(7) Rural Water Supply System Expansion Project in Rukara

This project is designed to expand the existing rural water supply system in Rukara. 120 m3/day of domestic water will be developed to supply the approximately 5,300 residents in Rukara and Kawangire.

7.2 EVALUATION OF DEVELOPMENT PLANS AND ACTIVITIES

(1) Outline of Phase II Project

GENERAL
The Phase II project is also planned to be implemented by the Government of Rwanda, with procurement under Japanese Grant. The Project of Phase II which was formulated by the F/S is outlined as below:

Zone	Commune	Design Population (1990)	Water Demand (l/day)	No. of well/well type S1	D1	Total
V	KIGARAMA	5,239	80,000	0	8	8
VI	RUKIRA/RUSUMO	12,952	180,000	0	18	18
VII	RUSUMO	4,786	180,000	0	18	18
VIII	"	2,101	50,000	5	0	18
IX	"	4,455	110,000	11	0	11
X	BIRENGA	12,368	160,000	0	16	16
XI	"	15,399	240,000	24	0	24
XII	SAKE	9,864	140,000	14	0	14
	TOTAL	67,164	1,140,000	54	60	114

Note : S1 = Shallow Well, D1 = Deep Well

The proposed zones of Phase II project are shown in Fig. F.7.

COMMENTS FROM THE GEOLOGICAL POINT OF VIEW
Based upon a review of existing data and field studies, the geological and hydrogeological features in the Phase II areas have been examined.

The comments on the groundwater development in each zone of Phase II are presented in Table F.7. The overall evaluations for groundwater development are outlined below:

- No constraint basically is found shallow groundwater development at low lying potential areas.

- As the survey and design of F/S level were not sufficiently to implement the project, further study is required to decide the detail location of well construction and well structure, based on a confirmation of the service area and/or of the point of the groundwater source. Hence, it is recommended that a foreign expert of hydrogeology shall manage the further study which shall be carried out.

COMMENTS FROM THE CONSTRUCTION/IMPLEMENTATION CONDITIONS

A few drilled boreholes of Phase I which had a groundwater table deeper than 50 m from surface, were eliminated from the Phase I project because the deep boreholes were not available to get water by hand-pumps.

Hence, it was recommended that a few wells shall be installed power pumps at Phase II stage to develop to bring deep groundwater into use.

The following attentions will be recommended to construct/install deep wells, power pump facilities as Phase II project.

- A large scale construction works of electric facilities, such as transmission line, control facilities, will be required, on the ground that the Phase II zones are all far from the existing service area of electricity.

- Once the project implementation is under way, there will be ELECTROGAZ and MINITRAPEE involved in the sites. Hence, it is strongly required that these agencies should coordinate in terms of planning, budget, etc. in advance.

- New operation and maintenance system should be provided for power pump facilities, i.e. generator unit, diesel engine due to decrease the burden of the water service charge for residents.

- It should be recommended that small scaled water distribution system shall be examined to construct in case power pump facilities will be proposed.

- Since the existing access roads to the Phase II site is not satisfactory, the repair/rehabilitation of existing road and new construction will be required.

The summary of the comments on Phase II zones is given in Table F.8.

In view of the points mentioned above, the following three recommendations should be considered, in case some modifications of the project planning will be required:

- Hand-pump wells for shallow groundwater development have priority over other water supply systems.
- Small type of drilling machine loaded on truck should be used.
- Casing for submerged pump installation should be set in the area where the water supply system will be upgraded to include water distribution facilities in the near future.

(2) IDA' Rehabilitation Project

The purpose of this project is to rehabilitate the existing water supply facilities located in 214 areas throughout Rwanda. With the assistance of IDA (International Development Association), the project's Phase I Report (Investigation Preliminaries) was prepared in June, 1989. The Phase II Report (Plan Directeur de Rehabilitation) was prepared in February 1991. Project implementation is thought to be urgent.

(3) Other Development Plans and Activities

Except for UNICEF's Domestic Water Supply Development Project which is still in the study stage, there are the following projects that are either under construction or are scheduled for construction. It is thought that these projects will be implemented in the near future, as will IDA's Rehabilitation Project.

i) Extension Project of Kibungo Water Supply System (under construction)
ii) Kabarondo Rural Water Supply Project(under construction)
iii) Extension Project to Muhazi West Area of Rwamagana water Supply System (design stage)
iv) Rukara Extension Project of Water Supply System (design stage)

8. ORGANIZATION AND SYSTEM OF OPERATION

8.1 CONDITIONS OF EXISTING OPERATION AND MAINTENANCE SYSTEMS

The operation and maintenance systems of the existing water supply facilities can be classified into four patterns, as follows:

Pattern "A"	ELECTROGAZ's direct operation and maintenance system for the urban water supply facilities. Example: Urban water supply systems in Rwamagana and Kibungo.
Pattern "B"	Operation and management system of the water management committee whose representatives are water supply recipients. Example: Water supply systems in Zaza, Kigarama, Rukira, etc.
Pattern "C"	A commune's operation and maintenance system known as Fountainie. Members of this group inspect and maintain the improved springs and piped water supply systems in the commune. Example: Improved springs and piped systems in each commune.
Pattern "D"	MINITRAPEE's operation and maintenance system of the water supply facilities. Residents do not participate in the operation and maintenance of the facilities. Example: Handpumps installed under the Phase I Project.

8.2 WATER FEE COLLECTING SYSTEM

Except for the urban water supply systems in Rwamagana and Kibungo, water fee collecting systems are not fully established. Most of the residents are still of the opinion that they should be able to obtain water free of charge. Thus, MINITRAPEE has been making a great effort to change the residents' concept but, thus far, no tangible results have been accomplished.

The existing water fee collecting systems that were confirmed during the field study period can be classified into the fixed rate system and the meter system as follows:

Fee Collecting System

Name	Management Agency	Collecting System	
Rwamagana/ Kibungo	ELECTROGAZ	House connection is fee by amount by meter. Kiosk is 2FRW/jerrican (20lit)	By Amount System
Rukara	Commune	2FRW/jerrican (20lit) Other account of commune not General	By Amount System
Rukira	Commune	100FRW/year/Family General Account of Commune	Fixed Amount System
Kigarama	Commune	100FRW/Month/Family General Account of Commune	Fixed Amount System
Rusumo	Commune	50FRW/Month/Family General Account of Commune	Fixed Amount System
Zaza	Water Committee	45FRW/m3, 2FRW/jerrican (20lit)	By Amount System
Sake	Commune	3FRW/jerrican (20lit)	By Amount System

8.3 REVIEW OF PRESENT OPERATION AND MAINTENANCE SYSTEMS

Except for the urban water supply facilities, the operation and maintenance conditions of existing water supply facilities in the Study Area are poor. The reasons for this can be attributed to inadequate operation and maintenance systems, lack of funds and spare parts, and a shortage of technicians.

For the residents' independent water supply facility management system to be an idealistic type, it is fundamentally important that the residents have a clear concept about their water supply. Thus, it is essential to alter the residents' present concept that water should be supplied free of charge by the Government and that the Government should maintain the water supply facilities.

The existing operation and maintenance problems in the Study Area are summarized below:

- As the spare parts for the handpumps are stored in Kigali, the country's capital, the local residents cannot perform prompt maintenance and repair work. Procedures should be established for storing the spare parts either in the Kibungo prefectural government office or in the concerned commune.

- Many of the water supply systems that are equipped with diesel engine operated pumps or electric motor operated pumps with generator units are inoperative due to mechanical failure, difficulties in obtaining fuel, or for financial reasons.

- Motor driven pumps utilizing public power supplies are in operation more frequently than diesel engine driven pumps. The reason for this is that even though the residents do not pay for the electricity, ELECTROGAZ provides it nevertheless.

If ELECTROGAZ discontinued supplying electrical power to water supply systems whose recipients do not pay the power fees, it is believed that the operating rates of motor driven pumps would be the same or even less than diesel engine driven pump operating rates.

- It is said that not all water fees collected by communes are used for the operation and maintenance of the water supply facilities. Such water fee collecting systems should be investigated to ensure that the fees will be used only for the purpose of operating and maintaining the facilities.

9. MINITRAPEE'S POLICIES CONCERNING WATER SUPPLY FACILITY OPERATION AND MAINTENANCE

In 1985, MINITRAPEE proposed a policy whereby water supply recipients must pay facility operation and maintenance costs. Since that time, MINITRAPEE has examined various water supply administrative structures including the promotion of a program aimed at making the residents more conscious of their water supply.

In an April 1991 report, water supply facilities' operation and maintenance organizational structures, and water fee collecting systems are clarified.

The report is summarized as follows:

9.1 ORGANIZATION AND ROLE

(1) Organizational Structures

MINITRAPEE's water supply facility operation and maintenance organizational structure has a commune as its basic unit.

Presently, MINITRAPEE is instructing the communes to establish their own "Public Association for Water Supply" to take care of their overall water supply administrative work.

In the Study Area, the Rutonde and Mugesera communes already have established functioning public associations.

The proposed Public Association for Water Supply is to be organized by representatives of the water supply recipients and commune office personnel as shown in the following figure. If the water supply recipients do not have management capabilities, it is proposed that the Public Association be managed mainly be commune office personnel.

(2) Roles

Organizations concerned with the above mentioned water supply administration have the following roles:

. Water Supply Recipients' Union

The union is organized by the recipients of the same water supply system. This is the smallest independent operation and maintenance organization.

. Water Management Committee

This is an organization that actually conducts facility operation and maintenance work within one water supply system. The committee is composed of more than three persons -- a manager, an accountant and technical specialists -- who are selected by the water supply recipients.

The committee is responsible for collecting water fees, conducting programs designed to educate residents in matters pertaining to the water supply system and public health, and for listening to the requests of the residents.

. Public Association for Water Supply

The Public Association is to be comprised of representatives of water management committees, and commune or secteur representatives. It will be responsible for the overall technical management, accounting and auditing, determination of activities and budgetary funds for the water supply systems in the commune or secteur.

The Public Association has an administration office with at least three officers: a manager, a secretary, and an accountant.

FNHR (Found National de Hydolique Rural) is to be established with CID which is being studied, will be the basic fund manager of the collected water fees.

It is proposed that CCDFP be newly established in each commune and should undertake resident promotion and education activities concerned with water supply and public health with the cooperation of recipient unions, water management committees, and the public association for water supply.

CCDFP's main theme will be to extend water supply knowledge to the residents and provide training for personnel in charge of accounting and technical matters.

9.2 IDEAS FOR WATER FEES

Costs for water supply facility operation and maintenance are classified into the following three categories:

i) Operating costs necessary for the entire commune's water supply administration work.

ii) System operating costs, such as for fuel, repairs, and personnel expenditures that are required for the system's direct operation and maintenance work.

iii) Equipment replacement costs necessary for the continuous operation of a water supply system.

According to the above cost classification, the water fee is thought to be composed of the following three levels:

-Level 1: Costs required for the management, operation, and maintenance work;[i) + ii)]

-Level 2: Costs of Level 1 plus non-machinery costs;[i) + ii) + a part of iii)]

-Level 3: Costs of Level 2 plus machinery costs;[i) + ii) + iii)]

MINITRAPEE's policy is to collect water fees at least for Level 1 from water supply recipients.

As shown in the following table, the estimated operation and maintenance cost for Level 2 is 14 FRW/month/family for a piped water supply system using spring water and 184 FRW/month/family for a piped water supply system equipped with a diesel engine driven pump.

Estimated Annual Cost for Operation/Management by MINITRAPEE(Apr., 1991) (unit:RWF)

Level of O/M Cost Cond.	Water Supply Facilities		
	Point Source	Piped System	
	Improved Spring	Distrib. by Gravity	Distrib. by Diesel-E
Level 1	57 (4.8)	168 (14.0)	1,588 (132.3)
Level 2	57 (4.8)	168 (14.0)	2,212 (184.3)
Level 3	64 (5.3)	416 (34.7)	2,521 (210.1)

( ) indicate monthly cost per payer

The three water fee collecting methods are outlined below. The details of these methods are not yet known.

METHOD	MERITS	DEMERITS
Method for collecting water fee in the same manner as the collection of taxes in each commune	. Easy to manage money . Equal to the recipients . Can obtain periodical revenue	. Low collecting rate . Recipients will to waste water . simple facility users will complain
Method for collecting water fees as management costs of each water supply system	. System costs will be collected . Can obtain periodical revenue	. Low collecting . Recipients will to waste water
Method for collecting water fees according to used water amount (meter method)	. Can secure revenue . Can reduce water waste . Can collect cash	. Complicated management . Increase of management cost . Need the management of small amounts of money

Table. Existing Rural Water Supply Systems (Piped Systems)

Urban/ Rural	No.	Name of System	Location	Administration	Water Sources	Production m3/day	Family No.	Popuration	Pump	Commence of Operation	Organization of Assistance	Remarks
Urban	1	KIBUNGO				250		7300	(6,851)			
	2	RWAMAGANA				500		17,100	(19,227)			
		Sub-Total				750		24,400				
Rural	1	FUKUWE-RWINTARE	Birenga	Commune	Spring	75	342	2,050		1970	IDA	under Rehabilitation Study by IDA
	2	GAHINI	Rukara	Commune	L.Muhazi	86	80	480	with	1957	IDA	under Rehabilitation Study by IDA
	3	NASHO I	Rukira	Commune	Spring	172	420	2,520		1978	AIDR	under Rehabilitation Study by IDA
	4	NASHO II	Rusumo	Commune	Spring	121	403	2,420		1982	AIDR	under Rehabilitation Study by IDA
	5	RUKIRA	Rukira	Commune	Spring	182	1720	10,320		1977	AIDR	under Rehabilitation Study by IDA
	6	RUSUMO I (Nyakiziba)	Rusumo	Commune	Spring	190	330	1,980		1970	AIDR	under Rehabilitation Study by IDA
	7	RUSUMO I (Nyakagezi)	Rusumo	Commune	Spring	217	470	2,820		1970	AIDR	under Rehabilitation Study by IDA
	8	RUSUMO II (Kamombo I)	Rusumo	Commune	Spring	217	100	600		1977	AIDR	under Rehabilitation Study by IDA
	9	RUSUMO II (Kamombo II)	Rusumo	Commune	Spring	86	294	1,760		1977	AIDR	under Rehabilitation Study by IDA
	10	AKAGERA A	Rusumo	Commune	Spring	43	187	1,120		1981	AIDR	under Rehabilitation Study by IDA
	11	AKAGERA B	Rusumo	Commune	Spring	145	459	2,750		1981	AIDR	under Rehabilitation Study by IDA
	12	AKAGERA C (Nyokibatika)	Rusumo	Commune	Spring	432	40	240		1982	AIDR	
	13	KIREHE	Rusumo	Commune	Spring	216	440	2,640	with	1989	-	
	14	RUSUMO-BGM	Rusumo	Commune	Spring	34.5	1030	6,180		1983	AIDR	
	15	MUSAZA BAS	Rusumo	Commune	Spring	207	640	3,840		1984	AIDR	
	16	RUKARA	Rukara	Commune	Spring	278	595	3,570	with	1986	HYDROBAT	
	17	ZAZA	Mugesera	ELECTROGAZ	Spring	250	-	2,500	with	1957	AIDR	
	18	KAMUSHIKUZI	Kigarama	Commune	Spring	51	350	2,100		1982	HYDROBAT	
	19	SAKE	Sake	Commune	Spring	111	120	720	with	1981	AIDR	
	20	NYANKORA	Kayonza	MINITRAPEE	Groundwater	80	360	2,160	with	1989	Japanese Grant	
		Sub-Total				3,477		52,770				
		Total				4,227		77,170				

FIRST QUESTIONNAIRE SURVEY

Survey execution period : September 1989

	Item of investigation \ Commune	Kabarondo	Kigarama	Muhazi	Rukara	Rukira	Rusumo
1	Distance for fetching water[House → Water source] (one way) Required time[House → Water source] (one way) (on foot)	(Average) 2.6km (Average) 60 min.	2.4km 50min.	2.0km 45min.	3.0km 50min.	3.3km 50min.	2.1km 30min.
2	Types of water source	Spring	①Spring – 3 locations ②Wells – 2 locations ③Communal water hydrants – 1 loc.	Communal water hydrant	①Wells – 2 loc. ②Lake&swamp – 4 loc.	①Communal water hydrant – 3 loc. ②Spring – 1 loc. ③Swamp – 1 loc.	①Communal water hydrant – 3 loc. ②Swamp,river&spring – 6 loc. ③Well – 1 loc.
3	Number of times of water fetching per day	①one – 3 cases ②twice – 1 case	①thrice – 3 cases ②twice – 2 cases ③once – 1 case	N.A.	①twice – 3 cases ②five times – 1 case ③once – 1 case	①twice – 1 case ②thrice – 2 cases ③N.A. – 2 cases	①twice – 4 cases ②thrice – 4 cases ③four times – 2 cases
4	Types of containers for fetching weater	20 liter Plastic tank 10 liter bucket	20 liter Plastic tank 10 liter bucket	20 liter Plastic tank	20 liter Plastic tank	20 liter Plastic tank	20 liter Plastic tank 15 liter bottle gourd
5	Persons fetching water (Water fetching shared within the members of the family)	①men – 2 cases ②children – 1 case	①children – 3 cases ②men&children – 2 cases ③men – 1 case	Whole family	①men – 3 cases ②men&children – 1 case ③Whole family – 2 cases	①men – 1 case ②women&children – 1 case ③whole family – 3 cases	①men – 6 cases ②men&children – 2 cases ③whole family – 2 cases
6	Situation of usage of water	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing
7	Is the source from which is fectched in dry weather the same as the source for daily needs ?	same source – 4 cases different source – nothing	same source – 6 cases different source – nothing	same source – 1 case different source – nothing	same source – 4 cases different source – 2 cases	same source – 4 cases different source – 1 case	same source – 8 cases different source – 2 cases
8	Do you fetch water from the same place always ? How many times per week ?	Yes – 3 cases N.A. – 1 case ①once – 2 cases ②four times – 1 case	Yes – 6 cases ①twice – 2 cases ②once – 1case ③N.A. – 3 cases	Yes – 1 case five times – 1 case	Yes – 5 cases N.A. – 1 case ①twice – 2 cases ②thrice & four times – 1case ③five times – 2 cases	Yes – 5 cases ①twice – 1 case ②thrice – 2 case ③N.A. – 2 cases	Yes – 9 cases N.A. – 1 case ①twice – 6 cases ②thrice – 2 cases ③five times and more – 2 cases
9	At this stage, in addition to the regular source for fetching water, do you fetch water from some other source also?	yes – nothing no – 4 cases	yes – 2 cases no – 4 cases	yes – 1 case	yes – 6 cases	yes – 4 cases no – 1 case	yes – 4 cases N.A. – 6 cases
10	At which water source do you wash clothes?	spring – 3 cases any place – 1 case	①spring – 4 cases ②well – 1 case ③N.A. – 1 case	river	①well – 2 cases ②lake&swamp – 3 cases ③N.A. – 1 case	①communal water hydrant – 1 case ②swamp – 2 cases ③spring – 1 case ④N.A. – 1 case	①Communal water hydrant – 3 cases ②swamp,spring & river – 4 cases ③well – 1 case ④N.A. – 2 cases
11	If suppose, there is a communal shower, who do you think will use this facility?	men & children – 4 cases	①men & children – 4 cases ②men – 1 case	N.A.	N.A. – 6 cases	N.A.	①men – 3 cases ②N.A. – 7 cases
12	Have you ever participated in the construction of water supply systems till now?	yes – nothing no – 4 cases	yes – 2 cases no – 4 cases	yes – 1 case	yes – 4 cases no – 2 cases	yes – 4 cases no – 1 case	yes – 9 cases no – 1 case
13	Have you participated in maintenance and control work of similar types of supply systems?	yes – 4 cases no – nothing	yes – 5 cases no – 1 case	yes – 1 case	yes – nothing no – 6 cases	yes – 4 cases no – 1 case	yes – 4 cases no – 6 cases
14	If suppose facilities for communal water hydrant or modified spring system is constructed, will you pay the charges ?	yes – nothing no – 4 cases	yes – 1 case no – 5 cases	yes – 1 case	yes – 3 cases no – 3 cases	yes – 4 cases no – 1 case	yes – 4 cases no – 6 cases
15	How many person in your family?	(Average) 6	6	8	9	8	8
16	Do you have any occupation other than agriculture?	yes – nothing no – 4 cases	yes – 1 case no – 5 cases	no – 1 case	yes – 1 case no – 5 cases	no – 5 cases	yes – 1 case no – 9 cases

(continue)

SECOND QUESTIONNAIRE SURVEY

Survey execution period : Februry 1990

	Item of investigation / Commune	Birenga	Kabarondo	Kayonza	Kigarama	Mugesera	Muhazi
1	Distance for fetching water[House – Water source] (one way) Required time[House – Water source] (one way) (on foot)	(Average) 1.1 km (Average) 26 min.	1.5 km 25 min.	1.5 km 23 min.	1.5 km 32 min.	0.9 km 25 min.	1.6 km 26 min.
2	Types of water source	①Spring – 14 locations ②Communal water hydrant – 4 locs.	①Spring – 12 locations ②River – 4 locations	①Spring – 10 locations ②Swamp – 8 locs.	①Spring – 8 locs. ②Communal water hydrant – 7 locs.	Communal water hydrant – 8 locs. ②Spring – 7 locs.	①Spring – 11 locs. ②Well – 4 locs.
3	Number of times of water fetching per day	①twice – 15 cases ②thrice – 4 cases	①thrice – 7 cases ②twice – 6 cases	①thrice – 8 cases ②twice – 7 cases	①twice – 10 cases ②thrice – 6 cases	①twice – 9 cases ②thrice – 4 cases	①twice – 7 cases ②thrice – 5 cases
4	Types of containers for fetching weater	20 liter Plastic tank	20 liter Plastic tank 12 liter bucket	20 liter Plastic tank	20 liter Plastic tank 15 liter bottle gourd	20 liter Plastic tank	20 liter Plastic tank 5 liter plastic tank
5	Persons fetching water (Water fetching shared within the members of the family)	①men ,women&children – 10cases ②men&women – 5 cases each	①children – 10 cases ②women – 6 cases	①children – 18 cases ②men – 2 cases	①men,women&children – 7 cases ②men – 7 cases	①men – 7 cases ②children – 6 cases	①children – 11 cases ②men – 6 cases
6	Situation of usage of water	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing
7	Is the source from which is fectched in dry weather the same as the source for daily needs ?	same source – 17 cases different source – 3 cases	same source – 15cases different source – 5 cases	same source – 20 cases different source – nothing	same source – 18 cases different source – 2 cases	same source – 18 cases different source – 2 cases	same source – 19 cases different source – 1 case
8	Laundry thimes per week	①twice – 10 cases ②once & seven times – 4 cases each	twice,five & seven times – 5 cases each	①twice – 9 cases ②once & thrice – 4 cases each	①twice – 10 cases ②thrice – 6 cases	①twice – 9 cases ②once – 5 cases	①twice – 7 cases ②thrice – 5 cases
9	At this stage, in addition to the regular source for fetching water, do you fetch water from some other source also?	yes – 4 cases no – 15 cases	yes – nothing no – 20 cases	yes – nothing no – 20 cases	yes – 1 case no – 19 cases	yes – 2 cases no – 18 cases	yes – 1 case no – 19 cases
10	Have you ever participeted in the construction of water supply systems till now?	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
11	Are you satisfied with the water supply at present? (from the viewpoint of quantity and quality)	satisfied – 10 cases not satisfied – 10 cases	satisfied – 11 cases not satisfied – 9 cases	satisfied – 4 cases not satisfied – 16 cases	satisfied – 14 cases not satisfied – 6 cases	satisfied – 10 cases not satisfied – 10 cases	satisfied – 12 cases not satisfied – 8 cases
12	Assuming that amenities for water supply such as communal water hydrants can be used, can you pay 2,000 francs a year as charges for using water?	yes – 5 cases no – 12 cases	yes – 14 cases no – 6 cases	yes – 14 cases no – 6 cases	yes – 14 cases no – 4 cases	yes – 13 cases no – 4 cases	yes – 10 cases no – 5 cases
13	How many person in your family?	①6 – 4 cases ②4 – 3 cases	①10 – 4 cases ②6,7 &3 – 3 cases each	①5 – 4 cases ②6 &8 – 3 cases	①6 – 10 cases ②4,8 & 9 – 2 cases each	①4,5,7 &8 – 3 cases each ②6,9 &10 – 2 cases each	①6 – 5 cases ②3 & 7 – 4 cases each
14	Do you have any occupation other than agriculture?	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
15	Occupation & monthly income	Agriculture – 1.245F	①Agriculture – 1.500F ②Public servant – 14.920F	①Agriculture – 2.350F ②Public servant – 12.500F	①Agriculture – 2.270F ②Independent – 3.250F	①Agriculture – 4.900F ②Public servant – 12.000F	①Agriculture 4, 900F ②Public servant – 13.000F
•	Average water consumption per head	6.2 l / man·day	10.0 l / man·day	7.2 l / man·day	13.8 l / man·day	9.0 l / man·day	9.6 l / man·day
•	Average persons in a family	8	7	8	6	8	6

Rukara	Rukira	Rusumo	Rutonde	Sake	TOTAL (Average value)
1.7 km 33 min.	1.0 km 19 min.	1.3 km 24 min.	0.6 km 7 min.	0.8 km 24 min.(?)	1.2 km 24 min.
① Spring – 7 locs. ② Swamp – 6 locs.	① Communal water hydrant – 9 locs ② Spring – 5 locs.	① Communal water hydrant – 7 locs. ② Spring – 6 locs.	① Spring – 8 locs. ② Communal water hydrant – 7 locs	① Spring – 7 cases ② Communal water spring – 5 cases	(① & ② total) Spring – 95 cases(58%), Communal water hydrant – 47 cases(29%), Swamp – 14 cases(9%) River – 4 cases(2%), Well – 4 cases(2%)
① twice – 14 cases ② thrice – 4 cases	① thrice – 8 cases ② twice – 7 cases	① thrice – 9 cases ② twice – 7 cases	① thrice – 9 cases ② twice – 6 cases	① once – 10 cases ② twice – 8 cases	(① & ② total) twice – 96cases(56%), thrice – 64 cases(38%) once – 10 cases(6%)
20 liter Plastic tank	20 liter Plastic tank	20 liter Plastic tank	20 liter Plastic tank	20 liter Plastic tank 15 liter bottle gourd	20 liter Plastic tank
① children – 11 cases ② men – 6 cases	① men & women – 7 cases each ② women & children – 4 cases	① women&children – 8 cases ② men – 6 cases	① children – 15 cases ② men – 3 cases	① women – 11 cases ② men – 7 cases	(① & ② total) Children – 71 cases(41%), Men – 44 cases(25%) Women – 17 cases(10%), Women & Children – 12 cases(7%), Other mix – 29 cases(17%)
Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing	Daily life necessities & banana liquor manufacturing
same source – 20 cases different source – nothing	same source – 16 cases different source – 4 cases	same source – 15 cases different source – 3 cases	same source – 20 cases different source – nothing	same source – 15 cases different source – 4 cases	(total) same source – 193 cases(89%) different source – 24 cases(11%)
① twice – 9 cases ② once – 6 cases	① twice – 8 cases ② thrice – 7 cases	① twice – 6 cases ② four times – 5 cases	① twice – 10 cases ② thrice – 5 cases	① once – 8 cases ② twice – 7 cases	(① & ② total) twice – 90 cases(55%), once – 27 cases(17%) thrice – 27 cases(17%), four times – 5 cases(2%), others – 14 cases(9%)
yes – nothing no – 20 cases	yes – 8 cases no – 12 cases	yes – 10 cases no – 10cases	yes – nothing no – 20 cases	yes – 3 cases no – 15 cases	(total) yes – 29 cases(13%) no – 188 cases(87%)
N.A.	N.A.	N.A.	N.A.	N.A.	
satisfied – 4 cases not satisfied – 16 cases	satisfied – 6 cases not satisfied – 14 cases	satisfied – 12 cases not satisfied – 7 cases	satisfied – 14 cases not satisfied – 6 cases	satisfied – 7 cases not satisfied – 13 cases	(total) satisfied – 104 cases(47%) not satisfied – 115 cases(53%)
yes – 16 cases no – 4 cases	yes – 8 cases no – 12 cases	yes – 10 cases no – 6 cases	yes – 15 cases no – 5 cases	yes – 7 cases no – 12 cases	(total) yes – 126 cases(62%) no – 76 cases(38%)
① 8 – 5 cases ② 7 – 4 cases	① 5,6 &10 – 3 cases each ② 2,3,7&8 – 2 cases each	① 8 – 5 cases ② 5 – 4 cases	① 6 – 4 cases ② 3,4,5,7,8 &10 – 2 cases each	① 5 – 7 cases ② 6 – 5 cases	(① & ② total) 7
N.A.	N.A.	N.A.	N.A.	N.A.	
① Agriculture – 1.500F ② Public servant – 13.450F	① Agriculture – 1.270F ② Public servant – 7.500F	① Agriculture – 1.220F ② Public servant – 12.870F	① Agriculture – 5.480F ② Public servant – 9.035F	① Agriculture – 4.660F ② Commerce – 3.000F	(① & ② total) Agriculture monthly income(average) 2.480F Public servant monthly income(average) 9.530F
8.6 l / man·day	9.0 l / man·day	9.5 l / man·day	10.7 l / man·day	6.3 l / man·day	9.1 l/man·day
7	6	7	7	6	7

Result of Questionnaire Survey

Occupation and Monthly Income

Occupation		Cases		(Average monthly income)
- Agriculture	---	158 cases	---	2,400 Francs
- Public Servant	---	30 cases	---	11,900 Francs
- Business	---	6 cases	---	11,500 Francs
- Police Officer	---	3 cases	---	10,700 Francs
- Teacher	---	4 cases	---	22,000 Francs
- Dietitian	---	1 case	---	7,500 Francs
- Clergyman, Abbot	---	2 cases	---	15,000 Francs
- Cellule Committee Member	---	1 case	---	835 Francs
- Secteur Assemblyman	--	1 case	---	4,500 Francs
- Stonemason	---	1 case	---	12,000 Francs
- Lawyer	---	1 case	---	6,000 Francs
- Attendant	---	1 case	---	5,000 Francs
- Driver	---	2 cases	---	18,000 Francs
- Bank Clerk	---	1 case	---	9,100 Francs
- Agricultural investigator	---	1 case	---	12,000 Francs
- Service Industry	---	1 case	---	7,000 Francs
- Not known	---	2 cases	---	? Francs

Average consumption per person

9.1 liter per person per day.

Actual Water Consumption of Existing System

TIME	CONSUMPTION													
	I(NYKR)-No.1		I(NYKR)-No.2		II-1603002		IV-1610010		III-1608002		KIOSK(RWMGN)		SP(ZZ-KBRZ)	
	pers./	m3	pers./	litter	pers./	litter	pers./	litter	pers./	litter	pers./	m3	pers./	m3
4 - 5		0.0	0	0	0	0	0	0	0	0	0	0	0	0.0
5 - 6	(no	0.1	13	90	5	80	7	105	7	100	6	0.1	-	-
6 - 7	count)	0.2	41	1,015	25	395	6	95	15	335	25	0.6	-	-
7 - 8		0.6	25	1,065	20	515	5	90	11	250	19	0.5	8	0.3
8 - 9		0.7	32	985	30	550	3	40	16	400	18	0.5	12	0.4
9 -10		0.4	42	990	52	1,000	4	55	13	330	14	0.5	18	0.6
10 -11		0.2	30	470	40	450	2	20	12	305	10	0.2	31	0.8
11 -12		0.3	26	695	51	1,145	1	10	9	230	16	0.3	35	1.1
12 -13		0.4	25	750	50	1,035	3	65	31	770	24	0.7	0	0.0
13 -14		0.4	15	745	45	870	4	75	19	455	9	0.2	0	0.0
14 -15		0.5	21	690	50	770	17	415	20	550	33	1.0	33	0.9
15 -16		0.7	29	840	45	815	9	210	17	455	26	0.7	40	1.0
16 -17		0.8	45	1,195	46	870	7	220	20	485	15	0.5	35	0.8
17 -18		0.9	41	1,140	42	1,020	3	40	23	505	24	0.8	37	1.2
18 -19		0.2	15	380	17	470	2	30	5	85	11	0.3	-	-
19 -20		0.1	3	35	0	0	0	0	0	0	0	0.0	-	-
20 -21		0.0	0	0	0	0	0	0	0	0	0	0.0	0	0.0
21 -22		0.0	0	0	0	0	0	0	0	0	0	0.0	0	0.0
TOTAL		6.5	403	11,085	518	9,985	73	1,470	218	5,255	250	6.9	249	7.1
Rate= Comsumption / Design Volume		0.93		1.01		1.00		0.15		0.53		0.73		0.52
												0.62		>1=1.0
												0.69		
												0.64		

Table F.5 (1)

Result of the Hearing Survey to Commune Office

	Hygenic Condition: General	Hygenic Condition: W-related diseases	Water source	Identified secteur	Problem of Water Supply	Institution for O/M: Existing W.S.S	Institution for O/M: Communal System	Target by 2000	Improv. Request	Possitive Actions	Future O/M Instit.	Planned water Charge
[RUKARA]	Lack of			▽								
GAHINI *	drinking	Diarrhea	Lake	Rv		Indipendent org.	Communal water	SP is required	yes	preparation		
KAWANGIRE *	water	Parasite	Riv	L		for existing	manager	=100%	yes		Public association	
KIYENZI *		Malaria	Rain...some	Rv		system	+	+	yes		for W.S.-O/M	200Rwf/M/fm
NYAKABUNGO	Poor		(Public Faci.)	Sp		(200Rwf/M/fm)	Operator	I-Spr				from beneficiary
NYAWERA	water			Sp			(7,500Rwf/M)					
RUKARA *	supply					<stuff>			yes	preparation		
RWIMISHINYA*	|		Spr..15(40l/fm)		->Shortage	Head/Assistant	W-charge from		yes			
RYAMANYONI *	8 secteur		I-Spr..8		during dry	Clerk/Acountant	users		yes	preparation		
-total-					season							
[MUHAZI]												
GATI *	Water related	Diarrhea		L		Managed by	non system	SP is required	yes		under considera-	under planning
GISHALI	disease of	Parasite	I-Spr....27		->Small amount	ERECTROGAZ					tion based on	but W-charge
KABARE	Diarrhea	Malaria	Lake		->Animal risk	<2Rwf/20l>	most of habitant				Goverment proposal	is not dicided
KITAZIGURWA*	|			L	Bad quality		use non-treated		yes		for enlightment &	
MUKARANGE *	7 secteur			L	at case of		lake-water		yes		O/M activities	
MUNYIGINYA					direct supply							
MURANBI *				L					yes			
NKOMANGWA *				L					yes			
NYAGATOVU *				L					yes			
NYARUBUYE *				L					yes			
NYARUGARI												
RUHUNDA												
-total-												
[MUGESERA]												
CYIZIHIRA	Bad quality				Poor W-supply	ELECTROGAZ	Communal water	SP is required			Water manage	same as present
GATARE *	of lake water	Direct water		L	condition	+	manager	+	yes		commitee will	2 Rwf/20l &
KAGASHI *		supply		L		Water manage	+	I-Spr	yes		be enlarged	45 Rwf/m3 for SP
KAREMBO	Poor	->Hevy			Shortage of	commitee	(Enguneer)				+	
KIBARE	sanitation	problem of	Spr/I-Spr..35		drinking water	<stuff>	for	Pipe-line to			Plan to setup	
KIBILIZI-1		Parasite				Head/Assistant	Enlightment &	Kibare/Matongo			Public association	
KIBILIZI-2	Poor/bad		Lake......many		->Animal risk	Clerk/Acountant	O/M activities	/Nyange &			for W.S.-O/M	
KIRAMBO *	drinking			L	Bad quality	menber(2)		Health center	yes			
KUKABUYE	water											
MATONGO *				L	Problem of	<2Rwf/20l>			yes	encave has done		
NGARA					existing faclty	<45Rwf/m3>						
NYANGE *				L					yes	encave has done		
SANGAZA *				L		W-charge to ELTGZ			yes			
SHYWA						100,000Rwf/M						
ZAZA												

(continue)

	Hygenic Condition General	W-related diseases	Water source	Identified secteur ▽	Problem of Water Supply	Institution for O/M Existing W.S.S	Communal System	Target by 2000	Improv. Request	Possitive Actions	Future O/M Instit.	Planned water Charge
[SAKE]												
GITUZA *	Poor/bad	Diarrhea		Rv/L		Communal manage	Communal water	SP=90%	yes		under considera-	same as present
MABUGA-1	drinking	..etc	Spr....13		->Shortage	<3Rwf/201>	manager	W-source:Spr			tion based on	3Rwf/201 for SP
MABUGA-2	water		I-Spr..17		->Low EV level	Communal water	+				Goverment proposal	50Rwf/an/fm for
MBUYE *				L	of source	manager	Engineer	Supply to	yes		for enlightment &	I-Spr
MURWA *	Many w-related			L		+	(charch)	Hospital	yes		O/M activities	
NGOMA	disease caused		Lake..8 secteur		->Animal risk	Funtain ope.	for piped system					
NSHILI-1	by Riv/Lake				Bad quality	Pump ope.						
NSHILI-2 *	water			L		7,000Rwf/M	<50Rwf/an/fm for		yes			
RUBAGO *				L		Total income:	I-Spr>		yes			
RUKUMBERI *				Rv/L		42,000-			yes			
RUYEMA-1					<very far to	45,000Rwf/M						
RUYEMA-2 *				L	water source>	electr. charge:			yes			
SHOLI *				L		25,000Rwf/M			yes			
[KAYONZA]												
GASOGI	Lack of	Diarrhea	Spr/I-Spr..75		->Shortage	Water users org.	Communal water	SP=70%			under considera-	Sustained by
KAYONZA	drinking	Parasite	(1,000fm)		during dry	<200Rwf/an/fm>	manager	HP=20%			tion to setup	useres
MBURABUTURO	water	Malaria			season		+	I-Spr=40%			water management	
MUSUMBA		|	Well.......10		->Shortage		Water users org.			Insti. setup	commitee	max. solvency
NYAMIRAMA		all secture	(922fm)	(R)	during dry							but not dicided
RUTARE				(R)	season					Insti. setup		
RWINKWAVU			Rain		->Shortage					L-prepar./Inst. setup		
SHYOGO				(R)						Insti. setup		
-total-												
[RUTONDE]												
KADUHA	Poor/bad	Diarrhea	I-Spr/Spr	Rv/L		Managed by	Communal water	SP=60%	yes		under considera-	2 Rwf/201 for SP
KIGABIRO	drinking	Malaria	...36		->Old	ERECTROGAZ	manager	W-source:			tion based on	or
NKUNGU	water			Rv/L		<2Rwf/201>		Lake+treatment	yes		Goverment proposal	50Rwf/M/fm for
NSHINDA			Well.....8		->bad quality		no other				for enlightment &	communal ope.
NYARUSANGE	bad quality of		Riv/Lake		->bad quality		institution	Supply to			O/M activities	as a max.
RUTONDE *	Riv/Lake water		...5 secteurt	Rv/L				Hospital	yes			
RWERU *				Rv/L					yes			
RWIKUBO												
SOVU *				Rv/L					yes			
-total-												
[KABARONDO]					Poor W-supply							
BISENGA *	Poor	Diarrhea	Spr.....40	Rn/S/Sw		non institution	Communal water	HP=80 wells	yes		under considera-	Sustained by
CYINZOVU	drinking	Parasite	I-Spr...53		Shortage of		manager	I-Spr=	yes	(broken of equip.)	tion to setup	useres but
KABARONDO	water				drinking water	Under planning		100 points		(broken of equip.)	water management	system is not
MURAMA *		(leech)		Rn/S/Sw		for new Piped-	non institution		yes		commitee	dicided
NKAMBA						system						
RUBIRA				Rn/S/Sw							Public association	
RUKIRA			Well....14		->bad quality					(non available)	for W.S.-O/M of	
RUNDU			Swamp....6	Rn/	(?)						(Goverment proposal)	
RURAMIRA			Rain....10	Rn/S								
RUSERA				Rn/S								
RUYONZA				Rn/S								
SHYANDA *				Rn/S/Sw					yes			
-total-												

(continue)

	Hygenic Condition General	W-related diseases	Water source Identified secteur	Problem of Water Supply	Institution for O/M Existing W.S.S	Communal System	Target by 2000	Improv. Request	Possitive Actions	Future O/M Instit.	Planned water Charge
[KIGARAMA]											
FUKWE	Poor/bad	Diarrhea	Spr....22		Existing but	Communal water	<<-Rehabili.	yes		under considera-	max. solvency
GASETSA	drinking	Parasite	I-Spr..38	->a few bad	un-controled	manager				tion based on	but not dicided
GASHANDA	water by HP	Malaria		quality	by Commune	+	SP W-supply	yes		Goverment proposal	
KABARE-1			HP......21	->Shortage &		Management	-> 100%			for enlightment &	collecting
KABARE-2	Poor		2=bad condition	bad quality		commitee by				O/M activities	system:
KABERANGWE	sanitation			during dry		users for					once/an/fm after
KANSANA				season		each W-source		yes		Public association	coffee yielding
REMERA	Poor		Swp.....many	->bad quality						for W.S.-O/M	
RUBONA	medical		<<-Rain					yes			
RURENGE	facility							yes			
VUMWE											
-total-											
[RUKIRA]											
GASIRU	Poor	Diarrhea	Spr....49		2 Communal	Communal water				Water Mangement	Collection
GITUKU	drinking	Parasite			water managers	manager			preparation(I-Spr)	Comitee with	system is
GITWE	water source	Malaria	I-Spr..25(911fm)	->Shortage(17)		+				Service Engineers	under planning
MUBAGO			<total=32.61/sec>		W-charge:	Management org.				for W.S.System	but W-charge
MURAMA	Many Swamps	Dirty foods			100Rwf/fm/an	for each I-spr.					is not dicided
MUSHIKILI	->insects &	(Contami-	HP......8(324fm)	->Shortage(8)		(2)			preparation(I-Spr)		
NTARUKA	disesses	nated)		during dry		<stuff>					
RUGARAMA				season &		-Head			preparation(I-Spr)		
RURAMA	Poor			bad quality		-Acountant					
RURENGE	sanitation					-Engineer			<total=10 Spr>		
-total-						<7,000Rwf/m>					
[BIRENGA]											
BARE	no problem	non	SP(Kibungo)	->Shortage							
BIRENGA			Spr....20	->Shortage	KIOSK System	Communal water				under considera-	System and charge
GAHARA			I-Spr..45		by ELECTROGAZ	manager				tion based on	will be dicided
GAHULIRE	Poor		Well...97 RV		<2Rwf/20l>					Goverment proposal	by REGIE Associ.
GASHONGORA	drinking		HP......2 RV	->Shortage		non institution				for enlightment &	
[illegible]	water of			bad quality						O/M activities	
KIBARA	existing		SW	during dry							
KIBIMBA	piped-system		SW	season						Public association	
KIBUNGO			Lake/Riv.2							for W.S.-O/M	
MATONGO			Swp.....13 SW	->bad quality							
NDAMIRA			Rain...some	->Shortage							
SAKARA			(Public Faci.)								
-total-											
[RUSUMO]											
GATORE											
GISENYI											
KANKOBWA			(Hearing data are not avilable)								
KIGARAMA											
KIGINA											
KIREHE											
MUSAZA											
NYABITARE											
NYAMUGALI											
NYARUBUYE											
-total-											

Table Classification of Existing Systems

		Facilities					O/M				Total	Facility of	Remarks
		Water Quality	Water Quantity	Approach	Condition of Adjust.	classifi -cation	O/M Agency	Fee Collect. System	Condition of O/M Facility	Classifi -cation	Evaluation	Improvement under Phase III	
Un-piped	Protected Spring	B	B	C	B	B	C	C	C	C	BC	[illegible]	Supporting Water Source
Water	Handpump	B	A	A	B	A	C	C	C	C	AC		
Supply System	Rain Harvest	A	C	A	B	B	-	-	B	B	BB		
Urban Water	Kibungo	A	A	A	A	A	A	A	A	A	AA		
Supply System	Rwamagana	A	A	A	A	A	A	A	A	A	AA		
Rural piped	IDA Rehabilitation												
Water	Facility (11Areas)	A	B	A	C	B	B/C	B/C	C	C	BC		IDA Rehabilitation Project
Supply System	AKAGERA C	A	A	B	B	A	C	C	C	C	AC		
	KIREHE	A	A	A	B	A	B	C	B	B	AB		
	RUSUMO BGM	A	B	A	B	B	B	C	C	C	BC	yes	
	MUSAZA BAS	A	C	B	C	C	B	C	C	C	CC	yes	
	RUKARA	A	A	A	B	A	B	C	C	C	AC		
	ZAZA	A	A	A	B	A	B	B	B	B	AB		
	KAMUSHIKUZI	A	C	B	C	C	C	C	C	C	CC	yes	
	SAKE	A	A	B	C	B	B	C	C	C	BC	yes	
	NYANKORA	A	A	A	B	A	C	C	C	C	AC		

Note :

Water Quality
- A : Good
- B : There is a few problem
- C : Bad

Water Quantity
- A : Good
- B : A few lack
- C : Lack

Approach
- A : Good
- B : Average
- C : Bad

Condition of Adjustment
- A : Good
- B : Partially Repair Need
- C : All Repair Need

O/M Agency
- A : ELECTROGAS
- B : Water Committee
- C : None

Fee Collecting System
- A : Good
- B : There is system but Collecting is not smooth
- C : None system

Condition of O/M Facility
- A : Good
- B : There is a few problem
- C : No good

Table F.7 (1)

COMMENTS ON PHASE II AREAS FROM THE GEOLOGICAL POINT OF VIEW

Zone	Geology	Hydrogeological Characteristics	Comments on Groundwater Development
V	- Alluvial deposits along Kibaya R.(EL=1,400-1,450m): .C to L textured,width of 50m to 150m,a few swampy lands	- Aquiferes within thin alluvial deposits	Shallow groundwater development on the zone within 100m far from alluvial lands is only proposed.
	- Talus sediments along alluvial land: .Bad sorted, C to P textured	- Recharge zone at upper parts, discahrge zone at lower parts	HAND-PUMP WELL
	- Basal rock: .mainly pelitic rock/schist and a few hard rock beds	- Aquicludes except fractured hard rock	
VI	- Alluvial deposits along main rivers flowing to W (EL=1,375-1,500m): .C to L textured,width of 50m to 400m,a few swampy lands	- Aquiferes within thin alluvial deposits except northen part where thick aquiferes may occure along fractual fault zone	Nothern part: high potentials of groundwater development on the areas under EL 1600-1650m
	- Talus sediments along alluvial land: (same as Zone V)	- (same as Zone V)	BOTH SHALLOW & DEEP GROUNDWATER DEVELOPMENT
	- Basal rock: .quartzite in nothern part, along Binoni R.	- Recharge zone at upper parts, transmission/discharge zone at lower parts with cracky hard rock	Southern part: (same as Zone V)
	.pelitic rock & schist in southern part along Nyagateme R.	- (same as Zone V)	HAND-PUMP WELL

(continue)

VII	- Alluvial deposits along Nyagasenyi R. flowing to W (EL=1,375-1,450m): (same as Zone V)	-	(same as Zone V)
	- Talus sediments along alluvial land: (same as Zone V)	- (same as Zone V)	HAND-PUMP WELL
	- Basal rock: (same as Zone V)	-	
	* quartzite is found on south and east margins in the area	- Transmission/discharge zone are developed at middle to lower parts on the very small parts in S & E margin	- margin of S & E: a few potentials of groundwater development on the areas
VIII	- Back swamp of Akagera R. and alluvial lands of its tributries(EL=around 1,300m): .C to CL textured,swampy	- Very high groundwater table	Shallow groundwater development on the zone within 200m far from alluvial lands is only proposed.
	- Basal rock: .massive granite surround the alluvial lands	- Aquicludes excpt parts of fractured fault zone	HAND-PUMP WELL
IX	- Alluvial deposits: (same as Zone VIII)	- (same as Zone VIII)	high potentials of groundwater development on the areas under EL 1450-1500m
	- Basal rock: .quartzite and dolerite in the nohern part and surround the alluvial lands	- Recharge zone at upper parts, transmission/discharge zone at lower parts & fault zone with fractured hard rock	BOTH SHALLOW & DEEP GROUNDWATER DEVELOPMENT
X	- Alluvial deposits(EL=1350-1400m): (same as Zone V excpt width of around 50m)	- (same as Zone V)	(same as Zone V)
	- Basal rock: (same as Zone V)	-	HAND-PUMP WELL

(continue)

XI	- Swampy alluvial deposits on broad dipression enclosed by Akagera R. & on lowlying lands of its trbutries (EL=around 1,325m): (same as Zone VIII)	-	(same as Zone V)	(same as Zone V)
	- Talus sediments along alluvial land: (same as Zone V)	-		
	- Basal rock: (same as Zone V)	-		HAND-PUMP WELL
XII	- (same as Zone XI)	-	(same as Zone V)	(same as Zone V) HAND-PUMP WELL

Roads and Electric Services Condition in Phase II Area

Zone	Area (km2)	Access from Main Road	Average Distance from P.T.L	
			Existing Line	Proposed Line
V	24.3	*** good	** from 5 to 10km	*** less than 5km
VI	85.3	* bad	* more than 10km	** from 5 to 10km
VII	41,7	** not so good	* more than 10km	*** less than 5km
VIII	30.6	** not so good	*(40km) more than 10km	** from 5 to 10km
IX	49.8	* bad	*(37km) more than 10km	** from 5 to 10km
X	21.8	* bad	** from 5 to 10km	*** less than 5km
XI	78.5	* bad	* more than 10km	*** less than 5km
XII	24.1	** not so good	** from 5 to 10km	no planning
Total	356.1			

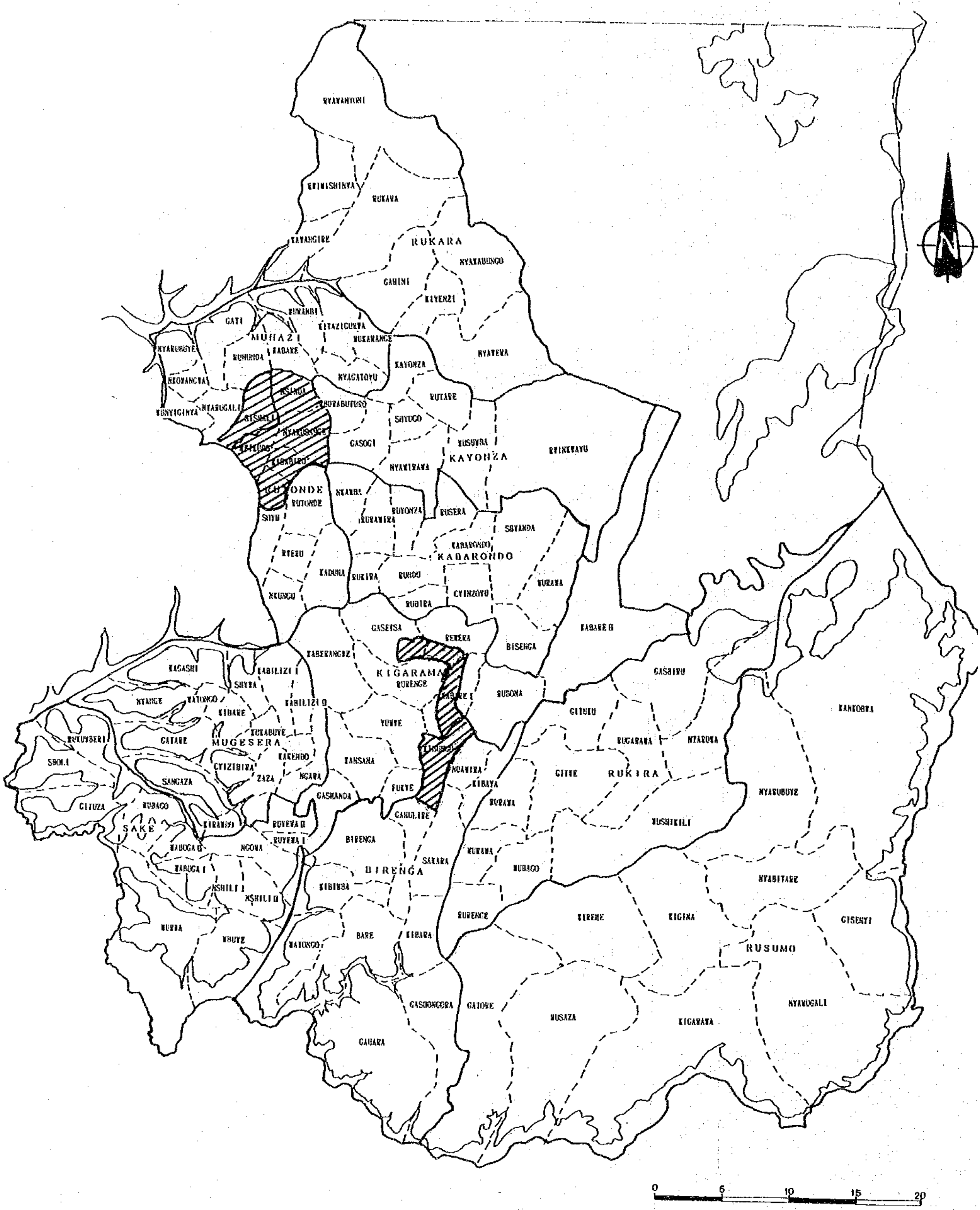
Source : Study Team, 1989
Note : P.T.L = Power Transmission Line

Water Supply Plan of Phase I and Phase II

Zone	No. of Communes	No. of Sectors	No. of Cellules	Population (1983)	Population Served (1990)	Water Demand (l/d)	Discharge Supplied (l/d)	No. of Wells Required	Type of Wells
I.	2	2	3	2,752	3,187	71,708	80,000	1	D1 (Electric pump)
II.	3	6	13	7,831	8,714	130,710	130,000	13	D1 (Manual pump)
III.	3	6	18	6,324	11,754	176,310	180,000	18	"
IV.	4	13	40	20,144	26,247	393,705	400,000	40	"
	Subtotal			37,051	49,467	703,912	720,000	72	
V.	1	2	7	3,823	5,239	78,585	80,000	8	D1
VI.	2	6	17	9,355	12,952	194,280	180,000	18	D1
VII.	1	5	19 1/	3,496	4,786	71,790	180,000	18	D1
VIII.	1	1	5	1,534	2,101	31,515	50,000	5	S1
IX.	1	3	11 2/	3,252	4,455	66,825	110,000	11	S1
X.	1	6	13	10,062	12,368	185,520	160,000	16	D1
XI.	1	6	18 3/	12,528	15,399	230,985	240,000	24	S1
XII.	1	6	14	7,596	9,864	147,960	140,000	14	S1
	Subtotal			51,646	67,164	1,007,460	1,140,000	114	
	Total			88,697	116,631	1,711,372	1,860,000	186	

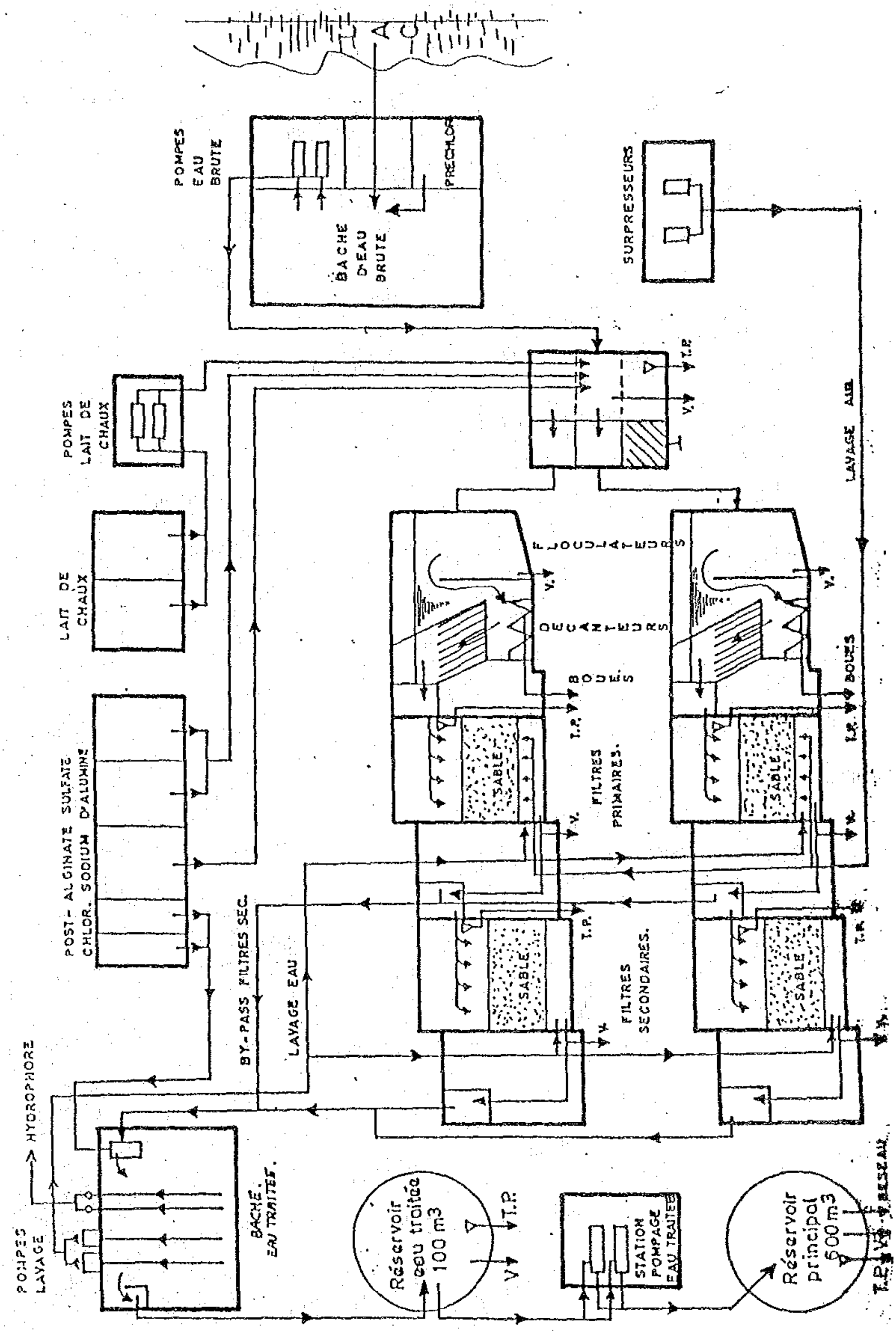
Note: 1/ 11 cellules have no population data
2/ 5 - " -
3/ 1 - " -

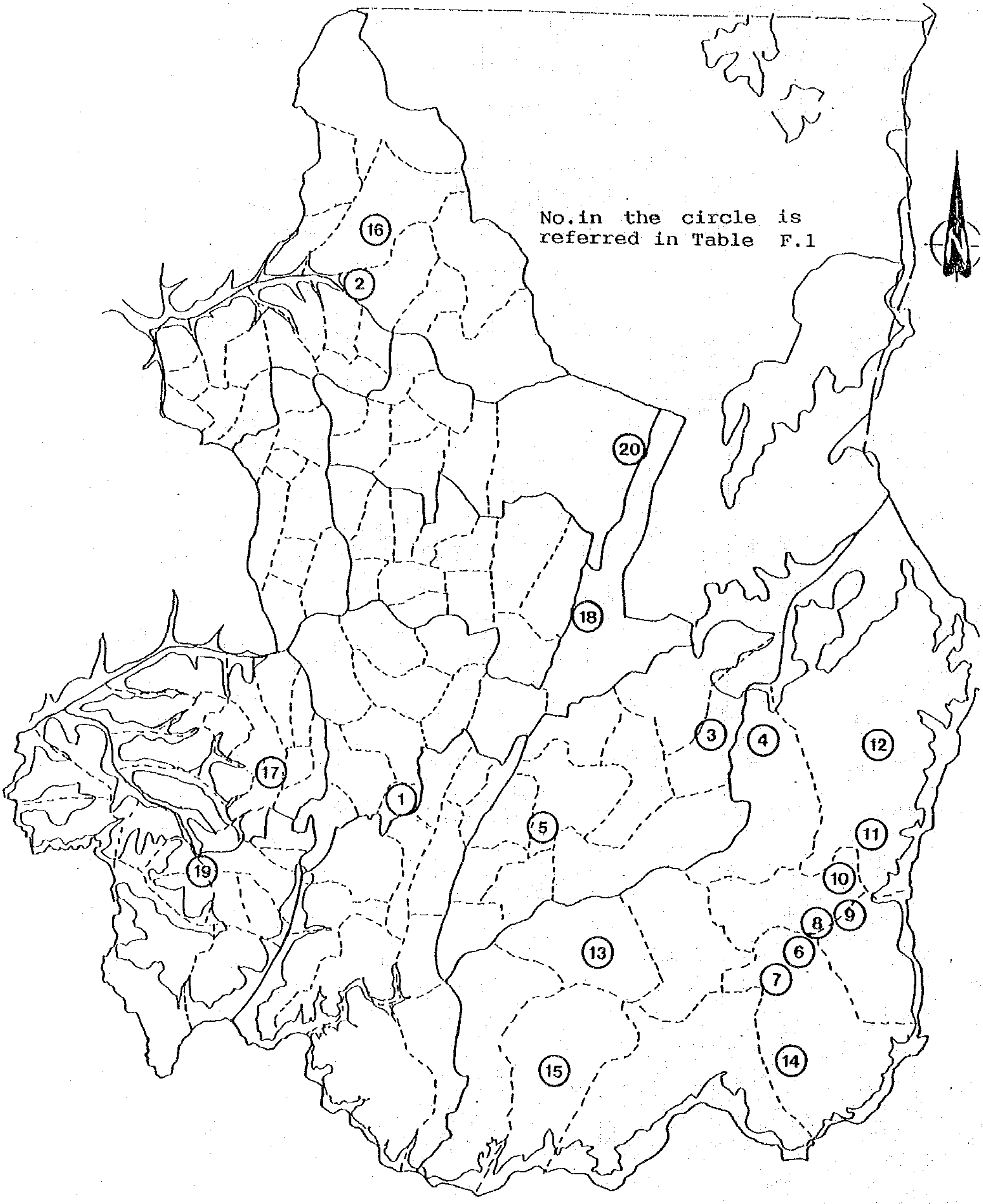
Fig. F.1



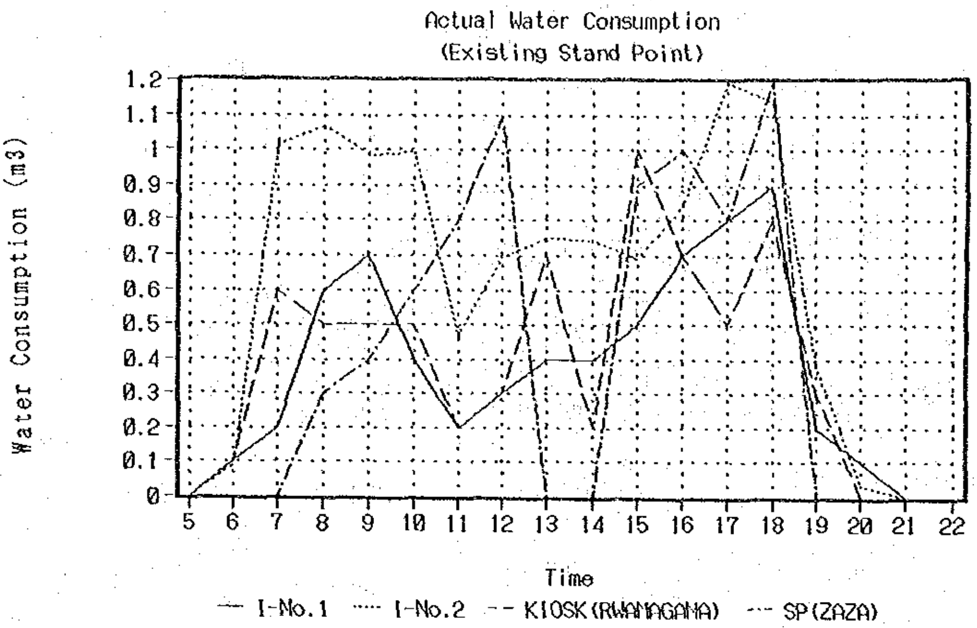
Service Areas of Urban Water Supply System

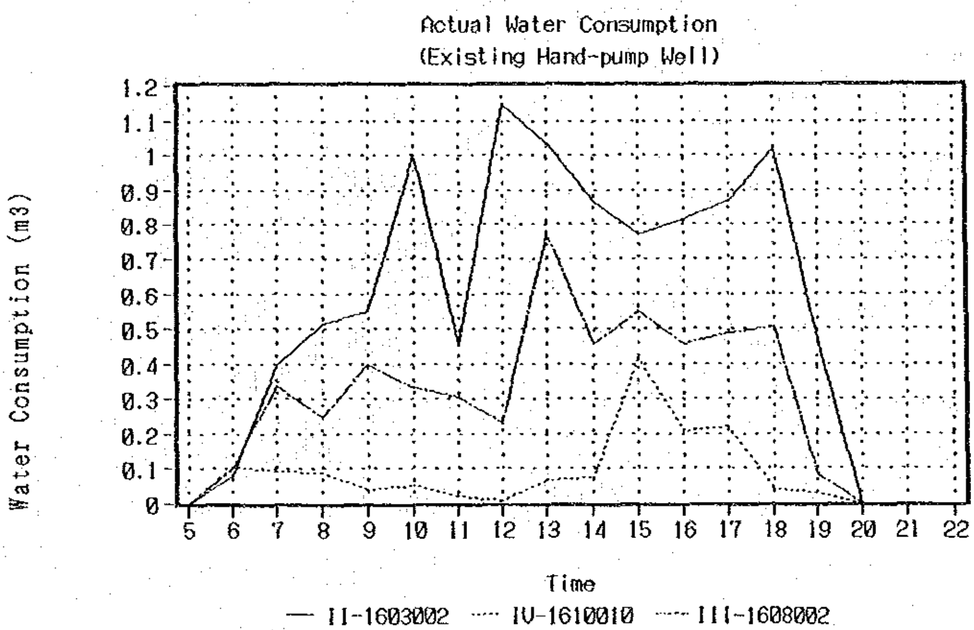
Diagram of Water Treatment System in Rwamagana





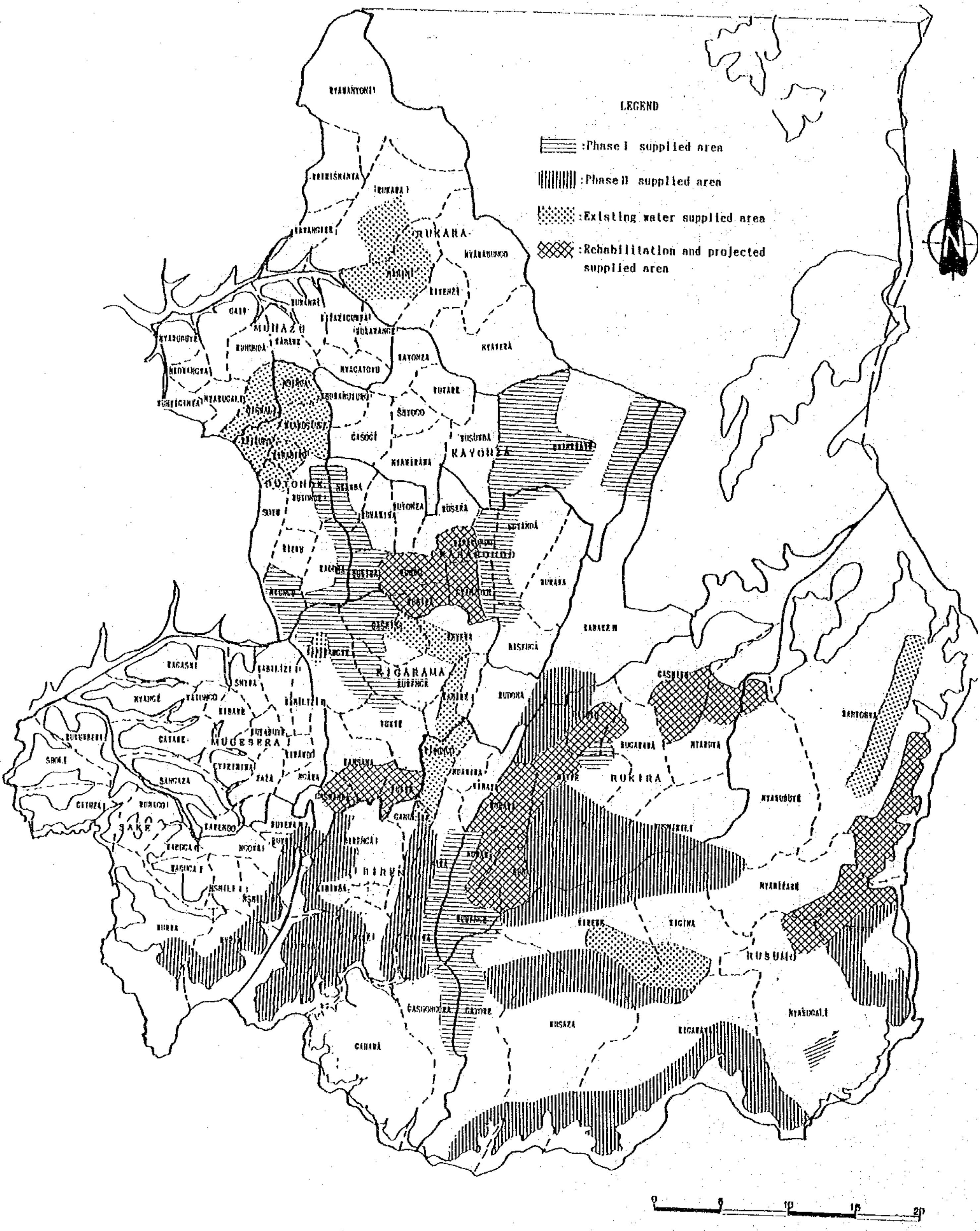
Existing Rural Water Supply Systems (Piped System)



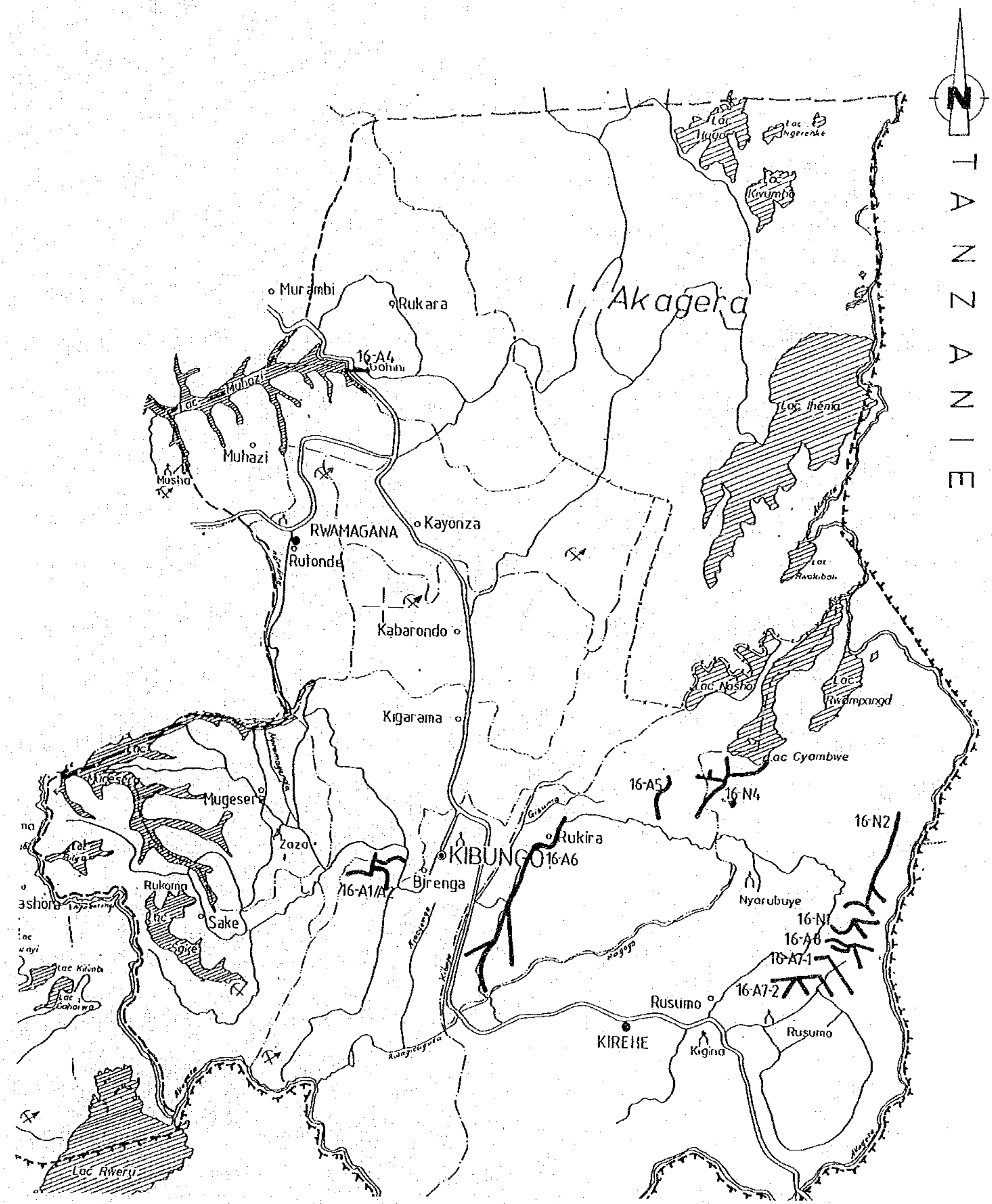


Result of Actual Water Consumption Survey

Fig. F.5

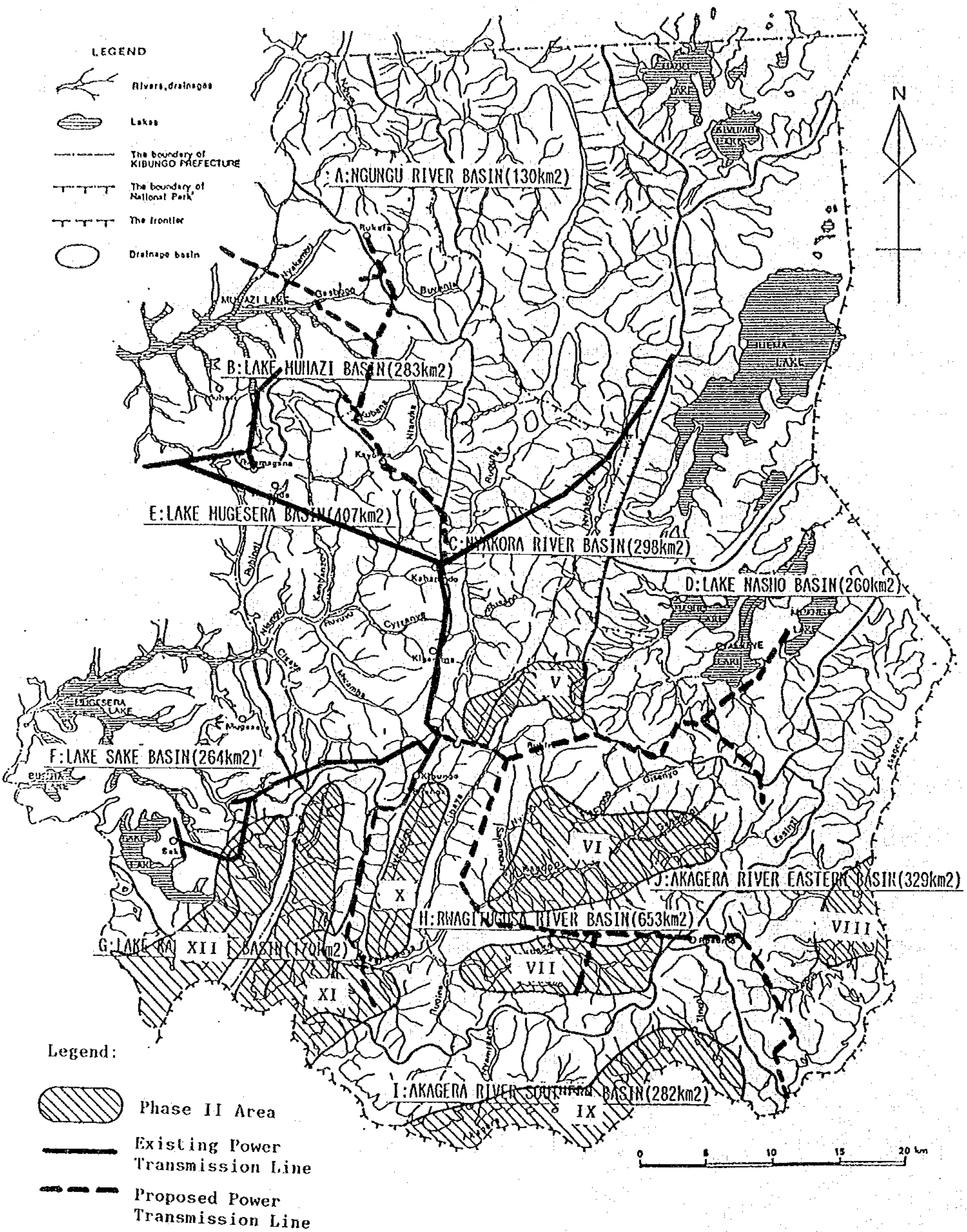


Service Areas of Existing Water Supply Facilities



Rehabilitation Project of Water Supply Facilities by IDA

Fig. F.7



Location of Water Supply Area in Phase II

APPENDIX G

GEO-ELECTRIC PROSPECTING

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

GEO-ELECTRIC PROSPECTING

1. GENERAL

Based on the results of hydro-geological surveys, geo-electric prospecting was conducted using the Schlumberger method and the new EM method in order to obtain the basic data necessary for determining the hydro-geologic structure of the Kibungo Prefecture in the eastern region of Rwanda and at select test well drilling sites.

Outline of the Geo-electric Prospecting:

. Prospecting Period
October 1 through December 14, 1989 (field work)

. Objectives
To obtain the basic data necessary for assuming the hydro-geologic structure of the Kibungo Prefecture in the eastern region of Rwanda and at select test well drilling sites.

. Contents of Prospecting

The Schlumberger method	98 points
The EM method	199 points

The approximate geo-electric prospecting locations are shown in Fig. G.1. The detailed locations are shown on the hydro-geologic map(Data Book). The number of measured prospecting lines are listed in Table G.1.

2. APPROACH OF PROSPECTING

Work procedure for the Study is as follows:

(1) Conducting geo-electric prospecting in large areas ... gross hydro-geologic structure survey

(2) Examination of gross hydro-geologic structure

(3) Selection of water sources by overlaying the socioeconomic factors on the gross hydro-geologic structure

(4) Planning of the groundwater survey at the planned water source points

(5) Conducting geo-electric prospecting at the planned water sources points ... hydro-geologic structure survey at the planned well drilling sites

(6) Examination of the hydro-geologic structure at the planned water sources

(7) Selection of test drilling sites

The organization structure established for the Study is shown in Data Book.

3. PROSPECTING METHOD

It was found that the developed fractures in the alluvial and Precambrian formations in the Study Area would be potential aquifers. Thus, the following two types of electrical resistivity measuring instruments were used for groundwater prospecting in the Study Area:

(1) Ground current receiving type: McOHM Model 2155 (Schlumberger Method)

(2) Electromagnetic type: EM 34 (EM Method)

3.1 INSTRUMENT SPECIFICATIONS

(1) McOHM Model 2155

Transmitter	:Voltage 400 vp-p Current 1,2,5,10,20,50,100 and 200 Ma
Receiver	:Input impedance 1 M ohm
Measurement Range	:-60 - +0.6V (automatic range)
Resolving Power	:0.001 ohm
Stacks	:1, 4, 16 and 64 times
Power Supply	:DC 12V

(2) EM34 (Geonics Co.)

Inter-coil Spacing	:10 meters at 6.4 Khz
Operating Frequency	:20 meters at 1.6 Khz 40 meters at 0.4 Khz
Power Supply	
Transmitter	:Disposable "0" cells
Receiver	:Disposable "0" cells
Conductivity Ranges	:3, 10, 30, 100, 300 Ms/m
Measurement Precision	:$\pm$ 2% of full scale

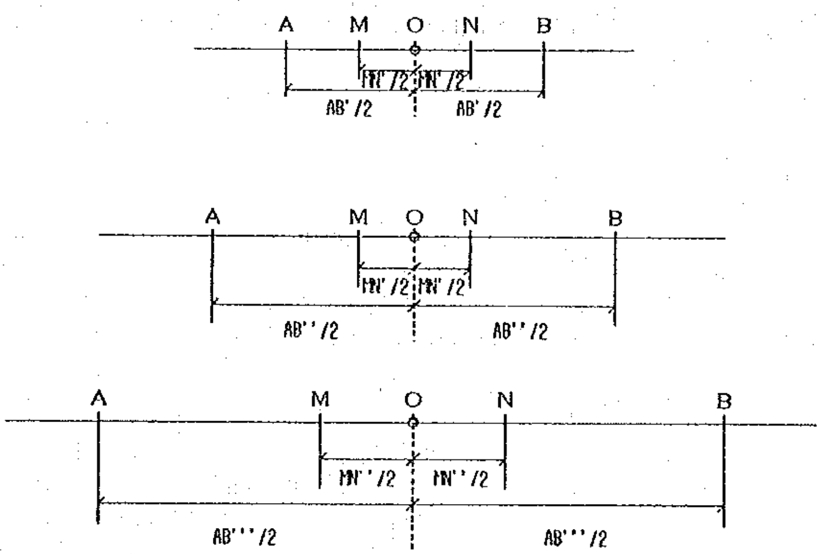
3.2 MEASURING METHOD

(1) Schlumberger Method

According to the locating methods of the current electrodes and the potential electrodes which are symmetrically arranged against the center points of the vertical direction prospecting method, the vertical direction prospecting method can be classified as two methods, the Wenner Method and the Schlumberger Method.

The Schlumberger method, which is characterized as being able to eliminate the effect of the surface ground layer to the resistivity values, was adopted for the Study.

In the Schlumberger Method the potential electrodes "M" and "N" are fixed at points that are symmetrically against the center point "O" (see figure below). The current electrodes "A" and "B" are changed by keeping the symmetrical relationship against the center point "O" and the apparent resistivities are measured.



Vertical Survey of Schlumberger Method

(2) EM Method

The Electromagnetic (EM) Method ... similar to the electric prospecting method ... measures the earth's magnetic contrasts when prospecting ground formations. The electric prospecting method uses direct or alternating current. Conversely, the EM Method uses electromagnetic fields of a certain frequency.

A magnetic field measured at ground surface is affected by the relative resistance distribution of the underground layers making it possible to determine the relative resistance of the underground layer.

Based on the objectives of electromagnetic prospecting, such as horizontal or vertical prospecting, various prospecting methods were developed. The purpose of the Study's prospecting is to detect the existence of aquifers having relatively small relative resistance: the loop-loop method, such as the EM Method, is quickly measurable and efficient.

In the EM 34 Method, two operators separated by a distance of 10 to 40 meters hold the transmitter coil (Tx) and the receiver coil(Rx). The response, through the ground, of the electromagnetic wave transmitted by Tx is measured by Rx.

The following relationship exists between the prospecting depth and the coil distance (the reason given in the latter part of this section):

Distance Between Coils and the Prospecting Depth

Distance Between Coils (m)	Prospecting Depth (m)	
	Vertical Loop	Horizontal Loop
10	7.5	15
20	15	30
40	30	60

In general, plane mapping of relative resistance can be made in the field from the directly obtained data. Analytical work is required to correct the deviation of values along the vertical direction based on the standard curve.

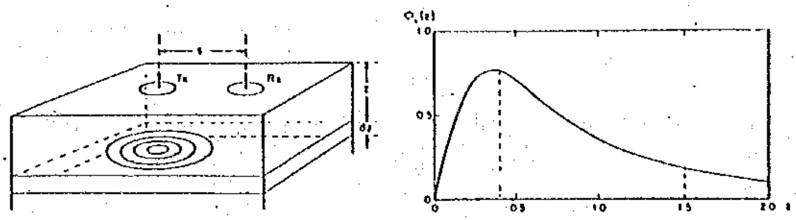


FIGURE Relative response versus depth for vertical dipoles. $\phi_v(z)$ is the relative contribution to H_s from material in a thin layer dz located at (normalized) depth z.

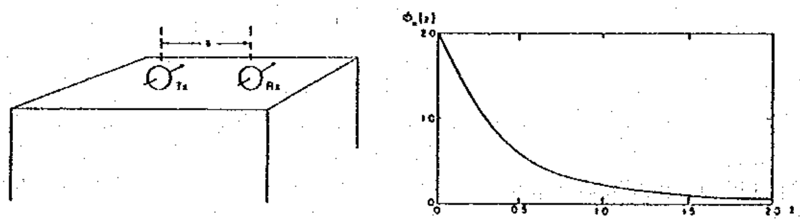


FIGURE Relative response versus depth for horizontal dipoles

Relationship between the Prospecting Depth and the Secondary Magnetic Field

Suppose there is a conductive object at the depth (value obtained by dividing the depth by the coil distance) when the earth is in isotropic conditions and a secondary magnetic field is created. As shown in figure below, the effect of the secondary magnetic field becomes largest at the depth of 1 = 0.4S (0.4 times of the coil distance) when the coils are set vertically. A relatively large effect exists even at the depth of 1 = 1.5S. This fact indicates that the variation of the relative resistance at the ground surface does not affect the secondary magnetic field.

When the horizontal component of the magnetic field is measured by setting the coils horizontally, the effect of the secondary magnetic field becomes largest at the ground surface and the strength of the secondary magnetic field attenuate in proportion to the depth.

For the above reasons, conductivities (relative resistance values) at different depths can be obtained by changing coil orientation.

3.3 DATA PROCESSING AND ANALYSIS

(1) Schlumberger Method

Electrodes are generally arranged on a straight line and the apparent resistivity can be obtained by the following equation:

$$\rho_a = \frac{\pi}{4} \times \frac{(AB)2 - (MN)2}{M} \times \frac{V}{I}$$

where, ρ_a : apparent resistivity(ohm-m)
AB: current electrode spacing(m)
MN: potential electrode spacing(m)
V: voltage difference between the potential electrodes(mV)
I: applied current(Ma)

An apparent resistivity curve(VES) which indicates the relationship between the depth AB/2 and the apparent resistivity can be prepared from the measured values. Theoretical values of resistivities are calculated by assuming a ground layer model. True resistivities can be obtained by repeating the curve matching method which compares the calculated values with the measured values. The cross sectional profile of resistivities can be prepared from the true resistivities.

(2) EM Method

For horizontal prospecting, a curve is to be prepared by plotting measured values on a graph having the abscissa to indicate distance and the ordinate to indicate apparent conductivities. The qualitative analysis of the measured values can then be made.

For vertical prospecting, one dimensional analysis is made by assuming a horizontal multi-layer formation. Depending on the case of a two layer model or a model having more than two layers, the procedure of its analysis is slightly different.

For the case of a two-layer model, the apparent conductivity(s) between the coil spacing of S is given by the following equation:

$$\sigma a(s) = \sigma 1 \times (1 - R(z/s)) + \sigma 2 \times R(z/s)$$
$$RH(z/s) = (4(z/s)2) + 1)^{1/2} - 2(z/s)$$
$$RV(z/s) = 1/(4(z/s)2 + 1)^{1/2}$$

where, σ_1 , σ_2 : difference of conductivities at the first and second layers
s: coil spacing
z: thickness of the first layer
RH(z/s): relative equation of secondary magnetic field for the case of horizontal coil positioning
RV(z/s): relative equation of secondary magnetic field for the case of vertical coil positioning

By introducing three measured values for the horizontal and vertical coil orientation cases into the above equations, conductivity and thickness of each ground layer can be calculated.

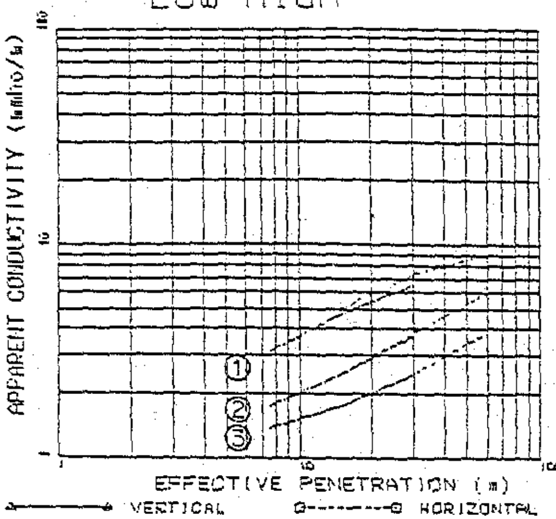
Variations of apparent conductivities for the two-layer model is shown in figure of next page.

For the three-layer formation case, apparent conductivity (s) between the coil spacing "S" is given by the following equation:

$$\sigma a(s) = \sigma 1(1 - R(Z1/s)) + \sigma 2(R(Z1/s) - R(Z2/s)) + \sigma 3 \times R(Z2/s)$$

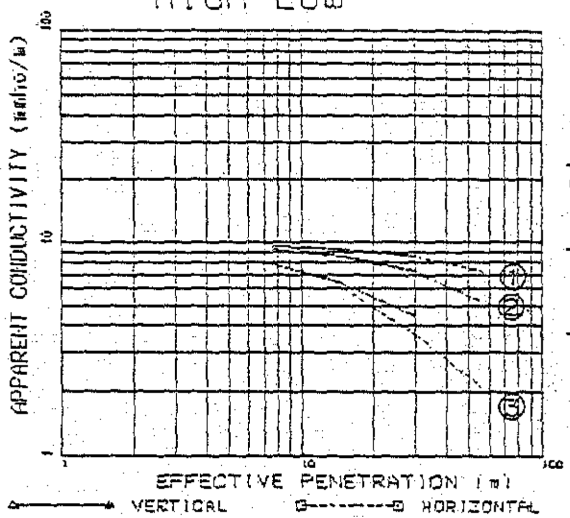
where, Z1: thickness of the first layer
Z2: total thickness of the second and third layers

For a model formed of more than three layers, each layer's apparent conductivity and thickness cannot be obtained directly from the measured values because there are too many variables. Thus, a multi-layer model should be made in advance and its true multi-layer formation will be prepared by repeating the curve matching method to compare the measured values and the theoretical apparent conductivities obtained by the above equations.



2 LAYERD MODEL

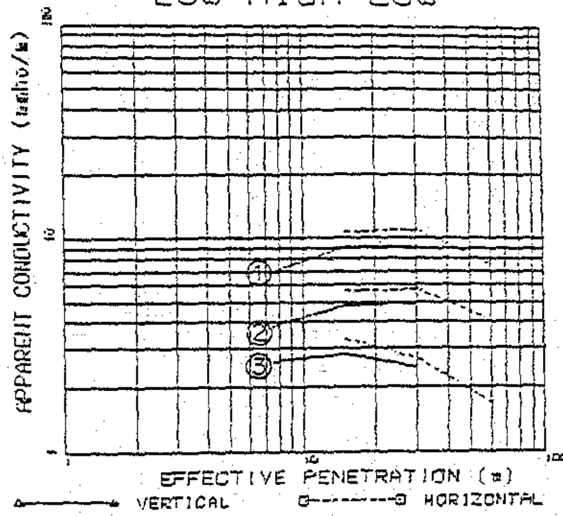
	CONDUCTIVITY	THICKNESS
③	1.00 10.00	10.00
②	1.00 10.00	30.00
①	1.00 10.00	60.00



2 LAYERD MODEL

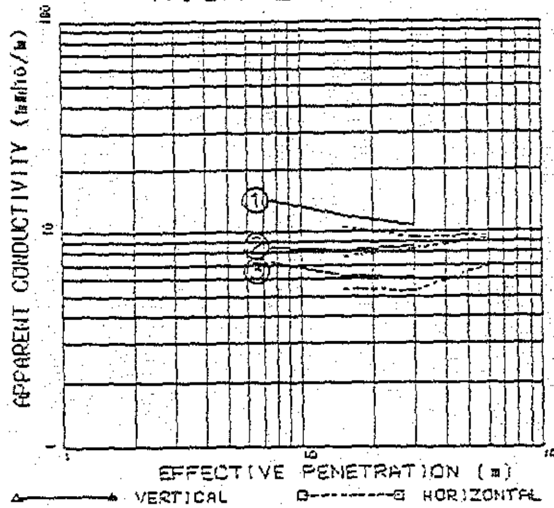
	CONDUCTIVITY	THICKNESS
①	10.00 1.00	10.00
②	10.00 1.00	30.00
③	10.00 1.00	60.00

Apparent Conductivity of Two-Layerd Model



3 LAYERD MODEL

	CONDUCTIVITY	THICKNESS
①	1.00 10.00 1.00	5.00 5.00
②	1.00 10.00 1.00	5.00 20.00
③	1.00 20.00 1.00	5.00 20.00



3 LAYERD MODEL

	CONDUCTIVITY	THICKNESS
②	10.00 1.00 10.00	5.00 5.00
①	10.00 1.00 10.00	5.00 20.00
③	20.00 1.00 10.00	5.00 5.00

Apparent Conductivity of Three-Layerd Model

4. THE RESULTS OF GEO-ELECTRIC PROSPECTING

4.1 RESULT OF THE HYDRO-GEOLOGIC STRUCTURE SURVEY IN THE STUDY AREA

As shown in the survey location map (Fig. G.1), the geoelectric prospecting conducted to examine the hydro-geologic structure of 24 areas (classified as Ep-1 through Ep-24) of the Kibungo Prefecture was made using the Schlumberger Method in 21 areas and the EM Method in 13 areas. The prospecting results are detailed in Data Book.

When the EM 34 Method is applied in an area having a low relative resistivity zone because of the existence of a vertical fault (the ground formation is not composed of horizontal multi layers), it indicates minus values. For such a case, the formation cannot be analyzed as a horizontal multi-layer formation model. Thus, the extent and pitch of the fault are detected from the result of horizontal prospecting having short measuring spaces.

During the hydro-geologic structure survey, areas having minus values were recorded, but no detailed horizontal prospecting was conducted.

The relative resistivity profile of each Ep area was prepared from the relationship between the depths and the relative resistivities analyzed by the curve matching method (see Data Book). As a result, the distribution of schist, quartzite, and granite was evaluated and fault locations were specified.

An analysis of the geoelectric prospecting results for each survey area is outlined below:

(1) Rukara Area (Ep-1 and Ep-2)

Schist is predominant in this area. The relative resistivity of the alluvium covering the lowlands is less than 20 ohm-m. It is considered, therefore, that the alluvium is mainly composed of clay.

In the ridge areas, the surface layer having relative resistivities greater than 1,000 ohm-m is underlaid with a 20 to 30 ohm-m thick weathered layer having relative resistivities of 100 to 500 ohm-m. The weathered layer covers the base rock.

In some ridge areas that are covered with schist, layers having relative resistivities of less than 100 ohm-m exist to the depth of approximately -20 m from the ground surface. Thus, it can be assumed that soil maturing(becoming clay) has progressed in these areas.

The analysis of the Schlumberger Method's results indicate the progress of rock fracturing to the depth of 50 to 60 m from the ground surface. However, the progress of rock fracturing is detected from analysis of the EM Method's results.

(2) Muhazi Area (Ep-4)

Granite is widely distributed in the area. The thickness of the alluvium layer covering the lowlands is less than 10 m. Its relative resistivities are less than 30 ohm-m. The alluvium layer is mainly composed of clay.

Except for the lowest horizon (1,350 ohm-m) at the S-3 point, layers having 100 to 500 ohm-m relative resistivities were detected. As these values are extremely small for granite, it is considered that the prospecting did not reach the fresh bedrock. In the area near the lake, intermediate layer having low relative resistivities of less than 100 ohm-m were detected. Thus, the existence of a clay layer is assumed.

The relative resistivity of the lake water was approximately 30 ohm-m.

(3) Kayonza Area (Ep-5, Ep-6 and Ep-7)

Schist is distributed in Ep-5 and Ep-6. The covering horizon of the alluvial lowlands and slopes is relatively thick. In particular, in the alluvial plain in Ep-6 it reaches 120 m.

The relative resistivities of the covering horizon are in the range of 50 to 90 ohm-m and indicates that the horizon is composed of clay.

In Ep-7, schist and quartzite are distributed. The thickness of the weathered layer is 10 to 25 m. It is thicker in the schist distributed area.

In the quartzite distributed area of Ep-7 there is an approximately 100 m wide area where all the value measured by the EM Method were minus. Thus, it is judged that a fault exists in the area.

(4) Kigarama Area (Ep-10, Ep-14 and Ep-22)

In Ep-10, schist and quartzite are distributed. A thin layer having relative resistivities of higher than 1,000 ohm-m cover the area. An intermediate layer(weathered layer) having relative resistivities of 100 to 300 ohm-m underlies the thin surface layer. The intermediate layer is 20 m thick.

The relative resistivities of the schist bedrock were determined to be about 2,000 ohm-m by the EM Method and are in the range of 427 to 690 ohm-m by the Schlumberger Method. The existence of faults was detected in the eastern part of Ep-10.

Schist is distributed in Ep-14 and Ep-22. A top layer having relative resistivities of 200 to 400 ohm-m is underlaid with an intermediate layer (weathered zone) which showed 100 to 150 ohm-m resistivities at the depth of 10 to 20 m.

At S-1 of Ep-22, the thickness of the alluvium is 30 m. It showed 80 ohm-m resistivities indicating the main composition is clay. The lower layer (quartzite) having a relative resistivity of 1,330 ohm-m is distributed at a depth deeper than 120 m from the ground surface.

(5) Mugesera Area (Ep-11 and Ep-12)

In Ep-11, granite and schist are distributed. In the vicinity of the lake, the lowest layer had relative resistivities of 1,000 to 2,000 ohm-m(measured by the EM Method) was detected.

At S-1, the relative resistivity of 675 ohm-m was obtained by the Schlumberger Method. Its true value may be smaller than the obtained value which is too small for fresh granite.

Most of the layers in Ep-11 have relative resistivities smaller than 140 ohm-m. It is assumed that the quartz sand produced from the granite distributed around the lake might contain a large amount of clay. The relative resistivity of the lake water was 36 ohm-m.

Ep-12 is considered to be a schist distributed area. The alluvium is composed of clay having a relative resistivity of smaller than 50 ohm-m. Its thickness is 5 to 10 m.

(6) Rukira Area (Ep-15 and Ep-16)

In Ep-15 and Ep-16, schist and quartzite are distributed. Large pieces of quartzite are seen on ridge areas, and alternate 20 to 60 m thick layers of schist and quartzite are distributed.

The relative resistivities of the quartzite were analyzed and found to be larger than 10,000 ohm-m by the EM Method. Values greater than several thousand ohm-m are considered to be unreliable.

The relative resistivities of the schist are about 1,000 ohm-m. The schist was clearly distinguished.

The thickness of the weathered layer is 5 to 20 m in general. However, at the saddled portion of the eastern part of Ep-16, the weathered layer reaches to the depth of approximately 40 m from the ground surface.

At areas approximately 100 m east of EM-1 and EM-6 of Ep-16, the existence of faults was detected. These areas are located on a line extending from the confirmed faults on the geological map.

At EM-7 ... located at the eastern part of Ep-16 ... the measured resistivity values reversed their patterns on each side of the detected fault line at EM-6. A layer with a relative resistivity of 500 ohm-m was detected at a deeper position. Thus, it is considered that a quartzite layer overlays the schist layer in this area.

The alluvium extending north from EM-15 is approximately 70 m thick. The alluvium is thought to be composed mainly of clay having a relative resistivity smaller than 100 ohm-m.

(7) Rusumo Area (Ep-17 through Ep-20, Ep-23 and Ep-24)

In the Ep-17 through Ep-20 areas, schist and quartzite are distributed while, in Ep-23 and Ep-24, schist, quartzite and granite are distributed.

In the quartzite distributed areas, large pieces of quartzite are seen on the ridges. The quartzite layer having relative resistivities larger than 10,000 ohm-m is distributed under the approximately 10 m thick top soil or weathered layer.

The relative resistivities of the schist were measured to be 1,000 to 5,000 ohm-m by the EM Method. However, in Ep-17, they were measured as being smaller than 200 ohm-m by both the EM Method and the Schlumberger Method.

The relative resistivity of the stream water (originating at a spring) in the southern part of Ep-18 was 400 ohm-m. The figure indicates that the water is coming down through quartzite.

The granite distribution areas form large basins and lakes.

The granite in Ep-23 and Ep-24 were measured as having infinite relative resistivity values by the Schlumberger Method. The relative resistivities of the granite are extremely large compared to that of ordinary granite. Large rocks having diameters of more than 10 m were seen. The EM Method conducted on a large rock at EM-4 in Ep-25 indicated a relative resistivity value of 10,000 ohm-m.

Judging from the above prospecting results, the granite in the area is thought to be a different type than those composing the formations of Muhazi, Nasho, Mugesera and Sake areas. It is considered to be newly formed rock.

In Ep-24, prospecting was conducted continuously from the granite distributed area to the quartzite and schist distributed areas. The prospecting results shows relative resistivities of 10,000 ohm-m(infinite) in the granite, greater than 2,000 ohm-m in the quartzite, and 1,000 ohm-m in the schist.

A rock formation having an infinite relative resistivity value that distributes at the lower horizon in the vicinity of S-1 of Ep-24 corresponds to the diorite distribution shown on the geological map.

4.2 RESULTS OF THE HYDRO-GEOLOGICAL STRUCTURE SURVEYS CONDUCTED IN THE VICINITY OF THE PLANNED WELL DRILLING SITES

Based on the results of the geoelectric prospecting conducted for the hydro-geological structure survey in the large Study Area and overlaying socioeconomic factors on the results, the following five areas were selected as the well drilling areas for obtaining potential water sources. Further detailed geoelectric prospecting was conducted in these areas:

Br-1:	Ep- 3	80 m deep well drilling areas
Br-2:	Ep- 8	- do -
Br-3:	Ep-13	- do -
Br-4:	Ep- 9	150 m deep well drilling areas
Br-5:	Ep-21	- do -

Based on the results of the hydro-geological reconnaissance survey and the Schlumberger method groundwater prospecting, the most suitable well drilling sites were selected. At the selected sites, vertical prospecting with 100 m coil spacings and horizontal prospecting with 10 m coil spacings were conducted by applying the EM Method.

Further prospecting was conducted by applying the Schlumberger Method at locations showing the highest resistivities or abrupt resistivity changes that were found by vertical and horizontal prospecting. By confirming low relative resistivity zones or discontinuity points of uniform relative resistivity formations, well drilling points were selected.

The horizontal prospecting results were shown on the relative resistivity profiles together with the measured values by the 10 m coil spacing horizontal loop(10 H) and vertical loop(10 V) and the 20 m coil spacing horizontal loop(20 H) and vertical loop(20 V).

The analysis of the results of each selected well drilling area is outlined below.

(1) Br-1 Rukara-Kayonza Area (Ep-3)

To center the measuring point S-1 of the Schlumberger method, a 1 km long east-west prospecting line and a 1.1 km long north-south prospecting line were set up. This area was selected for a shallow well(80 m deep) drilling site.

. North-South Prospecting Line:

The line crosses the river which flows into Lake Muhazi. The river crossing point is near the 3N.

The horizontal prospecting result shows the highest apparent conductivity in between S-1 and 5N which is in the alluvium distribution zone. Both sides of the alluvium distribution zone are slopes reaching to ridges. The relative resistivities of the slopes are 20 ohm-m larger than those for alluvium.

As a result of the vertical prospecting using the EM Method, the relative resistivities of the bedrock were in the range of 1,000 to 5,000 ohm-m (the relative resistivities of the bedrock obtained by the Schlumberger Method were 440 to 730 m). The bedrock was therefore evaluated as being schist.

The between S-1 and 5N there is a layer having relative resistivities less than 30 ohm-m at a depth of 10 to 20 m from the ground surface. This layer was evaluated as being clayey soil.

. East-West Prospecting Line:

The prospecting line was set up parallel to the river on its left bank. The line location is 10 to 20 m higher than the alluvium.

40 H horizontal prospecting revealed high apparent conductivities along 1E and 4E. As a result of vertical prospecting, the bedrock in the area was detected at a very deep level. Thus, additional prospecting by using the Schlumberger Method was conducted in the vicinity of 1E through 4E.

As shown in the relative resistivity profile diagram, bedrock in the area is schist having relative resistivities of 400 to 700 ohm-m. The top face of the bedrock is bowl shaped at 1E through 5E. The top portion of the bedrock at a depth of about 80 m from the ground surface has relative resistivities of less than 200 ohm-m. This portion was assumed to be the weathered zone of the bedrock.

In view of the above, the weathered zone of the schist in the vicinity of S-4(4E) is believed to be a suitable area for well drilling.

(2) Br-2 Kigarama-Rukira Area (Ep-8):

To center the measuring point S-7 of the Schlumberger Method, a 2.4 km long curved prospecting line stretching towards the northwestern and southwestern direction from S-7 was set up. This area was selected for a shallow well(80 m deep) drilling site.

The prospecting line passes the alluvium developed between the steep ridge formed of quartzite schist and Lake Nasho. The area was thought to be a granite distributed area, but the analysis results of the Schlumberger Method conducted on the prospecting line shows low relative resistivities of less than 200 ohm-m. No original rock was confirmed. The horizontal prospecting results shows high apparent conductivities in between 11N and 4N and in between 4S and 9S.

As a result of the vertical prospecting analysis, it was evaluated that a thick clay layer having relative resistivities less than 40 ohm-m distributed in the high apparent conductivity zone. Thus, prospecting using the Schlumberger Method was again conducted in between 4N and 4S which revealed that the area had comparatively low relative resistivity (low conductivity).

As shown in the relative resistivity profile diagram, a weathered granite layer of the deepest, horizon having relative resistivities of about 200 ohm-m is distributed in a ridge-like shape throughout the area. The concave portion of the deepest horizon is filled with a small relative resistivity layer which is thought to be clay. Above the small relative resistivity layer there is a clayey soil layer that is distributed to a depth of 30 to 40 m from the ground surface.

In between 3N and 1S there is a comparatively large relative resistivity zone of 100 to 500 ohm-m. This zone is thought to be the distribution of either sand or gravel. As a result of the above prospecting, the S-7 area where the sand or gravel is deposited on the weathered granite distribution is thought to be a suitable well drilling site.

(3) Br-3 Kabarondo Area (Ep-9):

A 1.4 m long north-south oriented prospecting line centering at the measuring point S-3 of the Schlumberger Method was set up. This area was selected for a deep well(150 m deep) drilling site.

The prospecting line runs parallel to a ridge formed of schist and quartzite.

The horizontal prospecting results revealed low apparent conductivities. The peak apparent conductivity recorded was at 0.5N.

The result of the vertical prospecting also indicated the relative resistivities of 2,000 to 10,000 ohm-m of the deepest horizon, except as 0.5N. The relative resistivity of the deepest horizon at 0.5N was 250 ohm-m, and the existence of a small relative resistivity zone was detected. Therefore, supplemental prospecting using the Schlumberger Method was conducted in the vicinity of 0.5N.

As shown in the relative resistivity profile diagram, cross sectional direction relative resistivities against the prospecting line vary greatly and no continuity is seen. Thus, it is considered that the prospecting line crossed the strata direction (N-S direction) at an acute angle and the strata characteristics change abruptly along the line.

The relative resistivities of the schist were in the range of 500 to 1,000 ohm-m while those for quartzite were larger than 2,000 ohm-m. The existence of a small relative resistivity zone of 200 to 250 ohm-m was found in the vicinity of 0.5N(S-10).

The fault direction in the area runs predominantly from north to south, but the existence of east-west faults is confirmed. Thus, the small relative resistivity zone is thought to be the fault zone.

Based on the results of the above prospecting, the fault zone in the vicinity of 0.5N(S-10) would be suitable for a well drilling site.

(4) Br-4 Sake Area (Ep-13)

A 1.4 km long north-south direction prospecting line centering the measuring point S-1 of the Schlumberger Method and a 1.05 km long prospecting line starting from 3.5S of the north-south prospecting line to the southeast direction were set up. This area was selected as a shallow well drilling site.

S-1 was located at a point approximately 100 m east of Lake Sake. The elevation of S-1 was about 25 m higher than the lake. S-4 of the north-south direction prospecting line was located close to the lake and its relative height from the lake was small. Thus, an additional prospecting line was extended from 3.5S towards the southeast.

This is a granite distribution area, but the results of a previous analysis of the Schlumberger Method showed small relative resistivity values (150 to 430 ohm-m).

The results of horizontal prospecting showed high apparent conductivity values in between 2S and S-1 and points further south than 7S. The high apparent conductivities obtained by vertical prospecting were interpreted as the effect of clayey soil having a relative resistivity of less than 60 ohm-m.

Further, the analyzed values of the horizontal and vertical loops conducted in between 7S and 4S and in between 11E and 8E deviated a great deal and it was considered that the relative resistivity values would also vary greatly in this area (variation away from the prospecting line). Thus, supplemental prospecting using the Schlumberger Method was conducted by avoiding the high apparent conductivity zone.

As shown in the relative resistivity profile diagram, it is considered that different stages of weathered granite layers are distributed below the 5 to 8 m thick sandy or gravelly soil top horizon. Weathering has progressed deep into each granite layer showing small relative resistivity values ... no fresh granite was detected.

In view of the above, it is considered that the most promising well drilling site is the lowland near the lake where the highly weathered granite layer having relative resistivities of about 150 ohm-m is covered by a gravelly soil top horizon (in the vicinity of 3S (S-6)).

(5) Br-5 Rusumo Area (Ep-21):

To center the measuring point S-3 of the Schlumberger Method, a 2.45 km long north-south oriented prospecting line was set up. The area was selected as a deep well(150 m deep) drilling site.

The prospecting line runs parallel to a ridge line on the middle part of its slope. The bedrock of the area consists of schist and quartzite.

The results of horizontal prospecting showed high apparent conductivities at points further south of S-3.

The results of vertical prospecting showed relative resistivities larger than 1,000 ohm-m at point north of 5N and smaller than 200 ohm-m at points to the south. The existence of faults or a strata boundary was detected in the area. At 14N, the northern end of the prospecting line, and S-4, the relative resistivities of the intermediate layer were small (showing a sign of strata variation).

Supplemental prospecting using the Schlumberger Method was conducted in the vicinity of 3N. According to the relative resistivity profile diagram, the relative resistivity value distribution can be divided into three zones: the upper layer's large relative resistivity zone (larger than 1,000 ohm-m) north of 3.5N; the lower layer's small relative resistivity zone (130 to 500 ohm-m) north of 3.5N, and the small relative resistivity zone (less than 200 ohm-m) south of 3.5N.

The area was classified as a quartzite distribution area. However, judging from the relative resistivity values, the large relative resistivity zone is thought to be a quartzite schist distribution zone and the small relative resistivity zone is though to be a schist distribution zone. Discontinuity of the relative resistivity value distribution is evident in the vicinity of 3.5N. The existence of existing geological map shows faults in this area, the faults was confirmed by geoelectric prospecting.

In view of the above, the vicinity of 3.5N is believed to be a suitable well drilling site.

The proposed test well sites therefore were listed as below:

Outline of Test Well

Description / Well No.	Location	Well Type	Site of Geo-physical Prospecting	Geology
No.1	SE of Lake Muhazi, Muhazi Kayonza	80m Depth	EP-3	Weathered schist over-lain by Alluvium
No.2	W of Lake Nasho, Gashiru, Rukira	80m Depth	EP-22	Alluvial fan deposits
No.3	Shore of Lake Sake, Rakama, Sake	80m Depth	EP-13	Weathered granite
No.4	Rurenge, Kabarondo	150m Depth	EP-9	Fracture zone of schist inter-bedded with sandstone and quartzite
No.5	Nganda, Rusumo	150m	EP-21	Quartzite

5. EVALUATION

(1) Schlumberger Method and EM Method

For the Study's geoelectric prospecting, the Schlumberger Method and EM Method were adopted. The Schlumberger Method utilizes the artificial relative resistivity method generally used for prospecting groundwater. The EM Method, by means of EM34, utilizes the loop-loop method of magnetic fields. The merits and demerits of the two methods are described in the following.

One of the characteristics of EM34 is that the prospecting can be accomplished during a short period of time by a small number of personnel. However, as only a small amount of information that corresponds to ground depth is obtainable as comparable to the Schlumberger method, it is impossible to obtain accurate relative resistivity variations towards the depth direction. Furthermore, as the strength of the magnetic field is measured in the EM Method, the measurements are affected by noise or thunder. Lightning storms that frequently occur in the Study Area in the afternoons make it particularly difficult to obtain stable data.

Relative resistivities of different rocks measured by the Schlumberger Method and the EM Method are shown in the following table:

Type of Rock	Prospecting Method: Schlumberger Method	Prospecting Method: EM Method
Schist	200 to 1,000 ohm-m	400 to 2,000 ohm-m
Quartzite	200 to more than 3,000 ohm-m	More than 2,000
Granite	100 to 700 ohm-m	More than 1,000 ohm-m

For an upper horizon distributed to the depth of 20 to 30 m from the ground surface, the EM Method's relative resistivity values (the reciprocals of conductivities) obtained from the results of the horizontal multi-layer formation analyses agreed with the analysis results of the Schlumberger Method. For the lower horizon, the EM Method's relative resistivity values were large than those obtained by the Schlumberger Method. Values measured with the coil spacing of 40 m(intended to measure values at deep points) are smaller than the actual values (minus values are occasionally measured). The smaller inputs signal than that used for smaller coil spacing prospecting and the weaker secondary magnetic field as a result of the bedrock's large relative resistivities are thought to be the reason for the value variation. For this reason, the true relative resistivities of the upper layers were obtained by both the Schlumberger and EM methods and the true relative resistivities of the lower layers (bedrock in particular) were obtained mainly by the Schlumberger Method.

For selecting well drilling sites, supplemental prospecting using the Schlumberger Method were conducted in the vicinities of the peak points or abrupt change points of the measured values of the EM Method's vertical and horizontal prospecting. As a result of the supplemental prospecting, local points having smaller relative resistivity or discontinued points of relative resistivity value distribution were confirmed.

In view of the above, it is considered that a quantitative evaluation, such as strata formation analysis, is impossible with the EM Method's horizontal prospecting. However, the EM Method is very useful for selecting potential well drilling sites within certain areas.

For horizontal prospecting by the EM Method, 10 m coil spacing, which makes the secondary magnetic field the strongest, was most suitable for taking measurements in a shallow bedrock area. In an area where the deposit of the quaternary period is distributed on the surface layer, 20 m coil spacing (data obtained by vertical prospecting was used for the Study) was thought to be very effective for evaluating the existence of aquifers.

(2) Strata Formation and Relative Resistivity

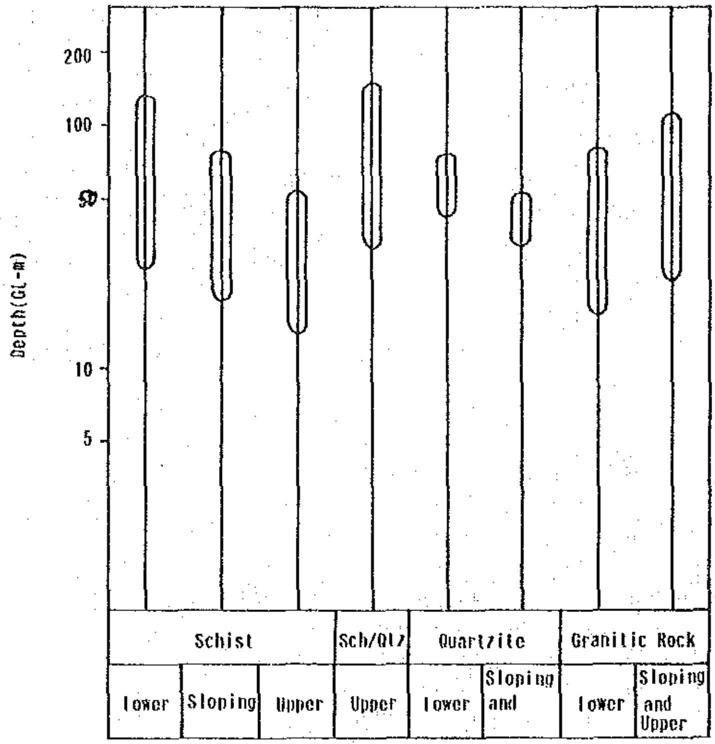
Based on the analyzed relative resistivities and depths, a relative resistivity profile diagram was prepared for each Ep area.

Rock formations in the Study Area can be classified as follows:

1) Schist(S)
2) Schist Quartzite(SQ)
3) Quartzite(Q)
4) Granitic Rock(Gn/Gr).

As the result of geoelectric prospecting, it is confirmed that each area is composed of more than three strata. The following figure shows the elevations of the tops of the deepest strata (bedrock) in each area.

By taking into account the vertical changes of each area's geological formation, the figure is shown by classifying the lowland area, slope area and ridge area.



Depth of Non-Altered Parts

The elevations of the tops of the deepest strata deviate to a great extent. In the schist and quartzite areas, the elevations become lower from the lowland areas towards the slope and ridge areas. In the granite areas, the elevations become higher from the lowland areas towards the slope and ridge areas. It is considered that this tendency is caused not only by the different stages of weathering progress (except in the Rusumo area where the weathering of granite is advanced) but also by the existence or thickness of the covering layer.

following tables "Summary of Geoelectric Prospecting" show the average elevation, relative resistivity value, and corresponding formation in each geologically classified area and topographically classified area.

Quality of Geo-electrical Prospection

Survey No.	Commune	Point No. of Survey Schlum. Method	EM Method
EP-1	RUKARA	4	13
EP-2	RUKARA	2	10
EP-3	RUKARA / KAYONZA	8	22
EP-4	MUHAZI	3	2
EP-5	KAYONZA	3	0
EP-6	KAYONZA	3	0
EP-7	KAYONZA	0	4
EP-8	KIGARAMA / RUKIRA	11	25
EP-9	KABARONDO / KIGARAMA	11	16
EP-10	KIGARAMA	2	3
EP-11	MUGESERA	3	3
EP-12	MUGESERA / SAKE	3	0
EP-13	SAKE	9	25
EP-14	KIGARAMA	2	0
EP-15	RUKIRA	0	2
EP-16	RUKIRA / RUSUMO	2	8
EP-17	RUSUMO	3	12
EP-18	RUSUMO	0	10
EP-19	RUSUMO	1	0
EP-20	RUSUMO	3	7
EP-21	RUSUMO	12	26
EP-22	KIGARAMA	2	0
EP-23	RUSUMO	3	4
EP-24	RUSUMO	8	7
Total		98 Points	199 Points

Summary of Geoelectric Prospecting

Characteristics of Underground Coditins Based on Geoelectric Prospecting

(Schist Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Lower	0 - 4	Less than	Deposits
	4 - 60	70～200	Deposits/Altered
	60 <	300～800	Massive
Sloping	0 - 3	50～300	Deposits/Altered
	3 - 45	20～100	Altered
	45 <	250～800	Massive
Upper	0 - 4	200～1000	Deposits/Altered
	4 - 30	70～200	Altered
	30 <	200～700	Massive

(Quartzite Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Lower	0 - 4	Less than	Deposits
	4 - 65	50～300	Deposits/Altered
	65 <	More than	Massive
Sloping and Upper	0 - 4	300～2000	Deposits/Altered
	4 - 40	200～500	Altered
	40 <	More than	Massive

(Schist/Quartzit Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Upper	0 - 4	-	Deposits/Altered
	4 - 75	-	Altered/Massine
	75 <	-	Massive

(Granitic Rock Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Lower	0 - 3	Less than	Deposits
	3 - 40	-	Deposits/Altered
	40 <	150～450	Massive
Sloping and Upper	0 - 4	200～1000	Deposits/Altered
	4 - 55	100～500	Deposits/Altered
	55 <	150～700	Massive

Characteristics of Underground Coditins Based on Geoelectric Prospecting

(Schist Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Lower	0 - 4	Less than	Deposits
	4 - 60	70～200	Deposits/Altered
	60 <	300～800	Massive
Sloping	0 - 3	50～300	Deposits/Altered
	3 - 45	20～100	Altered
	45 <	250～800	Massive
Upper	0 - 4	200～1000	Deposits/Altered
	4 - 30	70～200	Altered
	30 <	200～700	Massive

(Quartzite Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Lower	0 - 4	Less than	Deposits
	4 - 65	50～300	Deposits/Altered
	65 <	More than	Massive
Sloping and Upper	0 - 4	300～2000	Deposits/Altered
	4 - 40	200～500	Altered
	40 <	More than	Massive

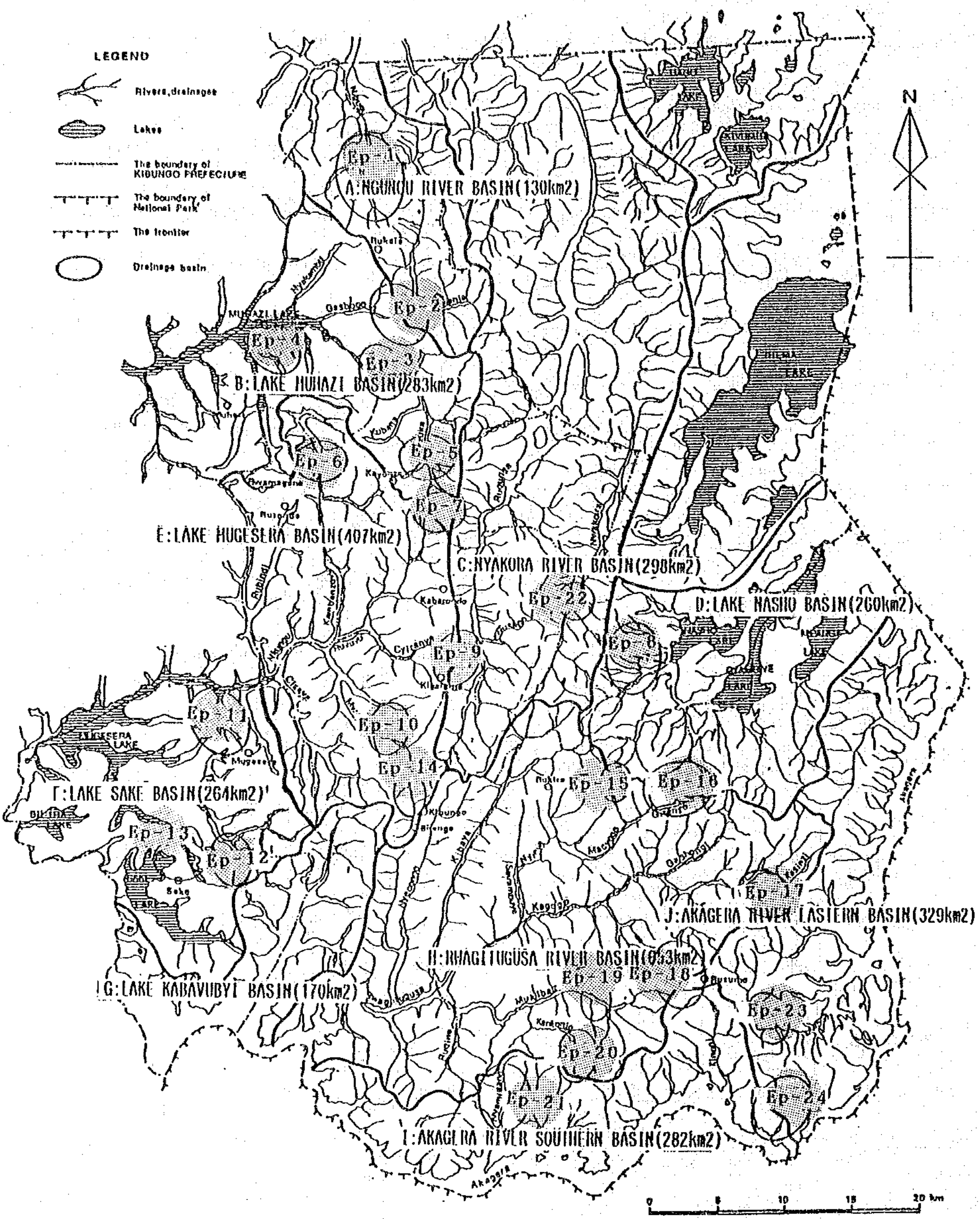
(Schist/Quartzit Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Upper	0 - 4	-	Deposits/Altered
	4 - 75	-	Altered/Massine
	75 <	-	Massive

(Granitic Rock Area)

	Depth GL-m	Residivity Ω・m	Geology (Faces of Rock)
Lower	0 - 3	Less than	Deposits
	3 - 40	-	Deposits/Altered
	40 <	150～450	Massive
Sloping and Upper	0 - 4	200～1000	Deposits/Altered
	4 - 55	100～500	Deposits/Altered
	55 <	150～700	Massive

Fig. G.1



Location Map