Kingdom of the
Ministry of
Foreign Affairs

WATER SUPPLY AND SANITATION

DOMESTIC WATER RESOURCES ASSESSMENT
DISTRICT

Republic of Kenya
Lake Basin
Development Authority

Kingdom of the Netherlands
Ministry of
Foreign Affairs

RURAL DOMESTIC WATER SUPPLY AND SANITATION PROGRAMME

RURAL DOMESTIC WATER RESOURCES ASSESSMENT KISUMU DISTRICT

September 1988

DHV

DHV Consultants

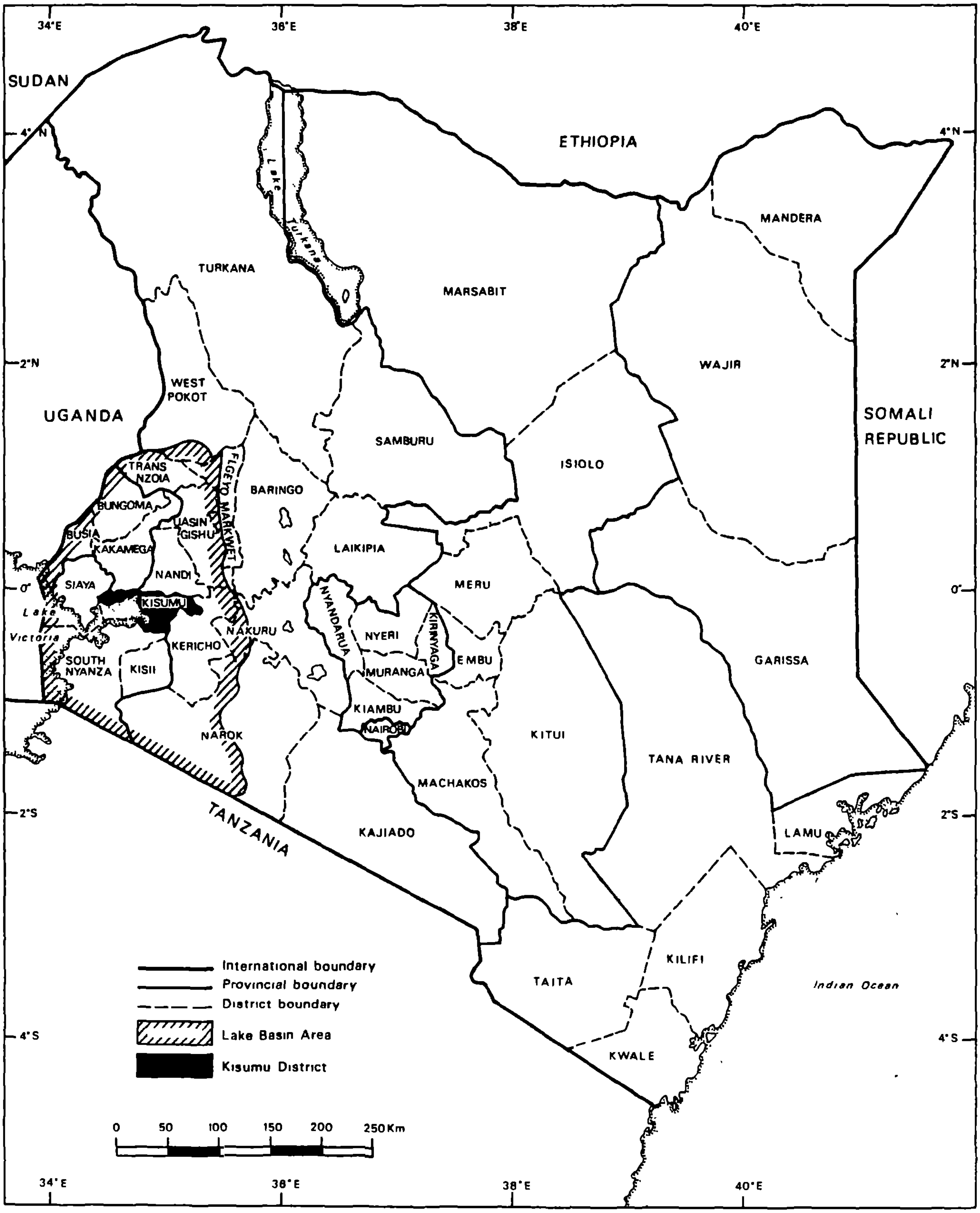

Figure A.1 Location of Lake Basin Area and Kisumu District in Kenya

PURPOSE AND CONTENTS OF THE REPORT

This report on rural domestic water supply in Kisumu District gives a review of information collected on the occurence, use, potential and exploration and exploitation possibilities of the water resources in the District.

It is the third of four District Reports which together will cover the whole of Nyanza Province.

The report is aimed at and to be used by District development planners, water supply implementing bodies and donors as a basis for the feasibility and cost analyses of water supply programmes in Kisumu District.

The report is based mainly on the results of systematic and detailed water resources assessment studies carried out in the District between 1986 and 1988 as part of the Lake Basin Development Authority's Rural Domestic Water Supply and Sanitation Programme (RDWSSP), which were subsequently published in five comprehensive Divisional Reports and a Main Report.

VOLUME	I	Main Report		-	September	1984
VOLUME	XIV	Nyakach	Division	-	April	1987
VOLUME	XV	Winam	Division	-	June	1987
VOLUME	XXI	Nyando	Division	-	January	1988
VOLUME	XXII	Muhuroni	Division	-	March	1988
VOLUME	XXIII	Maseno	Division	-	May	1988

The Main Report includes a review of literature on water supply in Nyanza Province as well as an explanation of the approach and methodology of the water resources assessment studies carried out.

In the Divisional Reports the data, results and conclusions of the water resources surveys are presented down to the level of Sub-locations and for technical information more detailed than presented in this District Report one is referred to these reports.

A new dimension is given to this District Report by the incorporation of valuable hydrogeological and technical data derived from 30 deep boreholes constructed in the District under the RDWSSP during 1988.

The report starts with the presentation of a:

RURAL DOMESTIC WATER SUPPLY PLAN FOR KISUMU DISTRICT.

In this plan, the options are given for the development of safe and reliable water sources.

Relevant information to back up the RURAL DOMESTIC WATER SUPPLY PLAN is subsequently presented in PART 1 to PART 7.

PART 1 : INTRODUCTION

PART 2 : DESCRIPTION OF KISUMU DISTRICT

PART 3 : EVALUATION OF EXISTING WATER SUPPLY SITUATION

PART 4 : ASSESSMENT OF WATER DEMAND

PART 5 : SURFACE WATER RESOURCES

PART 6 : GROUND WATER RESOURCES

PART 7 : CONSTRUCTION OF POINT SOURCES

To further illustrate the results of the studies, surveys and constructions carried out, five thematical maps on scale 1:100,000 are annexed to the report.

MAP - 1 TOPOGRAPHY
MAP - 2 ADMINISTRATIVE SUB-DIVISION
MAP - 3 WATER SUPPLY SITUATION (1987)
MAP - 4 GEOLOGY
MAP - 5 WATER DEVELOPMENT OPPORTUNITIES

Water collection along Lake Victoria, Nyakach Division

KISUMU DISTRICT

RURAL DOMESTIC WATER SUPPLY PLAN

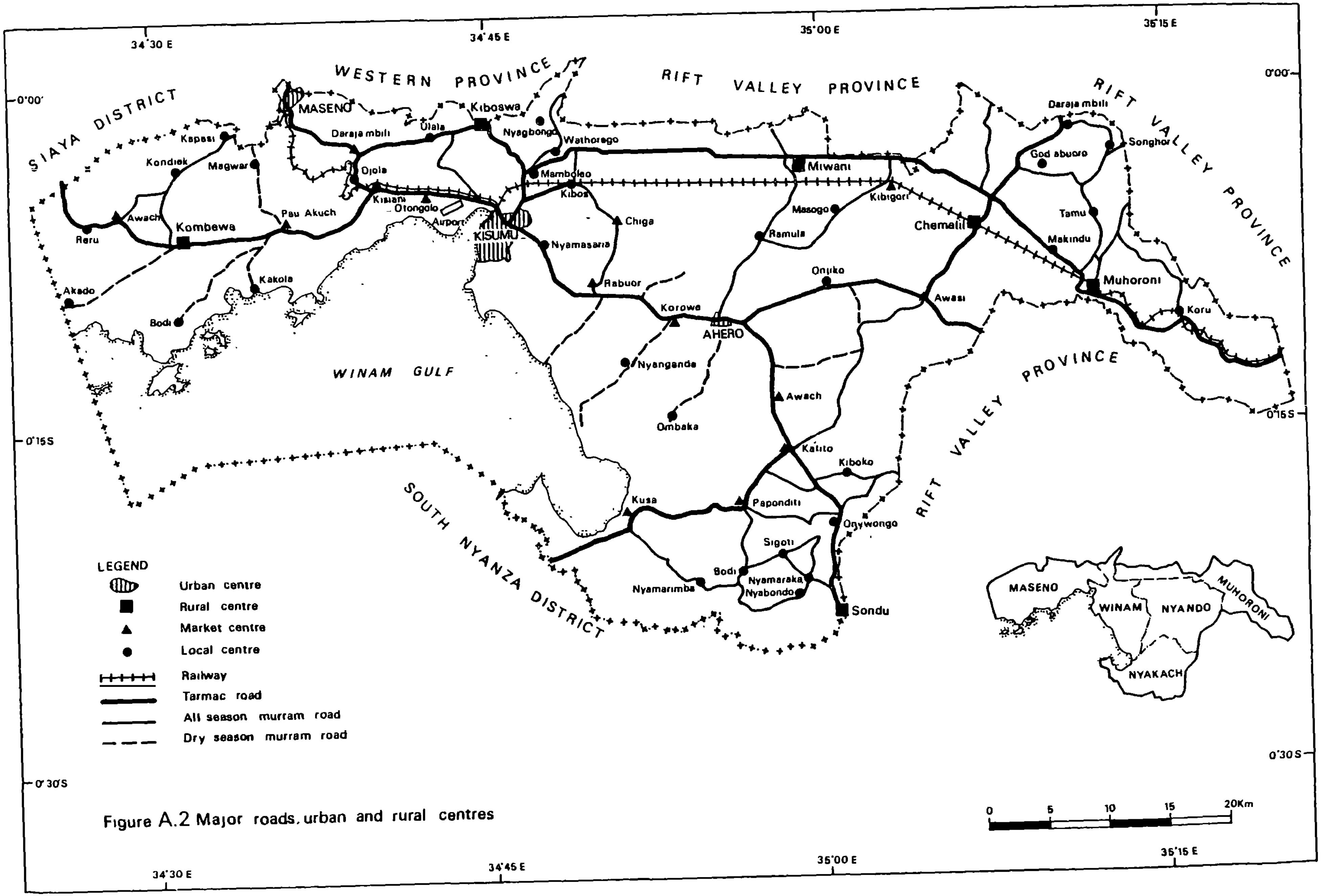

Figure A.2 Major roads, urban and rural centres

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CONTENTS OF THE RURAL DOMESTIC WATER SUPPLY PLAN

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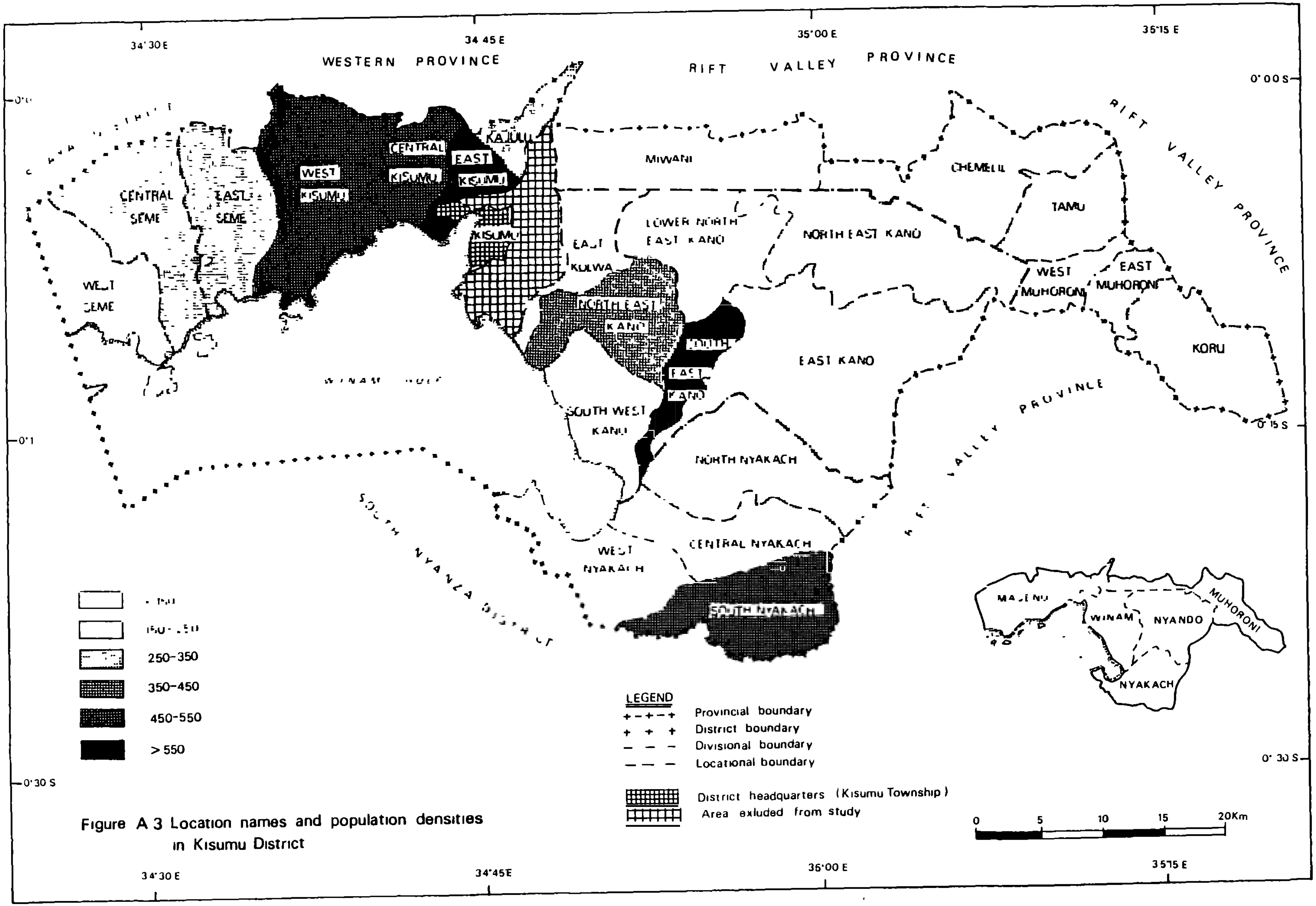


Figure A 3 Location names and population densities in Kisumu District

A INTRODUCTION TO THE PLAN

In and outside Kenya, rural water supply projects often were designed with emphasis mainly on their technical feasibility, with little attention to their sustainability and without much involvement of the recipients, the rural population.

Pretentious piped supply schemes were brought to rural communities that were not ready to sustain these schemes, which has resulted in a growing number of completed projects that are broken down and abandoned, or functioning much below capacity. But also there are numerous examples of low cost water supply projects involving handpump technology which have failed.

Lessons have been learned both from failing and successful rural water supply programmes and presently wealth of information is available on all sorts of subjects and aspects related to the provision of rural water supply.

During the 1987 African Water Technology Conference in Nairobi, the Worldbank/UNDP presented results of recently completed worldwide studies on Communal Water Supply, in which a structured assessment is given of technology and management options available today.

The RDWSSP's approach towards improving the rural water supply situation in its area of operation is based largely on the significant conclusions and recommendations drawn and given in these recent studies, taking due account also of local conditions.

Thinking along the lines of modern communal water supply development, it would be wrong to provide a ready-made water supply plan for the District.

Instead, based on the availability of the physical, financial and organizational resources as well as the assessment of the water need, the suitable options are given and elucidated.

Also, based on criteria such as the quality and reliability of the sources used as well as the walking distances to the sources, areas of higher and lower priority in implementation have been indicated.

The aim of any implementation programme or project should be to give the communities the service level that it is willing to pay for, will benefit from, and has the institutional capacity to sustain.

Since RDWSSP only aimes at rural areas, urban area's in casu Kisumu Township , has been excluded from the present study. Moreover, semi-urban wards adjecent to Kisumu Township , which will shortly be supplied with water from the water works of Kisumu Municipality have not been studied.

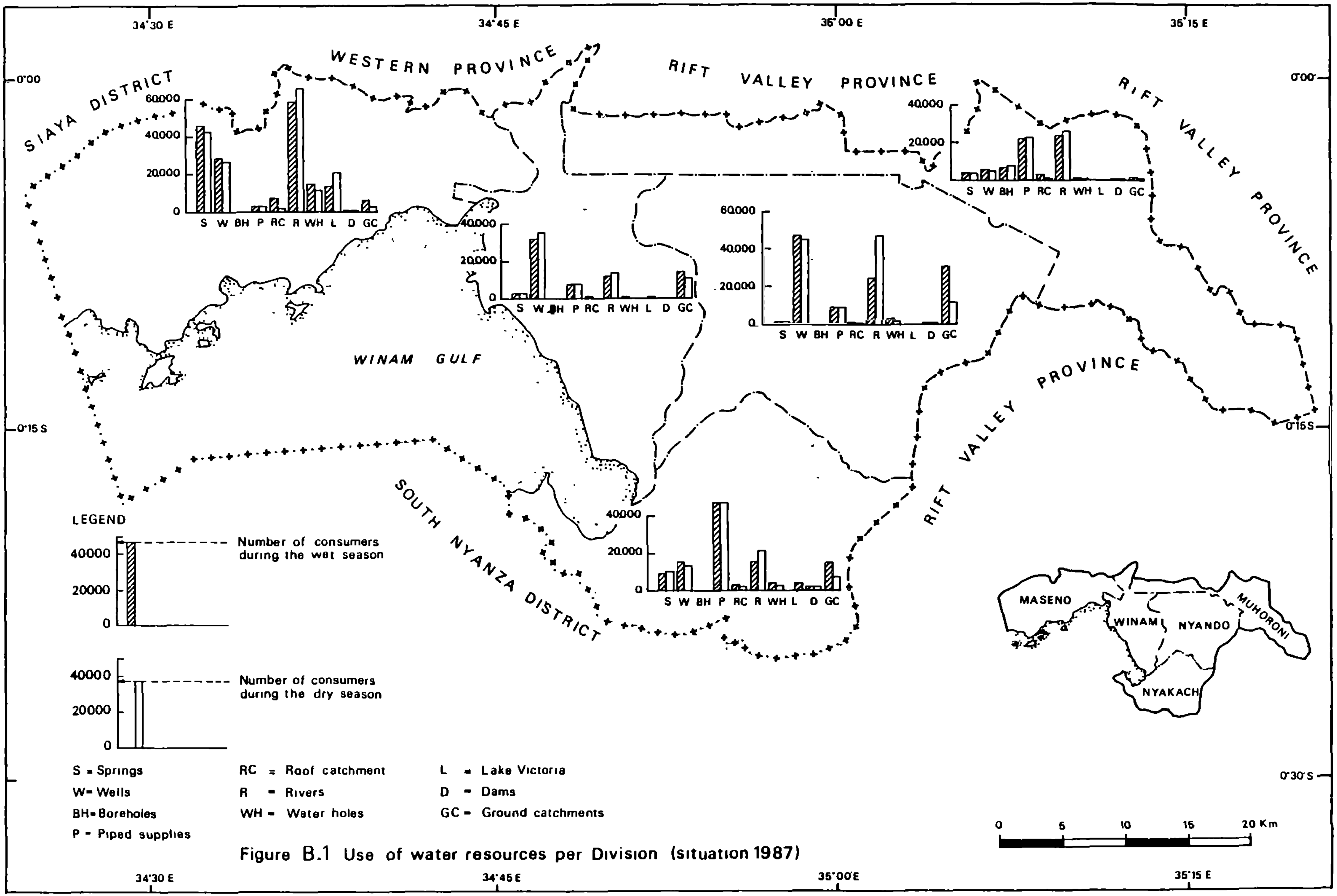


Figure B.1 Use of water resources per Division (situation 1987)

For identification of these areas use has been made of the socio-economic study, executed as part of the RDWSS Programme and the study of water supply and sanitation within Kisumu Municipality (Ref.15). The excluded areas are indicated in the same figure.

Where ever the term Kisumu District is used in this report, it should be considered that the mentioned areas are not included.

B SUMMARY OF THE PRESENT WATER SUPPLY SITUATION

B.1 Introduction

As part of the RDWSSP an extensive survey has been carried out with the aim to assess and evaluate the use of water resources in Kisumu District. The approach and results of the inventory are given in Part 3 of this report. A summary of the findings is given below.

B.2 Use of water sources

Altogether 550,000 consumers have been recorded during the inventory survey, making use of ten different types of water points. The relative importance of the different kinds of water sources in the Divisions of Kisumu District is illustrated in Figure B.1. Table B.1 shows the number and percentage of users per type of source during the wet and the dry season.

TABLE B.1 USE OF TYPES OF WATER POINTS DURING WET AND DRY SEASON

Type of water point:	N° of consumers during wet season		N° of consumers during dry season	
Wells:	122,800	23 %	120,400	22 %
Springs:	61,500	11 %	59,500	11 %
Boreholes:	10,700	2 %	11,400	2 %
(Total ground water:)	(195,000	36 %	191,300	35 %)
Rivers:	133,300	25 %	174,600	32 %
Ground catchments:	67,600	13 %	32,800	6 %
Water holes:	23,100	4 %	15,100	3 %
Lake Victoria:	13,500	3 %	23,400	4 %
Dams:	1,600	0 %	1,600	0 %
(Total surface water:)	(239,100	45 %	247,500	45 %)
Roof catchments:	14,900	3 %	4,600	1 %
Piped water:	98,700	18 %	108,100	20 %
Total Kisumu District	**547.700**	**100 %**	**551,500**	**100 %**

It shows that during the dry season the contribution of ground and roof catchments reduces considerably. Contrary, more consumers are served by rivers, the lake, and piped water.

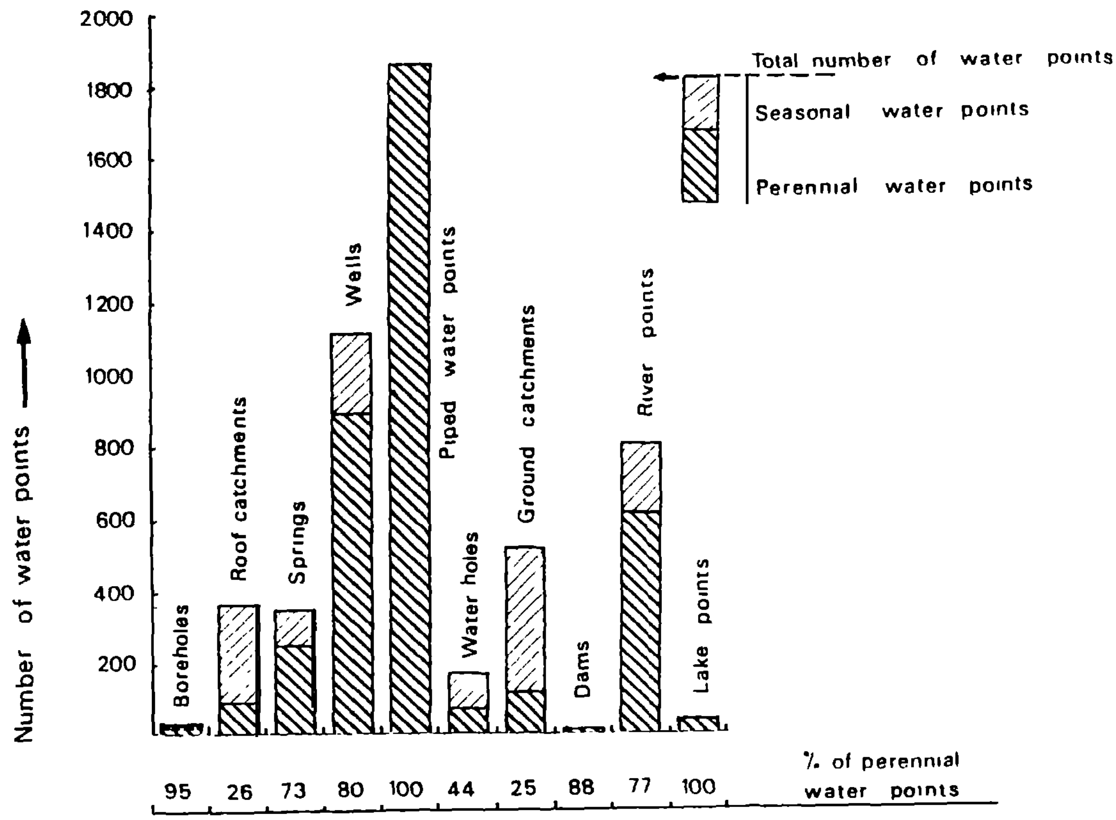


Fig B.2 Number of seasonal and perennial water points

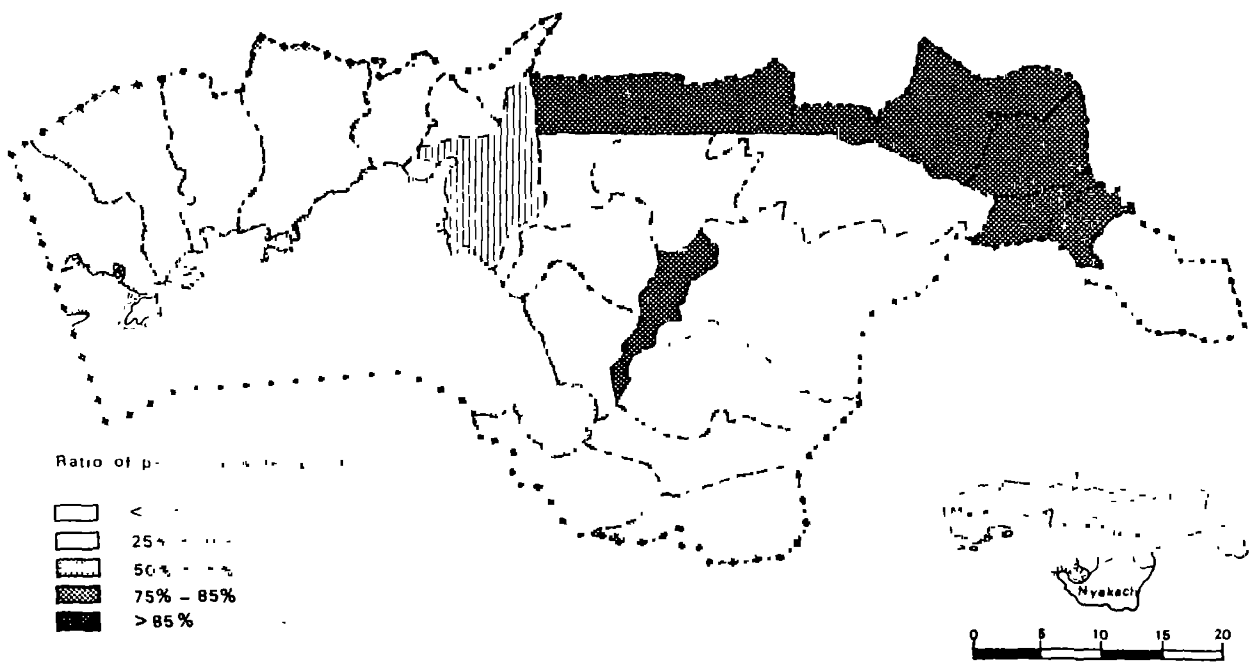


Fig B.3 Perennial water points as ratio of all water points

Regarding the number of consumers counted, it can be concluded that the number of approximately 550,000 agrees reasonably with the projected rural District population for 1987 as shown in Table C.3.

B.3 Constraints of water sources

B.3.1 Point sources

The people of Kisumu District make presently use of 5,250 water points (Section 6.4). Included in this number are 1,865 standpipes of piped supplies. Out of the 3,385 point sources only 2,080, or 60% are perennial water points. Figure B.2 shows the present number of each type, and the distinction between seasonal and perennial water points.

B.3.2 Piped water

Presently 28 different operational piped water schemes exist in the District, serving around 100,000 consumers (Section 3.3). Due to an irregular supply of the systems however about 40% of these consumers also depend on alternative sources. Constraints can occur the year through and are mainly caused by silted intakes, lack of fuel or system breakdowns.
Concerning the present contribution of the Nyakach water supply, which is the major scheme in the District it is estimated that around 38,000 consumers are being served, of which 50% regularly.

B.3.3 Seasonal water points

Figure B.3 displays the ratio of the perennial water points to the total number of water points per Location. It appears that the East Kano Location is very badly off; here less than 25% of the water points are perennial. A poor situation is found also around Kisumu Town and in the Seme Locations in the east of Maseno Division. The situation in Muhoroni Division is relatively favourable, as more than 90% of the water points is perennial (thanks to a large number of piped water taps which are not seasonal).

B.4 Walking distances

Average walking distances to public water points during the dry season are depicted in Figure B.4. Again East Kano Location is worst off, with an average walking distance of more than 700 meters. Considerable walking distances occur also in North and West Nyakach Locations and in southern Winam Division. Average walking distances in the east of Muhoroni and north-east of Nyando Divisions are slightly overestimated since extensive areas within these Locations are uninhabited (sugar plantations).
The centre of Maseno Division, the area south of Ahero and the Nyabondo Plateau show short walking distances due to the abundant existence of perennial wells.

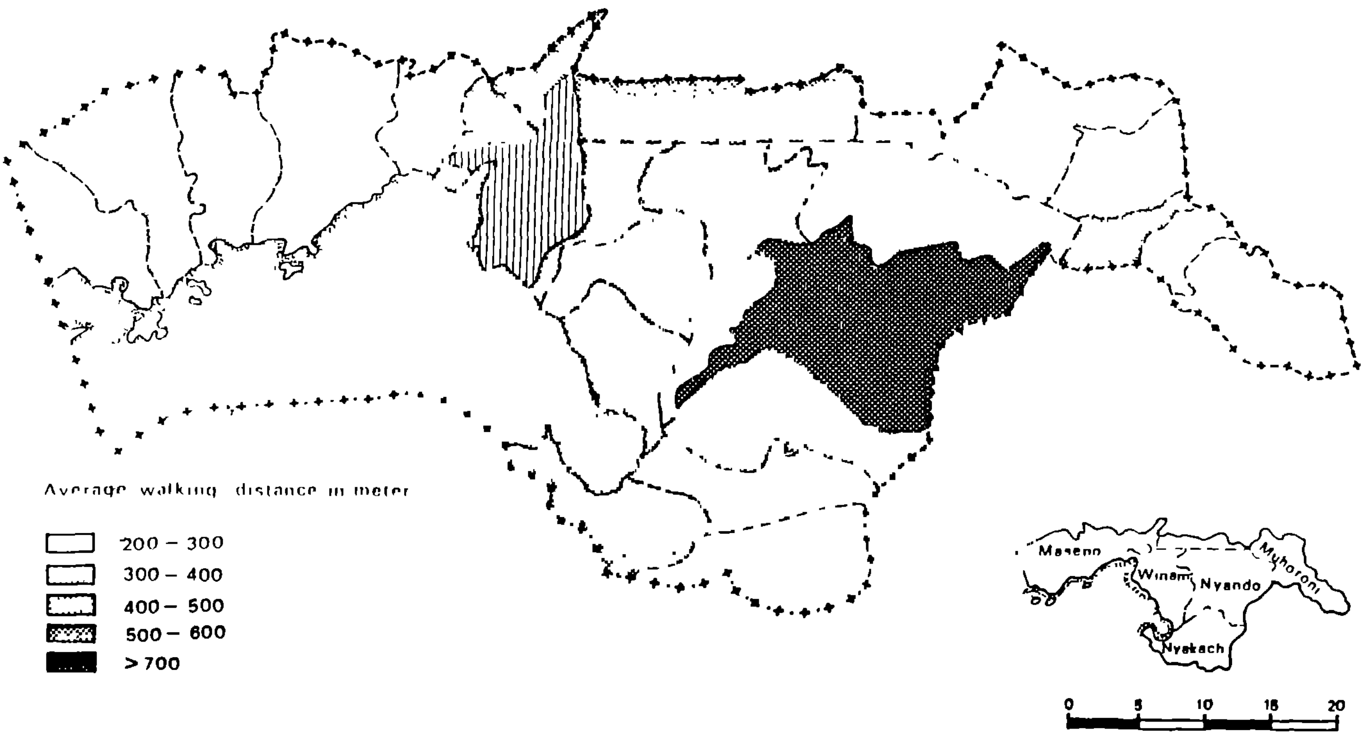


Fig B.4 Average walking distances for public water points during dry season

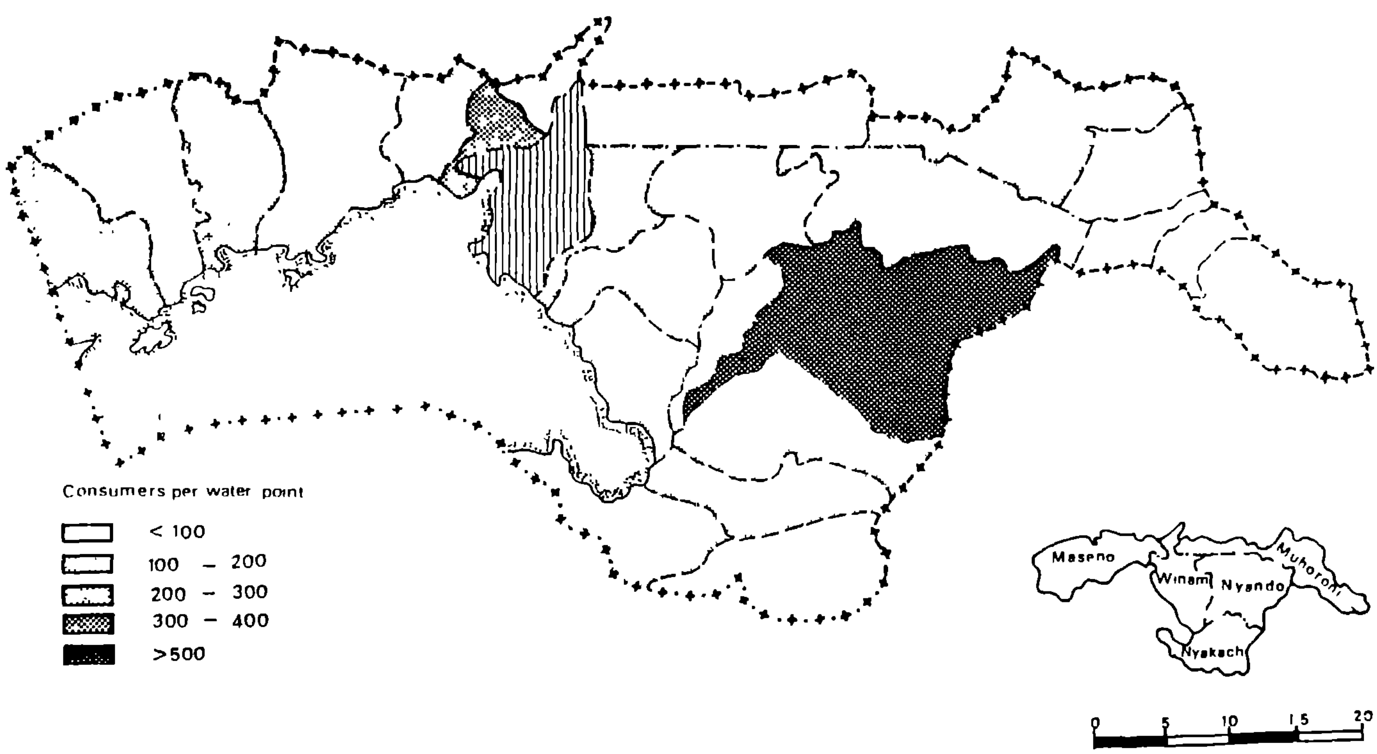


Fig B.5 Average number of consumers per water point during the dry season

B.5 Number of consumers per water point

Figure B.5 gives an overview of the average number of consumers per water point during the dry season, considering both private and public water points.

B.6 Water quality

B.6.1 Point sources

Nearly all surface water sources as rivers, Lake Victoria, water holes, ground catchments and dams are moderately to heavily polluted and bacteriologically contaminated.
The sampling of ground water sources as springs and wells has learned that respectively 51% and 66% of these water points are contaminated. This is in many cases due to poor drainage which causes that unsafe water flows into the source, contaminating the water point and often the aquifer itself.
Only boreholes which use ground water from deep aquifers and roof catchments provide safe drinking water.

Considering the use of the different point sources as presented in section B.2 this implies that less than 20% of the users of point sources dispose over safe water.

B.6.2 Piped water

Piped water schemes are assumed to provide water of good quality, if proper treatment is effected in accordance with the source used; surface water ,shallow or deep groundwater.

In this matter, only water from boreholes is safe without treatment. If the source of the piped water scheme is either a spring or a well, at least chlorination is required. Surface water needs a full treatment before it can be consumed safely.

Although the treatment system of the Nyakach water supply is currently not yet fully in operation, the 38,000 users of the system are in this context nevertheless assumed to be provided with safe water. According to these assumptions, around 50% of the users of piped water dispose over safe water.

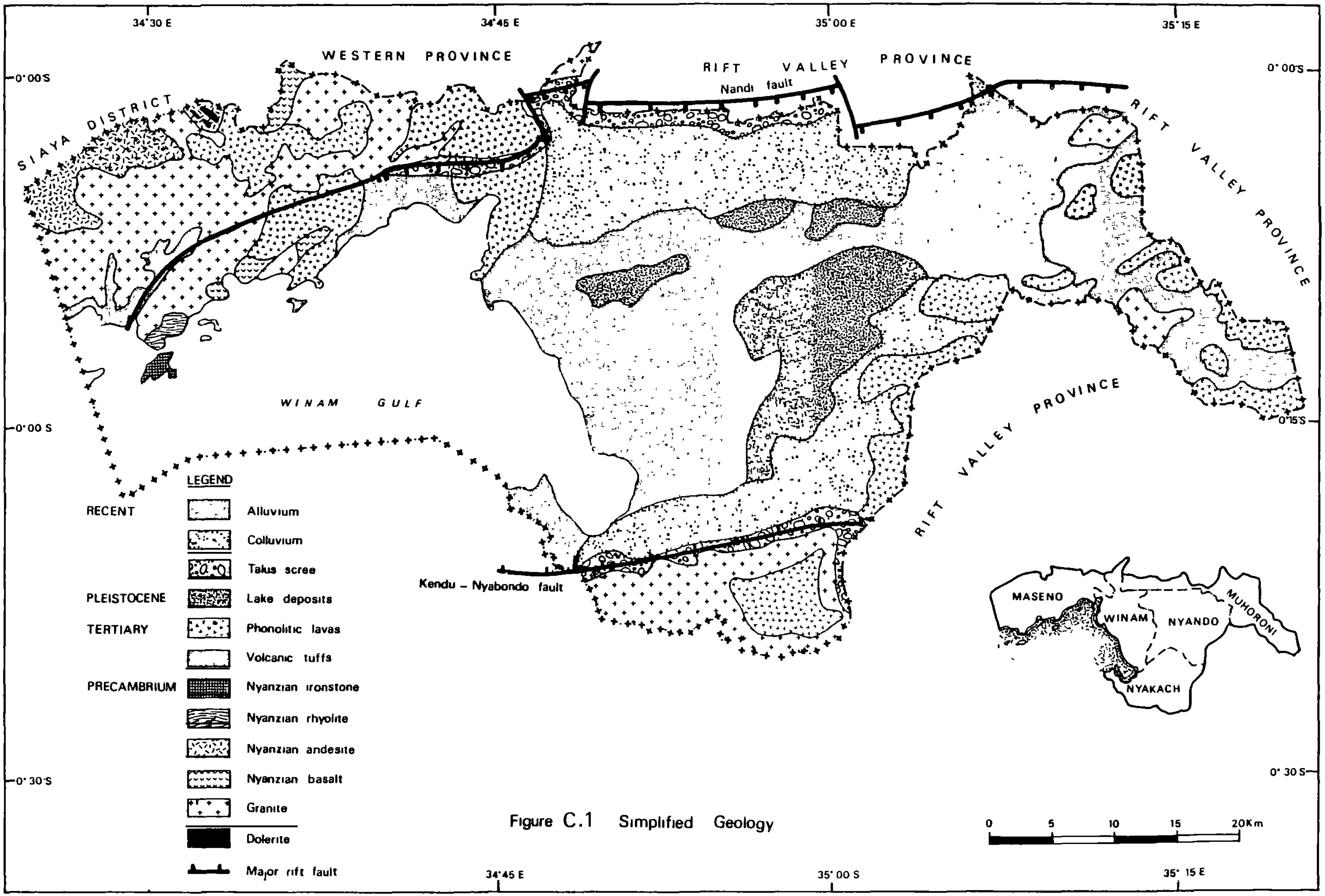


Figure C.1 Simplified Geology

C WATER RESOURCES COMPARED WITH WATER DEMAND

C.1 Surface water resources

Except for the Kano Plain, surface water is amply available the year through in Kisumu District.
But due to the contamination and the high turbidity, water from the rivers and Lake Victoria need elaborated and costly treatment before safe human consumption. A proper treatment system must include:

- coagulation
- sedimentation
- filtration
- chlorination.

This implies that river water is only suitable for supply through piped water systems with treatment plants which were found to be difficult to operate and maintain in rural areas. Since in the most regions of Kisumu District safe ground water is abundantly available, the use of surface water is not recommended here.

One single sample was taken from the River Nyando and analyzed by the Kenya Bureau of Standards. This institution found that Nyando water was heavily polluted by high concentrations of cadmium, DDT's, Hexachlorobenzene, Aldrin and Phenols, as presented in chapter 8. This pollution is probably caused by insecticides, herbicides and pesticides in the sugar cultivation.

C.2 Ground water resources

C.2.1 Introduction

As part of the RDWSSP, comprehensive surveys have been carried out with the aim to assess as accurately as possible the ground water resources available for rural domestic water supply development.

The studies included but were not limited to:

- study of existing literature and data
- geological mapping
- mapping of geological faults and structures through remote sensing
- mapping and investigation of existing wells and boreholes
- comprehensive geophysical surveys
- borehole drilling and testing.

The results of the surveys were subsequently presented in five different Divisional reports (Ref.13).
After the completion of these reports, additional geophysical investigations were carried out to further explore the ground water potential in the Kano Plain area.

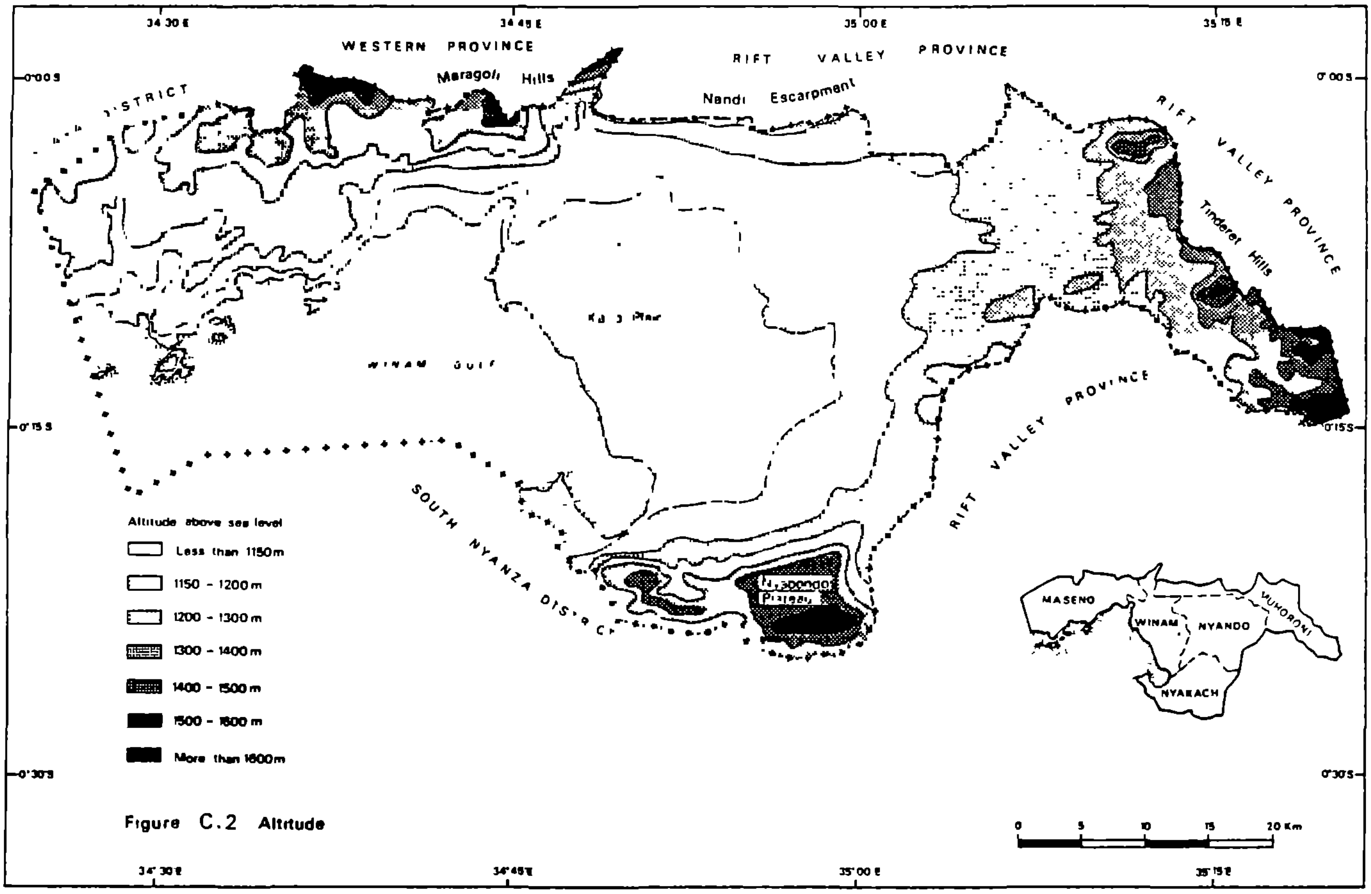


Figure C.2 Altitude

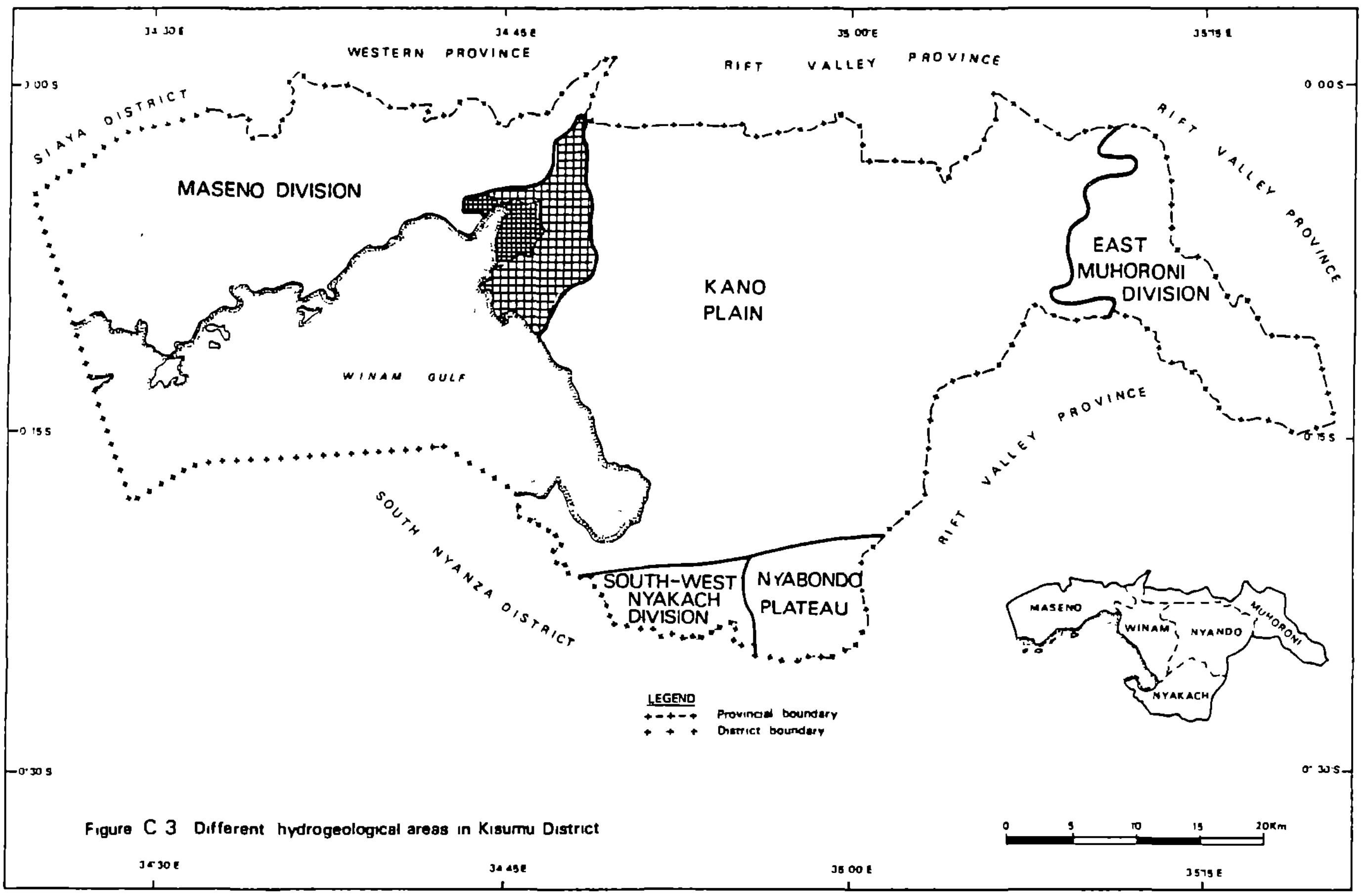


Figure C 3 Different hydrogeological areas in Kisumu District

The promissing results of these additional survey moreover resulted in the construction of 32 boreholes in the Kano Plain during the second half of 1988.

Taking into account also the new data, the ground water resources development opportunities for the District have been partly re-evaluated.
For a proper presentation of results, Kisumu District is divided into five different areas (Figure C.3):

- the Kano Plain
- Maseno Division
- East Muhuroni Division
- the Nyabondo Plateau
- south-west Nyakach Division.

The ground water resources of these areas are described comprehensively in chapter 12.
Section C.2.3 to C.2.7 summarize the most relevant results.

C.2.2 Present use of ground water

Approximately 194,000 people, amounting to 35 % of the rural population of Kisumu District, make use of ground water resources.

Shallow ground water is by far the most important ground water resource used; the total of 1150 dug wells found in the District together are supplying some 122,000 people with water.
Relatively large concentrations of dug wells are found in three different areas in the District:

- the Kano Plain
- the Nyabondo Plateau
- the north-east of Maseno Division.

Deeper ground water is used only by an estimated 11,000 people.
A total of 20 operational boreholes was found as point sources, all located in the sugar belt area of Muhuroni Division.
Another 9 boreholes are used for piped supply schemes.

The present total annual abstraction of shallow and deep ground water together is estimated to be one million m^3 per year.

C.2.3 Ground water resources in the Kano Plain

The area

The Kano Plain comprises Winam Division, Nyando Division, the west of Muhuroni Division and the north of Nyakach Division.
The area is inhabited by some 230,000 people which is almost 40 % of the total rural District population.
There are 550 wells and 20 boreholes in the area which are used by roughly 94,000 people.

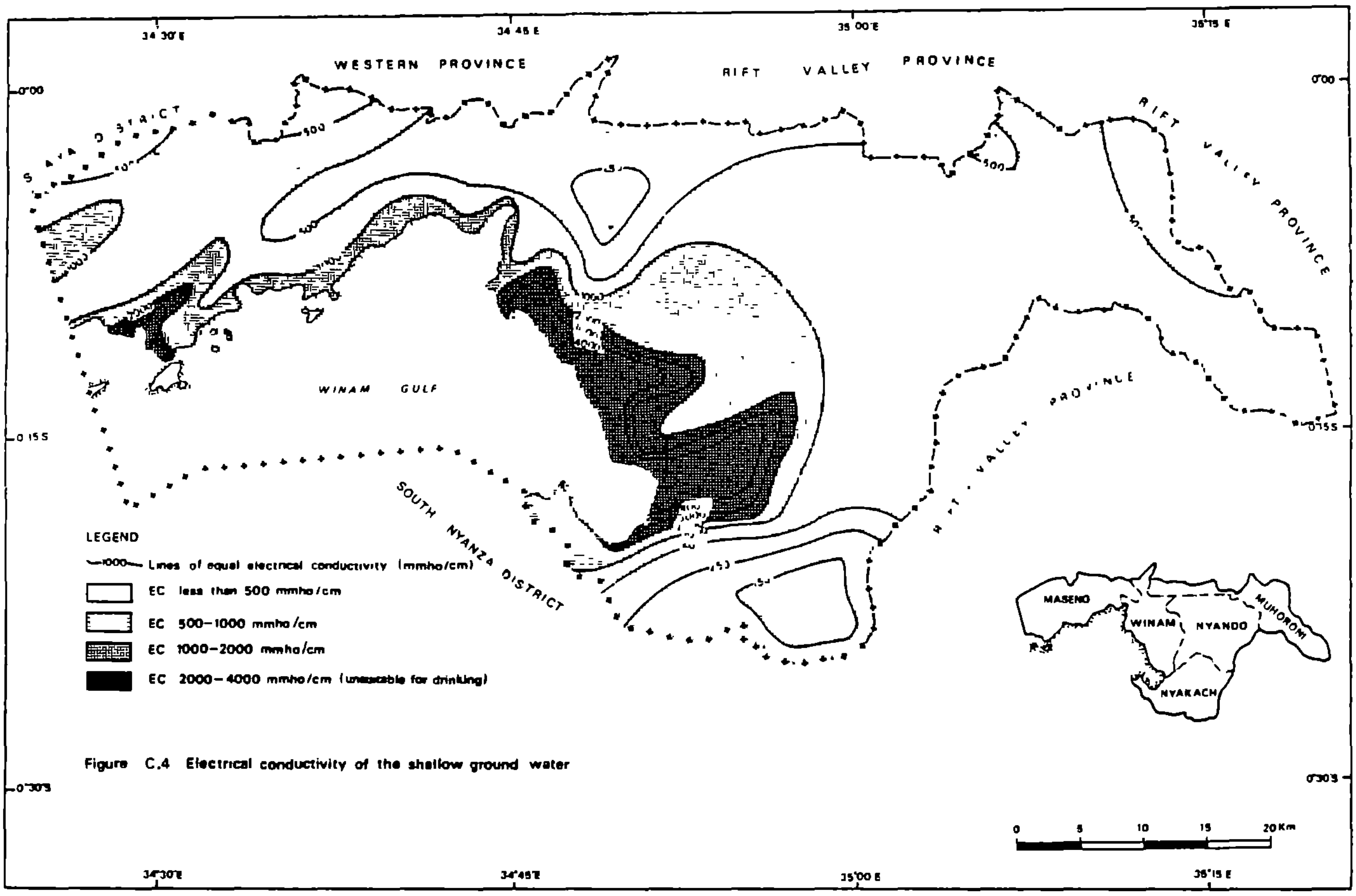


Figure C.4 Electrical conductivity of the shallow ground water

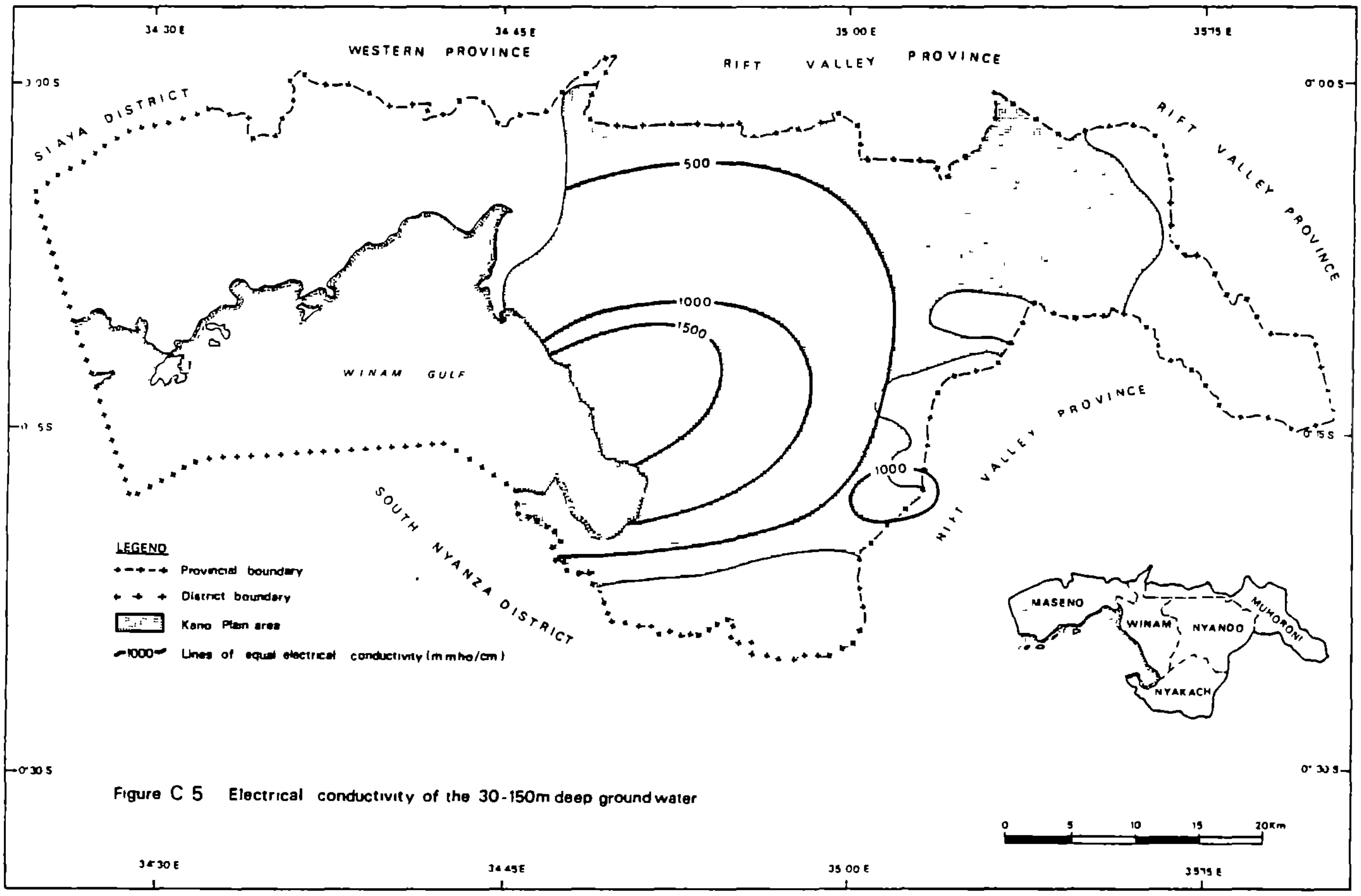


Figure C 5 Electrical conductivity of the 30-150m deep ground water

Geologically the Kano Plain forms part of the Kavirondo Rift valley which is a down faulted area filled with sediments of Pleistocene to Recent age.

The sediments are both lacustrine and fluviatile and include silty gravels and sands to gravelly silts and clays.
The total thickness of the sediments varies from 200 m to over 350 m.

Aquifers

Aquifers are found at various depth levels.

The first aquifer is found between 10 and 25 m depth.
This shallow aquifer is relatively thin and it's yield low.
Most existing dug wells in the Kano Plain are in this aquifer.

A second and third aquifer level usually is found between depths of 30 to 80 m. These aquifers are sufficiently productive for hand pump and limited capacity motorized pumping.
Most boreholes constructed by the RDWSSP draw water from these aquifers.

Between 80 and 150 m depth other ground water bearing levels are found with characteristics similar to the second and third aquifers.

Below 150 m depth progressively thicker and better developed aquifers are expected to occur.

With the present knowledge of the geology of the Kano Plain sediments, it is not necessary to carry out geophysical surveys to indicate borehole locations.

Aquifer parameters

Because the average depth of the tested boreholes amounts to 90 m, the aquifer parameters given below are representative only for the upper 90 m of sediments.

Aquifer transmissivity and therefore well yields are higher along the boundaries of the Kano Plain, than in the central and western parts.

Parameters for aquifers in both areas are given in Table C-1.

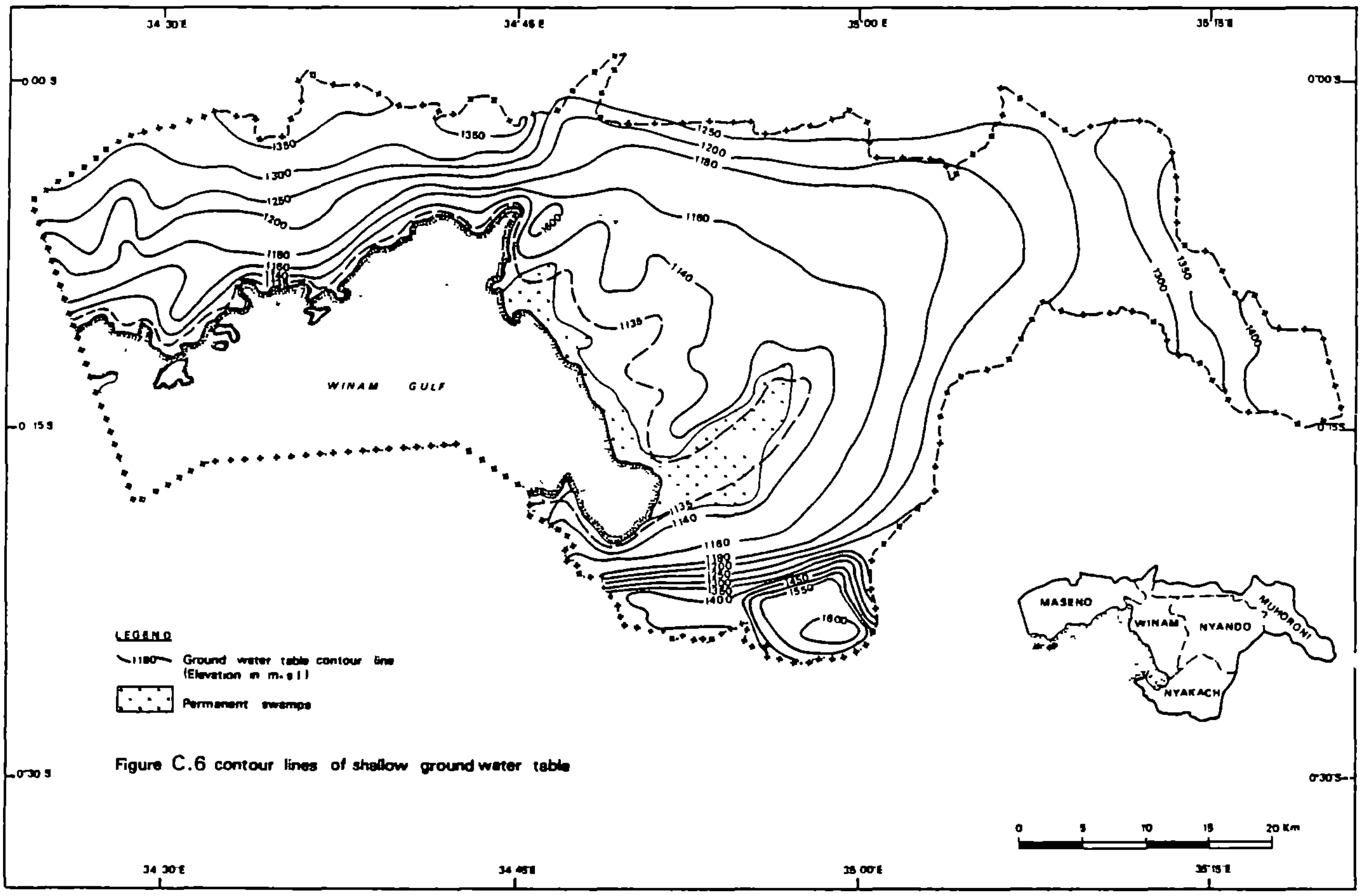


Figure C.6 contour lines of shallow ground water table

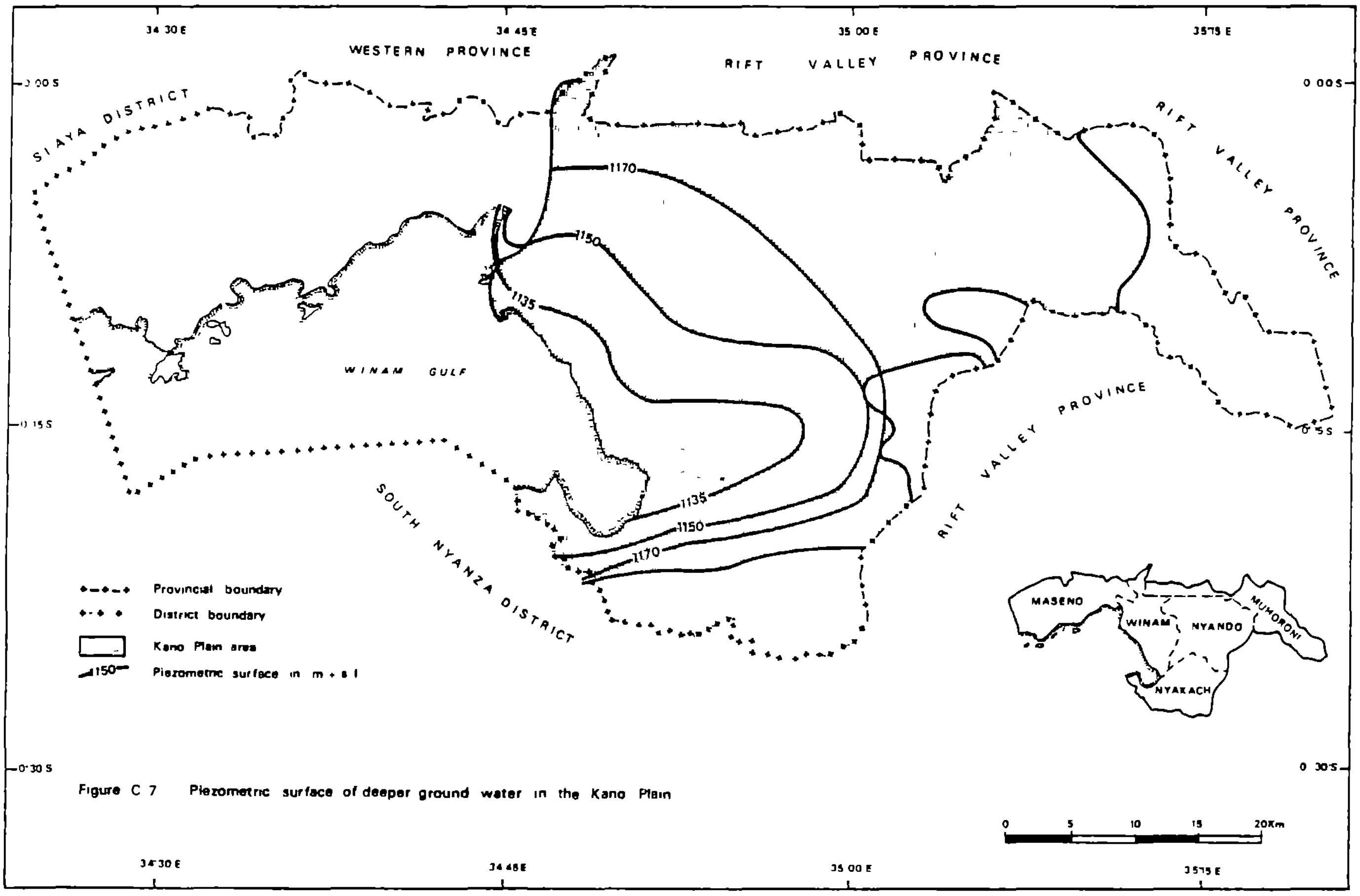


Figure C 7 Piezometric surface of deeper ground water in the Kano Plain

TABLE C-1 HYDRAULIC PARAMETERS OF AQUIFERS IN KANO PLAIN AREA

Tested Boreholes		Water level		Yield		Aquifer thickness	KD	K
No.	mean depth	struck	static	range	max.			
	m-gl	m-gl	m-gl	m^3/hr	m^3/hr	m	m^2/day	m/day
30	90	15-80	5-45	2-18	10	10-30	1- 20	0.1- 4
60	90	10-50	10-20	6-40	18	10-30	60-100	2-10

Ground water quality

Quality wise there is an essential difference between the shallow and deeper ground water in the Kano Plain.
This difference manifests itself mainly in the salinity and the bacteriological quality.

Due to evapo(trans)piration, the salinity of the shallow ground water in the western part of the Kano Plain appears to be 2 to 3 times higher than the deeper ground water (see Figures C.4 and C.5).

In the approximately 4 to 10 km wide zone bordering the Winam Gulf, the salinity of the shallow ground water exeeds the maximum standard of 2500 mmho/cm.

Almost everywhere in the Kano Plain the shallow ground water is bacteriologically contaminated and not safe for consumption.

On the contrary, the deeper ground water was found to be free from bacteriological contamination.

Futher, in particular in areas where cash crops are grown, pollution of the shallow ground water from fertilizers and pesticides can be expected.

Ground water flow and potential

Ground water flow is according to a radial pattern, from the main recharge areas in the east, north and south to the central area of the Kano Plain and eventually to the Winam Gulf.

The total ground water recharge of the Kano Plain is estimated to be 15.8 x 10^6 m^3/year.

Out of this volume 5.3 x 10^6 m^3/year percolates to the deeper aquifers and the remaining 10.5 x 10^6 m^3/year mainly feeds the shallow aquifers. Approximately 0.7 x 10^6 m^3/year of this volume is presently withdrawn for domestic use.

The remaining 9.8 x 10^6 m^3/year flows towards the coastal area where most of the shallow ground water emerges in the extensive swamps along the lake shore where it partly dissapears through evapotranspiration and it partly flows into the Winam Gulf.

Considering that the shallow ground water is unsuitable for exploitation because of it's poor quality, the ground water potential of the Kano Plain equals the ground water potential of the deeper ground water: 5.3 x 10^6 m^3/year.

C.2.4 Ground water resources in Maseno Division

The area

The surface area of Maseno Division is 460 km^2 which is 25 % of Kisumu District.
Likewise, the Division's rural population, 135,000, comes to 25 % of the District's rural population. Approximately 29,000 people make use of the 300 wells found in the Division.

The area completely falls within the Lake catchment area 1 HB. Drainage is through parallel rivers and streams flowing from north to south, debouching into the Winam Gulf.

Hard rocks crop out in 90 % of the area and include granite, andesite and phonolite. Lacustrine and alluvial deposits are found along the Winam Gulf and in major valleys.

Aquifers

Ground water relatively is abundant.
Three different types of aquifers are found:

- ground water in the weathered zone of hard rocks
- ground water in faults and fractures in hard rocks
- ground water in sediments.

Shallow ground water (12-25 m) of a good physio-chemical and bacteriological quality occurs throughout the area in the weathered zone and in areas of accumulated sediments.

Its successful development will be restricted mainly to the topographical lower areas as valleys, intermountaineous flats, foot slopes etc.

By using hydrogeological knowledge of the area it should be possible to indicate hand dug well locations without geophysical surveys.

Medium depth ground water (25-60 m) occurs in faulted and fractured hard rocks and in sediments along the Gulf.
In the hard rock areas, borehole locations will always have to be sited by means of geophysical surveys.

Ground water quality

Due to a relatively high rainfall, the ground water recharge conditions in this area are better then elsewhere in Kisumu District. This results in agenerally good ground water quality; the chemical quality of the ground water is excellent and the salinity (EC) is between 100 and 500 mmho/cm and everywhere below 1000 mmho/cm. None of the chemical parameters exceed the Kenyan Standards.

The bacteriological water quality appears to be much better than in other parts of Kisumu District. About 65 % of the ground water sources show no contamination and the remaining sources only slight contamination.

Ground water flow

Ground water flow is from north to south according to a hydraulic gradient of 1-1.5 %.
An average annual reacharge of 30 mm over the whole area was calculated, which would add 13 x 10^6 m^3/year to the ground water. Present ground water abstraction is low and comes to only 0.2 x 10^6 m^3/year.

C.2.5 Ground water resources in the eastern part of Muhuroni Division

The area

The area is 220 km^2 and includes Tamu, Muhuroni West, Muhuroni East and Koru Locations as well as West Songhor Sub-location of Chemelil Location.
The total population amounts to 39,000.
There are only 14 wells in the area which are used by 1,000 people.
Most of the area is underlain by volcanic rocks tuffs.

Aquifers

The occurrence of shallow ground water is very local and restricted to valley bottoms.
Medium depth water is found between depths of 20 and 80 m.
Yields from weathered rock aquifers will be low to modest.

It is recommended to carry out geophysical survey for the siting of borehole locations.

Ground water quality

The physio-chemical and bacteriological quality of the shallow ground water is excellent.
EC values are between 200 and 600 mmho/cm.
Locally the deeper ground water may be saline. Therefore it is recommended to drill some test boreholes to investigate the quality of the deeper ground water.

C.2.6 Ground water resources of the Nyabondo Plateau

The area

The area comprises the Nyabondo Plateau which covers 40 km^2.
The total population of this area is 31,000.
Average population density is extremely high: 775 people per km^2.
Most of the people make use of shallow dug wells of which 260 were counted.

Geologically the area is underlain by 30-65 m thick phonolitic lava on top of granite.

Aquifers

Investigations have shown that below 20 m of depth there is an abundance of clay and no deep ground water.
Shallow ground water however is abundant.
It is found in weathered rock, directly below the soil cover at depth between 2 and 15 m.
Most existing wells are between 5 and 8 m depth and draw water from this aquifer.
Ground water moreover occurs in a zone of broken, fissile rock at depth between 10 and 20 m, which may offer possibilities for development.

Ground water quality

The chemical quality is extremely good with salinity values not exceeding 150 mmho/cm.
Bacteriologically the shallow water is of poor quality.
Contamination is not local but comprises the whole aquifer.

Ground water flow and recharge

The flow of ground water is radial; towards the edges of the Plateau where it emerges as springs and small streams.

For an average rainfall of 1,300 mm/year and a recharge index of 6 %, the total annual recharge would be 2.8 x 10^6 m^3/year.

The present total ground water withdrawal comes to some 0.3 x 10^6 m^3/year.

C.2.7 Groundwater resources of the south-west of Nyakach Division

The area

The area is hilly and comprises 40 km^2.
In contrast to the Nyabondo Plateau, the population density is as low as 150 people per km^2.
The population (6000) makes use of surface water resources as there are no existing wells or boreholes.

Aquifers

The occurrence of ground water is restricted to medium depth ground water (25-70 m) in faults and fracture zones in the granite.
Borehole locations typically will have to be selected by means of geophysical surveying.

Ground water quality

No data are available of the ground water quality.
Fluoride may be high.

Ground water flow and recharge

Based on an annual rainfall of 1,150 mm and a low recharge index of 2 %, the annual recharge amounts to 1 x 10^6 m^3/year.

Approximately 50 % of the flow is towards the north, the remaining ground water flows towards River Sondu in southern direction.

C.2.8 Ground water development possibilities

At present 25 % of the rural District population makes use of ground water sources.
It is recommended and has been proven feasible, to increase ground water use to almost 90 % of the population.
Moreover, there will have to be a shift from the exploitation of shallow ground water to the use of deeper water.
The ground water development possibilities for different characteristic areas in the District are summarized in Table C.2.

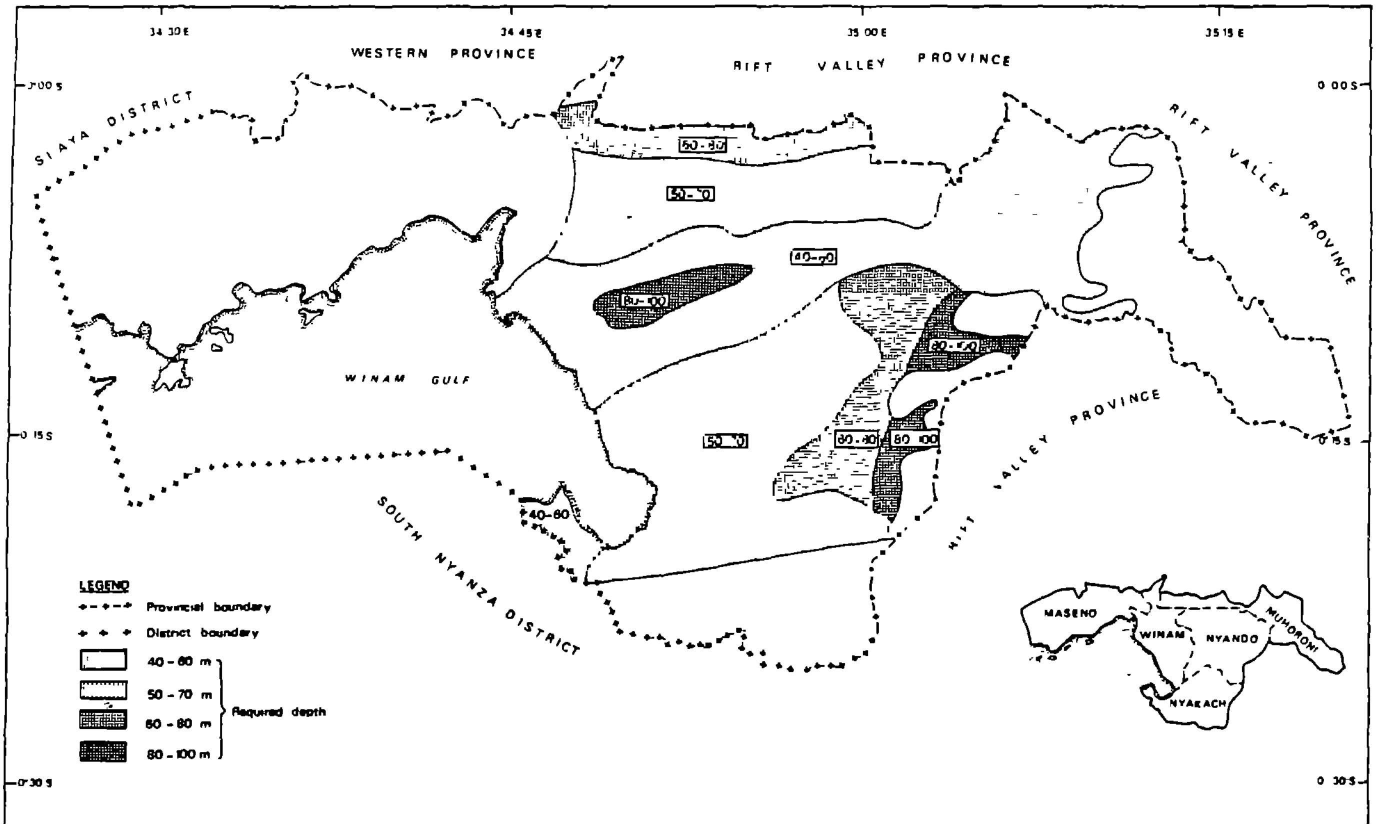


Figure C.8 Required borehole depth in the Kano Plain area

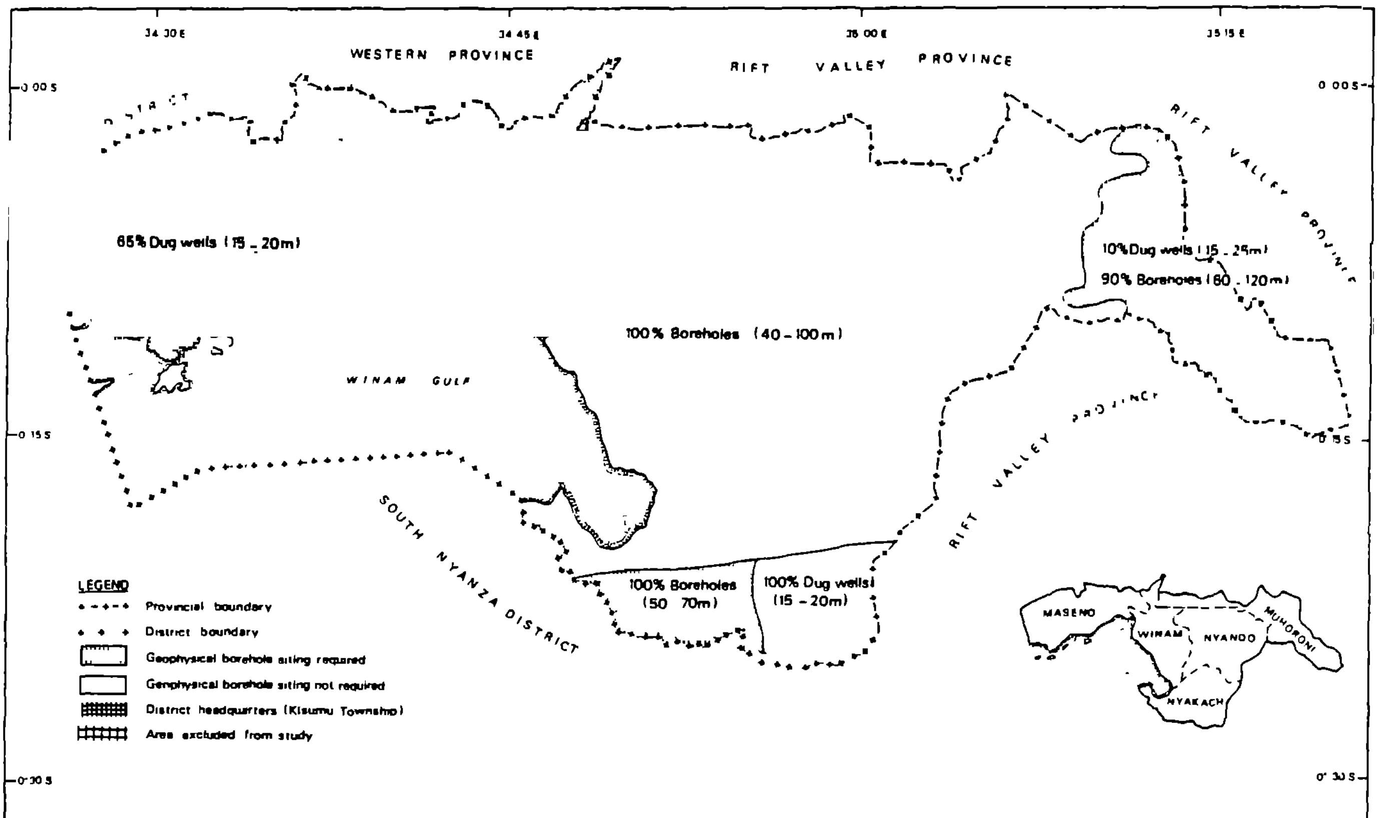


Figure C 9 Ground water exploitation opportunities

TABLE C.2 GROUND WATER DEVELOPMENT OPPORTUNITIES

Area	Boreholes			Dug wells		
	Depth range	average depth	relative feasibility	Depth range	Average depth	relative feasibility
	m	m	%	m	m	%
Kano Plain	40-100	60	100			
Maseno Div.	40- 60	50	40	12-25	15	60
E.Muhuroni Div.	60-120	80	80	15-25	20	20
Nyabondo Plateau				10-25	15	100
S.W.Nyakach Div.	50- 70	60	100			

C.3 Water demand

The importance of realistic water demand estimates is that they have a long range influence on the planning and design of water supply projects, they determine adequacy of the water resources and they provide the basis for financial and economic analyses of water programmes.

The water demand projections given in this report (chapter 7) are derived from:

- population growth projections up to the year 2005
- projected growth of urban and rural centres within the District
- water consumption rates for rural areas and rural centres.

C.3.1 Projections of the total District population

Because of a proven gross under counting in Western Kenya and Kisumu District in particular, during the latest (1979) census, the population projections given in this document (section 5.3) are based on the revised growth rates for the 1969-1979 period, published by the CBS in 1983, 3.3 % for Kisumu District.

In order to assess the 1987 population, the same growth rate was used.
Because the thus projected 1987 population comes very close to the 1987 consumers (=population) count carried out by the RDWSSP, from 1987 onward, the population is assumed to grow according to the same growth rate of 3.3 % per year.

The projected District populations calculated in this manner are shown in Table C.3.

TABLE C.3 REVIEW OF DISTRICT POPULATION PROJECTIONS

	1987	1990	1995	2000	2005
District population	699,000	772,000	907,000	1,074,000	1,255,000

Included in this figures are the projected populations for the extended Municipality of Kisumu.
During the survey however it was found that at present large parts of the extended Municipality should still be considered as rural areas.

Subtraction of the 1987 rural population within the Municipality gives a 1987 Urban population for Kisumu Township of about 146,000.
By using an urban growth rate of 6.5 % (Ref.39 and 66) for Kisumu Township and subtracting this projected urban population from the total District population, the total rural population projections are found.

TABLE C.4 PROJECTIONS OF RURAL DISTRICT POPULATION

	1987	1990	1995	2000	2005
District population	699,000	772,000	907,000	1,074,000	1,255,000
Kisumu Urban population	146,000	176,000	241,000	330,000	452,000
Rural District population	553,000	596,000	666,000	774,000	803,000

C.3.2 Population projections for rural areas, rural centres and urban centres

The Ministry of Lands and Settlement has given service centres in rural areas the following designation:

- Urban centres : more than 5,000 permanent residents
- Rural centres : 2,000-5,000 permanent residents
- Market centres : less than 2,000 permanent residents
- Local centres : less than 2,000 permanent residents

The projections of these various population categories as given in Table C.5 have been obtained by using an annual urban growth rate of 5.0 % for the present urban centres in the District and a rate of 3.3 % for growing smaller service centres.

TABLE C.5 REVIEW OF URBAN AND RURAL POPULATION PROJECTIONS

SERVICE AREA	1987	1990	1995	2000	2005
URBAN CENTRES POPULATION (growth rate 5 %)	20,000	23,000	29,000	37,000	47,000
RURAL CENTRES POPULATION (growth rate 3.3 %)	52,000	60,000	77,000	98,000	125,000
RURAL AREAS POPULATION (growth rate 3.3 %)	481,000	513,000	560,000	639,000	631,000
RURAL DISTR. POPULATION	553,000	596,000	666,000	774,000	803,000

C.3.3 Water consumption rates

Water consumption rates adopted and recommended by the Programme for planning purposes are presented in chapter 7 of this report. They are based on field investigations into the present water use practices of the rural population and take into account increased consumption rates from improved facilities such as handpump wells, springs and communal standpipes.

The adopted rates fall well within the rates recommended by the Worldbank/UNDP (Ref.67) and in the Design Manual for Rural Water Supply in Kenya (Ref.42).

TABLE C.6 RDWSSP DESIGN CRITERIA FOR RURAL DOMESTIC WATER SUPPLY

SUPPLY AREA	HIGH POTENTIAL AREAS l/c/d	MEDIUM POTENTIAL AREAS l/c/d	LOW POTENTIAL AREAS l/c/d (not applicable in Kisumu District)
Rural areas	30	30	20
Market centres	30	30	20
Local centres	30	30	20
Rural centres	50	50	40
Urban centres	100	100	100

It is assumed that improved water sources will be used for all domestic purposes including; drinking, cooking, personal hygiene and laundry washing.
Moreover, the consumption rates are subject to the following conditions:

- the rates do not include any provision for irrigation, besides for very limited garden watering
- the rates include 20 % allowance for water losses through spill and wastages
- for cattle watering the traditional water sources (rivers, dams, Lake Victoria, water-holes) are retained.

C.3.4 Rural domestic water demand projections up to 2005

When assigning the proposed water consumption rates, 30 l/c/d for rural areas, 50 l/c/d for rural centres, and 100 l/c/d for urban centres to these projected populations and, and after multiplying these figures by 365, the annual rural domestic water demand is obtained (Table C.7).

TABLE C.7 RURAL DOMESTIC WATER DEMAND PROJECTIONS KISUMU DISTRICT (rounded figures)

	1987	1990	1995	2000	2005
WATER DEMAND IN M3/YEAR *	7×10^{6}	8×10^{6}	9×10^{6}	10×10^{6}	11×10^{6}

* Demand figures exclusive of Kisumu Urban Centre.

TABLE D.1. TECHNOLOGY OPTIONS FOR COMMUNAL WATER SUPPLY

Type of Service	Water source	Quality protection	Water use l/c/d	Energy source	Operation and maintenance needs	Costs	General remarks
Yardtaps	Groundwater Surface water Spring	Good, no treatment Needs 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	Very good access to safe water; fuel and institutional support critical
	Groundwater Surface water Spring	Good, no treatment Needs treatment Good, no treatment	50	Gravity Electric Diesel Wind Solar	Well trained operator; reliable fuel and chemical spare parts	Moderate capital and O & M costs, collection time	Good access to safe water; cost competitive with handpumps at high pumping lifts
New wells with handpumps	Groundwater	Good, no treatment	30	Manual	Trained repairer; few spare parts	Low capital and O & M costs; collection time	Good access to safe water; sustainable by villagers
Improved traditional sources (partially protected)	Groundwater Surface water Spring Rainwater	Variable Poor Variable Good, if protected	30	Manual Gravity	General upkeep	Very low capital and O & M costs; collection time	Improvement if traditional source was badly contaminated
Traditional sources (unprotected)	Surface water Groundwater Spring Rainwater	Poor Poor Variable Variable	20	Manual Gravity	General upkeep	Low O & M costs (buckets, etc) collection time	Starting point for supply vements

D RURAL WATER SUPPLY TECHNOLOGY OPTIONS IN KISUMU DISTRICT

D.1 The key to sustainability of water supplies

There is evidence from within and outside Kenya that it are the supplies owned, managed and maintained by the community (with technical assistance from outside) which stand the greatest chance of being sustained in good working order. Therefore, regardless of how the capital costs of community water supplies are financed:

- THE RECURRENT COSTS FOR OPERATION AND MAINTENANCE SHOULD BE BORNE BY THE COMMUNITY.

One of the main reasons why past projects have failed to live up to expectations was the choice of a water supply technology which was not sustainable with the resources available to the communities. The important conclusion drawn from this is:

- ANY WATER SUPPLY PROGRAMME SHOULD OFFER THE COMMUNITY A SERVICE LEVEL NOT HIGHER THAN THAT IT IS WILLING TO PAY FOR, WILL BENEFIT FROM, AND HAS THE INSTITUTIONAL CAPACITY TO SUSTAIN.

D.2 Technology options

Table D.1 shows the available community water supply technology options. Assuming that equal system reliability can be achieved, the technology options generally represent progressively increasing service levels which call for increasing financial and technical resources for their implementation and maintenance.

Improvement of traditional sources

Improvement of existing wells without a handpump or of surface water sources hardly offers benefits in terms of walking distance or improved water quality.

Improvement of reliable springs and rain catchments, if protected, at least have the advantage of an improved water quality and in case of rain catchments also quantity improvement.

Handpumps

Handpumps, fitted on wells and boreholes have clear advantages over the improvement of traditional sources.
By constructing wells or boreholes closer to the communities than their traditional sources, walking distances can be reduced.
If properly located, wells and boreholes are safe and reliable water sources. A good cover of the source plus the handpump prevent contamination of the well and aquifer.

Standpipes and yard taps

The step from manual to motorized pumping and from a point source to a piped system, markedly increases the costs and complexity of the system.
The increased complexity of communal water supply systems designed to provide higher service levels brings added risk of failure.
As a result the level of service actually provided by motorized pump schemes often is much lower than planned, though costs remain high. Moreover much attention must be paid to the quality of the supplied water.

D.3 Choice of resources

D.3.1 Water resources

In general the choice is between the use of surface water, ground water or rain water.
The advantages and disadvantages these different water resources offer have since long been established and were found to apply in particular also to Kisumu District.

Ground water

The use of ground water where possible should be the first choice.
Ground water has many advantages over surface water as a source for community water supplies.
The main advantage is that, provided wells are judiciously sited in relation to existing or future sources of contamination, safe water should generally be assured without the need for treatment.

Borehole with hand pump; a ground water source

Besides the safety that ground water offers, other advantages over surface water include:

- ground water aquifers can provide a substantial storage buffer to cope with seasonal variations in supply and demand and with prolonged droughts
- it enables a variety of relatively simple installations to supply water directly to the user at low cost
- it allows for phased development without the high initial costs for storage, transmission lines, treatment plants etc.

Surface water

It has been shown that surface water sources in Kisumu District generally are contaminated and polluted, which necessitates proper treatment.
Use of untreated surface water thus frequently represents an unacceptable health risk.
Additionally many of the surface water sources are seasonal.
The financial resource demands of water treatment plants needed to make supplies from surface water sources safe to drink are beyond the reach of most communities. Additionally, treatment plants proved to be difficult to manage and often are not functioning.
Thus it is not commendable to base communal water supply projects on surface water as the source.

Rain water

Due to a poor construction or design,in Kisumu District 80 % of the roof catchments are seasonal or otherwise inadequate to meet the demand.

The feasibility of rain water harvesting depends in the first place on the amount of rainfall, its probability and dispersion over the year.
As a rule, the lower the rainfall and the less its probability, the larger the catchment areas and storage facilities will have to be.

If rain water is properly stored and protected from contaminating sources, it can offer modest supplies of safe water.
Because of the good quality that rain water can provide, it generally is a good policy to consider the use of rain water for drinking and cooking where other water sources are not up to drinking standards.

Since relatively large areas of hard cover roofs are required for roof catchments, institutions such as schools, health centres and churches are the most logical places for implementation of roof catchments. This implies that roof catchments often are private or institutional systems.

D.3.2 Energy resources

Energy resources available in Kisumu District primarily include: gravity, human, animal, diesel, electric and renewable energy sources (wind and solar energy).

Basically any community water supply system which depends on something other than human or gravity energy for its operation involves an added risk of failures which will leave a large group of consumers without water.
These risks can be minimized by proper design, but often this means higher costs and forces the communities to rely on external resources outside its control.

Gravity energy

Water discharged by a spring flows by gravity.
Piped supplies make use of gravity by diverting spring water or by construction of an intake in a stream at an altitude higher than the points of delivery.

Human energy

Pumping of water by human energy (handpumps) has proven to be the most reliable and economic energy for community water supplies.

Animal energy

Although not used in Kisumu District for water lifting, animal energy is one of the relatively low cost pumping methods available.

Diesel energy

There are few examples of diesel-powered rural water supply systems operating successsfully in the long term.
Although diesel is a costly energy source the cost of the fuel is less significant than its reliability, since the logistic problems of ensuring dependable diesel supplies for dispersed communities have rarely been overcome.

Added to these logistical problems, all to often diesel fuel is diverted to other buyers rather than the isolated pump.

Electric energy

In cases where reliable low-cost electric power is available, an electric pump can be a relatively inexpensive and operationally simple means of lifting water, provided the organization exists to collect revenues and pay for repairs.
Communities which have the financial and technical means available to implement and sustain projects based on electric pumping should be encouraged to do so.

Wind and solar energy

These types of energy have the advantage over diesel and electricity that there is no dependence on external fuel supplies. They have however substantially higher initial costs than handpumps operated by human energy. Besides, they require more sophisticated and costlier maintenance skills and spare parts that usually are not readily available to the communities.

In comparison with handpumps, other extra costs with renewable energy systems involve the construction of back-up water supply, needed to cope with times when the energy source is not available.

D.3.3 Organizational resources

Significant is not the organization of the authorities implementing water supply projects and programmes, but the organizational skills and resources of the communities.

If the supplies are to continue to operate satisfactorily, the communities have to recognize the need for improved service, be able and willing to manage the operation and maintenance. As a consequence special attention will have to be given to training of pump caretakers and mechanics, if feasible within the communities. Other organizational aspects might include involvement of the private sector and contracting of maintenance and repair jobs.

Organization and management of available skills and equipment becomes more complex as the service level increases.

Improved traditional sources

These types of supplies have the advantage that normally very little maintenance is required.

Handpump supplies

The organizational structure needed involves creation of a water committee to manage collection of revenue from users, to initiate repair and maintenance activities, to pay for maintenance services and to procure spare parts.

Motorized pumping schemes

Motorized pumping includes the elements of handpump supplies and, in addition, requires a trained operator, a reliable power supply, a greater variety of spare parts and tools and more advanced mechanical repair skills.

D.4 Types of water supply facilities commended and constructed by the RDWSSP

Based on the preliminary findings of investigations carried out between 1980 and 1984 (Ref.11, 12, and 13) and taking into account the options explained in the previous sections , during the first years of the RDWSSP's implementation programme (1985 and 1986), the activities were focused mainly on the construction of hand dug wells and boreholes fitted with handpumps, for rural communities.
Comprehensive surveys into the water supply and socio-economic conditions of Kisumu District, carried out between 1986 and 1987 confirmed the rightness of this choice.
The inventory of water resources moreover showed the existence of a number of traditional sources with a potential for improvement into safe and reliable water points, in particular wells, springs and some roof catchments.
Because of the proven extremely poor bacteriological water quality, the improvement of all other types of existing surface water sources is not commended.

Where the population density is high, e.g. at well developed service centres in the rural areas, small scale piped schemes are considered.
A pre-requisite will be a full commitment by the respective community to be responsible for operation and maintenance.

Summarizing, the types of water supply facilities commended and constructed by the RDWSSP in Kisumu District today, arranged in order of increasing construction costs include:

Improvement of existing water supply facilities

- improvement of springs
- improvement of roof catchments
- improvement of hand dug wells
- improvement and/or extension of piped supplies.

Construction of new water supply facilities

- hand dug wells fitted with handpumps
- roof catchment systems
- boreholes fitted with handpumps
- small scale piped supplies.

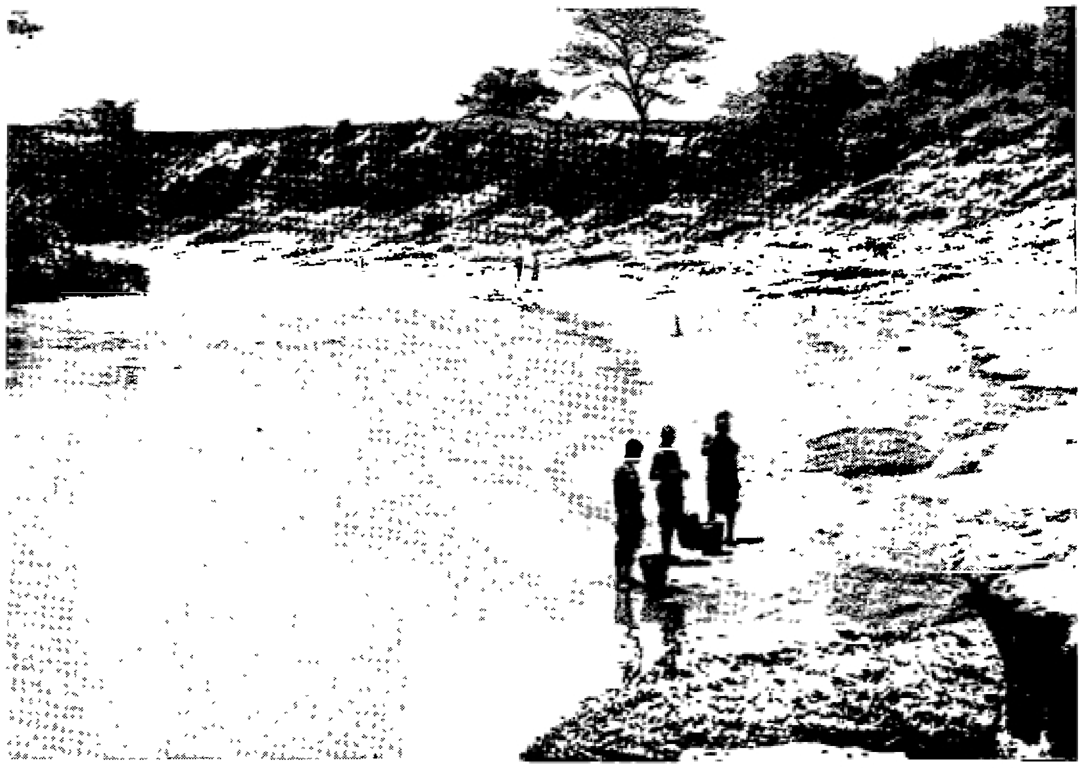
D.5 Possibilities for upgrading of the water supply facilities constructed under the RDWSSP

If financial and institutional resources are available to support operation and maintenance, in certain cases it may be both practical and economical to upgrade the facility to a higher level of service.
Communities or institutions who have the desire and means to sustain a higher level of water supply facility for instance in the future could switch from manual pumping to electrical pumping into a storage reservoir from which water is distributed to standpipes.
Out of the various types of water supply facilities mentioned above it is mainly boreholes which can be suitable water sources for upgraded supplies.
The other types of water supply facilities, i.e. hand dug wells, springs and roof catchments normally do not allow for an upgrading, simply because their yields are to low for motorized pumping.

All boreholes drilled under the RDWSSP are designed to give a maximum yield from the aquifer(s) struck and a long lasting life. Moreover, the boreholes are tested for their yield/drawdown performance from which the maximum pumping capacity is deduced, a figure required when motorized pumping is considered (section 12.5.3).

In section D.3 it has been argued that a reliable supply of electricity offers the best possibilities for the sustainability of upgraded systems, followed by renewal energy.
The use of diesel as an energy source is not recommended.

Piped supply using electricity as energy source



Water collection along River Nyando

Drilling of a deep well

E WATER SUPPLY STRATEGY

E.1 Improvements aimed for

The primary aim of the RDWSSP is:
to provide safe water, easily accessible in quantities adequate for drinking, food preparation and personal hygiene, at a cost in keeping with the economic level of the communities and through facilities which can be operated, managed and sustained by the beneficiaries.

Benefits arising from improved community water supply may include:

- reduction in the time and energy required to collect water, thus creating resources which could be spent on alternative productive activities

- better living conditions through the easy availability of sufficient water for washing and bathing

- better health through the provision of safe water.

The relative importance of these major benefits depends on the types of facilities constructed and the local water supply situation.

For instance, in areas with a relatively high density of existing perennial water sources, such as the north of Maseno Division, parts of the Kano Plain and the Nyabondo area in Nyakach Division, the improvement of traditional water sources or even the creation of new water points may not much affect the walking distances to the sources although higher yields might reduce waiting time at the sources.

In areas with mainly seasonal water sources such as the southern and eastern parts of Nyando Division and the west of Maseno Division, the construction of new water facilities usually will reduce walking distances for the consumers from the communities, privileged with new facilities. It should be realized however that in such areas a large number of new facilities will have to be implemented before the overall water supply situation can be considered improved and average walking distances have been sufficiently reduced.

Considering the above, it appears that in Kisumu District the initial benefit obtained from improvement and construction of water supply facilities is the provision of uncontaminated, safe water.

Full benefits of improved health conditions through the provision of safe water however depend also on additional inputs such as sanitation improvements and hygiene education, for which the need is stressed once more again here.

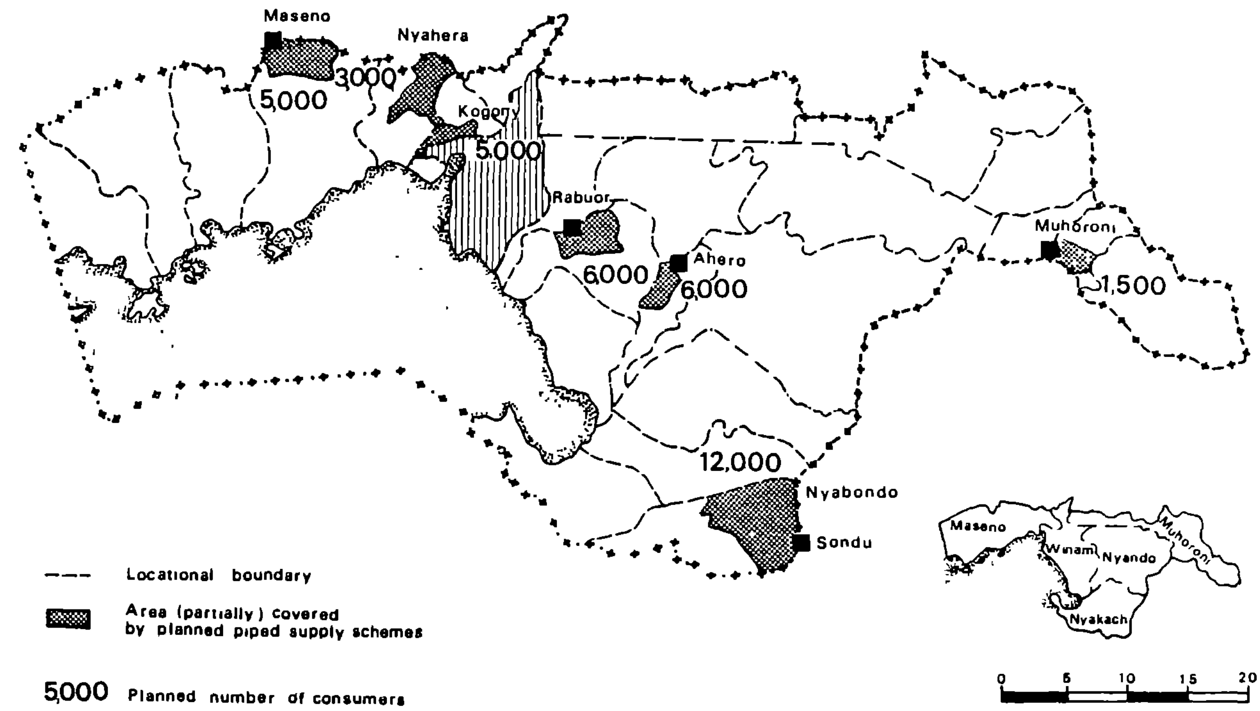


Fig. E.1. Planned piped supply schemes

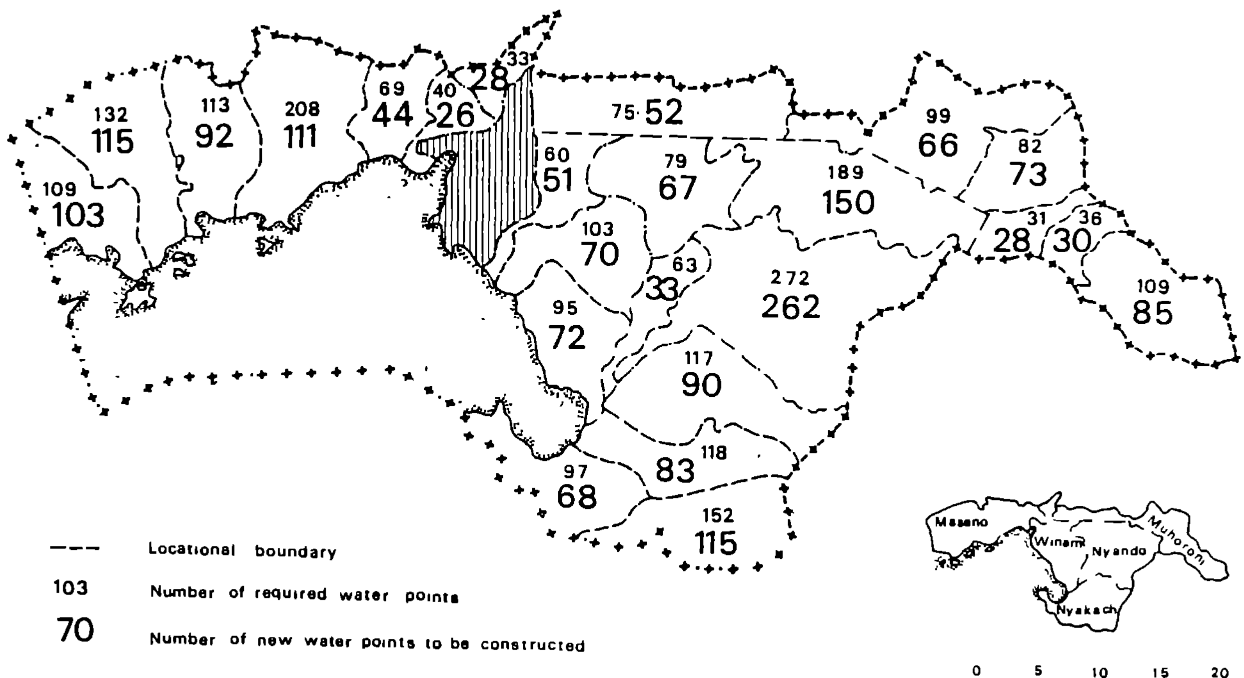


Fig. E 2. Number of required points sources (based on 1987 situation)

E.2 Piped water schemes

Currently, nearly 53,000 or around 50% of all piped water consumers dispose over safe and reliable piped water.
According to the District Engineers' office it is assumed that the Nyakach water supply will serve around 20,000 more people adequately in a few months time. Moreover employees of the Miwani sugar mills and their families, around 4,500 people, will receive good water when the factory will be reopened.

Although Kisumu District is generally considered as rural area, in some regions people have started to live concentrated in and around rural centers. Here the population densities become very high, which would necessitate a large density of point sources if this option was chosen for. Taking into account the present developments of urbanization in these rural areas, it has been decided to supply the consumers here with piped water.

Since piped water schemes in rural are very vulnerable, a good technical and direct financial management is a prerequisite to maintain a reliable system. For this reason simple systems are proposed to serve up to 6,000 people, and is determined by the number of people who can easily be supplied by a system serving a limited area.

Further application of piped water schemes is proposed for the areas shown in Figure E.1, the following list indicates the size of each system.

1. Ahero: new system for 6,000 consumers
2. Muhoroni: extension of the existing system for 1,500 consumers in accordance with the proposal of M.o.W.D.
3. Rabuor: new system for 6,000 consumers
4. Nyahera: rehabilitation of the existing system or construction of a new one for 3,000 consumers.
5. Maseno: extension of the existing system for 5,000 consumers.
6. Nyabondo Plateau: rehabilitation and enlargement of the existing system or new systems to serve 12,000 consumers.

E.3 Point sources

E.3.1 Average number of consumers of point sources

For planning purposes it is important to have an understanding of the number of consumers that can make use of a single water point. Therefore assessments are made for the three types of constructed and improved point sources, using as much as possible the experiences gained in Nyanza Province. The assumed water consumption per head is 30 l/c/d.

Table E.1 Numbers of required, potential and new to construct water points per Location.

	<------- CRITERION 1 -------> 250 consumers per water point		<------ CRITERION 2 ------> 500 m walking distance		DECISIVE NUMBER OF REQUIRED WATER POINTS:	POTENTIAL EXISTING <----- WATER POINTS ---->			NUMBER OF NEW WATER POINTS TO BE CONSTRUCTED:
	No. of consumers to be served:*	required No. of wtp:	Surface to be served (km2):*	required No. of wtp:		Good	recommended for improvement	Total	
West Seme	20,456	82	83	106	109	0	6	6	103
Central Seme	31,333	125	98	124	132	0	17	17	115
East Seme	26,028	104	81	104	113	0	21	21	92
West Kisumu	51,026	204	123	157	208	42	57	99	111
Central Kisumu	17,329	69	39	50	69	7	18	25	44
East Kisumu	9,306	37	22	28	40	1	13	14	26
MASENO DIVISION:	155,478	622	447	570	671	50	132	182	491
Kajulu	4,733	19	25	32	33	0	5	5	28
Koiwa	10,490	42	47	60	60	2	7	9	51
North West Kano	20,162	81	67	85	103	11	22	33	70
South West Kano	11,717	47	74	94	95	18	5	23	72
WINAM DIVISION:	47,102	188	213	271	291	31	39	70	221
Miwani	10,777	43	53	67	75	6	17	23	52
Chemelil Location	17,072	68	76	97	99	73	5	78	66
Tamu	10,261	41	64	82	82	2	7	9	73
West Muhoroni	2,894	12	24	31	31	3	0	3	28
East Muhoroni	5,886	24	28	36	36	4	2	6	30
Koru	13,018	52	86	109	109	24	1	25	85
MUHORONI DIVISION:	59,908	240	331	422	432	112	32	144	334
Lower North East Kano	14,077	56	61	78	79	6	6	12	67
North East Kano	33,263	133	139	177	189	17	22	39	150
South East Kano	15,614	62	29	37	63	13	17	30	33
East Kano	40,276	161	214	272	272	0	10	10	262
NYANDO DIVISION:	103,230	413	443	564	603	36	55	91	512
North Nyakach	14,970	60	88	112	117	17	10	27	90
Central Nyakach	16,810	67	93	118	118	17	18	35	83
West Nyakach	9,451	38	76	97	97	7	22	29	68
South Nyakach	34,444	138	91	116	152	4	33	37	115
NYAKACH DIVISION:	75,675	303	348	443	484	45	83	128	356
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KISUMU DISTRICT:	441,393	1,766	1,782	2,270	2,481	274	341	615	1,914

* SEE SECTION E.3.3

Hand dug wells

The yield of wells depends on the discharge of ground water to the well and the capacity of the pump. The consumption pattern at many operational hand dug wells is found to take place during two periods of four hours per day in the morning and the afternoon. During these periods the water quantity which is stored sometimes is completely used. Since the storage in a well is approximately three cubic meters, the yield amounts 6,000 l/day.
The average SWN hand pump with a two inch cylinder in most cases, has a capacity of about one cubic meter/hr.This limits the output to 8,000 l/day.
Assuming a consumption of 30 l/c/d it can be deducted that a hand dug well can serve 200 to 250 consumers.

Boreholes

The experience has learned that the yield of borehole with handpump is not a limiting factor. Its water potential exceeds the capacity of the pump which can be used throughout the day. Since hand pumps used for boreholes are basically similar to those for wells, the number of consumers is limited to around 250 consumers.

Springs

The yield of springs varies considerably; from a few to a few hundreds of liters per minute. As shown in chapter 6, it has been found that the number of consumers per spring, varies from 50 to 400. Nearly all springs in Kisumu District are shallow well type springs which need a similar investment for improvement as wells. Therefore only springs serving more then 100 consumers are recommended for improvement.

Conclusion

Since most of the constructed water points in Kisumu District will either be hand dug wells or boreholes, an average number of 250 consumers per water point is used for the required number of water points assessment.

E.3.2 Design criteria

In the RDWSSP the following two basic criteria have been developed for the design of rural domestic water supply. They are used for the determination of the minimum number of water points required per Sub-location to obtain a basic water supply level. The criteria assume an uniform distribution of inhabitants over the described area.

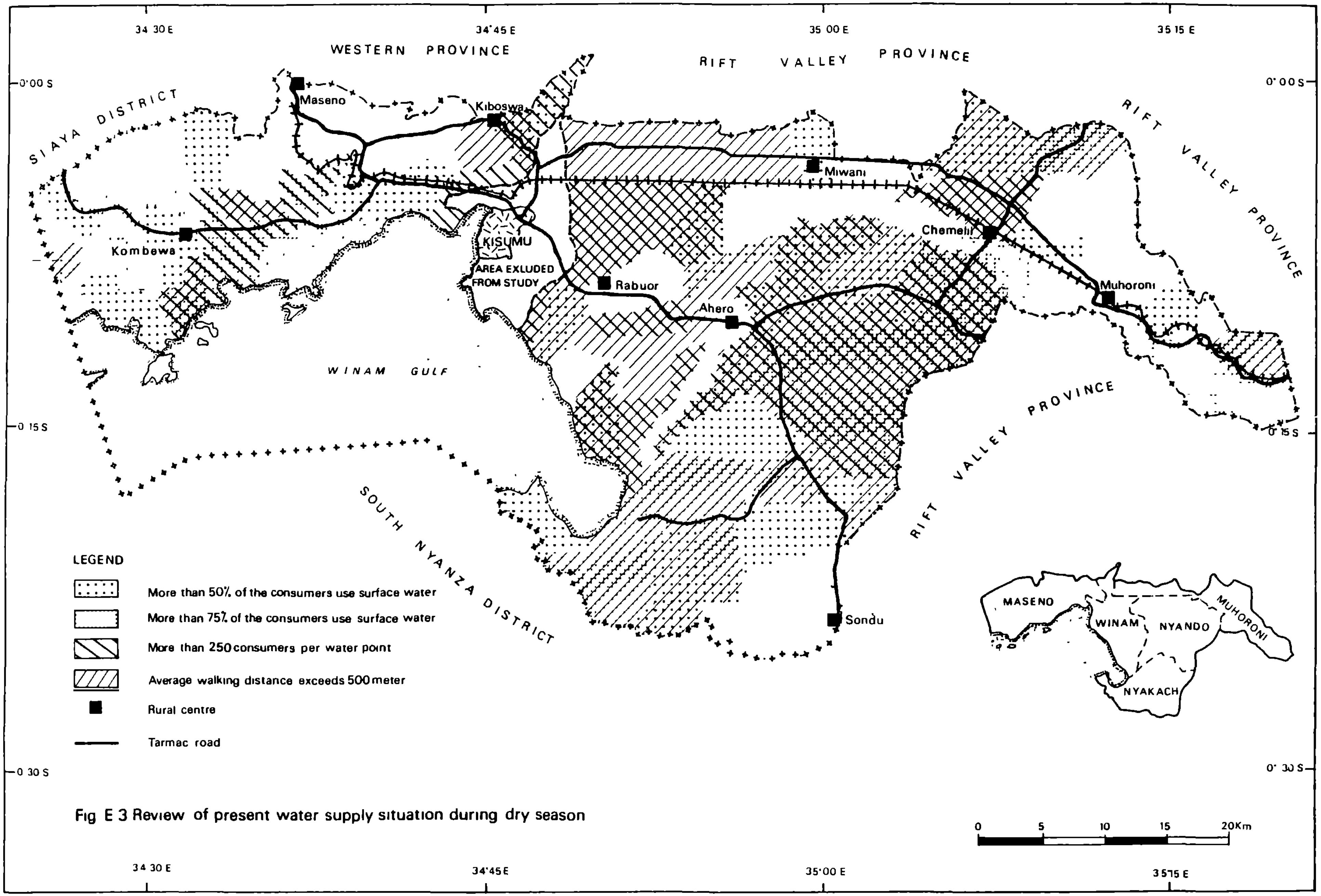


Fig E 3 Review of present water supply situation during dry season

1. In accordance with the average yield of point sources, the number of consumers per water point is limited to 250.
2. The average maximum walking distance for consumers to reach a water point should be 500 meters. Since a circular area with this radius covers 0.785 km^2, this is the maximum area to be supplied by a single water point.

Both criteria result in a minimum number of public, safe and reliable water points. The largest number however is decisive for the required number of water points.

E.3.3 Required number of point sources

Applying the above criteria to the Sub-locations in Kisumu District the required number of public safe and reliable water points has been calculated. With reference to the first criterion, it should be noticed that private consumers of existing safe and reliable piped water schemes, all consumers of planned schemes and present users of good private water points have been deducted. To calculate a realistic number of water points, virtually uninhabited areas as e.g. the large sugar cane areas have been deducted for the second criterion.

In accordance with the two criteria the required number of water points has been calcultated seperately on Sub-locational level, which is done to make optimal use of the available information.
The result of addition of the required number of water points per Sub-location per criterion is shown in column three and five of Table E.1.
The decisive number of water points per Sub-location were added for each Location, and are presented in column six of the same table.
The fact that the decisive number of water points per Location in many cases exceeds the numbers in the previous colums is caused by the calculations on Sub-locational level.
Also the discrapancy between new water points and the required minus potential water points is caused by this reason.

<u>Potential point sources</u>

Not all required water points have to be newly constructed. From the inventory survey as described in chapter 6, it is known that 274 existing public water points, shown in column seven of Table E.1, in Kisumu District provide safe and reliable water, while another 341 can be improved (column eight). So approximately 600 potential water points can be deducted from the number of required water points to give the number of required new water points in the District.

<u>Required number of new points sources</u>

In Figure E.2 and Table E.1, the required number and the number of new to be constructed water points are depicted per Location. In accordance with the criteria, altogether 1,914 new water points have to be created in the District, based on 1987 figures.

E.4 Priority areas within the District

Priority areas have been determined on Sub-locational level utilizing three characteristics of domestic water use; the type of source used, average number of consumers per water point and the average walking distance. For these three characteristics the dry season situation has been considered.

Surface water is usually heavily contaminated. Areas in which people depend mainly on untreated surface water (Lake Victoria, rivers, ground catchments, dams or water holes), badly need improvement of their water supply situation. Figure E.3 shows the areas in which more than 50% and more than 75% of the population make use of this source.

The second characteristic shown in Figure E.3, is the average number of consumers using a water point. If many people use the same source it will be contaminated more easily and queuing might occur. Moreover many consumers will benefit from an improved water point in a region where water points are intensively used. The figure presents areas with more than 250 consumers per water point.

In the present situation the average walking distance in some Sub-locations is considerable during the dry season. Improvement of the water supply situation in those zones does not only give people better water, but it saves them also a lot of time. In the same figure the areas with an average walking distances exceeding 500 meters is indicated.

Emerging from Figure E.3 are three main high priority areas:

- the south eastern part of Nyando Division
- west Nyakach
- the eastern part of Maseno and it's strip along the Winam Gulf.

E.5 Recommended implementation strategy in priority areas

Areas deserving consideration in priority for the implementation of water points are found mainly in Nyando Division, the west of Nyakach Division and the east of Maseno Division.

Taking into account the relatively low density of water sources in these areas and the aims and development strategy recommended by the RDWSSP, than to really have a positive impact on the situation, the construction of approximately 350-500 mainly new point sources is required per Division at present.

The RDWSSP's implementation programme initially foresees in the construction of not more than 50 point sources per Division, which appears to be only about 13 % of the number of point sources required today.

This makes it clear that additional major efforts are necessary and it is one of the tasks of the LBDA to attract other donors, programmes and projects, for the implementation of additional water points.

It is commanded that such projects closely follow the strategy developed by the RDWSSP. Depending on the size of such programmes or projects and the funds available, their implementation efforts should preferably be concentrated on a smaller area within the District as for instance a Division, a number of Locations, or even Sub-locations. This, in order to reach the required density of safe and reliable water sources in these areas.

Because technically the improvement of existing water sources as springs, dug wells and roof catchments is not only less costly but also simpler than the construction of new boreholes and wells, which also partly need to be surveyed by means of geophysics, projects with less technical know-how and financial resources might want to choose for these implementation options. In such cases it is commanded that such projects or programmes operate mainly within Maseno Division and parts of Nyando Division where a relatively large number of existing springs and wells were found, suitably for upgrading to safe and reliable water sources.

Possibilities of the implementation of water points within the District are given in Chapter F.

TABLE F.1 SUMMARY OF RURAL DOMESTIC WATER SUPPLY DEVELOPMENT PLAN PER LOCATION (based on 1987 water demand)

LOCATION	IMPROVEMENT OF EXISTING WATER SOURCES					CONSTRUCTION OF NEW WATER SOURCES	
	Wells	Springs	Roof catchments	Boreholes	Piped supply taps	Hand dug wells	Boreholes
W. Seme	2	4				85	18
C. Seme	8	9				73	42
E. Seme	5	16				58	34
W. Kisumu	13	44				79	32
C. Kisumu	7	11				20	24
E. Kisumu	2	11					26
MASENO DIVISION	37	95				315	176
Kajulu		5					28
Kolwa	7						51
N.W. Kano	21		1				70
S.W. Kano	5						32
WINAM DIVISION	33	5	1				221
Miwani	2	1		3	11		52
Chemelil Location	1	1		3			66
Tamu	1	4	2				73
W. Muhoroni							28
E. Muhoroni		2					30
Koru	1					30	55
MUHORONI DIVISION	5	8	2	6	11	30	304
Lower N.E. Kano	6						67
N.E. Kano	20		1	1			150
S.E. Kano	15			2			33
E. Kano	7	2	1				262
NYANDO DIVISION	48	2	2	3			512
N. Nyakach	1		2		7		90
C. Nyakach	1	2			15		83
W. Nyakach		6			16	20	48
S. Nyakach	5	10	6		12	100	15
NYAKACH DIVISION	7	18	8		50	120	236
KISUMU DISTRICT:	135	118	13	9	61	465	1,449

F IMPLEMENTATION OF WATER SOURCES

F.1 Introduction

In order to improve the water supply situation in Kisumu District, after taking into account all options and conditions, the following types of constructions are recommended.

Improvement of existing water supply facilities:

- improvement of springs
- improvement of hand dug wells
- improvement of roof catchments
- improvement of boreholes
- improvement of piped supplies.

Construction of new water supply facilities:

- hand dug wells with hand pumps
- machine drilled boreholes with hand pumps
- piped water schemes.

In chapters D and E the choice for these types of facilities was fully explained. All other types of water sources are not to be considered for improvement or construction for rural domestic purposes.

In the following sections a brief explanation is given on the feasibility of these water supply facilities in Kisumu District and the kinds of construction activities involved.

The water development possibilities given in this report are mainly on Locational basis. For planning and design on Sub-locational basis more detailed and comprehensive information on water development opportunities can be found in the Divisional Reports.

F.2 Improvement of existing water supply facilities

The improvement of existing water sources has some advantages over construction of new point sources.

- No additional survey is necessary to locate the water sources.
- Construction costs are less than for the implementation of similar new constructions.
- Communities are already used to draw water from these sources and one may find concentrations of inhabitation around such sources, so that walking distances can remain short.

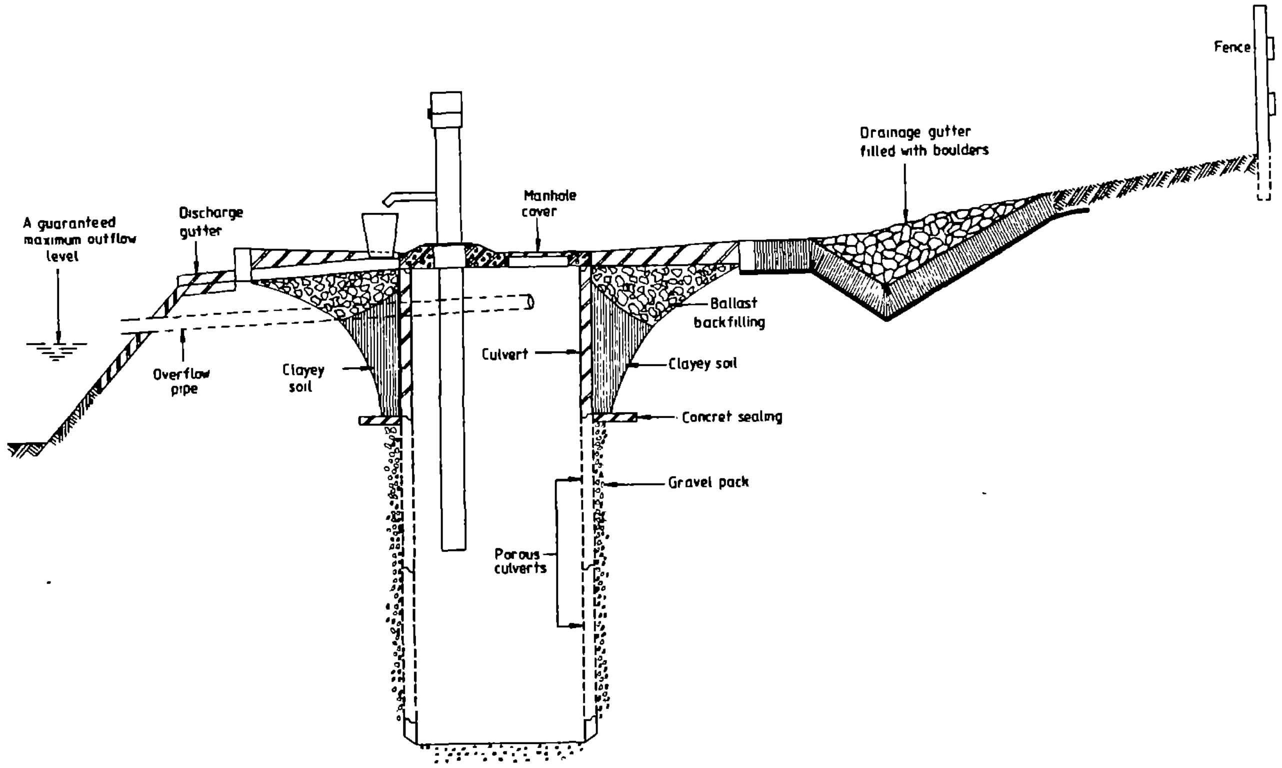
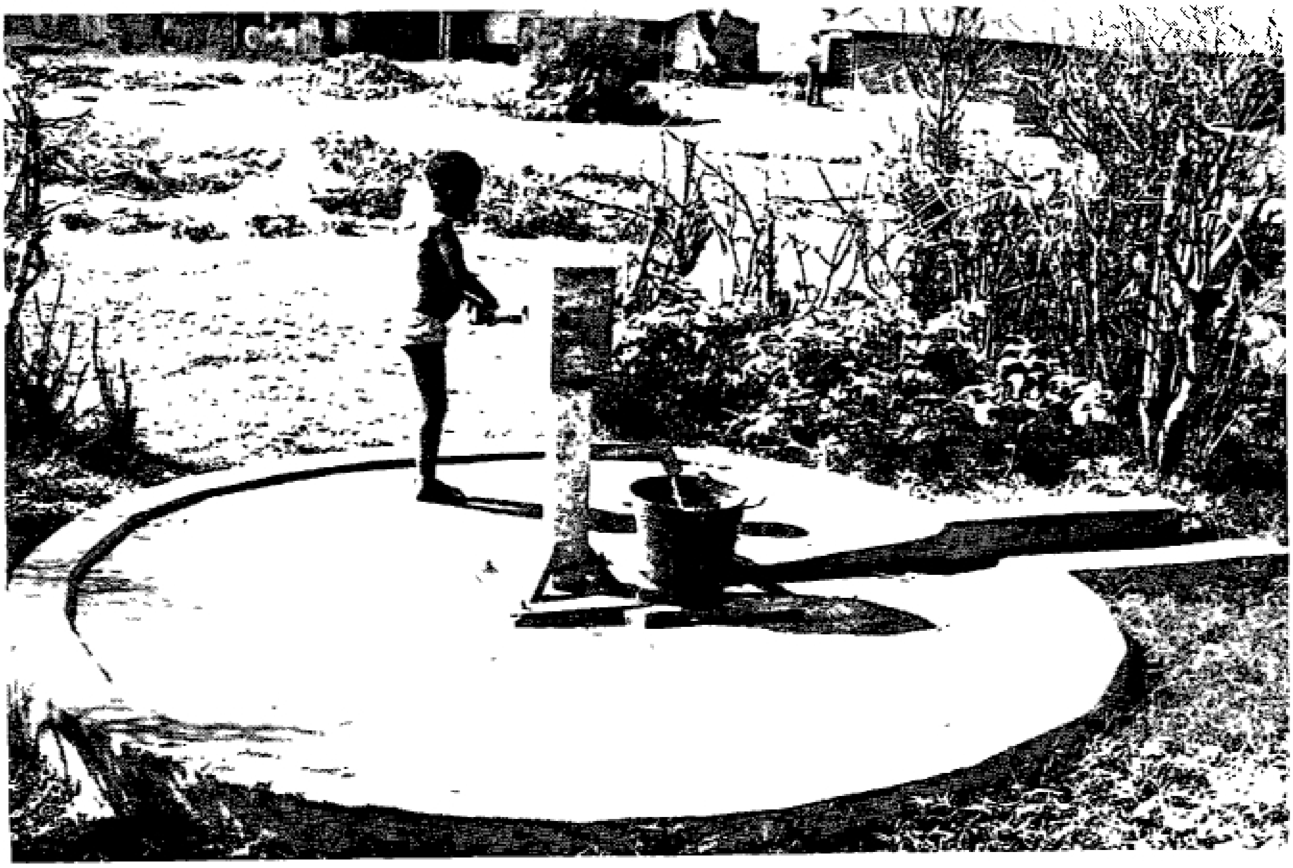


Figure F 1 Design of a well-type spring protection



Existing point sources recommended for improvement include springs, communal wells, boreholes and roof catchments.

Table F.1 summarizes the findings and recommendations on the possibilities for improvement of existing water supply facilities as given in the Division Reports (Ref.13). It appears that within Kisumu District, a total of 336 point sources could be improved, which comes to about 14 % of all water points required at present.

Relatively large numbers of point sources suitable for upgrading are found in Maseno (132), only few point sources suitable for improvement occur in the other Divisions:Nyando (55), Winam (39), Nyakach (33) and Muhuroni (21).

The majority of the facilities recommended for improvement are wells (135), followed by springs (118).

F.2.1 Improvement of springs

A total number of 118 springs are planned to be rehabilitated; most of them in Maseno Division. In Kisumu District mainly well type springs occur and only a few gravity type springs.

Improvement of well type springs

Springs situated in locations with insufficient gradient for a gravity type of protection, can be protected by construction of a shallow well, fitted with a hand pump upslope of the spring, as depicted in Figure F.1.

The construction works include:

- digging of an approximately 3 m deep well with a concrete lining
- construction of a covering concrete superstructure with overflow
- installation of a handpump
- drainage works
- fencing.

The costs for this type of improved spring may amount to between KSh. 30,000/= and KSh. 40,000/= (1987 price level).

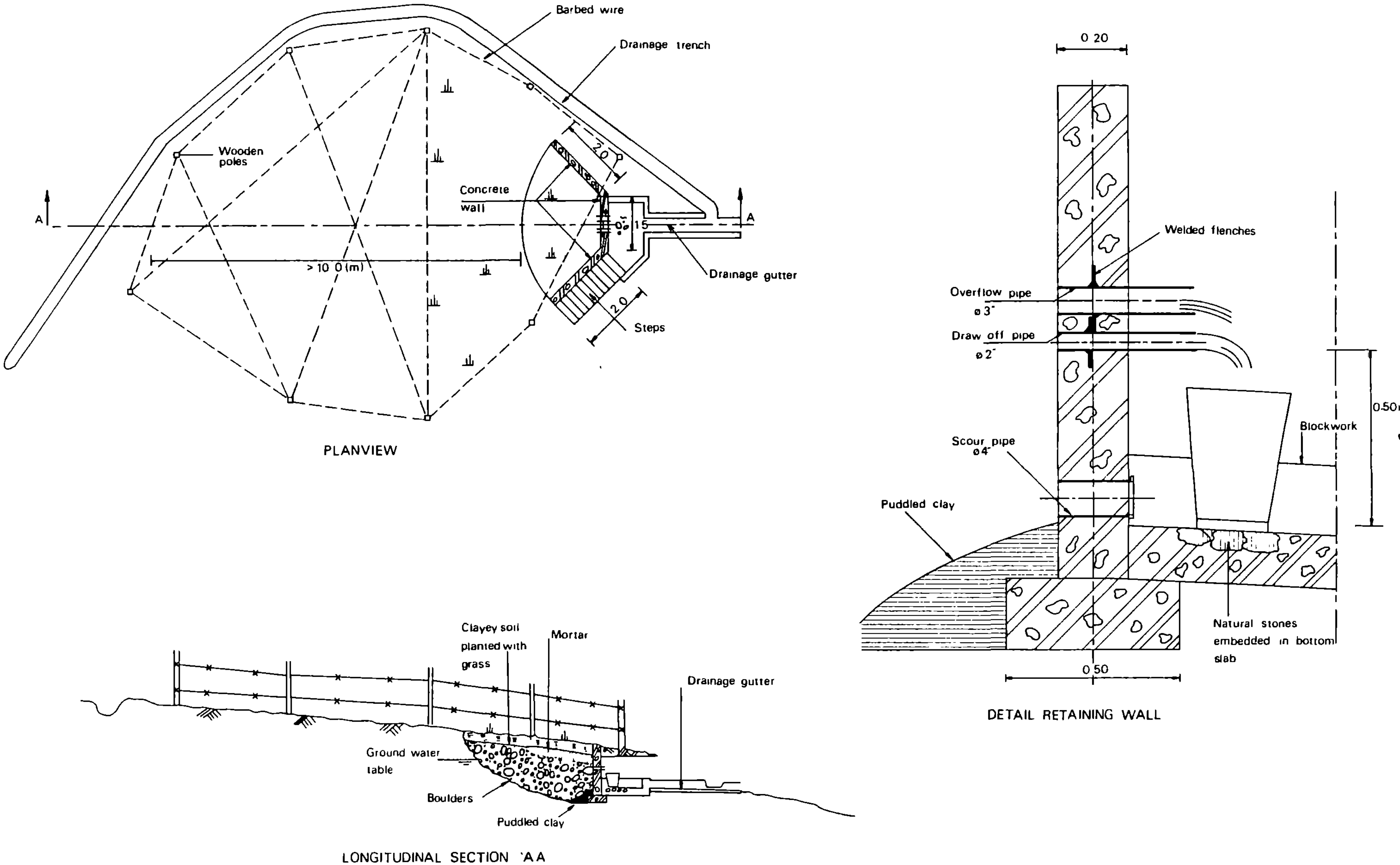


Figure F.2 SPRING PROTECTION RDWSSP.
GOOD DRAINAGE OPPORTUNITIES

Improvement of gravity springs

This type of construction is the relatively simplest and least costly of all options and can be applied to springs at places with sufficient topographical gradient to make gravity flow possible. Normally the improvement activities will include:

- drainage works around the spring
- opening of the spring
- back filling and covering of the spring
- construction of a concrete protection wall with an overflow and spillway
- fencing of the immediate surroundings or the upstream catchment area.

The construction costs of a gravity type protection depend mainly on the size and maximum discharge of the spring and will be between K Shs.15,000/= and K Sh.25,000/= (1987 price level).
A design of this type of improved spring is presented in Figure F.2.

F.2.2 Improvement of hand dug wells

In Kisumu District a total of 135 existing hand dug wells satisfy the technical criteria which render them suitable for improvement. All of these are communal water points. Most wells recommended for improvement are found in Nyando (48), Maseno (37) and Winam Division (33).

Construction works required to upgrade the existing dug wells include:

- deepening of 2-3 m
- construction of a top lining or full lining
- installation of a handpump
- fencing.

The total costs for improvement of wells depend on their depth and the length of lining required and may vary between K Sh.45,000/= and K Sh 70,000/= (1987 price level).

F.2.3 Improvement of roof catchments

In Kisumu a total of 13 roof catchments were found suitable for rehabilitation on technical grounds, of which 8 were found in Nyakach Division.

Rehabilitation works will include:

- repair or replacement of gutters
- improvement of the connection pipes between gutter system and storage tank
- repair and protection of the storage reservoir
- construction of additional storage capacity.

F.2.4 Improvement of boreholes

Altogether 9 boreholes are recommended for rehabilitation. Rehabilitation works consist in the renewal of the slab and/or repair or replacement of the handpump. Some boreholes need to be cleaned also.

F.2.5 Improvement of piped water points

All piped water points suggested for improvement belong to the Miwani Sugar Mills Water Supply and Nyakach Water Supply. At the reopening of the Sugar Mill the Water supply is assumed to restart operation. Construction of the planned (communal) water points of the Nyakach system is expected to be completed during 1988. As presented in chapter E, three existing piped water schemes are proposed to be extended. These are:

- Muhoroni water supply, 1,500 consumers
- Maseno water supply, 5,000 consumers
- Nyabondo (Nyakach) water supply, 12,000 consumers.

Designs for these works fall outside the scope of the present study.

F.3 Construction of new point sources

Because of the poor water quality of the surface water resources, all new water points to be constructed in Kisumu District should make use of ground water exclusively.
Also any new to be constructed piped water supply should be designed to use ground water.
This is possible because ground water resources in the District many times exceed the present and future water demand.

F.3.1 Development of shallow ground water

In general the development of shallow ground water is considered more attractive than the development of deeper ground water because the construction of dug wells is simpler and cheaper than for boreholes.
Dug well construction also may involve more community involvement.

In many areas in Kisumu District however, the quality of the shallow ground water is poor to such extend that its use can endanger human health.
Pollutants are human, animal, agricultural and even industrial wastes.

Therefore, development of shallow ground water should be restricted only to those areas where:

- the population density is low
- there is no use of fertilizers, pesticides,herbicides, insecticides
- there are no other forms of pollution.

In the rural domestic water supply plan summarized in Table F.1 the maximum number of dug wells to be used to satisfy the present water demand is shown to be 465.

Areas where dug wells can be constructed

In Kisumu District the areas where dug wells can be safe and reliable water points are limited to the following regions:

- the west and south-east of Maseno Division (in particular West, Central and East Seme Locations and West Kisumu Location)

- the east of Muhuroni Division (Koru Location)

- the Nyabondo Plateau in Nyakach Division (mainly south Nyakach Location).

Shallow ground water development in the last mentioned area, the Nyabondo Plateau, is not without risk because the area is densily populated.
Everywhere, but in this area in particular, well sites and depth will have to be choosen carefully, taking into account all local conditions influencing the water quality.

Geophysical siting for well locations is not considered necessary but within the three areas indicated as suitable for dug well construction, potential well locations will be restricted to the topographically lower areas such as valleys, intermountaineous flats, foot slopes etc.
Concentrations of inhabitation, schools, institutes, missions are usually found in topographically elevated areas and consequently it is in those areas where wells often are preferred but at the same time difficult to construct.

Well depth and design

The depth of hand dug wells depends mainly on local conditions but generally will be between 15 and 20 m.
It is recommended to make dug wells as deep as possible into the aquifer and to provide them with a full lining and sealed cover since this will prevent seepage of possibly polluted or contaminated surface water to enter the well.
A pervious lining should be installed only in the bottom few meters of the wells.

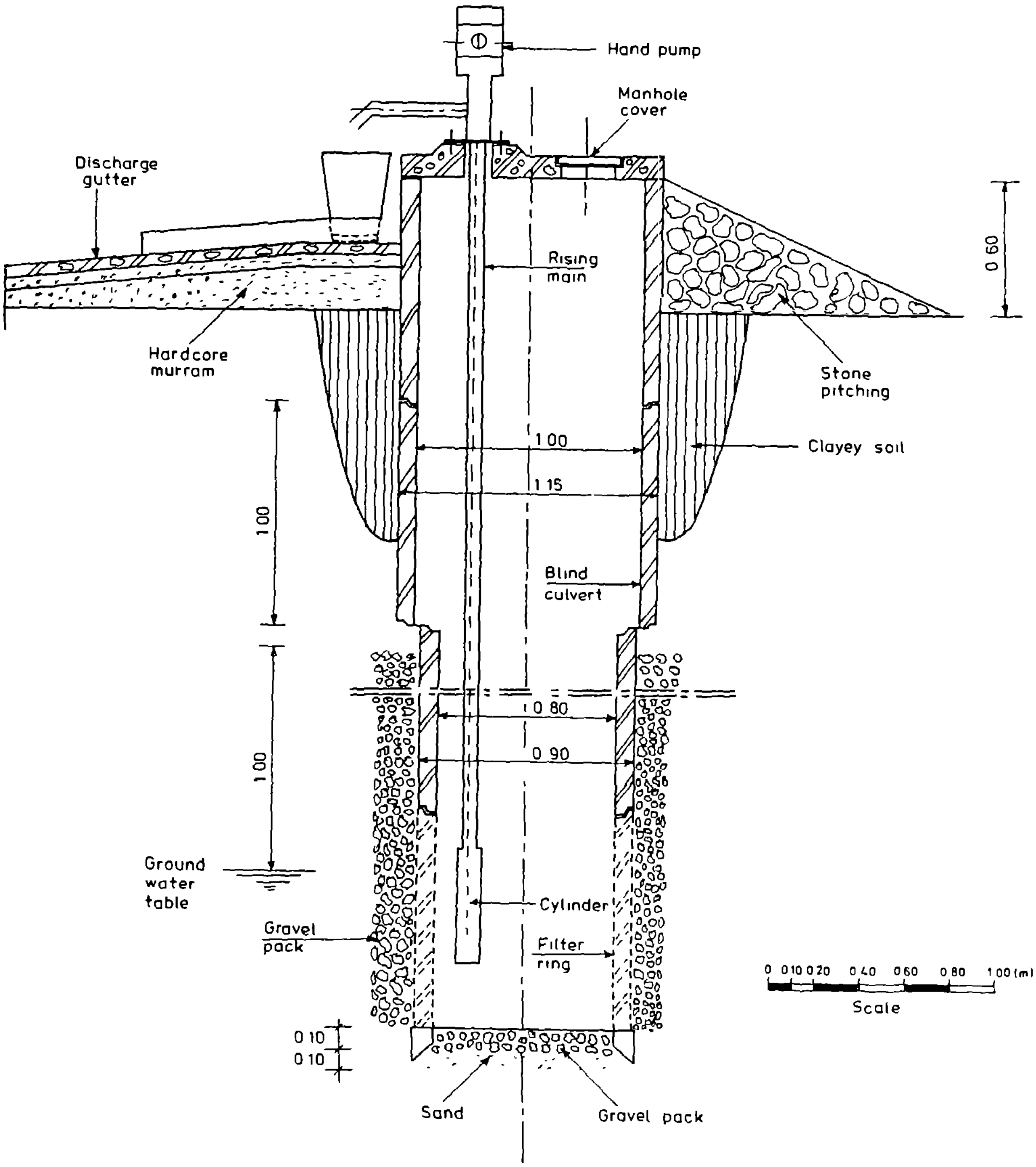


Figure F.3 Hand dug well RDWSSP

Sufficient well depth and a proper design is critical in particular on the Nyabondo Plateau.
Existing wells which often are contaminated are only 5-10 m deep.
Where possible new wells should be made as deep as 20-25 m.
Particulars on well design and construction are given in chapter 15.
The total construction costs for a fully lined well may range from about KSh. 55,000/= for a 10 m depth well, to KSh. 85,000/= for a 20 m depth well.

Well yield

The yield of hand dug wells depends on the type of a aquifer, on the depth of the well and the seasonal ground water table fluctuations which may amount to 1-5 m. Low yields and seasonal wells can be avoided by bringing the wells to a depth of at least 3 m below the lowest dry season water table. If this can be accomplished than most hand dug wells will be able to provide the required 7.5 m^3/day (250 people a 30 l/c/d).

F.3.2 Development of deeper ground water

In Kisumu District the exploitation of deeper ground water by means of machine drilled boreholes is the most suitable and often the only feasible way to improve the rural domestic water supply situation.
Deeper ground water was found to be of a good quality and its overall potential can satisfy the water demand at least for the next twenty years or beyond.

The relatively high construction costs of boreholes which are two to three times the costs for a dug well, are counter balanced by some advantages boreholes offer such as:

- safe and reliable sources
- long life time
- a relatively high yield which allows for future motorized pumping also.

In the presented water supply plan (Table F.1) the construction of 1,449 boreholes is recommended.

Areas where boreholes can be constructed

Boreholes can be constructed successfully almost everywhere in the District.
In the Kano Plain where the chances for productive boreholes are almost 100 % there is no need for geophysical borehole siting.
Elsewhere in the District these chances are estimated to be 75 %, provided that thorough geophysical surveys are carried out to determine borehole locations.

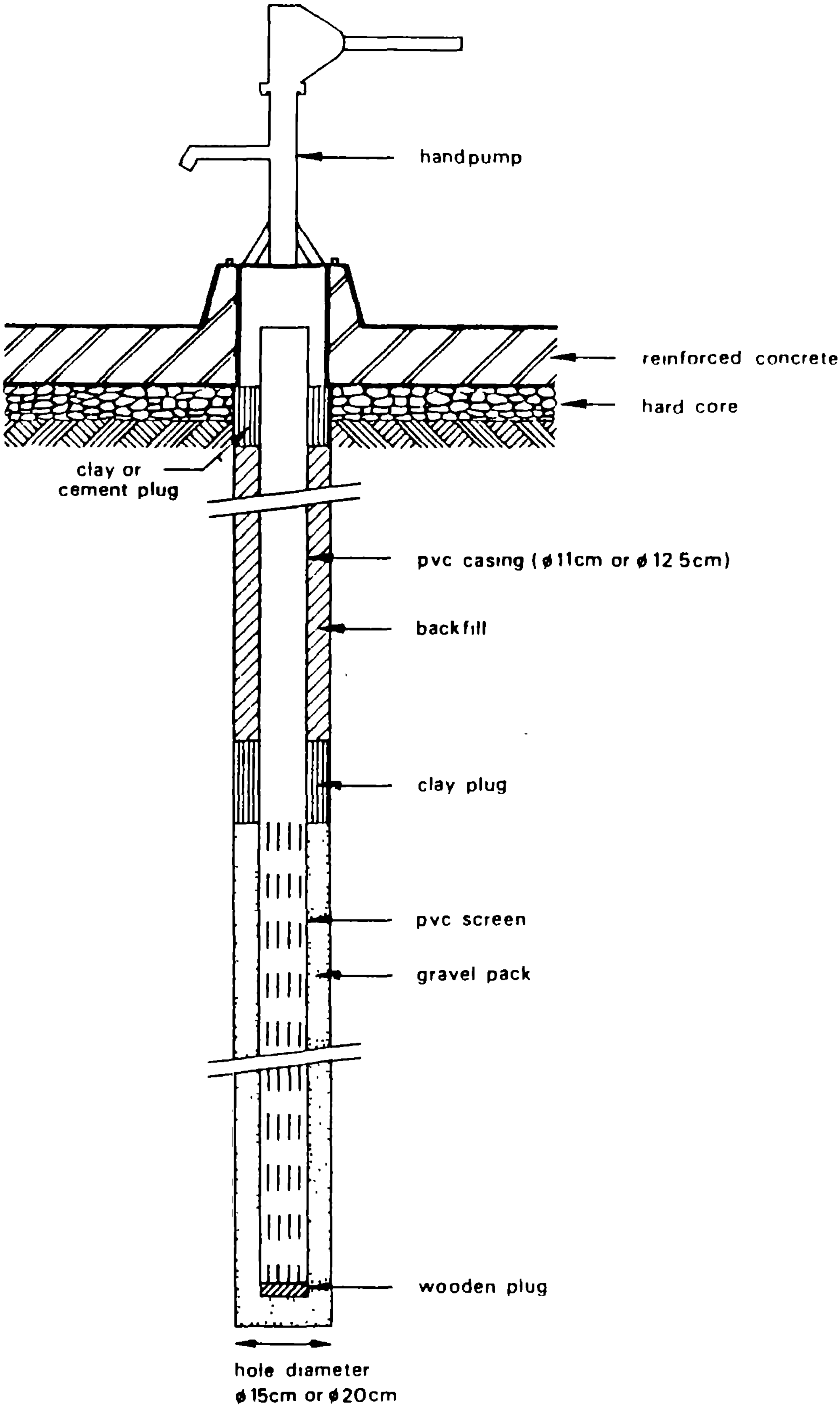


Figure F.4 Design of a borehole fitted with a hand pump

Additional advantages obtained through geophysical survey are higher well yields and the reduction of drilling costs.

Borehole depth and design

The required borehole depth in most parts of the District is between 50 and 80 m.
In some areas of the Kano Plain 40 m deep boreholes can be sufficient, while in other areas in particular in the higher elevated eastern part of the District, boreholes as deep as 100-120 m may be required occassionally.
For planning purposes an overall average depth of 70 m can be used.
Particulars and details on borehole drilling, testing and completion are given in chapter 15.
Total construction costs of a borehole fitted with a hand pump may range from KSh 125,000/= for a 60 m depth borehole to KSh.162,000/= for a 100 m depth borehole.

Borehole yield

For abstraction of water from a borehole by means of a hand pump, a yield of approximately 1.5 m^3/hr is sufficient for a 3 inch cylinder, and 0.6 m^3/hr for a 2 inch cylinder.
The yields of the boreholes constructed by the RDWSSP show a large variation, from occassionally less than 1 m^3/hr to a calculated maximum yield that varies considerably from one area to another and is related in the first place to the type of aquifer (rock type) and secondly to the annual rainfall.
In the Kano Plain, yields may range from 2 to 40 m^3/hr and are 14 m^3/hr on an average.
Elsewhere average yields vary from 2 m^3/hr in the drier areas to 15 m^3/hr in higher rainfall areas.

F.4 Design criteria for roof catchment systems

The construction of new roof catchment systems is not incorporated in the present water supply plan since the construction costs of the storage tanks and the maintenance of these systems are high in comparison with the yield.

In some circumstances however one might find special reasons to choose for a roof catchment system. To facilitate the design of roof catchment systems, the results are presented of the simulation process of the storage in an imaginary tank, using rainfall series as recorded at several stations in the District. For this simulation process a computer program has been used which was developed within the RDWSSP.
This program recorded the maximum yield of the system (which is the annual rainfall divided by 365 days) and the maximum volume of stored water.
It will be clear that the storage volume depends mainly on the distribution of rainfall over the year.

Table F.2 presents the rain gauging stations' codes (the stations are described in chapter 14), the years of available records, the minimum maximum yield and the largest stored volume over the years of records. It appears that in Kisumu District daily two to three liters water can be obtained per m^2 of roof surface. The required storage capacity amounts 0.4 to 0.5 m^3 per m^2 roof.

TABLE F.2 SIMULATED YIELD AND REQUIRED STORAGE CAPACITY PER M^2 OF ROOF SURFACE

STATION CODE*	YEAR OF RECORDS	MISSING YEARS	MINIMUM. MAX. YIELD (LITERS/DAY)	REQUIRED STORAGE (M^3)
90 34 008	1931-1985	8	2.9	0.43
90 34 086	1962-1985	4	2.3	0.23
90 35 046	1971-1985	N.A	2.9	0.47
90 35 142	1961-1983	2	2.4	0.53
90 35 148	1962-1985	3	2.0	0.48
90 35 220	1963-1985	N.A	2.9	0.50
90 35 258	1964-1985	5	2.4	0.41
90 35 274	1961-1985	5	2.3	0.46

*FOR STATION NAMES REFERENCE IS MADE TO CHAPTER 14

F.5 Piped water schemes

F.5.1 Construction of new schemes

Some parts of Kisumu District are so densely populated that the number of new water points to be constructed to fulfil the 250 consumers per water point criterion is considerable. It was found that in such areas, the construction of medium size, simple piped water schemes may be similar or even less than the construction costs for boreholes as point sources. Hence, in some urban and urban fringe areas in Kisumu District new piped water schemes are recommended.

Since existing schemes using diesel fuel appeared to be difficult to operate (Chapter 6), new schemes can only be established in electrified areas. To have an easy manageable system with short distribution lines, it's number of consumers should be limited to 5,000 or 6,000. And to prevent costly and difficult treatment, boreholes should be chosen as water sources. Generally one borehole will be sufficient.

To come to a price indication a tentative budget is shown for a system which serves 5,000 consumers by means of 240 private metered taps and 10 water kiosks. The prices are mainly based on KEFINCO data (1988) since RDWSSP has no experiences with the construction of piped water schemes yet.

Drilling of a borehole:	KSh. 150,000
Submersible pump: (installation costs included.)	KSh. 60,000
Storage tank $45m^3$ incl. rising main and valves	KSh. 300,000
Distribution line 7km using 3" PVC pipe:	KSh. 368,000
Branch lines 15km using 1" polyethylene:	KSh. 178,000
Excavation and back filling	
-Distribution line 0.80 m depth:	KSh. 280,000
-Branch lines 0.60 m depth:	KSh. 450,000
250 Stand pipes, water meters and taps:	KSh. 325,000
Sub-total:	KSh.2,111,000
unanticipated 10% :	KSh. 211,000
Total:	KSh.2,322,000
Design and supervision 15% :	KSh. 348,000
TOTAL:	KSh.2,700,000

The construction costs per capita turn out to be KSh 540/=, which is about similar to the per capita costs for a borehole, but still expensive compared to hand dug wells (+/- KSh. 200/= per capita).

F.5.2 Maintenance

Study of the existing piped water schemes has learned that operation and maintenance is the Achilles' heel of piped water schemes, and should therefore be well organized. If the system is out of use all 5,000 consumers will lack water. Since in the proposed systems treatment works have been omitted, operation problems are minimized.

For maintenance, availability of the following elements is crucial.

1. A well trained operation and maintenance team.
2. A well supplied stock of spare parts and tools.
3. Direct available financial funds for unanticipated expenditures needed for a well functioning system.
4. A well functioning organization responsible for the collection of water charges and financial management.

Concerning the latter point it is recommended that the organization will only be responsible for one system and is appointed and controlled by it's users. Charged money will be kept within this organization.

The next overview gives an estimation of the current running costs (prices 1988) of the in the previous section described system on an annual basis:

Energy costs: 100 KWh during 365 days @ KSh. 1/=	KSh. 40,000
Operation and maintenance team: one operator and three fundis	KSh. 60,000
Spares and tools:	KSh. 20,000
Sub-total:	KSh.120,000
unanticipated 10% :	KSh. 12,000
TOTAL:	KSh.132,000

Hence the running costs per capita will come to KSh. 26/= per capita per year.

F.6 Recommended implementation programme per Location

In each Divisional Report (Ref.13) a water development plan has been given, including the anticipated types, numbers and depths of the wells and boreholes.
These plans were based mainly on surveys carried out.
On basis of data which became available through the construction of wells and boreholes, more insight has been gained into the ground water development opportunities.
For this reason, the Divisional ground water resources development programmes have been slightly adjusted.
Considerations which led to the differences with the previous Divisional plans are given below.

- It was found that the potential for hand dug wells was slightly overestimated, in particular in the Kano Plain.

- At the same time the possibilities for successful boreholes appeared to be better than was anticipated.

- It appeared to be impossible to drill boreholes on the Nyabondo Plateau

- The recommended depth for boreholes in the Kano Plain initially has been slightly over estimated.

Table E.1 showed that the total number of safe and reliable point sources required in the District in 1987 amounted to approximately 2,481.

In the assessment of the 1,914 required and feasible types and numbers of new point sources to be constructed in Kisumu District as given in Table F.1, the view is taken that all 336 existing sources which are suitable for improvement will be improved.

The construction of roof catchment systems, although feasible, is not taken into consideration because the first choice is for use of safe and reliable ground water sources.
Only where it has been proven that such sources cannot safely be exploited, the possibilities for new roof catchments will be taken into consideration.

The sub-division of the ground water extraction points into wells and boreholes is based on the results of surveys carried out, geophysical surveys in particular, but above all on the experience gained from the already completed wells and boreholes.

Projections of numbers and types of water points beyond the 1987 programme are not given yet because:

- it is not likely that the programme in Table F.1 will be completed within the first 10 years
- future planning should be based upon the experiences gained from the ongoing implementation programme
- no firm projections are available of the socio-economic development of the District.

It is anticipated that gradually medium size (5000-6000 consumers) piped supply schemes using boreholes as water source and electricity as energy source will play a more important role in the District.

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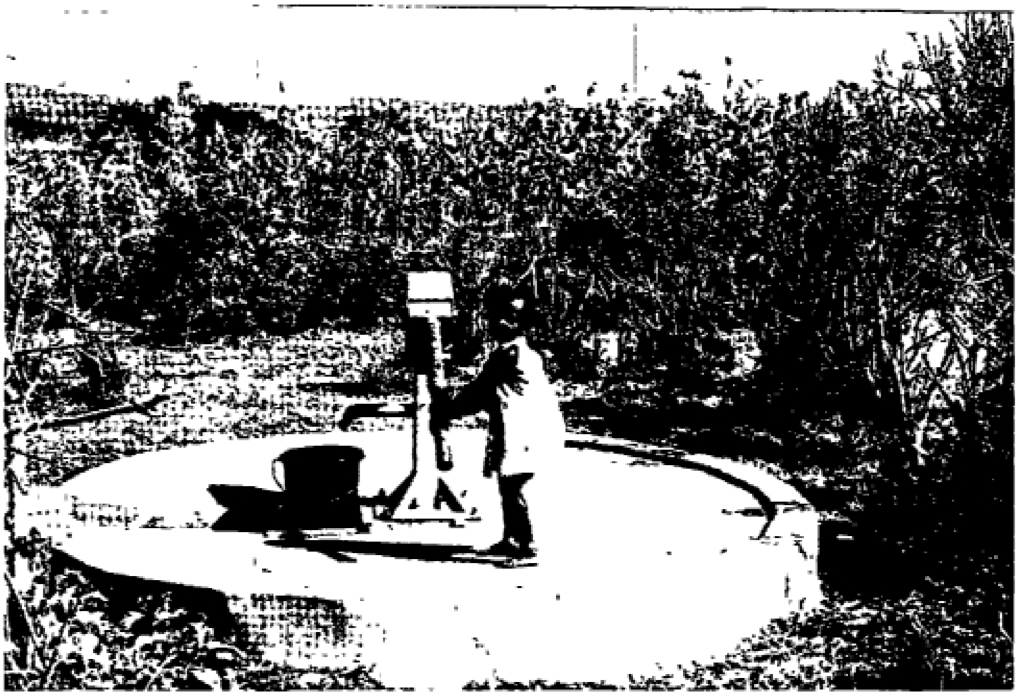
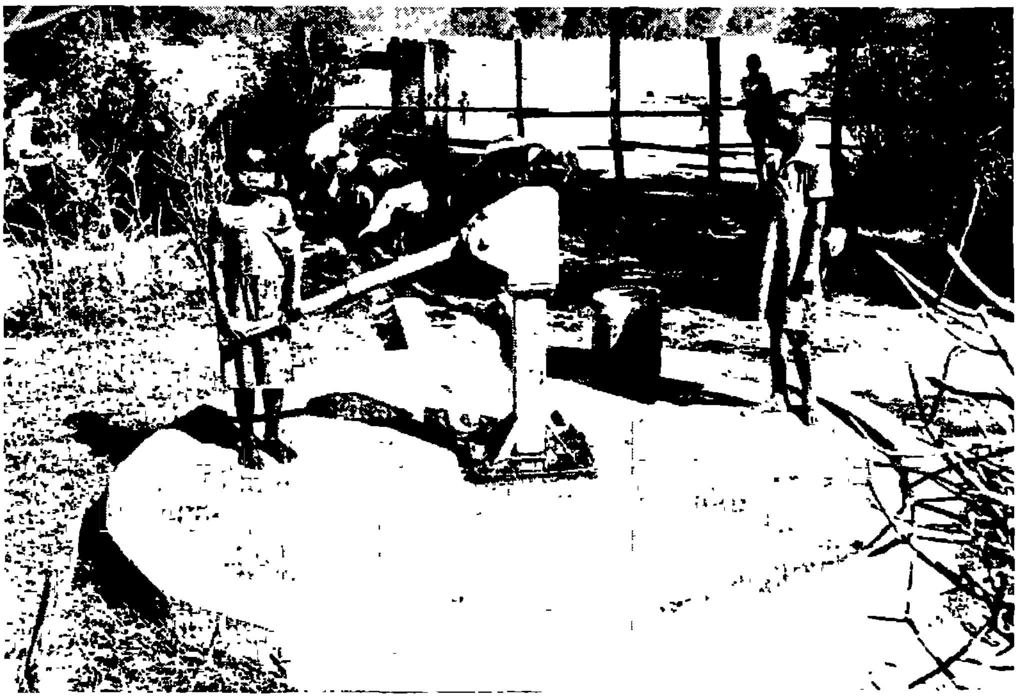
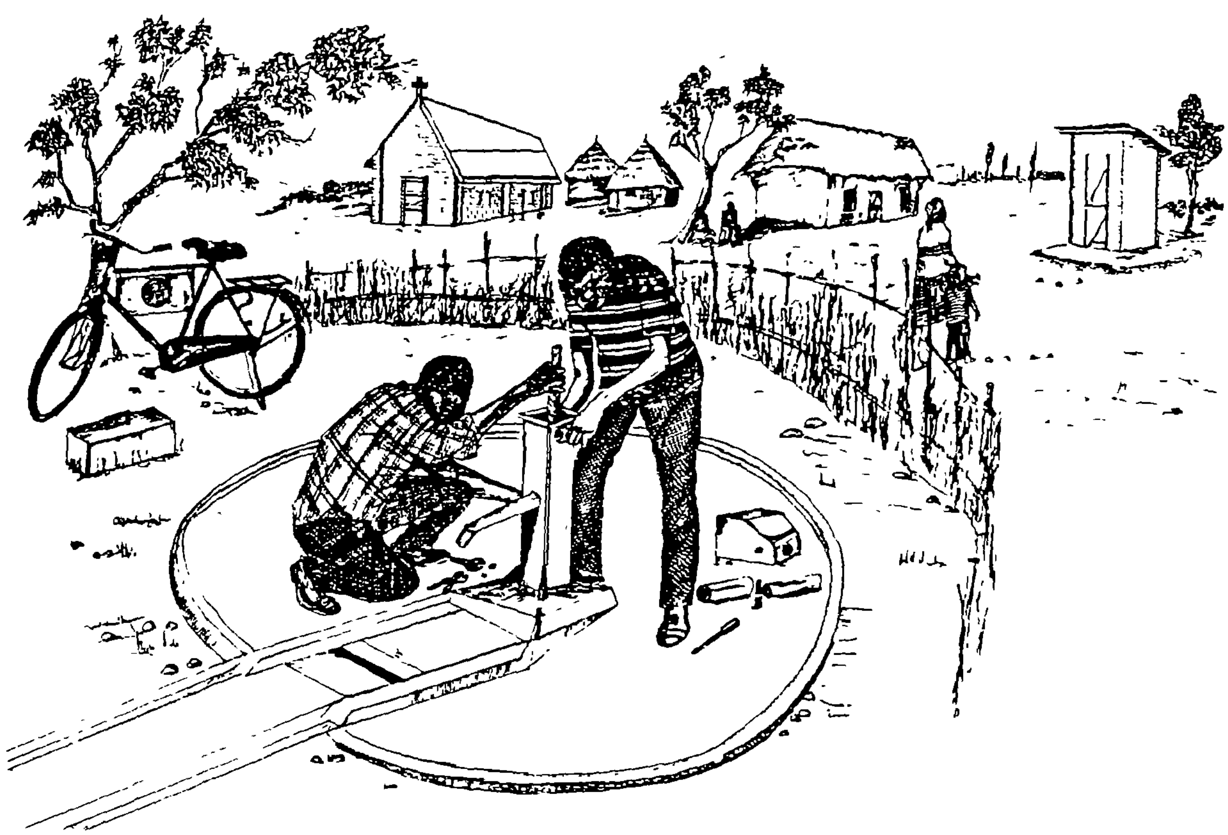


Children fetching water from RDWSSP hand pump wells



PART 1

INTRODUCTION



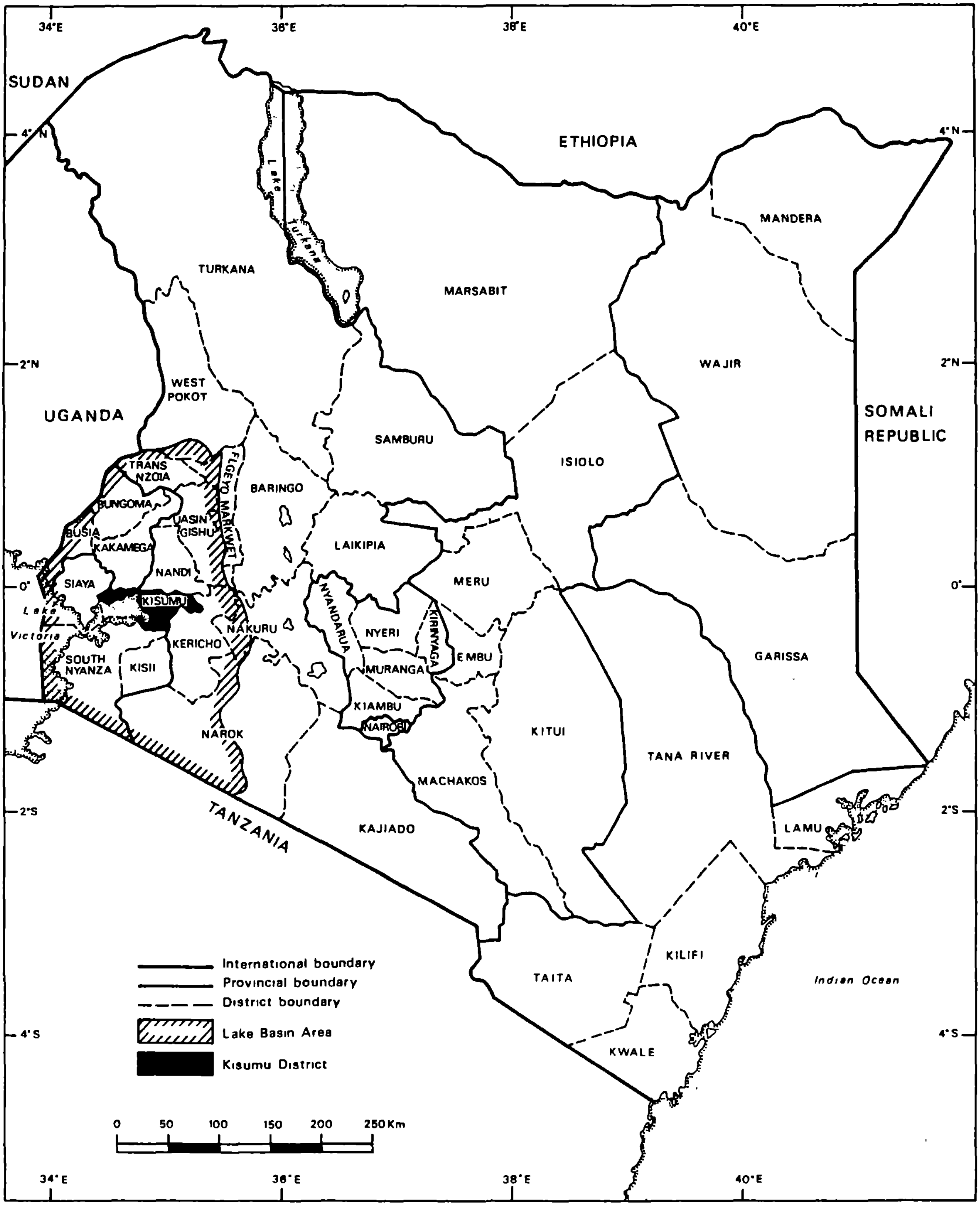


Figure 1.1 Location of Lake Basin Area and Kisumu District in Kenya

1 INTRODUCTION

1.1 Purpose and contents of the report

This report on rural domestic water supply in Kisumu District gives a review of information collected on the occurence, use, potential and exploration and exploitation possibilities of the water resources in the District.
It is the third of four District Reports which together will cover the whole of Nyanza Province.

The report is aimed at and to be used by District development planners, water supply implementing bodies and donors as a basis for the feasibility and cost analyses of water supply programmes in Kisumu District.

The report is based mainly on the results of systematic and detailed water resources assessment studies carried out in the District between 1986 and 1988 as part of the Lake Basin Development Authority's Rural Domestic Water Supply and Sanitation Programme (RDWSSP) , which were subsequently published in five comprehensive Divisional Reports and a Main Report.

VOLUME	I	Main Report		-	September	1984
VOLUME	XIV	Nyakach	Division	-	April	1987
VOLUME	XV	Winam	Division	-	June	1987
VOLUME	XXI	Nyando	Division	-	January	1988
VOLUME	XXII	Muhuroni	Division	-	March	1988
VOLUME	XXIII	Maseno	Division	-	May	1988

The Main Report includes a review of literature on water supply in Nyanza Province as well as an explanation of the approach and methodology of the water resources assessment studies carried out.

In the Divisional Reports the data, results and conclusions of the water resources surveys are presented down to the level of Sub-locations and for technical information more detailed than presented in this District Report one is referred to these reports.

A new dimension is given to this District Report by the incorporation of valuable hydrogeological and technical data derived from 30 deep boreholes constructed in the District under the RDWSSP during 1988.

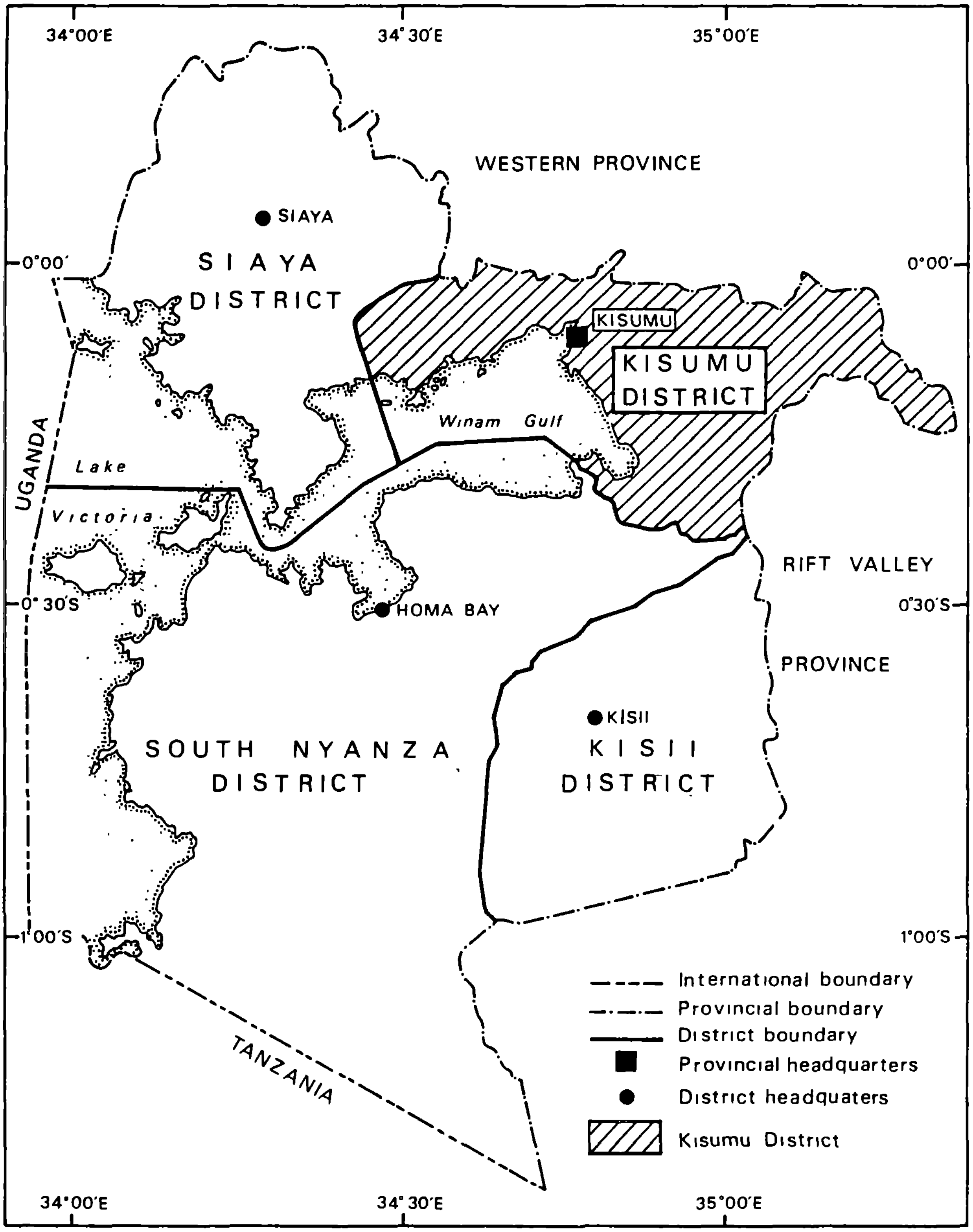


Figure 1 2 Location of Kisumu District in Nyanza Province

The report starts with the presentation of a:

RURAL DOMESTIC WATER SUPPLY PLAN FOR KISUMU DISTRICT.

In this plan, the options are given for the development of safe and reliable water sources.

Relevant information subsequently presented and evaluated in this report includes:

- general information about the District's population, socio-economic situation, and administration
- the administrative sub-division of the District
- population projections up to the year 2005
- rural domestic water use patterns and demand up to the year 2005
- physiographic characteristics influencing the water regime in the District
- a detailed evaluation and description of the present water supply situation in terms of the sources used, their quality and reliability, with special attention to the improved water supply systems i.e piped supplies and boreholes
- an assessment of the available water resources
- ground water exploration and well and borehole siting techniques developed and used by the RDWSSP
- recommendations on the development of safe and reliable water sources in the District.

The above information is shown moreover on five scale 1:100,000 thematical maps annexed to this report.

Further technical information is given on the designs and cost aspects of the various types of water points constructed by the Programme.

Last but not least, the operation and maintenance system for the types of water supply facilities promoted in the District is explained.

1.2 Background to the Rural Domestic Water Supply and Sanitation Programme

Nyanza Province, in Western Kenya, forms part of the development area of the Lake Basin Development Authority (LBDA); a statutory organisation established in 1979, to accelerate and co-ordinate development in the region.
The Province, which covers a land area of 12,500 km2, is inhabitated by approximately 3 million people, amounting to almost 20 % of Kenya's population. The area is practically all rural.

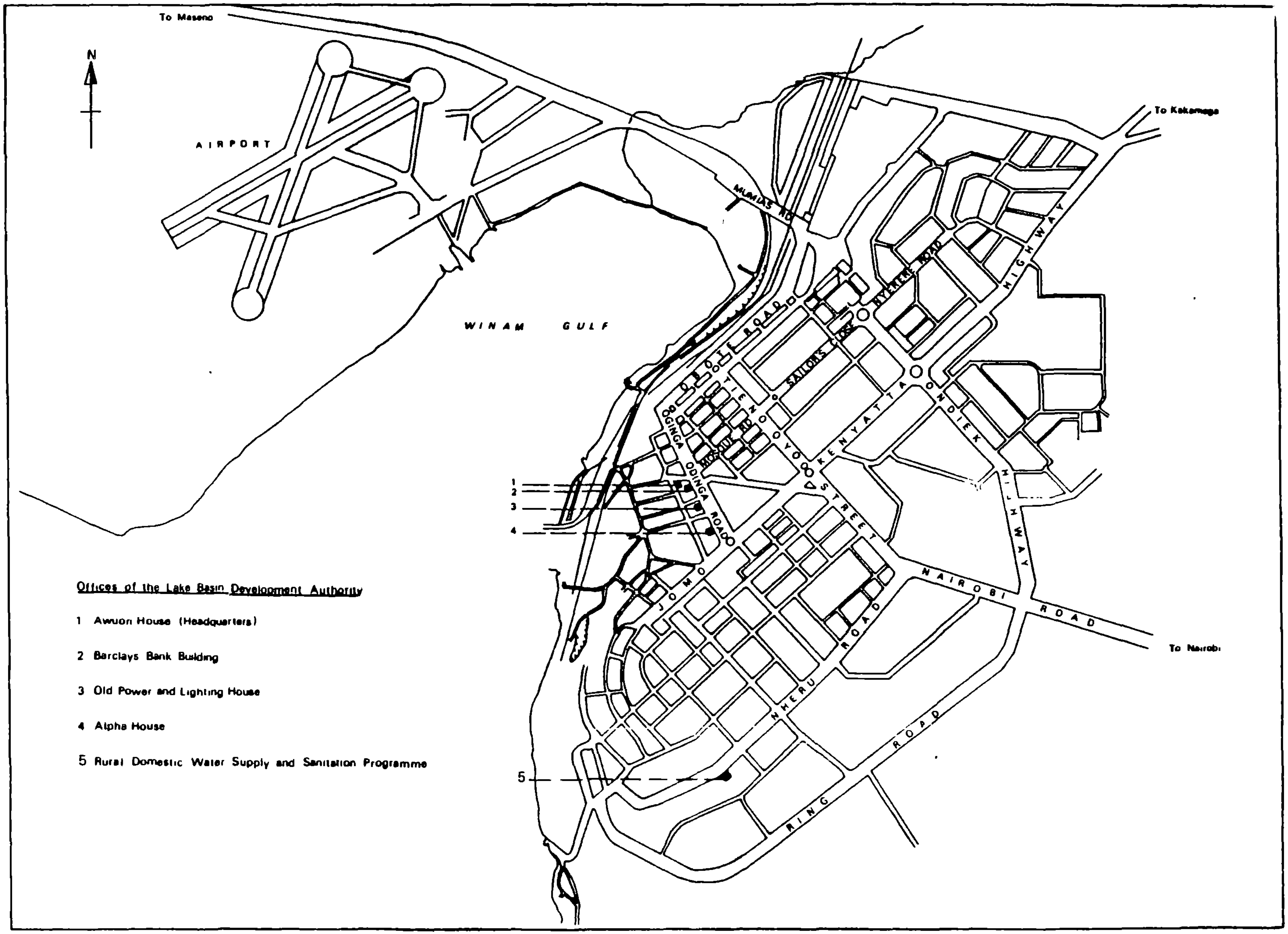


Figure 1 3 Offices of the LBDA in Kisumu

The average population density (250 per persons per km2) as well as the annual population growthrate (3.5-4.0%) are amongst the highest in Kenya.

During the past 20 years numerous Governmental and non-Governmental organisations have been involved in rural water supply activities, but despite all their efforts the situation has not noticeably improved. The main reasons are the rapidly growing water demand, a lack of maintenance of all types of constructed water supplies and the tendency to design mainly large scale supplies which so far have proved to be difficult to manage and sustain in the rural areas.

In 1984 less than 10 % of the rural population in Nyanza Province had access to a properly constructed water supply. The reliability of these water supply systems in most cases was far from satisfactory. The vast majority of the rural population carries water over considerable distances, from natural sources which are often polluted, insufficient or unreliable.

It is against this background that the LBDA in 1984 initiated the Rural Domestic Water Supply and Sanitation Programme with the primary aim to provide safe and reliable water to the rural areas of the Province.

The Programme is financially supported by the Netherlands Government under the bilateral development co-operation programme with the Government of Kenya.

The LBDA has engaged DHV Consultants of the Netherlands to provide professional services to the technical activities of the Programme and to train its personnel and staff.

1.3 The LBDA's involvement in the provision of water supply

The Act of Parliament by which the LBDA was established, empowers the Authority to undertake overall planning, co-ordination and implementation of programmes and projects in its region.
Regional development demands an integrated and comprehensive approach to planning development and an integrated management of all major sectors of the regional resources.
With the constitution of the LBDA therefore, the development of Western Kenya underwent a shift from a fragmented approach to one of co-ordination and integration.

The Authority covers an area which is 8 % of the total of Kenya, yet the nearly 9 million people residing in the area represent 42% of the total population of the country, with upto 600 persons per square kilometre.

Since it's inception, the LBDA has initiated a series of projects and programmes aimed at the maximum utilization of human, water, animal, land, power and other resources, together with a programme of monitoring and evaluation.
These projects are many and varied and include:

- master planning
- integrated land use studies
- hydro-electric schemes
- fisheries development
- lifestock multiplication
- irrigation and drainage
- flood control
- agriculture
- bee keeping and honey production
- brick manufacture
- food production and agro based industries
- effluent monitoring.

Of the thirteen functions deliniated in the Act of Parliament establishing the LBDA, seven specifically refer to development of the water resources.
This emphasizes the importance the Authority attaches to the management and development of this most valuable of natural resources.

Additionally, the health of the population is of great concern to the LBDA and consequently it has initiated also a series of projects related to health, sanitation and water supplies.

One such project is the Rural Domestic Water Supply and Sanitation Programme in Nyanza Province.

For the management and execution of the RDWSSP the LBDA has developed official links with the District Offices of the Ministries charged with the development of water supply, sanitation and health i.e the Ministry of Water Development, the Ministry of Health and the Ministry of Social Services.
Representatives of these and other Ministries form part of the Management Steering Committee of the RDWSSP and some geologists, technicians and other civil servants are actively involved in the Programme activities.

2 THE RURAL DOMESTIC WATER SUPPLY AND SANITATION PROGRAMME

2.1 History of the Programme

2.1.1 The Shallow Wells Pilot Project (1982-1983)

In 1981 the Lake Basin Development Authority initiated a Shallow Wells Pilot Project with the objectives to investigate the feasibility of shallow well construction in the rural areas of Nyanza Province and to study the most appropriate methods, equipment and materials to be used.
Furthermore, the various applications of shallow wells and ownership and maintenance options were looked into.
The Government of the Netherlands under a bilateral aid programme, subsidised the project which was undertaken during 1982 and 1983.

Information was gathered on the physiographic, demographic and water supply situation of the area and knowledge was gathered on the potential and methods of exploration and abstraction of ground water.
Additionally a total of 41 different types of handdrilled and handdug wells were constructed and fitted with hand pumps.

The technical findings and recommendations of the Pilot Project were presented in a Final Report (Ref. 11).

2.1.2 The Shallow Wells Workshop (1983)

Early in 1983 a Netherlands Government Evaluation Mission concluded that the physical feasibility of the abstraction of safe drinking water by means of handpump technology in the Province had been established and at the same time emphasized the need for a viable maintenance system, community mobilisation and the relationship between safe water and sanitation in the improvement of health. The mission called for a Shallow Wells Workshop, which was held in October 1983.

The principal objectives of the Workshop were:

- to establish the preferred basis and methods for the continuation of a wells construction programme taking due account of technical, social, cultural, organisational and financial aspects

- to create the opportunity for presentation and exchange of information between organizations which are and may be involved in water supply provisioning in the Lake Basin area.

Findings and conclusions were written down in the Proceedings of the Workshop (Ref.21).

2.1.3 The Interim Project Phase (1984)

On the basis of the recommendations of the Workshop, two survey activities were started early 1984, a technical and a socio-economic survey.

Technical survey

The comprehensive technical survey was started in Ndhiwa and Mbita Divisions of South Nyanza District; Divisions which both were known to be badly off in terms of water supply and socio-economic development.
The main objectives of the technical survey activities were:

- to set up and commence a systematic survey in preparation of a Rural Domestic Water Supply Programme for the entire Nyanza Province
- to undertake a detailed mapping of the available water resources
- to identify all rural domestic water supply possibilities as a basis for future construction or improvement of water sources.

The activities carried out during the Interim Project Phase as well as the results and recommendations of the various surveys undertaken were recorded in the Final Report which consists of three volumes: the Main Report and Ndhiwa and Mbita Survey Reports (Ref.13).

Socio-economic survey

The primary aim of the socio-economic survey was, to identify target communities on the basis of the selection criteria established as a result of the Workshop.
The survey consisted of:

- a literature review of documents dealing with the selection criteria
- administration of a formal questionnaire to household heads and key informants
- collection of soci-economic data on Sub-locational level
- collection and evaluation of data from health institutions.

During the Interim Project Phase, in 1984, two Districts were covered: South Nyanza and Kisii District.

2.1.4 Phase I of the Rural Domestic Water Supply and Sanitation Programme (1985-1988)

The findings of the Pilot Project, the recommendations of the Shallow Wells Workshop and the preliminary results of the surveys carried out during the Interim Project Phase, formed the basis for the formulation by the LBDA of the proposal for the Rural Domestic Water Supply and Sanitation Programme (RDWSSP) in Nyanza Province. This Project was approved and is funded in an agreement between the Government of Kenya and the Netherlands Government for the period 1985-1988 (Phase I).

2.2 Objectives of the Programme

The primary aim of the RDWSSP is to improve the water supply situation in the rural areas of Nyanza Province.

This is achieved in a direct way by:

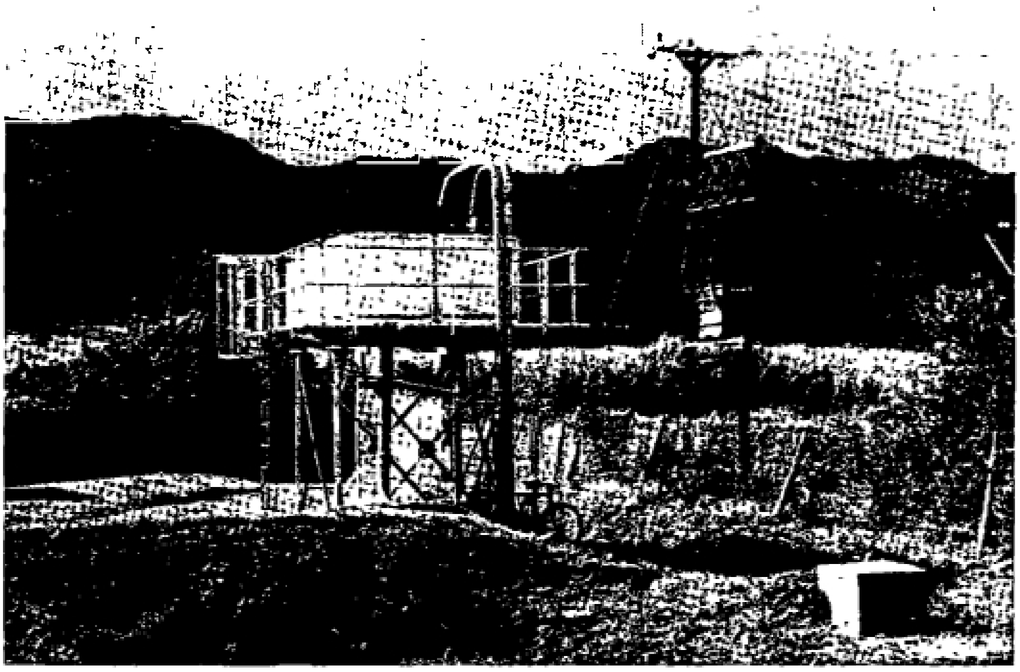
- providing safe water, easily accessible in quantities adequate for domestic use at a cost in accordance with the economic level of the communities and through facilities which can be easily operated and maintained at the local level;

- providing health education with emphasis on safe disposal of human excreta through low cost and easily maintained facilities with the explicit aim of protecting the health of the people from water related diseases.

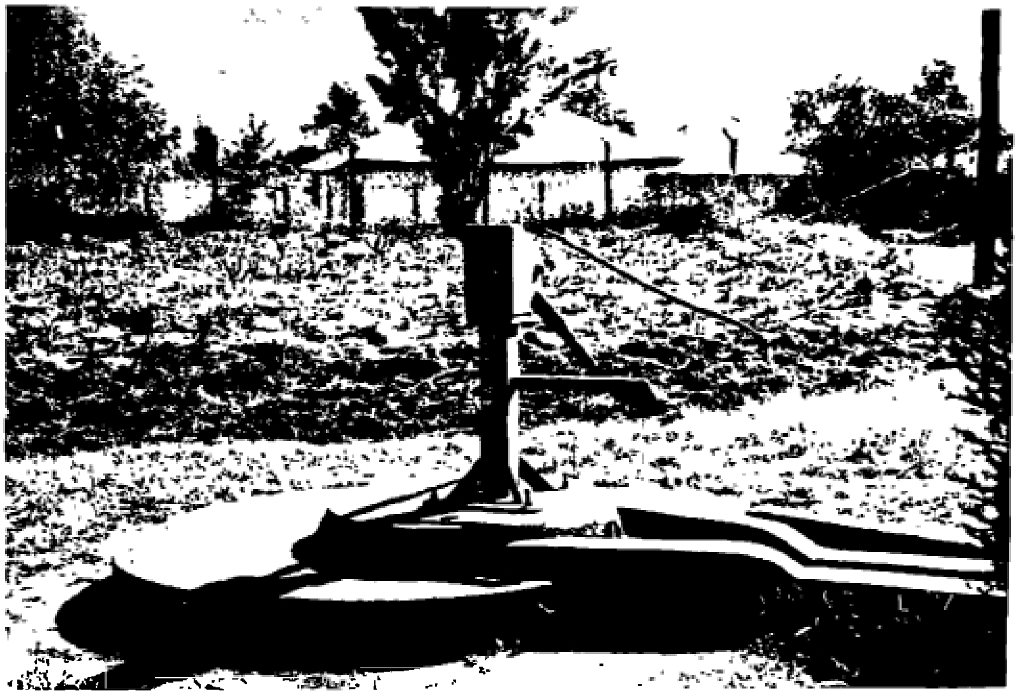
In an indirect way by:

- establishing the required organizational framework and self-sustaining structures which can take care of the implementation and maintenance of water supply and sanitation schemes;

- making available to other implementing bodies the results and recommendations of the surveys carried out and assisting and advising such bodies on all matters concerning water supply, sanitation and health education.



Water storage tank at Kibos fish farm (LBDA)



Dug well fitted with a SWN-81 hand pump

2.3 Activities of the Programme

In order to achieve the objectives of Phase I (1985-1988) of the Programme, a defined series of activities are being undertaken.

- A systematic and comprehensive water resources survey, to form the technical basis for rural domestic water supply programmes.

- A socio-economic survey to form the non-technical basis for rural domestic water supply and sanitation programmes.

- A construction programme which aims at developing approximately 500 water points, executed mainly by local contractors and community involvement.

- A construction programme of 160 institutional public sanitary facilities as demonstration models, by local contractors.

- The provision of 1,800 slabs and vent pipes for the construction of communal sanitary facilities.

- A comprehensive community development programme including information campaigns as to the benefits of safe and potable water, sanitation and public health.

- An institution building programme with the aim of establishing self-sustaining structures to take care of construction and maintenance of water supply and sanitation.

- A training and manpower development programme to support both the technical and non-technical departments of the RDWSSP as well as the institution building operations.

- The establishment of a production line in Kenya which will manufacture hand pumps, spare parts and related equipment, inclusive of a distribution network of the manufactured goods.

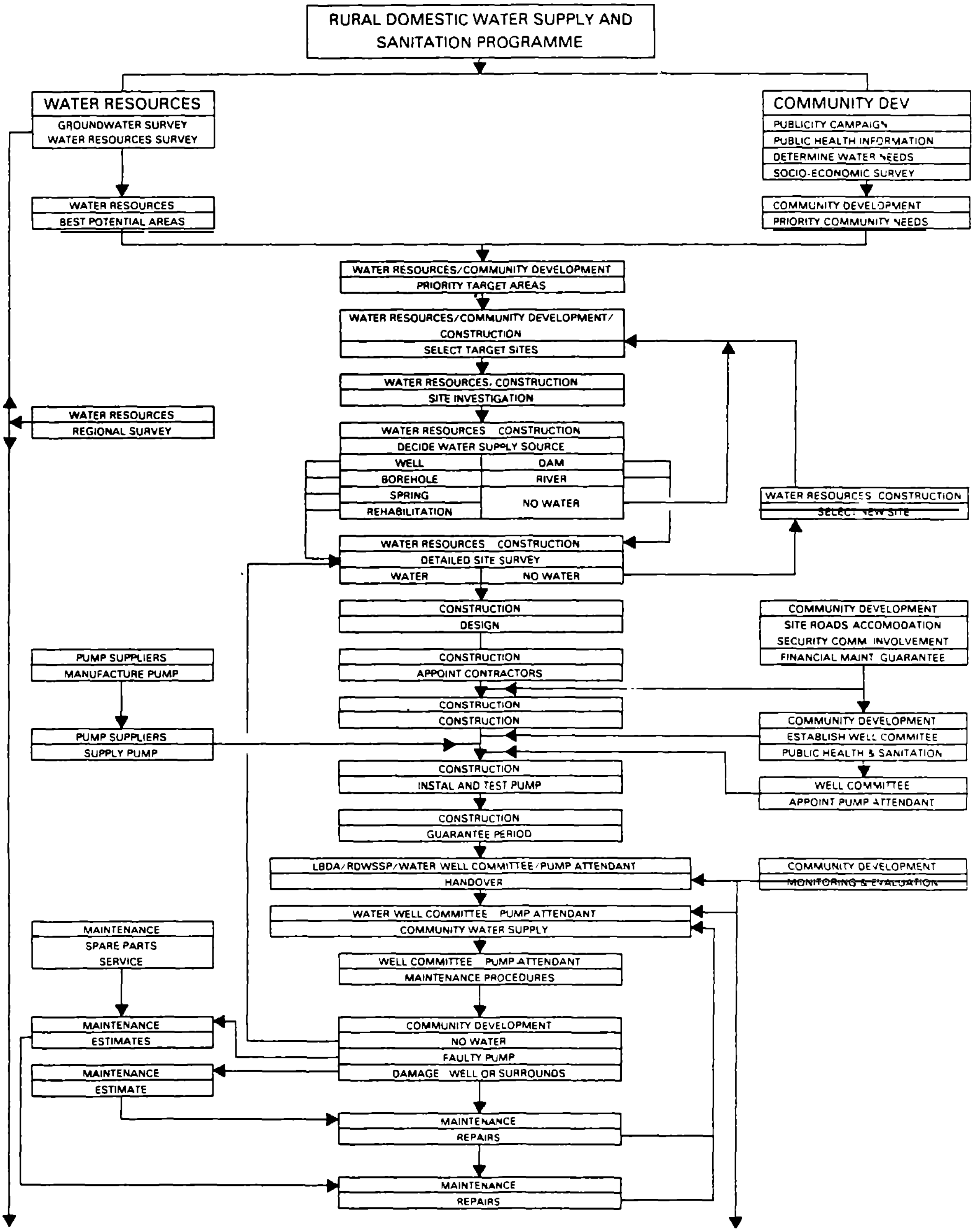


Fig 2 1 Flowsheet of Programme activities towards the construction and maintenance of water points

2.4 Organization and co-ordination of the Programme

The activities as summarized in section 2.3 are being undertaken by two major departments within the Programme: the Community Development Department and the Technical Development Department. Both departments, which have an integrated approach towards the targets of the Programme, are supported by two small service departments for accountancy and administration.

The Community Development Department is responsible for the following Programme components:

- socio-economic survey
- community development and mobilization
- sanitation and health education
- construction of sanitary facilities
- monitoring, evaluation and reporting.

The Technical Development Department is responsible for:

- detailed mapping of the existing water supply situation
- systematic and comprehensive water resources survey
- source identification and design
- construction of water points
- training of technical staff
- monitoring, evaluation and reporting.

Both departments together are in charge of the organization of an operation and maintenance system for the water points and other facilities constructed under the Programme.

Also, an institutional development, training and manpower development programme is being undertaken through co-operation between the two major departments and the LBDA.

The overall management of the Programme is with the Programme Co-ordinator who reports directly to the Steering Committee which is composed of experts of the LBDA, representatives of the Ministry of Water Development, Health, Social Services and Agriculture as well as representatives of the District Development Committees.
The integration of the various Programme components towards the Programme's major targets, the construction of waterpoints, is shown in Figure 2.1.

Landscape of Muhoroni Division

Water hole in Nyando Division

PART 2

DESCRIPTION OF KISUMU DISTRICT

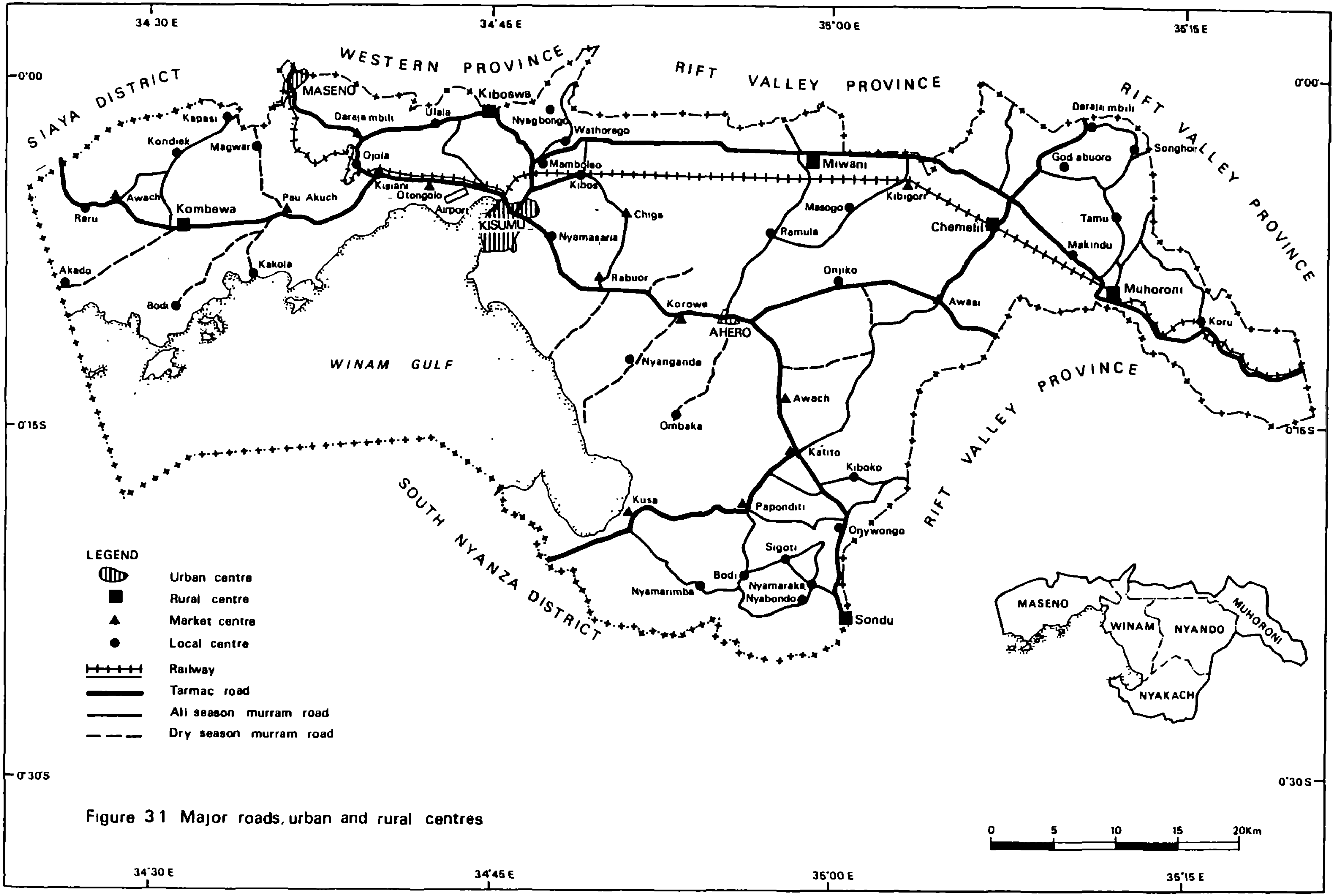


Figure 3 1 Major roads, urban and rural centres

3 GENERAL INFORMATION

3.1 Location and infrastructure

Kisumu District is located in south-western Kenya, enclosing the Winam Gulf, an embayment of the Lake Victoria.
The District was established in 1967 following the split up of the old Central Nyanza District into Kisumu and Siaya Districts. These two Districts, together with South Nyanza and Kisii Districts, constitute Nyanza Province.

From north to south the District stretches from 0^{o} 00' to 0^{o} 25' South. From west to east it is situated between 34^{o} 25' East and 35^{o} 20' East.

The southern border of Kisumu District is with South Nyanza District; its western boundaries are with Rift Valley Province. To the north-west it is bounded by Western Province and to the west by Siaya District.
The position of Kisumu District in relation also to neighbouring Districts is shown in Figure 1.1.

The total land area covered by Kisumu District comes to about 2090 km^2 or 17 % of Nyanza Province.
Located in the centre of Kisumu District is the Provincial and District Headquarters, Kisumu town.
Other urban centres in the District are Maseno, Muhuroni and Ahero.
Additionally there are sixteen rural centres and a large number of market and local centres (Figure 3.1).

There is a well developed and maintained network of roads in Kisumu District with five major tarmac roads branching from Kisumu town:

- Kisumu (Ahero) - Nairobi
- Kisumu (Ahero, Sondu) - Kisii
- Kisumu (Kiboswa) - Kakamega
- Kisumu (Maseno) - Yala
- Kisumu (Kombewa) - Bondo

Other tarmac roads connect Daraja Mbili with Kiboswa and Awasi with Chemelil and Nandi.
Further, a network of all-weather roads makes the area well accessible.

A railway connects Kisumu Town in eastern direction with Nairobi and Mombasa; in north-western direction this railway connects Kisumu Town with Maseno and Butere.
From Kisumu Airport there are daily flights to and from Nairobi. Airstrips suitable for twin engined light aircraft, are further located near Chemelil, Koru and Nyabondo.
Regular connections by ferry on Lake Victoria are maintained between Kisumu and several ports in South Nyanza District as well as Mwanza in Tanzania and Jinja in Uganda.

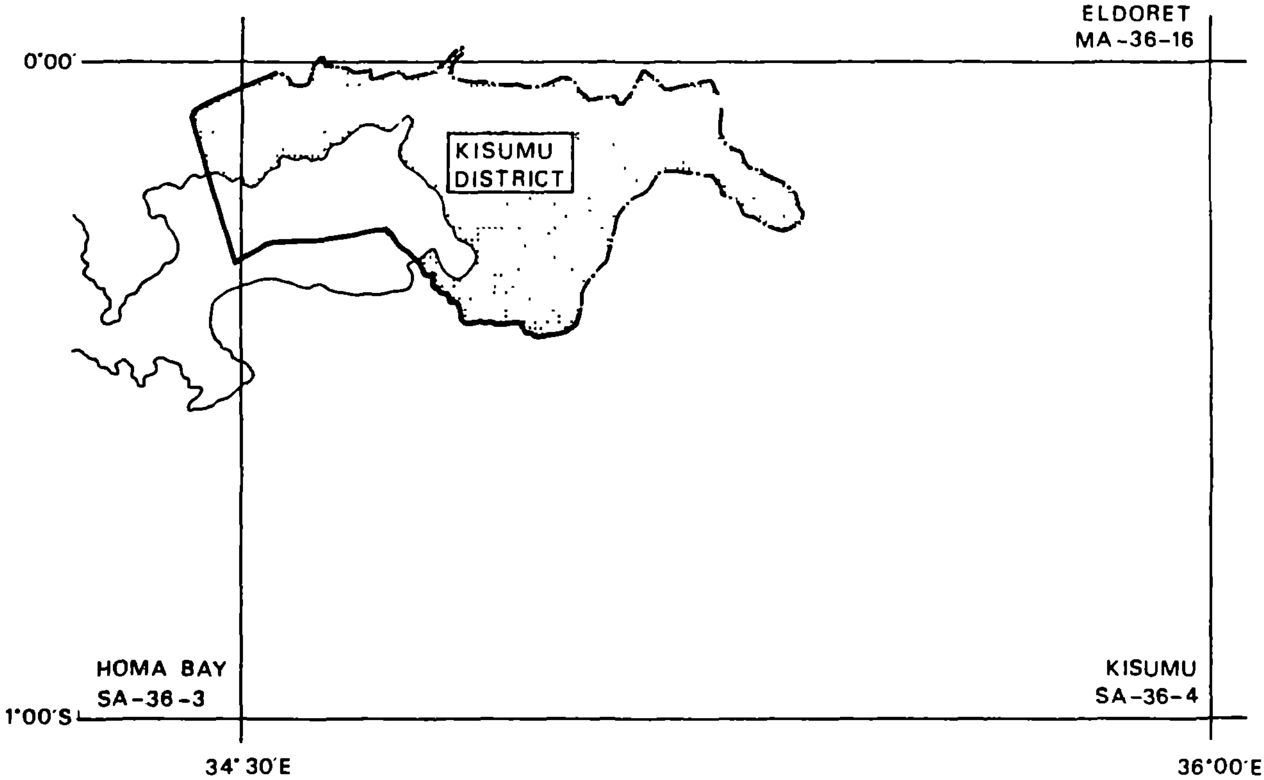


Figure 3 2a Scale 1 250,000 Topographical maps covering Kisumu District
Survey of Kenya - Series Y503

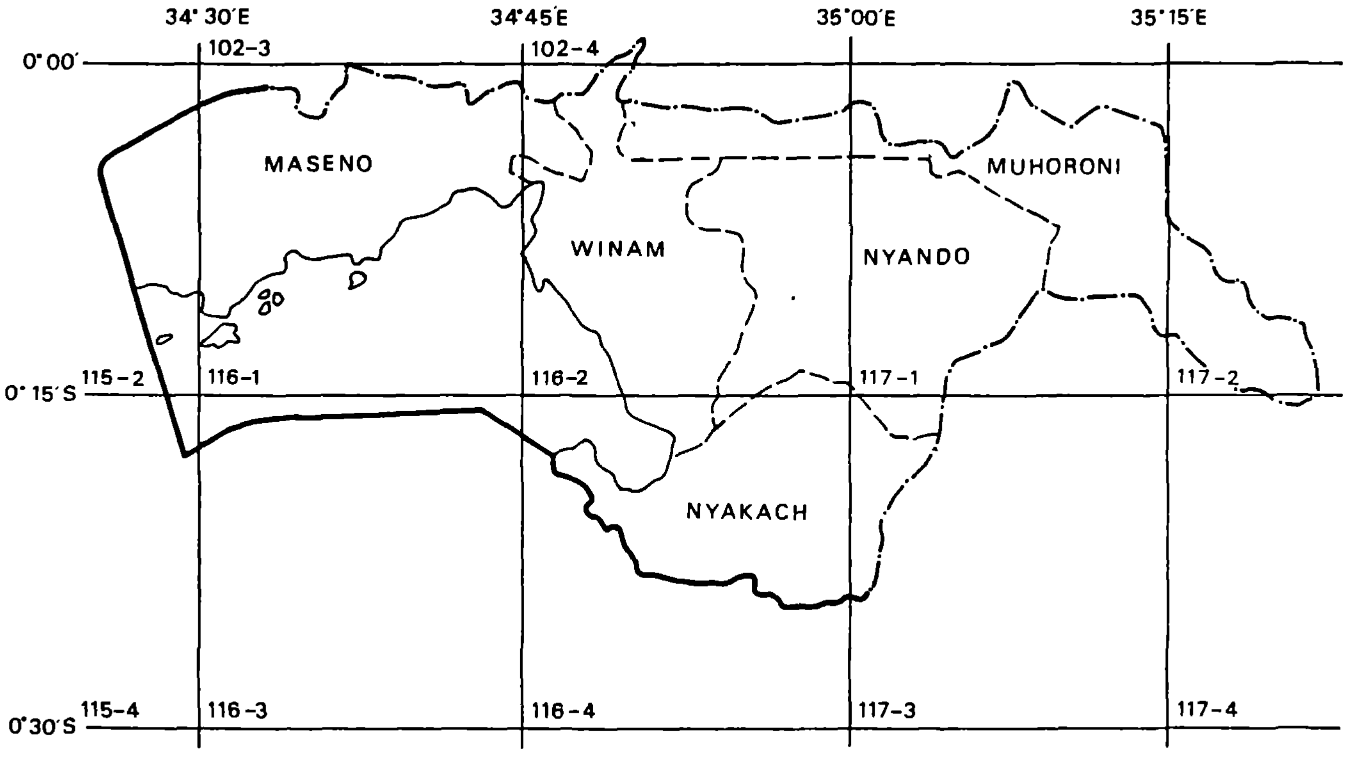


Figure 3 2b Scale 1 50,000 Topographical maps covering Kisumu District
Survey of Kenya - Series Y731

3.2 Topographical maps

As shown in Figures 3.2 a and b, Kisumu District is covered by two series of topographical maps published by the Survey of Kenya.

The KENYA Y-731 series on scale 1:50,000

These maps are in five colours.
Generally they give 20 m vertical contours with some sheets contoured at 50 ft intervals.
The maps are based largely on 1967 aerial photography and show great detail in physical features but are outdated for such information as roads, population centres, vegetation and even parts of the Lake Victoria coast line.

The KENYA SK-61 series on scale 1:50,000

This series of scale 1: 50.000 maps basically is a violet overprint of the Y-731 series, showing Locational and Sub-locational boundaries and names.
The maps were published in 1979 and are of limited availability.
Because of changes of administrative boundaries and names since 1979, already these maps are outdated.

The EAST AFRICA Y-503 series on scale 1:250,000

These maps, printed in six colours with additional layer tints, show form lines at either 200 ft or 60 m vertical interval.
The last revision of this series is from 1973, but because the maps are based largely on 1957 and 1967 aerial photography, they are outdated as to infrastructural features and vegetation.

The LBDA series SK-104 on scale 1:250,000

In 1983, the Survey of Kenya published a special map for the LBDA on scale 1:250,000.
The series exists of two maps, a north and south sheet.
The maps are printed in six different colours and show vertical contour lines with 200 ft interval.
Since this series basically is a direct extract from the EAST AFRICA Y-503 series, with nothing added, they show an outdated infracture and names of local and market centres and schools shown on the maps appear to be choosen at randomly.

The RDWSSP Kisumu District Maps on scale 1:100,000

Annexed to this report are scale 1:100,000 thematical maps of Kisumu District.
For the preparation of the topographical base map (MAP-1), the topographical contour lines and grid system of the scale 1:50,000 Y-731 series were used.
Other features shown however, i.e roads, rivers, administrative centres and market centres, were updated as a result of excessive field work, carried out as part of the RDWSSP.

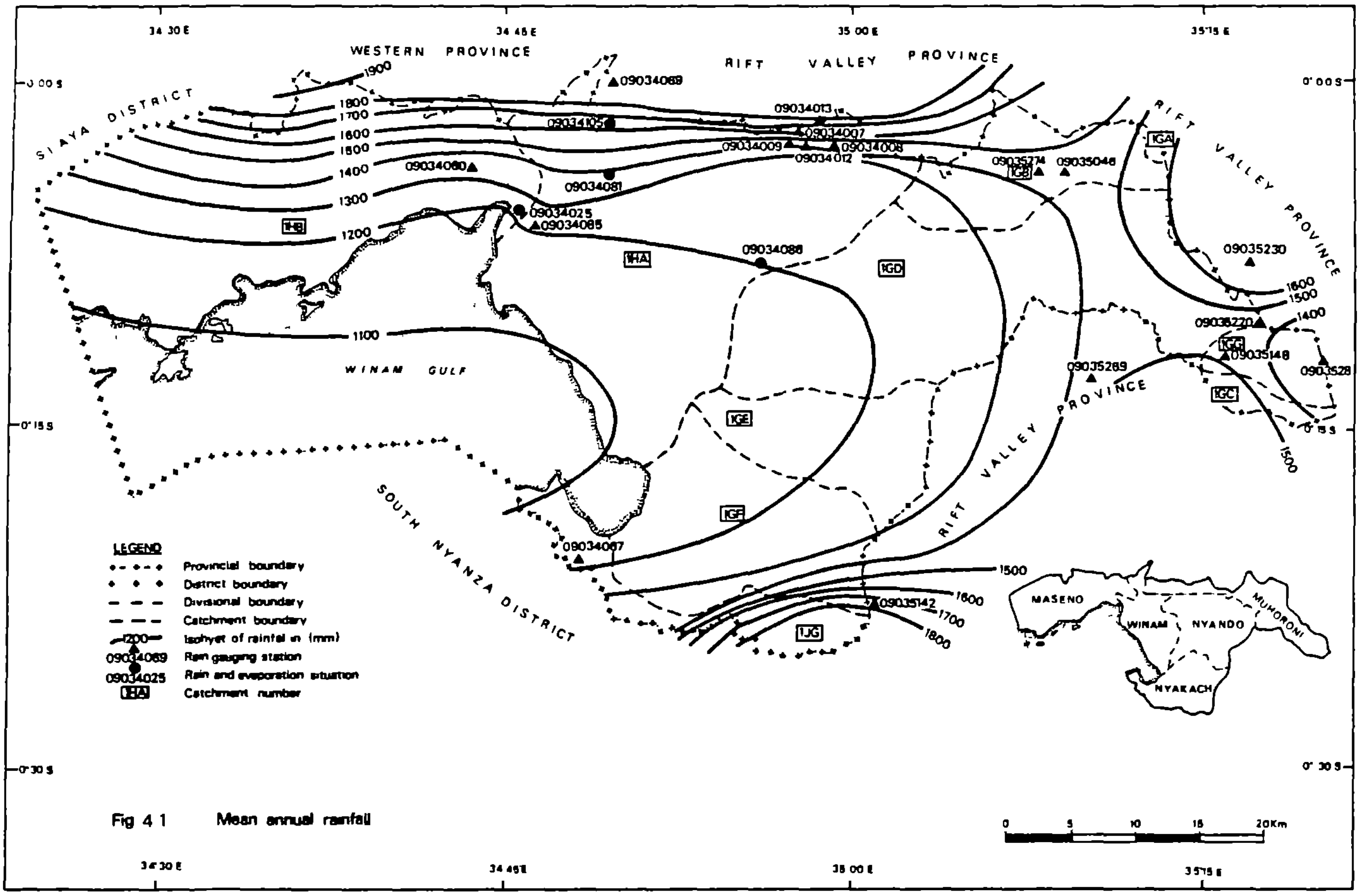


Fig 4 1 Mean annual rainfall

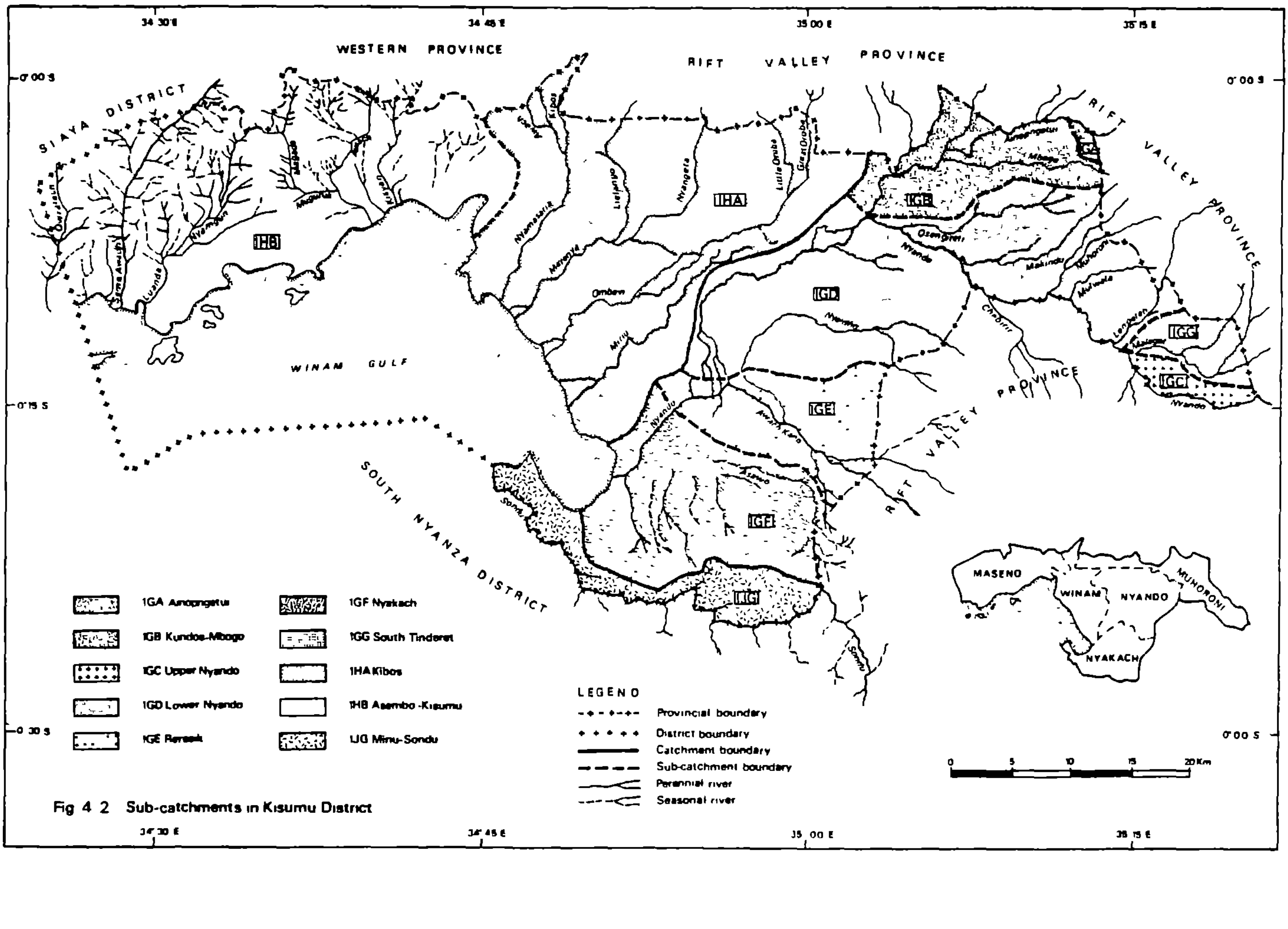


Fig 4 2 Sub-catchments in Kisumu District

4 PHYSIOGRAPHIC FEATURES

4.1 Climate

The climate in Kisumu District is basically an inland equatorial type, modified by the effects of altitude, relief and the influence of the large body of water in the form of Lake Victoria.
Because of the cooling influence the Lake exerts, temperatures are a little lower than in an equatorial climate.
Temperatures in the lower parts of the District (1,135 to 1,300m+sl) range from a mean minimum of 17^{o} to a mean maximum of about 30^{o}C. In the higher areas (1,300-1,600m + sl) the mean minimum and maximum temperatures vary between 14^{o}C and 25^{o}C.

Rainfall in the District shows considerable variations which are closely related to the altitude of the area.
Mean annual rainfall varies from less than 1,000 mm/year along the shores of the Winam Gulf, to 1,500 mm/year in the east of the District and over 1,800 mm/year along the northern boundary (Figure 4.1).
Two relatively dry and two relatively wet seasons can be distinguished:

- major rainy season : March - May with main rainfall in April
- minor rainy season : October - November
- dry season : December - February with December being the driest month
- dry season : June- September with July being the driest month

Potential evaporation is 1,800 to 2,200 mm per year and in most months exceeds the monthly rainfall.

More specific data on rainfall and evaporation are given and used in chapter 15 for ground water recharge calculations.

4.2 Drainage

The whole of Kisumu District drains to the Winam Gulf.

By far the largest perennial river is the River Nyando, whose catchment area occupies the eastern half of Kisumu District.
The Nyando itself, and its main tributaries all take their rise in the high rainfall region of the Tinderet Hills.
River Nyando ends in the Nyando Swamp; other rivers debouching into this swamp, the Awach Kano and the Asawo, are considered tributaries of the Nyando as well.

In the western part of Kisumu District there are about six major perennial rivers that all take their rise along the northern Escarpment and in the Maragoli and Maseno Hills.
These rivers flow more or less parallel in southern direction to flow into the Winam Gulf.

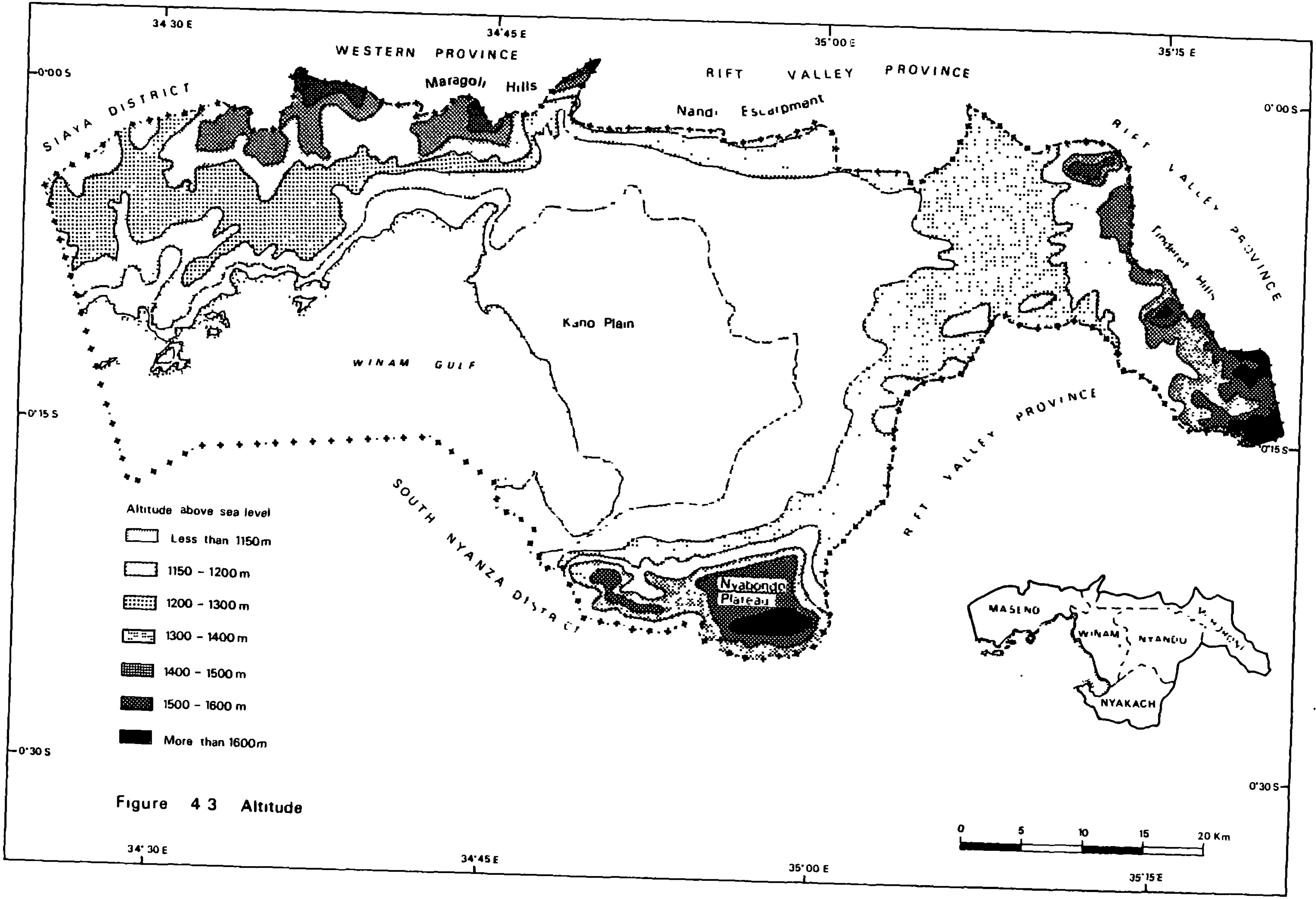


Figure 4 3 Altitude

Another large perennial river is River Sondu which forms the boundary between Kisumu and South Nyanza Districts.
Only a very minor part of Kisumu District however falls within its catchment area (1 JG,see Figure 4.2).
From south-east to north-west, going anti clockwise, the following (sub) catchment areas have been distinguished by the MoWD:

River Sondu Catchment	1 JG
Nyakach catchment	1 GF
River Reresik Catchment	1 GE
Lower Nyando Catchment	1 GD
River Kundos-Mbogo Catchment	1 GB
Kibos Catchment (including River Miriu, River Ombeyi, River Luanda and River Kibos)	1 HA
Asembo Catchment (including River Magada and River Seme Awach)	1 HB

The drainage pattern of the perennial rivers is shown in Figure 4.2.

Stream flow data are presented and used in Part 4 to assess the surface water potential and the ground water recharge.

4.3 Topographical relief (Figure 4.3)

Dominating the central area of Kisumu District is the Kano Plain, a flat tract of land which is at altitudes between 1,135 m along the Winam Gulf, to about 1,300 m in the north, east and south.

To the north the Kano Plain is bounded by the Nandi Escarpment which steeply rises from the Kano Plain reaching altitudes of over 1800 m just north of the District boundary.
The western part of the District (Maseno Division) shows a more gradual increase in altitude from the south (Lake level) to the north, culminating in the Maragoli Hills and the hills around Maseno which reach altitudes to slightly over 1,600 m.

To the south, the Kano Plain is bounded by another escarpment which rises upto the Nyabondo Plateau (1,550 m - 1,620 m).

Geologically the Kano Plain is an lacustrine and alluvial plain of Quarternary sediments lying on the floor of the Kavirondo Rift Valley that resulted from down-faulting between two parallel faults, the Nandi fault and the Nyabondo fault (see Chapter 9).
To the east, the Kano Plain merges into the volcanic area of the Tinderet Hills which in Kisumu District rise upto about 1,600 m.

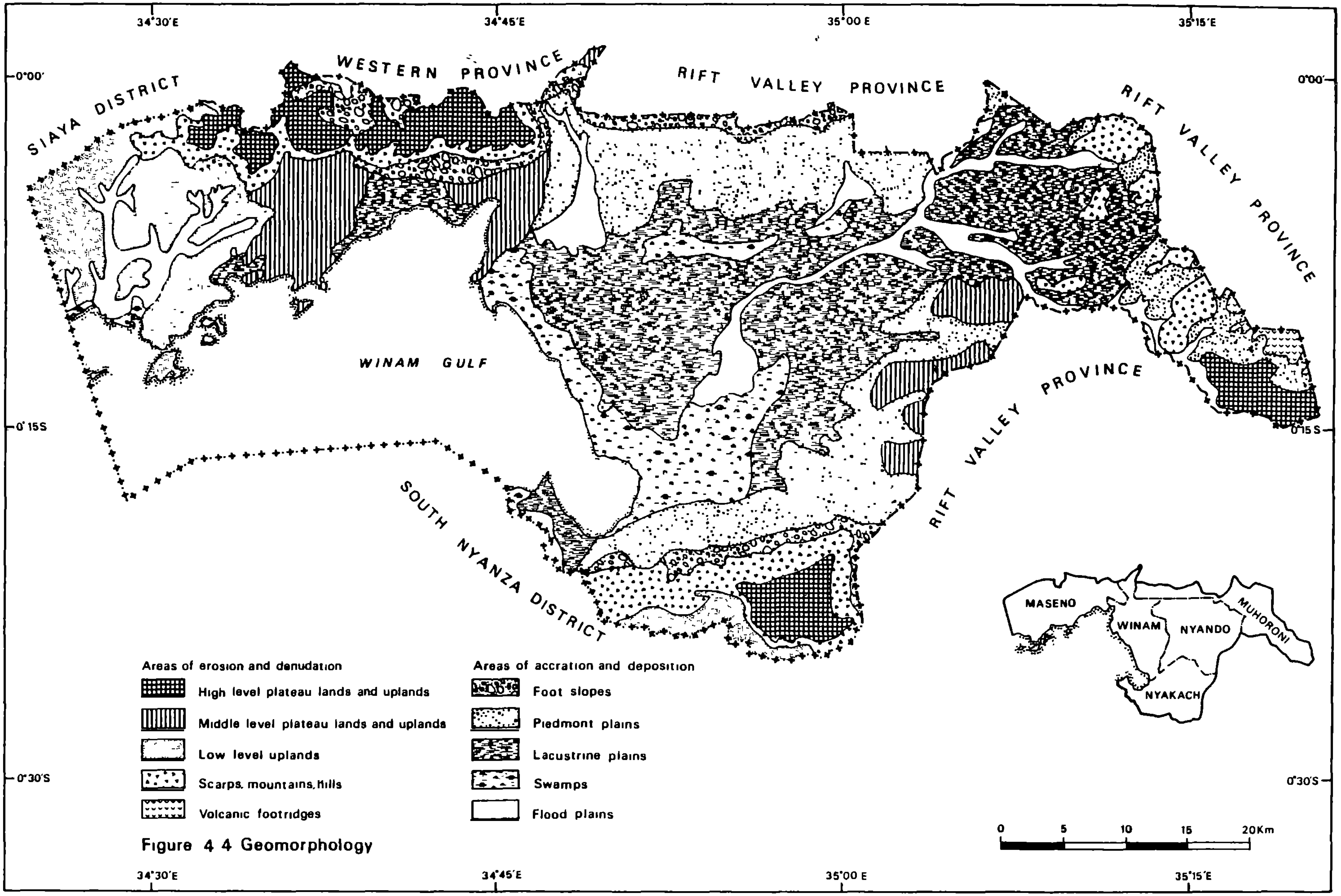


Figure 4 4 Geomorphology

4.4 Land forms (Figure 4.4)

Several land forms can be distinguished in Kisumu District:

- mountains, hills and scarps
- uplands and plateau remnants
- footslopes
- plains.

Mountains, hills and scarps

Some isolated hills and mountains occur in the very east of Kisumu District. Mostly they are erosion remnants of granite rock which is more resistant than the surrounding volcanic rocks.

Scarps are found along the Nyabondo Plateau in the south and along the Nandi Hills in the north of the District.

Uplands and plateau remnants

The uplands are divided into three levels, based on criteria as altitude and geomorphology.
The highest upland level, between 1,500 and 1,650 m, is found at three different places: the Maragoli Hills in Maseno Division, the Nyabondo Plateau in Nyakach Division and the Plateau area in the eastern corner of Muhuroni Division.

Middle level upland areas (1,200-1,400 m) are found around Kisumu Town, in Central Maseno Division and in the east of Nyando Division.
The western part of Maseno Division is considered to be a low level upland area with altitude ranging between 1,200 and 1,300m.

Both the high level and mid-level uplands are underlain by sub-horizontal lava flows.
As a result of the erosion surface of these upland areas is flat and dissected by streams.

Footslopes

Footslopes typically are found along the Nyabondo Escarpment in the south and the Nandi Escarpment in the north.
They exist of course talus scree.

Plains

The area known as the Kano Plain occupies most of Winam Nyando and Muhuroni Division as well as the northern part of Nyakach Division.
It is at elevations between 1,135 and 1,300 m and can be divided into northern and southern piedmont plain areas and a central lacustrine/alluvial plain.

Sugar cultivation in Muhuroni Division

5 SOCIO-ECONOMIC INFORMATION

5.1 Administration

Figure 5.1 and MAP-2 (annexed to this report) show the subdivision of Kisumu District into Divisions, Locations and Sub-Locations as it was found during the RDWSSP surveys in 1987 and 1988.
The smallest administrative unit is a Sub-Location which is administered by an Assistant Chief.
Several Sub-Locations (3-8) together form a Location headed by a Chief. A number of Locations in turn are grouped together and form a Division which is administered by a District Officer (DO).

The Divisional and Locational boundaries largely are the agreed boundaries, used for the parliamentary and local government elections of 1983.
The Sub-Locations boundaries have been confirmed and mapped during the RDWSSP water resources survey.

It is necessary to point out that some boundaries are not as clearly defined as they seem to appear on the maps. In cases where rivers or roads are used as boundaries, there is no query. Sometimes however, they are defined along more doubtful lines.

Basically the District is divided into 5 administrative Divisions, which are sub-divided into 24 Locations and 113 Sub-Locations.

The administrative sub-division, is shown in Table 5.1.

Table 5.1. Administrative sub-division (January 1988 situation)

Division Name	Size* (km^2)	Headquarters Name	Nr of Locations	Nr of Sub-Locations
Maseno**	460	Maseno	6	33
Winam**	230	Kisumu	4	13
Nyando	500	Ahero	4	24
Muhuroni	440	Muhuroni	6	21
Nyakach	360	Paponditi	4	17
Kisumu Urban area	100		-	5***
KISUMU DIST.	2090	KISUMU TOWN	24	113

* Only land area is considered
** Excluded are the present urban areas of Kisumu Municipality
*** Sub-locations within Kisumu Municipality that are considered Urban extensions of Kisumu Township.

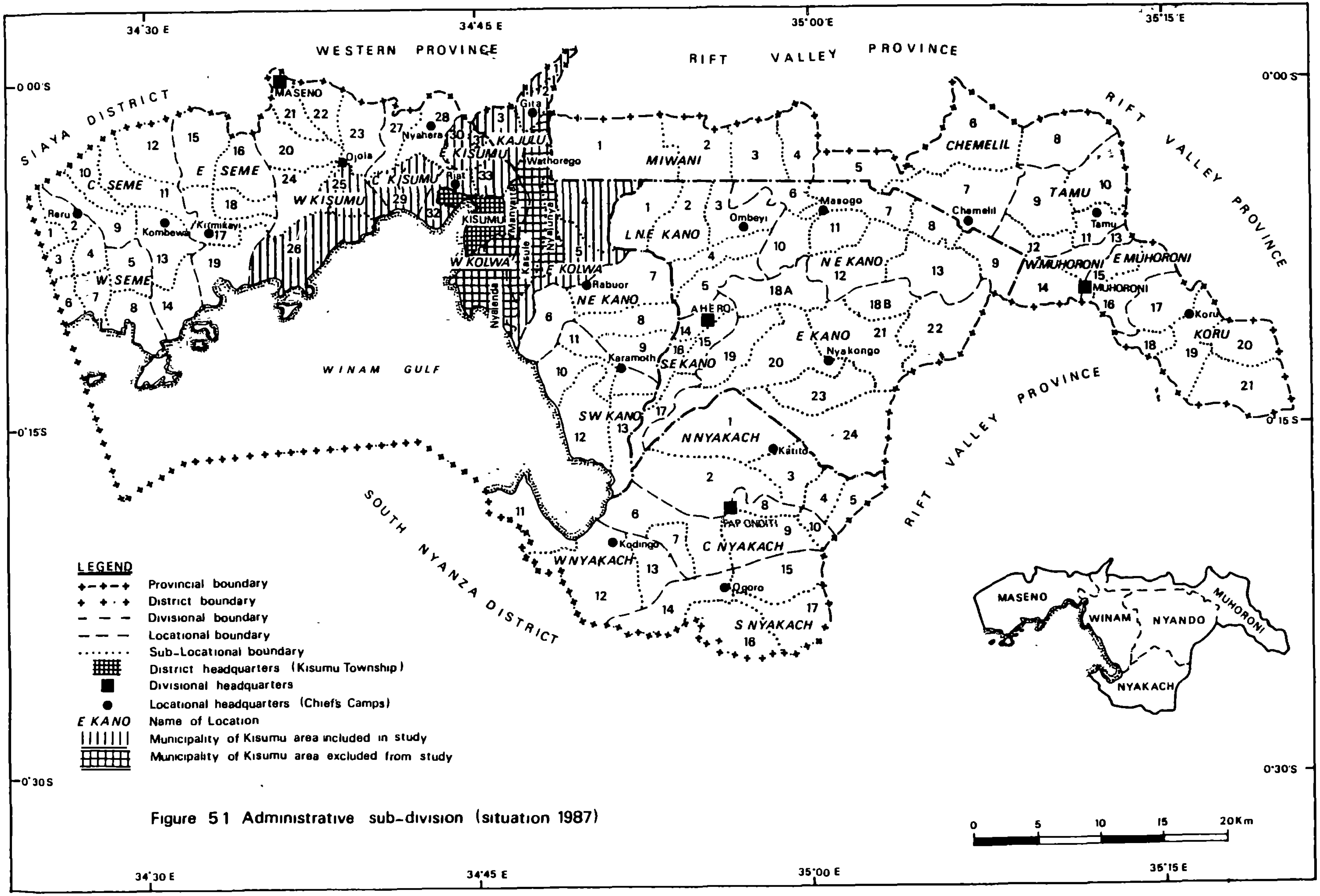


Figure 5.1 Administrative sub-division (situation 1987)

MASENO DIVISION

WEST SEME LOCATION
1 West Reru
2 Reru
3 West Ngere
4 Ngere
5 Angoga
6 Kadinga
7 East Kadinga
8 Alungo
CENTRAL SEME LOCATION
9 Kanyadwera
10 Kadero
11 Katieno
12 Kowe
13 Kombewa
14 Othany
EAST SEME LOCATION
15 Rata
16 Kolunje
17 Kitmikaye
18 Kaila
19 Kajulu Koker
WEST KISUMU LOCATION
20 Marera
21 West Karateng
22 East Karateng
23 Kapuonja
24 Kadongo
25 Ojola
26 Kanyawegi
CENTRAL KISUMU LOCATION
27 Bar
28 Nyahera
29 Korando
EAST KISUMU LOCATION
30 Dago
31 Mukenda
32 Kogony
33 Kanyakwar

WINAM DIVISION

KAJULU LOCATION
1 Got Nyabondo
2 Kadero
3 Konya
EAST KOLWA LOCATION
4 Chiga
5 Buoye
NORTH WEST KANO LOCATION
6 Nyamware
7 Kochieng
8 Kombura
9 Katho
SOUTH WEST KANO LOCATION
10 Kawino
11 Upper Bwanda
12 Kadhiambo
13 Lower Bwanda

MUHORONI DIVISION

MIWANI LOCATION
1 West Miwani
2 Central Miwani
3 East Miwani
4 North Miwani
CHEMELIL LOCATION
5 Kibigori
6 Nyangore
7 Chemelil
8 West Songhor
TAMU LOCATION
9 Godabuoro
10 East Songhor
11 Upper Tamu
12 Lower Tamu
WEST MUHORONI LOCATION
13 Central Muhoroni
14 West Muhoroni
EAST MUHORONI LOCATION
15 East Muhoroni
16 Owaga
KORU LOCATION
17 Home Lime
18 Nyando
19 Koru
20 Fort Ternan
21 Ochoria

NYANDO DIVISION

LOWER NORTH EAST KANO LOCATION
1 West Sidho
2 Central Sidho
3 North Kamagaga
4 South Kamagaga
5 Irrigation Scheme
NORTH EAST KANO LOCATION
6 West Kabar
7 East Kabar
8 East Sidho I
9 East Sidho II
10 Wangaya II
11 North Kamswa
12 South Kamswa
13 Wangaya I
SOUTH EAST KANO LOCATION
14 North Kakola
15 North Kochogo
16 South Kakola
17 South Kochogo
EAST KANO LOCATION
18 Wawidhi A
19 Kakmie
20 Wawidhi C
21 Border I
22 Border II
23 Wawidhi B
24 Katolo

NYAKACH DIVISION

NORTH NYAKACH LOCATION
1 Gem Rae
2 Middle Jimo
3 West Agoro
4 Awach
5 East Agoro
CENTRAL NYAKACH LOCATION
6 West Kabodho
7 West Jimo
8 Lisana
9 East Kabodho
10 East Jimo
WEST NYAKACH LOCATION
11 Lower Kadianga
12 West Koguta
13 Upper Kadianga
SOUTH NYAKACH LOCATION
14 West Kadianga
15 East Koguta
16 Kajimbo
17 East Kadianga

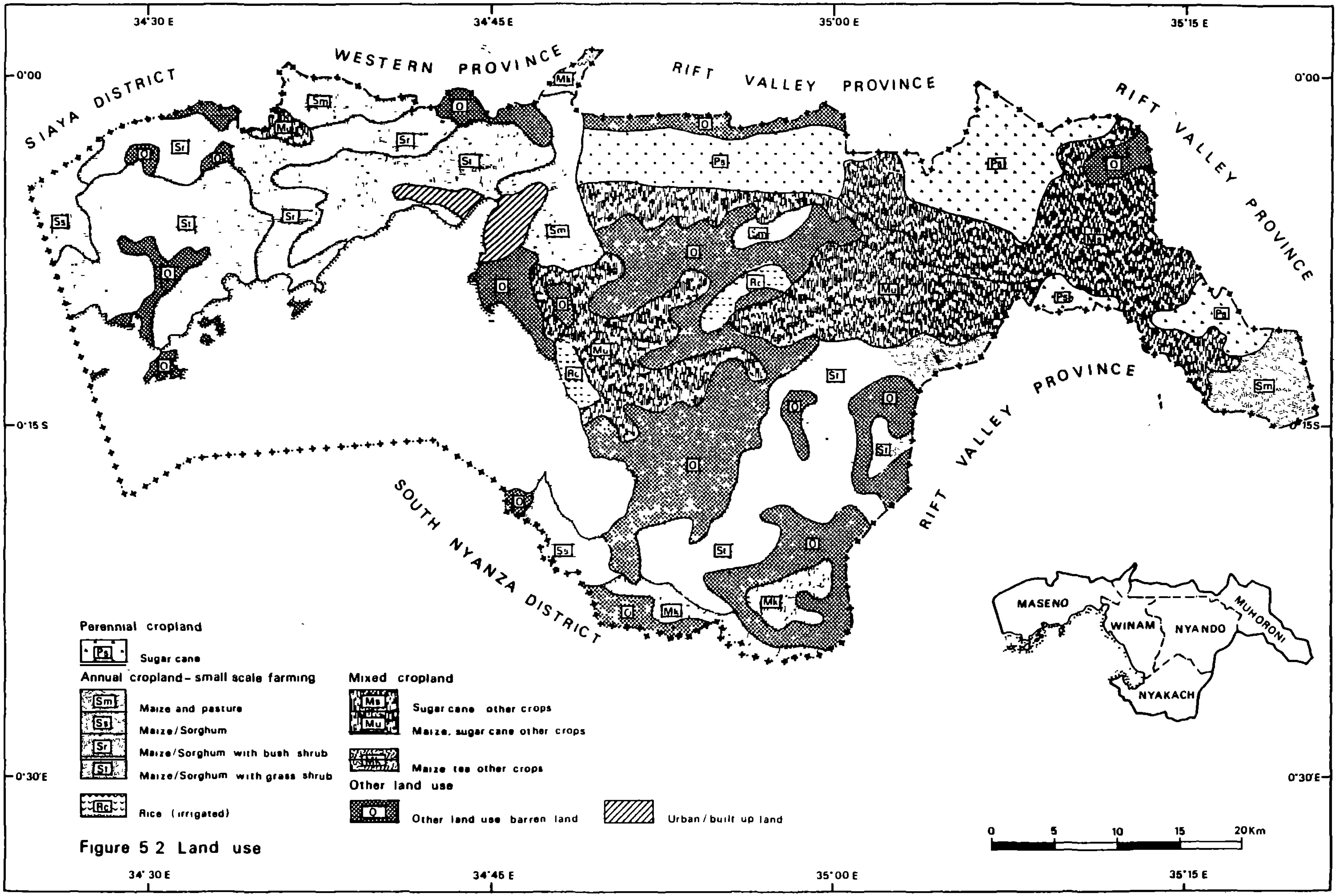


Figure 5 2 Land use

Politically Kisumu District is divided into five constituencies, each choosing its own Member of Parliament;

- Kisumu Township (old Municipality boundary)
- Kisumu Rural (Maseno Division)
- Winam (Winam Division and part of Muhoroni Division)
- Nyando (Nyando Division and part of Muhuroni Division)
- Nyakach (Nyakach Division)

Kisumu Municipality is the largest and most important urban centre in Western Kenya.
Prior to the extension of the Municipal boundaries in 1971, Kisumu Municipality covered only 19 km^2; in this report the old Municipality is referred to as Kisumu Township.
The extension raised the total land area of Kisumu Municipality to 260 km^2.
The new municipality now includes the northern part of Winam Division and the south-eastern part of Maseno Division.

5.2 Land Use (Figure 5.2)

The current distribution of land tenure and use in Kisumu District involves primarily small-scale, subsistence orientated agriculture, together with large scale sugar cultivation.
There are no large forest areas, national parks or other government reserve areas.
In 1982, the land use distribution was as follows (Ref.39):

Government land	18 %
Freehold land	10 %
Trust land	72 %

During this time, only 30 % of the land potentially available for small holder registration was officially registered while 70 % remained unregistered.
About 210 km^2 of land is categorized as large scale farms (8 ha. or larger), representing 10 % of the District's land area.
Two third of this land was planted with sugar cane and one third was cultivated pasture.
In addition, 20 km^2 are under sugar or rice in various irrigation schemes.

In Kisumu District food and cash crop production both play an important, although occasionally conflicting, role.
Livestock production is important mainly at the household level.
Food crops grown in Kisumu District include:
maize,sorghum, rice, millet, beans and groundnuts.
The main industrial crop in the District is sugar cane, followed by cotton, coffee and rice.

According to the Farm Management Handbook of West Kenya (Ref.20), the total rural land area of Kisumu District comes to 1926 km^2, out of which 1573 km^2 can be classified as agricultural land and 353 km^2 as non-agricultural land (steep slopes, swamps, roads etc.).
In the same manual it is shown that in Kisumu District the average small, medium and large size of a farm amounts to 2,4 and 8 ha. respectively.
Further it appears that in 1982 the average size of agricultural land per household and per person amounted to 2.4 and 0.5 ha respectively.

Agriculture in Maseno Division

5.3 Demographic Characteristics

The population growth throughout Kenya is one of the highest recorded in the world. The present combination of high fertility, declining mortality and a relatively young population implies that this high rate of growth will most probably persist well into the next century.
In Nyanza Province, which is one of the most densily population clusters of Kenya, a clear relationship between rainfall pattern and population density exists. Low rainfall areas as Siaya and South Nyanza District have about 200 people per km2 ;Kisii District with the highest rainfall has an estimated 1987 density of about 600 people per km2 while in Kisumu District being the area with intermediate rainfall on an average 300 people per km^2 are found (Figure 5.3).

Up to the present, in Kenya four nation wide population censuses have been carried out respectively in 1948, 1962, 1969 and 1979. The results of these four censuses as published by the Kenyan Central Bureau of Statistics (CBS) (Ref.6) for Nyanza Province and Kisumu District, are given in Table 5.2.

TABLE 5.2 POPULATION GROWTH ACCORDING TO FOUR CENSUSES

	Total Population according to census results			
	1948	1962	1969	1979
KENYA	5,406,000	8,636,000	10,942,000	15,327,061
NYANZA PROVINCE		1,645,000	2,122,045	2,643,956
KISUMU DISTRICT		301,000	400,643	482,327

	POPULATION GROWTH RATES ACCORDING TO CENSUS RESULTS		
	1948 -1962	1962-1969	1969-1979
KENYA	3.3 %	3.4 %	3.4 %
NYANZA PROVINCE		3.7 %	2.2 %
KISUMU DISTRICT		4.1 %	2.0 %

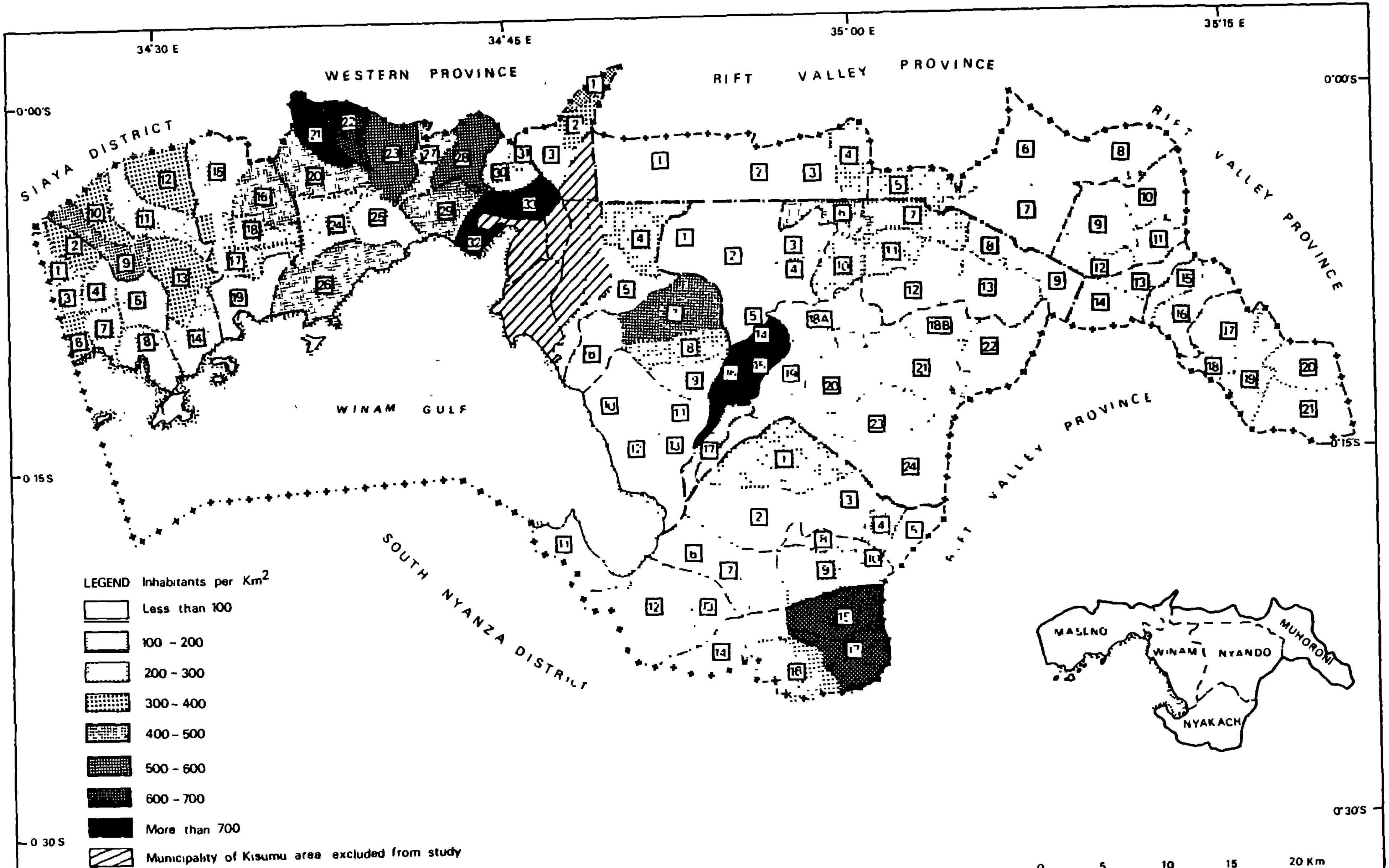


Figure 5.3 Population density per Sub-location (situation 1987)

The sharp declining population growth (from 4.1 % to 2.0 %) in Kisumu District as well as the whole of Nyanza Province between 1969 and 1979 was caused by a considerable under counting of the population in this part of Kenya during the 1979 census. Revised growth rates for this period were published by the CBS in 1983 (Ref.7). A more realistic figure of 3.3 % was calculated based on fertility and mortality data. Hence the 1979 total population of Kisumu District was corrected to be about 538,000.

During the inventory survey carried out under the RDWSSP in 1987-1988 , a population estimate per Division was based on the number of water consumers (Table 5.3). The last two columns of Table 5.3 show that the projections of the CBS match very well with the RDWSSP's consumers count. Comparing both 1987 population estimates with the corrected 1979 census figure the average growth rate for the entire Kisumu District appears to have been 3.3 % indeed.
Using the same annual population growth rates of 3.3 %, Table 5.4 presents the 1990 to 2005 population predictions.

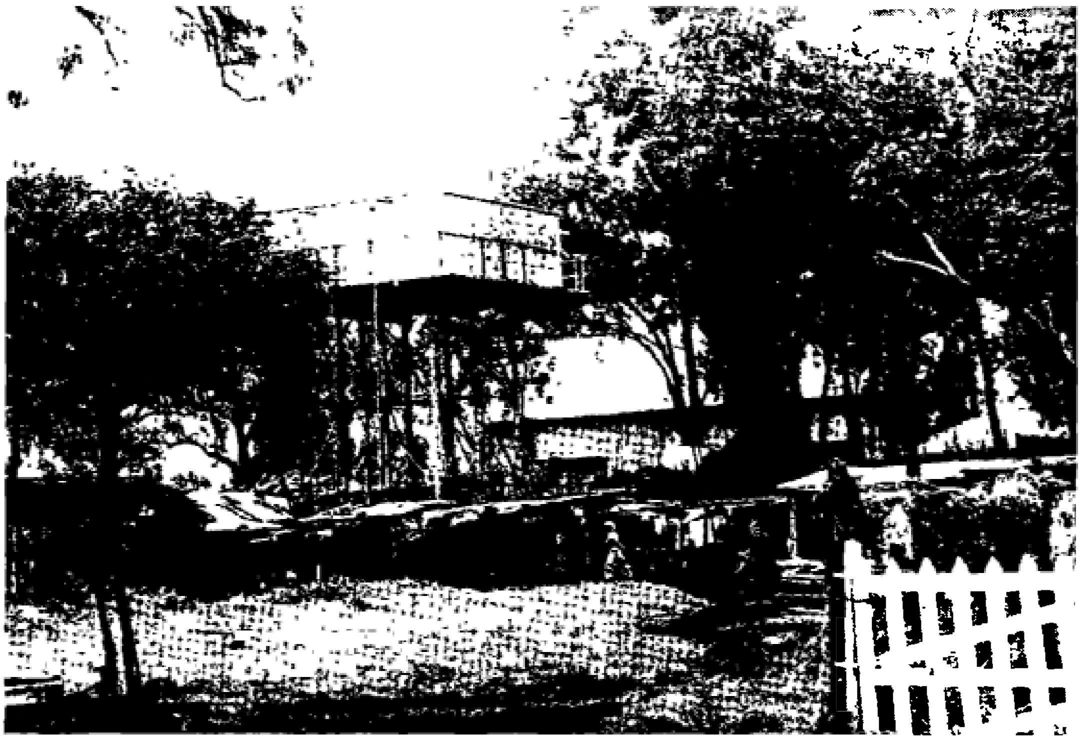
TABLE 5.3 PRESENT POPULATION OF KISUMU DISTRICT AS COMPARED WITH THE POPULATION OF 1979

DIVISION	1979 Census	1979* Corrected	1987* growth rate 3.3 %	1987** population
Maseno	93,188	103,423	134,437	140,866
Winam	32,305	36,090	46,913	47,426
Nyando	78,981	85,647	113,431	112,645
Muhuroni	48,520	54,945	71,420	67,868
Nyakach	76,690	87,264	111,331	104,010
KISUMU*** MUNICIPALITY	152,643	170,757	221,961	221,961
KISUMU DISTRICT	482,327	538,126	699,493	694,776

* Adjusted population based on census (1979) results CBS-population projections for Kenya 1980-2000, 1983.

** Population estimates based on consumers counted during the inventory survey (RDWSSP, 1987-1988).

*** Population within the extended Municipality boundaries as shown on Figure 5.1 Population by CBS (1983).



Storage reservoir at a Market Centre

Hand drilled well at Miwani Secondary School

TABLE 5.4 POPULATION PROJECTIONS OF KISUMU DISTRICT ACCORDING TO A 3.3 % GROWTH RATE

DIVISION	1987	1990	1995	2000	2005
Maseno	134,437	148,000	174,000	205,000	241,000
Winam	46,913	52,000	61,000	72,000	84,000
Nyando	113,431	125,000	147,000	173,000	204,000
Muhuroni	71,420	79,000	93,000	109,000	128,000
Nyakach	111,331	123,000	144,000	170,000	200,000
KISUMU MUNICIPALITY	221,961	245,000	288,000	339,000	398,000
KISUMU DISTRICT	699,493	772,000	907,000	1,074,858	1,255,000

These population estimates agree well with the projection as given in the Integrated land Use Survey (Ref.14, 1983) and the Integrated Regional Development Master Plan (Ref.22,1987).

It should be noted that these projections are based on a derived growth rate of 3.3 % for the whole District, which does not distinguish between the municipality and rural areas. Consequently, the projections for the municipality may well be underestimated.
In addition, it is likely that the most densely populated rural areas are likely to experience a lower growth rate, due to out migration, as pressure on the landholdings renders them unable to support the full brunt of increases. The more sparsely populated areas may experience immigration (as will the municipality), leading to the likelihood of a higher growth rate in those areas. These projections are likely to be under or over estimated, accordingly.

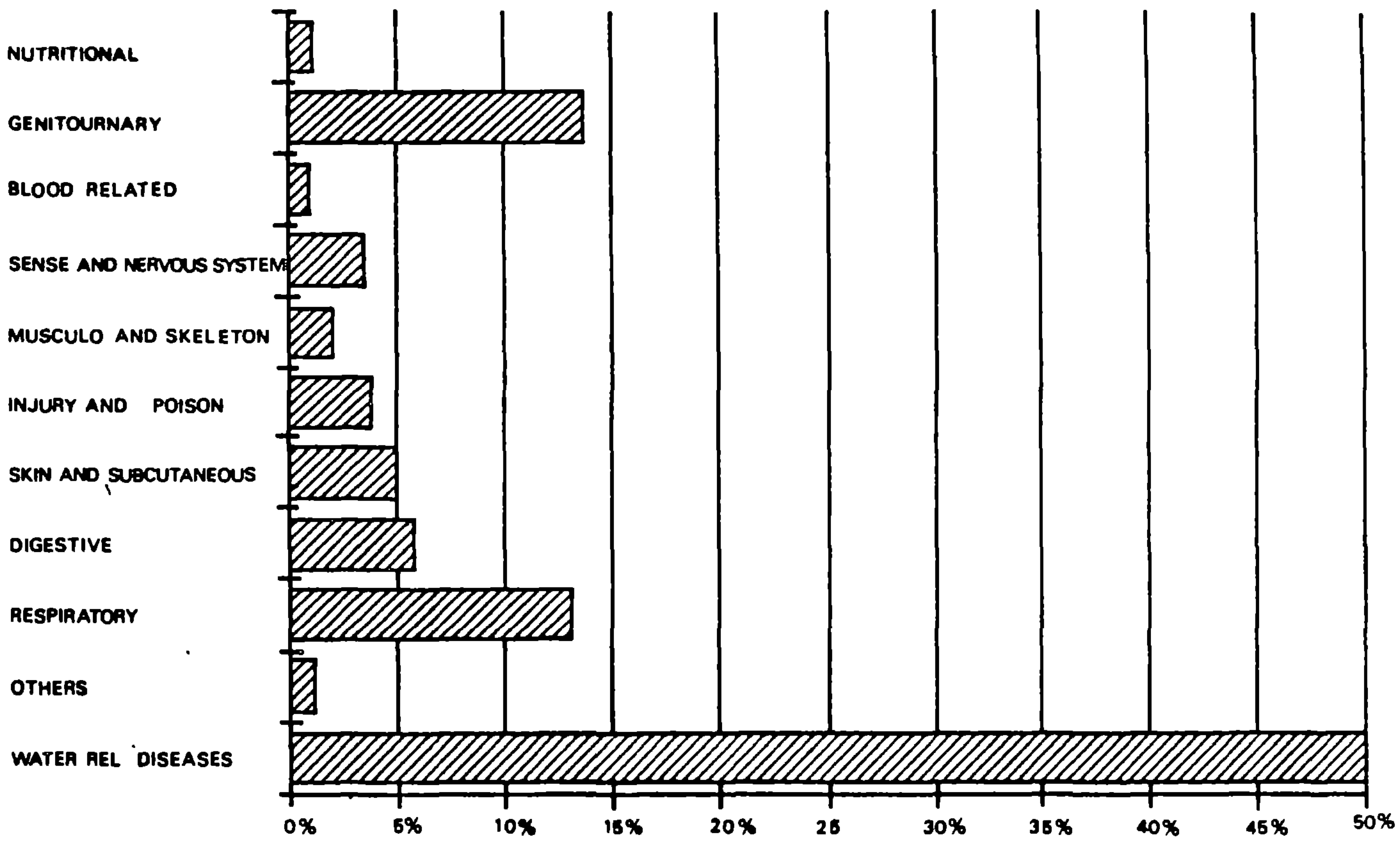


Figure 5.4 Comparative diagnosed disease rate of hospitals and health centres in Kisumu District

5.4 Health aspects

In Kisumu District a total of 61 health institutions are found from which 51 are managed by the Government and 10 by private institutions, and missions.

There are 5 hospitals located in Kisumu Town and one in Nyabondo. Further, 26 health centres and 30 dispensaries are operating in the District.

TABLE 5.5 HEALTH INSTITUTIONS IN KISUMU DISTRICT

Type of health institution	Government	Mission	Private	Total nr
Hospital	2	2	2	6
Health Centre	23	1	1	25
Dispensaries	26	1	3	30
Total	51	4	6	61

Generally the Health Centres offer more comprehensive services than Dispensaries, including beds for patients, maternity services, mother and child health care and family planning.

A socio-economic survey carried out in Kisumu District in 1987 revealed the most common diseases in the region, which are illustrated in Figure 5.4. From this figure it is evident that water related diseases are the most frequently occurring (50 %) followed by genitourinary (14 %) and respiratory (13 %) diseases.

Water related diseases include malaria, gastro-entritis, dysentry, typhoid fever and schistosomiasis.
Infant mortality and the child mortality rates in Kisumu District, 200 respectively 239 per 1,000, are amongst the highest of Nyanza Province.
This is also illustrated in the average life expectancy figure of 42.3 years in the District.

When considering that 60 % of the infant mortality is caused by diarrhoea, the need for safe and reliable drinking water in Kisumu District is evident.

Figure 5 5 Birth rates

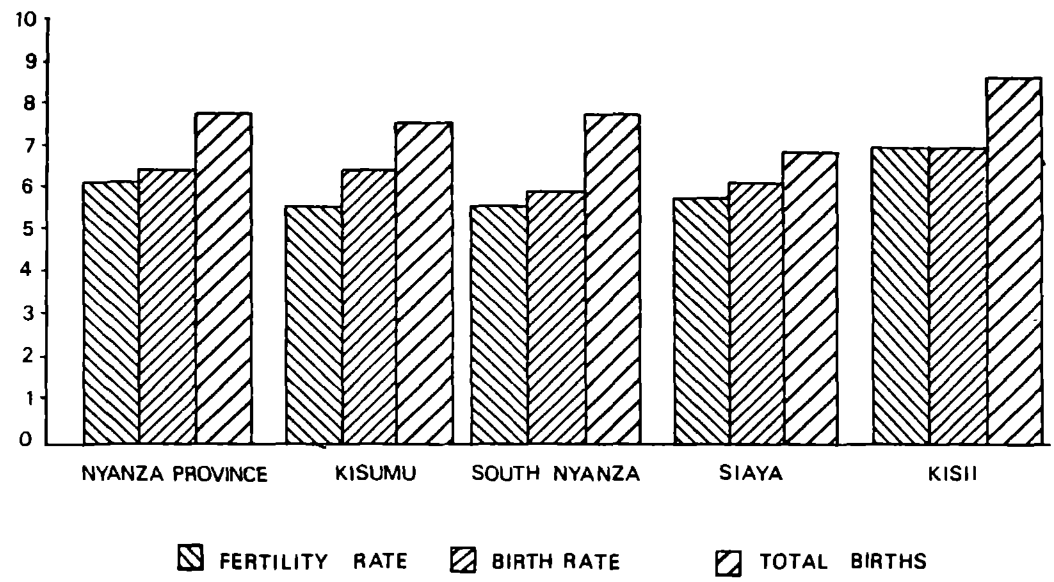


Figure 5.6 Infant and child mortality rates

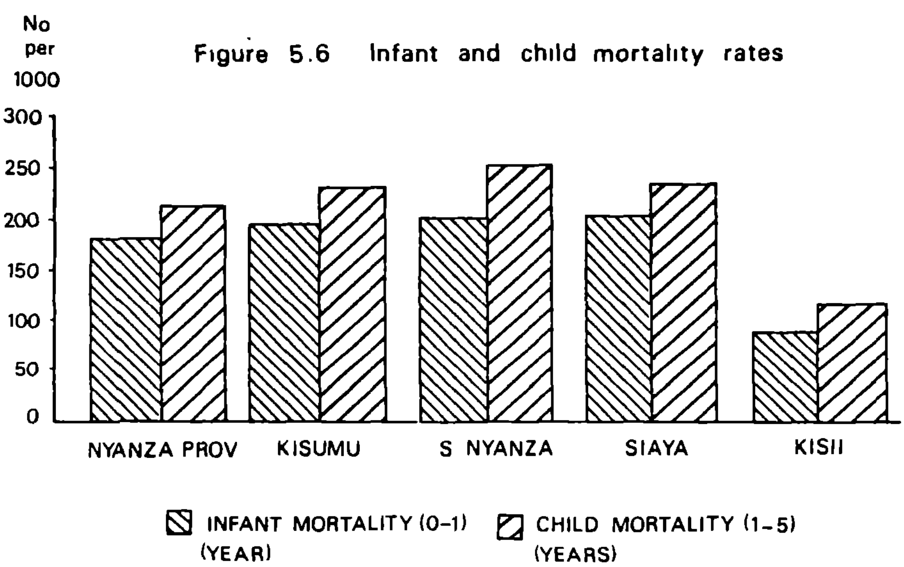
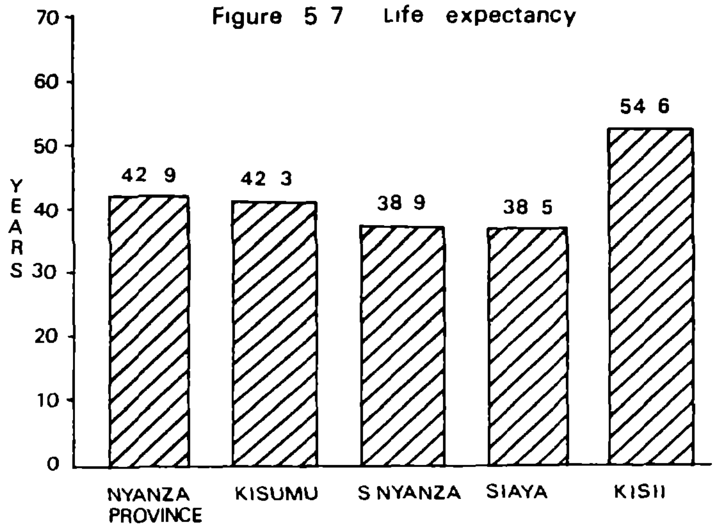


Figure 5 7 Life expectancy



5.5 Summary of socio-economic facts (1987)

General

Population	:699,493
Population density	:334
Population growth	:(1979-1987) 3.3 %
Size	:2,090 km^2
Altitude	:1,135-1,625 m
Tribe	:Luo

Administration

District Headquarters	:Kisumu
Number of Divisions	: 5
Number of Locations	: 24
Number of Sub-Locations	:113
Number of constituencies	: 5

Education

Number of primary schools	:530
Number of secondary schools	:104
Number of vocational Schools	: 24
Number of other schools	: 66

Education level

None	:20 %
Primary	:36 %
Intermediate	:26 %
Secondary	:15 %
Teacher Training	: 2 %
University	: 1 %

Health Institutions

Hospitals	: 6
Health Centres	:25
Dispensaries	:30
Family Planning services	:21

Village Organizations

Women groups	: 480
Farmers association	: 73
Self help groups	: 60
Cattle dips	: 76
Market places	: 123

Infrastructure

Post offices	:24
Credit institutions	:16
Telephone (public)	:66

Major occupations :

Farmer	:76 %
Teacher	:15 %
Other	9 %

Average monthly income :

Ksh 0 - 500	:22 %
Ksh 500 - 1,000	:40 %
Ksh 1,000 - 2,000	:4 %
Ksh 2,000 - 3,000	:20 %
Ksh > 3,000	:14 %

Livestock

Grade cattle	: 1,000
Local cattle	: 161,000
Sheep & goats	: 69,000

Fetching of surface water in Nyando Division

PART 3

EVALUATION OF EXISTING WATER SUPPLY SITUATION

5th Edition May 1987

NUMBER
Name of site
Village
Sub-Location
Location
Division
District
Map sheet
Grid ref
Date of visit

INVENTORY OF EXISTING AND CONSTRUCTED WATER COLLECTION POINTS

NATURAL			CONSTRUCT						
Water Hole	Spring	River	Hand dug well	Hand drilled well	Roof catch ment	Bore hole	Ground catch ment	Dam	Spring improve ment
(WH)	(S)	(R)	(W)	(W)	(RC)	(BH)	(GC)	(D)	(S)

TECHNICAL INFORMATION
width / diameter (m)
depth (m)
water level (m-gl)
discharge (estimate) (l/min)
type of material (lining or tank)
(handpump present (yes/no)
type of handpump (brand)
slab present (yes/no)
constructed by
year of construction

WELLS/ROOF CATCHMENT
condition lining (good/fair/poor)
if lining necessary-
top lining (how many m)
full lining (m)
bottom lining (m)
condition of slab (good/fair/poor)
pump working (yes/no)
condition of reservoir (good/fair/poor)
condition of gutters (good/fair/poor)

GROUND CATCH./DAMS
erosion (yes/no)
spillway (silted/eroded/good/no)
reeds (yes/no
dam silted (yes/no)
leakage down (yes/no)
outlet pipe (yes/no)
tap (yes/no)
cattle trough (yes/no)
fenced (yes/no)

SPRINGS
leakage sides/underneath (yes/no)
condition of slab (good/fair/poor)
undermined (yes/no)
protect against surf water (yes/no)
presence of fence upstream (yes/no)
possib. of groundwater poll. (yes/no)
proper drainage downst (yes/no)
presence of overflow pipe (yes/no)
height of drawoff pipe (m above gl)
handpump working (yes/no)

APPRAISAL OF FACILITY
general condition (good/fair/poor)
rehabilitation recommended (yes/no)
accessibility (foot/car)
type of protection (grav/shallow well)

rehabilitation works: new well ☐ deepen ☐ lining ☐ pump ☐ drain upstr ☐ spillway ☐ cattle tr ☐ connection to storage tank ☐ drain downstr ☐ fence ☐ cover ☐ overflowpipe ☐

water quality: milky ☐ muddy ☐ smelling ☐ salty ☐ clear ☐ colour ☐

WATER USE PATTERN
number of families served
total population served

use	yes	no
drinking		
cooking		
washing		
bathing		
cattle		
shamba irrigation		
brick making		
others		

if not used for drinking
number of alternative source

settlement pattern around point
scattered S
concentrated C

villages from which people originate

WATER QUALITY FROM LABORATORY

		unit
temperature		°C
conductivity		μ mho/cm
pH		
faecal coliforms		/100ml
turbidity		ntu
alkalinity		mg/l ($CaCo_3$)
hardness		mg/l ($CaCo_3$)
calcium		mg/l
magnesium		mg/l
chloride		mg/l
fluoride		mg/l
manganese		mg/l
iron		mg/l
sulphate		mg/l
phosphate		mg/l
ammonia		mg/l (as N)
nitrate		mg/l (as N)

WATER QUALITY OPINIONS
what does the community think of the water quality

	good	fair	poor
drinking			
cooking			
washing			

CONSTRAINTS OF WATER SUPPLY

	yes	no
is the source drying up		
during how many months no water		

if the source is drying
what action is taken

	yes	no
- deepening		
- longer waiting periods		
- reduced water consumption		
- dependent on more remote sources		
- number of alternative source		

OWNERSHIP
is the waterpoint public or private (public / private)
who owns the water point
who owns the land on which the water point is located
who can use the source

REMARKS

MAINTENANCE
is maintenance carried out (yes / no)
if yes is it carried out regularly (re) or irregularly (irr) (re / irr)
with what frequency is the maintenance carried out

daily	weekly	monthly	6monthly	yearly	other

who carries out the maintenance

Figure 6 1 Inventory form used for data collection on existing water points

6 EVALUATION OF THE EXISTING WATER SUPPLY SITUATION

6.1 Set up of the survey

In order to assess the present rural domestic water supply situation in Kisumu District a field survey was carried out to map and evaluate all existing water supply resources. The resources fall into two categories:

1. point sources, which supply water at the spot of the source only

2 piped water supply schemes, which transfer water from the source to several points of extraction.

The first category has been investigated by RDWSSP field surveyors who traced and visited each individual point source. From each water point the geographical position was plotted on a 1:50,000 scale topographical map. Information was recorded using forms as shown in Fig 6.1 on:

- type of water point
- condition and functioning
- water use pattern
- possibilities for improvement.

All collected data on point sources have been stored in a (dBASEIII+) data base, facilitating easy access and statistical processing.

The piped water supply schemes were reviewed by a specialist who made a technical description of each system, reported on its functioning, and made an assessment of its water use. These data have in most cases been confirmed with the organization responsible for its operation.

The inventory survey was executed between December 1986 and December 1987. Table 6.1 shows the survey periods for each Division.

TABLE 6.1 SURVEY PERIODS PER DIVISION

Division:	Survey period:	
Nyakach	December 15th 1986	- February 28th 1987
Winam	February 15th	- March 31st 1987
Nyando	July 22nd	- September 27th 1987
Muhoroni	September 23rd	- October 25th 1987
Maseno	October 14th	- December 17th 1987

To get a complete picture of the existing situation, key figures as the number of consumers, number of taps and water quality data of the piped supply systems are combined with the point sources data.

Water points are used for different purposes as drinking, cooking washing etc. It is possible that a person uses a certain water point for drinking and cooking, whilst washing and bathing is done using in another source. This consumer is then double counted in the inventory survey. Checking of data has learned that double counting seldom occurs since less than five percent of the water points is not used for drinking. Nevertheless a small discrepancy between the number of consumers and the actual population remains.

All recorded point sources and piped water schemes are indicated on Map 3 which is annexed to this report.

In the next sections, the present rural domestic water supply situation is discussed from different points of view. Section 6.2 gives a description of the characteristics of point sources as found during the survey, while in the next section piped water water systems are discussed. Aspects related to the use of the different water sources are described in section 6.4, followed by an evaluation of the present water supply situation in section 6.5.

Fetching of surface water near Ahero

6.2 Point Sources

6.2.1 Introduction

In the rural parts of Kisumu District point water sources are most commonly used for domestic water supply. Characteristic for these water points is that the water is fetched at the source. Point sources can be natural as well as man made. The following types of water points are found:

Natural sources	Man made sources
- Springs	- Boreholes
- Water holes	- Wells
- River and lake points	- Roof catchments
	- Ground catchments
	- Dams

Water points characteristics are discussed generally in section 6.2.2. The specific characteristics for each type of point source are described in section 6.2.3.

6.2.2 Water point characteristics

Each type of water point has its characteristics which are decisive for its use. These features are:

- the water quality
- the walking distance
- status and number of consumers
- water yield and constraint during the dry season
- number, regions and density of occurrence.

Water quality

The quality of water fetched at the different types of water points depends both on its origin, and on pollution or contamination at the water point itself. The quality of surface and ground water resources is discussed in Parts 5 and 6. A summary of the findings is given below.

- Ground water from confined aquifers is good and can be used all over the District. The Kenyan standards for drinking water are met almost everywhere.
  Contamination is observed in water from shallow unconfined aquifers due to the percolation of polluted surface water, and the presence of pit latrines nearby. Especially in densely populated areas pit latrines are an important source of contamination.

- Surface water appears to be contaminated almost everywhere. Moreover, B.O.D. and turbidity are generally high. Chemical constituents are mostly within Kenyan standards.

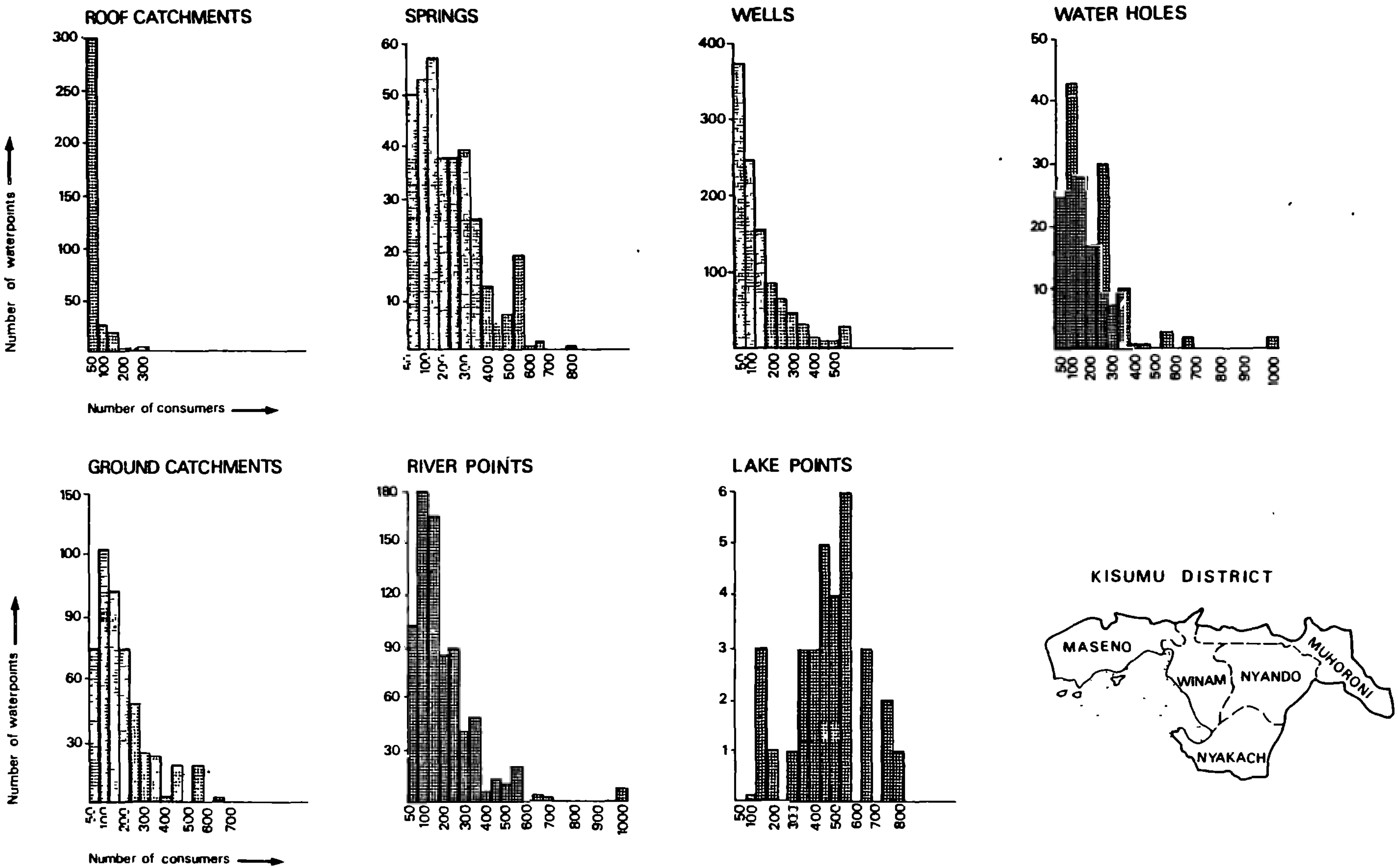


Fig 6 2 Consumption pattern histograms for different sources

Walking distance

The walking distance that consumers have to bridge to reach the water point depends mainly on the density of all water points in the area. Hardly any relation can be found between the walking distance and the type of water source.

Great efforts made to create a water point like a dam or ground catchment, indicate generally the lack of alternative water sources and a considerable walking distance.
In many cases it was found that people come from far to use perennial rivers and Lake Victoria as alternative source when other water points are found dry.

Status and number of consumers

The status indicates the communal or private use of the point source. Water points that can be used by the community are called communal water points regardless of the ownership. Privately owned water points are indicated as private if only a limited group of people, mostly the family, uses the source.

Evidently there is a strong relation between the status of a water point and the number of consumers. It was found that private sources serve up to 30 people whilst communal water points serve 120 consumers on an average.

Fig. 6.2 shows the division of the numbers of consumers per type of water point for all registered point sources. Data of boreholes and dams have been omitted since their number is too small for statistical analyses.

Water yield and constraint during the dry season

The water yield of point sources depends on the flow capacity of water to the collection point as well as the storage capacity of the water point.

Examples of water points for which the first criterion is decisive are boreholes, wells and springs; the maximum yield is limited by the ground water flow.

The yield of the water points from the second group is endless as long as the stored volume is not yet finished. Dams, ground catchments, lake points and roof catchments belong to this group.

Constraint is an frequently occurring shortcoming of nearly all types of water points, especially the latter group. If, and how long a water point falls dry is an important aspect. When a source dries up, people will start to use another one. Measures to reduce constraint are rarely taken.

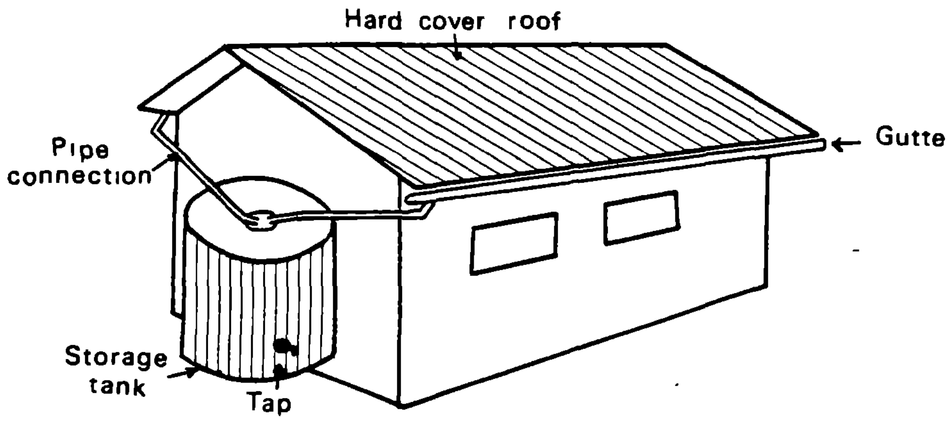


Figure 6·3 Typical roof catchment system

Number, regions and density of existence

The total number of a type of water point indicates the importance of its contribution to the rural domestic water supply.

The physical circumstances often cause that a type of water point often mainly appears in certain regions.

6.2.3 Description of different types of point sources.

Boreholes

Boreholes are machine drilled small diameter deep wells made to pump ground water from deep aquifers. Since the construction of a borehole needs a relatively large investment, boreholes are generally found at places where no other options for safe water supply are available. For this reasons, walking distances up to 3-4 km do regularly occur.

Generally, the yield of boreholes is abundant, serving many consumers. The water quality is excellent in most cases. Boreholes are perennial water points.

Only 17 boreholes which are used as point source, were recorded in Kisumu District. Nearly all of them in Muhoroni Division, where they serve the employees of the sugar factories.

Roof catchments

Roof catchments are constructions to intercept and to store rain water that falls on a roof. Its components should include of a hard cover slanting roof, gutters and pipe connections to collect the water and lead it to a storage tank. From this storage tank water can be fetched for consumption.

Most roof catchment systems are so small that they serve only the people living in the house as a private facility. But even for such few consumers, the storage capacities often are too small to bridge the dry season. This is generally due to inadequate design, or a poor condition of the system.

In order to make optimal use of both roof surface and storage tank capacity and create a perennial roof catchment, much attention must be paid to the design of the system.

Water quality of roof catchments can be considered as good and the risk of contamination very limited, if the system is flushed during the first rains and the water in the tank is well protected. Evidently the average walking distance is small.

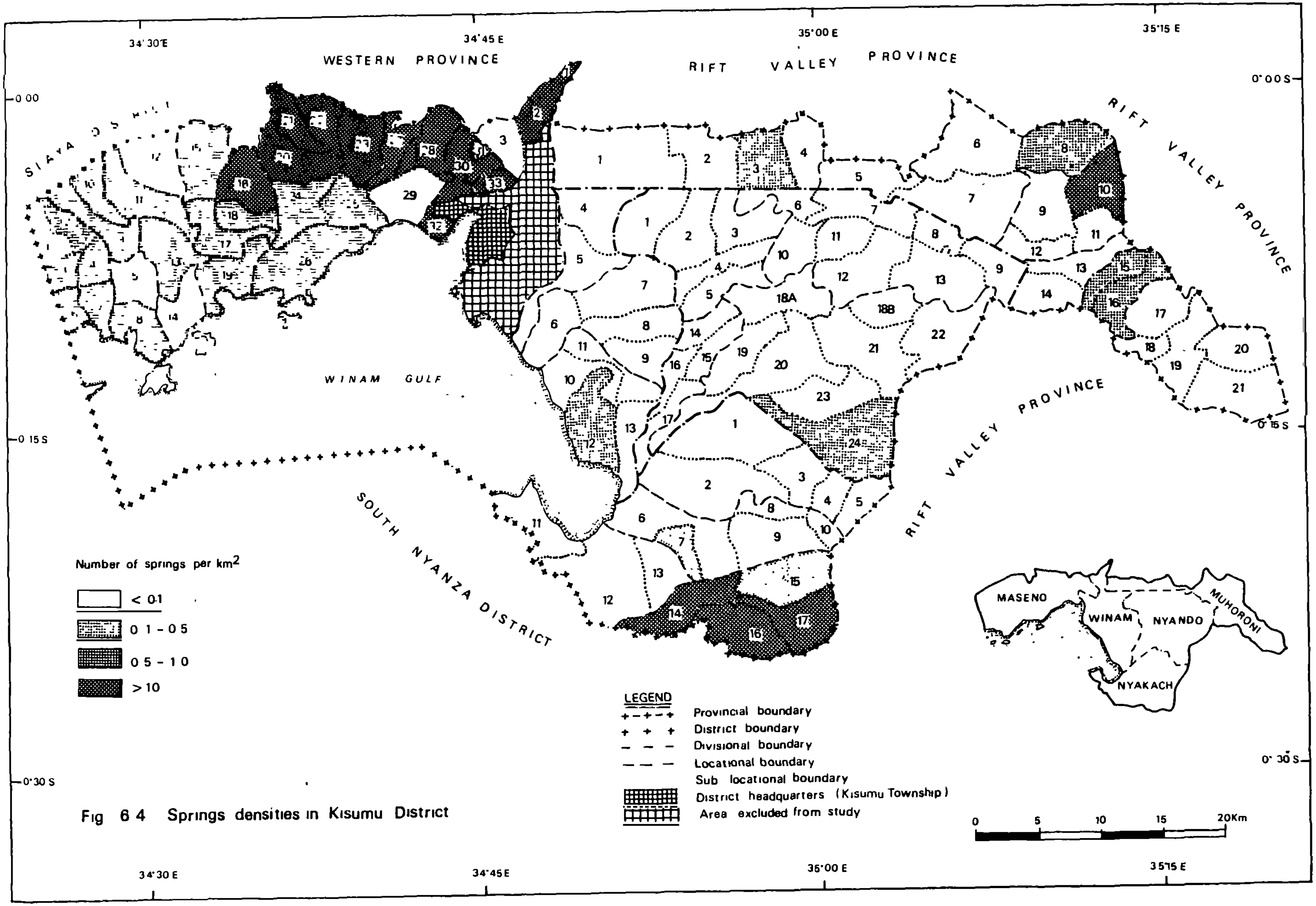


Fig 6 4 Springs densities in Kisumu District

Springs

At places where an aquifer intersects the earth's surface, springs can occur as concentrated streams of seeping ground water. Springs therefore mostly occur in mountainous areas and at the foot of escarpments. Figure 6.4 shows the springs occurring in Kisumu District. The types of springs as found in Kisumu District are mainly valley springs and some are overflow springs.

Of all sampled springs, 51% was found to be contaminated. Spring water itself is often of good quality. But many springs however are surrounded by pools of stagnant water which are mostly contaminated by washing, bathing, cattle and insects. A proper downstream drainage is a typical shortcoming of most springs.

Springs are mostly communal water points supplying water the year through. Yields generally vary between a few and some tens of liters per minute.

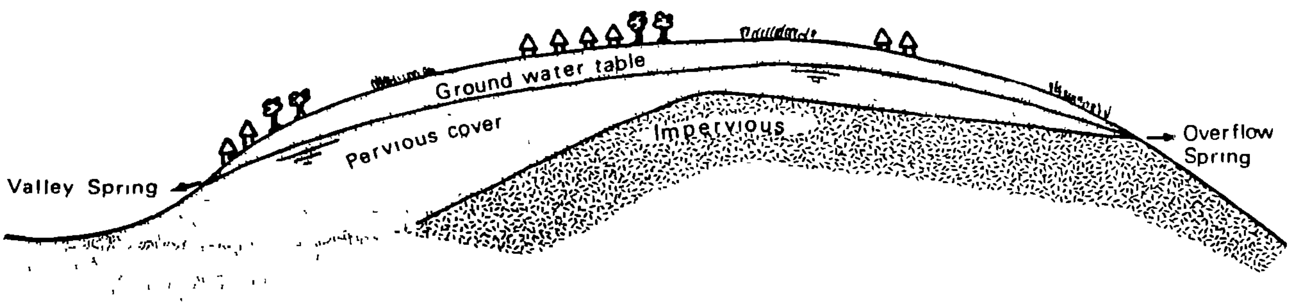


Figure 6 5 Typical cross section of different types of springs

Spring in Maseno Division

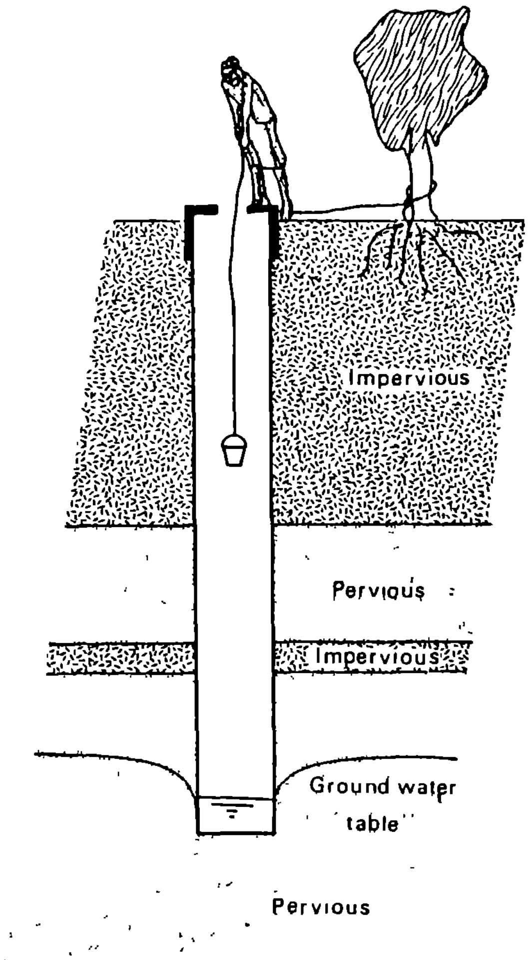


Figure 6 6 Typical cross section of a well

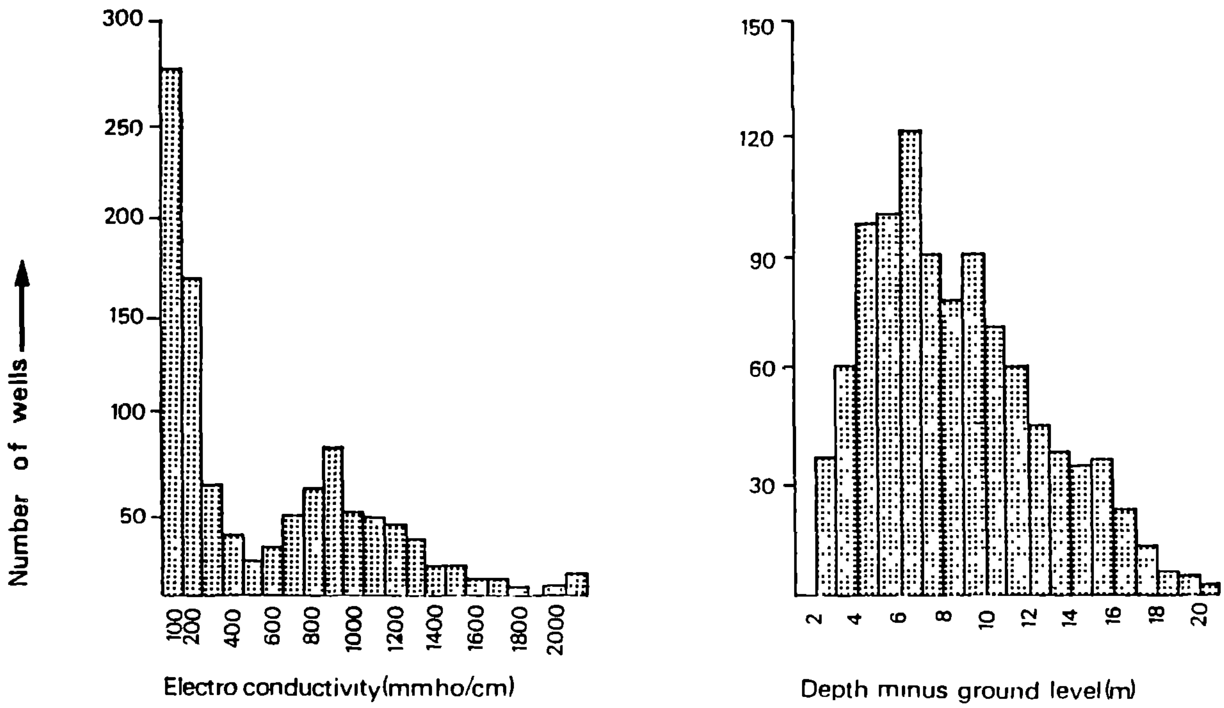


Fig 6·7 EC and depth of ground water in wells

Wells

Wells are hand dug holes made into the ground to exploit ground water. They occur in regions where the depth of the aquifers and the structure of the ground layers facilitate the use of ground water. In these regions wells have been dug in large numbers, most of them as private facilities. This results in limited walking distances.

The diameter of a well is around 1 m, and depths vary up to 20 m. 66% of all sampled wells in Kisumu District appeared to be contaminated. Contamination is often caused by:

- inflow of polluted surface run off due to the lack of a cover
- inflow of contaminated ground water from nearby pit latrines due to the lack of upper lining
- the use of dirty buckets.

To avoid these types of contaminations, wells should not be constructed in the vicinity of pit latrines, and be provided with a lining, a cover and a pump. The water quality of such protected wells is considered to be safe.

Many existing wells have a limited capacity because digging was stopped when the ground water table was reached, often resulting in a low inflow and storage capacity of the well.

Fig 6.8 shows that wells are mainly found in a few regions:

- around Maseno Town
- south-east of Rabuor
- south of Ahero
- in the north of the Kano Plain
- on the Nyabondo Plateau.

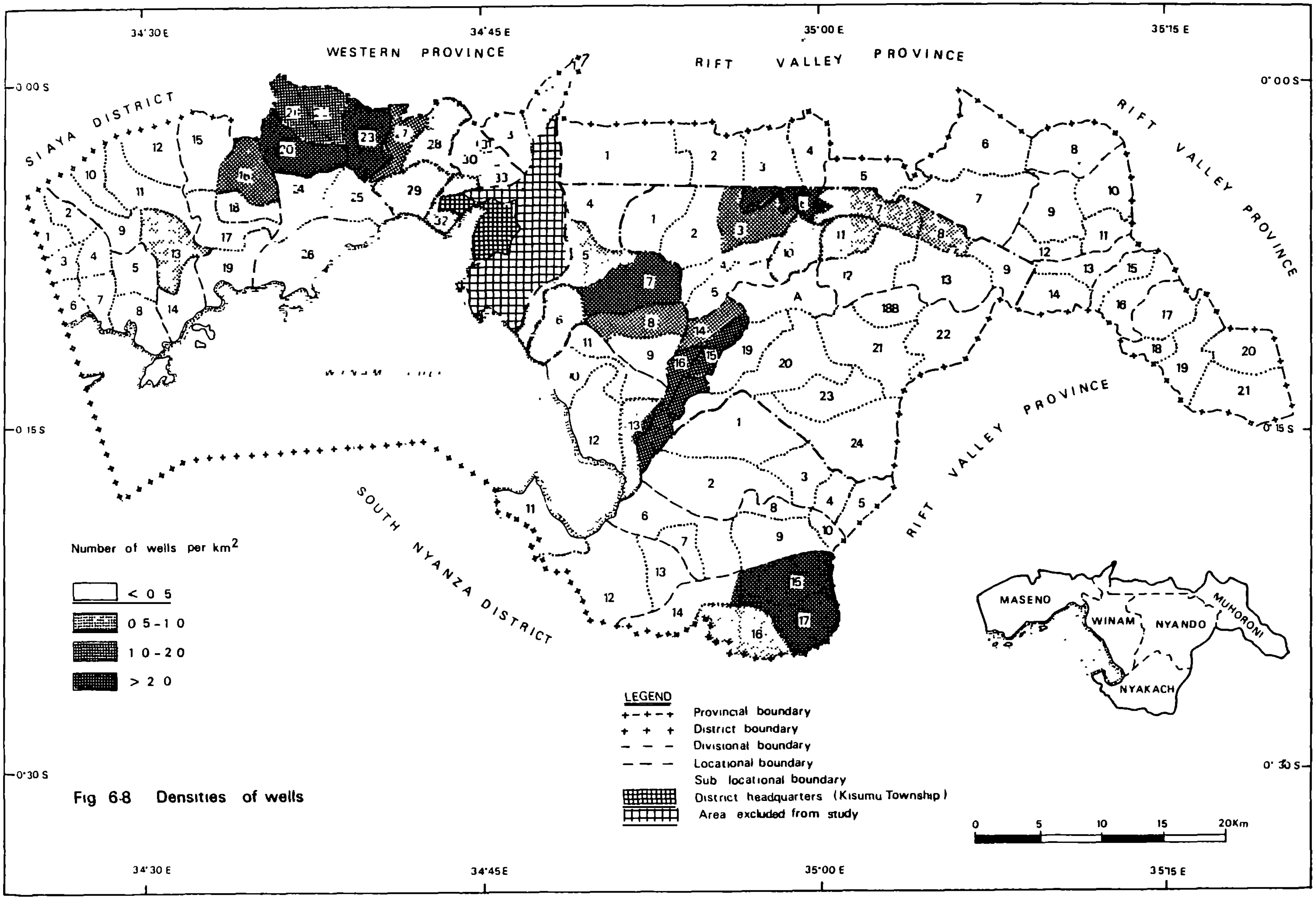


Fig 6.8 Densities of wells

Water holes

Water holes are terrain depressions filled with stagnant ground or surface water. Water holes need no special physical or geographical conditions for its existence.

Since water holes contain always stagnant water, they often are polluted by cattle and people. The water quality is mostly very poor. Water holes fed by ground water can be potential safe water points as long as good up and downstream drainage facilities are present.

Especially water holes fed by surface water, are found dry during the dry season.

MAP 3 shows that water holes are found mainly in Maseno Division.

Water hole in Nyando Division

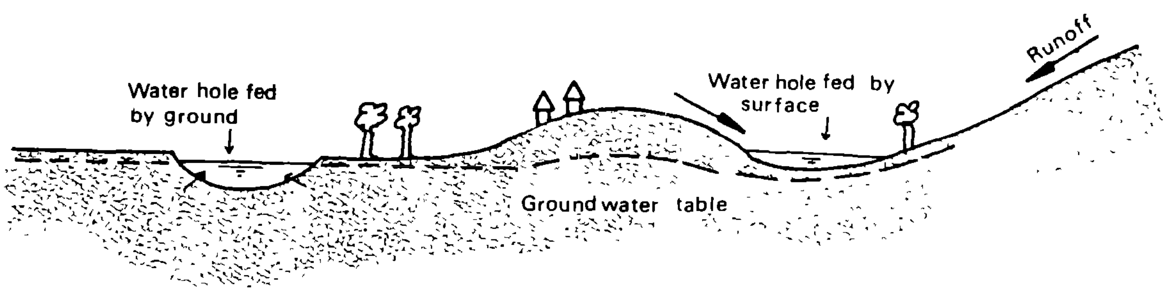


Figure 6·9 Typical cross section of different types of waterholes

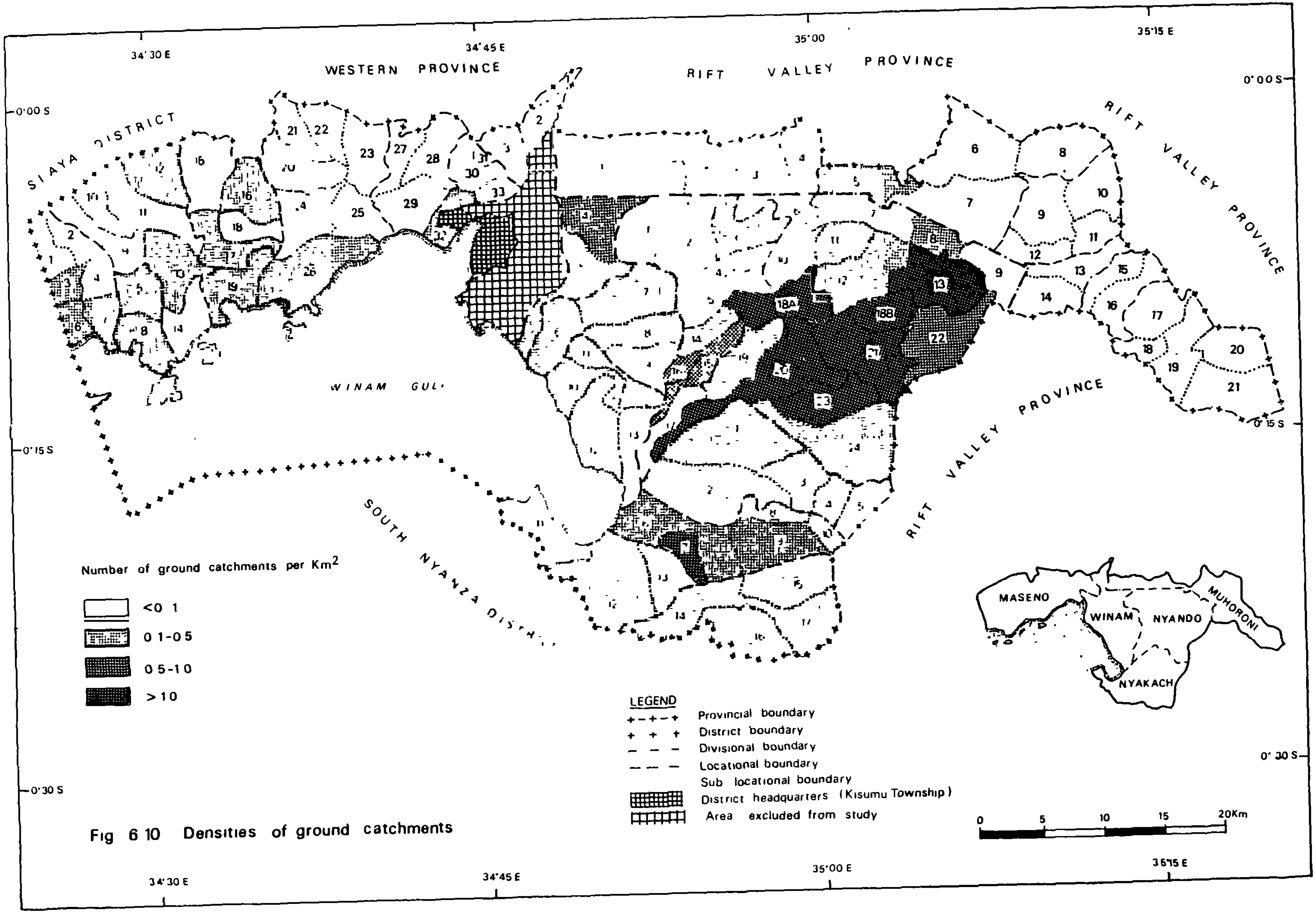


Fig 6 10 Densities of ground catchments

Ground catchments

These are man made half circular earthern dikes, made to intercept and store runoff water in shallow reservoirs. They are generally constructed in areas where alternative water sources are scarce, what implies that walking distances to ground catchment are normally long.

The diameter of ground catchments varies from around 15 m and may go up to 50 m. Since the runoff water can transport a lot of sediments, ground catchments need to be deepened regularly.

Many ground catchments run out of water during the dry season.

Fig 6.10 clearly indicates the important contribution to domestic water supply of ground catchments in the eastern part of the Kano Plain, where other types of water points are hardly available.

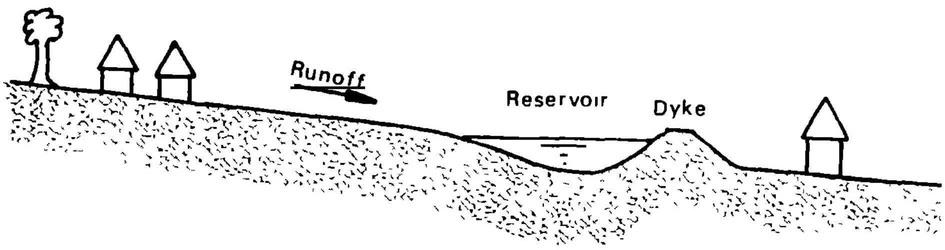


Figure 6.11 Typical cross section of a ground catchment

Dams

Dams are open water reservoirs, created by damming a seasonal or perennial river. As long as the water level in the reservoir, does not exceed the spillway, the river water will be captured in the reservoir.

The length of a dam is always less than 50 m. Since the water in the reservoir is stagnant and often contaminated by washing, bathing, cattle and insects, it's quality must be considered as poor.

Nearly all dams are perennial. Walking distances to dams are long since this type of water point is mostly constructed in dry areas.

The volume of the reservoir upstream of the dam will gradually be reduced by sedimentation. Dams need therefore regular maintenance.

The number of dams in Kisumu District is very limited.

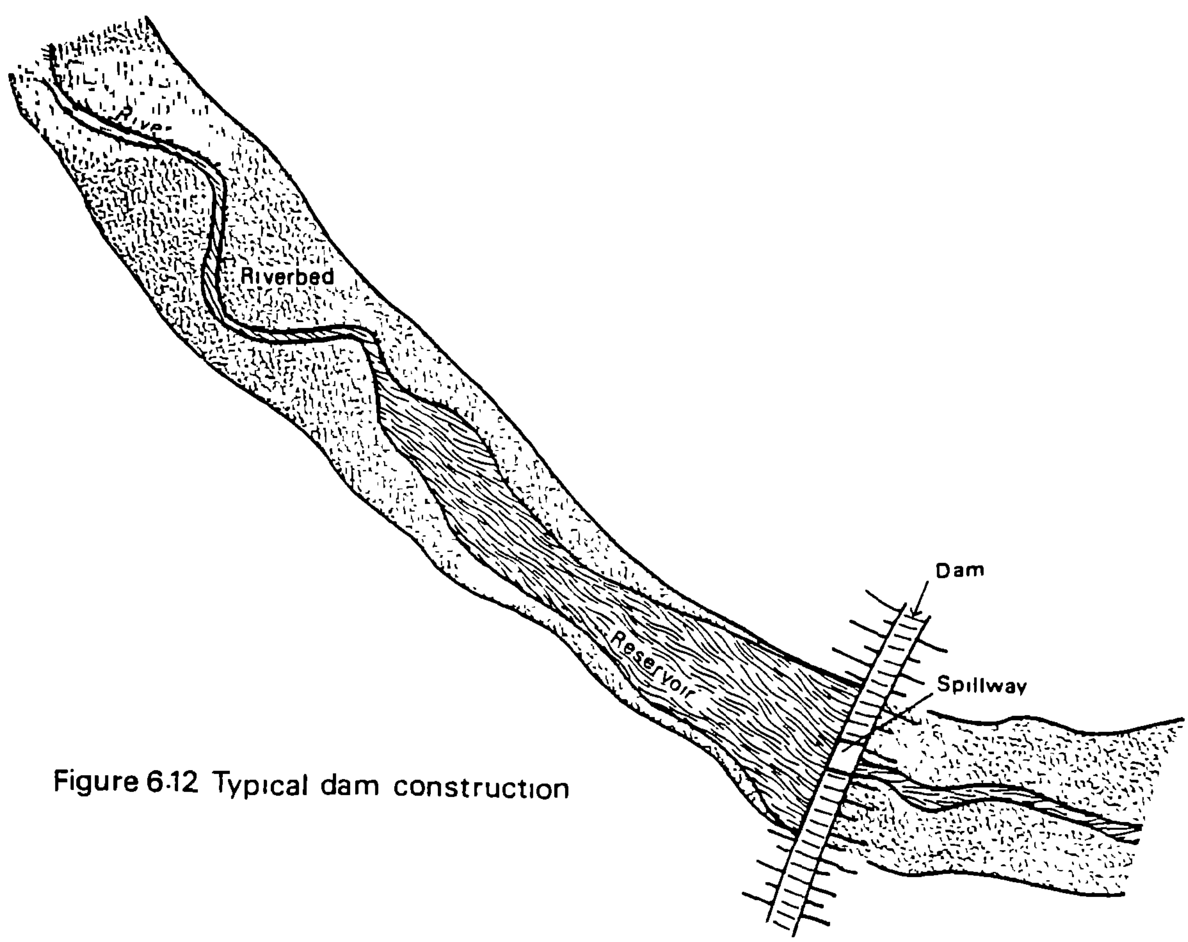


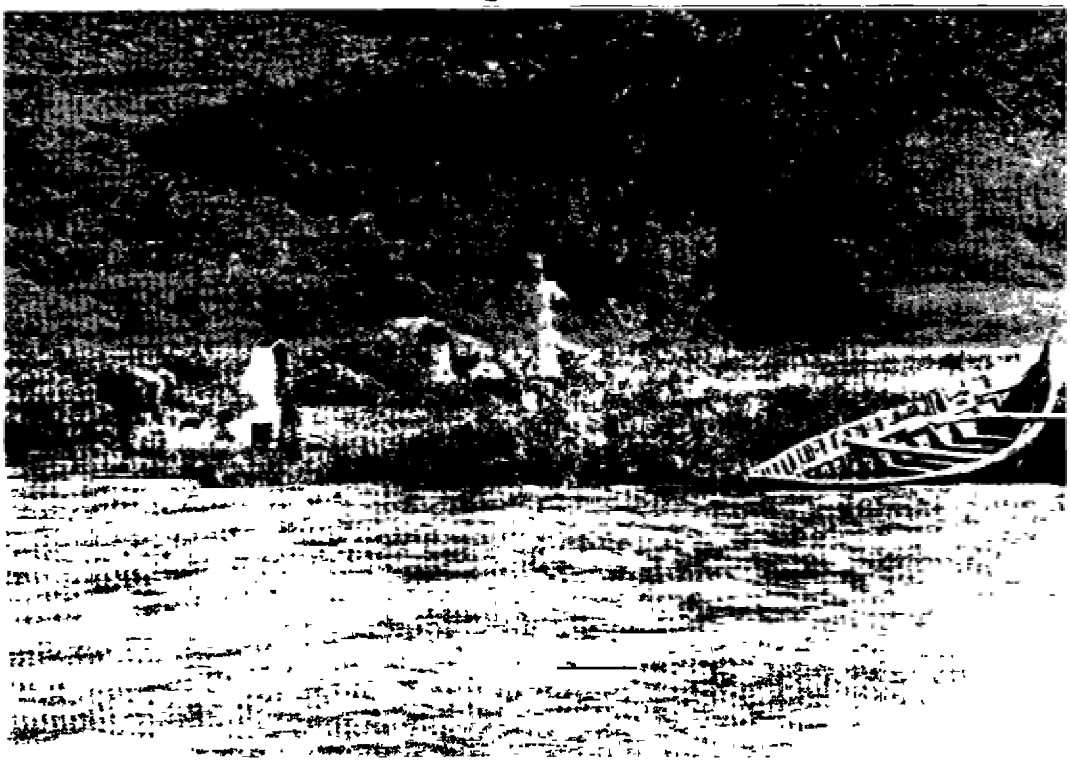
Figure 6.12 Typical dam construction

River points

River points are places along seasonal or perennial rivers where people usually fetch their domestic water, bath and wash their clothes. Except for domestic water supply, the rivers are also used by cattle and to dispose waste. Due to this, rivers are usually contaminated and its water quality should be considered as poor. Only some small seasonal streams in eastern Muhuroni were found to be uncontaminated.

Many rivers in Kisumu District are seasonal. This may lead to walking distances of 5 km or more if no alternative water points are present.

Rivers are a very important source of domestic water in almost all rural areas of Kisumu District, especially in the Seme Locations in Maseno and the east part of Muhoroni Division. Here rivers are almost the only source for domestic water.



Lake points

Lake points are points along the Winam Gulf where people usually fetch their domestic water, bath, wash their clothes and water their cattle. Since water at these places is stagnant it is easily contaminated and causes many water related diseases. The quality of lake water is therefore poor.

During periods of drought, the lake shore is for many people the nearest place to fetch water. This may lead to walking distances up to 5 km or more if no other water sources are available.

6.2.4 Good water points

In order to examine which existing water points could be marked as good, a detailed evaluation of the inventory data was carried out by means of a computer programme. Good water points are here defined as "probably safe and reliable ". Good water points are hand dug wells, improved springs and roof catchments, which fulfil the following requirements.

- The source is being used for drinking.
- The source does not dry up, or there is always enough water stored.
- Wells should have a slab which is in a fair or good condition. If chemical and bacteriological analysis were done no unacceptable values are found.
- Springs should have a covering slab which is in a fair or good condition. Furthermore there should be a proper drainage of spilled water and no possibility of upstream pollution of spring water.
- For roof catchments, both gutters and storage reservoir should be in a good condition.
- Boreholes should have a functioning pump.

Over the whole District 106 point sources, serving nearly 15,000 consumers can fulfil these criteria. This number consists of 53 roof catchments (50 %), 43 wells (41 %), six springs (6 %) and four boreholes (4 %).

Example of a "good water point"

6.3 Piped water supplies

6.3.1 Introduction

A piped water supply system transfers water direct from the source or after treatment, through a distribution network to the consumers. Although piped supply systems in Kisumu District may have different configurations they normally exist of the basic elements as depicted in Fig. 6.13.

Section 6.3.2 gives a description of the most important characteristics of piped supply schemes in relation to their contribution to rural domestic water supply in general.

All existing water supply schemes in the District have been recorded regardless of their status: functioning, out of order or still under construction. An outline of the findings is given in section 6.3.3. Plans for the new piped water supply systems and the extension of existing systems which are due to be implemented in the coming five years are discussed in section 6.3.4.

An evaluation of piped water supplies is found in section 6.3.5

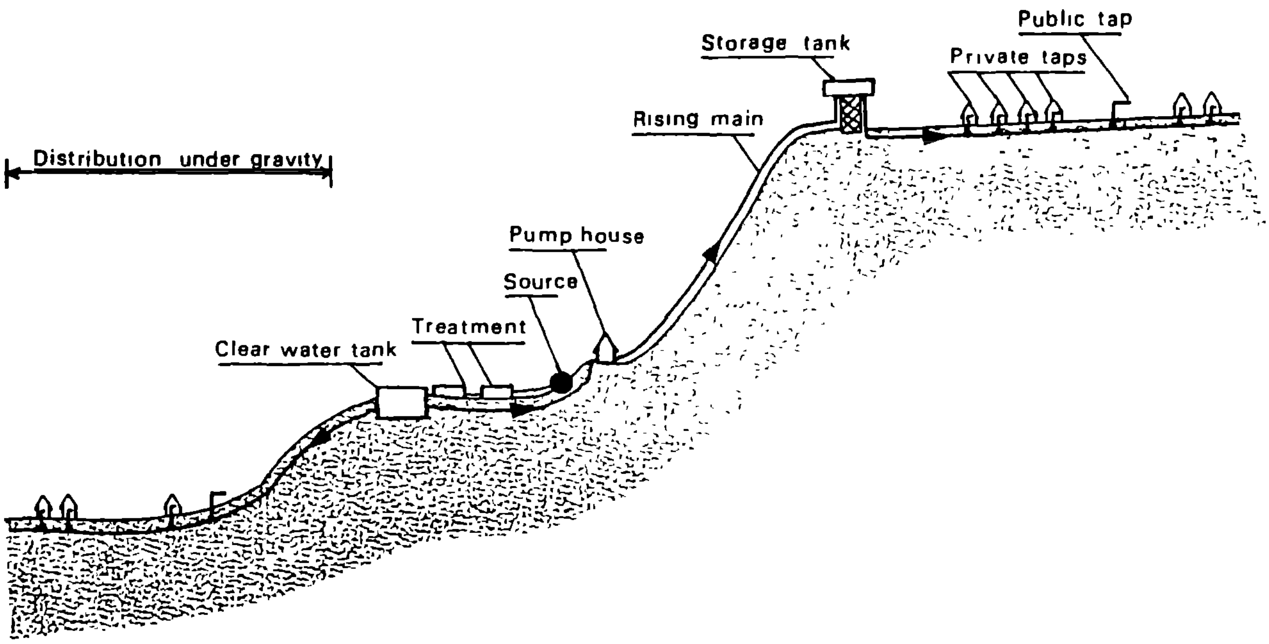


Figure 613 Schematic impression of a piped supply scheme

6.3.2 Characteristics of piped water supplies

Water quality

For point sources the quality of supplied water depends mainly on the source used. For piped water schemes a distinction can also be made between deep ground water, shallow ground water and surface water as described in section 6.2.2. Consequently the following general remarks can be made concerning the sources of piped water supplies and the need of water treatment.

- The water quality of boreholes is good. No treatment is necessary before distribution.

- Water from springs and wells does normally meet the Kenyan standards for drinking water except for the bacteriological quality. Therefore chlorination is mostly required to supply safe drinking water.

- Surface water as from rivers or the lake definitely needs an elaborated treatment before distribution due to contamination a high turbidity and sometimes pollution. Depending on the source, a good treatment system generally will include the following elements:

    - sedimentation
    - coagulation
    - filtration
    - Chlorination.

Many piped water supplies using surface water include a full treatment system. In discussions with several operation managers it appeared that the chemicals required in the treatment process are sometimes lacking for shorter or longer periods. In many cases this shortcoming results of a limited budget or logistic problems. If chlorine has run out, this may sometimes lead to the distribution of contaminated water.

Treated water is in most systems regularly tested on chlorine contents or pH at the beginning of the distribution network. The water quality as supplied through the network is sampled only occasionally. Contamination within the distribution network due to leaking pipe connections etc. are therefore not regarded.

In the next section it is assumed that all treatment systems work adequately throughout the year, although some might be considered as doubtful. This means that all piped water schemes are assumed to supply safe water if the necessary treatment works are present.

Reliability of supply

A reliable piped water system supplies water such that it's consumers can depend on it as their only source. It gives sufficient water at fixed hours and should not fail for more than a few days per year. Reliability gives no indication of the quality of supplied water in this context.

The main causes for unreliable supply are:

- blockage of the intake
- broken pumps
- lack of fuel for the pumps
- pipe breakages
- lack of pressure at the end of a pipeline.

For several piped water schemes it was found that some branches supply regularly while others don't.

Communal and private taps

Communal taps are free taps meant for communal use or water kiosks supplying charged water. Private taps are generally in-house connections to be used by the family. Private connections are often charged with a flat rate; some are metered.

It is difficult to estimate the number of consumers for each type of tap. The number of consumers of a communal tap exceeds normally 150. In some cases however, it is less due to a high density of taps. Private taps may serve a lot of consumers since the owners often allow others to use it. Especially if flat rates are applied.

Number of consumers

The number of consumers was received from the system manager or estimated considering the number and status of the taps, and the way that the water is charged for.

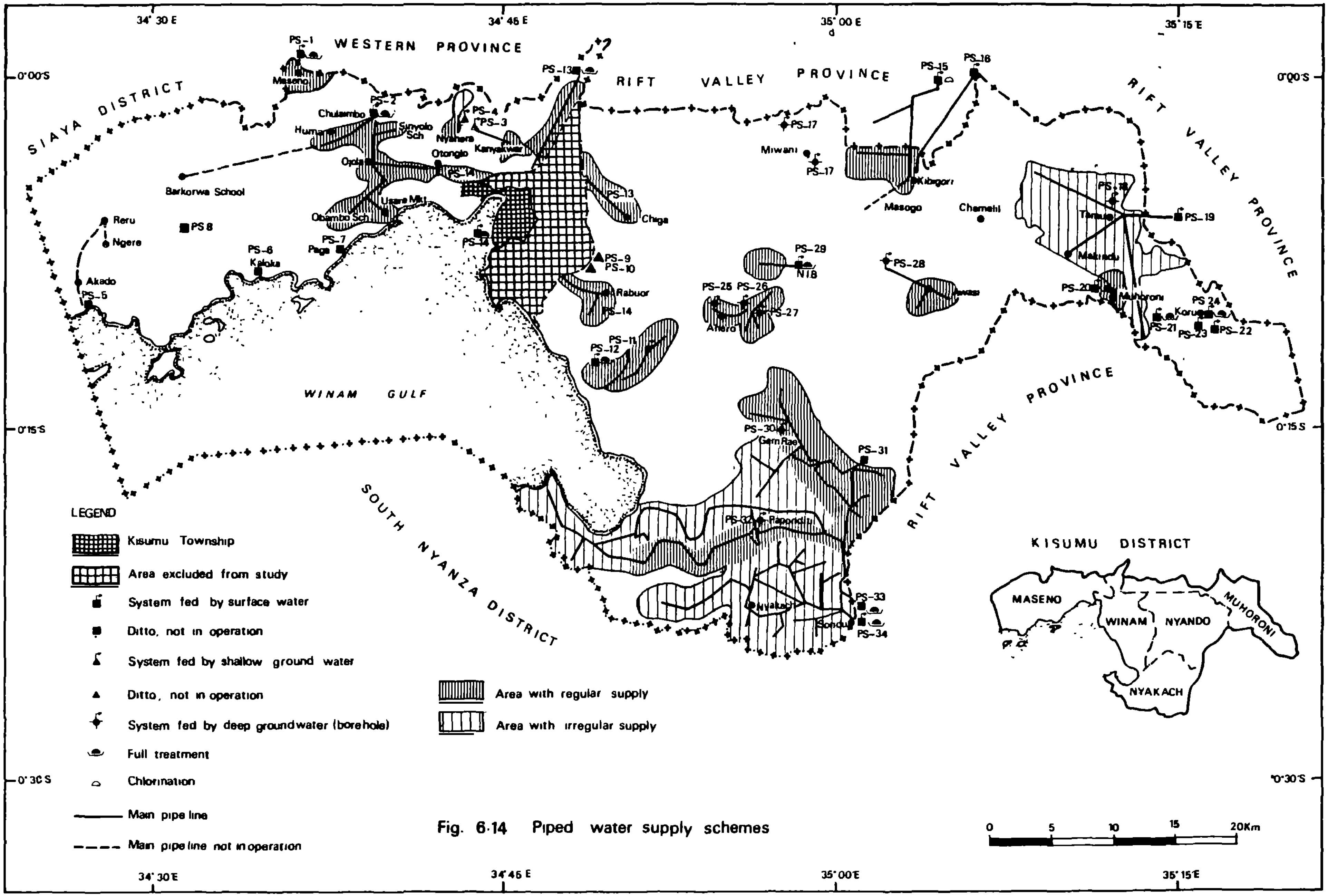


Fig. 6·14 Piped water supply schemes

6.3.3 Existing water supplies

Features of piped water supplies

Altogether 34 piped water supplies have been visited and described in the Divisional Reports of Kisumu District.

Table 6.2 gives an outline of the data of piped water supplies as found at the time of visit. It shows that 20 out of all systems supply safe water and 21 out of 34 have a regular supply. Seventeen or 50 % of all piped water systems supply safe and reliable water according to the given standards (section 6.3.2).

Fig. 6.14 shows for all piped water supplies:

- location of the intake
- main pipe lines and a schematic view of the covered areas for the larger schemes
- type of source used
- existence of a treatment system
- functioning of the system.

Around 100,000 consumers make use of piped water schemes in Kisumu District. Figure 6.15 shows that nearly 65% of them make use of the 14 systems which are operated by the Ministry of Water Development. All other organizations responsible for the operations of rural piped water supplies serve less than 10,000 consumers. The Ministry of Health is responsible for the operation of two small systems which were found to be out of use. The same figure shows that the average number of consumers is relatively high for M.o.W.D. schemes. This is mainly caused by the large Nyakach Water Supply. Without this scheme the average would drop to less than 2,300.

Related to the total number of piped water systems, electricity is the most important source of energy. It is used for 15 schemes which serve around 75% of all consumers. Diesel is used by 12 schemes, serving less than 10% of the consumers, as depicted in Fig. 6.16. The only system relying on wind energy happened to be out of order.

Of all present consumers 60% meet a regular supply, whilst the other 40% do need additional sources for their domestic water demand, as presented in Figure 6.17. Except for the 21 systems with regular supply, there are 12 systems supplying irregularly, three out of order and another three under construction. The major number of schemes with irregular supply or those out of order depend on diesel as its energy source. Although more systems use electricity than diesel, six diesel systems show constraint against only two electrified systems. Apparently, diesel systems are more vulnerable.

TABLE 6.2 INFORMATION OF PIPED WATER SYSTEMS.

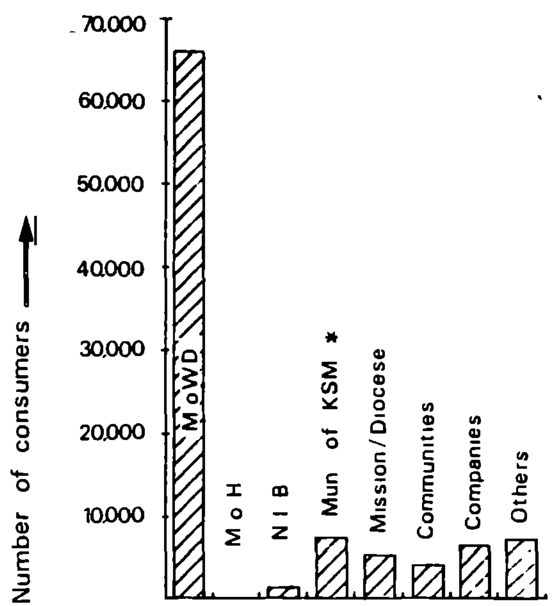
	Name:	Division:	Operated by:	Source:	NO. OF TAPS Publ.	Priv.	No. of Cons.	TREATMENT Full	Chl.	Req.	SAFE	ENERGY	SUPPLY Reg.	S & R	REMARKS:
PS-01	Maseno W.S.	Maseno	M.o.W.D.	River Jordan	11	20	3,300	Yes			Yes	Electricity	Yes	Yes	Rehab works nearly finished.
PS-02	Maseno Kombewa W.S.	Maseno/ Western P.	M.o.W.D.	Stream	21	211	4,630	Yes			Yes	Gravity	Yes	Yes	Contamination found.
PS-03	Kanyakwar W.S.	Maseno	M.o.W.D.	Springs	2	53	1,030			Yes		Electricity	Yes		Branch out of order
PS-04	Nyahera W.S.	Maseno	M.o.W.D.	Springs	20	42	2,820			Yes		Diesel	Yes		Pressure problems.
PS-05	West Seme W.S.	Maseno	Community	Lake Victoria			0			Yes		Diesel			Under construction
PS-06	Kaloka W.S.	Maseno	Community	Lake Victoria			0			Yes		Wind-mill			Mill out of order.
PS-07	Paga W.S.	Maseno	M.o.W.D.	Lake Victoria			0			Yes		Diesel			Under construction
PS-08	Koruenje W.S.	Maseno	M.o.W D.	River Awach			0			Yes		Diesel			Under construction
PS-09	Bouye W.S.	Winam	Min.of Health	Well			0			Yes		Diesel			Out of use
PS-10	Kaloo W.S.	Winam	Min.of Health	Well			0			Yes		Diesel			Out of use.
PS-11	Withur W.S.	Winam	Community	Borehole	9	30	3,150				Yes	Diesel	Yes	Yes	
PS-12	West Kano Irr. Scheme	Winam	N.I.B	Irr.Canal	14	4	320	Yes			Yes	Electricity	Yes	Yes	
PS-13	Kajulu Water Works	Winam	Municipality of Kisumu	River Kibos	1	8	2,000	Yes			Yes	Gravity	Yes	Yes	
PS-14	Kisumu Water Works	Winam	Municipality of Kisumu	Lake Victoria	3	25	3,600	Yes			Yes	Electricity	Yes	Yes	
PS-15	Kibigori W.S.	Nyando/ Muhoroni	M.o.W.D.	Stream	80	10	3,700		Yes		Yes	Gravity	Yes	Yes	Branche out of order.
PS-16	Kibigori Ken. Railroad W.S.	Nyando/ Mihoroni	Kenya Railways	River Kundos	1	2	540			Yes		Gravity	Yes		Mainly for railroad station.
PS-17	Miwani Sugar Mills W.S.	Muhoroni	Miwani Sugar Mills co.	Boreholes	11	300	4,500				Yes	Electricity			Mainly for employer's camps. Factory closed recently
PS-18	Tamu W.S	Muhoroni	M.o.W.D	Borehole	1	37	500				Yes	Diesel	Yes	Yes	

Note: Chl.=chlorinaton,Req.=required,Reg =regular,S&R=safe and reliable

See next page.

TABLE 6.2 INFORMATION OF PIPED WATER SYSTEMS (CONTINUED).

	Name:	Division:	Operated by:	Source:	NO. OF TAPS Publ.	Priv.	No. of Cons.	TREATMENT Full	Chl.	Req.	SAFE	ENERGY	SUPPLY Reg.	S & R	REMARKS:
PS-19	Tamu Settlement W.S.	Muhoroni	Muhoroni Water Association	River Mombwo	33	66	6,000			Yes		Gravity			
PS-20	Muhoroni W.S.	Muhoroni	M.o.W.D.	River Nyando	7	106	2,500	Yes			Yes	Electricity	Yes	Yes	
PS-21	Koru-Mnara W.S.	Muhoroni	D.D.C.	Stream	10	1	800	Yes			Yes	Electricity	Yes	Yes	
PS-22	Koru Cath. Mission W.S.	Muhoroni	Cath. Mission	River Koru	20	55	2,950			Yes		Electricity			Pipes breake regularly.
PS-23	Koru Nursing Home	Muhoroni	Koru Hospital	River Koru		1	30			Yes		Gravity	Yes		
PS-24	Homa lime Co.	Muhoroni	Homa lime Co.	River Koru	14		1,650	Yes			Yes	Electricity	Yes	Yes	Employers' camp only
PS-25	Ahero Cath. Mission W.S.	Nyando	Cath. Mission	Borehole	2	5	870				Yes	Electricity	Yes	Yes	
PS-26	Onjiko W.S.	Nyando	School/B.O.G	Borehole		3	550				Yes	Electricity	Yes	Yes	Mainly for the school.
PS-27	Boya W.S.	Nyando	Community	Borehole	30	72	4,550				Yes	Electricity	Yes	Yes	Pressure problems.
PS-28	Awasi W.S.	Nyando	M.o.W.D.	Borehole	3	22	900				Yes	Diesel	Yes	Yes	
PS-29	Ahero Irr. Scheme W.S.	Nyando	N.I.B	Irr.Canal	3	17	1,370	Yes			Yes	Diesel	Yes	Yes	
PS-30	Gem Rae Water Supply	Nyakach	Diocese of Maseno South	Borehole	2	7	500				Yes	Diesel			
PS-31	Thur Gem Water Supply	Nyakach	M.o.W.D.	PS-34	4	11	450			Yes		N.A.			Engine and treatment are stand-by for PS-34
PS-32	Pap Onditi/ Olembo	Nyakach	M.o.W.D.	Borehole	2	2	400				Yes	Diesel			Pump broken.
PS-33	Nyabondo W.S.	Nyakach	M.o.W.D.	PS-34	12	268	7,000				Yes	N.A.			Engine and treatment are stand-by for PS-34
PS-34	Nyakach W.S.	Nyakach	M.o.W.D	River Sondu	70	100	38,000	Yes			Yes	Electric	Yes		Construction works are nearly finished.
				Totals:	386	1,478	98,610	10	1	12	21		21	16	



* in study area only

Fig 6 15a Breakdown per number of consumers

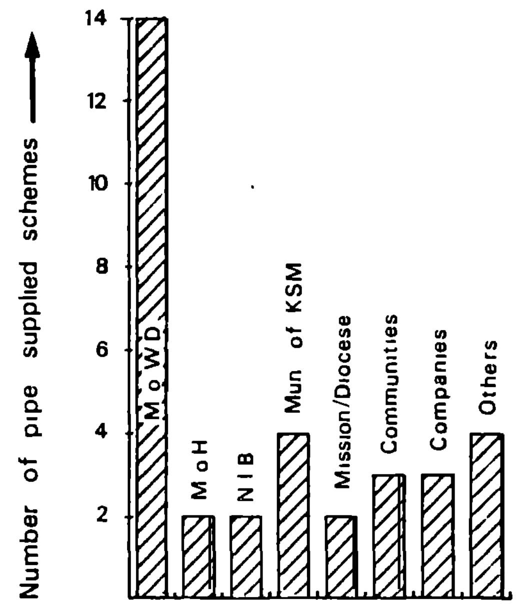


Fig 6 15b Breakdown per number of schemes

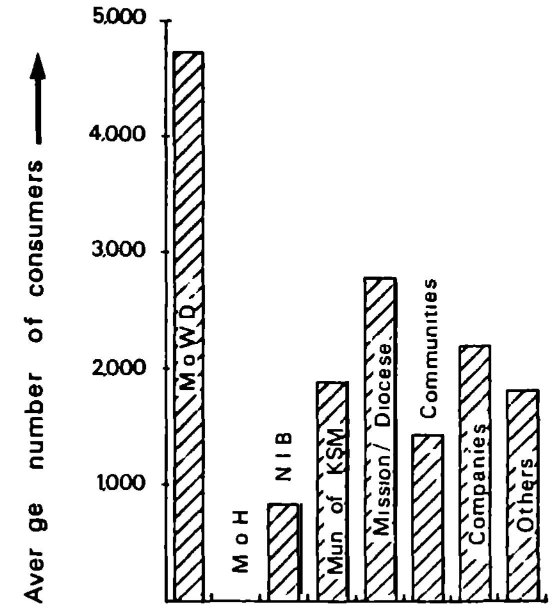
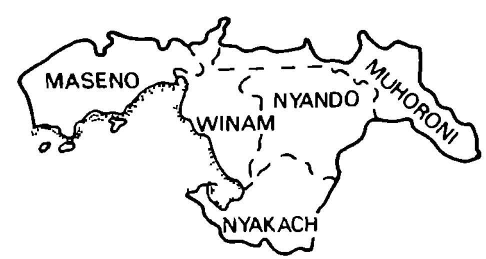


Fig 6 15c Average number of consumers per scheme

Fig 6.15 Organisations responsible for operation and maintenance of pipe supplied schemes.

KISUMU DISTRICT



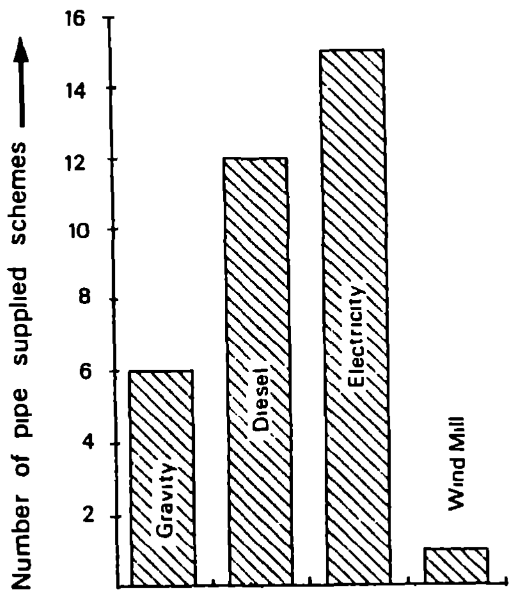


Fig 6 16a Breakdown per number of schemes

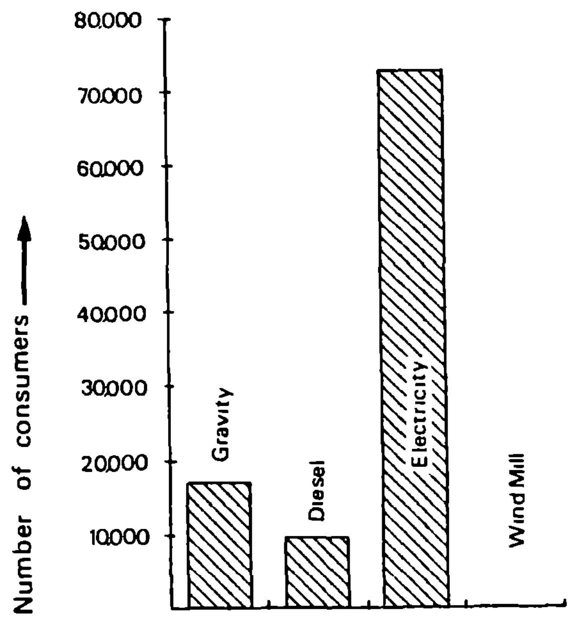


Fig 6 16b breakdown per number of consumers

Fig 6 16 Energy sources for pipe supplied schemes

Figure 6.18 shows a histogram of the water sources used. It appears that most (21) systems make use of surface water of which only 13 systems give a treatment before distribution. Shallow ground water from springs is used by two relatively small systems and another two which are presently out of order use wells. Nine systems use boreholes.
Treated surface water is supplied to around 70,000 consumers, making surface water the most important source for water supply systems in Kisumu District. Boreholes serve around 15,000 consumers through piped water supplies. The average number per system making use of boreholes however is less than 2,000.

Nyakach Water Supply

Nyakach water supply is designed to serve the whole of Nyakach Division through communal water points only. Its distribution network was designed to reach 132,000 people, the estimated population in 1988. The capacity of the system is around 5,000 m3/day.

During the construction period, which is still ongoing, a large number of illegal private taps have been connected to the system. To distribute water on the Nyabondo Plateau, use is made of the existing distribution network of the Nyabondo water supply. Operation has started in September 1987 and the final handing over is scheduled for February 1989. At the time of visit -June 1988-, approximately 50% of the network received water. No funds for chemicals had yet been allocated, resulting in supply of poorly treated water.

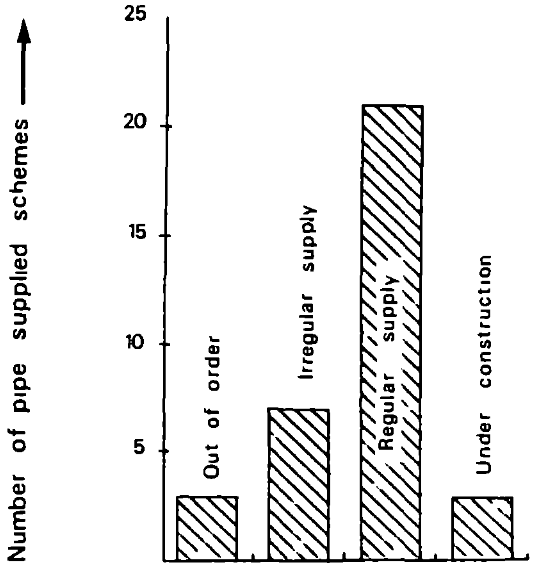


Fig 6 17a Status of pipe supplied schemes

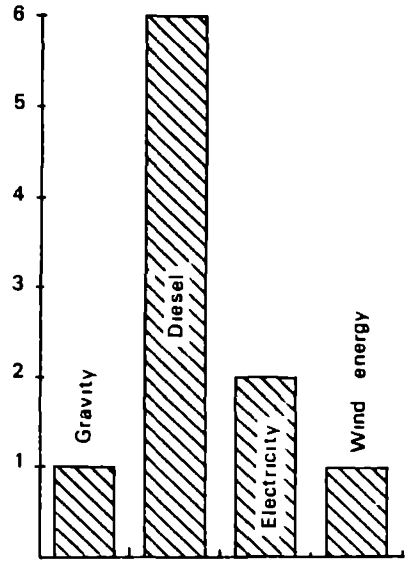


Fig 6 17b Energy source of schemes with irregular supply or which are out of order

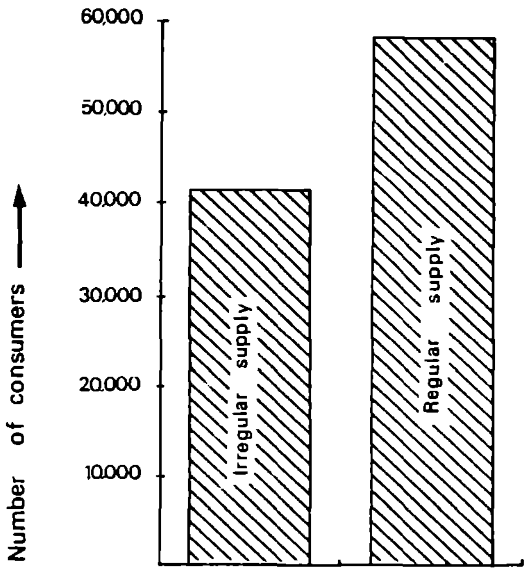


Fig 6 17c Consumers with (Ir)regular supply

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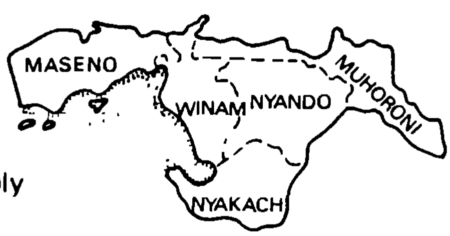


Fig 6.17 Regular and irregular water supply histograms

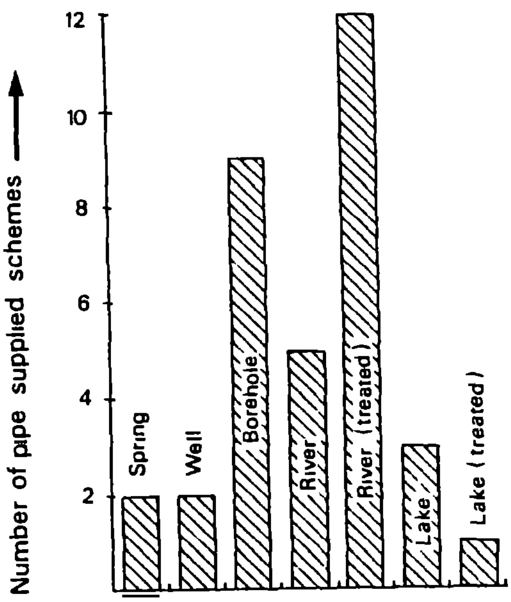


Fig 6.18a Breakdown per number of schemes

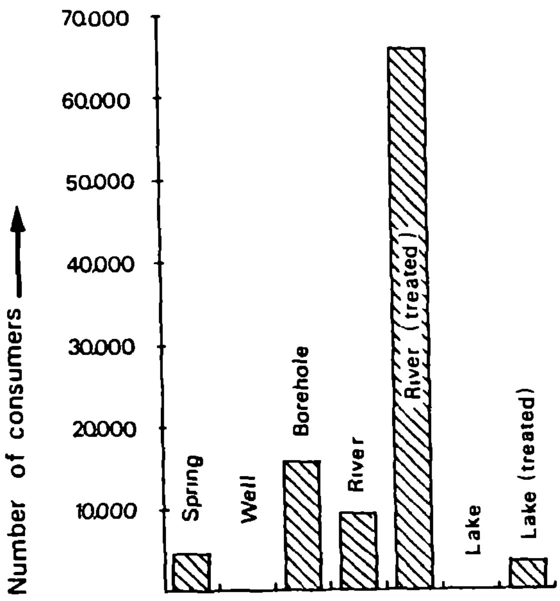


Fig 6.18b Breakdown per number of consumers

Fig 6.18 Water resources of pipe supplied schemes

At this time the following way of supply was recorded along the major pipe lines:

- Katito--Ahero line: regular supply
- Katito--Pap Onditi line: irregular supply
- Pap Onditi--Kusa: irregular supply
- line along the escarpment: regular supply
- Nyabondo Plateau: irregular supply

Based on the observations in the field the present number of consumers of the whole system is estimated to amount 45,000, of which 19,000 have regular supply. However this assessment depicts the present situation, while the number of consumers is probably not stable yet. New lines will be opened, and some broken lines might stay without repair. Also the treatment system as yet has to prove its value.

Because of the large scale of the Nyakach water supply system, it's development is very important for the future contribution of piped water schemes in rural domestic water supply within Kisumu District.

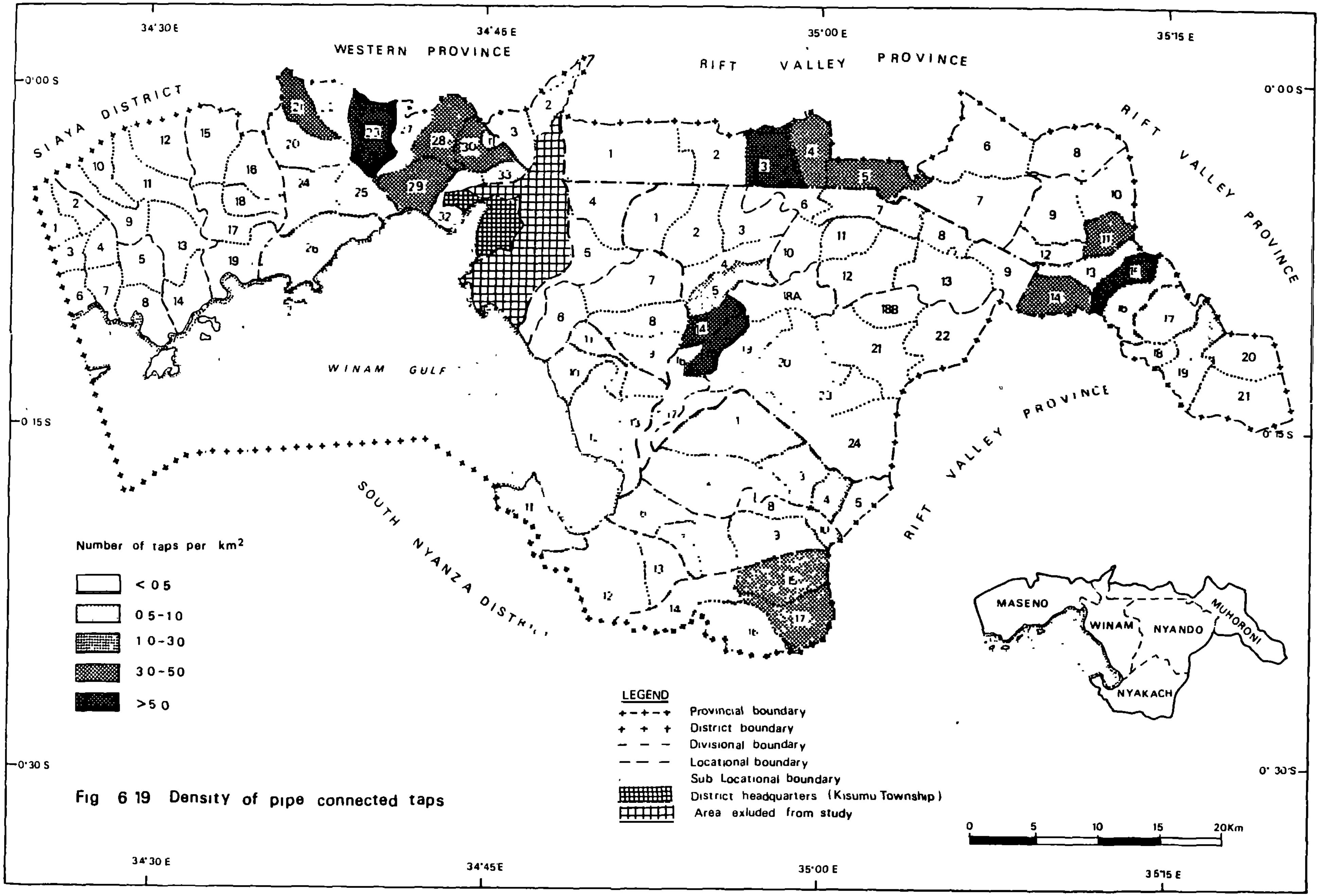


Fig 6 19 Density of pipe connected taps

Density of piped water points

Altogether almost 1,900 piped water taps have been found in Kisumu District. The density of piped water points is shown on Fig. 6.19. As can be noticed taps are concentrated in the following area's.

- The eastern part of Maseno Division
- Around the factories and labour lines in Muhoroni Division
- Around Ahero
- In the south-east of Nyakach Division

Communal water tap near Ahero

6.3.4 Development of piped water supply

An increase of the number of consumers, using piped water schemes will result from completion of piped water systems under construction, extension of existing systems or implementation of new piped water schemes.

Systems under construction

The Nyakach water supply, as described in the previous section, is the most potential water supply. If all the existing distribution lines can be completed, such that they will supply water regularly, a great number of people will make use of it.

Moreover, three other systems under construction have been found in Kisumu District. The most important of them is Koruenje water project in Central Seme Location, which is designed to serve 10,000 consumers by the year 2002. Construction works have started in 1983. Since then only the pumping house has been finished. Presently the construction works have been stopped due to lacking funds.

The other systems, West Seme water project and Paga water supply are small systems. The first is completed but has never worked since somebody stole the airvalves. Construction works of the latter have been stopped due to the lack of funds.

Extensions

Designs have been made for extension of Kibigori and Muhoroni schemes. Extension of the first system consists of rehabilitation of the broken line to Masogo. A design was made for the latter to serve 1,500 more consumers. Requests for funds have been made to the Ministry of Water Development in June 1988, but these have not been awarded for the financial year 1988-1989.

Planned piped water systems

The only planned system that has passed it's design phase is West Kano Water project. It is designed to serve approximately 120,000 consumers in an area of 170 km2 in North and South West Kano Locations in Winam Division. It will have its intake and treatment works in Wath Nduru. A request for funds for its execution, made in June 1988, has not yet been awarded.

Other planned piped water schemes are the East Kano water project and the Songhor-Muhoroni-Fort Ternan water project. None of both has presently passed the phase of feasibility study.

6.3.5 Evaluation

Existing piped water systems

It appears that piped water supplies contribute significantly to the existing rural domestic water supply, both in number of water points as well in the number of consumers. However notice must be taken of the following remarks considering the quality and reliability of the presently functioning piped water schemes in Kisumu District.

1. In spite of a quite flexible definition of safe water, 25% or 7 piped water schemes supply unsafe water. The remaining systems were found to have a regular shortage of chemicals required for the water treatment. Moreover the quality of delivered water is seldom checked.

2. 25% of the systems, serving 40% of all consumers, can not meet the description of regular supply. Many systems often suffer from a silted intake, pipe breakages, a lack of diesel for the pump engines, pump breakages and too low pressure at the end of the pipe lines.
   The repair of system failures may sometimes take a few days but often much longer.

The shortcomings are in many cases the result of the lack of financial means, trained manpower and adequate hardware for a proper operation and maintenance of the systems.

Systems under construction

Of the three piped water schemes which were found to be under construction in the District one was commenced in 1974, another in 1981 and the last in 1983. The progress of construction works is little which is caused by shortages in materials and funds. It is questionable if they ever will reach completion. This way of building results in a loss of investments costs and the postponement of the systems' productivity.

Piped water in rural areas

Piped water schemes enable to bring water to the places of consumption regardless of physical circumstances in the area, only a sufficient and adequate source needs to be available. While the distribution network brings the water to the points of extraction. These are important advantages of piped water.

However, it should be noticed that investments for construction of piped water schemes are high compared with the construction of point sources. Moreover, the running costs are to be met with. This causes that piped water systems can only be properly operated and maintained with subsidization, or with consumers who can be charged, for the running costs.

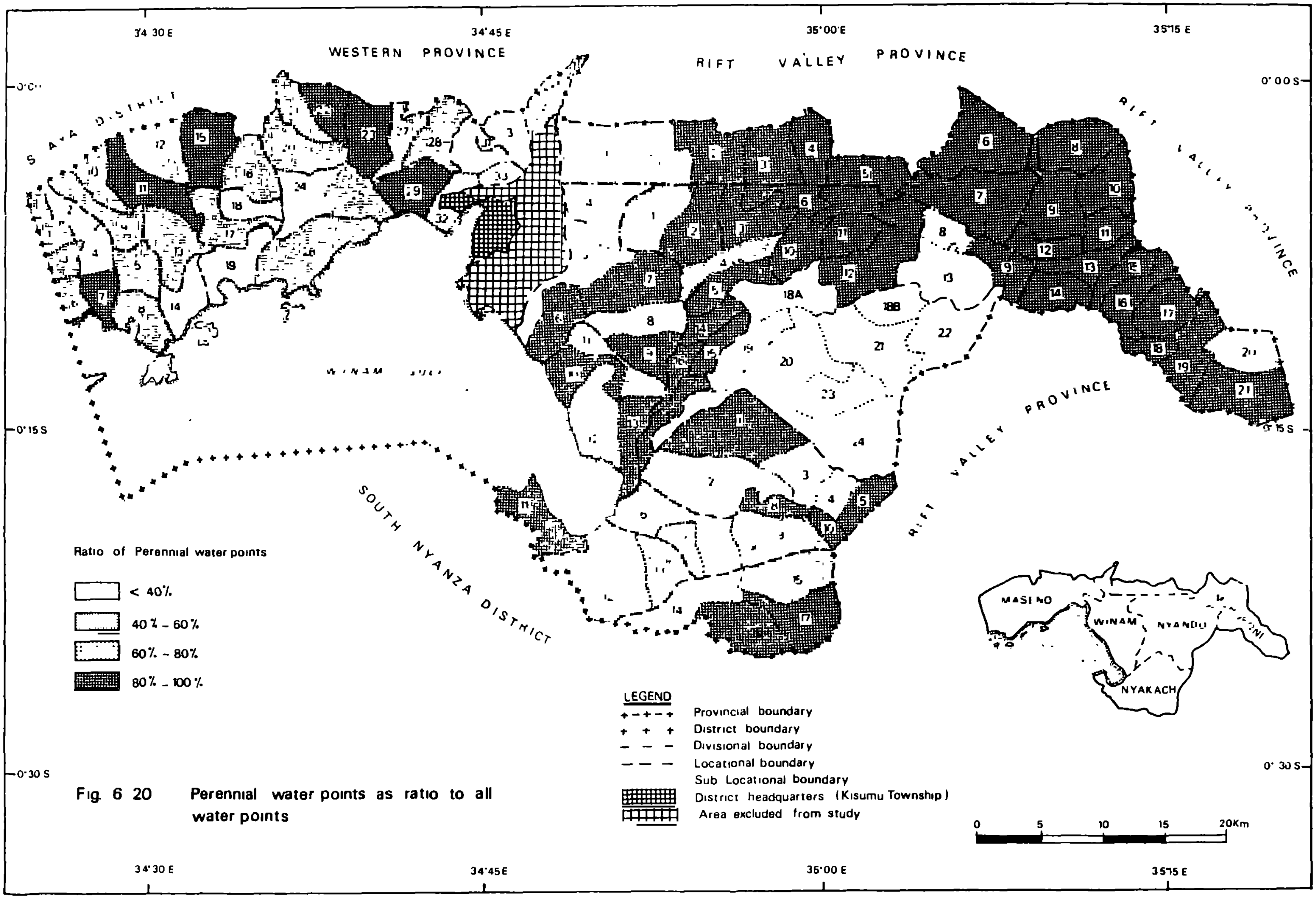


Fig 6 20 Perennial water points as ratio to all water points

Unfortunately subsidization is seldom sufficient and the people living in rural areas of Kisumu District are generally not able to effort this water charge, what often result in deterioration of the piped water system since .

Therefore, the construction of piped water schemes should be limited to those rural areas where no alterative proper water points can be created, or where people can economically effort it's water use. The design of the systems should be such that only little operation and maintenace costs will be required.

6.4 Use of different water supply resources

6.4.1 Differences between wet and dry season

Many point sources in Kisumu District dry up during the dry season. Especially in the Kano Plain, a large part of the water points are seasonal as shown in Figure 6.20. People using such a seasonal point during the wet season, have to find an alternative water point in times of drought. The constraint of the seasonal water points affects the consumption patterns significantly in some regions. Differences between the dry and wet season imply:

- an increase of the average walking distance and an increase of the average number of consumers per water point.

- backslide of the quality of the water fetched. In case of constraint, the people are compulsed to leave their trusted water points which causes that the remaining ones will be used intensively and will often be used for all purposes.

The aspects of drying water points will be discussed in the next sections.

Seasonal traditional well


Seasonal stream in Kano Plain


Perennial well

6.4.2 Number of available water points

Altogether 5,249 water points have been found in Kisumu District, of which 75% are perennial. Fig. 6.21 indicates the number of all available water points for each type. The piped water tap is farout the most numerous type of water point. It's number is nearly 1,900. However,many are private and do therefore serve a few consumers only. The figure indicates that 100% of all taps are perennial. This does not imply that they give water throughout the year though, as discussed in section 6.3.

Besides taps, many wells, river points and springs are found as water points. Ground and roof catchments play only a role outside the dry season since 75% of them dry up.

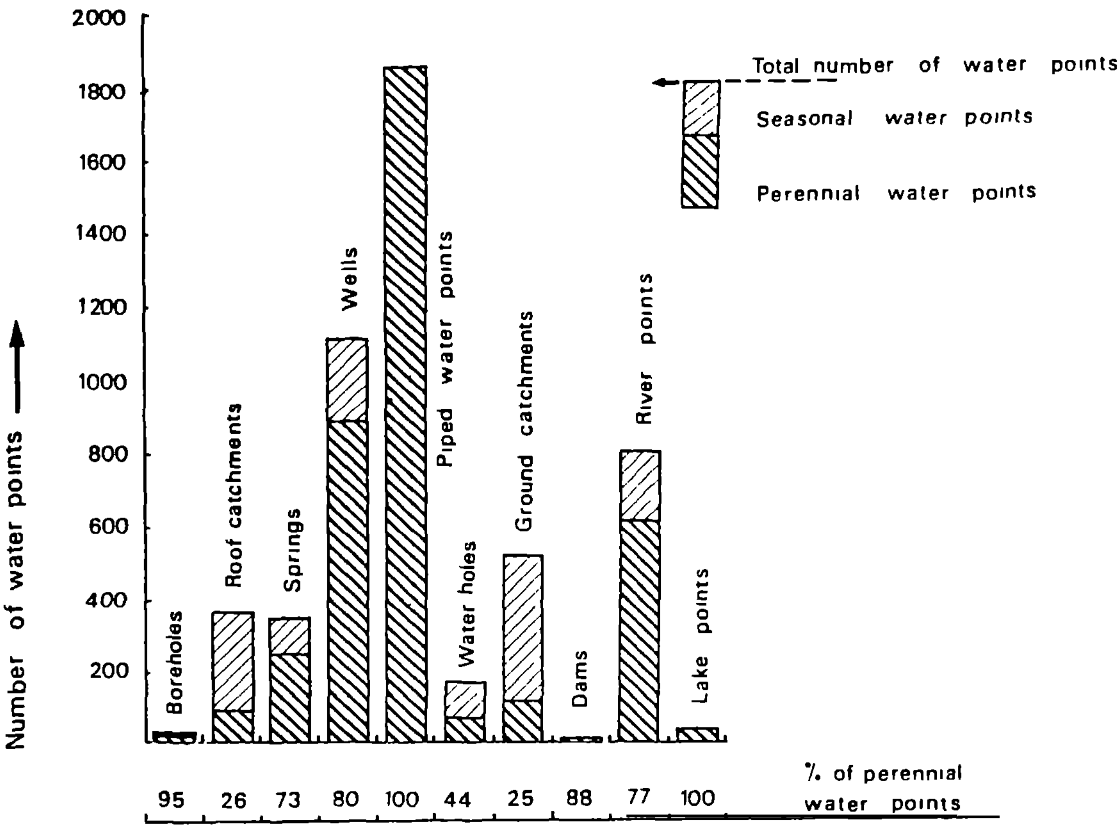


Fig 6 21 Number of seasonal and perennial water points

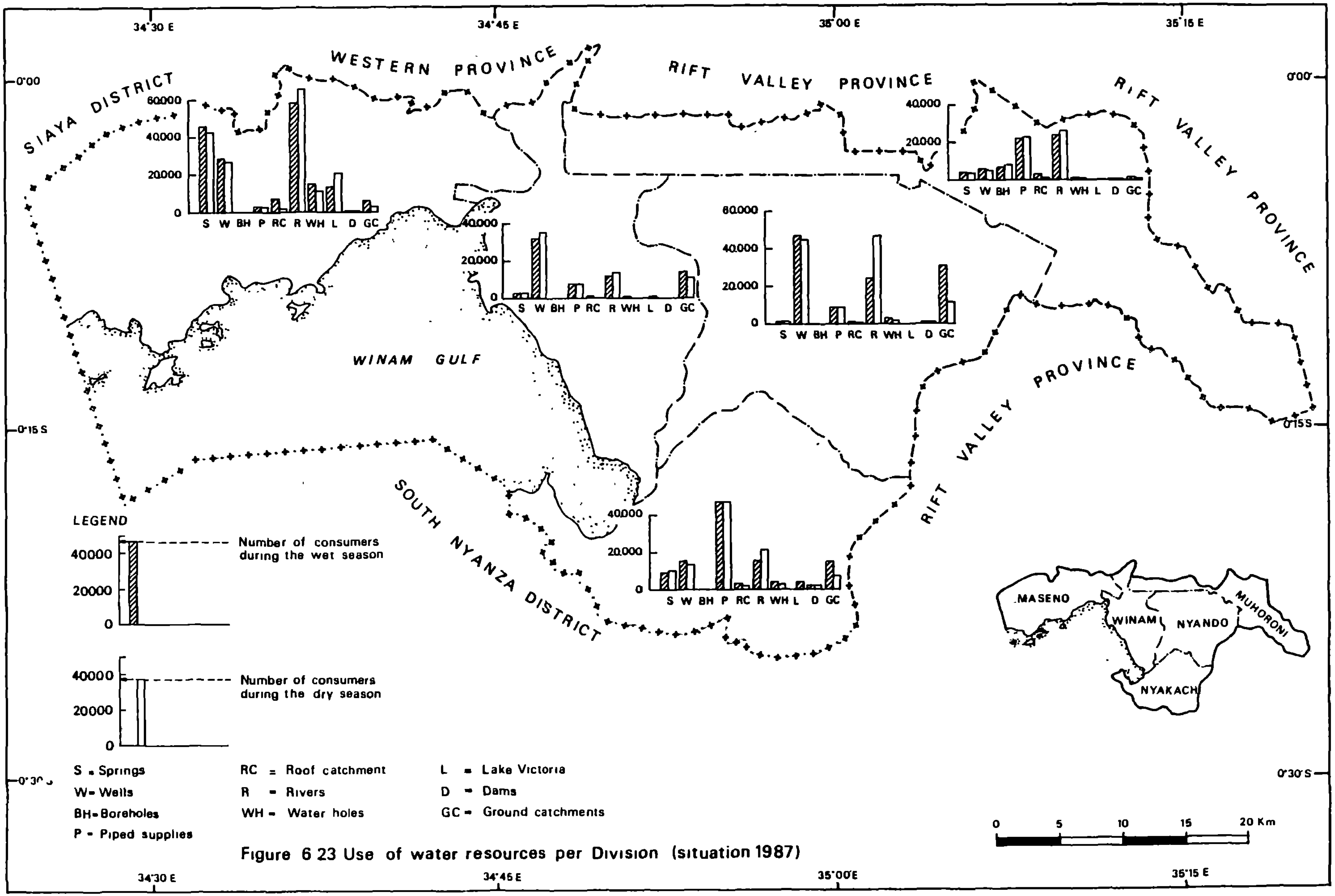


Figure 6 23 Use of water resources per Division (situation 1987)

6.4.3 Breakdown per type of water point

Figure 6.22 depicts the number of consumers for each type of water point. Particularly rivers, wells and piped water supplies are important sources for domestic water. Less significant are springs and ground catchments. The remaining types of water points play only a minor role.

During the dry season the perennial rivers, the lake and piped water schemes are often used as altenatives for drying water sources. The figure shows that around 175,000, or 32% of all 540,000 consumers counted, depend on river water during this period

The use of the types of water points in the different Divisions is shown in Fig 6.22.

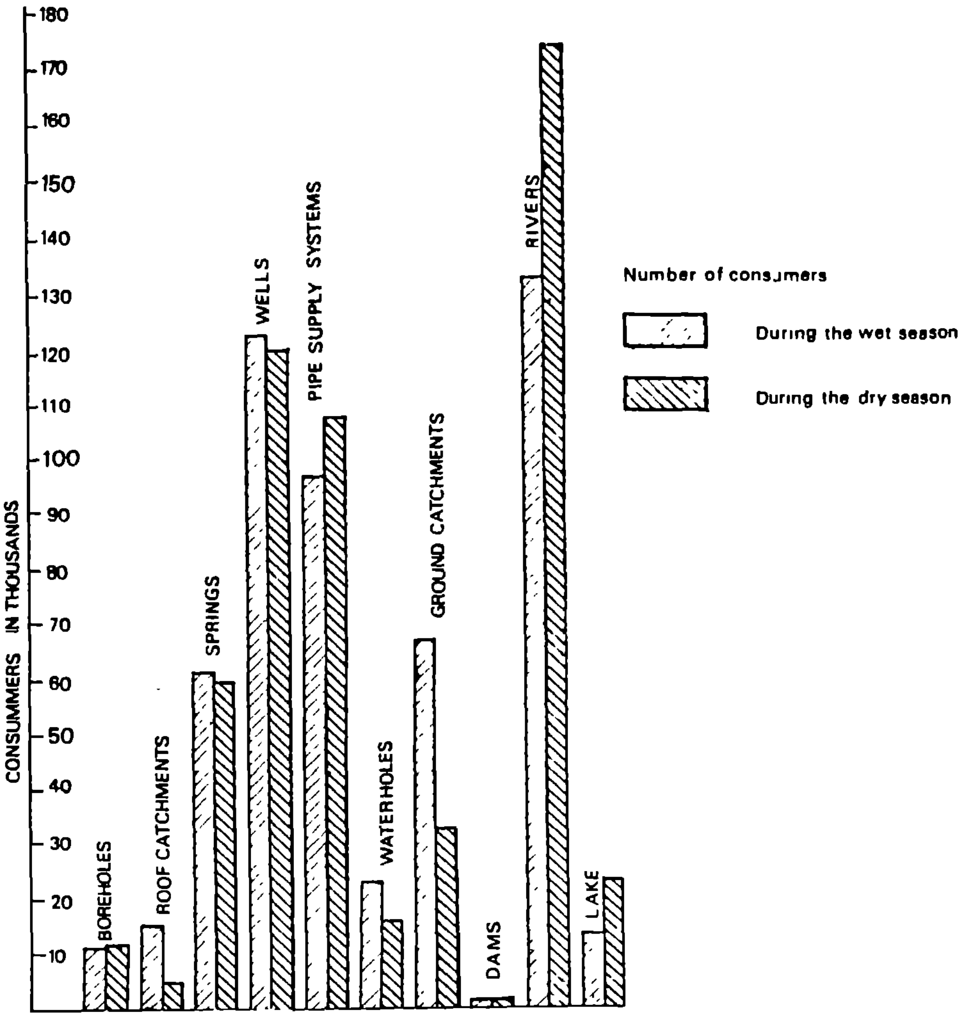


Fig 6 22 Use of different types of water points in Kisumu District

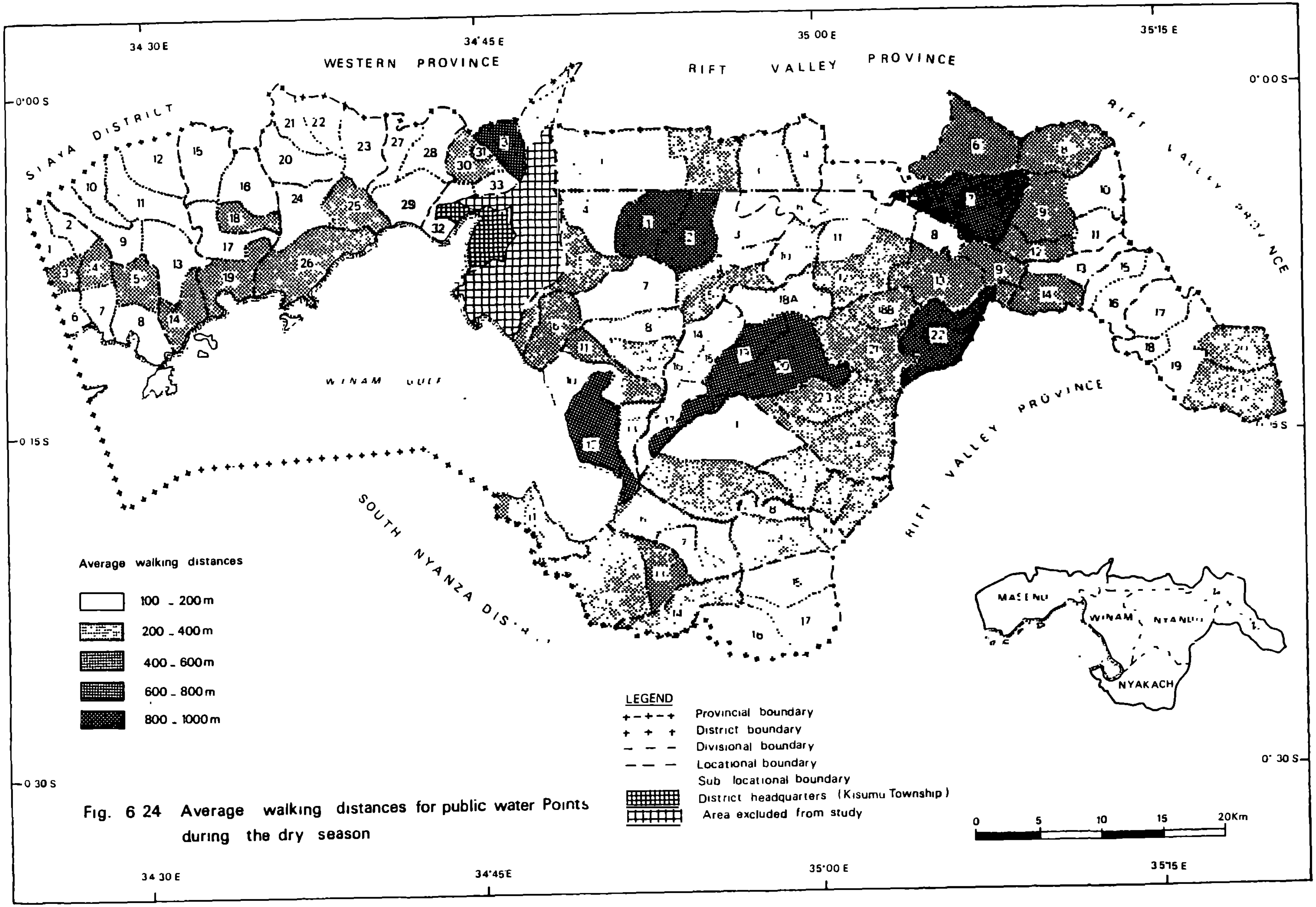


Fig. 6 24 Average walking distances for public water Points during the dry season

6.4.4 Water point density and walking distance

The average walking distance to a water point in a certain region is obviously related to the presence of water points , expressed in the water point density. To obtain an impression of the actual walking distances for the majority of the population only communal water points are regarded.

To create a contrast between those areas which are well off with water points and those suffering from many constraints, the average walking distances have been determined for the situation during the dry season.

Figure 6.24 shows this average walking distances per Sub-location. It must be noticed that the walking distances are average figures, based upon an uniform distribution of both water points and population. Although this might not always agree with reality, the overall pattern will give a reliable picture of the actual situation.

The figure shows clearly the considerable walking distances which occur in the south-east and west parts of the Kano Plain.

Water hole in Kano Plain

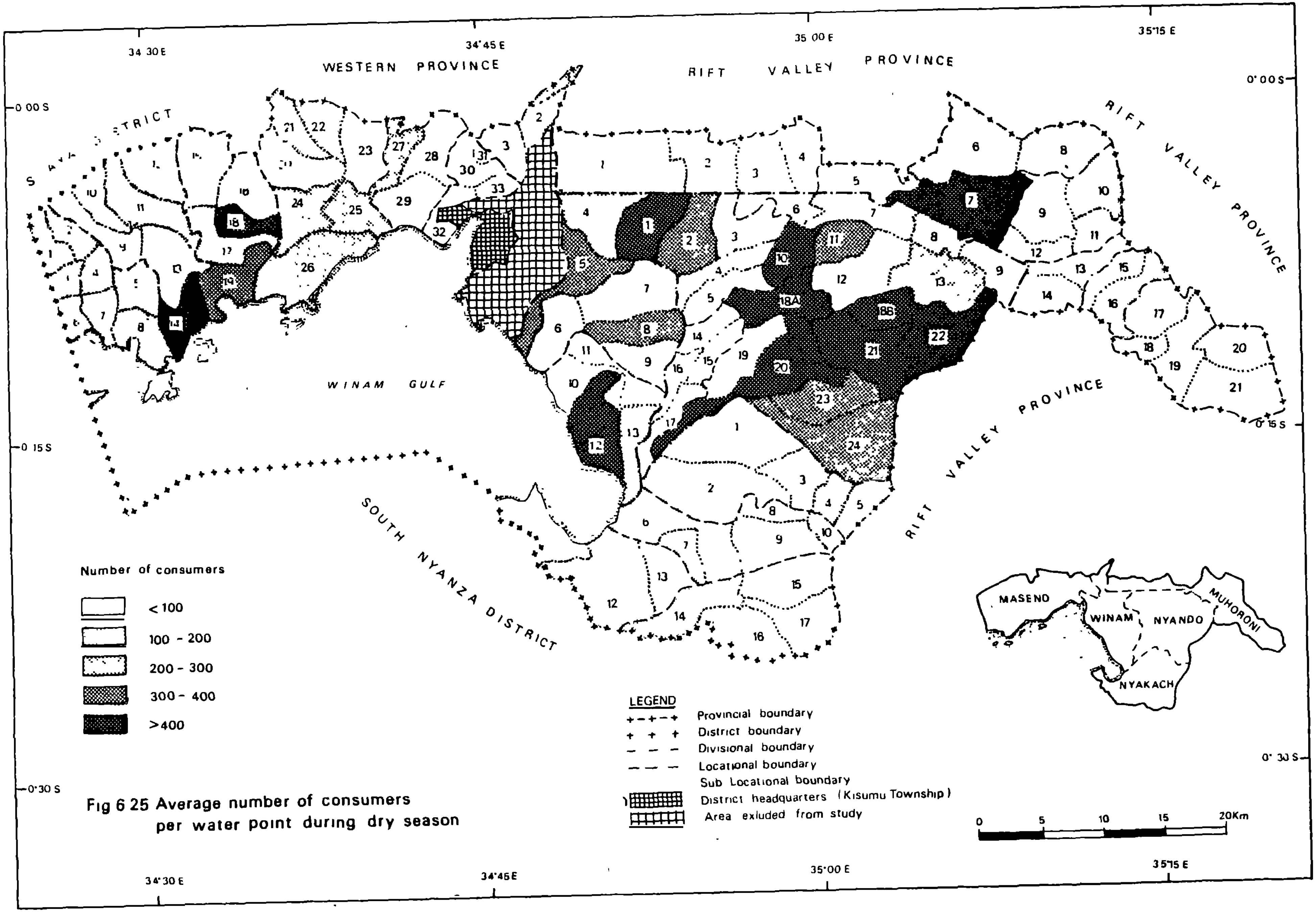


Fig 6 25 Average number of consumers per water point during dry season

6.4.5 Number of consumers per water point

This figure gives the relation between the available number of water points and the population density per Sub-location. Disadvantages of a large number of consumers per water point is that it will become contaminated more easily, and long queuing may occur at those places with a limited space where water can be fetched.

In areas where the water points are used by many people, many will benefit from its improvement or the construction of a new water point. Figure 6.25 points out that mainly water points in the eastern part of the Kano Plain and the westers part of Maseno Division are very intensively used.

6.4.6 Communal versus private water points

A total number of 2,943 communal water points have been found, implying that only 56% of all water supply facilities are for public use.

According to the information in Fig 6.26 more than 2,300 water points are private facilities. This high number is particularly due to the great number of private taps, which serve only a very limited number of consumers. For an average number of 15 consumers is estimated per tap it appears that the 1,478 private taps, being 28% of all water points in the Kisumu District, serve only 4% of it's population.

6.4.7 Choice of water point to be used

For the water supply plan, it is important to know why people choose to use a certain water point. The different aspects which may influence this choice are:

- the walking distance to the water point
- the water quality
- the amount of available water
- private or communal use and related costs.

The walking distance appears to be the most decisive criterion. In general it can be stated that people use the most nearby water point available. Deviations of this rule are found in cases that people are charged for it's use, or the water quality is considered poor.
It must be stated however, that the consumers in the rural areas generally are not much concerned about the quality of their fetched water. This is proved by the many water points supplying unsafe water, but nevertheless still used for drinking while safer water points are near.

As good as all point sources in Kisumu District are used free of charge. Even the use of public piped water taps is seldom charged for. Most users of private water tapes pay a flat rate for it.

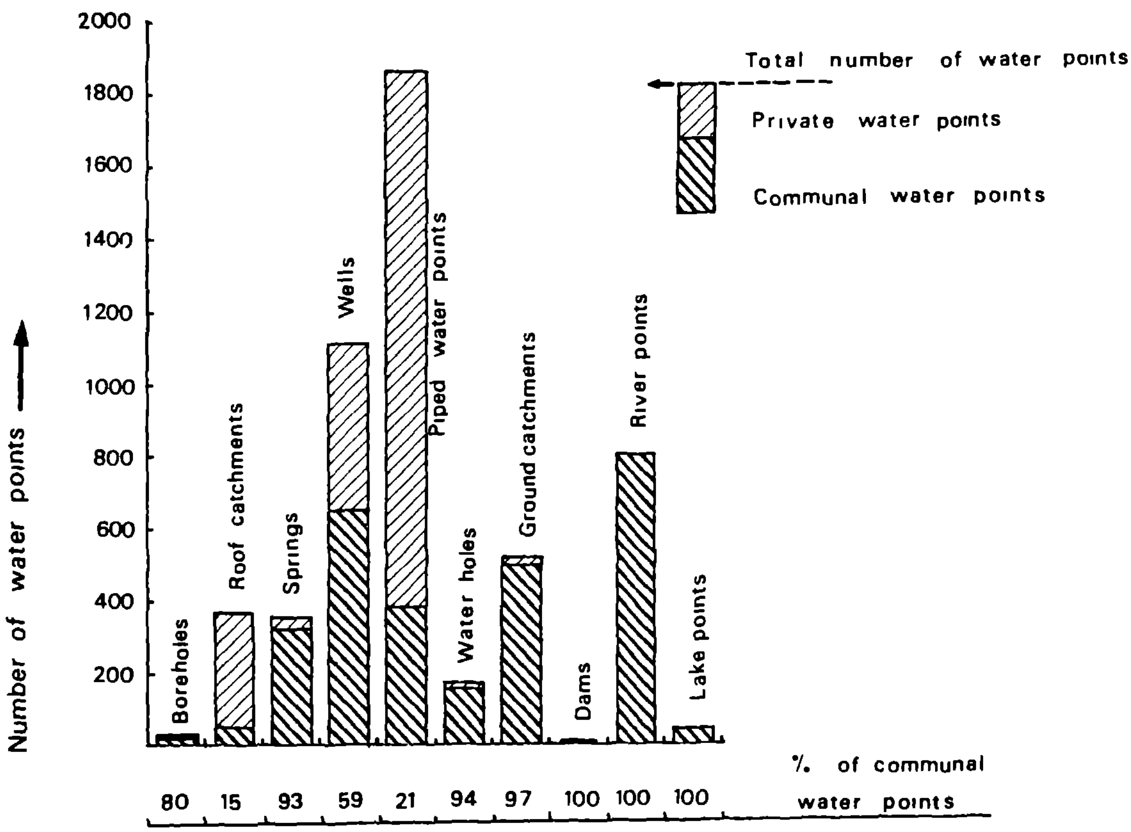


Fig 6 26 Number of communal and private water points

Private spring

6.5 Evaluation of the rural water supply situation.

The overall water supply situation in Kisumu District is very poor. In most regions only a few percent of the consumers have safe and reliable water available. Except for a few restricted areas, people have to go far to collect their water, which is not safe and in most cases seriously contaminated.

Nevertheless, the water supply situation differs considerable from place to place. The different regions and their characteristics are discussed with reference to MAP 3.

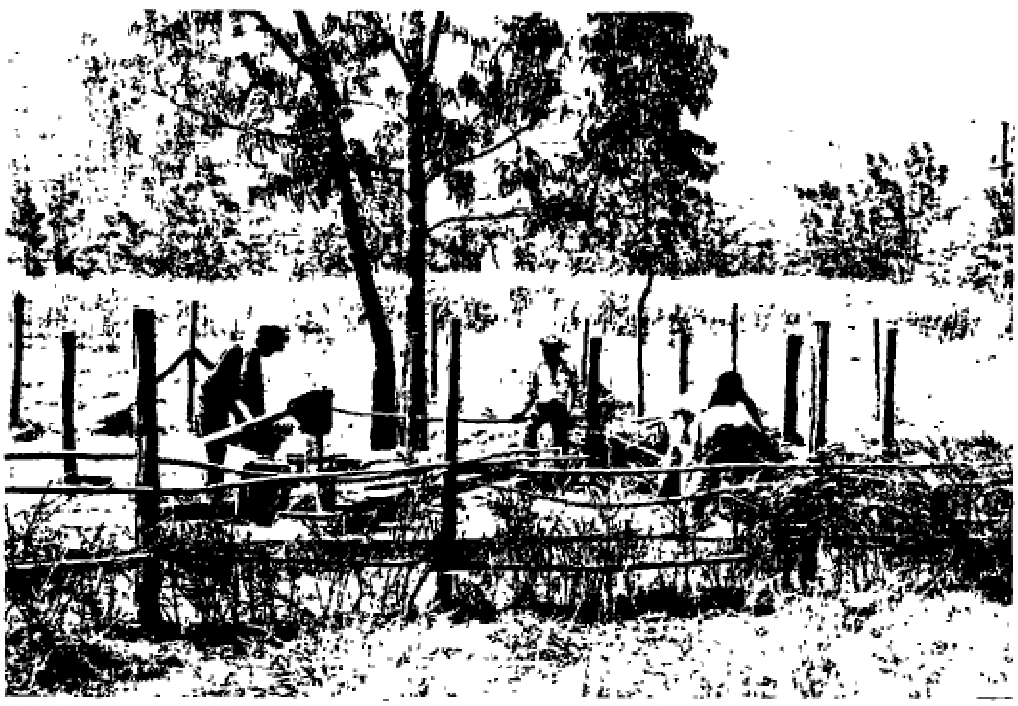
In general it can be concluded that the water supply situation is most difficult in the Kano Plain area, as most people depend on polluted surface water as ground catchments and rivers. The number of ground water sources is scarce and many water points, especially in the eastern part, dry up during the dry season. Compared with the rest of Kisumu District, this part is the worst off. As MAP 3 shows, not all places are that bad in the plain. Clusters of wells are in found in some areas south of Ahero, east of Rabour and south of Miwani. However it was found that a large part of the sampled wells in these areas are contaminated. At some places, piped water schemes bring local improvement in the water supply situation in the Kano Plain.

Other consumers who are confined to the use of merely surface water live in west Maseno and the eastern appendix of Muhoroni Division. Especially in the south of Seme Location many water points are seasonal.

The availability of water on the Nyabondo Plateau is relatively favourable. The plateau has many springs and wells and many of them are perennial.
Also in the northeast of Maseno many consumers dispose over a nearby perennial spring or well. Sampling of these water points has proved that many of them supply water of good quality.

An absence of water points in some areas as indicated on MAP 3 does not necessarily indicate a poor water supply situation, since these regions can be allocated to agriculture. E.g. west Muhoroni and north-west Nyando are nearly completely used by the sugar estates. In Winam and Nyando Divisions much land is brought under large scale cultivation by irrigtion projects.

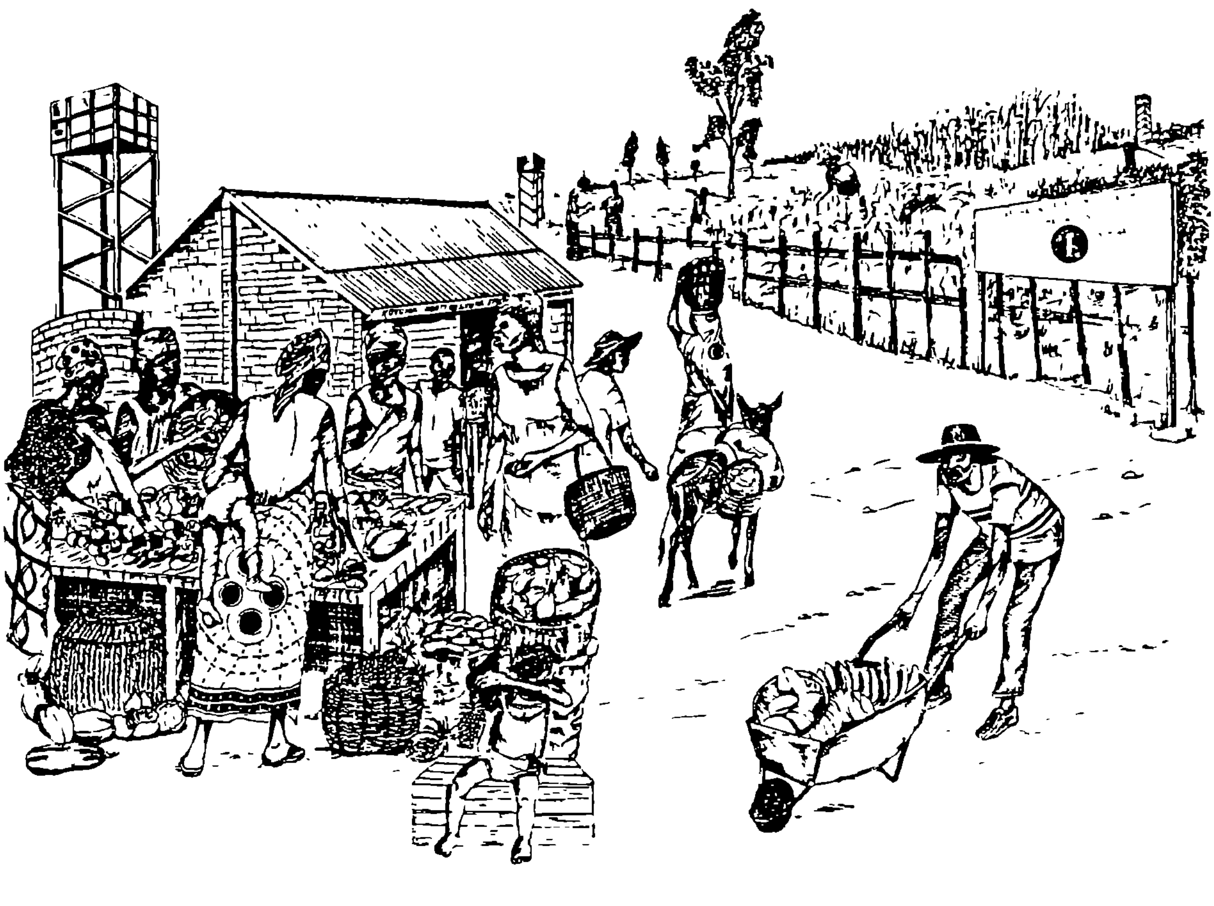
Masara Primary School Well

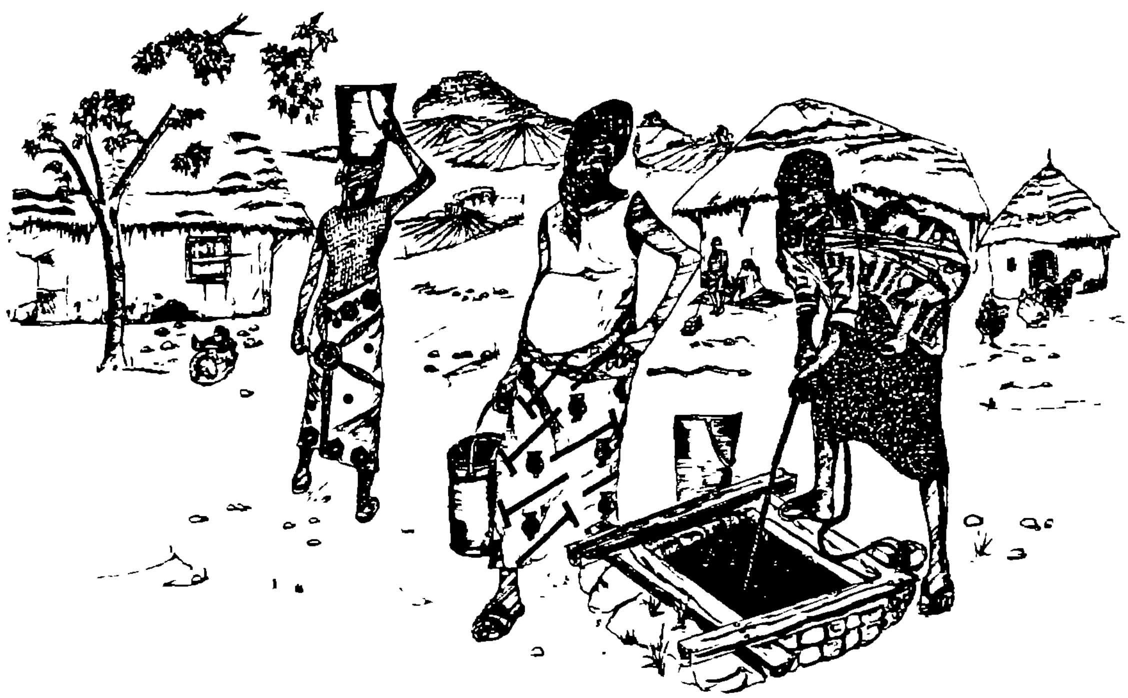


Miwani Secondary School well

PART 4

ASSESSMENT OF WATER DEMAND





7 RURAL DOMESTIC WATER DEMAND

7.1 Introduction

The importance of realistic water demand estimates is that they have a long range influence on the planning and design of water projects, they determine adequacy of the water sources and they provide the base for financial and economic analyses of water programmes.

The rural domestic water demand for Kisumu District, is the volume of water required by the rural population for domestic purposes, per year.
The water demand is determined by two major elements:

- the size of the rural population
- the water consumption rates,

which both are not constant, but vary with time.

According to the Design Manual of Water Supply in Kenya (Ref.42), water demand projections should be made for the initial, the future and the ultimate year, whereby the future is 10 years and the ultimate year 20 years from the initial year.
In this report 1987 is chosen as the initial year, with 1995 beeing the future and 2005 the ultimate year. The water demand for the intermediate years, 1990 and 2000, is estimated as well.

In the following sections, first an assessment is made of the different categories of rural consumers and their water use.

The next step taken is the division of the present and projected rural population into these different categories.

Next, by ascribing the estimated water requirements to each category, the water demand for 1987 upto 2005 is given.

7.2 Assessment of water consumption rates

7.2.1 Rural domestic water consumption in a general context

Water is used for many domestic purposes including:

- drinking
- cooking
- personal washing
- laundry washing,

and there are wide variations in the amounts of water people want to or are able to use.
A WHO study (Ref.67) showed the average daily consumption figures in litres per capita per day (l/c/d) for rural areas in different parts of the world to vary from a minimum of 5 l/c/d to a maximum of 40 l/c/d.

In the same study it was established that the major physical factors influencing the amount of water used by rural people are:

- the distance to the water source
- the level of service
- the reliability of the water source.

Distance to the water source

As a general rule water consumption rates decrease with increasing distance to the source.
If water has to be carried over a considerable distance, say over 2.5 km, the consumption may fall to as low as 5 l/c/d.

Level of service

The lowest and most frequently used level of service are the unimproved traditional sources; the ultimate service level are individual house connections of a piped supply, with various levels in between.
It has been established that the higher the level of service is, the more water is used.
When for instance there is a supply in the house or courtyard, the demand may be five times or more the demand if water has to be drawn and carried from a communal water source or water kiosk.

The World Bank (Ref.67) suggests the following consumption rates for various levels of service.

TABLE 7.1 RURAL DOMESTIC WATER CONSUMPTION RATES FOR VARIOUS LEVELS OF SERVICE

TYPE OF SERVICE	WATER USE l/c/d
Unimproved traditional sources	10- 40
Improved traditional sources	10- 40
Hand pumps	10- 40
Stand pipes	10- 40
Yard taps	50-100
House connections	100-150

Large variations in consumption rates may occur even within one region because besides the three major factors mentioned above, the following factors are also affecting the amounts of water used by individual households:

- size of the household
- income level
- education
- cultural heritage
- cost of obtaining water expressed in energy or cash
- climate and terrain.

7.2.2 Consumption rates used for design of water supplies in Kenya's rural areas

Water demand criteria for Kenya are given in the Design Manual for Water Supply in Kenya (Ref.42).
Taking into account only the rainfall, the manual classifies rural areas into high potential (over 1,000 mm rainfall per year), medium potential(500-1,000 mm/year), and low potential areas (less than 500 mm/year).

Next, the manual gives water consumption rates for these three classified areas whereby a distinction is made between communal water points and consumers with individual connections or water sources.
The suggested consumption rates are given in Table 7.2

TABLE 7.2 WATER CONSUMPTION RATES IN RURAL AREAS USED FOR DESIGN OF WATER SUPPLIES IN KENYA

CONSUMER	HIGH POTENTIAL RURAL AREAS l/c/d	MEDIUM POTENTIAL RURAL AREAS l/c/d	LOW POTENTIAL RURAL AREAS l/c/d
Communal waterpoints	20	15	10
Individual connections or sources	60	50	40

The recommended design rate for consumers in rural areas using communal water sources or kiosks is 10-20 l/c/d.
People having house connections or owning their own water source (i.e a well, borehole, watehole, spring), supposedly will be using 3 to 4 times these amounts(40-60 l/c/d).

The water consumption rates given in the Design Manual further are subject to the following conditions:

- for cattle watering the traditional sources are retained except where these sources are seasonal or otherwise unreliable

- rural domestic water consumption rates should not include any provision for irrigation, besides for very limited garden watering which is include in the per capita consumption rates

- water consumption figures should include 20 % allowance for water losses through spilling and wastage.

Service centres in rural areas

The Ministry of Lands and Settlement has given service centres in rural areas the following designation:

- Rural centres : 2,000-5,000 residents
- Market centres : less than 2,000 residents
- Local centres : less than 2,000 residents

For these types of concentrated rural settlement, the Design Manual gives overall water consumption rates of 40-60 l/c/d.

7.2.3 Current water collection and use practices in Kisumu District

As part of the survey of the existing water supply situation which is described in chapter 3, at each water source questions were asked on its usage.
The recorded data include information on:

- number of homesteads using the source
- number of consumers per homestead
- use of water
- settlement pattern around the source
- if the source is not used for drinking, which other source is used for drawing of drinking water
- if the source is seasonal, what alternative source is used.

Some of the results of these inquiries are summarized in Table 7.3

TABLE 7.3 NUMBER OF HOMESTEADS AND PEOPLE USING ONE WATER SOURCE

DIVISION	PRIVATE WATER POINTS			COMMUNAL WATER POINTS		
	No. of home-steads	No. of people	People per home-stead	No. of home-steads	No. of people	People per home-stead
Maseno	3	42	14	20	184	9
Winam	5	49	10	31	267	9
Nyando	2	30	15	14	151	11
Muhuroni	2	21	10	11	141	13
Nyakach	3	26	12	20	205	10
KISUMU DISTRICT	3	34	12	19	190	10

It appears that the number of homesteads using a water source varies from only 2 for private water sources upto 31 for communal water sources, while on an average 3 homesteads are using one private source, and 19 homesteads are communal source. The number of people per homestead varies from 9 to 15 and amounts to 11 for the District.

It was found also that 95 % of all sources is used for personal hygiene and laundry washing and 90 % for drinking and cooking. Moreover, 30 % of all sources is used also for cattle watering. The use for other purposes as garden watering and brick making appears to be almost negligible.

During the survey it was established that by tradition woman and children carry water for domestic purposes, the men drawing water only for lifestock purposes.

The results of the survey furthermore showed that the human head predominates by far as the means of water transport (95 %) followed by bicycle (3 %), push cart (1 %) and donkey cart (1 %).

In addition to the data collected during the survey of the existing water supply situation, an attempt was made to assess the daily water consumption from relatively remote water sources (walking distance 2-4.5 km) in the project area by interviewing woman at a selected number of such sources.
From these enquiries it apeared that under these unfavourable conditions the average daily water volume carried home per capita is about 7 litres.

The explanation for this seemingly low consumption is not lack of water or a small demand.
The limiting factor is the amount of water which can be carried by one person over the distance involved and the number of water collection trips one cares to undertake (one or at most two).
To avoid excessive water catering, laundry and personal washing is always undertaken at the water source.

Based on the results and observations of the various formentioned field surveys, the average water consumption per capita per day in Kisumu District has been assessed using the following assumptions:

- the water source is less than 1.5 km from the homestead
- water is collected twice per day
- the average household exists of 12 persons out of which 2 are adult females and 2 are girls able to fetch water; 2 are males 4 are children under 10 years old and 2 are elders
- the 4 females wash themselves daily at the source, thereby drawing water from the source
- the males and elders wash themselves at the homestead
- the children are washed at the homestead
- laundring is done twice per week whereby water is drawn from the source.

The current daily water use under the above conditions which comes to 20 l/c/d, is worked out in Table 7.4

TABLE 7.4 BREAKDOWN OF AVERAGE DAILY WATER USAGE PER CAPITA

DAILY WATER COLLECTION TRIP	COLLECTOR	VOLUME COLLECTED l/d	VOLUME USED FOR PERSONAL WASHING l/d	VOLUME USED FOR LAUNDRY WASHING l/d	TOTAL DAILY WATER USE l/d
Early morning	2 adult females	40			40
	2 girls	20			20
Late afternoon	2 adult females	40	40	20	100
	2 girls	20	20		40
	sub-totals	120	60	20	200
Add 20 % for spilling and wastages					40
TOTAL DAILY WATER USE PER FAMILY OF 12 PERSONS					240 l/d
TOTAL DAILY WATER USE PER CAPITY					20 l/d

Under less favourable conditions i.e when the distance to the water source is over 1.5 km or when the source is unreliable or having a low capacity, only one water collection trip is made. Including wastages the total volume of water used and collected under these conditions comes to about 120 litres per family or 15 l/c/d.

If the water source is closeby, say within 500 m of the homestead, than even three water collection trips per day might be made in which case the total daily volume used and collected per family comes to about 240 litres (including 40 litres for wastages) or 30 l/c/d.

7.2.4 Anticipated changes

It was established that in Kisumu District, the current total water use per capita per day varies from 15 to 30 litres and comes to about 20 l/c/d on an average.

Out of these total volumes, between 5 and 15 l/c/d and on an average approximately 10 l/c/d of water are collected and carried home.
The balance being used for personal and laundry washing at the source.

If an improved water supply situation is to have an effect on the incidence of water related diseases, both an increase and change in water use is required.

Therefore, newly constructed safe and reliable water points should be able to supply all the water people need for their various domestic purposes.
Where these water points have been constructed, traditional sources should be used only for cattle watering and if applicable small scale irrigation.

7.2.5 Recommended design criteria for rural domestic water supply in Kisumu District

Based on the studies carried out and described in the previous sections, the RDWSSP recommends the use of the following design criteria for rural water supply in Kisumu District.

TABLE 7.5 RDWSSP DESIGN CRITERIA FOR RURAL DOMESTIC WATER SUPPLY

SUPPLY AREA	HIGH POTENTIAL AREAS l/c/d	MEDIUM POTENTIAL AREAS l/c/d	LOW POTENTIAL AREAS l/c/d
Rural areas	30	30	20
Market centres	30	30	20
Local centres	30	30	20
Rural centres	50	50	40
Urban centres	100	100	100

These recommended quantities are 50 % higher than the current average consumption rates.

7.3 Population projections for different categories of rural areas and rural centres

Population projections for Kisumu District are given in section 5.3. Table 7.6 shows a review of the estimated total District population up to the year 2005.

TABLE 7.6 REVIEW OF DISTRICT POPULATION PROJECTIONS

	1987	1990	1995	2000	2005
District Population	699,000	772,000	907,000	1,074,000	1,255,000

Included in this figures are the projected populations for the extended Municipality of Kisumu.
During the survey however it was found that at present large parts of the extended Municipality should be considered as rural areas.
Table 5.4 shows the 1987 population of the extended Municipality to be 221,961.
Subtraction of the rural population within the Municipality gives a 1987 Urban population for Kisumu Township of about 146,000.
By using an urban growth rate of 6.5 % (Ref. 39 and 66) for Kisumu Township and subtracting this projected urban population from total District population, the total rural population projections are found.

TABLE 7.7 ESTIMATES OF RURAL POPULATIONS

	1987	1990	1995	2000	2005
District Population	699,000	772,000	907,000	1,074,000	1,255,000
Kisumu Urban Population	146,000	176,000	241,000	330,000	452,000
RURAL DISTRICT POPULATION	553,000	596,000	666,000	774,000	803,000

In section 7.2 it is argued that different water consumption rates should be attributed in the first place to rural areas classified as high, medium or low potential and secondly that a distinction should be made between rural areas with scattered population and rural areas with a concentrated population such as local centres, market centres and rural centres (Table 7.5).
Consequently, in the following sections first the urban population is estimated and subtracted from the total projected population after which the rural population is sub-devided according to the different categories.

7.3.1 Population of high, medium and low potential rural areas

Figure 4.3 shows that the average annual rainfall on Kisumu District is between 1,000 mm and 1,800 mm.
Hence, according to the land classification system which takes in account only the rainfall, the whole of Kisumu District can be classified as high potential land.
However, when a more accurate land potential classification system is applied, taking into account also soil types and topography ,it appears that 80 % of the District is high potential land and 20 % medium potential land Ref.42).
Water consumption rates for medium and high potential rural areas are summarized in the table below.

TABLE 7.8 WATER CONSUMPTION RATES FOR HIGH AND MEDIUM POTENTIAL RURAL AREAS

SUPPLY AREA	POPULATION	WATER CONSUMPTION RATE
Rural areas		30 l/c/d
Local centres	less than 2,000	30 l/c/d
Market centres	less than 2,000	30 l/c/d
Rural centres	2,000 - 5,000	50 l/c/d
Urban centres	more than 5,000	100 l/c/d

7.3.2 Projected population for urban centres and rural service centres

Included in the rural District population projections given in Table 7.7 are the populations of a few smaller urban centres and a large number of rural centres.

Present urban centres are:

Maseno	(8,000)
Ahero	(5,500)
Muhuroni	(6,500)

With a total urban population of 20,000.

Present Rural and larger Market centres are (Figure 7.1):

Maseno Div.	Winam Div.	Muhuroni Div.	Nyakach Div.
Daraja Mbili	Rabuor	Fort Ternan	Kusa
Kombewa	Korowe	Songhor	Pap-Onditi
Kiboswa	Nyang'ande	Kibigori	Sondu
Otonglo	Mamboleo	Miwani	
Paw Akuche		Kibos	
Lela		Chemelil	

The present total population of these 19 rural centres in Kisumu District amounts to 52,000 people.

By using an average urban growth rate for small towns in Nyanza Province of 5 % (Ref.66), the project populations are obtained.

Table 7.9 summarizes the projected populations for small urban centres, rural centres and the rural areas up to the year 2005.

TABLE 7.9 REVIEW OF URBAN AND RURAL POPULATION PROJECTIONS

SERVICE AREA	1987	1990	1995	2000	2005
URBAN CENTRES POPULATION	20,000	23,000	29,000	37,000	47,000
(growth rate 5 %)					
RURAL CENTRES POPULATION	52,000	60,000	77,000	98,000	125,000
(growth rate 3.3 %)					
RURAL AREAS POPULATION	481,000	513,000	560,000	639,000	631,000
(growth rate 3.3 %)					
RURAL DISTR. POPULATION	553,000	596,000	666,000	774,000	803,000

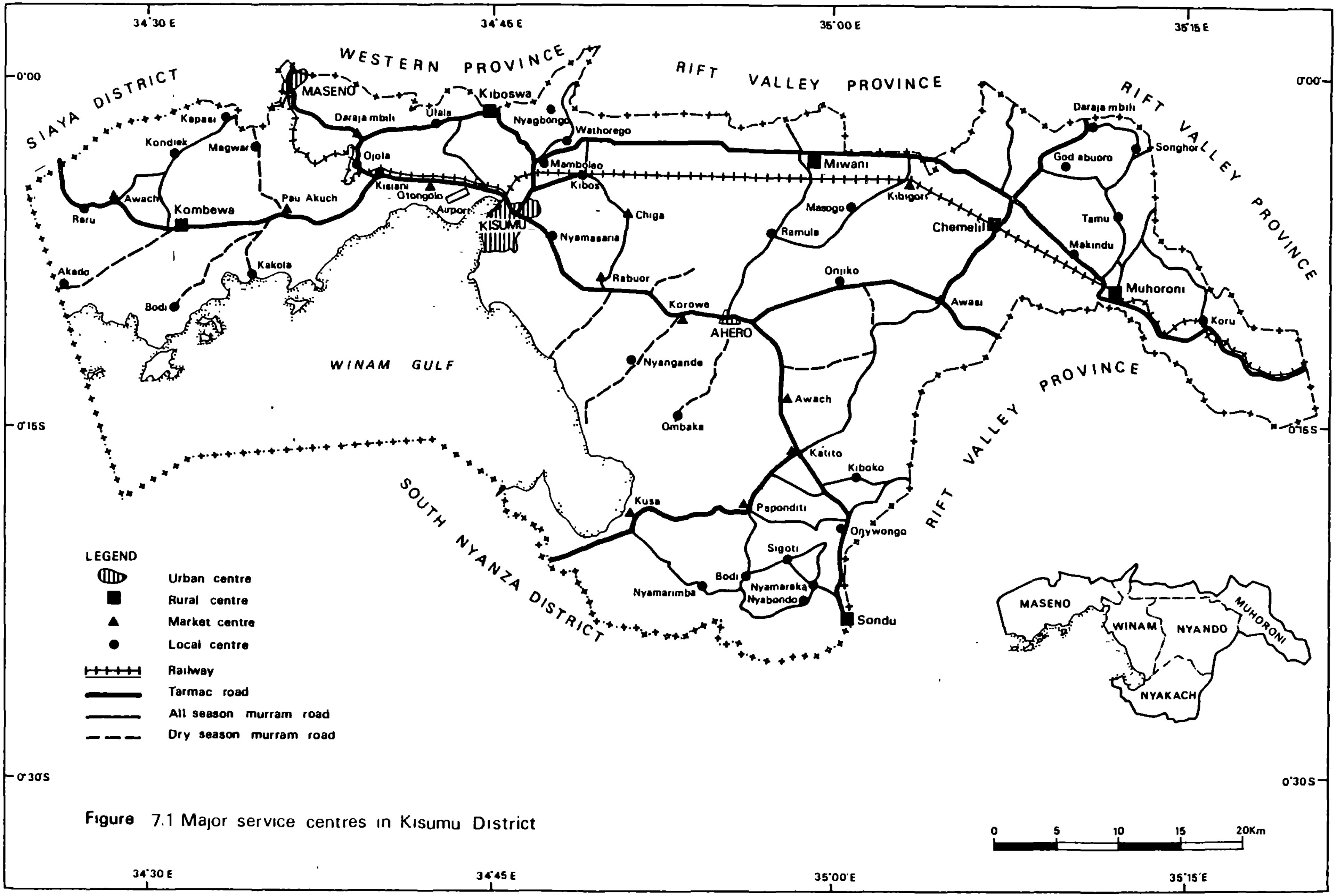


Figure 7.1 Major service centres in Kisumu District

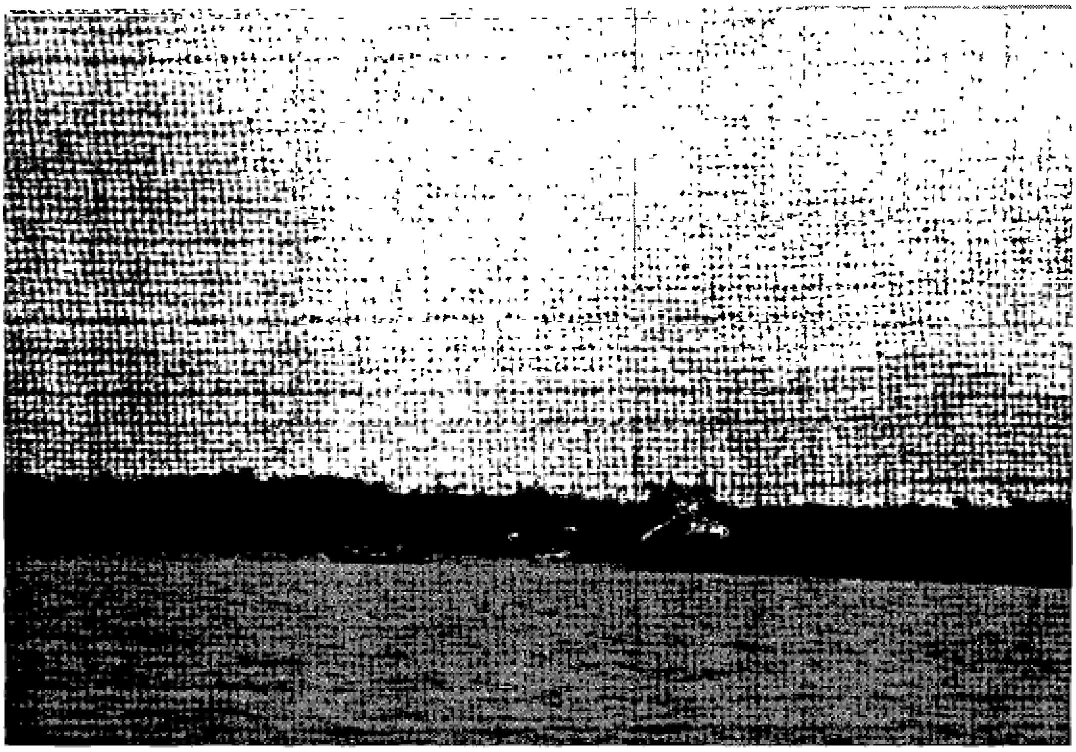
7.4 Water demand projections upto 2005

When assigning the proposed water consumption rates, 30 l/c/d for rural areas, 50 l /c/d for rural centres, and 100 l/c/d for urban centres to these projected populations and, and after multiplying these figures by 365, the annual rural domestic water demand is obtained (Table 7.9).

TABLE 7.10 RURAL DOMESTIC WATER DEMAND PROJECTIONS KISUMU DISTRICT (rounded figures)

	1987	1990	1995	2000	2005
WATER DEMAND IN M3/YEAR *	7×10^6	8×10^6	9×10^6	10×10^6	11×10^6

* Demand figures exclusive of Kisumu Urban Centre.



Winam Gulf

River Nyando

PART 5

SURFACE WATER RESOURCES

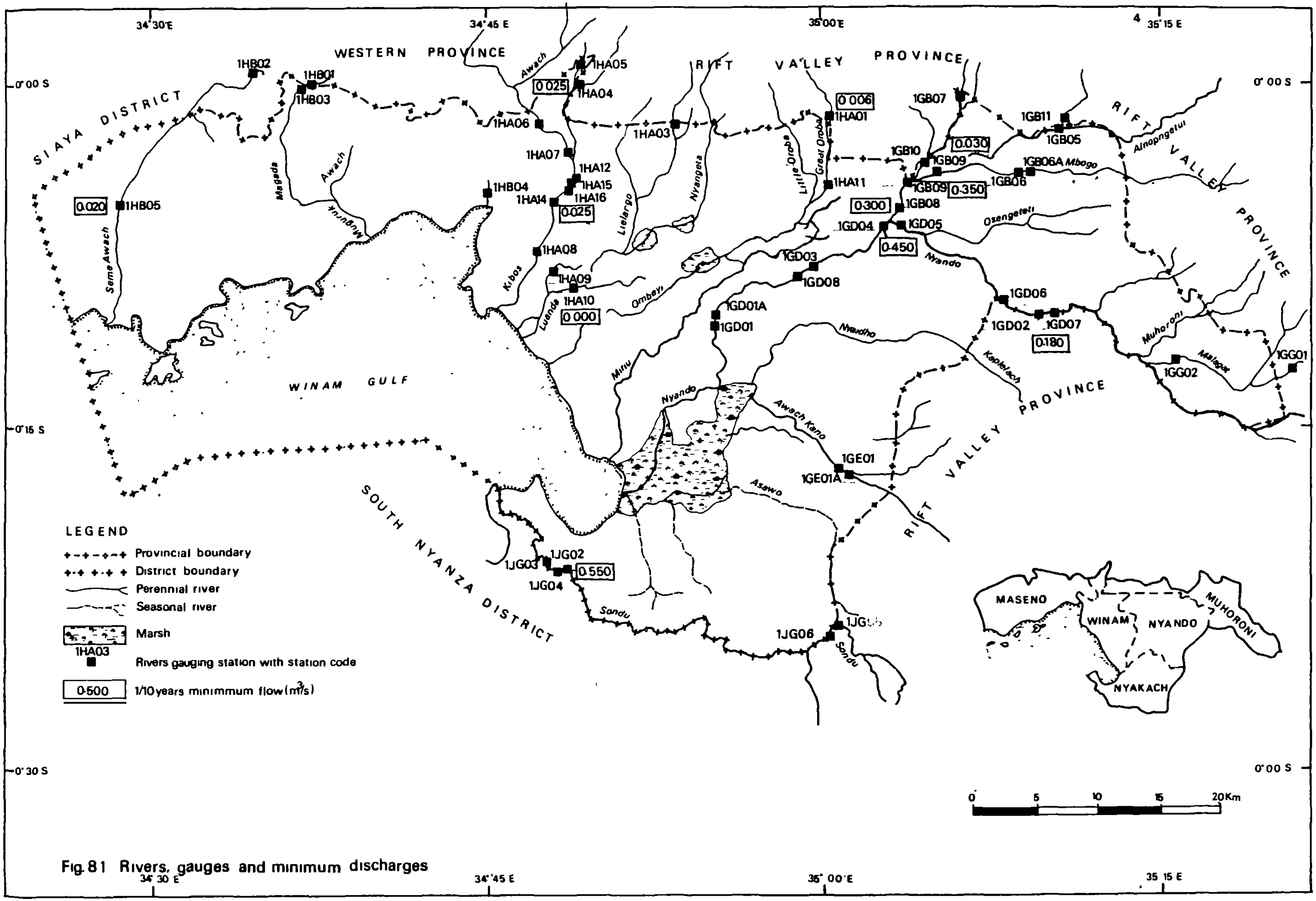


Fig. 8.1 Rivers, gauges and minimum discharges

8 SURFACE WATER

8.1 Introduction

As evaluated in section 6.3.3, 62% of the piped water schemes in the District make use of surface water; 17 use rivers and 4 exploit water from Lake Victoria. In this chapter the opportunities for use of surface water for domestic supply are discussed. Since the characteristics of water from rivers and the Lake are often similar, no distinction is made between these two sources.

It has been shown that direct use of surface water must be rejected for reasons of health. Because of the availability of ground water through out the District, an extensive surface water survey has been omitted. In the following sections a brief summary of the presence and quality of surface water will is given.

8.2 Presence of surface water

The sub-catchments in Kisumu District were already shown in Figure 4.2. It appeared that especially in the mountainous areas as west Maseno and east Muhoroni a dense network of perennial and seasonal rivers occurs. In the Kano Plain however, the density of rivers is found to be much less. The flow direction of all rivers is towards Winam Gulf.

In Figure 8.1 the major rivers within the District are presented, together with all river gauging stations and their codes as used by the Ministry of Water Development. Data of those gauging stations have been screened by LBDA's Data Centre (Ref.10) and for some stations preliminary daily discharges have been calculated. These results however are not yet approved by the MoWD. Making use of the available results one in ten years minimum discharges as presented in the same Figure, have been determined statistically.

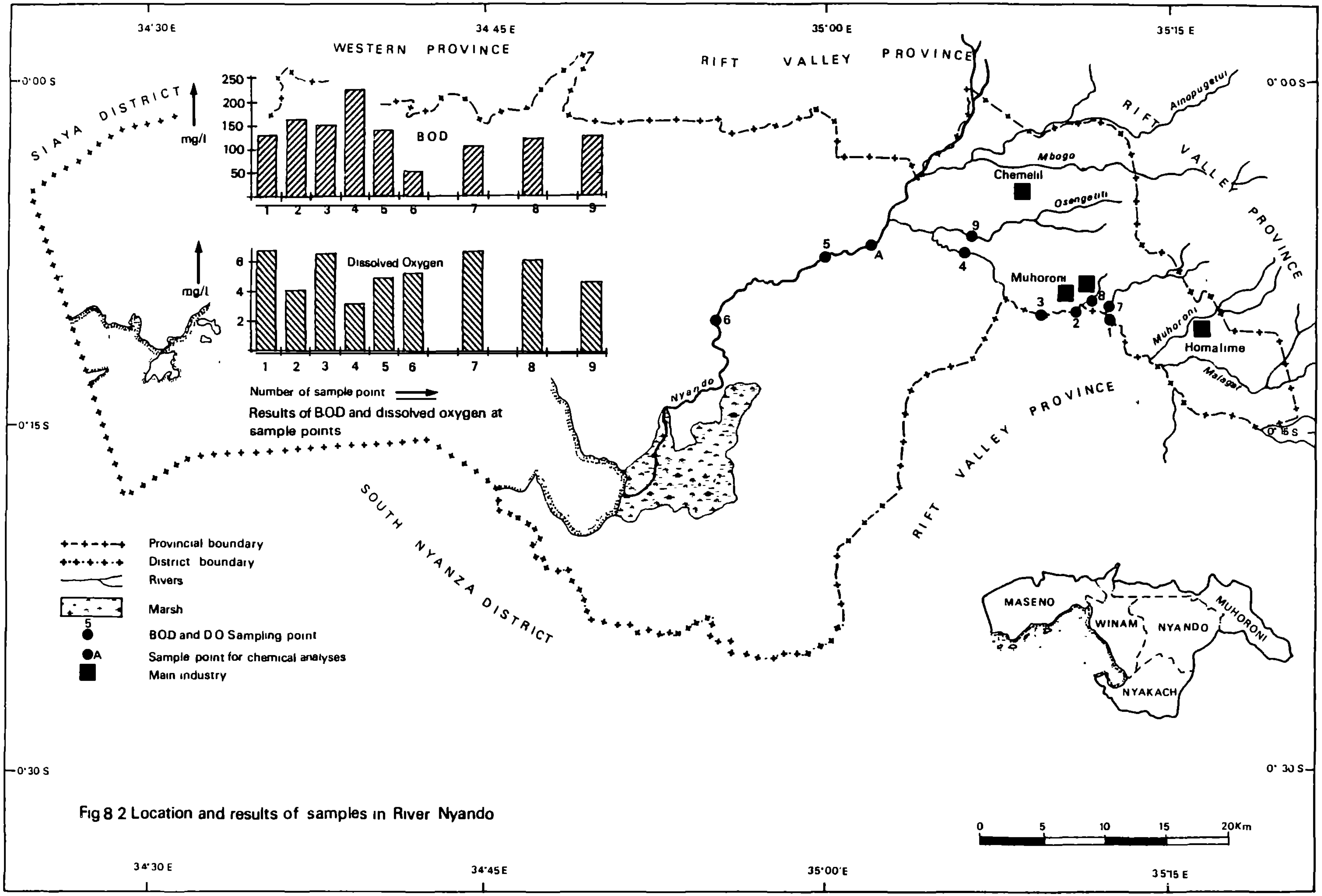


Fig 8 2 Location and results of samples in River Nyando

8.3 Water quality

8.3.1 General

During the inventory, samples have been taken and analysed from many rivers, flowing through Kisumu District. The results from the laboratory tests, which usually show the same pattern, can be characterized as follows.

- The turbidity of the water is always high. Concentrations ranging from 40-500 NTU are far above the Kenyan Standard for drinking water of 25 NTU. Treatment as coagulation, sedimentation and filtration will always be required to meet this standard.

- Faecal coliforms have amply been recorded in surface water, except for a few small (seasonal) streams. Chlorination is therefore always necessary to obtain safe drinking water. Figures for conductivity are seldom higher than 200 uS/cm, indicating a low content of ions.

- pH figures are generally between 7.0 and 8.0

- Hardness figures are all low; figures less than 100 mg $CaCO_3$/l indicate 'soft' water.

- Concentration of nitrate is generally low, and fluoride is below 1.0 mg/l.

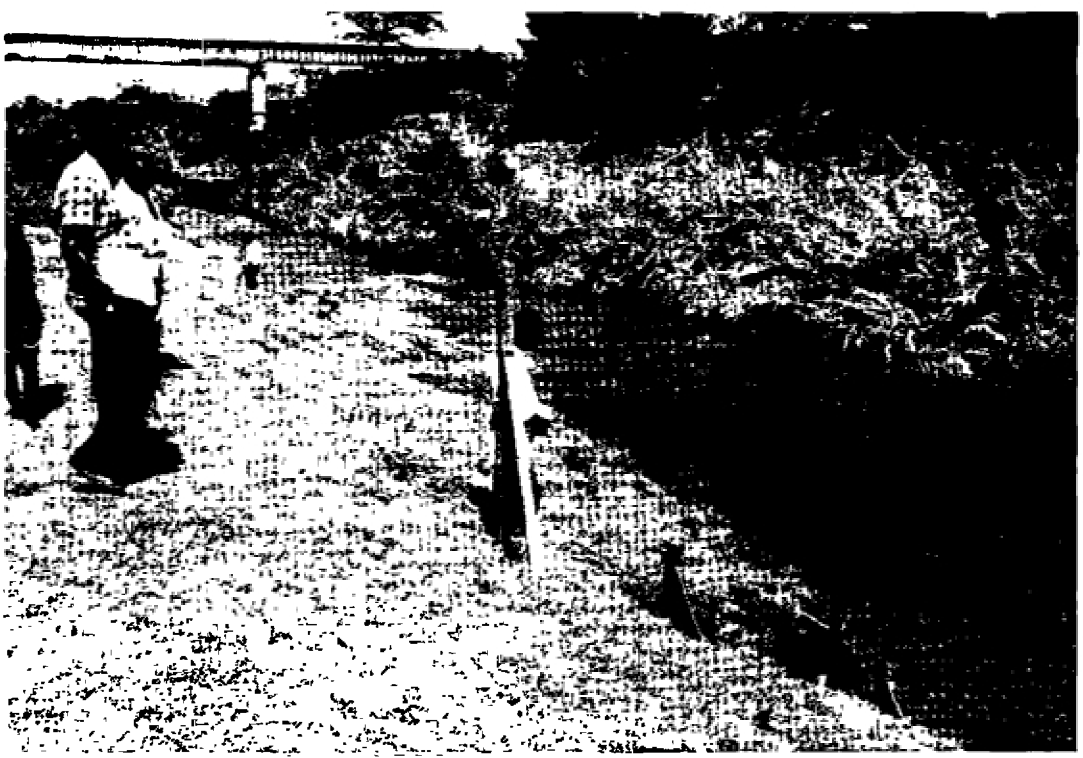
- Low concentrations of dissolved oxygen in general are not found. The measured concentrations vary between 6.0 and 9.0 mg O_2/l, which is nearby the maximum solubility of oxygen at 20 degrees Celsius. This indicates a minor organic pollution combined with a large reaeration capacity of the rivers.

8.3.2 River Nyando

The catchment area of the River Nyando covers a large part of the Muhoroni sugar plantations and some major industries drain their effluents in this river. For this reason a detailed investigation was carried out to check the water quality of this river.

Biological oxygen demand (B.O.D.) and dissolved oxygen have been determined during the rainy season at six downstream sample points in the River Nyando and another three tributaries as indicated in Figure 8.2. The results of this sampling is shown in the same figure and might lead to the preliminary conclusion that a moderate and a considerable organic pollution occurs between sample point two & three and three & four respectively.
This had resulted in an increased B.O.D. and a decreased concentration of dissolved oxygenin these river stretches.

Water treatment lagoon of sugar factory



Waterlevel gauges in River Nyando

It has been calculated that if the same charge of waste had been disposed in the river during a dry season discharge, this might have lead to an exhaustion of the dissolved oxygen and an anaerobic destruction of organic materials which would have caused the production of the poisonous nitrate and bad smelling river water.

A sample for more detailed chemical analyses has been taken at sample point A, indicated in Figure 8.2, when the discharge of River Nyando was close to 200 m^3/s. The results of the chemical analyses as executed by the Kenyan Bureau of Standards in Nairobi together with M.o.W.D.standards for drinking water (Ref.40) are presented in Table 8.1.

TABLE 8.1 RESULTS OF CHEMICAL ANALYSES RIVER NYANDO

Chemical constituent:	concentration found 27/8/88 p.p.billion	acceptable concentration p.p.billion
1.Lead:	30	50
2.Cadmium:	158	5
3.Chromium:	20	50
4.Mercury:	0	0
5.Arsenic:	0	50
6.Cyanide:	5	10
7.Total DDT's:	4.4	1
8.Hexachlorobenzene:	11.6	0.01
9.Aldrin:	2.00	0.03
10.Phenols:	63	(10)*

*Dependant on the kind of phenol.

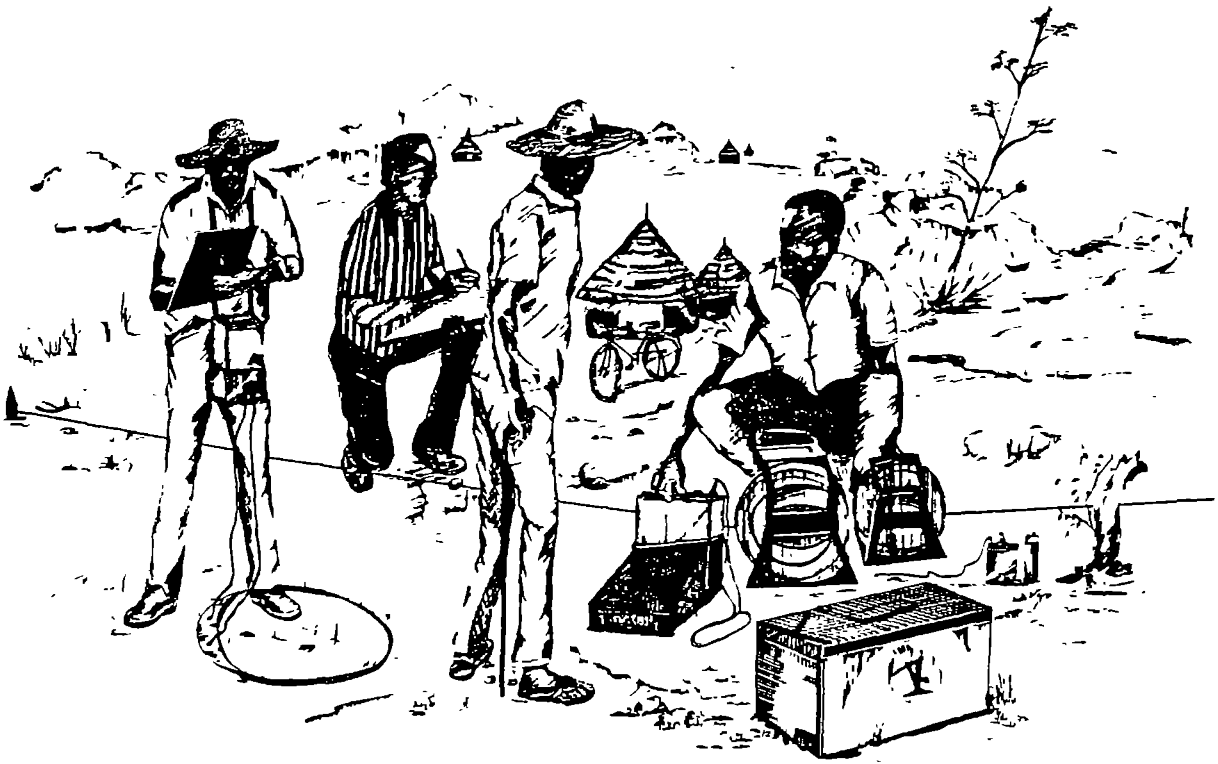
The Table shows that the existence of some heavy metals and toxic organic substances exceed the standards significantly. DDT's, HCB, and Aldrin will probably originate from insecticides, herbicides or pesticides used on the sugar plantations. Phenols and Cadmium can have any industrial origin. It can be assumed that the above concentrations increase during the dry season.

Although these findings are based on a single record of samples, it can be concluded that River Nyando is no logic source for drinking water. A high B.O.D. reduces the effect of chlorination and moreover special treatment will be necessary to eliminate toxins. Since Muhoroni Water Supply and Ahero Irrigation Scheme Water Supply use water from River Nyando, the existence of unwanted chemicals should be carefully monitored.

Geophysical survey for ground water

PART 6

GROUND WATER RESOURCES



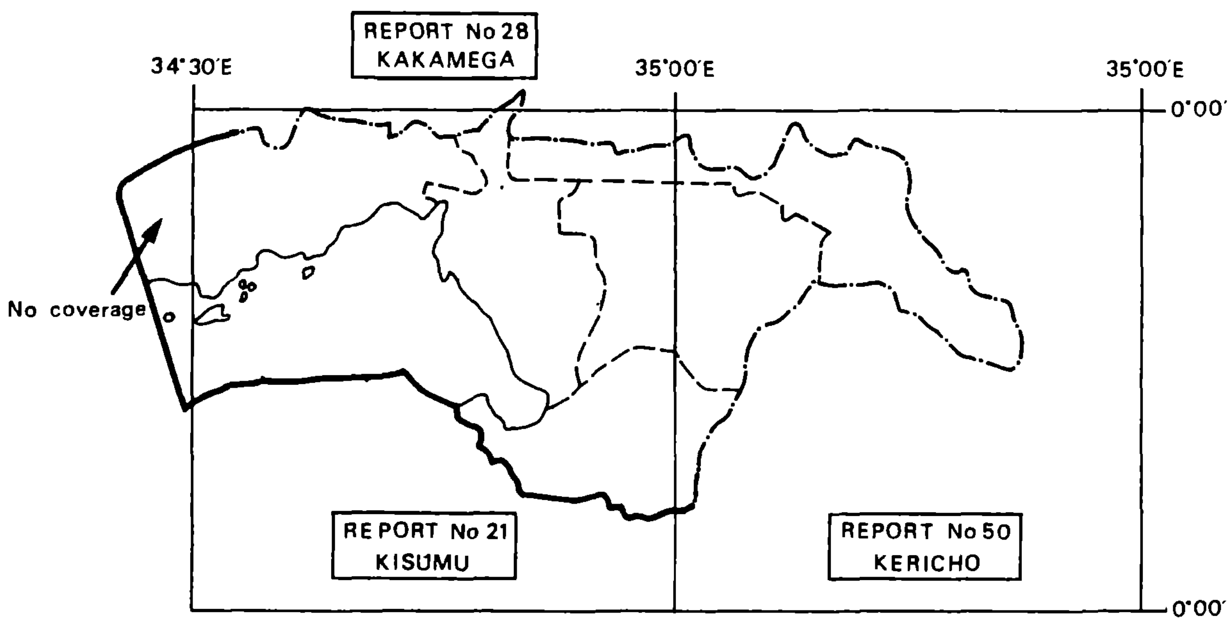
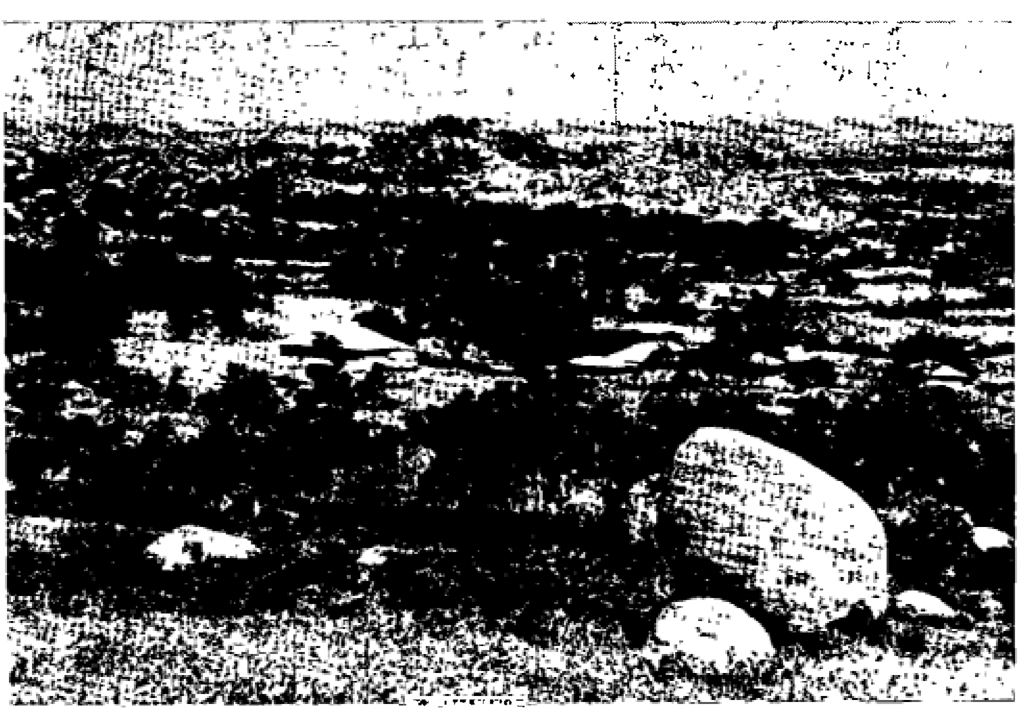


Figure 9 1 Index of geological maps and reports published by the Geological Survey of Kenya covering Kisumu District



Granite erosion landscape in Maseno Division

9 GEOLOGY

9.1 Introduction

Ground water presence and consequently the exploration techniques depend to a large extend on the geology of the area. Other factors which influence the ground water occurence as morphology, topography and pedology are strongly related with the geological setting of the region as well.
Without a proper understanding of the geological framework of a ground water system, it is impossible to quantify the resources. The initial stage of the ground water resources assessment must therefore be the study of the geology.

For this purpose a study has been made of the existing geological maps and reports, supplemented with geological field investigations and remote sensing studies.

9.2 Previous investigations

The geology of Kisumu District has been surveyed between 1948 and 1950, by geologists of the survey of Kenya who published a number of comprehensive reports and maps on a scale 1:125,000.

- Report No.21
  "Geology of the Kisumu District"
  by E.R. Saggerson (1952)

- Report No.28
  "Geology of the Kakamega Area"
  by A. Huddleston (1954).

- Report No.50
  "Geology of the Kericho Area"
  by F.W. Binge (1957).

Figure 9.1 shows that the area west of 34^{o} 30′ E (part of Maseno Division) has not been mapped before.

Although 30 to 40 years old, the geological maps and descriptions of the stratigraphy and lithology are detailed and of a good standard.
However, there are a few shortcomings. For the preparation of the geological maps, topographical maps were used which were on a scale of 1:250,000 and not very detailed. The topographic control of the geological maps therefore is generally not very accurate.

Because of the lack of good quality aerial photographs and satellite images, often geological structures as faults, fractures and joint patterns which are quite relevant in ground water occurence, do not appear on the existing geological maps.

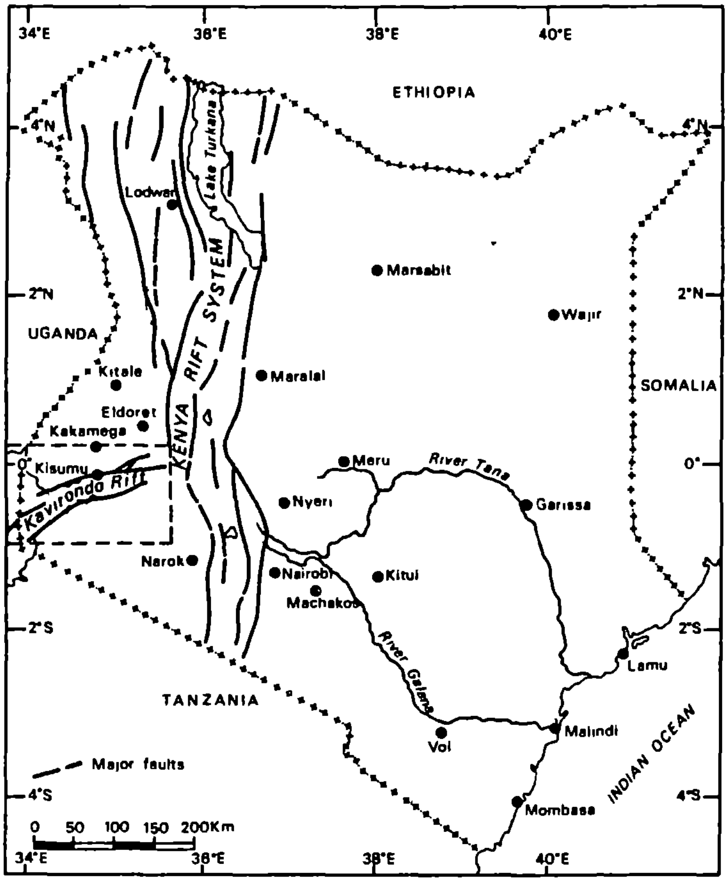


Figure 9.2a Rift valleys of Kenya

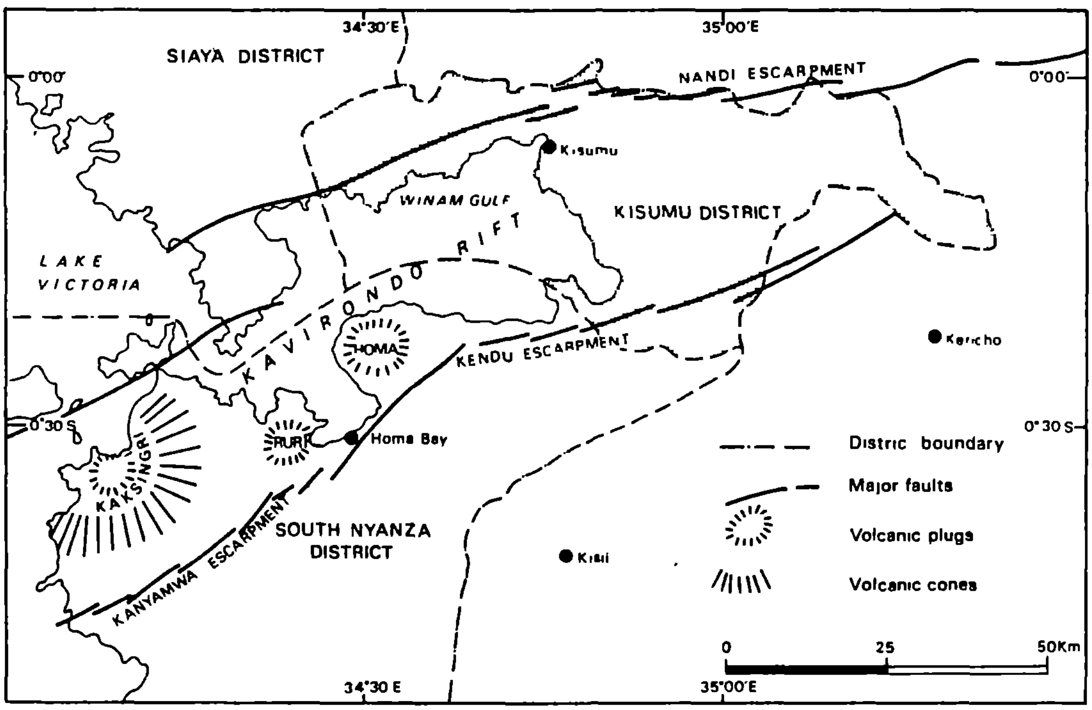


Figure 9.2b Extension of the Kavirondo rift valley in Kisumu District

9.3 Geological maps prepared by the RDWSSP

Annexed to the five RDWSSP Water Resources Survey Divisional reports which cover Kisumu District (Ref. 13) are scale 1:50,000 geological maps.
The basis for the preparation of these maps was formed by:

- scale 1:50,000 topographical maps of the Survey of Kenya
- the scale 1:125,000 geological maps indicated in section 9.2.

However, because of the forementioned shortcomings of the existing geological maps, a considerable amount of additional geological information was collected and used in preparing the 1:50.000 maps.
The supplementary data included:

- detailed geological boundaries from scale 1:50,000 aerial photographs
- major geological structures from satellite images
- geological faults, fractures and other lineaments from scale 1:50,000 aerial photographs
- geological field reconnaisance to clarify uncertain boundaries.

A geological map (Map-4) is annexed to this report covering Kisumu District on a scale of 1:100,000. the map is generally a compilation of the above mentioned Divisional maps with some minor simplifications and eliminations of irrelevant details.

9.4 Regional geology

Rocks in Kisumu District range from early Precambrian (2,200 million years) to Quaternary (2 million years-Recent). The Precambrian rocks which include mainly volcanic series have been extensively invaded by granites and underwent a low grade metamorphism.

The main geological feature in Kisumu District is the Kavirondo Rift.
This rift branches from the main north-south oriented Kenya Rift Valley system, trending east-west and north-east to south-west towards Lake Victoria (Figure 9.2 a and b).
To the south the Kavirondo Rift is bounded by the Kanyamwa and Kendu faults which show maximum throws of 300 m; its northern boundary is the Nandi fault.
The evolution of the Kavirondo Rift involved two stages:

- a stage of down warping related to the formation of a shallow basin during the Miocene
- a stage of rift faulting during the Pliocene to Pleistocene.

TABLE 9.1 STRATIGRAPHY IN KISUMU DISTRICT

TIME PERIOD	ROCK SYSTEM	GEOLOGICAL UNIT Symbol	Lithology	DESCRIPTION OF GEOLOGICAL EVENTS
QUATERNARY	RECENT	R	Alluvium Superficial deposits Talus scree	Sedimentation of erosion products
	PLEISTOCENE	Pl	Lake deposits and fluviatile sediments intercalated tuffs	Sedimentation in Karvicondo Rift Valley
TERTIARY	PLIOCENE			Development of Kavirondo Rift Valley
	MIOCENE	Tp	Phonolitic lavas	Development of major faults and fractures with associated fissure eruptions
		Tt	Tuffs Agglomerates	
PRECAMBRIAN		D	Dolerites	Intrusions
		G	Granites	
	NYANZIAN	Ni	Ironstones, cherts	
		Nr	Rhyolites, tuffs, agglomerates	
		Na	Andesites, tuffs	
		Nb	Basaltic lavas	

The faulting has allowed the accumulation of Pleistocene sediments and possibly tuffs of a vast thickness in the Kano Plain, which are now largely covered by alluvial deposits.

Tertiary faulting was accompanied by sheet eruptions of phonolitic lavas which are found north and north-west of Kisumu Town in the east of Muhuroni Division and on the Nyabondo Plateau.

9.5 Stratigraphy

For descriptive purposes, the rocks occuring in Kisumu District fall into four well defined groups, based on their geological age:

- Precambrian (volcanics, intrusives)
- Tertiary (volcanics)
- Pleistocene (sediments,tuffs)
- Recent (alluvium, soils).

Between the early-Precambrian and the Tertiary there is a major geological hiatus as there is no evidence of sedimentation, volcanic activity or igneous intrusion during the Palaeozoic and Mesozoic.

The rock systems of the four groups and their further sub-division into geological units are shown in Table 9.1.
The areal distribution of the geological units is shown simply on Figure 9.3 and in detail on MAP-4, annexed to this report.
The lithology of the geological units is briefly described in section 9.6.

9.6 Brief description of the rock systems

The Nyanzian System

Rocks of the Nyanzian System are found only in the eastern part of Kisumu District.
The rocks of this system which are the oldest exposed in the area, are predominantly volcanic in origin.
They consist of basaltic, andesitic and rhyolitic lavas together with pyroclastic rocks and tuffs.

Nyanzian basalts (Nb)

Basalt outcrops are found in the north of Maseno Division, around Maseno, and in the central-southern part of this Division along the Winam Gulf.
The rocks mainly consist of highly weathered metamorphic pillow lavas. Unweathered outcrops of the basalts, are almost completely absent within the area. The parent rocks are dark-green, fine grained, sheared, altered and metamorphosed, while original structures can hardly be recognized anymore.

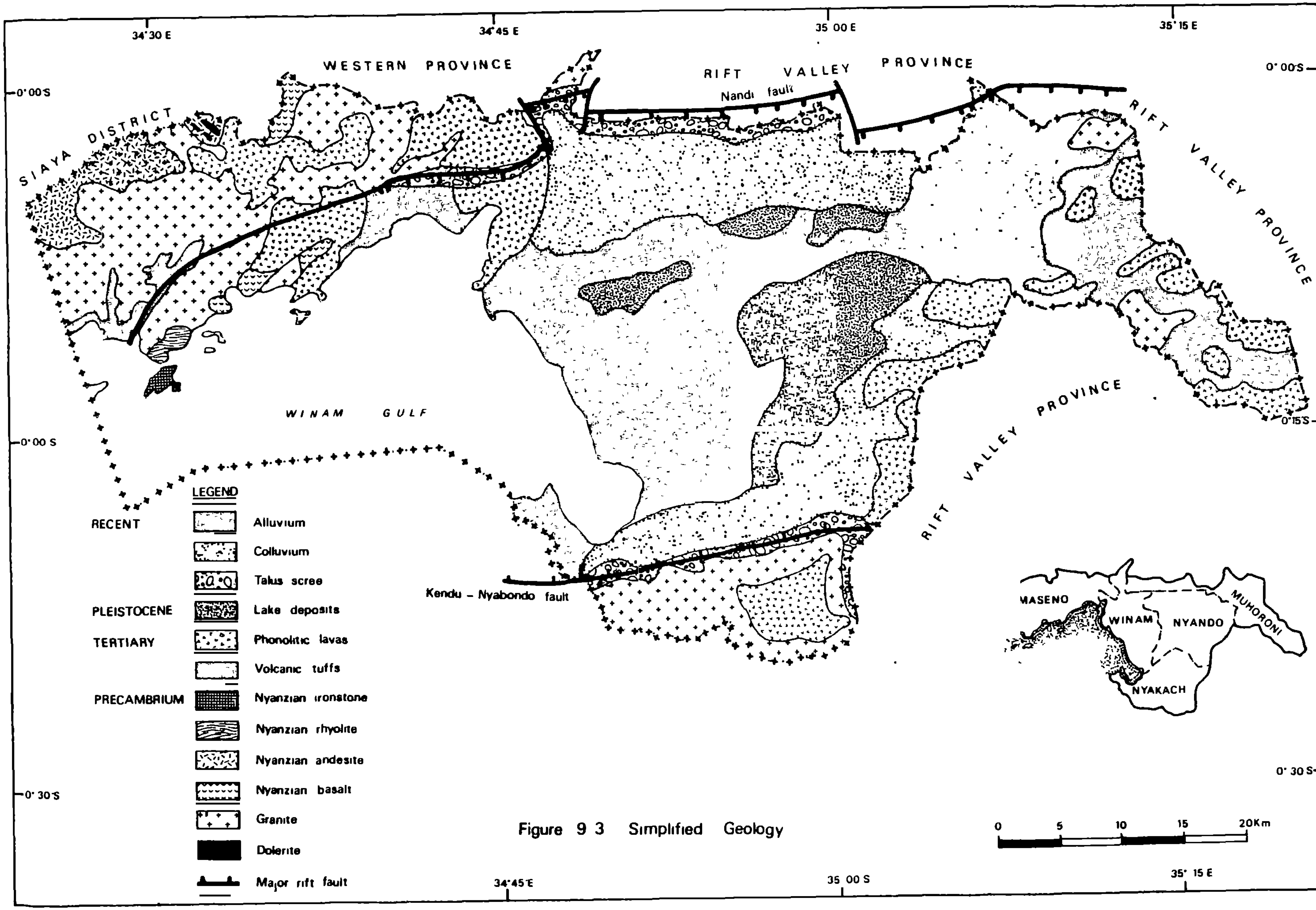


Figure 9 3 Simplified Geology

Nyanzian andesites (Na)

Andesite rocks are exposed in the north western corner of Maseno Division. These rocks range from fairly coarse grained types to medium and fine grained porphyritic varities.
The former have white and pale green feldspar phenocrysts set in a fine grained matrix. The dioritic-prophyrite variety is coarser in grain than the former type, carrying feldspar phenocrysts upto several centimeters in length. Colours range from medium green to blue green. Weathering colours are usually cream and brownish.

Nyanzian rhyolites (Nr)

Two small outliers of this rock type are found in the southern tip of Maseno Division, opposite Ndere Island.
Also, the small islands east of Ndere Island are underlain by rhyolite.
This rock type consists of acid volcanic lavas and associated pyroclasts.
The rocks have a rhyolitic composition, consisting of mainly quartz and feldspar.

Nyanzian banded ironstones (Ni)

Fine grained banded ironstones and cherts are usually found associated with rhyolite. The ironstones consist mainly of dark bluish chert, alternated with thin layers of reddish brown limonite and hematite. The ironstones are exposed as bands, of 15 to 70 m thick.
They are found only on Ndere Island in Maseno Division.

Precambrian Intrusives

During the late-Precambrian large granitic bodies and associated quartz porphyries intruded the older Nyanzian rocks and later dolerite dikes cut through the older rocks, including the granites.

Granites (G)

Granitic rocks crop out in approximately 60 % of Maseno Division.
The granite is usually fairly fine grained, pale, grey pinkish coloured and moderately porphyritic, with pink and greenish feldspar phenocrysts up to one centimeter in diameter.
Related to these granite instrusions are quartz porphyries. They consist of entirely large feldspar phenocrysts set in a fine grained quartz matrix. The colour of the quartz porphyrities is pink greenish and pale yellow when weathered.

Another large granite body crops out in the southern half of Nyakach Division.
The northern margin of this granite which is bounded by the Kendu-Nyabondo faults, is foliated and highly broken.
This granite varies considerably, from a pinkish coloured leucocratic type in the west, to a grey hornblende rich type in the east.

Smaller granite intrusions are found also in the east of Muhuroni Division.

Dolerites (D)

Dolerite dikes occur only in the north of the Division, west of Maseno. They are emplaced in and cut through Nyanzian rocks. They vary from fine to moderately coarse grained rocks usually dark green with green augite phenocrysts ophitic intergrown with plagioclase crystals.
The dolerite dykes follow the dominant fracture trends.

Tertiary volcanics (Tp and Tt)

Volcanic rocks of Tertiary age are found in three different areas of Kisumu District:

- the east of Muhuroni District
- the east of Maseno District
- the south-east of Nyakach Division.

The volcanic rocks of Tertiary age that crop out in the eastern part of Muhuroni Division were extruded from the Tinderet Volcano complex in Kericho District.
According to Binge (Ref. 14) basalt lava's (Tp) flowed extensively to the west across the head of Kano Plain during the Pliocene.
The lava's rest on tuffaceous and agglomeratic beds of Miocene age (Tt).
Phonolitic lavas are found in large areas of the central and eastern parts of Maseno Division, where they cover granites.
The lavas are related to the late Tertiary-Pleistocene faults and commencement of movement along what later were to be fault lines.

The lava itself has been affected by Pleistocene faulting as well and is found at various heights between 1,600 m and lake level (1,135 m).

Saggerson (Ref.10) classified the phonolite as being of the Losanguta type.
In hand specimen this rock is porphyritic, varying from greyish-blue to greenish-black, fissile and having a conchoidal to splintery fracture.
The phonolites are often overlain by only a thin soil cover, the surface strewn with a mass of boulders.

Phonolite also caps the granite escarpment in the south-eastern corner of Nyakach Division. This Nyabondo flow is part of the phonolite which now covers the Kericho District.
The lava flowed from the area immediately to the east, in western direction across the sub-Miocene peneplain.

The lavas are related to the Miocene/Pleistocene faulting and it is likely that they are fissure eruptions associated with the commencement of movement along the fault lines.
The Nyabondo phonolite is 30 m - 60 m thick.

In hand specimens the rock is blue-black, porphyritic and fissile with an uneven fracture.

Lateritic ironstone is a common weathering product. The phonolites are often overlain by only a thin soil cover, the surface strewn with a mass of boulders.

Pleistocene deposits (Pl)

The whole of the Kano Plain is underlain by Pleistocene deposits. The Pleistocene deposits are both lacustrine and fluviatile in origin.
They vary from gravels to mudstones derived from erosion of the neighbouring land masses. Deposition of the sediments took place in several stages, mainly during pluvial periods, alternated by erosion phases during inter-pluvial periods. Faulting continued throughout the Pleistocene.

Boreholes in Nyando Division and elsewhere in the Kano Plain, penetrate up to 250 (m) of varying sequences of siltstone, sandstone, gravel and claystone.

In the north and in the south, respectively along the foothills of the Nandi Escarpment and Nyabondo Escarpment, the Pleistocene deposits are covered by talus scree and colluvium of Recent age.
Elsewhere in the Kano Plain, most of the Pleistocene is covered by upto 20 m of alluvium.

<u>The Recent System (R)</u>

Deposits of Recent age include talus scree, alluvium, gravels, lateritic ironstones, and soils.
The importance of these superficial deposits lays in the fact that they affect the amount of recharge received by underlying rocks through infiltration from rainfall.
This is controlled by their lateral extend, thickness and nature of composition.
A brief summary of the most characteristic Recent deposits is included below.

Talus Scree

Hill wash accumulations occur along the foot hills of the Nandi and the Nyabondo Escarpments. They include coarse talus as well as alluvial fan materials (gravels, sands) and their thickness can reach up to 30 m.

Alluvial flats

Alluvial flats are of two types; the first genetically connected with the Winam Gulf, the second with the rivers.
During the Pleistocene, the whole of the Kavirondo Rift Valley was part of the lake but since the fall of the lake, rivers have meandered across the old bottom and deposited large quantities of clay, silt and sand and extended their courses.
Near the lake, the flats are extremely marshy.

Upland valleys only have narrow strips of gravel and sand while near the Winam Gulf, the major rivers have mainly silt and clay.

Soils

The soils in the area may be divided into three principal types: black cotton soils, red laterized soils and granitic soils.

The black cotton soils are calcareous and black or grey in colour. Invariably they occur on the alluvial flats.
The phonolites carry a laterized soil cover or a lateritic ironstone capping. Many of the phonolite outcrops however carry practically no soil cover. The soils on the granites are white to light grey, consisting of quartz and feldspar and generally have arisen by residual accumulation of granite debris.

10 PREVIOUS GROUND WATER RESOURCES ASSESSMENT STUDIES

10.1 Preliminary Hydrogeological Investigation Nyanza and Western Provinces

The first comprehensive investigation into the ground water potential of Kisumu District was carried out in 1980 by Ker and Priestman, for the Ministry of Water Development (Ref. 26).
The main purpose of this hydrogeological study was to determine the availability of ground water and its potential as a water source for the rural population.

The assessment of the ground water resources by Ker and Priestman essentially has been a desk study wherein available information was assembled and analyzed.
Information collected and presented in the report include rainfall, evaporation and streamflow as well as geological data.
Extensive use was made also of borehole completion records, on file with the MoWD.
Generally the following approach was followed:

- a climatological and hydrological study of the water balances of catchment areas was carried out to evaluate the amounts of water available for recharge of the aquifers

- geological rock types were studied in order to define the aerial distribution of potential aquifers

- borehole data were analysed to delineate aquifers and their hydraulic properties.

The report concluded that the major ground water resources in Kisumu District are to be found in the sedimentary rocks of the Pleistocene system which underlies the Kano Plain and that local supplies can be derived also from Tertiary and Nyanzian volcanic rocks.

Ker and Priestman's preliminary assessment of the ground water potential of the various rock types in Kisumu District can be summarized as follows.

Table 10.1 CLASSIFICATION OF ROCK TYPES AS POTENTIAL AQUIFERS ACCORDING TO KER AND PRIESTMAN

Rock Type	Aquifer type	Aquifer Potential	Remarks
Recent sediments	unconfined	moderate	superficial deposits of limited extent
Pleistocene sediments	semi-confined	very good	occurring in Kano Plain and locally along Winam Gulf
Tertiary volcanics	confined	low-moderate	
Granites	confined	poor	
Nyanzian volcanics	confined	low-moderate	

According to Ker, Priestman and Associates, the Pleistocene aquifer is and has been producing large quantities of ground water, despite of a moderate recharge potential.

By using very approximate hydraulic parameters, they conclude that it is possible that ground water resources under the Kano Plain are abstracted already in excess of the natural recharge of the ground water flow systems.

Therefore, they attach great importance to the assesment of the total ground water resources of the Pleistocene sediments found in the Kano Plain. Their suggested work scheduled would include:

- assessment of the vertical and lateral extent of sediments by geophysical methods and field mapping.
- quantifying the areal distribution of important hydraulic parameters by pump testing of boreholes
- assessment of recharge mechanism to the Pleistocene aquifers by geological and hydrochemical field studies
- determination of the total output from the system by a field survey, including the monitoring of borehole abstractions.

Recommendations given by Ker and Priestman on further investigations of the ground water resources included:

- development of ground water in areas underlain by sedimentary and Nyanzian volcanic rocks
- investigations to determine the optimal location for borehole sites
- drilling and testing of boreholes.

Additionally the report recommends the rehabilitation of some existing boreholes.

Various design reports on rural water supply are using the findings of the Ker and Priestman report in the assessment of the ground water potential of the areas concerned. Generally outside the Kano Plain the use of ground water is not considered feasible and no designs are known, relying on boreholes only.

10.2 Lake Basin Shallow Wells Pilot Project

A description of this Project, carried out during 1982 and 1983 by DHV Consulting Engineers for the Lake Basin Development Authority (Ref. 11), is given in section 2.1.1.
The major aim of the Project was to investigate the feasibility of shallow well construction in Nyanza Province.
In order to gather knowledge on the occurrence of shallow ground water, the following activities were undertaken:

- a field inventory of the use of water resources, with emphasis on the occurrence of wells

- hydrogeological field investigations into the occurrence and hydraulic properties of shallow aquifers by means of boring and testing of hand drilled survey holes

- the actual construction of 41 hand dug and hand drilled wells

- analyses of shallow ground water samples.

Based on the results of these field investigations it was tentatively concluded that:

- around 30 % of the population of Kisumu District could be supplied by dug wells of 10-25 m depth

- a substantial part of the population could be supplied by machine drilled boreholes of 45-75 m depth

- because of the complicated hydrogeological situation in the District, adequate methods would have to be developed to investigate the occurrence of deeper ground water and to locate well and borehole locations amongst others by means of detailed geophysical investigations.

10.3 Hydrogeological Investigation at Miwani Sugar Estates

This desk study was carried out by Ground water Survey (Kenya) Ltd., during 1987 for the Sucrose Marketing co. Ltd.
The aim of the study was to evaluate ground water resources at the Miwani Sugar Estate, Muhoroni Division, in the light of planned ground water abstraction for irrigation. The study concludes that detailed (field) investigations are necessary in order to quantify and clarify:

- aquifer geometry
- aquifer hydraulics
- recharge mechanism
- impact of long term abstractions.

The following types of studies and surveys are proposed to collect this information:

- remote sensing study to reveal details of fault structures distribution and extent

- the execution of surface geophysical methods to establish potential aquifer geometry

- the execution of a number of pumping tests on existing boreholes to establish aquifer hydraulics

- exploratory borehole drilling to confirm certain features, tentatively interpreted from the geophysical investigations.

11 THE RDWSSP APPROACH TO GROUND WATER EXPLORATION IN KISUMU DISTRICT

11.1 Introduction

The RDWSSP has set up and carried out a comprehensive ground water resources exploration in Kisumu District.
The purposes of these investigations were:

- to delineate aquifers in all parts of the District
- to develop survey methods for location of promising well and borehole sites
- to quantify the volumes of ground water stored and available for domestic use
- to investigate the ground water quality in relation to domestic use.

In chapter 9 it is shown that Kisumu District is underlain by a large diversity of rock types which vary in age from Recent to Pre-Cambrian.

Table 11.1 gives a review of the major rock types and their outcrop areas in the District.

TABLE 11.1 REVIEW OF MAJOR ROCK TYPES IN KISUMU DISTRICT

Rock type	Relative occurrence	Main areas of outcrop
Recent sediments Pleistocene sediments	60 %	Kano Plain Isolated patches along the Winam Gulf Alluvial valleys
Tertiary volcanics	20 %	Maseno Division Eastern part Muhuroni Division Southern part Nyakach Division
Precambrian volcanics and intrusives	20 %	

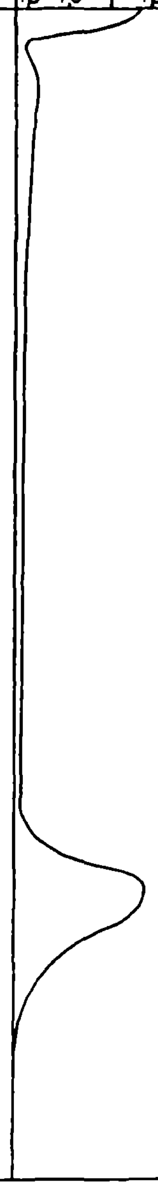
LITHOLOGY	DESCRIPTION	WEATHERING PROFILE	DEPTH (m)	HYDRAULIC CONDUCT (m/day) 10^{-2} 10^{-1} 1 10	GROUND-WATER POTENTIAL
Top soil	Residual, clayey soils		0 - 3		seasonal groundwater
Duri crust	Lateritic hard pan		3 - 5		
Completely decomposed					very poor
	Zone of alteration massive accumulation of secondary clay minerals commonly plastic		5 - 30		
Weathered rock					poor
Slightly weathered rock					
Active weathering front	granular layer of desintegrated rock fragments		10-50		very good
	Fractured and fissured rock		20-70		good
Fresh rock					no groundwater

Figure 11.1 Typical weathering profile in hard rock

With respect to the occurrence and exploration of ground water, the rock types prevailing in Kisumu District can be placed into two groups:

- hard rocks ; which include the Pre-Cambrian volcanic and intrusive rocks as well as the Tertiary volcanic rocks
- sediments ; which include both Pleistocene and Recent deposits.

The methods of groundwater exploration developed by the RDWSSP for these two groups of rocks will be explained separately in sections 11.2 and 11.3.

11.2 Groundwater exploration in hard rock areas

11.2.1 Occurrence of groundwater

Ground water in the weathered layer (Figure 11.1)

The chemical and mechanical disintegration of the hard rocks has resulted in a cover of weathered rock material overlaying the fresh parent rock. The higher horizons of the weathered layer are usually very clayey, consisting of completely weathered and highly altered rock, in which no original rock structures can be found anymore. Feldspar minerals are commonly completely altered to clay minerals, creating high porosities, but extremely low permeabilities. The thickness of this decomposed layer may range from 5 - 50 m and is 20 m on an average.
Between the decomposed layer and the fresh bedrock the weathered layer consists of less weathered, partly altered rock material, which usually has a higher permeability. The average thickness of this part of the weathered layer is 10 - 20 m in the topographically lower areas, but may be totally absent on steep slopes and hill tops.

Ground water, is usually found within this less weathered zone with relatively higher permeabilities, at depths between 10 and 60 m. Where the depth to the ground water is less than 30 m below ground level, and when seasonal ground water level fluctuations are not exessive, this type of aquifers can be exploited by means of hand dug wells. Because the relatively low well yields of this type of aquifer, boreholes, which almost have no storage capacity, usually have a low productivity or can be even unproductive.

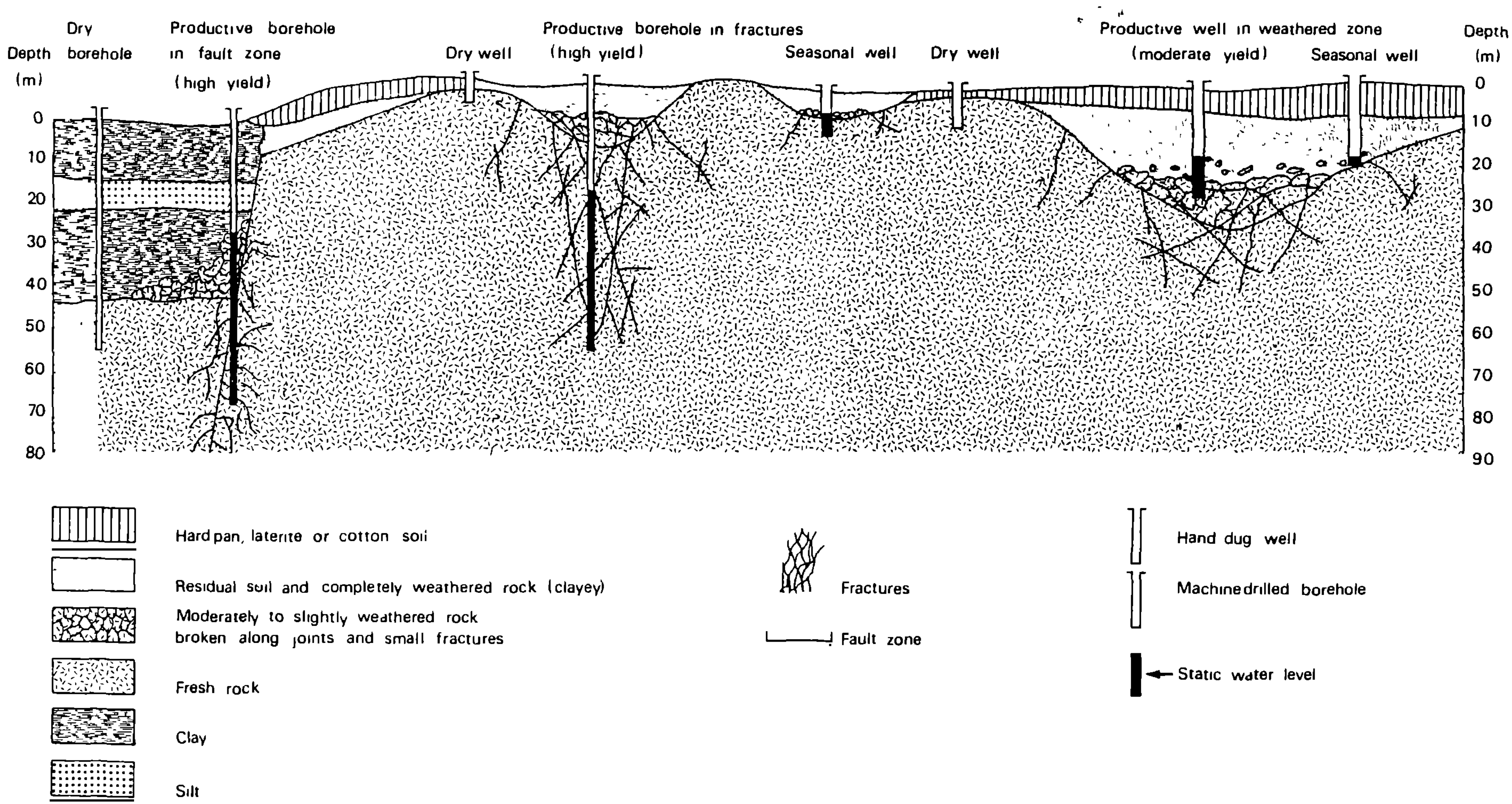


Figure 11 2 Occurrence of ground water and suitable well types in hard rock

Groundwater in faults and fractured aquifers (Figure 11.2)

Although ground water usually is present within the weathered layer, for boreholes with moderate and high yields this type of aquifer generally is not sufficient . Recent investigations carried out in areas with a similar geological environment revealed that high yield boreholes can be located in major fault fracture zones. (UNESCO, Ref.42).

The Precambrian and Tertiary rock formations in Kisumu District underwent a long history of rock deformations which resulted in a large number of joints, fractures and faults.

From the results of the on-going borehole drilling programme in Nyanza Province it appears that frequently high yield wells (10-50 m^3/hr) can be constructed in major fault zones while the surrounding areas have only a moderate-low ground water potential.
This can be explained as follows:

- Along fault or fracture zones weathering can penetrate much deeper, thus creating sub-vertical zones filled up, with coarse weathered rock material having generally much higher transmissivity values than the surrounding areas.

- ground water accumulates from large areas to these faults or fracture zones producing therefore a steady recharge.

Exploration methods

The exploration method for this type of aquifers developed by the programme is aimed at the accurate detection of such fault or fracture zones in the field.

For this purpose the following survey components can be distinguished:

- mapping of the most important fault and fracture lineations by means of remote sensing and aerial photo interpretations;

- geophysical field surveys along profiles across these fracture or fault lineations.

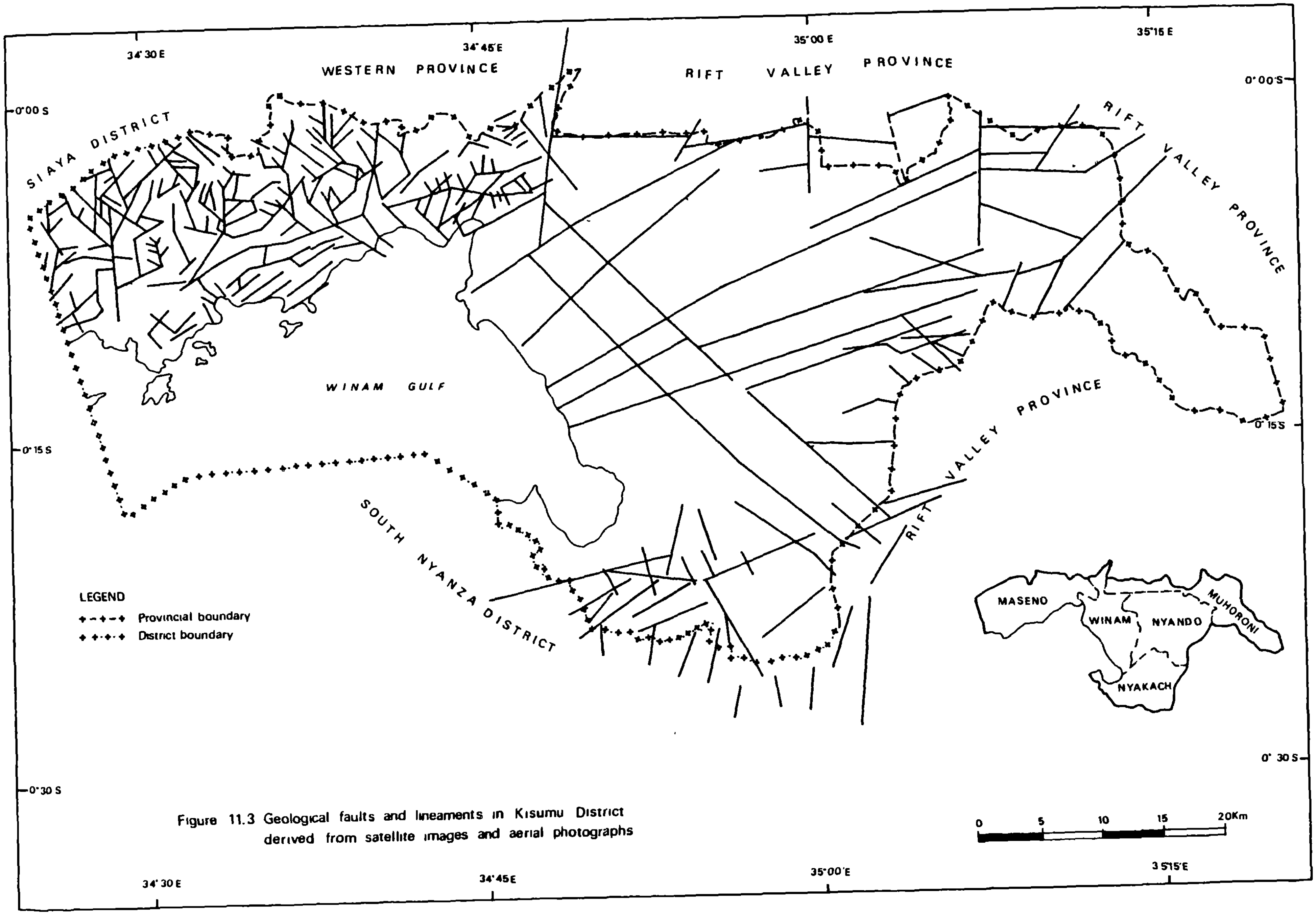


Figure 11.3 Geological faults and lineaments in Kisumu District derived from satellite images and aerial photographs

11.2.2 Mapping of faults and fracture zones

Existing geological maps at a scale of 1:125,000, although giving a good picture of the lithology and stratigraphy, are lacking any detailed structural features which are considered essential in ground water occurrence and exploration.

For this reason detailed Divisional geological maps at a 1:50,000 scale have been prepared containing the existing geological data, supplemented with structural data derived from satellite images and aerial photographs.

Aerial photographs were used of the V-13-B series taken in 1967 with an approximate scale of 1:50,000.
For the interpretation of satellite images use was made of the Landsat MSS false colour composite exposures number of 181/60 and 181/61 (January 1979) on a scale of 1:250,000.

Because of a limited spatial resolution, satellite images reveal mainly the major fault structures.
Further on satellite images generally regional scale geological features as fault escarpments, volcanic complexes and differences in major rock types can be recognised.

Faults and fractures generally appear on aerial photographs as linear features. Steep to sub-vertical faults form straight lines, while low angle faults appear as curved lines. Indications for the presence of faults or fractures are frequently found as elongated valleys or linear vegetation patterns. Map-4, which basically is a compilation of the 5 Divisional geological maps, shows the results of this remote sensing study of faults and fractures.

From existing data and experience gained during the Programme, it became evident that boreholes were most successful when accurately located on fault structures and that a location error of 10 (m) can make the difference between a high yield borehole and an unproductive one.
It is therefore necessary to precisely locate the faults in the field, initially identified by the above described satellite image and aerial photograph interpretation, which is done by detailed on-site geophysical survey.
Figure 11.3 shows the faults and lineaments found through the remote sensing surveys carried out.

Electro magnetic profiling

11.2.3 Geophysical survey method

After experiencing and comparing several geophysical survey methods, a combination of geo-electrical (GE) and electromagnetic (EM) measurements was chosen which appeared to produce the best results.
A standard survey set-up was designed which can simply and quickly be applied.
The standard field survey comprises:

- horizontal loop EM conductivity profiling
- horizontal GE profiling
- vertical electrical soundings.

For the geo-electrical measurements, use is made of the SAS-300 Terra-Meter from ABEM. The electro-magnetic survey is done with an EM-34 conductivity meter from GEONICS.

Electro-magnetic profiling

The geophysical field survey commonly starts with electromagnetic profiling, perpendicular to an inferred fault or fractured zone. Generally the vertical dipole mode is used (coils aligned in parallel horizontal position).
First a coil spacing of 40 m is used after which the same profile is measured again with a coil spacing of 20 m.
Using a configuration with a coil spacing of 20 m a maximum exploration depth of about 15-20 m is obtained, while with a coil spacing of 40 m the maximum exploration depth is increased to approximately 30-40 m .
The intervals between each consecutive measuring point along the profile normally is 10 m . The length of the profiles varies from 400 to 600 m.

Horizontal electrical profiling

After completion of the EM profiles a horizontal electrical profile is measured along the same line.
For this type of survey the Wenner configuration is used, with the distance between the current electrodes AB fixed at 60 m and the distance between the potential electrodes MN at 20 m.
Like the EM profiles, the interval spacing between the measurement normally is 10 m .

Vertical electrical resistivity sounding

Qualitative evaluation of profiling data in the field

Both the EM and GE profile data reflect lateral changes in electrical resistivity, corresponding with variations in lithology, weathering, fracturing, thickness of layers, water content or salinity up to a depth of 20-40 m.

Although generally the EM profiles reflect the same lateral changes as the GE profiles, the EM profiles, in particular, proved to be very sensitive to fault and fractured zones which can be traced by this method with an accuracy to within a few meters.

The recorded data of EM and GE consequently is plotted and interpreted in the field and where a fracture or fault is inferred, a number of vertical electrical soundings (VES) are measured along the profile line.
If no clear anomaly on the profiles is recognized, additional profile lines are measured, commonly running parallel to the first line.

Vertical electrical sounding

After completion of the profiles, along the most promising profile line 4-6 vertical electrical soundings are measured. The soundings are performed according to the Schlumberger configuration with a maximum current electrode spacing of 200 m, AB/2 = 100 m . The spacing between the soundings is variable, ranging from 70-170 m.

From the vertical electrical soundings carried out this way, the resistivity and thickness of (sub) horizontal layers is interpreted to locate the depth of potential aquifer zones at all sites.

Information derived from the combined results of the GE and EM surveys

The geophysical data is interpreted and elaborated by micro computer, and results are plotted in schematic cross-sections (Figure 11.5).
From the elaborated geophysical data, for each surveyed site, conclusions are drawn regarding:

- presence and depth of different zones of weathering
- depth to the unweathered bedrock
- presence and depth of ground water table
- thickness of aquifers
- presence and accurate location of (sub) vertical discontinuities as faults, intrusive dykes and lithological boundaries etc.
- salinity of ground water.

Based on these conclusions, the best well site, the depth and type of well, a hand dug well or machine drilled borehole, can be selected.

With this standard procedure of geophysical survey a certain routine is achieved by the field surveyors, which results in a high accuracy of measurements and a minimum of errors. In 90 % of the initial surveys, sufficient information is gathered to fully interpret the data in terms of ground water potential and to indicate the most promising well locations.

11.2.4 Applicability of the ground water survey method

Advantages of the method

The ground water survey method adopted and developed by the RDWSSP is applicable almost everywhere in rural areas and can be executed in a quick and effective manner in the field.
With the method, it is possible to study large areas in a relatively short period while at the same time it is suitable also for detailed surveys of well and borehole locations.
Both sub-horizontal as well as sub-vertical water bearing zones can be detected down to a depth of 75 m, which proved to be sufficiently deep in hard rock areas.
Advantages which the survey method offers over other geophysical methods include:

- the geophysical instruments used by the Programme are easy to operate and need little maintenance

- most of the instruments are available and servicable in Kenya and are already beeing used by the MoWD and ground water exploration companies in the country

- in contrast to most other geophysical exploration methods, both the GE and EM surveys results give an indication of the ground water salinity

- without the use of high voltages, explosives or radioactive sources, the method is completely safe and without risks for the surveyors and public.

Based on the geophysical survey results, recommendations can be made which may considerably reduce the costs of a construction program.

- By accurately establishing the most suitable well location, the percentage of productive wells is increased whereby the expenses for dry holes are reduced.
- By indicating in which cases wells can be hand dug, high costs for unnecessary boreholes can be avoided.
- By reducing the depth of boreholes on interpreted hydrogeological grounds, considerable costs can be saved.

Limitations of the method

- The geophysical methods cannot be applied in areas with intense shrub vegetation or a dense pattern of fences, without cutting and clearing them first.

- The survey results become disturbed and unreliable in areas close to power lines, metal fences, underground pipe systems and telephone cables.

- Highly conductive mineralized zones (base metals, graphite, laterite etc.) influence and may disturb the interpretations of the geophysical data.

When to apply geophysics in ground water surveys

From the ground water investigations in all parts of Nyanza Province during the past 4 years, the following advice can be given on the necessity of geophysical field surveys:

- In areas with a mean annual rainfall of less than 1200 mm/year a geophysical survey is always required . Exploitable amounts of ground water are almost exclusively found in faults or fracture zones.

- In areas with a mean annual rainfall between 1200-1600 mm/year generally a geophysical survey is recommended for an increased success rate. It is strongly cost reducing in any well construction programme.

- In areas with a mean annual rainfall of more than 1600 mm/year usually no geophysical survey is necessary for the siting of hand dug wells. However for medium to high yield boreholes a detailed geophysical survey is recommended.

It should be stressed, however, that the above stated is a generalization and that other factors than rainfall as topography geomophology and geology will also influence the decision whether to apply geophysical survey methods or not.

SITE: OMBOGA SECONDARY SCH. SITE No: KB-18

KENDU DIVISION SOUTH NYANZA DISTRICT

MAP SHEET 116/3 GRID REFERENCE 680 6 – 9951 0
LOCATION SOUTH KARACHUONYO SUB-LOCATION NORTH KAMENYA

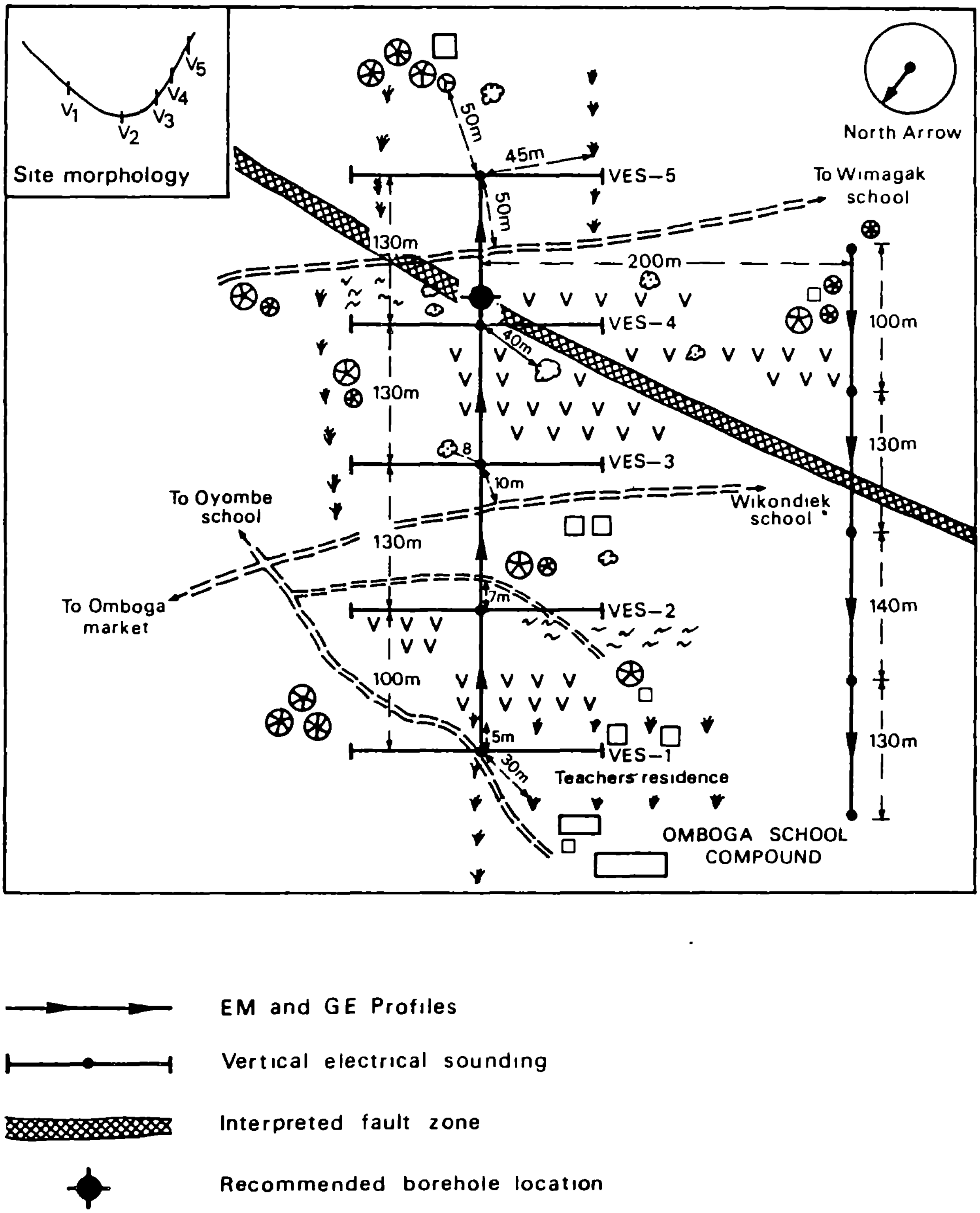


Fig 11 4 Location of geophysical soundings and profiles carried out at Omboga School, Kendu Division

11.2.5 Successful example of the survey method

An example has been selected to illustrate the importance and accuracy of the survey method, developed by the RDWSSP to locate boreholes in hard rock areas.

The site is Omboga Secondary School, located in South Nyanza District.
The school is situated in a rather dry area where water is drawn mainly from roof catchments and ground catchments of seasonal character.
The nearest perennial sources, a well and River Awach Tende, are at distances of 4, respectively 6 km from the school.

Study of aerial photographs had revealed the possible existence of a south-west to north-east trending fault, just south of the school.

Next a detailed geophysical field survey as explained in section 11.2. was carried out and interpreted (Figure 11.5).
The vertical electrical soundings confirmed the area to be underlain by granite but also revealed the existence of a narrow dolerite dike which did not appear on the geological map of the area.
The electro-magnetic profiles in particular indicated the occurrence of a pronounced fault or fractured zone along the granite/dolerite contact.
The exact location and slope of this sub-vertical zone were assessed and a borehole location was selected near sounding Ves-4

A borehole was drilled with a total depth of only 52 m.
Confined ground water was struck at various levels in the fractured rock. The static water level appeared to be 24 m-gl.
After completion, the borehole was developed and pump tested in four steps of respectively 3,6, 9 and 12 m3/hr.
The drawdown of the last high discharge step was only 2.5 m.
Evaluation of the pumptest showed a theoretical maximum capacity of 24 m3/hr which is very high in general and extremely high when considering the relatively poor ground water potential of the area.

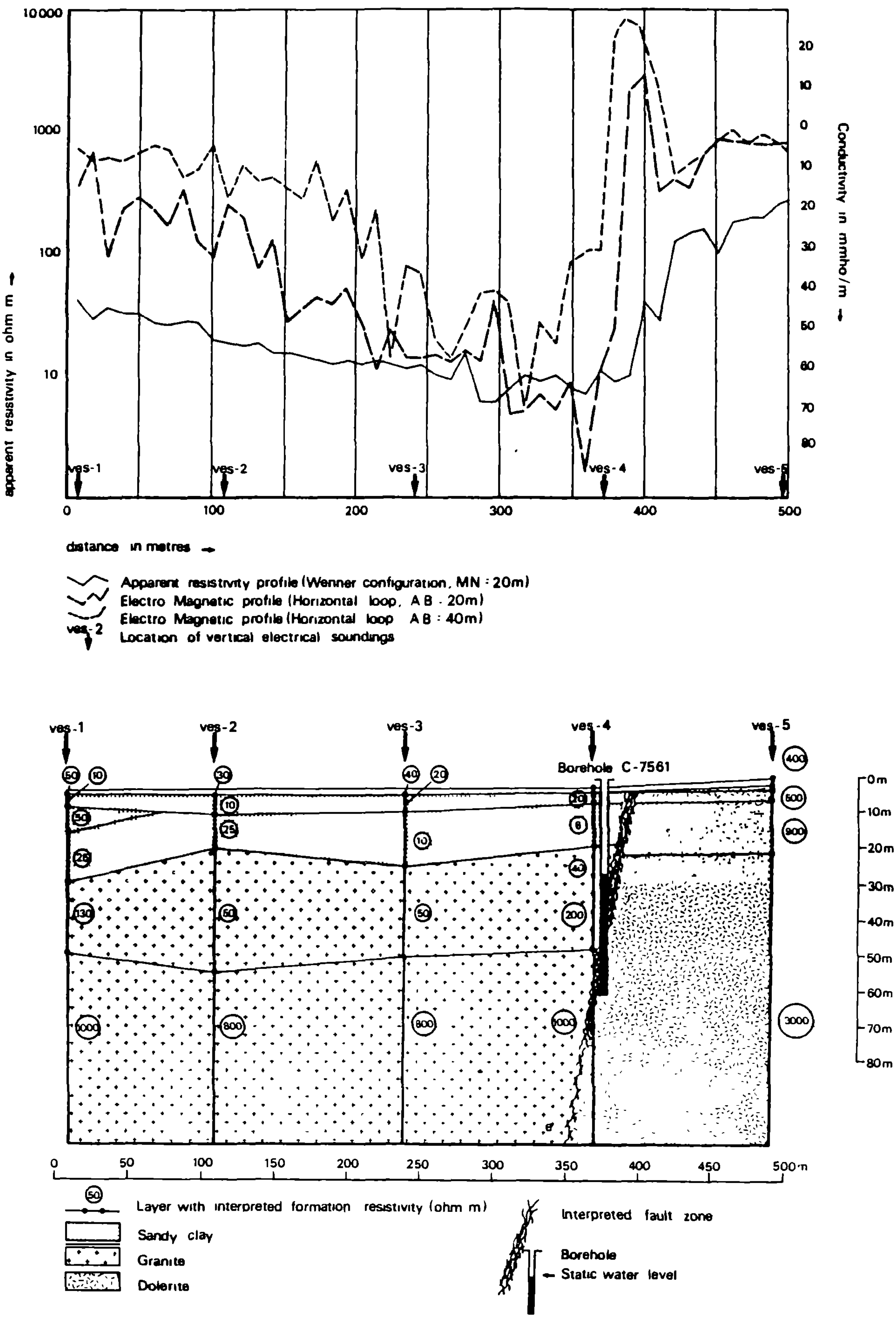


Figure 11 5 Geophysical and interpreted geological profiles of Omboga Schoool in Kendu Division

11.3 Ground water exploration in sedimentary areas

Almost 60 % of Kisumu District, the Kano Plain area, is underlain by sediments.
The sediments are Pleistocene to Recent in age and include mainly lacustrine and fluviatile deposits.
The investigations carried out subsequently by Ker and Priestman (Ref. 26) and the RDWSSP pointed out and confirmed the importance of these sediments as aquifers.
The ground water exploration of the Pleistocene and Recent deposits is discussed separately because the approach differs from the survey methods used to detect ground water in hard rock areas as described in section 11.2.

11.3.1 Pleistocene sediments

Thick sequences of Pleistocene sediments accumulated in the Kano Plain area.
It was found that the hydrogeological information on these deposits was limited mainly to borehole drilling and testing in the northern most part of the Kano Plain, the sugar belt area.
As part of the ground water resources survey of the RDWSSP, the entire Kano Plain area was exploited by means of deep vertical electrical soundings.
In total 135 soundings were carried out with a length of 1,000 m (L/2 = 500 m). The maximum penetration depth of the soundings appeared to be approximately 300 m.
Additionally and more exact information subsequently became available from 30 deep boreholes, drilled in (the western part of) the Kano Plain during July-September 1988.

The evaluation and results of these investigations are presented in a separate chapter, Chapter 12.

11.3.2 Recent sediments

Superficial deposits of Recent age cover the Pleistocene in the Kano Plain. Isolated patches of Recent sediments are further found along the Winam Gulf and major rivers.
Often these sediments exist of alternating thin layers of various grain sizes; sands and gravels within these deposits usually are water bearing.
There are however two aspects which limit the potential of Recent sediments as aquifers.

- In particular along the lake shore, the salinity of the ground water in Recent sediments may be high and exceeding the standard for drinking water (EC 2,500 mmho/cm).

- In densily populated areas the shallow aquifers often are bacteriologically polluted.

Recent sediments commonly are less than 25 m thick.
Instead of geophysical survey methods which basically are indirect methods, the RDWSSP adopted and developed a direct method of ground water exploration for Recent sediments.

The method involves the drilling by hand of small diameter (7-10 cm) test holes.
In case that ground water is found, temporary casing and screen is installed in the holes, after which they are pump tested.
In view of the water quality problems, this direct method offers the advantage that water samples can be taken and analyzed.

For an extensive and detailed description of ground water survey by means of the hand drilling method, the method's applicability and its limitations as well as a review of the tools and equipment used, one is referred to the Main Report of the RDWSSP (Ref.12) and the Final Report of the lake Basin Shallow Wells Pilot Project (Ref.11).

12 GROUND WATER RESOURCES IN THE KANO PLAIN

12.1 Introduction

Occupying approximately 60 % of Kisumu District's land area, the Kano Plain certainly is the dominant land form within the District.
It's relatively fertile and easy to cultivate soils have attracted intensive small scale farming as well as large scale growing of sugar cane and rice.
This plus the high natural population growth, have resulted in population densities of 300 to over 600 people per km^2 in the Kano Plain.

The domestic water supply situation in this largely rural area causes anxiety.
In the lower elevated western part of the Plain, shallow dug wells are the main sources of water supply.
It was found that most wells and apparently most shallow ground water is bacteriologically contaminated and therefore unsafe for consumption.
In the eastern part of the Kano Plain the water supply situation is even worse since here people mostly depend on surface water from ground catchments and streams that have a seasonal character and are polluted as well.

As will be shown in this chapter, the hydrogeological investigations by the RDWSSP and others proved, that the Kano Plain area is underlain by various medium depth (25-75 m) and deep (75-150 m) aquifers which hold ground water of a good quality.

The obvious solution for the rural domestic water supply problems in the area would be the exploitation of this deeper ground water by means of boreholes.
Provided the boreholes are properly constructed and protected, such supplies would be completely safe and reliable.

Questions that immediately arise are:

- are the ground water resources sufficient to provide the present and future population with their increasing demands for domestic water

- how deep do we have to drill

- are detailed geophysical surveys to establish borehole locations necessary or not?

The purpose of this chapter amongst others is to give answers to these and other basic questions.
The information given is the status-quo on the hydrogeological study of the Kano Plain and is based mainly on surveys and borehole construction carried out by the RDWSSP respectively during 1987 and 1988.

According as more boreholes are drilled, tested and in particular monitored, gradually better insight will be gained into the hydrogeological situation of the area.
Hence it is to be expected that as a result of such future data gathering and evaluation, the hydrogeological picture given here might have to be supplemented or adjusted.

12.2 Data from existing boreholes

Between 1940 and 1980, approximately 70 registered boreholes were drilled in Kisumu District of which 60 were drilled in the Kano Plain.
These sixty boreholes however are all located in the so called sugar belt, which is the northern most area of the Kano Plain between Kibos, Miwani and Chemelil.

An evaluation of these boreholes is given by Ker and Priestman (Ref.26).
It appeared that the boreholes varied in depth from 30 to 250 m and penetrated alternating lacustrine and fluviatile sediments. Ground water has been encountered between 10 and 50 m below ground level as well as in deeper water bearing layers and has resulted in confined or occassionally flowing artesian conditions. Yields were variable but high, averaging about 18 m^3/hr.

A summary of the borehole evaluation by Ker and Priestman (Ref.26) is given in Table 12.1.

TABLE 12.1 HYDROGEOLOGICAL PARAMETERS OF PLEISTOCENE AQUIFER IN THE NORTH OF THE KANO PLAIN (Sugar belt area)

Boreholes		Water level		Yield		Trans-missi-vity	Aquifer Potential
No.	Mean depth	struck	static	range	mean		
	m-gl	m-gl	m-gl	m^3/hr	m^3/hr	m^2/day	
60	90	10-50	10-20	6-40	18	60-100	"very good"

12.3 Investigations carried out by the RDWSSP

12.3.1 Remote sensing

The RDWSSP's investigations into the hydrogeology of the Kano Plain started with the scanning of Landsat and Erts satellite images to confirm the geological boundaries and establish the regional geological structures.
Figure 12.1 shows the results of the study.

The northern and southern boundaries of the Kano Plain are formed respectively by the Nandi and Nyabondo fault scarps which both run in an east-west direction.
Both faults appear to be complex as they exist of 5-10 km long fault lines, interrupted by cross faults which displace the main fault and divide the Nandi and Nyabondo Plateau areas into several fault blocks.

Within the area of the Kano Plain itself, surprisingly fault lines could be distinguished as well.
Surprisingly, because practically the whole of the Kano Plain is covered with alluvium.
They occur as two sets of parallel faults, one system running south-west to north-east and one running south-east to north-west.

The fact that these faults are visible at the surface indicates movement along the faults during Recent times.

With the discovery of the faults, the model of a simple rift valley in between two major faults had to be abandoned as it appeared that within the rift valley relatively uplifted and down faulted areas are found.

12.3.2 Vertical electrical sounding

The next step taken to further investigate this new concept of the internal structures of the Kano Plain has been the execution of deep geo-electrical soundings.
This geophysical investigation method is extensively described in the Main Report (Ref.13, 1984).
Basically the electrical resistivity of (sub) horizontal layers is measured.
Different lithological units may be distinguished on their difference in electrical resistivity.
A range of resistivity values for the different rock types occurring in and around the Kano Plain is given in Table 12.2.

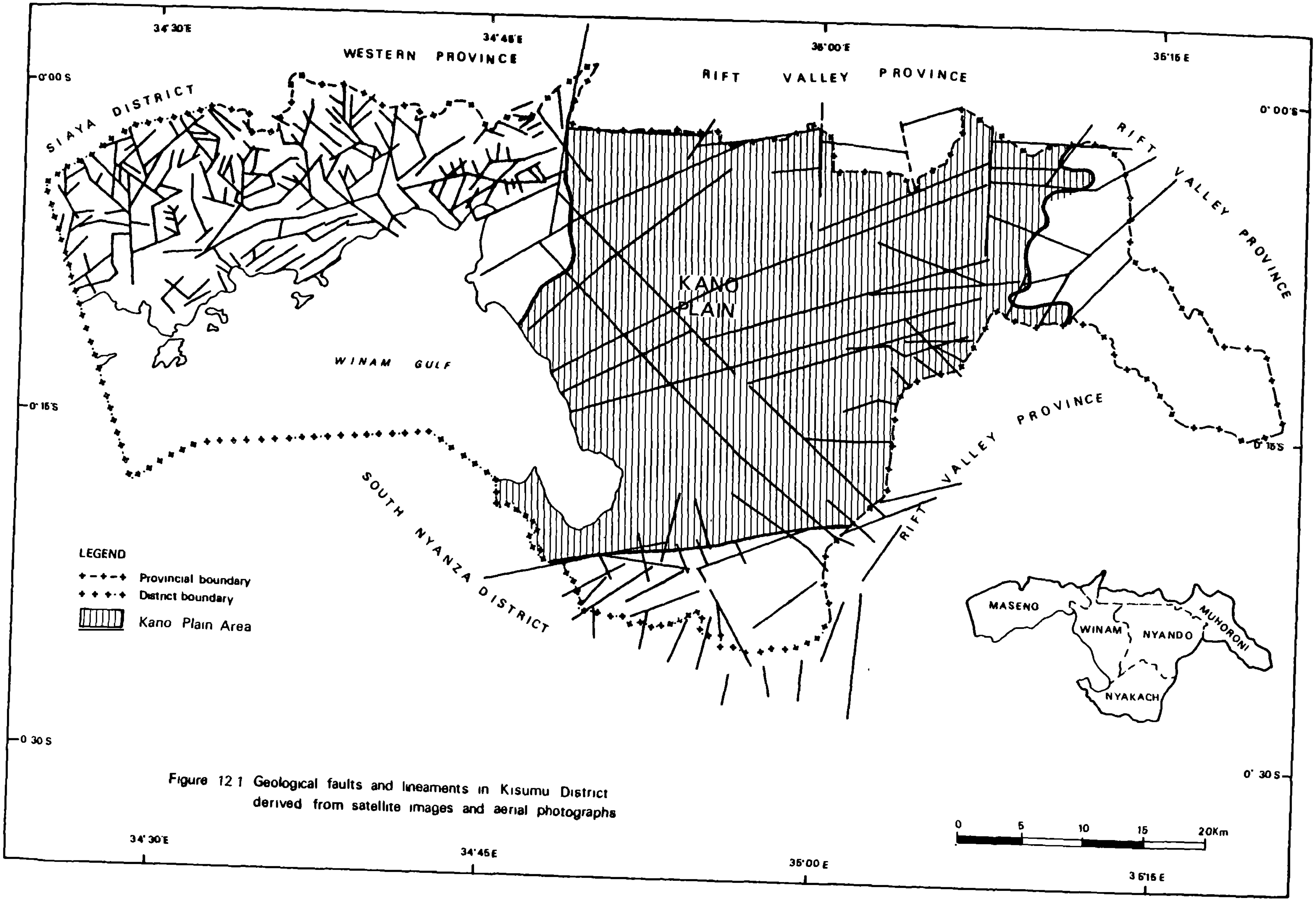


Figure 12 1 Geological faults and lineaments in Kisumu District derived from satellite images and aerial photographs

Typical landscape Kisumu District

Remote Sensing

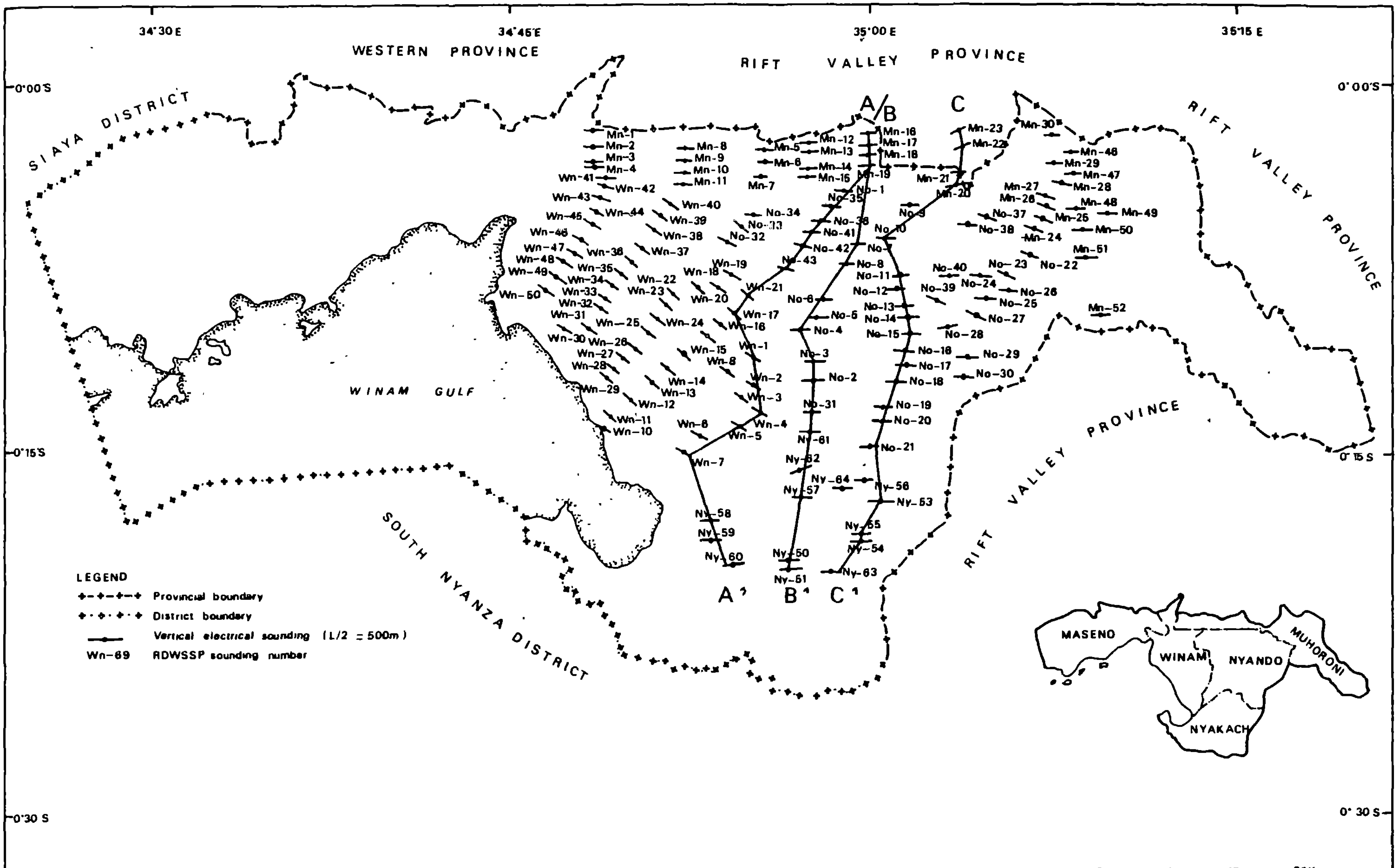


Figure 12 2 Location of deep geo-electrical soundings in the Kano Plain

TABLE 12.2 FORMATION RESISTIVITY OF ROCK TYPES IN KANO PLAIN

Type of rock	Average formation resistivity in Ohmm
Clay	< 5
Mudstone	3 - 8
Silt/siltstone	5 - 10
Sand/sandstone	10 - 20
Gravel/talus scree	20 - 40
Phonolite, weathered, broken	50 - 150
Phonolite, fresh	150 - 350
Granite, weathered, broken	150 - 500
Granite, fresh	500 - 1000

During 1987 and 1988 a total of 135 soundings were carried out (Figure 12.2).
The maximum separation used was 1,000 m (L/2 = 500 m) which appeared to allow for a maximum vertical penetration depth of about 300 m.
The soundings are orientated along 8 different north - south profiles with a mutual distance 1.5 - 2.0 km.

The results of this comprehensive survey are shown and explained on the basis of these profiles, with the different interpreted electrical resistivity layers plotted and correllated (Figures 12.4 to 12.6).

Based on the geo-electrical soundings alone however, only predictions can be made on the possible occurrence of different lithological units.
In order to be able to transfer the resistivity layers into geological layers, information from strategically located boreholes was required.

12.3.3 Borehole drilling and testing

Between June and September 1988 the RDWSSP drilled 32 boreholes in various parts of the Kano Plain (Figure 12.3).
This relatively large number of boreholes makes accurate correlation with and interpretation of the geo-electrical survey possible.

The depth of the boreholes varied from 40 m to 150 m and was about 90 m on an average.
The holes were drilled and tested according to the methods and specifications explained in section 15.6.

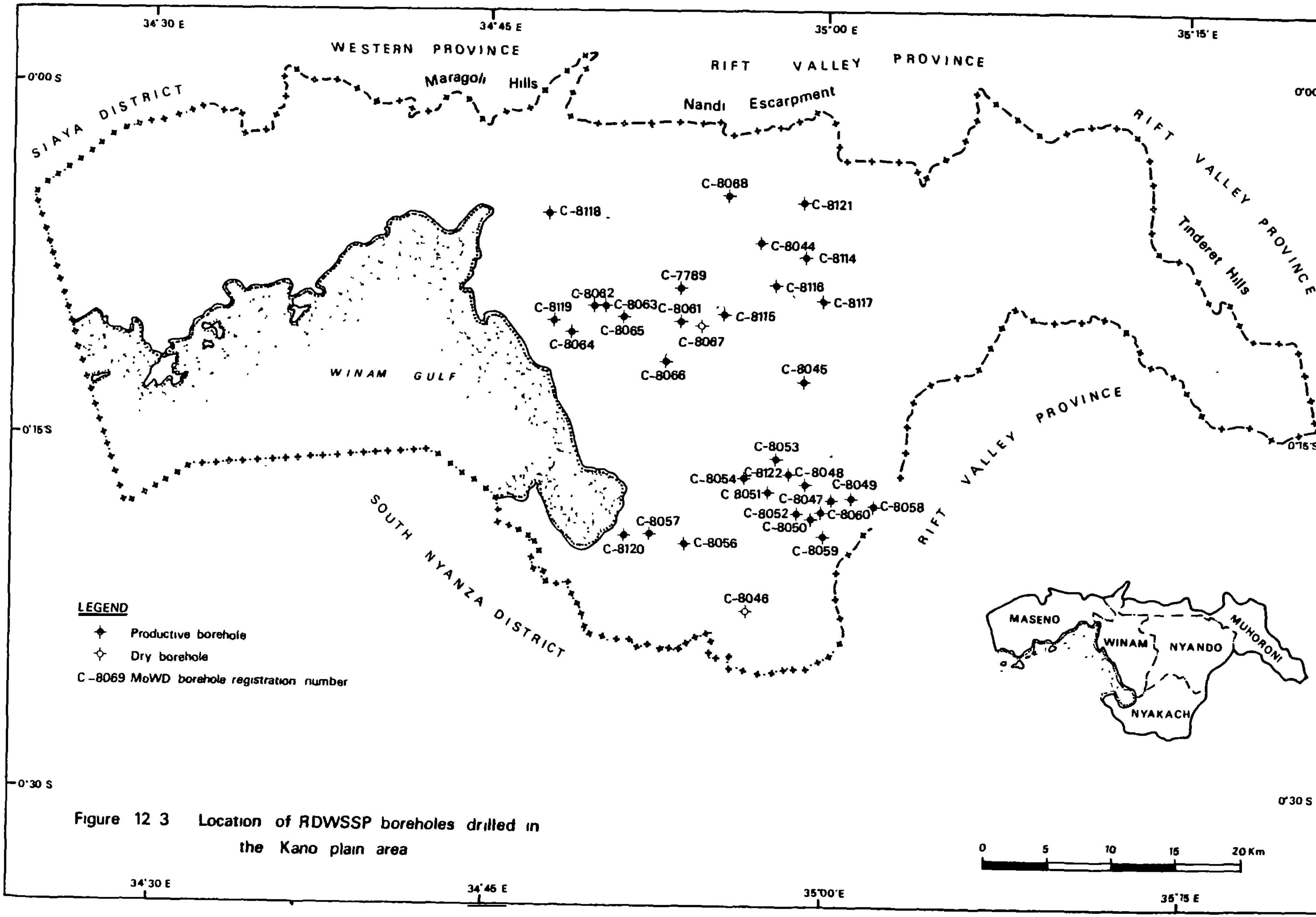


Figure 12 3 Location of RDWSSP boreholes drilled in the Kano plain area

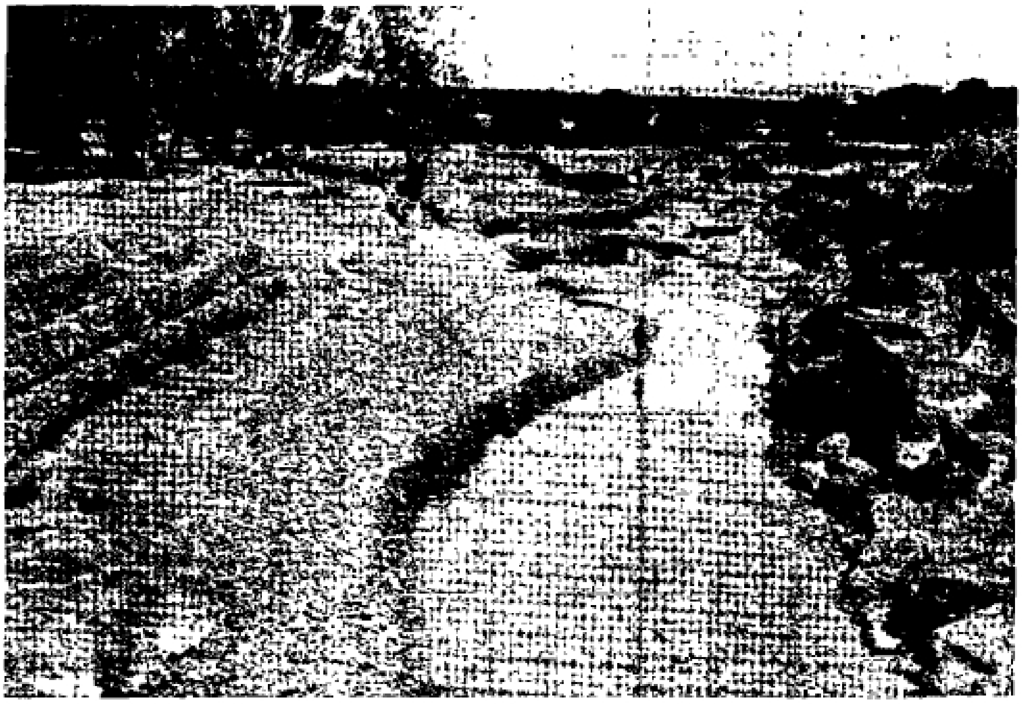
Borehole drilling

TABLE 12 3 SUMMARY OF RDASSP BOREHOLES DRILLED IN KISUMU DISTRICT

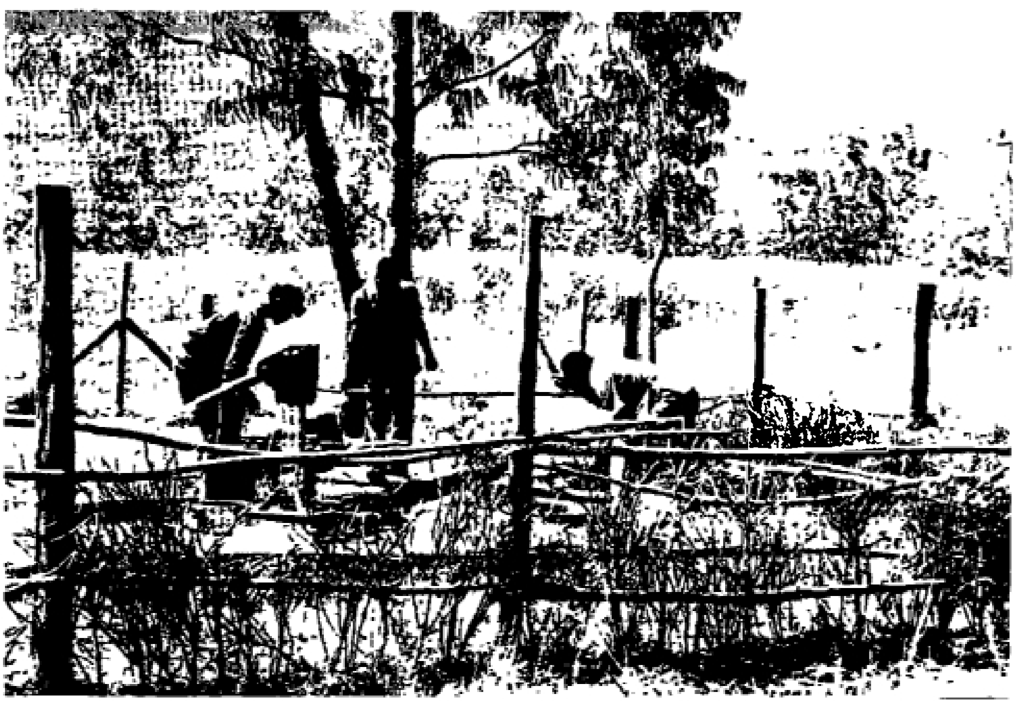
Borehole No	Site Name	Division	Year of Constr.	Grid ref.	Total depth m-gl	Water struck levels m-gl	Static W.l. m-gl	Aquifer data: lithology	total thickness m	Pump test data: Type (steps)	Tested yield m3/hr	Calculated max. yield m3/hr	Transmissivity m2/day	Permeability m/day	Storage coefficient	EC mmho/cm
C-7789	Nyakakana Sch.	Winam	1988	710 2/9984.9	140	30,54,82,104	9.0									820
C-8044	Ombeyi Mkt	Nyando	1988	718 0/9988.3	150	23,33,42,82, 42,125,141	3.0	sandy/silty/ gravelly	35	1	18		19	0.5		840
C-8045	Ayueyo Luora	Nyando	1988	717 0/9977.4	90	38,52	19.5	gravel	12	4	10	13	2	0.2	8.8 x 10-2	1000
C-8046	Okeyo Ogoro	Nyakach	1988	715 0/9958.8	147	DRY										
C-8047	Kanyarieko W G.	Nyakach	1988	722 7/9968.4	83	61,75	44.5	sandy/gravel	16	4	4	7	5	0.3	1.8 x 10-2	1400
C-8048	Magunga Sch	Nyakach	1988	720.6/9969.5	114	58,80,102	34.5	gravelly/sand	25	4	8	20	6	0.2	2.8 x 10-3	820
C-8049	Kibogo Mkt	Nyakach	1988	724 0/9967.3	68	34	29 8	gravelly/silt		4	2	3				
C-8050	Kombundi/Kokech	Nyakach	1988	721.0/9966.9	83	30,60	28.2	silty/gravelly gravelly/sandy	18	4	5	8	12	0.1	1.8 x 10-3	800
C-8051	Urudi Sch	Nyakach	1988	717 4/9968.5	153	38,128,137	21 3	gravelly/sandy silty/gravelly	17	3	6	12	12	0.1	9.8	1200
C-8052	Nduga Sch	Nyakach	1988	720 0/9967.0	75	23,60	17.7	sandy/gravel	12	4	12	15	4	0.3	4.1	600
C-8053	St Aloys Sch.	Nyakach	1988	718 3/9971.3	83	22,59,67	15 7	gravelly/sand	8	4	16	17	7	1	4.8	800
C-8054	Kanyalwal Sch.	Nyakach	1988	715 9/9969.8	150	18,111,137	6.0	silty sand	18	4	7	12	1	0.1	3.9 x 10-4	900
C-8056	Ragen Kasham	Nyakach	1988	710 8/9964.8	90	28,40,57 64,74	18.0	gravel/sandy	20	4	12	17	4	0.2	1.2 x 10-3	1100
C-8057	Bugo School	Nyakach	1988	679.9/9965.7	84	34,5,60 68	12 1	gravelly/sandy	21	4	12	15	4	0.2	1 3 x 10-4	450
C-8058	Cherwa Sch	Nyakach	1988	726 0/9967.9	149	94,119,148	15 8	clayey/gravelly sandy		3	4	8	1		2.8 x 10-32	1300
C-8059	Got Onyuongo	Nyakach	1988	722 2/9965.0	38	22,32	8 7	talus scree	16	1	18		470	90		840
C-8060	Hon Kombudo	Nyakach	1988	721 9/9967.0	76	48,53,58 63,70	28.5	gravelly/sand	10	4	12	50	40	4	6 1 x 10-4	440
C-8061	Lela Sch.	Winam	1988	710 5/9982.0	68	15,37,43 53	6 5	gravelly/silty	15	7	18		190	13		1400
C-8062	Rabuor Chief's camp	Winam	1988	703 8/9988 8	100	93,98	18.6	sandy/gravel	15	2	12	30	30	2		1000

TABLE 12 3 Cont SUMMARY OF ROWSSP BOREHOLES DRILLED IN KISUMU DISTRICT

Borehole No	Site Name	Division	Year of Constr.	Grid ref.	Total depth m-gl	Water struck levels m-gl	Static W l. m-gl	Aquifer data: lithology	Aquifer data: total thickness m	Pump test data: Type (steps)	Tested yield m3/hr	Calculated max. yield m3/hr	Transmissivity m2/day	Permeability m/day	Storage coefficient	EC mmho/cm
C-8063	Otieno Oyoo Sch	Winam	1988	704 5/9983.0	92	70,84,92	20 8	gravelly/sand	30	4	8	16	4	0.1	6.6	130
C-8064	Migingo Sch	Winam	1988	701.8/9981.3	53	25,38,47	7.5	sandy/gravel	15	2	14	20	17	1	8.2 x 10-5	1700
C-8065	Kowiny/Kachola	Winam	1988	705 8/9982 3	83	31,40,54 64	12.0	silty/sandy gravel	20	3	9	16	4	0.2	7.9 x 10-4	800
C-8066	Kawuor W G	Winam	1988	709 4/9978.8	83	15,65,70	5.9	gravelly/sand	10	4	8	10	2	0.2	8.5 x 10-3	1500
C-8067	Kayugi village	Nyando	1988	719 8/9981 3	98	DRY										
C-8068	Orenge Sch	Nyando	1988	714 7/9997.2	51	32,45,48 50	5.9	gravelly/sand	10	1	18		32	3	1.23	800
C-8114	Obago Sch.	Nyando	1988	720 3/9986 7	75	29,38,52 58,70	6 8			4	12					750
C-8115	Oblayo Sch	Nyando	1988	713.8/9982 3	44	18,30,40	4 5			1						1400
C-8116	Osembe Sch	Nyando	1988	718.1/9984 6	47	18,22,28 36	14.8									2000
C-8117	Nyalenda Sch	Nyando	1988	722 0/9983.5	90	64,75,84	27.6									900
C-8118	Mbeme Vill	Winam	1988	699 7/9990 1	68	43,47,52 60	15 5									840
C-8119	Alendu Sch	Winam	1988	701 0/9982 7	45	15,31,37 40	10.9									880
C-8120	Kusa Vill	Nyakach	1988	706 0/9965.5	75	15,24,31 45,50,60 66,72	18.6									600
C-8121	Kamagaga Vill.	Nyando	1988	720 2/9990 7	75	23,27,33 43,50	11.7									520
C-8122	Baptist Bible Coll.	Nyakach	1988	719 2/9969 1	83	40,55,61 72,79	23 4									760



River Awach Seme in Kano Plain



Well in Kano Plain

12.4 Geology of the Kano Plain

The geology of the Kano Plain as described in this section is a synthesis of the results of the various surveys carried out by the RDWSSP.

12.4.1 Structure of the rift valley

Part of the fault lines that were found by the remote sensing survey, were confirmed by the geo-electrical survey. The other faults found through remote sensing might be there also but probably their throw is not sufficient to be detected by the soundings.

Cross-sections AA' and BB'(see Figure 12.2) through the central part of the Kano Plain both show the existence of 4 different blocks. Two relatively up lifted and two relatively down faulted blocks.
As reference level, the top of the phonolite is taken.

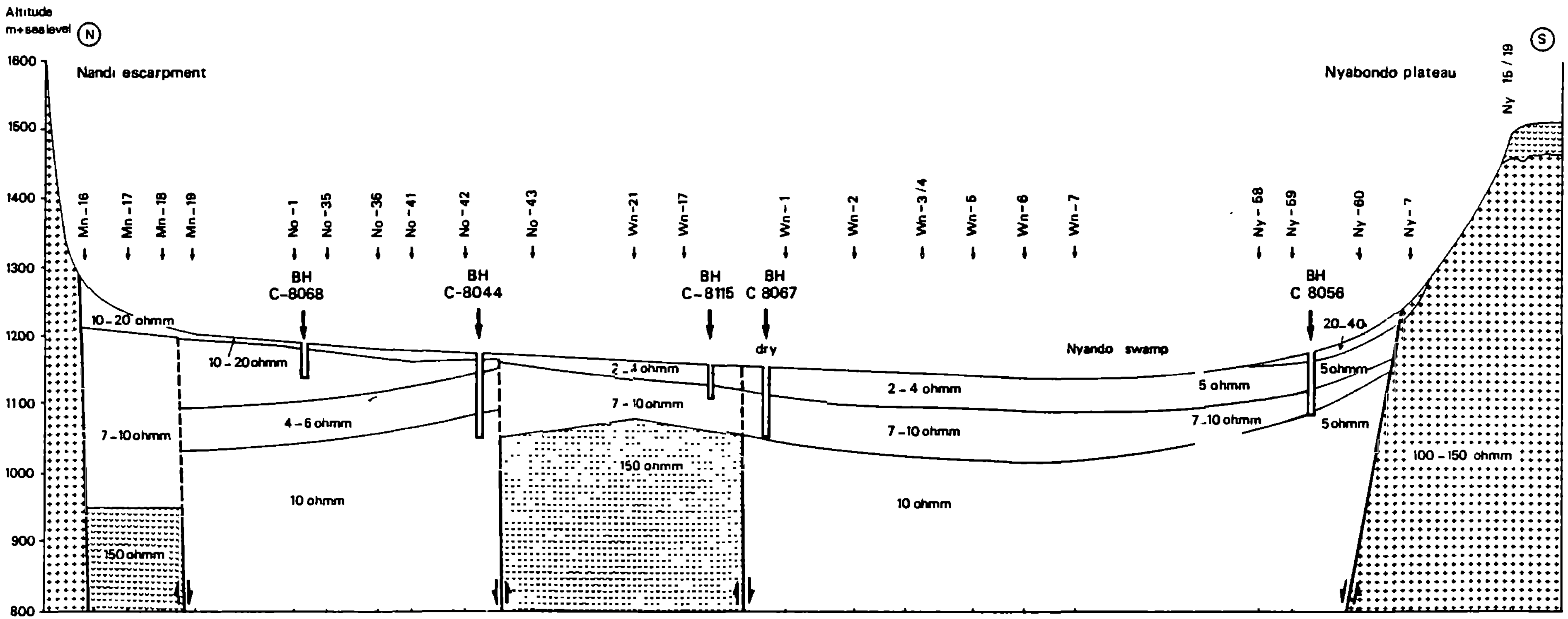
From north to south in the rift valley the following blocks are distinguished (MAP-4):

- a relatively high block with the top of the phonolite at 250 - 300 m.
- a down faulted area where the bottom of the sediment fill could not be detected.
- a relatively uplifted area with 200 - 250 m thick sediments on top of the phonolite.
- a down faulted area where the phonolite occurs below detection depth.

Cross-section CC' which shows the structure of the eastern part of the rift valley is different from AA' and BB'.

In this part the uplifted area which is found in the centre of the rift valley on profiles AA' and BB' is more pronounced, closer to the surface and moreover broken into 3 different blocks.

It is clear that the deeper part of the rift valley thus is divided into at least four and probably more different tectonical blocks.
For the aquifers and ground water occurrence within the upper 200 m of sediments there is no influence from this faulting.
The aquifers occurring below this depth however are affected and it is possible that the uplifted blocks divide the deeper part of the rift valley into different ground water system.



LEGEND

Granite

Phonolite

Major fault

2-4ohmm Formation resistivity

No-69 Vertical electrical sounding

RDWSSP borehole

C-8069 MoWD borehole number

Figure 12 4 North-south cross section A A' through Kavirondo Rift Valley

0 1 2 3 4 5 Km

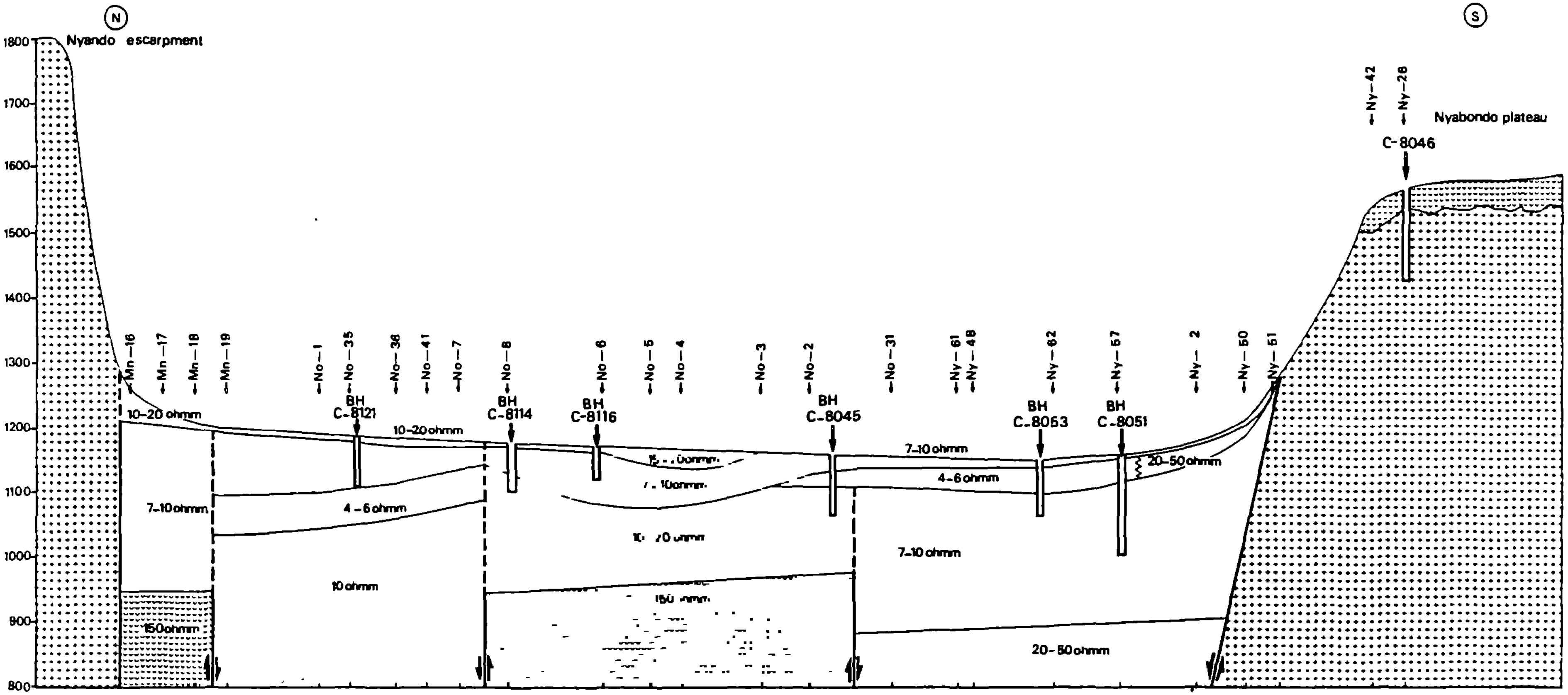
12.4.2 Lithology of the sediments in the rift valley

Based on the geo-electrical soundings, three to four different lithological units could be recognized, that appear to be consistent over large parts within the rift valley.
From the boreholes it appeared however that these different units represent a diversity of sediments.

Tables 12.4 a,b and c summarize the different resistivity layers and their corresponding lithology for the various cross sections.

TABLE 12.4A CROSS-SECTION AA' (Figure 12.4)

Resistivity layer	Depth	Lithology
2 - 4 ohmm	0 - 50 m	clay with thin silt and sand lenses with saline ground water
7 - 10 ohmm	50 - 150 m	Alternating gravelly, silty sand silt, clay and silty gravel
4 - 6 ohmm	50 - 150 m	Silt and clay
10 ohmm	below 150 m	Alternating silty gravel, silty sand and silt layers.
10 - 20 ohmm	0 - 50 m	Colluvial sand and gravels with intercalated silt and clay layers
20 - 40 ohmm	0 - 20 m	Coarse talus scree
150 ohmm	variable but below 200 m	Phonolite



LEGEND

Granite

Phonolite

Major fault

4-6ohmm Formation resistivity

No-35 Vertical electrical sounding

RDWSSP borehole

C-8045 MoWD borehole number

Figure 12 5 North South cross-section B B' through Kavirondo Rift Valley

0 1 2 3 4 5 Km

TABLE 12.4B CROSS-SECTION B-B' (Figure 12.5)

Resistivity layer	Depth	Lithology
4 - 6 ohmm	20-100 m in the south 100-150 m in the north	Silt and clay wih thin sand lenses
7 - 10 ohmm	20-100 m in the centre 50-250 m in the north and south	Alternating gravelly silt, silty sand, silt, clay and silty gravel
10 ohmm	below 250 m in the north	Silty gravel, sand, gravel, silt
10 -20 ohmm	0-40 m	Talus scree and colluvium
10 - 20 ohmm	100-250 m in the centre	Silty, sandy gravel, sand, silt
20 - 50 ohmm	below 250 m in the south	Gravel, sand
150 ohmm	variable but below 200 m	Phonolite

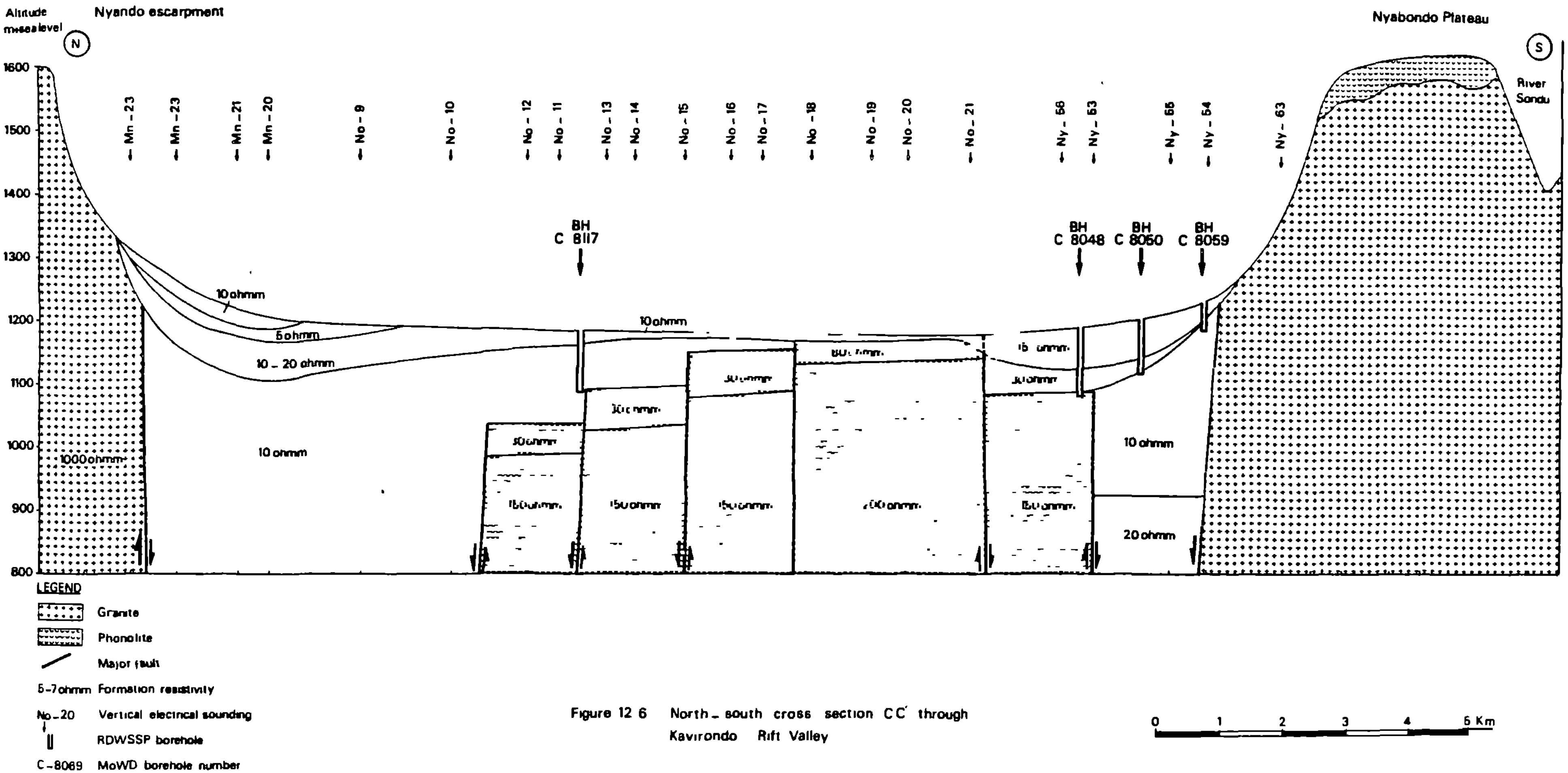


Figure 12 6 North - south cross section CC' through Kavirondo Rift Valley

TABLE 12.4C CROSS-SECTION CC'(Figure 12.6)

Resistivity	Depth	Lithology
5- 7 ohmm	100-200 m in the north	Silt, silty sand and silty gravel, clay.
10-20 ohmm	0-100 m in the north	Talus scree and colluvium gravels, sand, some silt or clay
10 ohmm	250-350 m in the north	Silty gravel, sandy gravel, silt
10-15 ohmm	0- 50 m in the south	Talus scree and colluvium gravel, boulders, sand, silt
30 ohmm	50-150 m in the south	Gravels, sand
150 ohmm	Variable	Phonolite

Characteristic for the sediments in the rift valley appears to be in particular the unsorted nature.
Gravels and sands are never clean but are found mixed and mixed with silt.
Silts and clays contain coarse material as gravel or sand which both occur mixed or in alternating layers.

Characteristic is moreover the gradual coarsening of the sediments in the rift valley in downward direction; gravels in the lower parts, sandy gravels and gravelly silts in the middle and sandy silts and clays in the upper parts.

From these different characteristics it is concluded that the sediments were deposited in a lacustrine deltaic environment, occassionally alternated by braided river environments.

The two major geological factors which have influenced the sedimentation in the Kano Plain are:

- the supply of different types of sediments by rivers debouching into the Kano Plain (during periods of high discharge gravels and sands and during periods of low discharge silts and clays)
- the development of the rift valley which largely controlled the hydraulic gradient of the rivers as well as the environment of deposition (land or lake).

The established general fining of sediments upward in the lithological section may be caused by the gradual filling of the rift valley with sediments thereby steadily reducing the hydraulic gradient of the rivers.

Since the rivers in the Kano Plain most probably always have flowed from east to west, in the eastern part of the rift valley relatively more coarser sediments can be expected.
This appeared to be confirmed by the occurrence of higher electrical resistivity values in the east of the area.

Layers or tongues of coarse sediments intercalated with finer sediments moreover are found along the northern and southern margins of the rift valley, where small streams flowing from the escarpments have deposited gravels and sands on the plain and where talus scree mixes with lacustrine and fluviatile sediments.

12.5 Aquifers

12.5.1 Aquifer depth

In the majority of the 32 boreholes drilled by the RDWSSP, ground water was struck at 2 - 4 different levels, which indicates the existence of various aquifers.

The first aquifer usually is found between 15 and 25 m depth.
This shallow aquifer is relatively thin and it's yield low.
Moreover, this aquifer was found to be bacteriologically contaminated at places.
For these reasons, the upper aquifer should not be used and always be sealed.

A second and third aquifer level usually is found between depths of 30 to 70 m.
The hydrogeological cross-sections A-A' to C-C' (Figures 12.4-12.6) show that the second and third aquifers correspond with the 7 -10 ohmm or the 10 ohmm layers which reach to a maximum depth of 150 m below ground level.

The deeper parts of the rift valley sediments have not been explored by means of boreholes.
The increasing resistivity values (10-20 ohmm) however indicate the occurrence of other and probably high potential aquifers.

12.5.2 Aquifer thickness

Due to the large variation of sediments drilled, it often was not easy to establish the thickness of the water bearing layers from borehole samples alone.
In some, but not all boreholes the geophysical well logs proved to be useful in delineating aquifers.

It appeared that the thickness of individual aquifers varies from 2 to about 10 m and is 6 m on an average.
The total aquifer thickness per average borehole of 90 m depth varied from 10 to 30 m and was 18 m on an average.

From the geo-electrical soundings it is moreover concluded that below a depth of about 150 m, relatively thicker aquifers occur.

12.5.3 Well yield

The RDWSSP boreholes have been test pumped with yields varying from 2 to 18 m^3/hr and an average discharge of 10 m^3/hr.

Characteristic for boreholes in the central part of the Kano Plain are the relatively low specific yields; high drawdowns for relatively low yields.
The draw-down per 1 m^3/hr discharge varied from 1 m up to 14 m and is 4 m per 1 m^3/hr discharge on an average. For hand pumps and small domestic supplies with yields of 1-5 m^3/hr maximum, most boreholes will deliver sufficient water. Where higher discharges are required, the capacity of each borehole will have to be considered individually.

The evaluation by Ker and Priestman (Ref.26) of the boreholes drilled in the sugar belt area shows, that in the northern and eastern part of the Kano Plain much higher well yields can be expected; 6-40 m^3/hr and 18 m^3/hr on an average. For those boreholes that were test pumped in 2 or more steps, the theoretical maximum yield could be calculated.

Table 12.3 shows that these yields may vary from 3 to 30 m^3/hr.
The yields plus their corresponding pumping levels are important figures when motorised pumping is considered.

12.5.4 Aquifer transmissivity

Generally the aquifer transmissivity values in the central and southern parts of the Kano Plain (RDWSSP boreholes) are between 1 and 20 m^2/day.
Only 4 holes showed higher transmissivity values (30-190 m^2/day).
The average value in this part of the plain amounts to 18 m^2/day.
These values are low as compared to the transmissivitiues given by Ker and Priestman for the northern and eastern parts of the Kano Plain, 20-60 m^2/day.

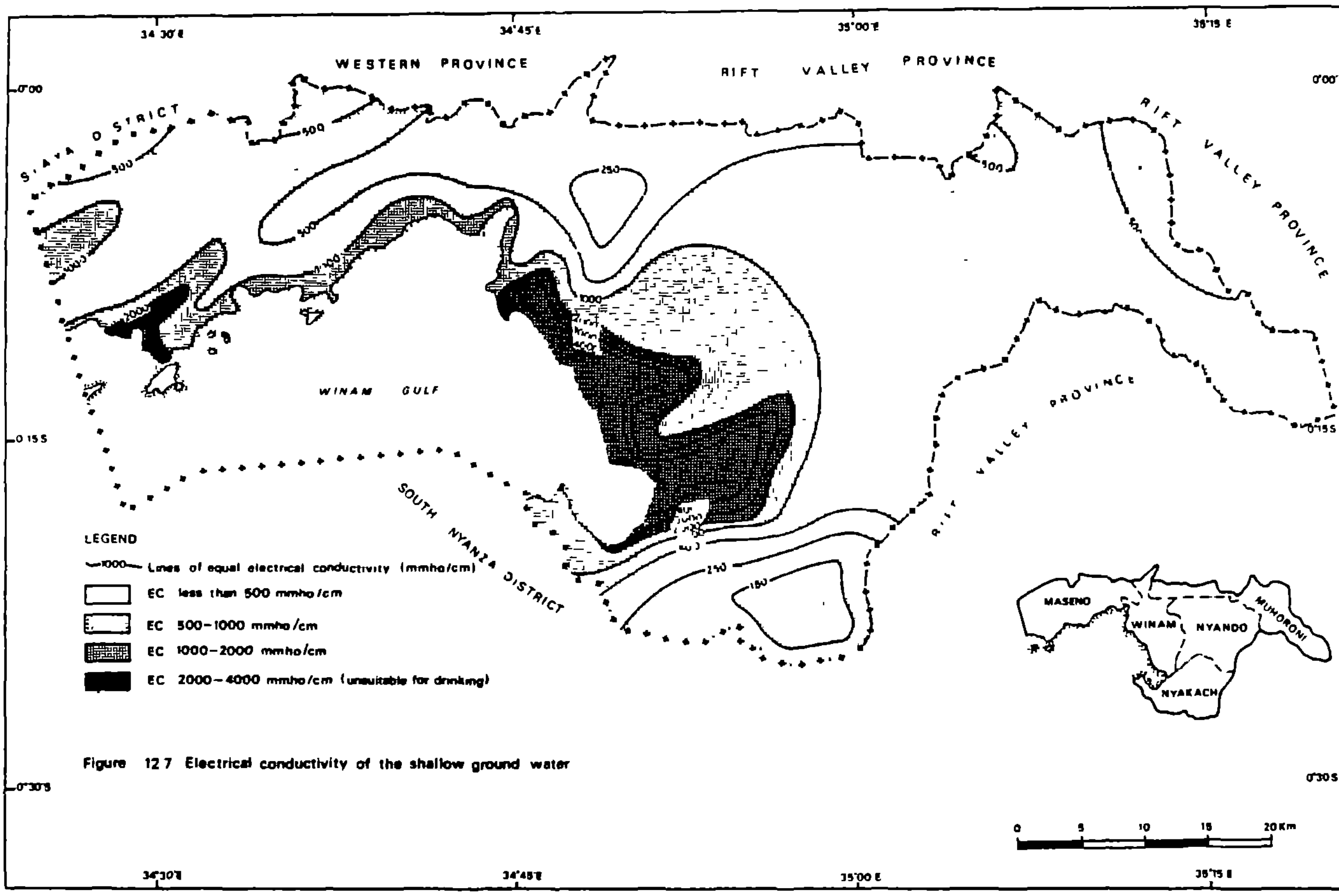


Figure 12 7 Electrical conductivity of the shallow ground water

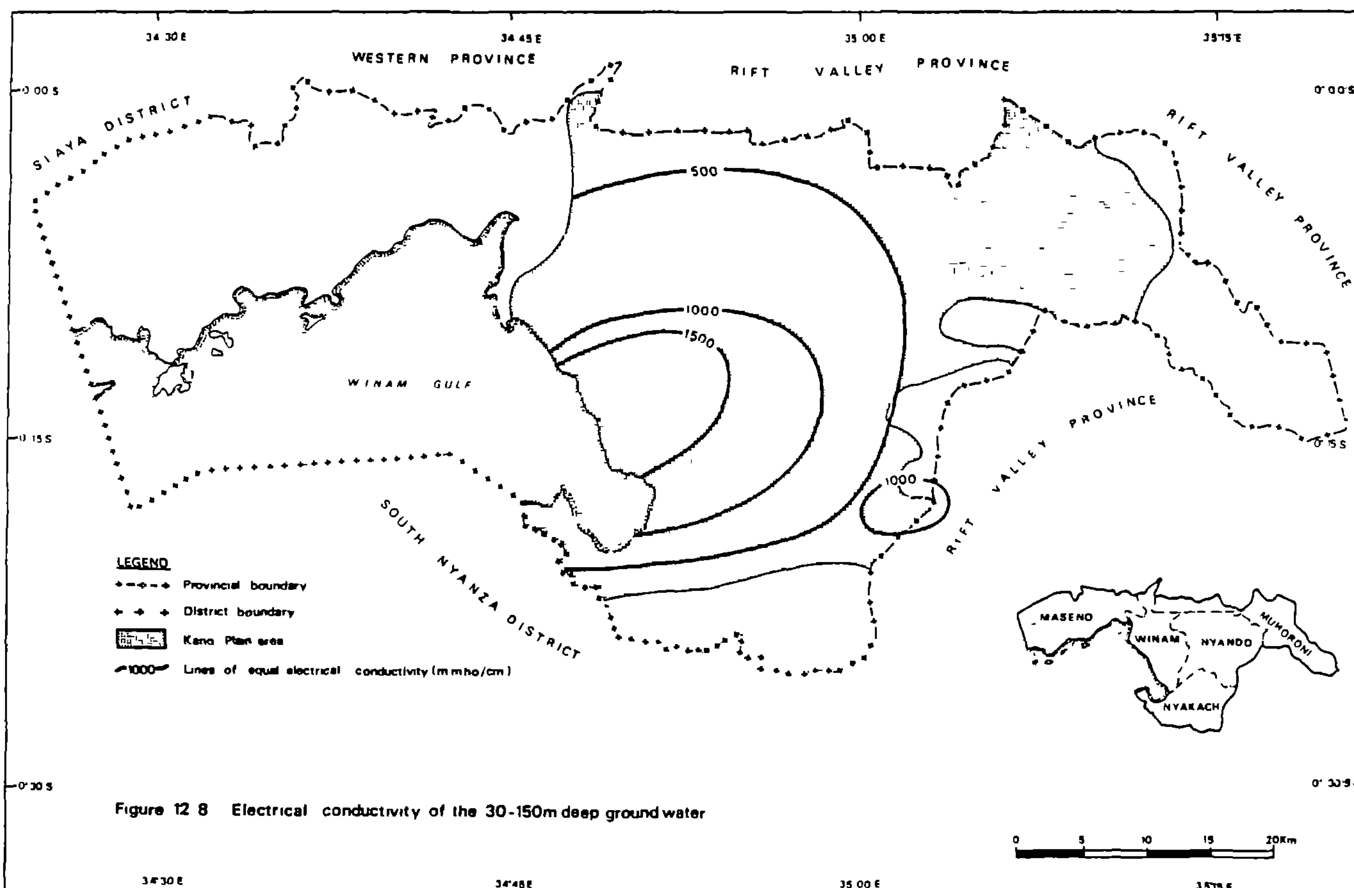


Figure 12 8 Electrical conductivity of the 30-150m deep ground water

12.5.5 Aquifer permeability and lithology

Table 12.3 shows that the aquifer permeability values range from 0.1 to 4.0 m/day and are 0.8 m/day on an average, with the exeption of borehole C-8061 where a permeability of 13 m/day is found.
This range of permeability values normally is representative for silts or fine sands.
Most of the aquifers however show a large proportion of gravels which, if clean and well sorted should have permeabilities as high as 10 -1,000 m/day. The low permeability values found indicate that the aquifers are unsorted and exist of mixtures of gravel, sand and silt.

12.6 Ground water quality

In order to investigate the water quality of the deeper aquifers in the Kano Plain, water samples were drawn from the 30 boreholes and analyzed.

A striking conclusion is that both the chemical and bacteriological quality of ground water from deeper aquifers is better than that of the shallow aquifers. This is most apparent when comparing the EC of the shallow ground water with the EC of the deeper ground water, as shown on Figures 12.7 and 12.8.

Besides an appraisal of the physical quality (colour,odour) and the measurements of the EC and PH, full chemical analyses was carried out. Tested parameters are:

- turbidity
- alkalinity
- hardness
- iron
- manganese
- fluoride
- nitrate
- phosphates
- faecal coliforms

Results of the analyses are given in Table 12.6. When these results are compared with the water quality standards for rural domestic water supply in Kenya, as shown in Table 12.5, it appears that none of the tested parameters exeed these standards. From this it is concluded that the deeper ground water in the Kano Plain is of good quality and safe for consumption without treatment.

TABLE 12.6 CHEMICAL AND BACTERIOLOGICAL ANALYSES OF RDWSSP BOREHOLES IN KISUMU DISTRICT

Borehole No.	Name	EC (uS/cm)	PH	Turb. NTU	Alka-linity	Hard-ness as $CaCO_3$	Mn^{2+}	Fe^{2+}	F^-	NH_3^-	Po_4^{3-}	Faecal coliforms in 100 ml
						miligrams per litre						
C-7789	Nyakakana Sch.	740	8	36	222	70	ND	0.05	1.0	0.15	0.84	0
C-8044	Ombeyi Mkt.	560	7.2	1.2	210	122	ND	0.01	1.05	0.08	0.08	0
C-8045	Ayueyo Luora	1500	7	3.5	620	490	ND	0.19	0.9	ND	0.02	0
C-8048	Magunga Sch.	800	7	3.8	408	104	0.01	0.65	0.8	ND	0.12	0
C-8051	Urudi Sch.	1200	7	32.0	470	54	1.0	0.01	0.03	ND	0.02	0
C-8052	Nduga Sch.	600	7.0	18	102	344	ND	0.04	0.8	ND	0.05	0
C-8053	St. Aloys Sch.	800	7	35	476	118	ND	0.19	1.0	ND	0.02	0
C-8054	Kanyalwal Sch.	900	7	2.7	460	68	0.03	ND	1.0	0.3	0.21	0
C-8056	Ragen Kasham	1400	8	42	576	144	0.01	0.09	1.01	ND	0.01	0
C-8058	Cherwa Sch.	1200	8	5.5	610	24	NB	0.25	1.0	ND	0.17	0
C-8059	Got Onyuongo	800	7.5	1.5	462	242	0.03	0.01	0.75	ND	0.03	0
C-8060	Hon. Kombudo	600	7	1.5	270	134	ND	ND	1.0	0.02	0.15	0
C-8061	Lela Sch.	140	7	1.5	80	56	0.8	ND	0.3	1.2	ND	0
C-8062	Rabuor Ch. Camp	1000	7	4.5	494	120	120	0.05	1.15	0.1	0.1	0
C-8063	Ootieno Oyoo Sch.	1200	7	4.3	236	240	240	0.1	0.95	ND	0.4	0
C-8064	Migingo Sch.	1700	7	1.6	562	204	204	0.01	0.9	ND	0.05	0
C-8065	Kowiny/Kachola	1800	7	6.3	490	112	112	0.06		0.05	0.26	0
C-8066	Kawuor W.G.	2100	7	3.4	340	372	372	0.1	0.1	0.1	0.31	0

TABLE 12.5 SUMMARY OF MOST RELEVANT WATER QUALITY STANDARDS FOR RURAL DOMESTIC WATER SUPPLY IN KENYA

Quality parameter	Kenyan Standard
Physio-chemical parameters	
Electrical conductivity at 25 C (EC)	2,500 (us/cm)
Total dissolved solids (TDS)	1,500 (mg/l)
PH	6.5-8.5
Colour	50 (mg pt/l)
Turbidity	25 (NTU)
Chemical parameters affecting human health	
Fluoride	1.5 (mg/l)
Nitrate	30 (mg/l)
Chemical parameters affecting salinity	
Total hardness	500 (mg/l)
Alkalinity	not mentioned
Calcium	200 (mg/l)
Magnessium	150 (mg/l)
Chloride	600 (mg/l)
Sulphate	600 (mg/l)
Phosphate	not mentioned
Non-toxic metals	
Iron	1.0 (mg/l)
Manganese	0.5 (mg/l)
Organic pollution	
Ammonia	not mentioned
Permanganate	10 (mg/l)
Bacteriological parameters	
E-coli	MPN/100 (m)

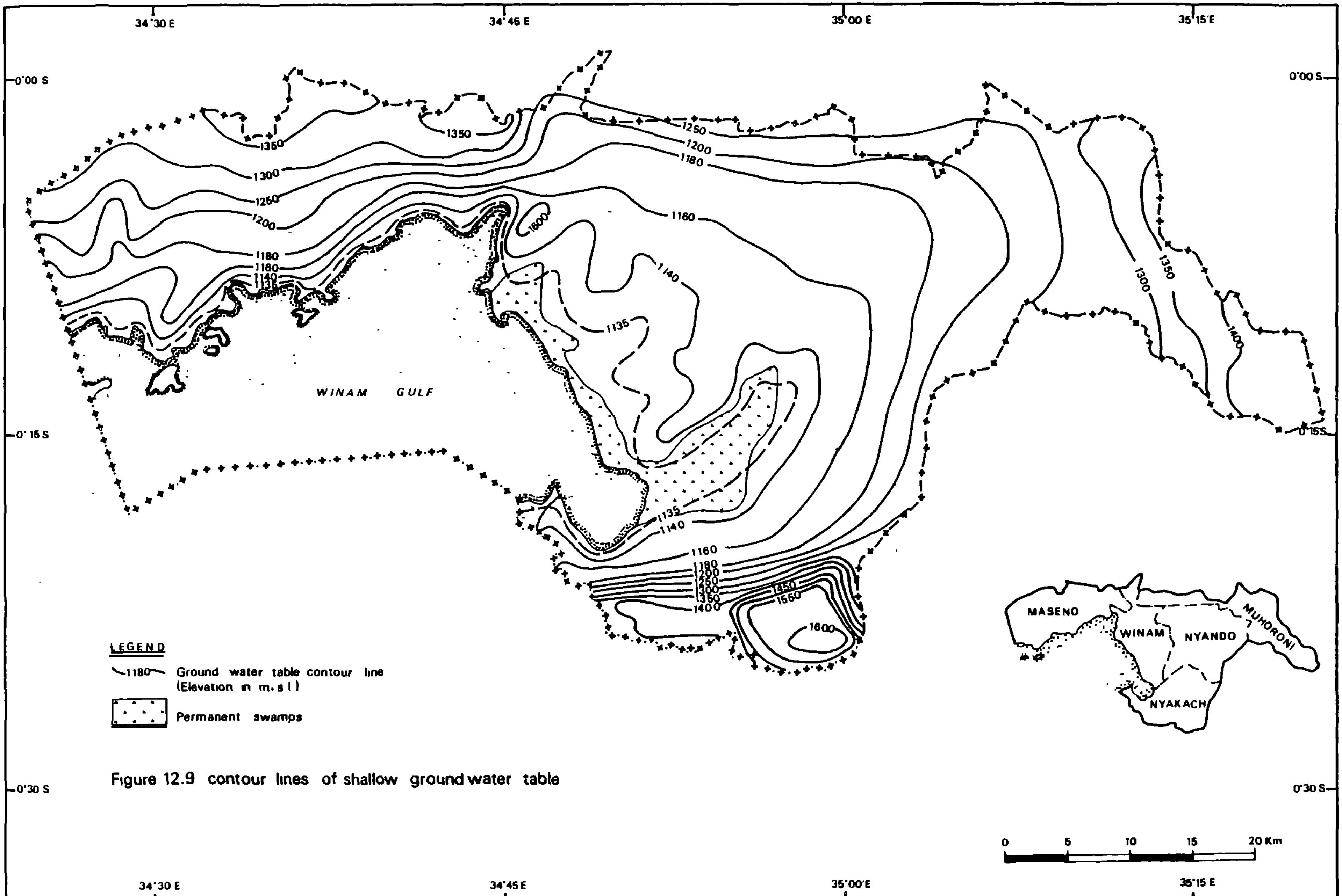


Figure 12.9 contour lines of shallow ground water table

12.7 Ground water recharge mechanism

The investigations carried out so far show recharge of the ground water to occur mainly in the east of the Kano Plain.
This area was found to be underlain by 25-40 m of alluvial gravel and sand through which downward percolation of water is possible. Moreover it was found that rivers in this part of the Kano Plain are influent, meaning that they loose water which infiltrates to the ground water.

Modest recharge also occurs along the Nandi and Nyabondo Escarpment where coarse talus scree and permeable colluvium allow surface water to infiltrate and recharge the ground water.

Towards the central and western parts of the Kano Plain, the soils become progressively more clayey as elevation decreases. With increased impermeability comes decreased infiltration and recharge must be considered effectively nil.

For a more thorough understanding and quantification of the recharge it would be necessary to drill and test boreholes also in the expected recharge areas and to monitor ground water levels over a number of years.

12.8 Ground water flow

Based on the hydraulic aquifer parameters as established from the 32 recently drilled boreholes plus some estimates based on the results of the geo-electrical soundings, a rough assessment can be given of the ground water flow.

The flow is maintained mainly by recharge in the eastern part of the plain as well as along the northern and southern margins.

Flow is towards the Winam Gulf.

The equation used to calculate the flow is:

$Q = k \times i \times A$ whereby,

Q= flow in m^3/day
k= hydraulic permeability in m/day
i= hydraulic gradient = head loss over the flow length
A= aquifer thickness times width of flow area in m^2.

It is assumed that the average total thickness of sediments in the Kano Plain comes to 250 m.
The total aquifer thickness in the upper 90 m was found to be 18m.

The total aquifer thickness over the 250 m sequence is estimated to be 60 m.

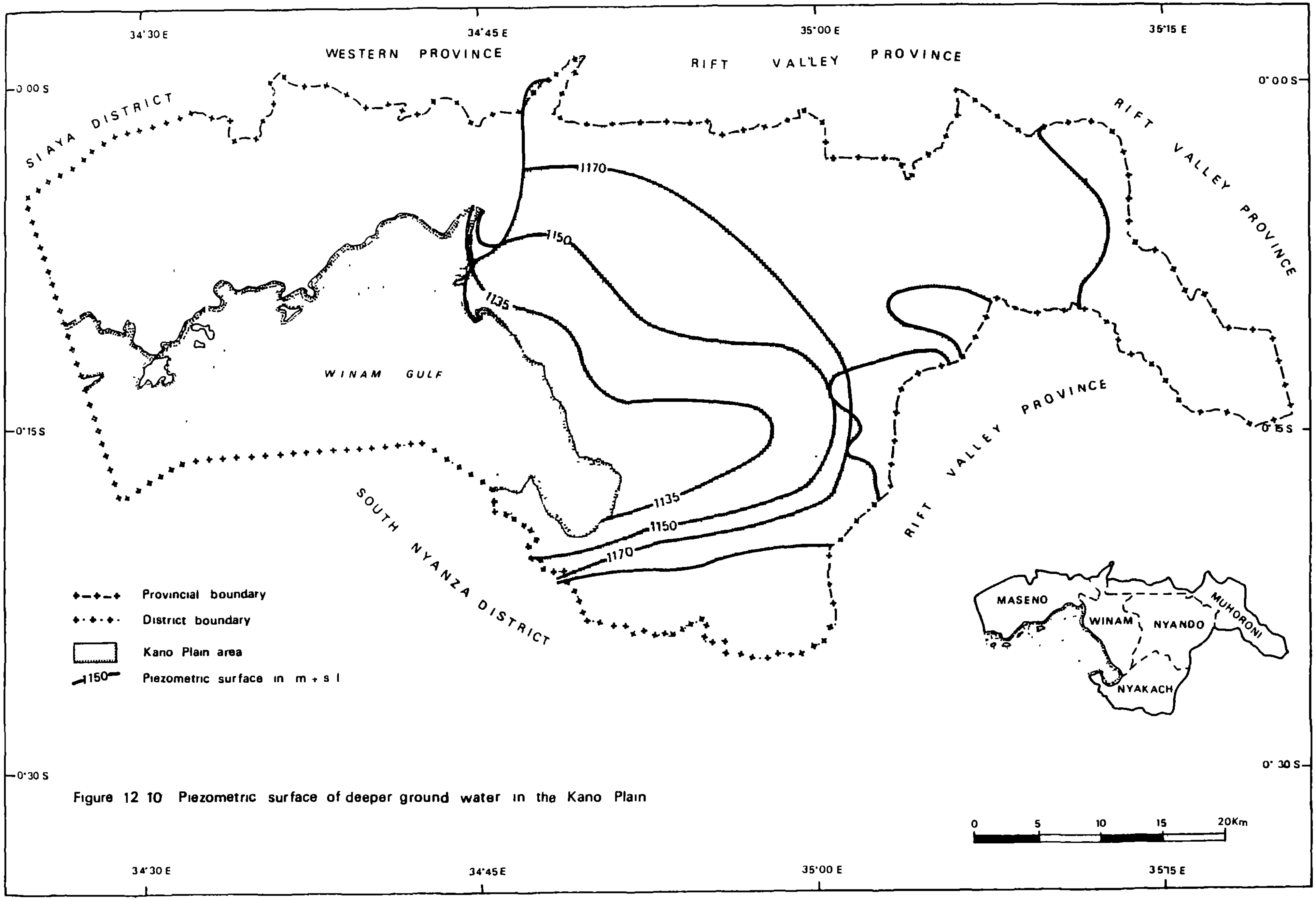


Figure 12 10 Piezometric surface of deeper ground water in the Kano Plain

The permeability of the 18 m of aquifer as calculated from pumping tests carried out was found to be 0.8 m/day.
Again assuming a higher permeability for the deeper aquifers, an average permeability of 2 m/day is used.

The flow equation becomes:

$$Q = 2 \times \frac{100}{20,000} \times 24,000 \times 60$$

$$= 2 \times 0.005 \times 1.44 \times 10^6$$

$$= 14,400 \text{ m}^3\text{/day} = 5.3 \times 10^6 \text{ m}^3\text{/year.}$$

12.9 Ground water potential compared with the demand

The ground water flow towards the Winam Gulf, which was calculated to be 5.3×10^6/year, is maintained mainly by recharge.
This simplification of the water balance of the Kano Plain is possible because:

- the area is an enclosed basin hence ground water inflow from outside the basin is very limited
- recharge occurs mainly along the boundaries of the basin
- present ground water withdrawal is negligible.

Hence the ground water flow = ground water recharge = ground water potential = 5.3×10^6 m^3/year.

The population of the Kano Plain includes the total populations of Winam and Nyando Divisions plus part of the populations of Muhuroni and Nyakach Divisions.

During 1987 the Kano Plain population amounted to some 230,000 people.
In Table 12.7 the projected populations plus their joint water demand are given based on an annual population growth of 3.3 % and a water demand per capita per day of 30 litres.

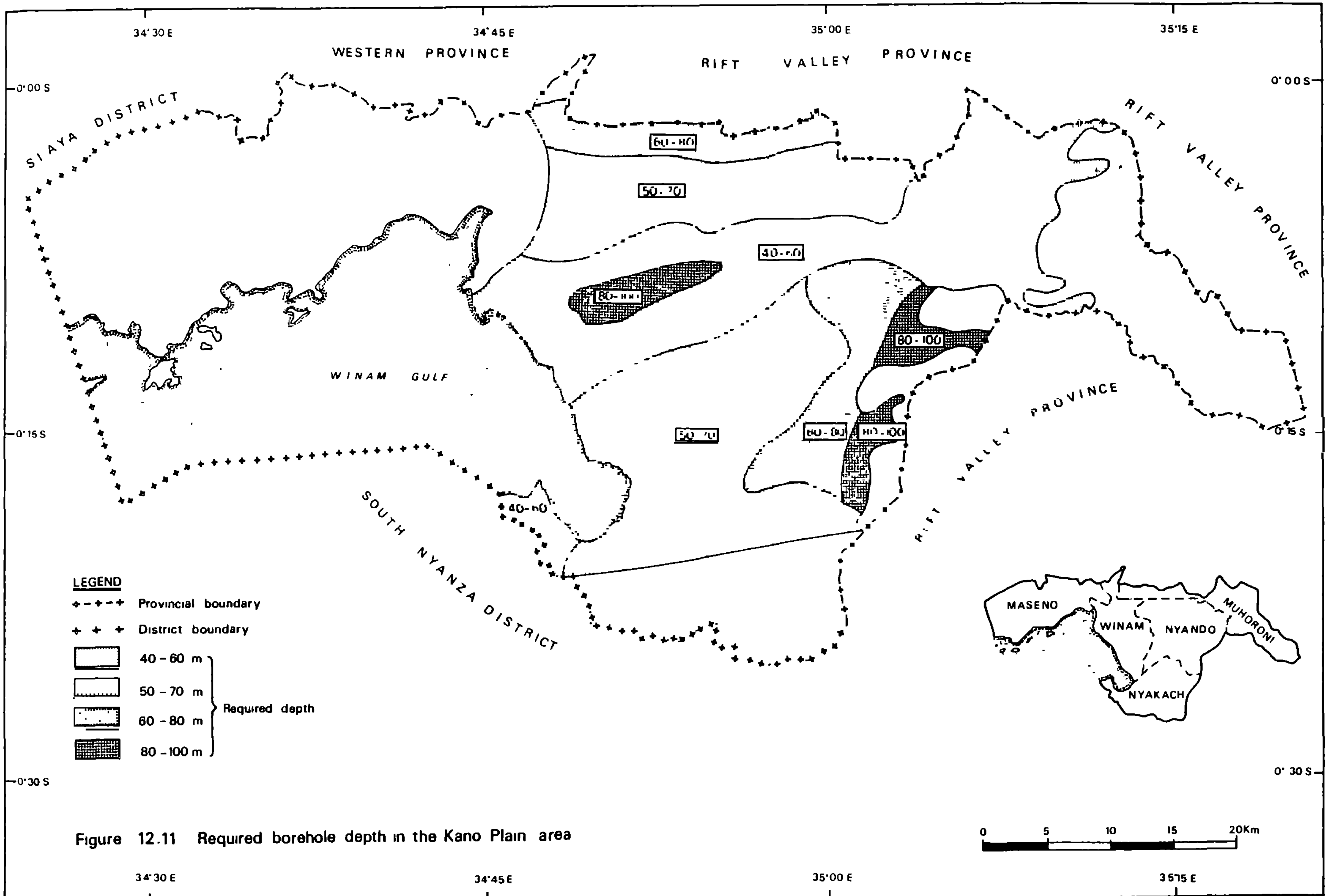


Figure 12.11 Required borehole depth in the Kano Plain area

TABLE 12.7 WATER DEMAND PROJECTIONS FOR THE KANO PLAIN AREA

	1987	1990	1995	2000	2005	2010
Population	230,000	255,000	300,000	350,000	410,000	482,000
Water Demand in m^3/yr.	$2.5x10^6$	$2.8x10^6$	$3.3x10^6$	$3.8x10^6$	$4.5x10^6$	$5.3x10^6$

From the table it appears that up to the year 2010, the estimated ground water potential of the Kano Plain will be sufficient to provide its total population with 30 l/c/d.

12.10 Recommended well type and depth in the Kano Plain

Everywhere in the Kano Plain productive boreholes can be constructed.
In some parts of the Kano Plain, e.g. the central area and the area bordering the Winam Gulf, dug wells can be constructed as well.
There are however a number of good reasons, not to construct dug wells which tap only the upper most , relatively shallow aquifer. Summarized, these reasons are:

- the shallow ground water often is bacteriologically contaminated
- the salinity of the shallow ground water in the western part of the Kano Plain in particular, is high and exceeding the standard of EC = 2,500 mmho/cm.
- both the bacteriological and the chemical quality of the deeper ground water is very good.

Hence it is recommended to construct only machine drilled boreholes in the Kano Plain.
Obvious advantages of boreholes include:

- safe and reliable water supply
- because of the relatively higher yields, boreholes are water sources which in future can also be used for motorized pumped supplies.

The approximate required borehole depth is indicated in Figure 12.11.
It is recommended that shallow aquifers (0-25 m depth) found during borehole drilling are not used but sealed.

In most of the Kano Plain, the required borehole depth is between 40 and 70 m and will be around 60 m on an average.
Only in the topographical higher elevated areas in the east and north of the Plain, borehole depths between 60 and 100 m are required.

Nandi Escarpment and Kano Plain

13 GROUND WATER RESOURCES IN HARD ROCK AREAS

13.1 Introduction

The area outside the Kano Plain, which is underlain mainly by hard rock, includes (Figure 13.1):

- Maseno Division
- the eastern part of Muhuroni Division
- the southern part of Nyakach Division.

The mode of occurrence of ground water in hard rock areas and the exploration methods for well and borehole siting were fully explained in Chapter 11.
The purpose of this chapter is to summarize the ground water situation in the areas above and to indicate the types of constructions required for ground water exploitation.

13.2 Maseno Division

In the area of Maseno Division, ground water relatively is abundant.
Three different types of aquifers are found:

- ground water in the weathered zone of hard rocks
- ground water in faults and fractures in hard rocks
- ground water in Pleistocene and Recent sediments.

Hard rocks, which crop out in 90 % of the area include granite, andesite and phonolite.
Sedimentary deposits are found only along the Winam Gulf and in some major valleys and include silts and clays as well as sands and gravels (see Map 4).

In most locations ground water is found between a depth of 10 to 50 m-gl.

13.2.1 Shallow ground water (0-25 m depth)

It was found that shallow ground water occurs throughout the Division. The shallow ground water is of a good physio-chemical and bacteriological quality.
It is possible to exploit the shallow ground water by means of hand dug wells which may range in depth from 12 to 20 m but will not be deeper than 15 m on an average.

However, shallow ground water cannot be exploited at each and every location.
A sufficiently developed aquifer generally is found only in topographical lower areas.

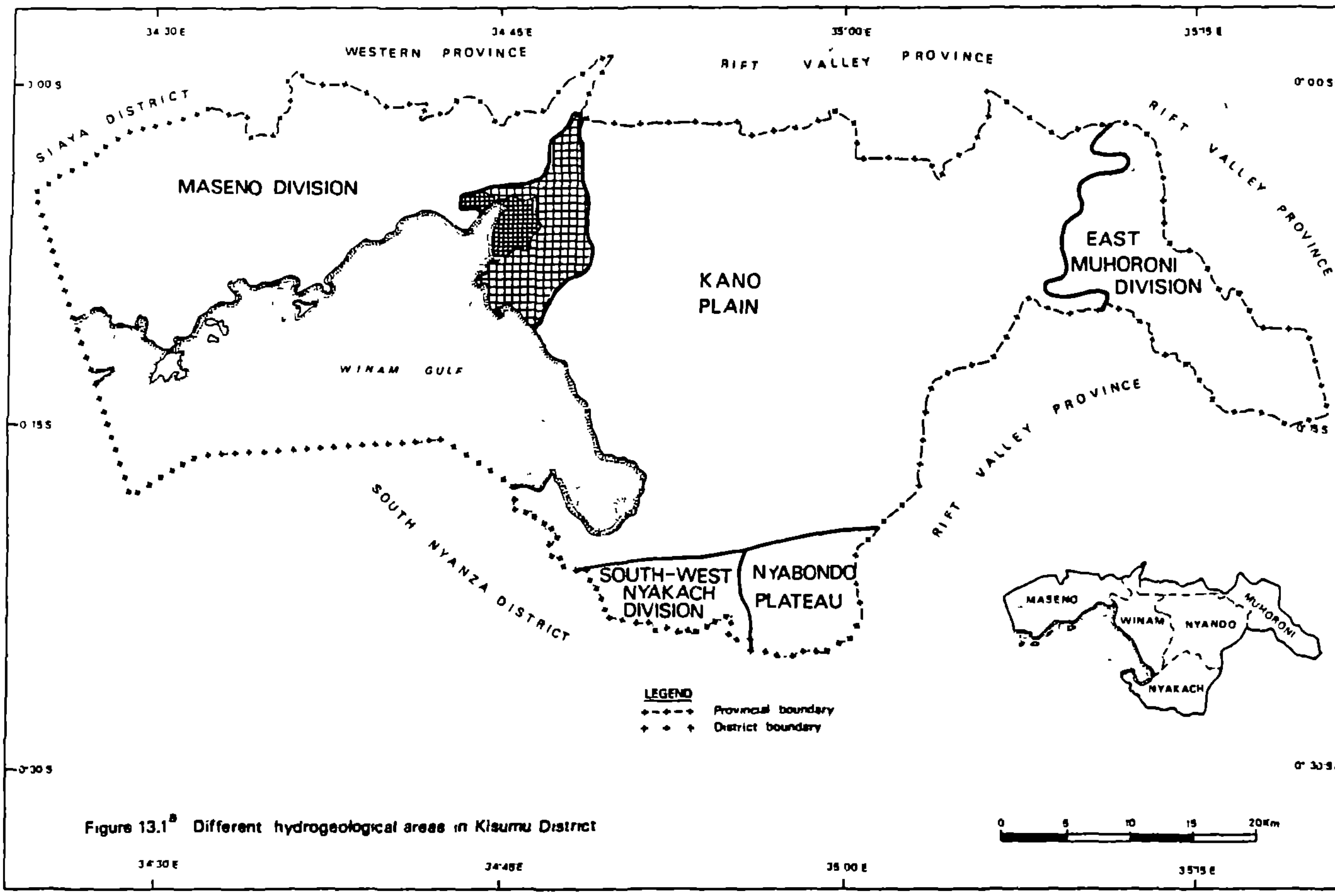


Figure 13.1[a] Different hydrogeological areas in Kisumu District

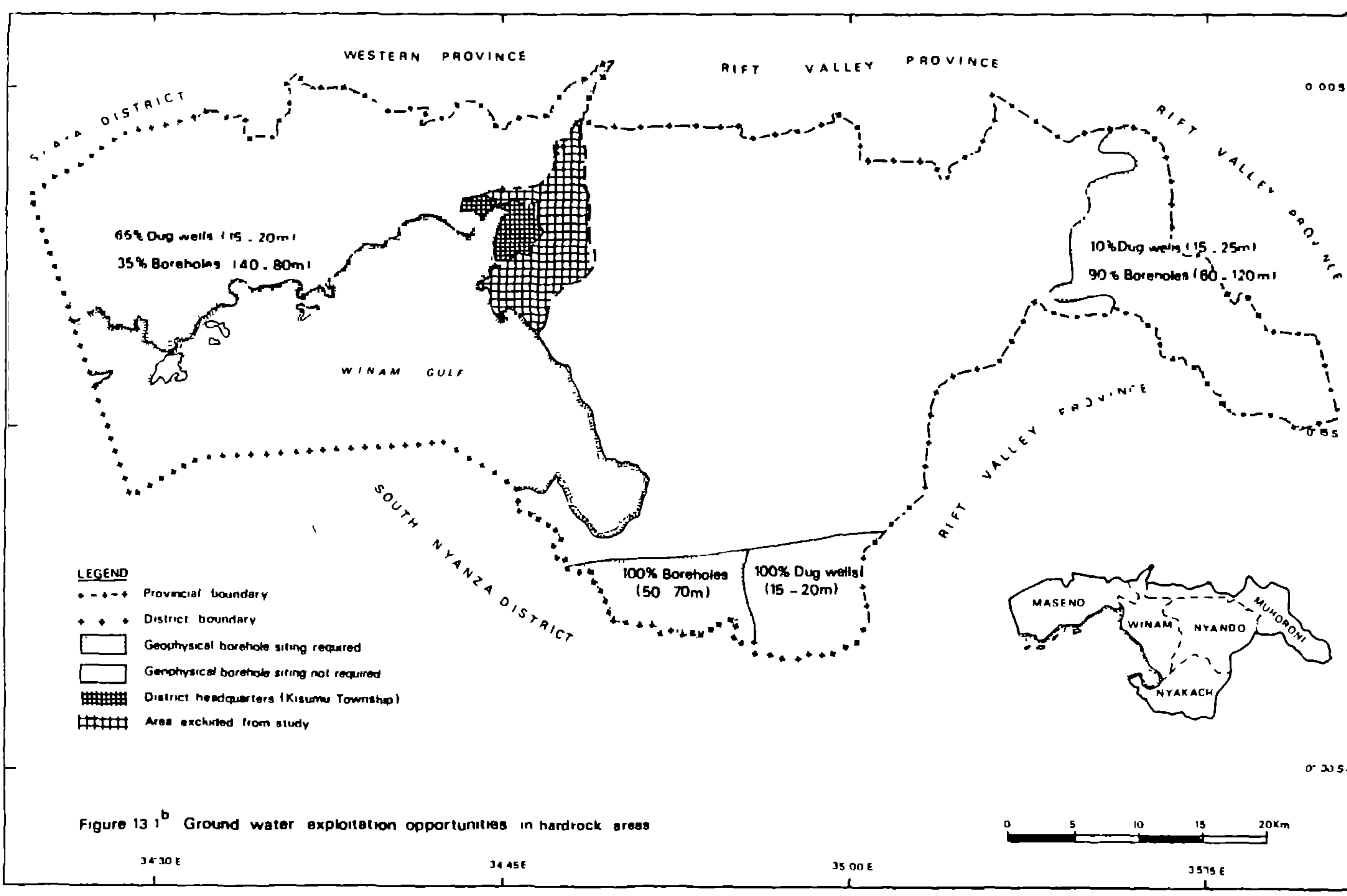


Figure 13.1[b] Ground water exploitation opportunities in hardrock areas

On slopes and hill tops a weathered layer often is quite thin or absent thus rendering such areas unsuitable for ground water exploitation from weathered zone aquifers.

Moreover, a ground water table in higher elevated areas may fluctuate considerably and even be seasonal only.
Hand dug wells have a limited penetration depth into the aquifer, usually not more than 5 m, and are therefore sensitive to seasonal water table fluctuations, which are less significant in topographical lower areas.

Hence, successful shallow ground water development will be restricted to the topographical lower areas such as valleys, intermountaineous flats, foot slopes along mountains and escarpments etc.

With some knowledge of the area and common sense, it will be possible to indicate hand dug well locations without carrying out a geophysical survey.

13.2.2 Medium depth ground water (25-50 m depth)

It was found that the weathered zone of the hard rock extends to a depth of 30-50 m-gl.
Moreover, the tectonical movements which accompanied the Tertiary rift faulting in the area, caused the occurrence of a well developed faults and fractures system.

Hence, besides the exploitation of shallow ground water by means of dug wells, it is possible also to develop the deeper, preferably faulted or fractured, aquifers by means of 40-60 m deep boreholes.

Where the upper part of the Pleistocene deposits are to clayey or silty to contain sufficient shallow ground water, boreholes of 40 to 60 m depth will be the solution since at these depths, more sandy and gravelly deposits are expected to occur.

In the hard rock areas borehole locations will always have to be sited by means of geophysical investigations.

In the Pleistocene deposits which are found along the shore of the Winam Gulf neither wells nor boreholes will have to be sited since in this case the aquifers are sub-horizontal sediment layers.

13.2.3 Ground water potential

By making use of rainfall, evaporation, run-off and soil moisture from various sources and data centres (Ref.10,13,20,22,42,45, 56,65) the annual recharge for the sub-catchments in Maseno Division was calculated.
Addition gives a total recharge of 13×10^6 m^3/year for the Division.

13.2.4 Construction of wells and boreholes

Owing to the occurrence of different kind of aquifers throughout the Division, and an estimated annual ground water potential of 77×10^6 m^3, the construction of new water points can be restricted to dug wells and boreholes.

As a result of the executed surveys, it was found that in most places in Maseno Division shallow ground water can be exploited by means of dug wells which range in depth from 12 to 25 m and will be 15 m on an average.

In addition to the development possibilities of shallow ground water, medium depth ground water can be exploited as well by means of 40 -60 m deep boreholes.

However successful borehole drilling will be restricted to faults and fractured zones in hard rock areas, and coarse sediments in the areas underlain by Pleistocene deposits.

It is anticipated that the ratio of wells to boreholes will be about 2:1.
This division between wells and boreholes is based mainly upon the topography and related depth to the ground water.
An exception to this is East Kisumu Location, where because of the proximity of Kisumu urban development, boreholes are to be preferred above dug wells.

Construction of a hand dug well

13.3 Eastern part of Muhuroni Division

13.3.1 Occurrence of aquifers

This area is underlain by different volcanic rock types. Volcanic tuffs crop out in most of the area. At places the tuffs are capped by phonolitic lava.

Information on the occurrence of ground water is available from 14 dug wells and 1 borehole. The borehole was drilled 140 m deep and is not in use because of low too a yield. The wells are quite shallow, between 2 and 9 m and most of them are situated in valley bottoms thus mainly tapping soil water. Hence neither the borehole nor the dug wells have been very helpful in evaluating the occurrence of groundwater.

The evaluation of the possible occurrence of aquifers therefore is based solely on the results of the geophysical surveys carried out and summarized below.

Layer	Formation Resistivity	Thickness	Interpretation
1st layer	2- 20 Ohmm	10-40 m	highly weathered tuffs
2nd layer	10- 50 Ohmm	20-70 m	slightly weathered tuffs
3rd layer	100-150 Ohmm	from 60-80 m depth	unweathered lava

The first layer, which often has a resistivity as low as 2-7 ohmm, is interpreted as beeing very clayey and therefore an aquiclude. The second layer, which starts from an average depth of 25 m and is about 40 m thick is assumed to be ground water bearing. Because of the rock type, well yields are not expected to be high, but to be adequate for hand pumps. Where the third layer is found, the boundary between the second and third layer might be an aquifer also.

In those parts of the area where phonolitic lava is capping the weathered tuffs, this lava was found to be approximately 30 m thick.
Because the underlying tuffs are largely impermeable, it is very well possible that ground water can be found in the lower parts of the basaltic lava.
Depending on it's thickness, ground water than could be exploited by means of dug wells (up to 20 m depth) or boreholes (30-40 m depth).

13.3.2 Ground water quality

The EC of the ground water from the dug wells in the area is between 200 and 600 mmho/cm.
It was found moreover that the shallow water quality is good to excellent with all physio-chemical parameters beeing within the Kenyan Standards for drinking water.

However, in several places extremely low formation resistivity values (1.5-2 Ohmm) were found.
Although these low resistivity layers could just be clay, alternatively it is possible that they represent the occurrence of saline ground water.
Therefore it is recommended to drill one or more boreholes into this low resistivity zone, to find out which of the two possibilities is right.
Should saline ground water be found, than this can be explained by the influence of the deep faults that were found to occur in the area.

13.3.3 Recharge mechanism

Geomorphologically the area belongs to the footslopes of Mount Tinderet.
Rainfall on this mountain is over 1,600 mm/year.
The annual rainfall on the area itself amounts to 1,300-1,500 mm.
Generally recharge of the volcanic tuff aquifer will be low because of the covering clayey layer.
However, the area is dissected by many valleys which possible cut through the highly weathered layer and recharge might occur through influent streams.
This however is all rather hypothetical.
Only after the drilling of a number of boreholes, and after monitoring of water levels for at least 1 or 2 years, something substantial can be stated on the occurrence and recharge of aquifers in this volcanic region.

13.3.4 Construction of dug wells

The construction of dug wells is considered only in those parts of the area where shallow aquifers are present and where the population density is relatively low. The latter to prevent that polluted ground water will be met.
Possible areas suitable for the construction of dug wells are Fort-Ternan and Ochoria Sub-Locations.

However, the feasibility of dug wells has to be studied on individual base.
Depending on the thickness of the phonolite, dug wells will vary in depth from 15-25 m.

13.3.5 Construction of boreholes

The estimated possibilities for the construction of dug wells in the area are rather limited.
Based on the surveys done it is tentatively concluded that in most of the area ground water can be exploited through 60-80 m deep boreholes.
In topographically higher areas, borehole depth might be up to 120 m.

It is recommended to carry out geophysical surveys for the siting of borehole locations in the area.

13.4 South eastern part of Nyakach Division (Nyabondo Plateau)

This area comprises the Nyabondo Plateau area.
It is underlain by phonolitic lava which caps weathered granite.
The large number of shallow dug wells (260) in this area indicates the occurrence of shallow ground water.

13.4 .1 Occurrence of ground water

Owing to a good secondary porosity and permeability of the generally fissile phonolite, there appears to be an abundance of ground water stored in the plateau phonolites.
Major aquifers are the zone of highly broken rock, which occur immediately below the shallow soil cover, at depths between 2 and 15 (m-gl) and the zone of moderately broken rock, at depths between 5 and 20 (m-gl).

The volume of ground water, permanently in storage can be quantified as follows:

- The average maximum depth of the major aquifer is 15 (m-gl).
- The average depth of the water table is 5 (m-gl).
- The storage capacity of the fractured rock is 2 %.

Using these figures, the volume of ground water in storage would amount to 7 x 10^6 m^3.

13.4.2 Ground water recharge

In the water balance studies of chapter 14, a recharge index of 6% is calculated for the phonolite of the Nyabondo Plateau. This figure agrees with the 5-10 % recharge indices given for this particular area by Ker, Priestman and Associates (Ref. 26).

For an average annual rainfall of 1300 (mm), the recharge of the ground water storage would amount to 2.8 x 10^6 m^3/year.

13.4.3 Ground water withdrawal for domestic use

The present annual ground water withdrawal for the 31,000 people living on the plateau amounts to:

population x 30 litres/capita x 365 = 0.33 x 10^6 m^3/year.

13.4.4 Ground water quality

The results of the ground water quality study can be summarized as follows.

- Apart from a slightly low pH (5.5-6.5), the chemical quality of the ground water is extremely good, with the EC varying between 50 and 150 (mmho/cm) and with none of the chemical parameters exceeding the standards.

- Bacteriologically the ground water is seriously contaminated. This contamination is not local but comprises the whole of the aquifer.

13.4.5 Ground water development possibilities

The annual recharge of ground water or the safe yield in this area is more than eight times the present withdrawal for domestic use. Quantity wise therefore, the ground water potential is very good.

Quality wise however, the situation is alarming. Apart from the 260 shallow hand dug wells there are an estimated 1,500 pit latrines on the plateau, through which human wastes are continuously polluting the ground water.
Complete bacteriological contamination of the shallow ground water has been determined.
As a consequence the water drawn from the existing wells should not be consumed without treatment, like boiling it.

From investigations by the RDWSSP, including a deep borehole (C-8046) drilled in this area, it appeared that medium depth or deep ground water does not occur in the area.
Hence only the shallow ground water can be used.

At present the RDWSSP is constructing a number of dug wells that penetrate deeper into the aquifer.
When these wells will show less or no contamination, the ground water development strategy for the area will be to construct carefully located and protected dug wells in the deepest parts of the aquifer.

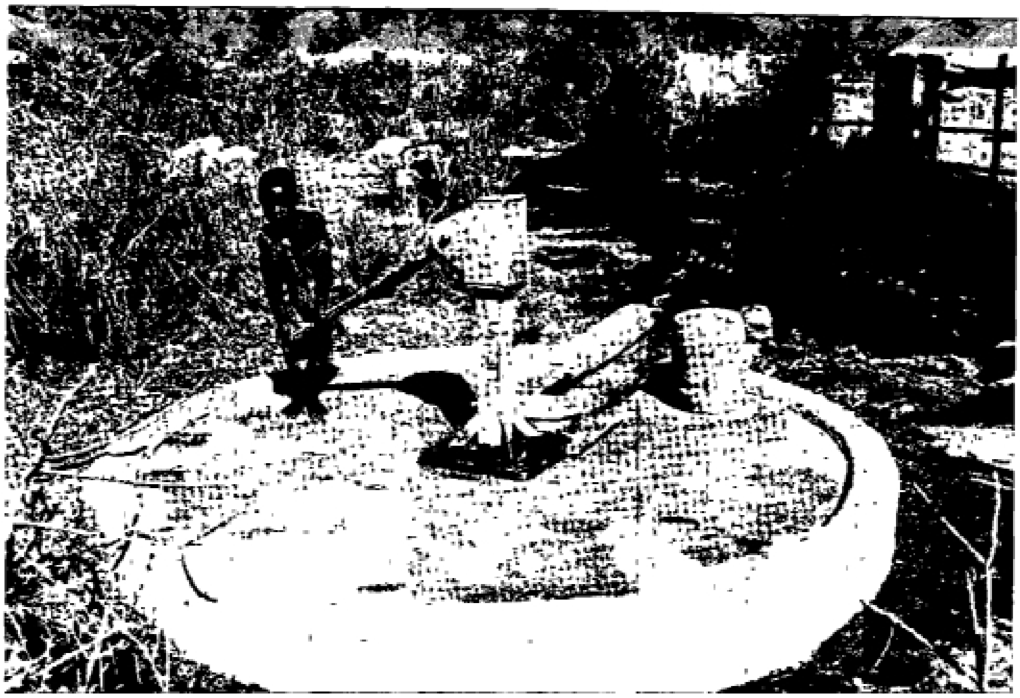
13.5 South-western part of Nyakach Division

13.5.1 Occurrence of ground water

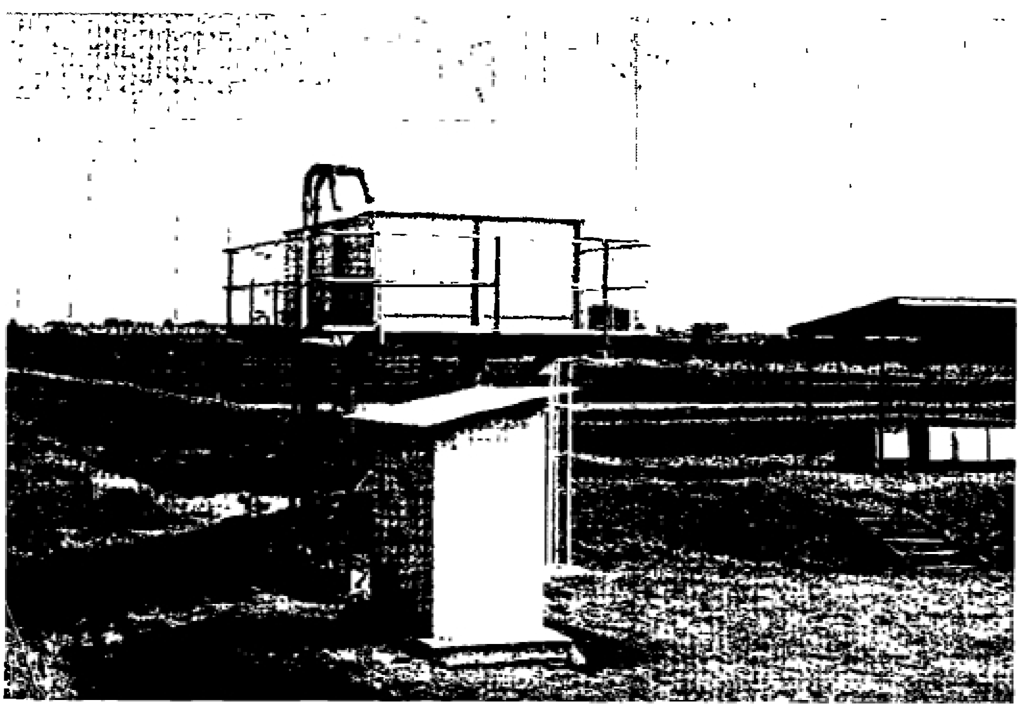
Wells do not occur, which limits the hydrogeological description to a theoretical reflection based solely on the results of the geophysical survey and the experience gained in areas of similar geology.

From the geo-electrical soundings it appears that the thickness of the weathering profile varies from 25 to 60 m depth.
From experience in other granite areas it is known that, although some ground water is stored in the weathered zone, usually ground water is moving along, and can only be exploited from, faults and fractured zones.

Assuming an aquifer thickness of 10 m , similar to the granites in the neighbouring Kendu Division, and a storage capacity of the major joints and fractures of 0.5 % than the theoretical volume of ground water in storage would be in the order of magnitude of 2×10^6 m^3.



Borehole fitted with hand pump



Hand drilled wells used for motorized pumping

13.5.2 Ground water recharge

A relatively low recharge index of 2 % is chosen, because of the following arguments:

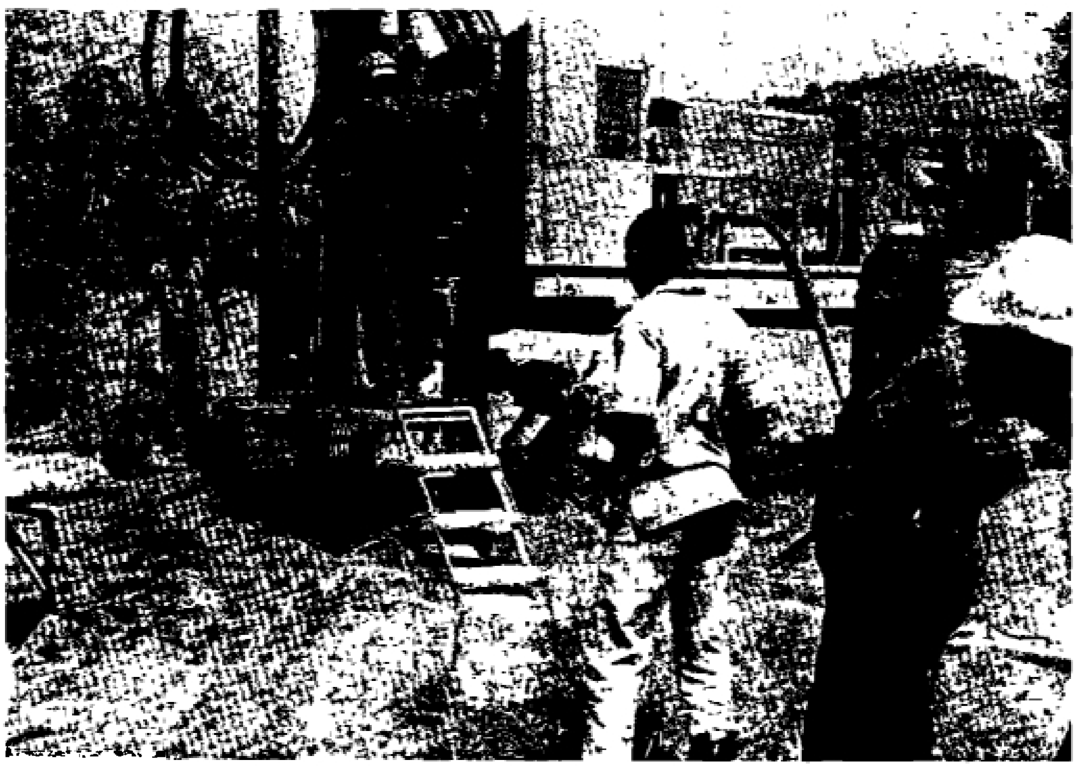
- dense vegetation;
- steep topography;
- relatively permeable (sandy) soil.

Using this index, the annual recharge of ground water would amount to 1×10^6 m^3/year.

13.5.3 Ground water development possibilities

The theoretically calculated ground water recharge, 1×10^6 m^3/year would be sufficient to supply twenty times the present population (6000) with 30 l/c/d.

Ground water should be exploited by means of (50-70) deep boreholes mainly.
These borehole locations should however, be sited very carefully since only pronounced faults and fracture zones will offer any substantial yield.



Borehole drilling

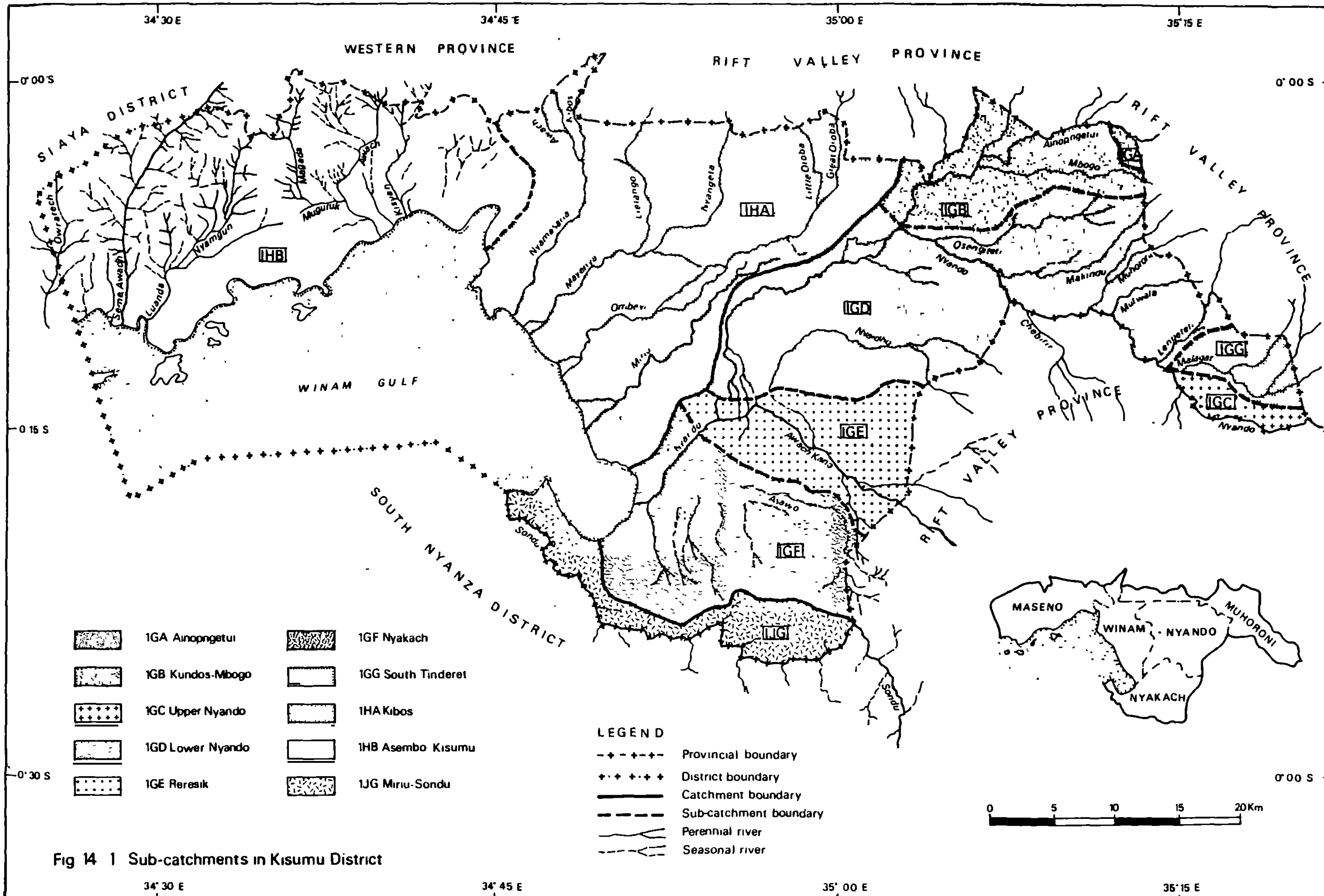


Fig 14 1 Sub-catchments in Kisumu District

14 GROUND WATER RECHARGE

14.1 Introduction

In order to obtain an impression of the ground water potential in Kisumu District, in this chapter an assessment is made of the ground water recharge .

According to the basic principle of the storage of water in the buffer zone of the top soil before percolating to the ground water, the following basis water balance equation is used to estimate the ground water recharge:

$$R = P - Q - dSm - Eta$$

in which:
R = Ground water recharge [mm]
P = Rainfall [mm]
Q = Runoff [mm]
dSm= Change in soil moisture [mm]
Eta= Actual evaporation [mm]

This formula is applied to determine the ground water recharge using mean hydrological data on a monthly bases. Addition of the monthly results gives the mean annual recharge in the area concerned.

The recharge calculation is done per sub-catchment since hydrological characteristics are not uniform over the District area. Maps from the Ministry of Water Development show that Kisumu District is covered by parts of ten sub-catchments as listed in Table 14.1 and shown in Figure 14.1.

Table 14.1 Division of Kisumu District over sub-catchments

Sub-catchment:	1GA	1GB	1GC	1GD	1GE	1GF	1GG	1HA	1HB	1JG
Surface (km^2)	5	124	29	436	129	215	35	504	421	97

For an accurate water balance, precise and extensive hydrological data are required. These are not always available for the sub-catchments of Kisumu District. Hence, the recharge figures calculated in this chapter should be considered as the presently best possible approximations.

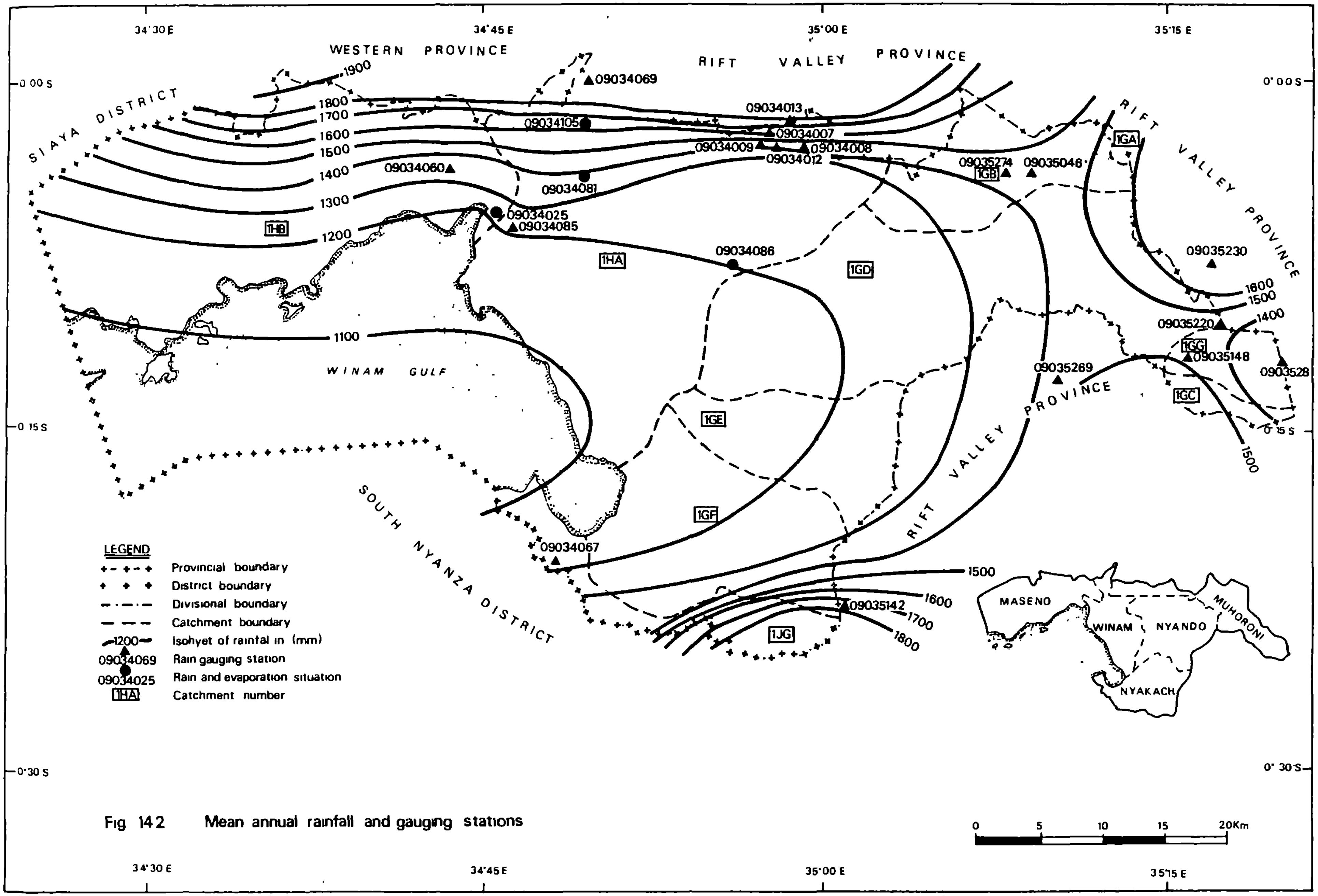


Fig 14.2 Mean annual rainfall and gauging stations

14.2 Rainfall

Mean annual rainfall data have been deducted from available data from rain recording stations as depicted in Figure 14.2. and listed in Table 14.2. Presently Lake Basin's Data Centre has provisional rainfall data for several of these stations in Kisumu District (Ref.10). Additionally, for four stations in the District the rainfall series have been analysed. The results are shown in Figure 14.4.

From this information, the mean annual rainfall map for the District had been elaborated as shown in the same figure. The division of monthly rainfall and mean annual rainfall per sub-catchment as calculated is shown in the histogram of Figure 14.3.

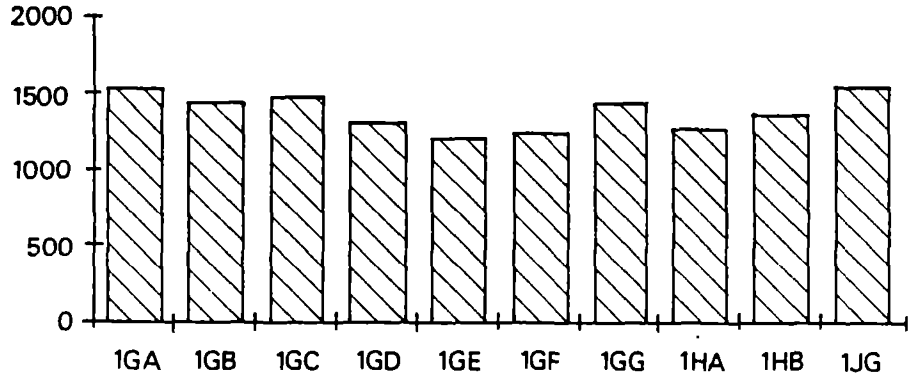


Fig.14 3 Mean annual rainfall per sub-catchment in Kisumu District(mm)

14.3 Runoff

Surface runoff is that part of the rainfall which travels overland and through channels. After overland flow enters a stream channels, it becomes stream flow.

Figures for mean monthly runoff per sub-catchment are presented in the National Master Water Plan (Ref.56). These data are listed in Table 14.3. The ratios of mean annual runoff to the mean annual rainfall in the corresponding sub-catchments vary between 19% and 29%.

14.4 Potential evapotranspiration

Potential evapotranspiration is deducted from open pan evaporation which is recorded at evaporation stations. To obtain a reliable picture of the actual open pan evaporation, the recorded data series of the four evaporation stations in Kisumu District, have been analyzed. The results of the screening and processing of these data, which were updated up to 1987 are shown in Figure 14.4. Moreover use has been made of information of open pan evaporation at Kericho meteorological station as found by JICA (Ref.22) to determine mean monthly open pan evaporation per sub-catchment. The Figures for mean annual open pan evaporation are shown in Figure 14.5.

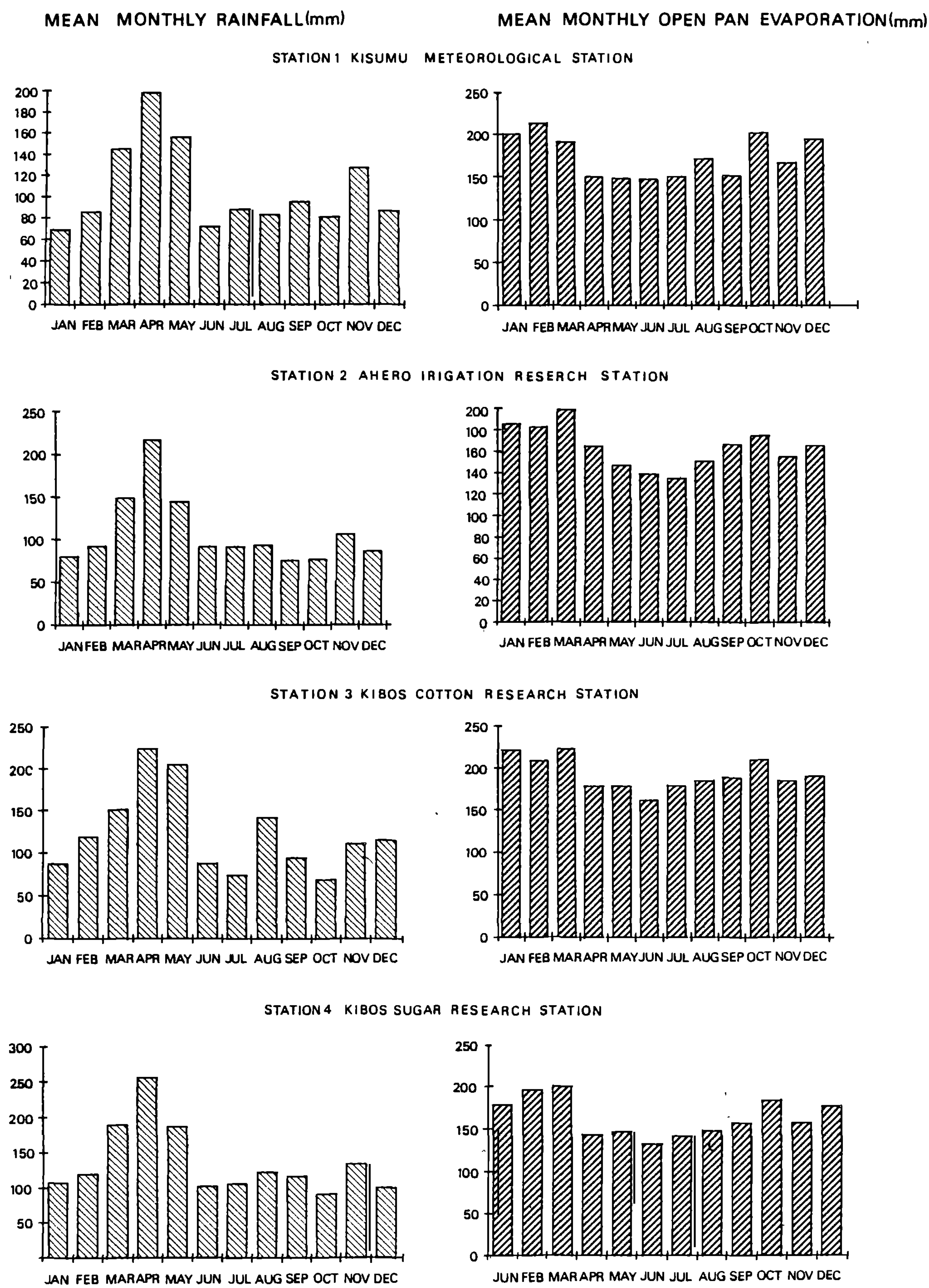


Fig 14 4 Elaborated rainfall and open pan evaporation data of M OW D stations

The potential evapotranspiration of an overgrown soil is defined as the evapo-transpiration that would occur if soil moisture would not be limited. It is usually expressed as a percentage of the open pan evaporation. It amounts generally around 75% of the open pan evaporation in overgrown highlands and 80% or more in hot and dry lowland areas according to TAMS (Ref.56). Since most parts of Kisumu District consists of overgrown lowlands, the figure of 80% is applied.

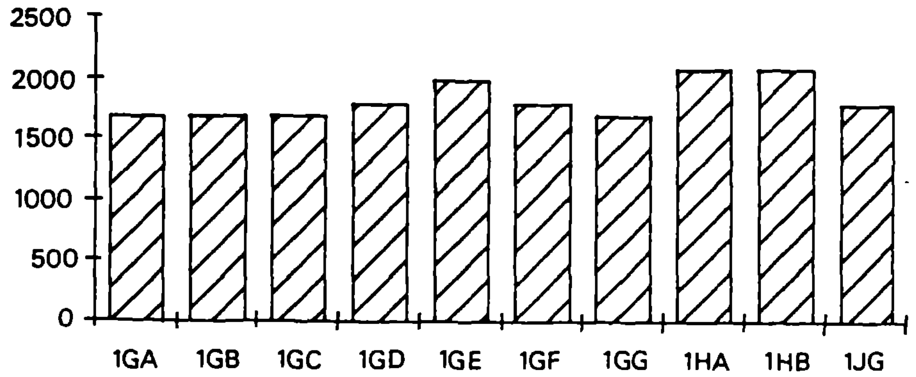


Fig.14.5 Mean annual open pan evaporation per sub-catchment in Kisumu District (mm)

14.5 Soil moisture storage

Not all water absorbed through the earth surface will seep to the permanent ground water. Only after the saturation level of the soil moisture has been reached, excess water will percolate to the deeper ground water. In the literature several values are used for the maximum soil moisture storage. Considering the grade and depth of weathering and the average soil structure in Kisumu District, a figure 120 mm is adopted for the recharge calculations.

14.6 Ground water recharge and actual evapotranspiration.

When rainfall, runoff and evaporation data are known for a given month in a particular area, the amount of infiltrated water is expressed by the following equation:

$$INF = P - Q$$

in which:
INF= infiltrated water [mm]
P = rainfall [mm]
Q = runoff [mm]

Table 14.2 Rainfall figures for various stations in and around Kisumu District

Station No:	Station Name	Altitude m above sea level	Latitude	Longitude	Years of records	Years of complete records	Mean annual rainfall (mm/year)
08934103	Vihiga Abrig. Office	5200	00.02N	34.43E	25	23	not available
09034007	Gendia Mission	4100	00.23S	34.39E	55	38	1,380
09034008	Miwani sugar Sec. II Office	4340	00.03S	34.57E	25	4	2,161
09034009	Miwani the hill	4500	00.03S	34.57E	51	1	1,423
09034012	Miwani Sugar Section I	4000	00.03S	34.57E	25	4	1,370
09034013	Miwani Sugar Section III	4000	00.02S	34.58E	25	13	1,847
09034022	Ongielo Asembo Dispensary	3730	00.11S	34.23E	25		not available
09034025	Kisumu Meteorological Stn.	3769	00.06S	34.45E	25	18	1,297
09034037	Akala Dispensary	4000	00.05S	34.26E	25	14	1,314
09034060	Kisumu New Prison	4000	00.04S	34.43E	25	0	not available
09034067	Sangoro Pr. School	3800	00.21S	34.48E	25		not available
09034069	Kibos Kisumu Water supply	5100	00.00	34.49E	25	0	not available
09034081	Kibos Cotton Exp. Station	3847	00.04S	34.49E	34	18	1,496
09034085	Kisumu Municipal Council	3870	00.06S	34.45E	24	14	1,704
09034086	Ahero Irr. Res Station	4000	00.08S	34.56E	24	20	1,321
09034105	Kibos Sugar Res. Station	3947	00.02S	34.49E	14	8	1,633
09034110	Mawego Technical School	4400	00.23S	34.46E	16		not available
09034112	Oriang Pr. School	3900	00.27S	34.56E	16	5	1,989
09035009	Songhor Mbogo Vale Pr.Sch.	6400	00.04S	35.19E	51	21	1,798
09035046	Chemelil Plantations	4032	00.04S	35.09E	23	16	1,477
09035142	Nyabondo Water supply	5000	00.23S	35.01E	25	11	1,802
09035148	Koru Bible School	5600	00.12S	35.16E	24	18	1,515
09035220	Koru Homalime Co. Ltd.	4900	00.10S	35.17E	24	16	1,348
09035230	Koru Coffee Board Sub-Stat.	5160	00.08S	35.17E	25	13	1,760
09035258	Kipkelion Water Supply	6300	00.12S	35.20E	22	11	1,160
09035269	Kericho Kipsitet	6115	00.13S	35.10E	18	10	1,524
09035274	Chemelil sugar Scheme	4163	00.04S	35.08E	15	10	1,496

TABLE 14.3 MEAN MONTHLY RUNOFF PER SUB-CATCHMENT IN MM.

Catchment code	Surface area (km2)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
1GA	5	14	11	16	32	48	32	27	28	25	19	17	19	288
1GB	124	17	14	18	34	48	31	24	26	24	20	22	20	298
1GC	29	16	13	18	33	47	40	38	48	44	30	25	23	374
1GD	436	17	17	27	44	48	30	30	29	23	18	24	24	330
1GE	129	15	11	21	41	51	30	40	41	30	22	25	24	351
1GF	215	13	10	18	35	43	26	34	34	26	18	21	20	298
1GG	35	14	13	17	30	49	40	34	36	35	26	22	20	336
1HA	504	17	19	28	53	52	30	21	21	18	17	24	26	326
1HB	421	15	18	32	57	49	25	18	19	16	16	23	27	315
1JG	97	21	19	27	50	65	40	26	22	23	23	31	31	378
Kisumu District:	1,995	16	16	26	47	50	29	26	26	22	18	24	25	325

As described earlier, infiltrated water will only seep to deeper ground water after the saturation level of the soil moisture has been reached. This is the ground water recharge. The amount of non-percolating water in the specific month remains as soil moisture. This may evaporate or must be forwarded as a balance to the next month.

In this procedure the actual monthly evapotranspiration is determined as well. This can never exceed the potential evapotranspiration as discussed in section 14.4, whilst at the other hand the actual evapotranspiration is limited by the available soil moisture.

Table 14.4 gives an example of the calculation of the annual recharge as executed for sub-catchment 1GB. It shows that the ground water recharge does only occur during a few months per year. The actual evapotranspiration is mostly less than the potential evaporation due to a limited amount of available soil moisture. The Figures 14.6 and 14.7 respectively show the calculated annual amounts of actual evapotranspiration and ground water recharge per sub-catchment.

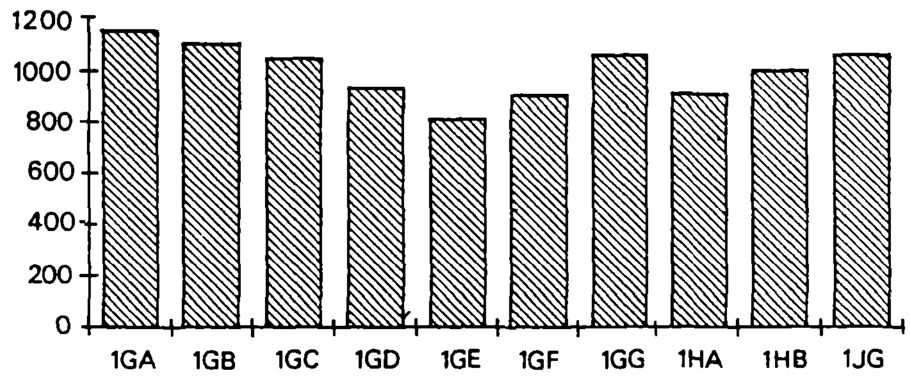


Fig.14 6 Mean annual actual evaporation per sub-catchment in Kisumu District (mm)

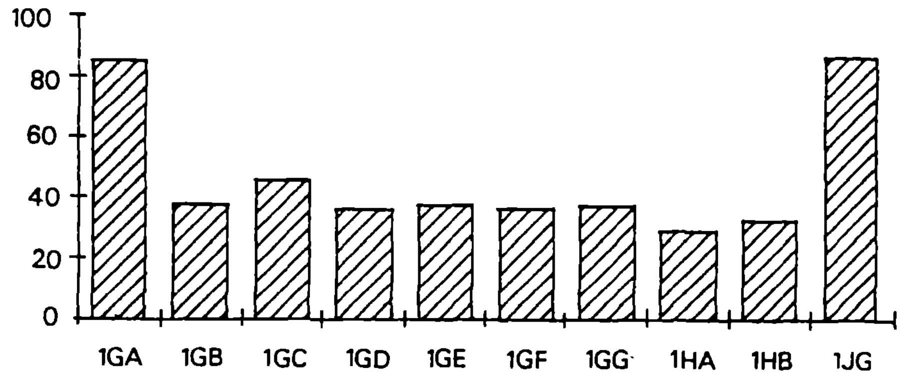


Fig. 14.7 Mean annual recharge per sub catchment in Kisumu District (mm)

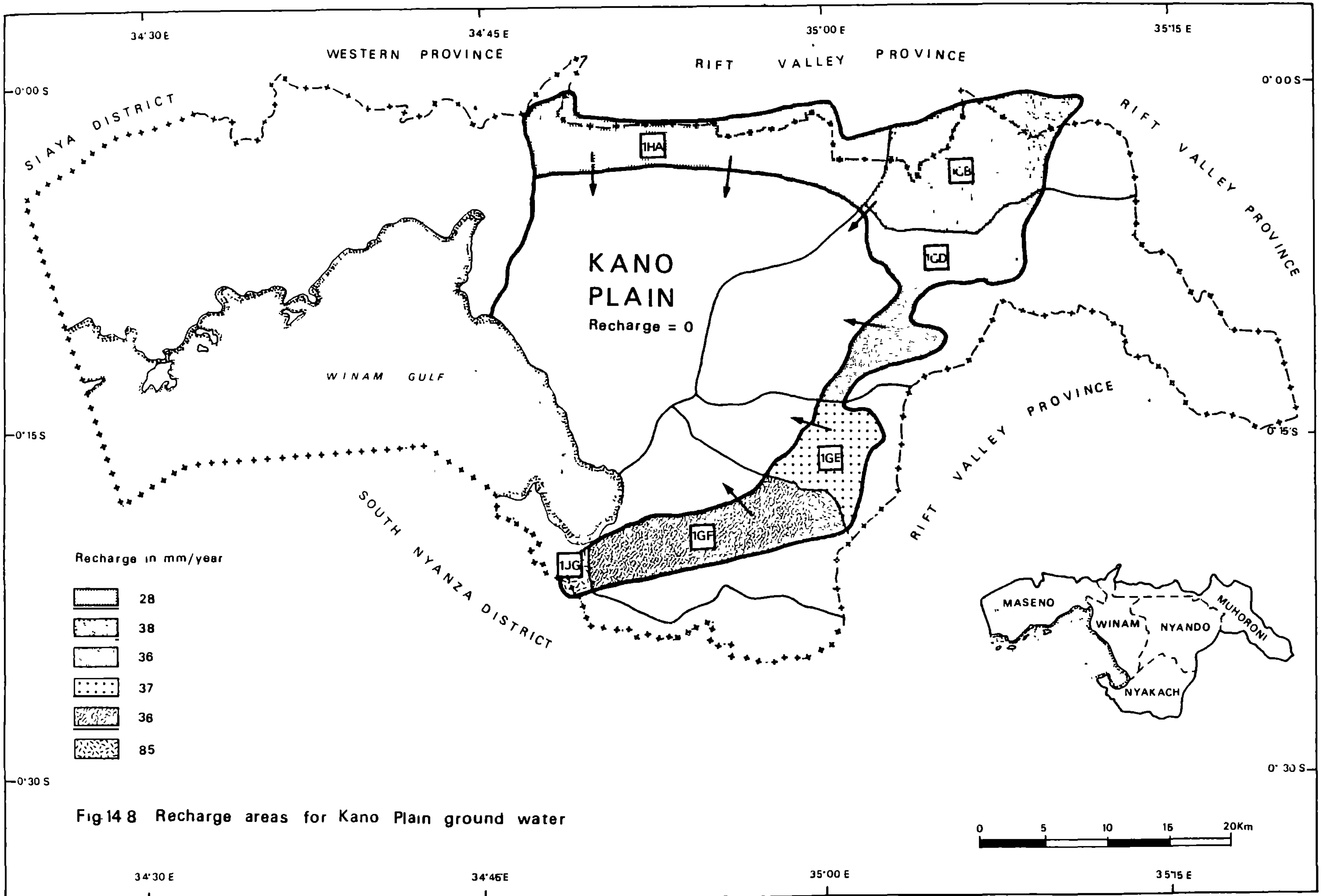


Fig 14 8 Recharge areas for Kano Plain ground water

TABLE 14.4 CALCULATION OF ANNUAL RECHARGE FOR SUB-CATCHMENT 1GB

SUB-CATCHMENT: 1GB SURFACE: 124 KM2 MAXIMUM SOIL MOISTURE CONTENT: 120 MM

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR	
RAINFALL (MM)	96	90	113	163	173	125	129	95	101	102	154	102	1,443	100%
RUNOFF (MM)	17	14	18	34	48	31	24	26	24	20	22	20	298	21%
INFILTRATION (MM)	79	77	94	130	124	94	105	69	77	82	132	82	1,145	
PAN EVAPORATION (MM)	168	163	170	136	126	123	117	126	142	143	130	145	1,690	
POT. EVAPORATION (MM)	134	131	136	109	101	98	93	101	114	115	104	116		
SMO=DSM+INF (MM)	79	77	94	130	135	113	120	96	77	82	132	98		
RECHARGE (MM)	0	0	0	10	15	0					12		38	3%
ACT. EVAPORATION (MM)	79	77	94	109	101	98	93	96	77	82	104	98	1,108	77%
DSM (MM)	0			11	19	15	27				16			

YEARLY RECHARGE= 4.7 *10^6 M3

14.7 Recharge and ground water potential in the Kano Plain

The above estimation of the recharge in Kisumu District is not exact for the Kano Plain (450 km^2), which boundaries are indicated in Figure 14.8. According to Ker, Priestman and associates (Ref.26) the recharge in the plain itself is almost neglectable due to the clayey character of the top soil.

Therefore a separate assessment was made of the total recharge in the areas surrounding the Kano Plain which feed its ground water.

Making use of the results of the recharge per sub-catchment as found in the previous section, the total recharge in this area amounts 15.8 million cubic meters.

Since this amount of water has to serve both the recharge area (600 km^2)and the Kano Plain, totally 1,050 km^2, an average of 15mm/km^2/year is available for ground water abstraction in the whole area.

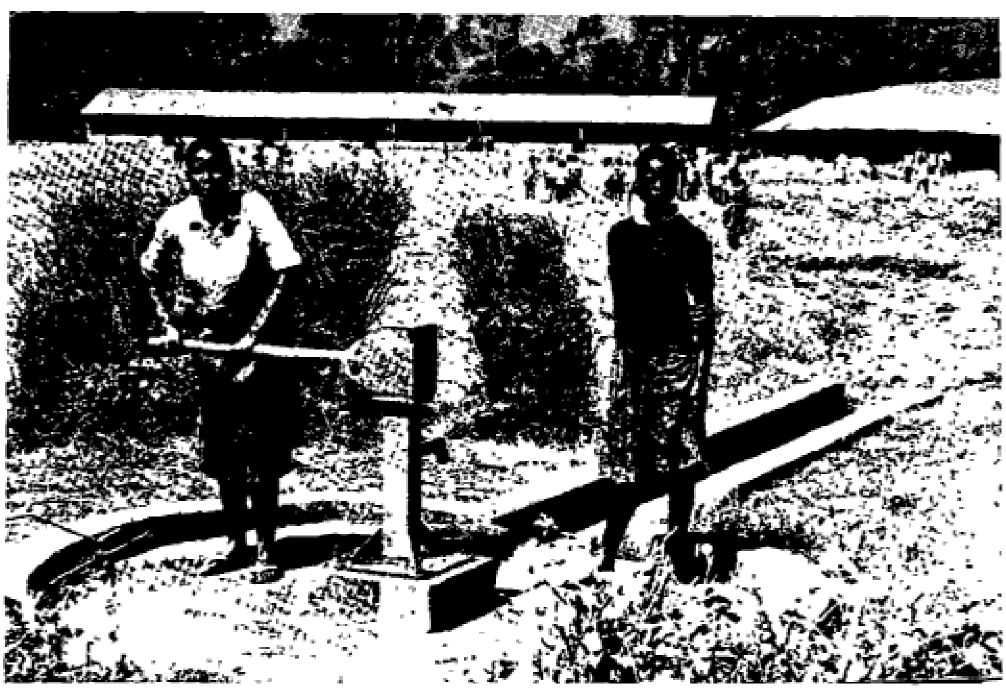
Hand drilled well

Roof catchment

PART 7

CONSTRUCTION OF POINT SOURCES

RDWSSP well at Kaeli Market



RDWSSP well at Ombaka School

15 PROVISION OF WATER POINTS BY THE RDWSSP

15.1 Water points constructed and planned in Kisumu District

By the end of September 1988 a total number of 57 water points will have been completed by the RDWSSP in Kisumu District.
This includes also the 19 wells constructed during the Pilot and the Interim Project Phases (1982 - 1984). A breakdown of the types of water points constructed per Division is given in Table 15.1.
The location of the constructed hand-dug and hand-drilled wells is shown on Figure 15.1. The boreholes completed by the RDWSSP were shown on Figure 12.3.

TABLE 15.1 NUMBER AND TYPE OF WATER POINTS COMPLETED UNDER THE RDWSSP BY SEPTEMBER 1988

DIVISION	WATER POINTS COMPLETED				
	Dug wells	Machine drilled boreholes	Hand drilled wells	Spring protections	TOTAL WATER POINTS
Maseno	2	0	1	0	3
Winam	6	9	6	0	21
Nyando	3	8	4	0	15
Muhuroni	0	0	1	0	1
Nyakach	0	15	2	0	17
KISUMU DIST.	11	32	14	0	57

The 1988 implementation programme of the RDWSSP furthermore foresees in the construction of another approximately 45 waterpoints in the District, with more emphasis on those Divisions where up to September 1988, relatively little implementation has been done.
The estimated total implementation target of Phase I in Kisumu District is summarized in Table 15.2, while specifications of data on the already completed water points are given in Tables 15.3 and 15.4.

TABLE 15.2. IMPLEMENTATION TARGET OF THE RDWSSP PHASE I IN KISUMU DISTRICT

DIVISION	NUMBER OF WATER POINTS COMPLETED BY SEPTEMBER 1988	WATER POINTS TO BE CONSTRUCTED DURING 1988		TOTAL NUMBER OF WATER POINTS RDWSSP - PHASE I
		Machine drilled boreholes	Dug wells	
Maseno	3	0	13	16
Winam	21	1	0	22
Nyando	15	11	0	26
Muhuroni	1	16	0	17
Nyakach	17	0	4	21
KISUMU DISTR.	57	28	17	102

15.2 Programme activities preceeding the construction of water points

15.2.1. Initial identification of the construction sites

Surveys carried out by the RDWSSP revealed that the need for safe and reliable water sources in Kisumu District is overwhelmingly large. It has been the responsibility mainly of the socio-economic survey, to identify the most needy communities, requiring priority in the provision of water supplies. As a result of this survey, continued community development work, and through meetings on Locational, Sub-locational and village level, possible water points sites are identified and selected. Recommendations are then made to the Sub-District Development Committee for final selection of sites.

15.2.2 Technical identification of the sites.

In chapter 13, it has been explained at length that, although the potential for in particular boreholes and wells is very good, these types of water points cannot be constructed just everywhere. In most cases a detailed technical field survey will be required in order to establish the site with the best prospects for a productive well or borehole.

This site may not coincide with the location or area initially selected by the community and at this stage, the role of the Community Development staff becomes critical again. In meetings with the communities the sites indicated on technical grounds will have to be accepted or rejected. Often this decision is influenced by local politics, land ownership etc.

In some cases, technical siting is not necessary. That is, when it concerns the improvement of an existing water source (spring, dug well), or when the site is located in the Kano Plain, an area which was identified as having a high potential for the construction of boreholes.

15.2.3. Community mobilisation and participation

Once the water point has been located, the Community Development staff initiates community mobilisation, in coordination with local government.
The water and sanitation extensionists help the community form water committees which are formally registered as self help groups by the Ministry of Culture and Social Services.

They furthermore motivate and assist the committees to collect money, Ksh 1,000/- for a spring protection and Ksh 2,000/- for a well or borehole, to establish, in a bank account, a maintenance fund.
During the process of community mobilization and education, the extensionists liaise with the local Chiefs and Social Development Assistants and hold meetings to inform the public on the objectives of the programme.

The involvement of the communities in the programme has so far taken the following forms:

- acceptance of the construction
- surrendering of land for the water source
- formation of water and sanitation committees
- appointing of pump attendants
- collecting funds for pump maintenance
- opening of bank account
- providing some materials for construction
- providing shelter to the well diggers
- attending workshops and meetings.

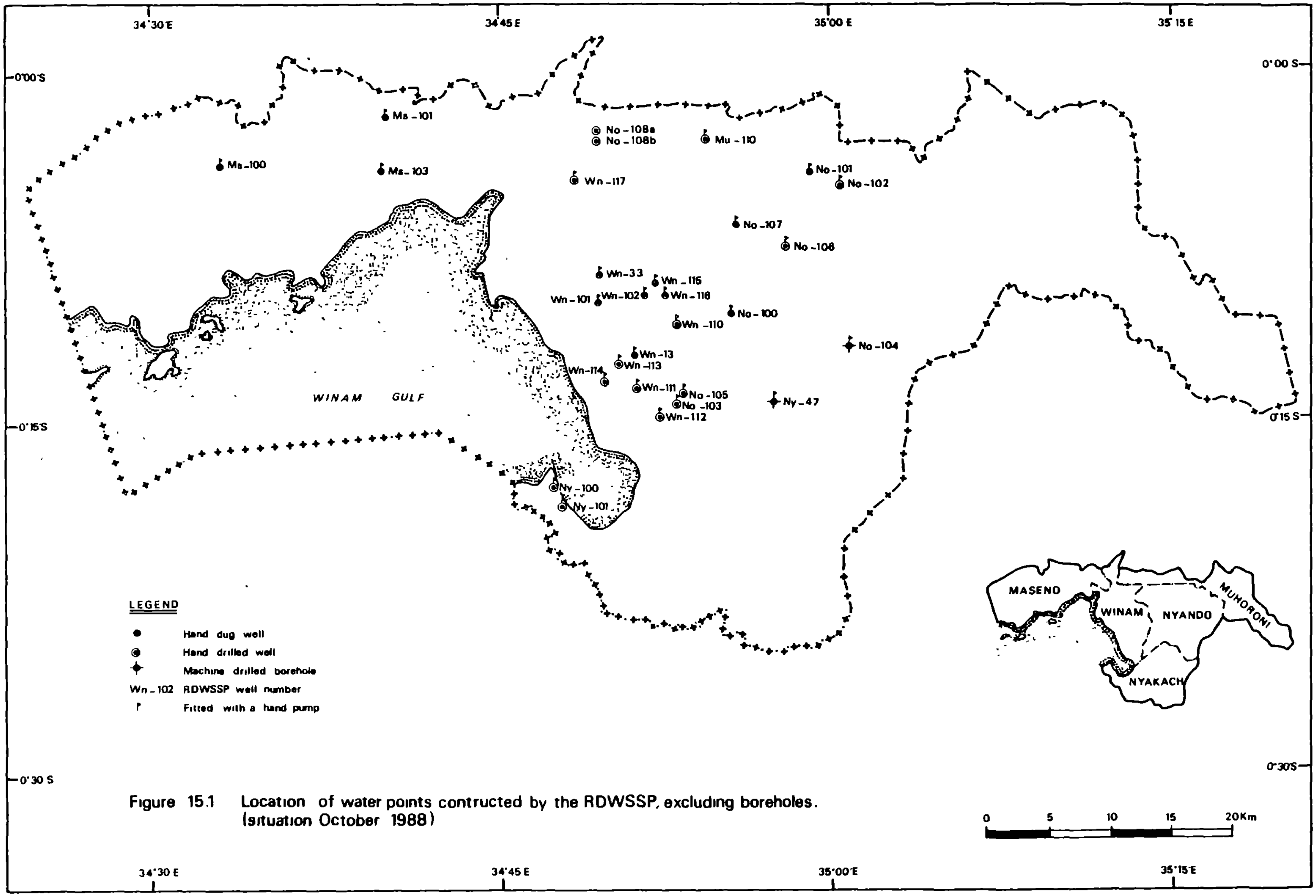


Figure 15.1 Location of water points contructed by the RDWSSP, excluding boreholes. (situation October 1988)

TABLE 15.3 SUMMARY OF WELLS COMPLETED BY RDWSSP (situation September 1988)

Well No.	Location	Site Name	Type Constr.	Year Constr.	Depth (m-gl)	Water level (m-gl)	EC umho/cm	Grid references
Ny-47	N. Nyakach	Rae Girls School	MD	1988	105	9.00	850	717.7/9973.7
Ny-100	W. Nyakach	Rota Market	HD	1983	8.25	2.10	2400	699.8/9966.8
Ny-101	W. Nyakach	Nyongonga School	HD	1983	9.00	2.70	1100	700.4/9965.2
Wn-13	S.W. Kano	Nyangande market	DG	1987	13.70	13.00	2800	705.7/9977.5
Wn-33	N.W. Kano	Rabuor market	DG	1987	21.52	17.10	830	703.2/9983.3
Wn-101	N.W. Kano	Oresa W.Group	DG	1988	17.50	3.70		714.3/9987.9
Wn-102	N.W. Kano	Kachola	DG	1987	15.30	10.70		
Wn-110	N.W. Kano	Ongecha Sch.	HD	1982	31.00	13.20		
Wn-111	S.W. Kano	Ugwe Sch.	DG	1988	9.45	13.20	840	709.3/9979.9
Wn-112	S.E. Kano	Ogenya Sch.	HD	1982	10.05	2.50	400	709.0/9974.8
Wn-113	S.W. Kano	Nduru Sch.	HD	1983	7.10	6.00	2000	708.0/9972.5
Wn-114	S.W. kano	Odienya Sch.	HD	1983	6.50	4.00	2400	704.5/9976.4
Wn-115	N.W. Kano	Ranjira	DG	1982	12.25	8.35	1800	703.1/9975.1
Wn-116	N.E. Kano	Masogo	DG	1982	13.70	2.65	2000	707.3/9988.0
Wn-117	Kolwa	Kunya Sch.	HD	1982	5.65	9.60	750	708.2/9981.5
No-100	N.E. Kano	Karanda School	DG	1983	13.70	3.95	520	901.0/9991.4
No-101	N.E. Kano	Kaali market	DG	1983	17.00	5.70	600	701.8/9995.2
No-102	N.E. Kano	Nyakoko Sch.	HD	1982	9.60	6.20		
No-103	S.E. kano	Ombaka Sch.	HD	1982	11.30	0.50	600	713.7/9980.9
No-104	S.E. Kano	Oren	MD	1983	15.50	3.95	600	720.4/9992.1
No-105	S.E. Kano	Mariwa market	HD	1982	17.00	5.70	620	723.0/9990.8
No-106	S.E. Kano	Masara Sch.	HD	1984	10.20	6.20	320	709.5/9973.5
No-107	S.W. kano	Oresa market	DG	1988	15.15	6.55	1820	723.9/9978.1
No-108a	Kiboe	Kiboe Fish Farm	HD	1984	5.65	39.00	2200	709.7/9974.1
No-108b	Kiboe	Kiboe Fish Farm	HD	1984	9.60	4.00	690	718.9/9986.0
Mu-110	Miwani	Miwani Sch.	HD	1982	8.90	2.45	400	712.0/9995.0
Ms-100	E. Seme	Asol Sch.	HD	1982	5.55	0.75	350	672.1/9992.9
Ms-101	W. Kisumu	Sinyolo Sch.	DG	1982	13.20	9.80	970	685.5/9996.6
Ms-102	C. Kisumu	Kotetni	DG	1988	31.00	13.20	540	

Community development and education

15.3. Management of the water points

15.3.1. Ownership

After the completion of the water point, from the day the communities start using the construction, a six months "guarantee" period commences. The philosophy behind this, is that during this period the quality of the water point is tested in terms of adequacy of the source, quality of the water and the quality of the construction and materials used and equipment installed.
Any failure or shortcoming that is detected or breakdown which occurs during the first 6 months after completion, is solved or repaired by the Programme without charging the community.

This initial period is used moreover to train the pump attendant and to educate the community in the benefits and proper use of the facility, in combination also with sanitation.

At the end of this period by signature of a certificate of ownership, the well is officially handed over to the community. From that moment onward, the management of the water point has become the full responsibility of the well committee, appointed by the community.

Although Programme extensionists advice the communities on such critical aspects as:

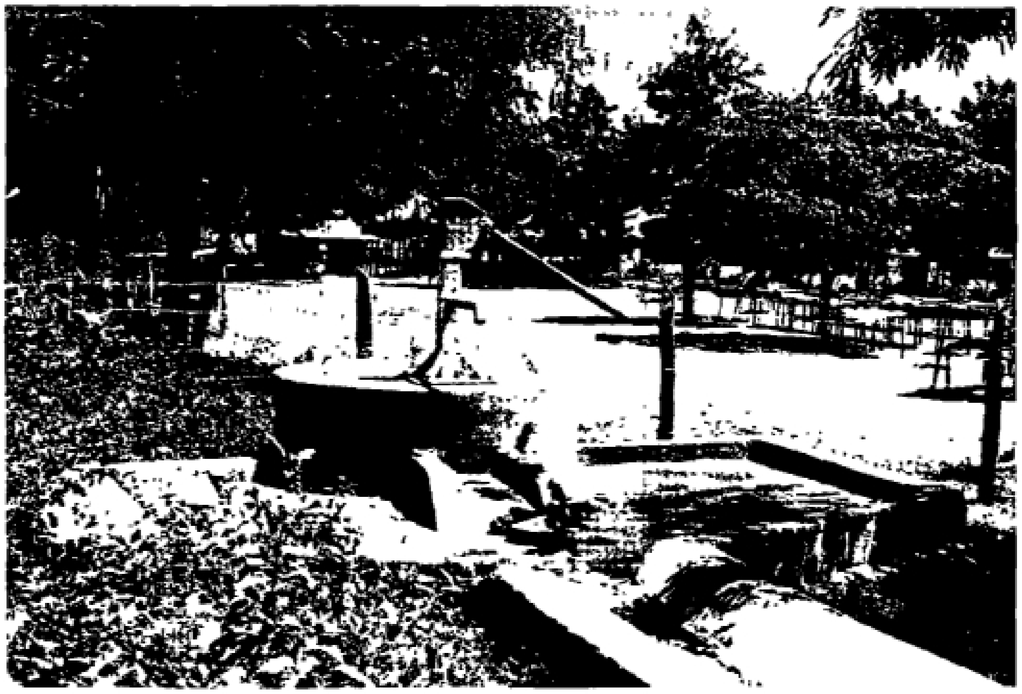
- management of the maintenance fund
- responsibilities of the pump attendant
- operation and maintenance of the water point,

no strict guidelines are given to the communities regarding the organisation of these aspects.
This has resulted in a divergence of approaches.

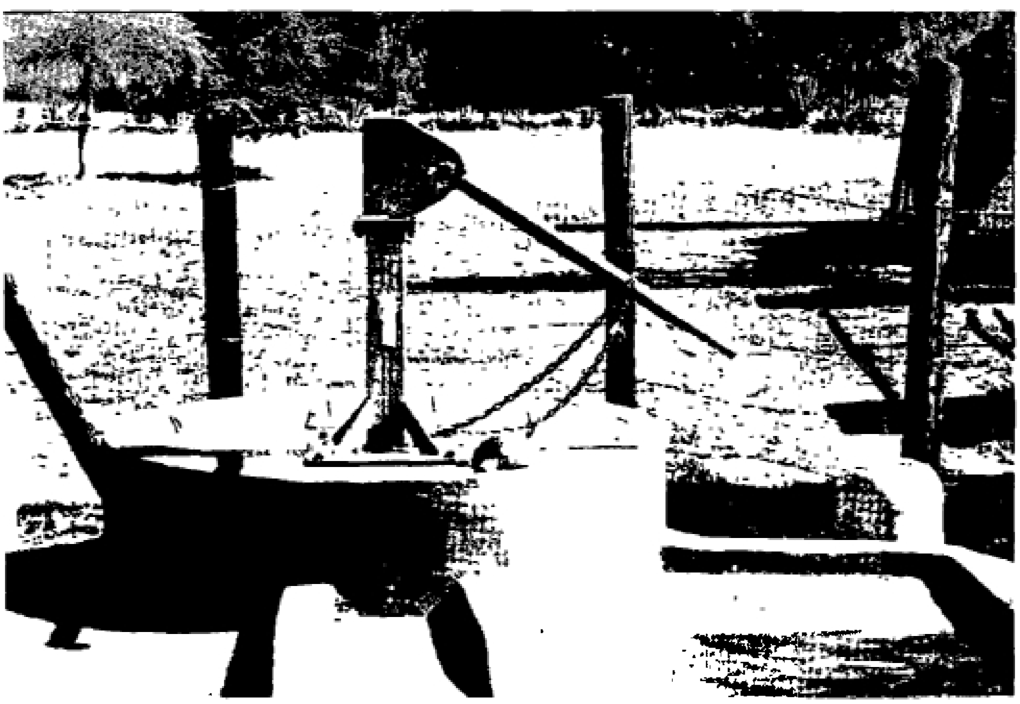
Contributions of the communities towards the maintenance fund are collected by the water committee on basis of family size and/or socio-economic status, per unit of water drawn or during harambees.

Part of the water points are accessible for everyone, 24 hours per day, while others are solely operated by the pump attendants during certain periods of the day only.

Communities may pay or not pay the pump attendant for his or her services.
Payment may be in cash but often is in kind or in the form of services.



Well maintained and operation wells



15.3.2. Operation and preventive maintenance

Approximately 95 % of all water points constructed to date under the RDWSSP are wells and boreholes fitted with handpumps.
Assuming that the wells, boreholes and superstructures are properly designed and completed, maintenance of the new water points revolves mainly around the handpump.
The handpumps being installed under the RDWSSP are of the SWN type; SWN 80 for water levels up to 30 m and SWN 80 with a counter weight for water levels between 30 and a maximum of 80 m depth.

Every well committee has appointed a pump attendant. Although the responsibilities of the pump attendant may vary, basically he is to take care of the day to day management of the water point. This includes taking care of the drainage around the slab, to prevent it's undermining, and trimming of the natural fence.

Preventive maintenance which can be carried out on the handpumps in a technical sense is minimal and restricted mainly to regular tightening of bolts and nuts. The non-technical aspect of corrective maintenance however should not be underestimated.

Breakdowns often may occur as a result of using a wrong pumping technique (too short strokes or horizontal movements accompanying the basically vertical pumping movements) or even vandalism, which both can be controlled and minimised by a well trained and motivated pump attendant.

Operation of the handpump is done by the pump attendant if he or she has time and is able and willing to do so. Alternatively the pumps are operated by the many individuals who come to fetch water, preferably in the presence and under supervision of the pump attendant.

A development coming mainly from the communities themselves is the provision of a locking device attached to the pump. The pump attendant unlocks the pump for use during certain hours of the day, as agreed within the community. Although a number of both pro's and contra's of this system could be listed, a major merit is that this way the well committee retains full control over the operation and management of the handpump. Water cannot be fetched "illegally," and misuse and vandalism are restricted by this system.

15.3.3. Organisation of the corrective maintenance

The corrective maintenance of handpumps in the present set up is carried out by field maintenance officers employed by the Programme, who are stationed in Rabuor Chief's camp, along the road between Kisumu and Ahero.

This service centre also has a store for spare parts.

The responsibilities of the Maintenance Officers include:

- financial control of the maintenance
- quality of the maintenance
- training of water committee pump attendants
- to act as field liaison between the staff of the Community Development and the Technical Department.

Additionally the Maintenance Officers inspect the quality of the pump installation activities.

When a breakdown occurs, the steps taken towards repair basically are as follows.

- The well committee reports breakdown to Maintenance Officer.

- The Maintenance Officer makes a diagnostic visit to the pump within 5 days.

- The Maintenance Officer diagnosis the breakdown, estimates the cost and hands over an order note for spares and tools to the Well Committee.

- The Well Committee arranges transportation of tools and spares from central spares depot to the well site.

- The Well Committee informs the Maintenance Officer that tools and spare parts are on site and that maximum 3 labourers will be available.

- The Maintenance Officer carries out the repair within 5 days.

- The Maintenance Officer mails the invoice to the Well Committee.

- The Well Committee pays the invoice from their bank account.

15.3.4. Anticipated evaluation of the maintenance system

Corrective maintenance of the water points and of the handpumps in particular at present is an interaction between the well committees and maintenance officers employed by the Programme. The much discussed maintenance system whereby the private sector is involved turned out to be not feasible mainly because of the relatively small number of water points to be maintained, the relatively few breakdowns and low density of the new water points.

If projects and programmes will continue to implement water points and when the present number of points, will have been increased from a few hundred to a few thousand, then feasibility of corrective maintenance to be undertaken by the private sector can be seriously considered.
But up to that time, maintenance will have to be carried out by officers employed by either the LBDA or the Ministry of Water Development, whereby the communities and well committee's capabilities to be actively involved in the maintenance should be used to its maximum.

15.4. The private sector role

It is the policy of the RDWSSP to contract out construction activities as much as possible to local contractors.
All constructions are implemented according to designs and specifications established by the RDWSSP and under close supervision of the RDWSSP.

15.4.1. Well digging

In Kisumu District, the well digging is solely carried out by individual, qualified diggers.
Contracts are being drawn between the diggers and the Programme, which are based on rates per foot of digging.

15.4.2. Borehole drilling and testing

After experimenting during 1984 and 1985 with different local drilling contractors using different kinds of drilling methods and equipments, in 1986 a drilling contract was awarded to a large Kenya based company which brought in a relatively new and powerful down-the hole hammer rig.
This unit performed quite well and it was proven in South Nyanza District that approximately 8-10 boreholes per month could be drilled in hand rock and tested by one of such rigs.
In the sedimentary area of Kisumu District (Kano Plain), as many as 12 boreholes per month could be realized.

All drilling and borehole testing operations are closely monitored and supervised by well trained and experienced water inspectors and technicians employed by the Programme or the MoWD, who have daily radio contact with the Programme's hydrogeologists in Kisumu.

15.4.3. Construction of superstructures

The superstructures of wells and boreholes provided under the RDWSSP are constructed by local contractors, under supervision of Programme technicians. These include a slab with a pump stand and a dewatering gutter, and a fence.
Concrete covers and culverts for well lining are pre-fabricated by local contractors as well.

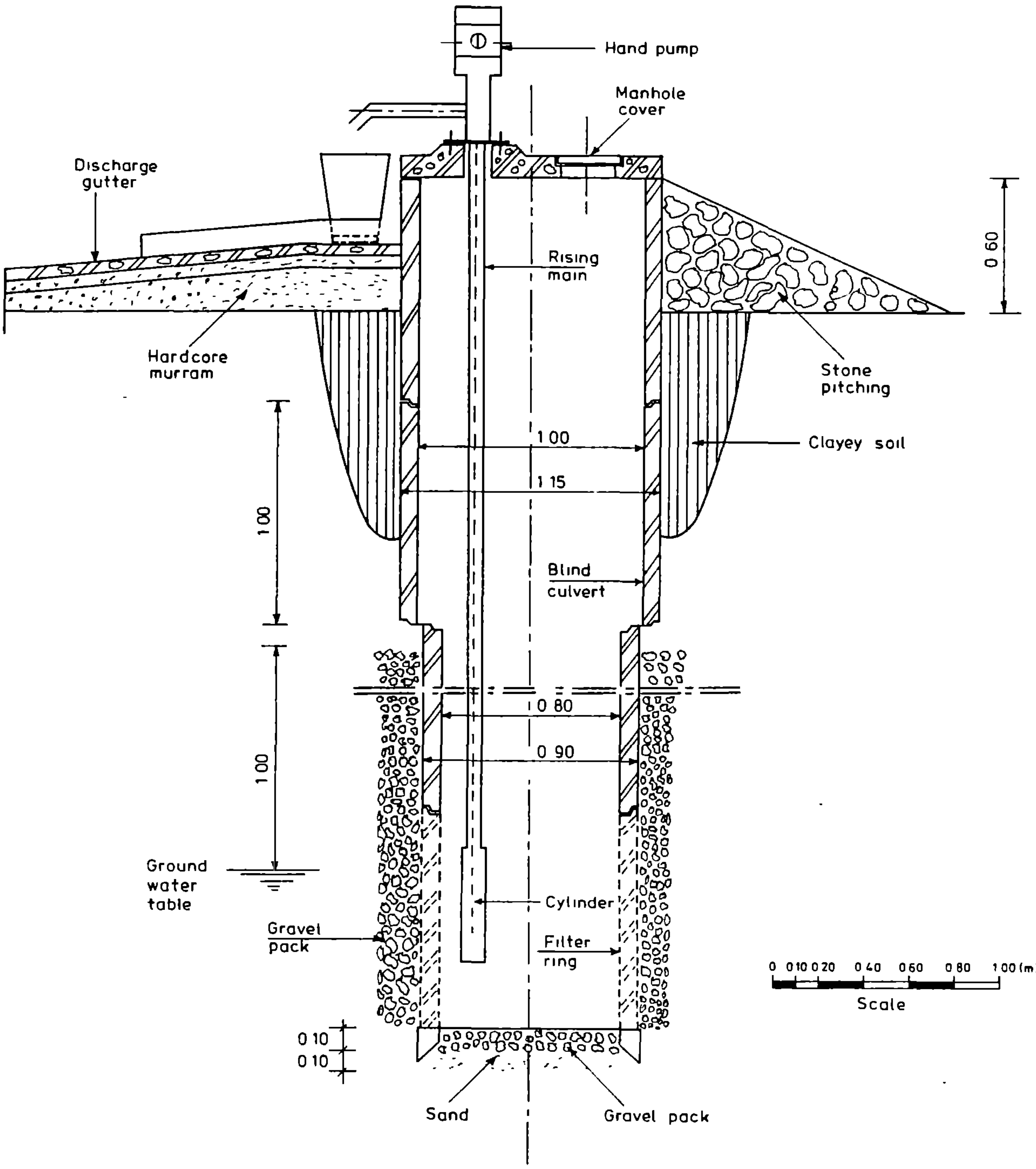


Figure 15 2 Hand dug well , RDWSSP

15.4.4. Hand pump installation

In Kisumu District, the installation of the temporary dewatering handpump as well as handpump on the completed constructions is done by a local contractor, based in Kisumu and operating from the field service and maintenance centre in Rabuor.

15.5 Construction of dug wells

15.5.1 Selection of construction sites

Basically there are three ways to come to the selection of a site where possibly a well can be constructed by means of hand digging.

a. A hydrogeological field reconnaissance of a a certain area, principally by means of a geological survey and measurements of ground water levels and quality in existing wells, may reveal the existence of an aquifer in that particular area. In addition the community's knowledge on local conditions such as ground water level fluctuations to be expected and possibilities of temporary flooding of potential sites should be used.

b. A survey has been carried out by means of hand drilling; ground water of an acceptable quality has been detected but the yield of the test holes was found to be insufficient for the construction of a handdrilled well.
Such sites may then be constructed by means of handdigging.

c. Where the presence of shallow ground water in general is more difficult to detect, the use of geophysics for handdug well siting is considered compulsory.

It is once more emphasized that even in areas with good possibilities for handdug wells, better results in terms of less unproductive or low yield wells are obtained by application of geophysical surveys.

15.5.2 Equipment

For the digging of a well, very simple hand tools as a small pick-axe, a hoe, hammer and chisel are used.
The broken rock is lifted out of the well by means of a rope and bucket. Safety equipment include a helmet, safety goggles and a harnass to quickly lift the digger out of the hole if necessary.
This equipment, together with other small tools, as a standard set, comes together in a steel box which is easy to handle and to transport to the sites.

A simple locally made wooden winch or a steel tripod with a wheel are used to ease lifting and lowering of materials, equipment and the digger.

15.5.3 The digging

Basically a vertical, circular hole of about 1.6 m diameter is excavated. Until ground water has been reached, digging normally is done by two people with one operating in the well and the second staying at the surface to lift and lower materials in and out of the well.

The digging of wells can be a lengthy procedure. Depending on the consistency and hardness of the rock, approximately 1 m to only 0.2 m per day can be dug. Thus the sinking of a 10 m deep well may take up to a month, a 20 m deep well 2 - 3 months and a 30 m deep well between 3 and 6 months.

By experience it was found that when the rock becomes so hard that further excavation by means of hand tools becomes almost impossible, usually the bottom of the weathered zone c.q. potential waterbearing formation has been reached.

15.5.4 Lining

Under certain circumstances, for instance when digging in hard formations without a soft top soil, it has been possible to excavate the well entirely without a lining. However, when digging through less consistent formations, and especially during the rainy season when the top soils are satured with water, excavation without a lining becomes very risky and consequently a lining will have to be installed.

Where the rock below the top soil is stable, wells can be completed with a lining installed only in the upper few m. This lining usually is cast in-situ.

Where a full lining is required, the RDWSSP has developed two alternative ways of lining.

- One way is to cast the lining in-situ.
  This type of lining is used when the top soil is unstable and the prospect to find water is favourable.

- Another method is to use pre-cast concrete rings.
  The rings are slightly more expensive than the cast-in-situ lining but with transport and lowering cost this type of lining costs almost double the in-situ lining.

- The third method, which is often applied in the relatively soft rock types in Kisumu District involves sinking the well down to the water bearing formation using an in-situ lining whereupon porous smaller diameter concrete rings are inserted in the bottom part of the well.

  Normally 1.15 m diameter reinforced concrete rings (culverts) are used. Porous concrete rings of the same diameter are installed in the aquifer.
  Occasionally two different diameter concrete rings are used for telescoping (1.15 m and 0.95 m diameter).

15.5.5 Dewatering

During the first few days after reaching the water table, dewatering is simply done by emptying the hole with a bucket and rope. When however water becomes abundant and removal of the water with a bucket becomes impossible, a SWN-80 type handpump with a 3" cylinder will have to be installed in the hole and usually one or two extra labourers, preferably from the community, will be needed for operation of the dewatering pump.

Very regularly as digging proceeds, the pump intake will have to be lowered by lengthening the rising main and pump rods of the pump. At this stage of the construction, usually every morning one to four hours are spent pumping in order to remove the water from the well so that digging can be continued.

If possible, digging is continued until a depth of 3-5 m below the dry season water level has been reached.

During the stage of the construction when water becomes abundant, the digging usually proceeds with a rate of only 0.2-0.5 m per day and in practice a minimum of 2 weeks have been necessary to bring the well to a sufficient depth.

When digging is done during or shortly after the rainy season, due to high ground water levels, the digging might have to be stopped temporarily, to be continued during the dry season.

15.5.6 Completion of wells lined with concrete culverts

- During or sometimes after digging the hole, concrete rings of approximately 1.15 outside diameter and 0.9 m height are installed, while making sure that the string of rings is as vertical as possible and each ring is fitted properly on the next one. In the aquifer porous rings are installed, with non-porous rings on top.
- If possible 3/8" - 1/4" crushed stone chippings are poured around the filter rings.
- A concrete seal is poured on top of the chippings around the rings.
- The space around the rings is backfilled using the original materials.

- A 5-10 cm thick layer of fine gravel (1.5-4 mm) is poured on the bottom of the well.
- A 10 cm thick layer of 3/8" - 1/4" chipping is poured on the fine gravel to stabilize it.

15.5.7 Completion of wells with a cast-in-situ lining

Where the water bearing formation is stable, the bottom part of the well may remain an open hole.
Where the aquifer is unstable, telescoping with porous 0.95 m diameter pre-cast concrete rings is used.
Completion of this type of wells is done in the way described under 15.5.6.

15.5.8 Superstructure

When the handdug well is sufficiently deep and the necessary lining has been inserted, a pre-cast concrete cover is placed over the well to properly seal it and on which the hand pump can be placed.
To minimize the chances of pollution of the well through infiltration of surface water, in most areas of Kisumu District the superstructure protrudes 0.5 - 1.0 m above the ground surface.
A manhole in the concrete cover gives entrance to the well in case down hole activities are required.

The superstructures are all constructed according to design and specifications of the RDWSSP, by use of a standard mold.

A dewatering gutter forms part of the superstructure, as does a fence.

15.5.9 Community assistance and participation

In the first place, the community assists the survey team in the selection of the construction site and solves any landownership problems.

Before the construction works start, the community prepares a motorable access road to the site.

During the digging phase, the community offers shelter to the digging team.
Preferably, the dewatering of the well is done by labourers, made available by the community.

Furthermore the community is involved in the digging of drainage channels for diverting surface run-off water and in the erection of a natural fence.

During installation of the handpump, the pump attendant appointed by the well committee should be present and assist in pump installation.

15.5.10 Improvement of existing wells

Most existing dug wells are unlined, poorly lined, or lined with non-porous culverts. Hence, the construction activities required to improve an already existing dug well are quite similar to the works required to construct a new handdug well. Time and costs are saved only in meterages of digging and by the fact that well siting is superfluous.

In Kisumu District, and in the Kano Plain in particular, existing dug wells have been lined with non-porous, 0.9 m diameter culverts without connections.
When these culverts are removed, usually the wall collapses which makes it impossible to control it's diameter and moreover endangers the well diggers.
Also, the diameter of the culverts (0.9 m) is too small to allow telexoping with smaller diameter porous culverts.
Hence, rehabilitation of existing wells often proves to be more cumbersome than digging a new well.

Semi improved dug well
further improvement is required

15.5.11 Costing of dug wells

The costs of handdug wells depend mainly on the depth of the well and whether a full lining is required or not.

The costs, according to the price level 1987, for various depths and ways of completion are summarised in Tables 15.5 to 15.7.

TABLE 15.5 COST ESTIMATES FOR UNLINED HAND DUG WELLS (1987)

ITEM	IMPROVED WELL		CONSTRUCTED WELL		
	10 m	20 m	10 m	20 m	30 m
Well siting			4,000	4,000	4,000
Digging	4,000	4,000	6,000	10,000	18,000
Superstructure	15,000	15,000	15,000	15,000	15,000
Handpump equipment	10,000	12,000	10,000	12,000	15,000
Pump installation	1,000	2,000	1,000	2,000	3,000
Supervision digging	2,500	3,500	5,500	8,500	11,500
Supervision superstructure	9,000	9,000	9,000	9,000	9,000
Supervision pump installation	500	500	500	500	500
TOTAL CONSTRUCTION COSTS	42,000	46,000	51,000	61,000	76,000

These costs are exclusive overhead costs which depend on the size and effectiveness of the implementing project or programme. Generally overhead costs for hand dug wells will amount to 20 % - 30 % of the total construction costs.

TABLE 15.6 COST ESTIMATES FOR CAST-IN-SITU LINED WELLS (1987)

	IMPROVED WELL		CONSTRUCTED WELL		
	10 m	20 m	10 m	20 m	30 m
Construction costs unlined well	37,000	41,000	46,000	56,000	71,000
Cast-in-situ lining	8,000	16,000	8,000	16,000	24,000
TOTAL COSTS	45,000	57,000	54,000	72,000	95,000

TABLE 15.7 COST ESTIMATES FOR CULVERT LINED WELLS (1987)

	IMPROVED WELL		CONSTRUCTED WELL		
	10 m	20 m	10 m	20 m	30 m
Construction costs unlined well	37,000	41,000	46,000	56,000	71,000
Culvert lining	15,000	30,000	15,000	30,000	45,000
TOTAL COSTS	52,000	71,000	61,000	86,000	116,000

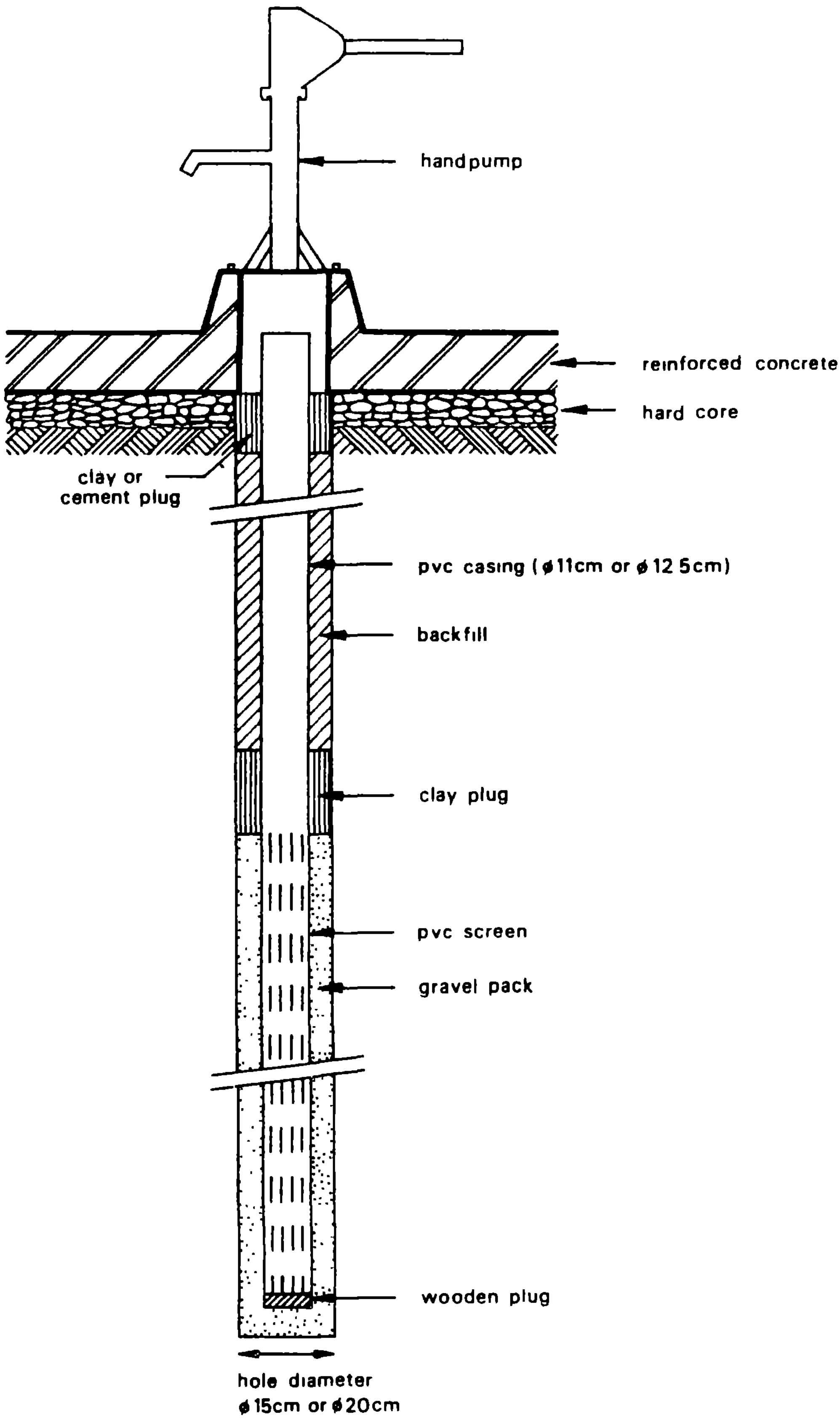


Figure 15 3 Design of a borehole fitted with a hand pump

15.6 Construction of machine drilled boreholes

15.6.1 Siting of the borehole locations

The hydrogeological surveys carried out by the RDWSSP have revealed that the occurence of ground water in the Kano Plain is such, that productive boreholes can be drilled almost everywhere without geophysical siting surveys.

Further it was proven that elsewhere in the District, geophysical surveys to determine borehole locations are necessary and justified.

The various siting methods developed and used by the RDWSSP are explained in Chapter 13.

15.6.2 Brief description of drilling and testing

Borehole drilling, completion and pump testing is carried out completely by Kenya based borehole contractors, according to bills of quantities and other specifications recorded in contracts drawn up by the RDWSSP. Water inspectors and technicians of the Programme monitor, record and supervise the works.

The present order of activities in borehole drilling and testing is as follows:

- mobilisation to the site, erecting of the rig
- drilling with the 8" bit to the required depth
- flushing and cleaning of the hole
- geophysical well logging
- installation of pvc casing, screens, gravelpack, seals etc
- development
- pump testing and recovery, measurement
- installation of 2-3 m of 8" steel casing for protection
- capping.

In order to properly record all technical and hydrogeological information an extensive set of forms has been designed comprising:

- a drillers and drillings rate log sheet
- an activities check list
- geophysical well log form
- pump test form
- hydrogeological well log form including geophysical well logging graphs
- borehole completion record form.

Besides, a daily progress report is being recorded by the water technicians supervising the drilling and testing programme. Below some of the activities will be further explained.

FIGURE

DRILLING COMPLETION AND TESTING DATA

LAKE BASIN DEVELOPMENT AUTHORITY
DHV CONSULTING ENGINEERS

BOREHOLE No.	Nd-82 (C-6617)	DRILLING CONTRACTOR	Instopump Ltd
TOTAL DEPTH (m)	56 m	START OF SITE PREPARAT.	26-11-1985
NAME OF SITE	Minya School	ABANDONING OF SITE	25-11-1985
DIVISION	Ndhiwa	RIG TYPE	Aqua drill
DISTRICT	S. Nyanza	DRILLING METHOD	Down the hole hammer
MAPSHEET	129/4	DEVELOPMENT METHOD	Air flushing
CO-ORDINATES	652 8 — 9916 2	WATER STRUCK (m-gl)	31 , 35
NATURAL SURFACE LEV.	1542 m	STATIC WATER LEVEL (m-gl)	19 60

DRILLING DATA

DEPTH BELOW NSL (m)	DRILLING AND REAMING		
	DIA (mm)	LENGTH (m)	DATE
0·00 - 55 00	6"	55 00	25 - 11 - 1985

CASING AND SCREEN SCHEDULE

DEPTH BELOW NSL (m)	WELL CASING			SLOTTED CASING / SCREEN			DATE OF INSTALLATION
	TYPE	DIA (mm)	LENGTH (m)	TYPE	DIA (mm)	LENGTH (m)	
STICKUP	Steel	150	0 5				
0·00 - 28 10	pvc	110/103	28 10				
28 10 - 51 14				pvc	110/103	23·04	27-11-1985
51 14 - 54 00	pvc	110/103	2 88				
0 00 - 1·50	Steel	150	1 5				
TOTALS							

SUMMARY OF PUMPING TEST RESULTS

DEPTH 53·50 PUMP INTAKE (m) DATE

TEST	PUMP HOURS	REC HOURS	DISCH (l/hr)	WATER LEVELS (m-GL) STATIC	WATER LEVELS (m-GL) DYNAM.	TRANS-MISSIVITY (m^2/day/m)	SPECIFIC CAPACITY (l/sec/m)
DEVELOPMENT	2						
STEP 1	4	1	800	19 60	42·78		
STEP 2							
STEP 3							

DEPTH PUMP INTAKE (m) DATE

TEST	PUMP HOURS	REC HOURS	DISCH (l/hr)	WATER LEVELS (m-GL) STATIC	WATER LEVELS (m-GL) DYNAM.	TRANS-MISSIVITY (m^2/day/m)	SPECIFIC CAPACITY (l/sec/m)
DEVELOPMENT							
STEP 1							
STEP 2							
STEP 3							

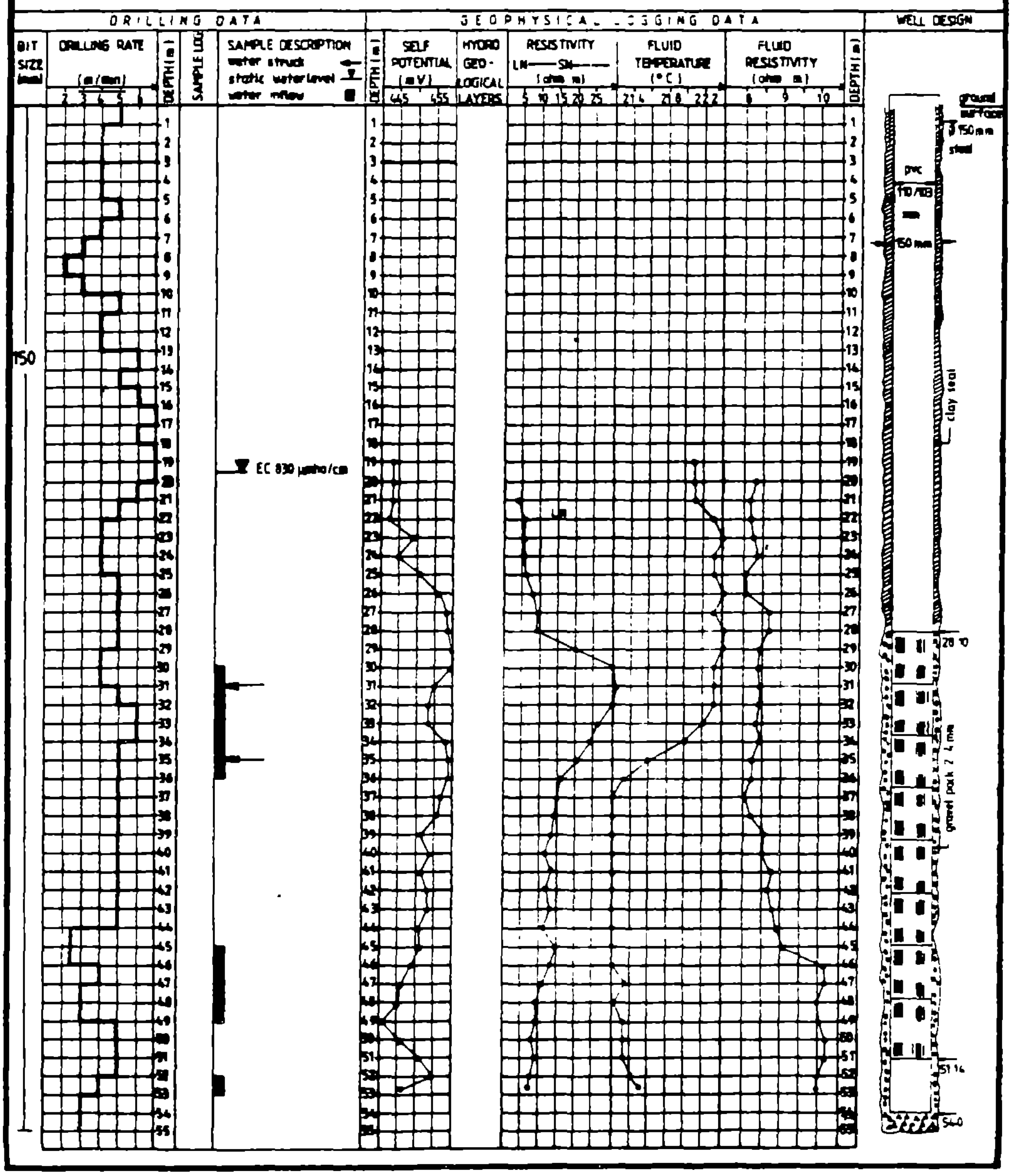


Figure 15 4 Example of a borehole well log

Drilling rate logging

A simple but quite useful log is the drilling rate log which is recorded by the water technicians monitoring the drilling. This log presents in a graphical way the number of minutes drilled per m. On these logs a good correlation can be seen between the hardness c.q. grade of weathering of the rock types drilled. Drilling rates of productive zones usually are faster than drilling rates of aquicludes.

Geophysical well logging

Well logging is done with the ABEM SAS LOG 200 using the ABEM SAS 300 TERRAMETER master unit. With this unit, the following measurements can be taken up to a depth of 200 m:

- self potential
- short normal resistivity
- long normal resistivity
- long lateral resistivity
- fluid resistivity
- fluid temperature.

In principle all except the long lateral logs are being recorded. Readings are taken every m.
By preference the logging is done after the flushing of the borehole, just before the static water level is reached completely.
This way it is usually possible to obtain information on zones of ground water inflow from the fluid temperature and fluid resistivity logs.

The logs are recorded in the following order:

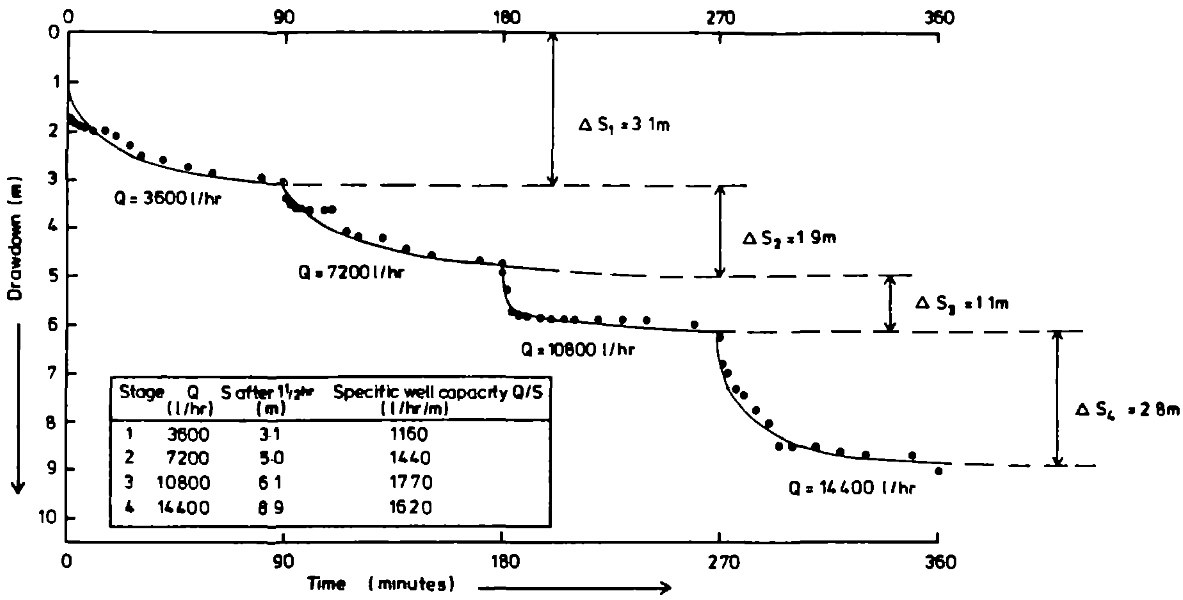
1. fluid temperature log while going down
2. fluid resistivity log while going up
3. long normal log while going down
4. short normal log while going up
5. self potential log while going down.

The logging of a 50 m deep borehole will take up to about 2 hours only.
An example of an interpreted set of well loggings is given in Figure 15.4.

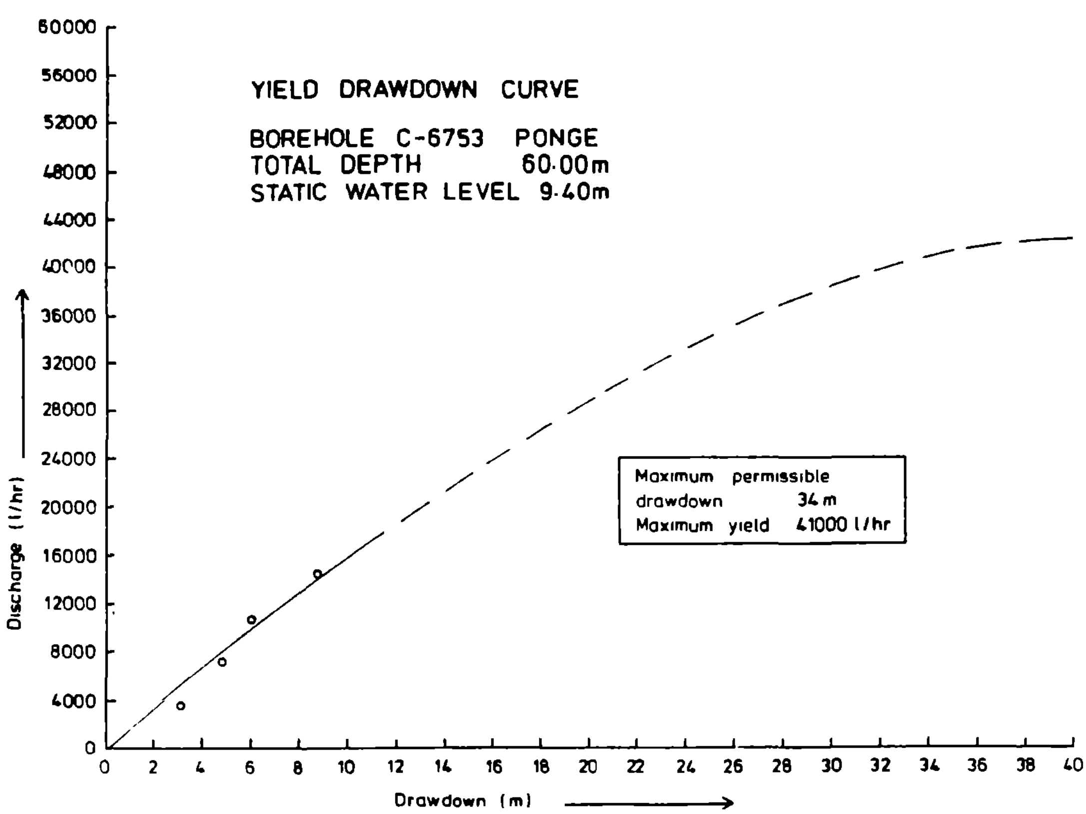
Pump testing

The pumping tests performed on the completed and developed boreholes essentially are well performance tests.
The tests consist of pumping the borehole at various discharges and usually are undertaken by incremental increases in step-wise fashion without recovery.

WELL PERFORMANCE STEP DRAWDOWN TEST BOREHOLE C-6753 PONGE



Stage	Q (l/hr)	S after 1½ hr (m)	Specific well capacity Q/S (l/hr/m)
1	3600	3.1	1160
2	7200	5.0	1440
3	10800	6 1	1770
4	14400	8 9	1620



Figuure 15 5 Example of a stepdown pumping test

Although the tests have been standardized to 3 steps of 2 hours each, followed by measurement of the recovery, it is of course possible to deviate from this routine should the circumstance request this.
During development,the approximate maximum yield is established which will be used as the maximum yield during the third stage of the pumping test.
The discharges of step 1 and 2 will respectively be 1/3 and 2/3 of the yield of step 3.

From this multiple rate test it is possible to establish the following parameters:

- specific well capacity
- maximum yield
- optimal well yield
- well efficiency.

Besides it is possible to estimate the order of magnitude of the aquifer transmissistivity from the first step of the pump test and from the recovery measurements.

In case several water bearing zones are contributing to the well yield, it sometimes is possible also to establish which zones are the most productive.

15.6.3 Superstructure

The superstructure of a completed borehole is almost identical to that of a handdug well and includes:

- a covering slab with a pump stand
- a dewatering gutter
- a fence.

15.6.4 Community assistance and participation

Borehole drilling and testing is a relatively sophisticated way of water point construction, carried out by professionals. Hence the involvement of the community in this type of operation is limited.

Essential is in the first place the construction of a good access road for the drilling rig by the community.
After successful completion of the borehole, the community brings ballast to the site and plants a natural fence around the site.

15.6.5. Costing of machine drilled boreholes

The cost of machine drilled boreholes are based on drilling and testing of the holes by a qualified contractor,and comprise the following activities: set-up of equipment, drilling of an 8" borehole, inserting of casing and gravel pack, top grouting, development and test pumping.
Prices of the superstructure and pump installation are based on rates of Kenyan contractors. Prices of pump equipment and pvc casing are based on tax free imported materials.

A cost estimate of boreholes with depths ranging from 60 m to 100 m is given in Table 15.8.

TABLE 15.8. COST ESTIMATES FOR BOREHOLES OF VARIOUS DEPTHS (1987)

CONSTRUCTION ACTIVITIES	DEPTH			
	60 m	70 m	80 m	100 m
Siting	4,000/-	4,000/-	4,000/-	4,000/-
Drilling & testing	68,000/-	74,000/-	85,000/-	95,000/-
Materials (pvc etc)	13,000/-	15,000/-	18,000/-	20,000/-
Superstructure	12,000/-	12,000/-	12,000/-	12,000/-
Handpump & installation	21,000/-	22,000/-	23,000/-	24,000/-
Supervision	7,000/-	7,000/-	7,000/-	7,000/-
TOTAL CONSTRUCTION COSTS	125,000/-	134,000/-	149,000/-	162,000/-

Project or programme overhead costs are not included in this Table but may amount to 10 % to 15 % of the total construction costs as given above.

15.7 Improvement of springs

Springs up till now have not been prominent in the Programme because in the area where implementation is presently in progress, springs did not qualify as being suitable for improvement.

15.7.1 Selection of springs to be improved

During the RDWSSP's survey of the existing water supply situation, springs in Kisumu District have been mapped and their specifications recorded.
Lists of springs suitable for improvement can be found in the Divisional reports (Ref. 13). Improvement of springs is attractive because the necessary constructions are relatively simple and costs are relatively low.
Selection of the springs to be improved under the RDWSSP is done in accordance with the policy explained in section 15.2.

Basically spring improvement involves:

- protection of the ground water from surface pollution
- proper drainage of the outflowing spring water.

The design of a spring protection depends much on the size of the spring, the topographical slope of the spring area and the drainage possibilities for superfluous spring water.
Basically the RDWSSP makes use of two different kinds of spring improvements.

a. Springs with sufficient drainage possibilities and sufficient height between the spring outlet and the ground surface to allow a bucket to be placed under the outlet, can be improved by a "gravity type" of protection.

b. Springs with insufficient drainage possibilities and slope are not tampered with.
The RDWSSP's solution for exploiting the ground water from such type of spring is to construct a shallow well upstream of the spring.
This way, the most suitable location for ground water abstraction and drainage possibilities can be selected.
Other advantages of this kind of spring improvement are:

    - the ground water flow to the spring is hardly affected
    - the risk of shifting the spring eye is removed.

    A disadvantage of this solution is the need for a handpump which increases the construction and maintenance costs.

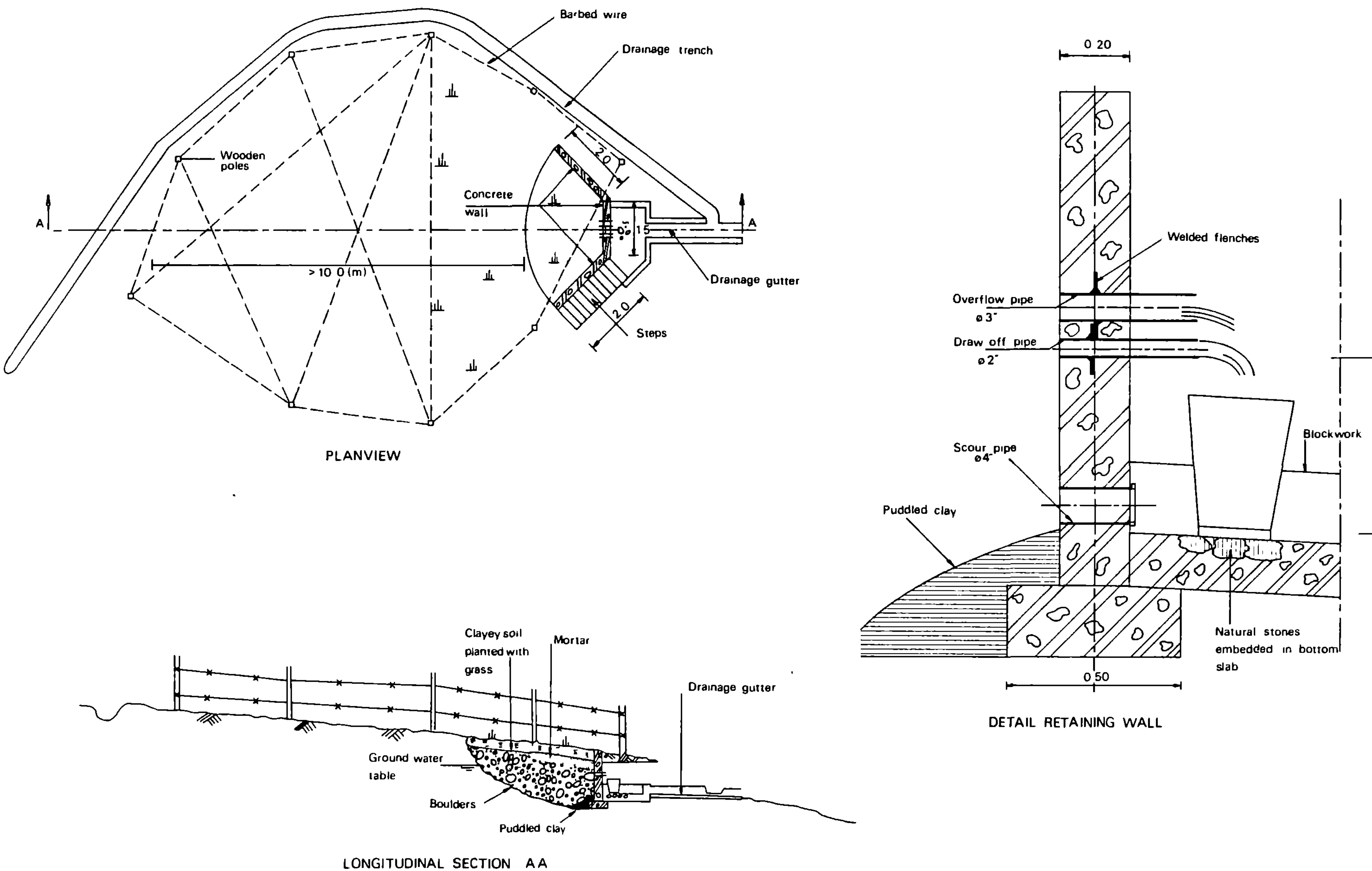


Figure 15 6 SPRING PROTECTION RDWSSP.
GOOD DRAINAGE OPPORTUNITIES

15.7.2 Monitoring of springs

The springs eventually selected for improvement are monitored for some months in order to establish their high and low flows, so that the design can be adapted especially to the high flows.

15.7.3 Improvement of springs with sufficient slope and drainageage

This type of construction is the relatively simplest and least costly of all options and can be applied to springs in locations with sufficient topographical gradient to make gravity flow possible.
Normally the improvement activities will include:

- drainage works around the spring
- opening of the spring
- back filling and covering of the spring
- construction of a concrete protection wall with an overflow and spillway
- fencing of the immediate surroundings of the upstream catchment area.

The construction costs of a gravity type protection depend mainly on the size and maximum discharge of the spring and will be between Kshs 15,000/- and Kshs 25,000/- (1987 price level).

15.7.4 Improvement of springs with insufficient slope and drainage

Springs situated in locations with insufficient gradient for a gravity type of protection, can be protected by construction of a shallow well, fitted with a hand pump, upslope of the spring.

The construction works include:

- digging of an approximately 3 m deep well with a concrete lining
- construction of a covering concrete superstructure with overflow
- installation of a handpump
- drainage works
- fencing.

The costs for this type of improved spring are considerably higher than for a gravity type of protection and may amount of between Kshs 30,000/- and Ksh 40,000/- (1987 price level).

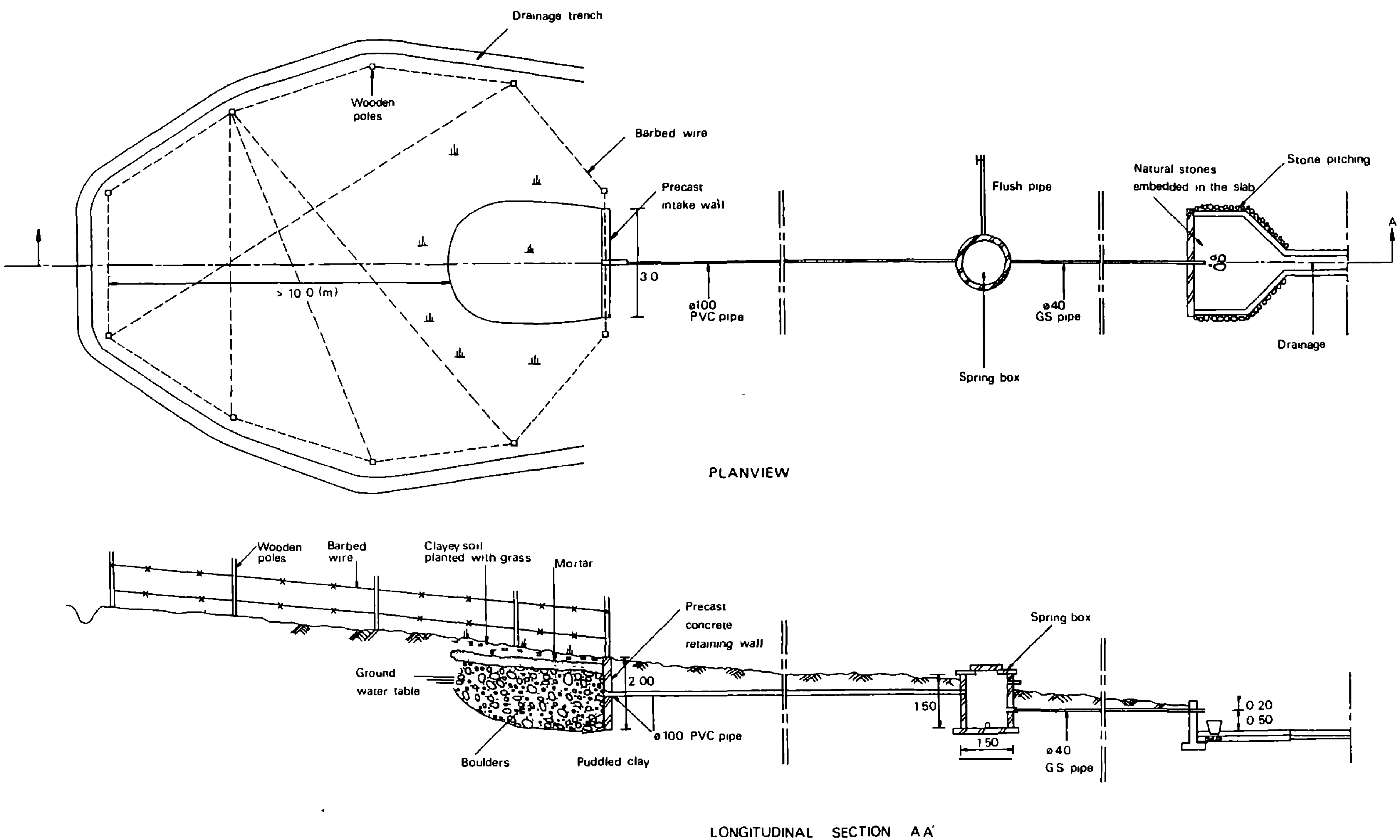


Figure 15 7 SPRING PROTECTION RDWSSP, INSUFFICIENT DRAINAGE OPPORTUNITIES

15.7.5 Community assistance and participation

A spring protection requires relatively simple excavation and construction works whereby the community can be actively involved by providing labour, particularly for excavation and drainage works.

Additionally the community is to prepare motorable access to the site and to provide shelter for the construction team.

15.8 Construction of hand drilled wells

Areas underlain by loose alluvial sediments with a high ground water table normally are suitable for the construction of tube wells by use of hand-operated drilling and testing equipment.
In Kisumu, such areas are found in the Kano Plain, and along the Winam Gulf and along some of the major rivers.
Elsewhere in this report it has been shown however that the application of this method of well construction is rather limited due to the extensive contamination of the shallow ground water in densily populated areas.

15.8.1 Well siting

Siting for this type of wells is done by means of the drilling by hand of 10 cm diameter test holes. If an aquifer is struck, temporary casing and screen are installed, a short pump test is done and water samples are taken for analyses.
Usually a number of survey holes are drilled and tested, out of which the best possible well location can be selected.

15.8.2 Construction

Because only few hand drilled wells have been constructed so far, this operation has not yet been contracted out, but is done by the RDWSSP.
The method is extensively explained in the Final Report of the Lake Basin Shallow Wells Pilot Project (Ref.11) and is therefore not repeated here.
A 10 - 20 m deep handdrilled well can be completed in 2-3 days.

15.8.3 Costs

Due to the lower time and material component, the construction costs for hand drilled wells are substantially lower than for hand dug wells.
It is estimated that a 10 and 20 m deep well will cost approximately Ksh 25,000/- to 35,000/-, inclusive of the costs for the survey.

15.9 Variation of construction costs for wells and boreholes in the Divisions of Kisumu District

In sections 15.5 and 15.6 reviews were given of the construction costs of unlined and lined dug wells as well as boreholes of different depths.
Experience in the RDWSSP has learned that besides the depth there are several other factors affecting the costs of wells and boreholes.
Such factors may include:

- the type of soil and rock through which has to be dug
- the accessibility of the site
- the distance of the site to the nearest RDWSSP field office
- the distance of the site to the pump installation contractor's office
- the distance between the sites.

As a consequence of these varying factors, the construction costs for wells and boreholes as given in Table 15.3 to 15.6 may vary from area to area with up to plus or minus 10 %.

Table 15.7 gives a review of the actual construction costs for dug wells and boreholes implemented in different parts (Divisions) of Kisumu District up to 1987.

Most of the dug wells have been fully lined.

Because of the relatively short construction time for a borehole as compared to a dug well, the supervision and Programme overhead costs for boreholes are about Kshs 3,000/- less than for dug wells.

16 PROVISION OF RURAL WATER SUPPLY BY OTHER ORGANIZATIONS

16.1 The need for increased implementation efforts

With a target of 83 water points to be completed in Kisumu District before the end of 1988, the RDWSSP presently is the largest rural domestic water supply programme in the area.

It was shown, that the number of safe and reliable water points required in the District today, amounts to about 5,000.
This number is 60 times the output of the RDWSSP during its Phase I. Because of the fast growing population moreover, each year some 150-200 extra water points will be required.

This clearly proves the need for increased implementation efforts.

The RDWSSP is not only implementing water points in Kisumu District but in the whole of Nyanza Province. With the present staffing and programme organization, the RDWSSP's maximum annual implementation capacity is 200 water points per year.

It is not very likely that this target can or will be increased.

Consequently there is an overwhelming need for other implementation programmes, to work side by side with the RDWSSP.

During the past few years, representatives of several non-governmental organizations and consultants have visited the area to open discussions with the LBDA and the Ministry of Water Development.
Amongst these were representatives of NORAD, NORCONSULT, UNICEF, JICA,Japanese consultants and others.
Some went as far as to write up project proposals.

In this connection it should be clear that the RDWSSP's Divisional and District Reports together with several other large studies carried out for the LBDA, have supplied a sound basis for implementation programmes for the next 10-20 years to come.

Organisations interested in supporting the development of rural domestic water supply in the area are therefore requested to concentrate their aid and assistance on implementation programmes, thereby taking into consideration the results and recommendation of the RDWSSP surveys.

Further, standardisation of methods, equipment materials and designs in the area is considered of utmost importance.

16.2 Data and services available from the RDWSSP to other implementing organisations

The history of the RDWSSP goes back more than five years now. During these years the Programme has gradually grown from a pilot stage to a large multi-disciplined programme, with an integrated approach towards development of communal water, health and sanitation.
Other donors and organizations that want to become active in the area should be able to profit from the experience gained and data collected by the RDWSSP.

The LBDA, as the highest programme coordinating Authority in the region, through the RDWSSP, is able to make available amongst others the following data and services:

- criteria for the selection of target communities
- Divisional reports and maps of the water resources survey
- field surveys for source identification
- standard designs for wells, boreholes, spring protections etc.
- list of local contractors trained by the programme
- supply of pumps and casings
- training programmes for staff
- training courses in modular format.

RDWSSP,s computerized data system

16.3 Summary of water points constructed by other organisations in Kisumu District

Besides the RDWSSP (construction of water points) and the MoWD (construction of piped supplies), the following organisations have been or will be active in the provision of water supply in the rural areas of Kisumu District:

- UNICEF
- DIOCESE OF KISUMU
- AGA KHAN FOUNDATION
- CARE KENYA
- DIOCESE OF MASENO SOUTH
- RURAL DEVELOPMENT FUND

The types of water points constructed by these organisations include: dug wells, spring protections, roof catchment systems and extensions of existing piped supplies with a few communal water points.
Most of these organisations have established a good working relationship with the RDWSSP.

The numbers of water points that will be completed through these organisations by the end of 1988 is shown in Table 16.1.
Table 16.2 gives an estimate of the number of water points to be constructed by the organisations during 1989.

Descriptions of the backgrounds, strategies, set-ups etc. of the organisation's water projects are given in section 16.4.

TABLE 16.1 SUMMARY OF WATER POINTS COMPLETED IN KISUMU DISTRICT AT THE END OF 1988 BY OTHER ORGANIZATIONS THAN THE RDWSSP

DIVISION	Diocese of Kisumu	Aga Khan Found-ation	Care Kenya	Rural Dev. Fund	Diocese of Maseno	TOTAL
Maseno	5		6	11		22
Winam	4	15	1	27	2	49
Nyando	5		2	14	1	22
Muhuroni	1		3	1		5
Nyakach	14	13	8	2		37
KISUMU DISTRICT	29	28	20	55	3	135

TABLE 16.2 ESTIMATE OF WATER POINTS TO BE CONSTRUCTED IN KISUMU DISTRICT BY OTHER ORGANISATIONS DURING 1989

Unicef	Diocese of Kisumu	Aga Khan Found.	Care Kenya	Rural Dev. Fund	Diocese of Maseno	TOTAL
40	10	24	-	-	2	66

16.4 Project descriptions of organisations active in the provision of rural water supply in Kisumu District

16.4.1 CIDA

Between 1979 and 1983 CIDA, in co-oporation with the MoWD initially supported investigations of water resources and the construction of piped supply systems.
Later on during the project, the implementation of piped schemes shifted from the design and construction of new schemes, to rehabilation of existing schemes.

16.4.2 UNICEF

Basis of strategy

The main concern of the UNICEF is child survival and development (CSD).
Since however health and water and sanitation are directly related, the methodology of linking water, sanitation and environmental health education with other CSD activities has become " a matter of paramount importance" to the UNICEF.
Unicef will co-operate fully and respect the principles and objectives of the Government's 1989-1993 Five year Development Plan.

Project formation

The Government of Kenya and the UNICEF Kenya Country Office have committed themselves to the achievement of "Water Sanitation and Health for all by the year 2000".

In 1988 the UNICEF formulated a "Plan of Operation for Community Based Water, and Sanitation Projects" in Kenya.
The proposed projects are to be undertaken in five Districts:
Kisumu, South Nyanza, Baringo, Kitui and Kwale.

Purpose of the projects

The purpose is "to provide potable water within convenient distances and effective sanitation to 25 % and 20 % of the population respectively".
These percentages constitute UNICEF's contribution to the overall target figures of 80 % and 70 % respectively by the end of the fiscal year 1993.
It is anticipated that the Government of Kenya and NGO's working in the sector will make up the differences to achieve the targets.

Concepts

Unicef's concepts in respect of water supply and sanitation in Kenya cover the following facets.

- Rehabiliation of small water supply systems.
- Spring protection, construction of dug and tube wells. (no construction of boreholes)
- All projects are to be planned and executed in closest collaboration with the District Authorities.
- The projects must integrate water, sanitation and hygiene education.
- Involvement of communities from the planning stage through to the sustained maintenance of the facilities.
- The operation and maintenance of systems are the responsibility of the community fully.

Strategy

The Unicef's fundamentals of their overall strategy are:

- recognition by authorities
  that afforable and sustainable progress depends on the adoption of low-cost technologies.

- Willingness of communities
  to take effective responsibilities for running their own water supply systems.

- Integrated approach
  to health related development.

- Choice of technology
  must match the resources of the community.

- Maintenance
  is essential to a sustained and un-interupted water supply.
  A policy of standardisation and distribution of spare parts is pre-requisite of efficient maintenance.

Project activities in Kisumu District

It is the intention of the UNICEF to carry out a "Community based Water and Sanitation Programme" in Kisumu District.
The duration will be five years, with the starting date planned for 1st July, 1989.
The Project is intended to cover the entire District, only excluding the urban centres.

The output of the project will be:

- 416 water points to serve 166,300 people.
  (spring protections, dug wells, roof and rock catchments).
- construction of 70 demonstration VIP's.

The Programme intends to co-operate at community level on social factors with KWAHO and with other NGO's working in the sector.

16.4.3 Diocese of Kisumu

Strategy and aim of the water programme

The Catholic Diocese of Kisumu considers the efforts aimed at the accessibility to and the availability of clean water supply as only one element of the integrated approach to rural development, which starts with general development education and whose other key components also include basic health care and improved food production.
The integrated development approach is finally aimed at alleviating the situation of the poor rural communities and to assist these communities to reach a level of self-sufficiency and self-reliance.
The community-based water programme emphasizes community involvement and full participation of the beneficiaries in all project phases, from project initiative and identification through planning and implementation to final project follow-up and evaluation.
An essential element of the Diocesan effort is the establishment within the development office of the Water Programme Planning Committee which is in charge of working with women's youth and community groups in water awareness and water use education, identifying water resources, planning for improviding the available water resources, implementing small water projects and also ensuring the total management responsibility for operation and maintenance of the completed water supply projects.
The activities of the water programme are concentrated in poor rural areas, focussing on the implementation of small scale community water projects such as dug wells, spring protections, small earth dams and rainwater catchments. The projects require maximal community participation and minimal recurrent expenditure, thus ensuring that the projects are sustainable by the communities.

Project activities

Since the start of the community-based water programme towards the end of 1985, 14 spring protection projects have been completed with a total number of over 6,000 beneficiaries, 5 institutional rainwater catchment tanks have been built and the rehabilitation of 1 small earth dam is nearing completion.
The construction of 3 dug wells has reached its final stages and another 5 wells have been completed in close cooperation with the construction department of the RDWSSP.

At present funds are available for the construction of 10 spring protections and 15 dug wells in Nyakach Division of Kisumu District, and during the course of 1988 more funds will be allocated to start the implementation of 25 shallow well water points in Alego of Boro Division in Siaya District.

As a result of the general awareness education within the water programme, approximately 200 potential well sites for various community groups have already been selected and have been included in the geophysical survey activities of the water resources survey programme of the RDWSSP.
So far a large number of sites have been identified for implementation pending on the availability of skilled manpower and funds.

According to the development plans for the near future it is expected that the water programme will have an estimated output of 15-25 shallow wells and about 15-20 spring protection projects per year.
Further extension of the construction activities will mainly depend on the technical and organisational capability of the water programme and also on the availability of finance.

Projects up to the end of 1988

A summary of the projects completed and under construction is given in Table 16.3.

TABLE 16.3 COMPLETED AND ONGOING WATER PROJECTS IN KISUMU DISTRICT BY THE DIOCESE OF KISUMU

DIVISION	Piped supplies	Dug wells	Spring improvements	Rain water catchments	TOTAL
Maseno		2	2	1	5
Winam	1	2		1	4
Nyando	2	1	1	1	5
Muhuroni		1			1
Nyakach		4	7	3	14
DISTRICT	3	10	10	6	29

Projects planned for 1989

The continuation of at least another 3 spring protections and 11 dug wells in Nyakach Division.

The construction of 5 wells per year and approximately 5 spring protections per year scattered over the District.

Projects planned beyond 1989

Another wells construction project in Seme area of Maseno Division (at least 25-30 wells).

Continuation of 5 dug wells per year and approximately 5 spring protections per year scattered over the District.

Rain water catchments for communities and schools on request of the respective communities.

16.4.4 Aga Khan Foundation

Project background

Kisumu Primary Health Project was the result of a meeting hosted by WHO with Aga Khan Foundation in 1981 on "The Role of Hospitals in Primary Health Care".

Aga Khan Foundation through the Aga Khan Health Service, had a number of Hospitals in different parts of the world. Primary Health Care was adopted as a strategy within AKHS. Aga Khan Hospital Kisumu was chosen to initiate the pilot experimental project.

In 1982, AKHS and AKF co-sponsored the Kisumu PHC Planning Seminar at which the local government health services, Central of Health, Provincial Administration, the Municipality of Kisumu, Lake Basin Development Authority of Kisumu, WHO, AKF, Ford Foundation, African Medical Research Foundation (AMREF) and AKHS were re-presented.

The seminar identified two areas for PHC i.e. North Nyakach and Kajulu Locations in Kisumu District.

In July 1983, the proposal was finally adopted. It was to be an experimental 7 year project.

Projects to be completed by the end of 1988

Up to date a total of 28 water projects have been completed e.g. 6 spring protections, 12 dug wells and 10 piped tap points.
At the same time a number of water projects are in various stages of construction.
The estimated total target at the end of 1988 is given in Table 16.4.

TABLE 16.4 COMPLETED AND ONGOING WATER PROJECTS IN KISUMU DISTRICT BY AGA KHAN

DIVISION	Piped tap points	Dug wells	Spring improvements	Total
Winam	10		5	15
Nyakach		12	1	13
Total	10	12	6	28

Projects planned for 1989

During 1989 a total of 24 projects will be carried out in Nyakach and Winam Division.
It is estimated that these will include 16 dug wells and 8 drilled boreholes.

16.4.5 CARE

Between 1968 and 1988, CARE International in Kenya has been assisting community projects in Kisumu and South Nyanza District as well as 8 other Districts in Kenya.

The goals of the projects were as follows:

- to provide greater quantities of water through more reliable and accessible systems.
- to reduce the amount of time woman spent on collecting water.

The water projects carried out upto June 1988 in Kisumu District are summarised in Table 16.5.

TABLE 16.5 COMPLETED AND ONGOING WATER PROJECTS IN KISUMU DISTRICT BY CARE KENYA

DIVISION	Piped tap points	Dug wells	Dams	Rain water catchments	Total
Maseno	1	2	1	2	6
Winam				1	1
Nyando				2	2
Muhuroni	2			1	3
Nyakach	1	3		4	8
DISTRICT	4	5	1	10	20

From mid-1988 onward, CARE is focussing water activities in three Districts i.e. Bungoma, Busia and Embu.
There are no plans to continue any activities in Kisumu District in the future.

16.4.6 Diocese of Maseno South

Strategy

Water projects should be requested and initiated by communities within the Diocese.
The policy stresses the involvement of the beneficiaries concerned in all stages of the water project and is comparable with the policy of the RDWSSP.

Projects carried out

Since 1982, the Diocesan Water Programme has implemented one to two dug wells annually; two were completed in Kisumu District.
In co-oporation with other Diocesan departments some roof catchment projects were initiated and spring protections were constructed.
Further the Diocese took part or initiated some small scale piped supply schemes.
In Kisumu District, the Gem Rae Water Supply was constructed.

Current activities in Kisumu District

Apart from some preliminary surveys, there are no construction activities going on in Kisumu District.

Future activities (in Nyanza Province)

A proposal was sent to a German Donor Agency applying for funds to establish a shallow well Programme and other water supply possibilities in Nyanza Province. This Programme also intends to improve sanitation facilities.
Within this Programme a total number of 56 water and sanitation projects are to be implemented under the policy of community participation.

Apart from this the present Water Engineer will try to initiate interdepartmental projects combining e.g. the work of agro forestry with water engineering.

Finally the Diocese (resp. CPK) plans to have a number of boreholes drilled by a drilling rig which was donated to CPK.

16.4.7 Rural Development Fund

Introduction and background

Based on a request in 1982 by the then Provincial Commissioner of Nyanza, the Government of Denmark agreed to give financial assistance for rehabilitation of existing wells dug during the cholera outbreak in 1974 to 1976.

In order to determine the number of wells which it was possible to rehabilitate, a survey was carried out and the result of this survey revealed that between 200 and 300 of these wells were viable for rehabilitation. All these shallow wells had been hand-dug and were partly or completely lined with non-porous concrete rings (culverts). Many were also completed with a concrete cover, fitted with a steel lockable manhole cover and a hand pump of local manufacture and design.

The survey also revealed that less than 10 % of the installed hand pumps were still operational.

Also it became clear that due to lack of proper de-watering equipment the majority of the wells were not dug deep enough, resulting in unsatisfactory low yields or drying up during the long dry season.

Objectives

The main objective of the project was to provide a clean and safe water supply in order to improve the health of the communities.

It was agreed that the project should concentrate on renovation of the existing wells, which needed repair of pumps, limited repair of the well lining or well cover.

Also it was agreed that other type of water resources should be given consideration such as protection of springs and roof catchments.

In principle it was agreed that only wells/springs which had an established well committee were to be included under programme and before construction could start a self-help contribution of Kshs. 600/= was to be paid to the District Treasury.

Project set up

As the wells to be rehabilitated were under the Ministry of Health jurisdiction it was decided that the programme in the Districts should be undertaken and implemented under the Ministry of Health with the District Public Health Officer being the responsible officer.
In the Kisumu Municipality it was decided that the Health Department should be the implementing agency.

Under this set-up it was agreed that the Ministry of Health and Kisumu Municipality were to provide and pay for skilled manpower and supervision during the construction of the wells. Costs of materials, transport and to some extend unskilled manpower were to be met by the project account.

Bearing in mind the relative limited funds available for this project, the programme should only be seen as a supplement to other programmes in the province carried out by the Lake Basin Development Authority, IFAD, various Dioceses, Aga Khan and other NGO's, whose programmes are aimed at improving the water supply situation in the rural areas.

Based upon previous experience where too many wells have been dug too shallow and springs have been protected and improved, but later dried up, it is strongly recommended that no sites are to be embarked on until all available information on occurrence and quality of the ground water is obtained from the data base which is now existing at the Lake Basin Development Authority or their consultants DHV, Consulting Engineers in Kisumu.

Projects completed by 1988

Since the start of the Programme in 1982, in Kisumu District a total of 37 hand pump operated wells have been completed.
Another 15 wells were constructed and protected but left without a hand pump for various reasons.
Further 3 springs located in Maseno Division were protected.
Table 16.6 summarizes the completed water points.

TABLE 16.6 COMPLETED WATER PROJECTS IN KISUMU DISTRICT BY THE RURAL DEVELOPMENT FUND

DIVISION	Rehabilitation Dug wells	Spring improvements	TOTAL
Maseno	8	3	11
Winam	27		27
Nyando	14		14
Muhuroni	1		1
Nyakach	2		2
DISTRICT	52	3	55

Future planning

The Programme is due to be phased out by the financial year 1988/1989.
Hence apart from completion of ongoing projects, no further projects are planned.

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