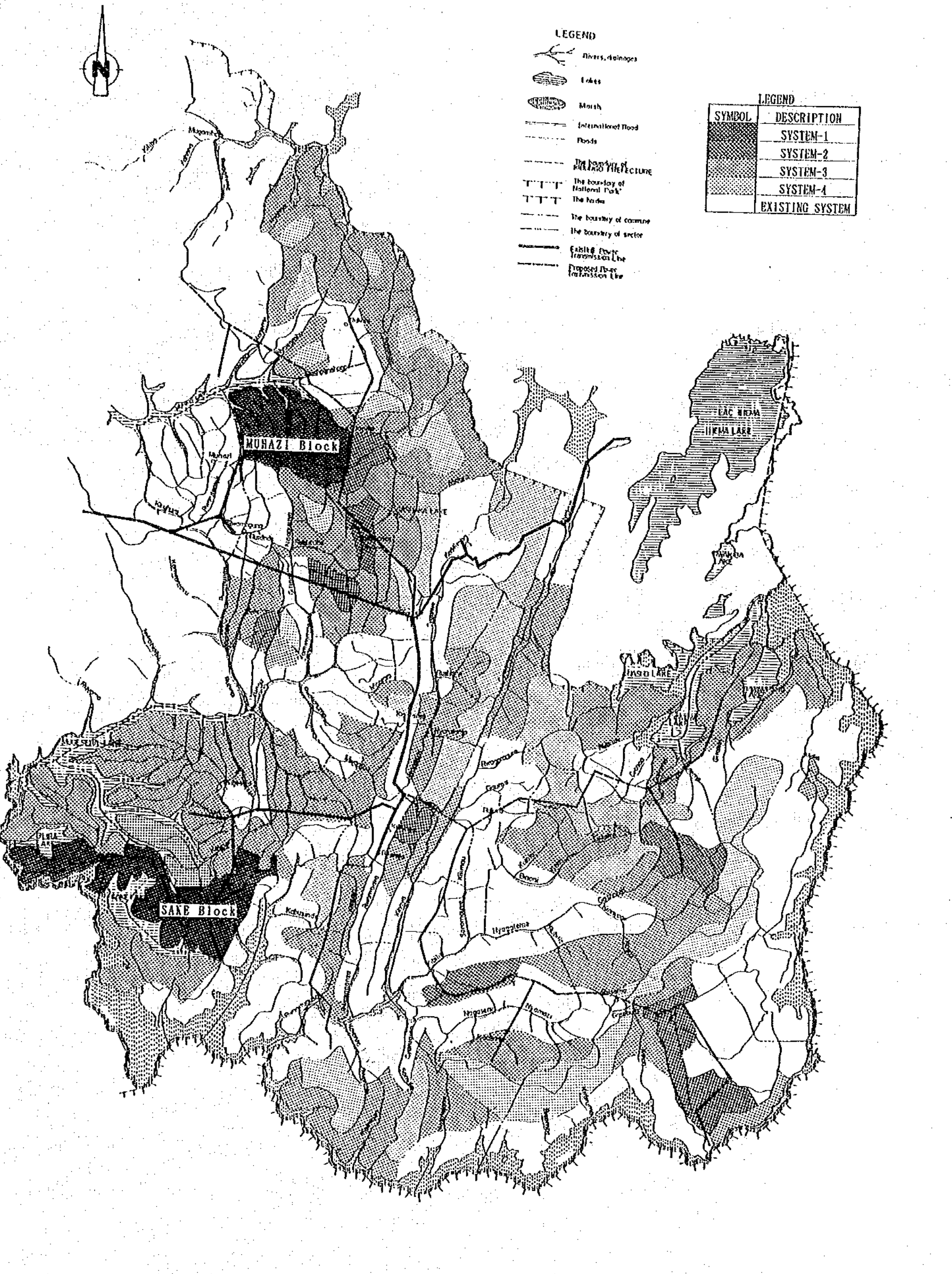


Classification of Rural Center for Development



Zoning Map of the Study Area


Selection of System 3
(Shallow Well Development area)
Shallow Well Potential Area
Sa","Sb","Sc","Sd",
neighboring
Yes
No
Selection of System-1
High Potential and
Developed Area,
and Popuration
more than 21,000
Comparative Selection of
Development Cost (Manual
Pump and Shallow Well)
and Total Pipe Length of
System 1,2
Population Density
more than Sa:700 person/km2
Sb,Sc:500 person/km2
Sd:400 person/km2
Yes
No
No
Developed Area of
Existing Piped
System Area
Yes
Yes
No
Close
Check of the Location
of System 1 and 2
Far
Check of Maximum
Investment Cost
Population Density
more than 600 person/km2
Yes
No
System-1
System-2
System-3
Check of Maintenance
Examination of O/M Cost,
Fee Collecting System and
O/M Organization
No
Proposal of Unsatisfied
Water Supply System
under Planning Policy
O.K
O.K
System-1
System-2
Further
Discussion
System-4
System-3


N
LEGEND
Rivers, drainages
Lakes
Marsh
The boundary of National Park
The boundary of commune
The boundary of sector
LEGEND
SYMBOL
DESCRIPTION
SYSTEM-1
SYSTEM-2
SYSTEM-3
SYSTEM-4
EXISTING SYSTEM
MUHAZI Block
SAKE Block