213.1-2878

Tampereen teknillinen korkeakoulu
Rakennustekniikan osasto
Vesitekniikka

Tampere University of Technology
Department of Civil Engineering
Water Supply and Sanitation
Post Graduate Course in Water Engineering 1982-84

N:o 17

In co-operation with
Finnish International Development Agency
FINNIDA

Omwenga John M.

Rainwater Harvesting for Domestic Water Supply in Kisii, Kenya

UDK 628.111:628.1 (676,2)
ISBN 951-720-857-X
ISSN 0357-8860

Tampere 1984

RAINWATER HARVESTING FOR DOMESTIC WATER SUPPLY

IN KISII, KENYA

By

John M. Omwenga

Thesis submitted as partial fulfillment for the requirements of Master of Science Degree in Engineering to Tampere University of Technology, Department of Civil Engineering.

Nairobi February 1984

To my wife Carren and sons, Arnold and Brian.

ACKNOWLEDGEMENTS

I wish to thank my Course Director and Supervisor, Mr. Pentti Rantala for guiding me through this work. I also thank Mr. J. Muraguri of the Department of Civil Engineering, University of Nairobi for making the necessary administrative arrangements to facilitate the success of this work and also for his generous assistance and encouragement.

Special thanks go to Mr. P.K. Weru of the Ministry of Water Development for his useful suggestions. I also wish to thank Mr. K.N. Mutaku of the Meteorological Department, Ministry of Power and Communications for assisting me with Rainfall data. Messrs. A.R. Gachui and B.G. Kibe of Kenya Industrial Research Development Institute are thanked for helping with the metal analysis. Not to be forgotten are all those persons in the study area who gave me the information I needed especially Mr. Jaakko Lounela and Zephania Ombeta of Matongo Mission and Sister Mary Pia and Francis Nyachio of Viongozi Centre, Kebirigo.

Lastly I thank the Ministry of Water Development for granting me study leave to pursue this work and the Laboratory staff and other staff in the Ministry for their generous assistance in many respects.

SUMMARY

Although the term Rainwater Harvesting includes the collection of natural precipitation from various prepared watersheds, I have only confined my discussion to the collection of precipitation from roof catchments.

An assessment of the current water resources in Kisii District has been carried out and the position of Rainwater Harvesting ascertained. The current state of some Rainwater Harvesting systems has been examined. In general many of the systems are not well maintained and managed. It has been observed that storage tanks are underdesigned in some cases while many households cannot raise money to buy gutters and storage tanks. Water samples have been collected from these systems and other traditional sources and analysed. The results show that the rainwater is generally of good chemical and bacteriological quality; whereas the water from other traditional sources is not as good in many cases. Corrugated galvanized iron roofs were found to offer the best catchment. Runoff is good from such roofs and they have no bad effects on water quality. Cheap but durable storage facilities like granary basket tanks have been recommended for small households, while the more expensive but strong concrete-block tanks

or sub-surface tanks can be used for large volume storages for communities. Finally a comparative cost analysis between Rainwater Harvesting and other sources of water supply has been carried out.
The results show that Rainwater Harvesting as a source of domestic water supply is feasible in the district since it has an average annual rainfall of over 2000 mm.

TABLE OF CONTENTS PAGE

PAGE

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

In November 1980, the United Nations launched an International Drinking Water and Sanitation Decade 1981 - 1990. In its action plan and in response to the United Nations move, the Kenya Government proposed to provide safe and adequate drinking water to every home by the year 2000. Indeed both of these are ambitious proposals, whose attainment and fulfillment would require the expenditure of large sums of money and the exploitation of all available water resources.

Rainwater catchment and storage has been practiced in some parts of the world for up to 4000 years. Yet despite the pressing need for adequate and safe drinking water supplies in many places especially arid and semi-arid areas, this water supply technique is still not used as widely as it should be. (National Academy of Sciences, 1974).

Although there are now over 3000 sizeable rainwater harvesting systems all over the world, this practice has not been accepted as a competitive method for providing water supplies. (Cooley K. R. et. al. 1975). Many countries do not incorporate rainwater catchment systems into their water development plans. This is partly due to the little emphasis placed on rainfall catchments by the World Bank and U.N. Agencies concerned with executing water supply programmes. The preferrance for groundwater over surface water as a source of Domestic Water Suppliers was expressed in a World Bank Paper in 1976 and this has been taken up in development policy. (Stern P. 1982). The World Health Organisation ranks rainwater fourth as a source of domestic supplies, lagging behind ground water needing no treatment, springwater, and ground water needing little treatment.

Few countries have encouraged rainwater harvesting practices. Among these are Israel, Australia, Botswana, Sudan and some Carribean Countries (I.R.C. 1981). In Australia, rainwater harvesting is being used in some municipal supplies (Hollick M., 1975) while in Japan plans are underway to use rainwater for toilet flushing to save on the use of treated water supplies for flushing (Ikebuchi S. et al, 1982).

In many developing countries, the majority of the people live in the rural areas. Many of them have little or no access to clean or treated water supplies. If Rainwater Catchment Systems are adopted, encouraged and treated as appropriate and necessary technology in such countries, they would help in providing the much needed clean water supplies.

In the study area, Kisii, many of the traditional water supply sources (rivers, streams, wells and springs) are being continually polluted by human and animal wastes, agro-chemicals used on the farms and effluents from coffee and tea factories. Many people also suffer from waterborne diseases spread by contaminated waters as shown by Kisii Hospital Medical records (National Environment Secretariat, DP-3, 1981). In addition it has been observed, that despite the fact that a lot of rain falls in the area, some schools and other social institutions are threatened with closure for lack of water during the dry months each year. The need to carry out rainwater studies and the use of rainwater from roof catchments for drinking and other domestic purposes; need not be over-emphasized in the light of the above problems.

2 WATER REQUIREMENTS FOR RURAL COMMUNITIES

Small rural communities will need water mainly for domestic purposes. These may be divided into various categories (Wagner E.G. 1959)

- drinking
- food preparation and cooking
- washing and general hygiene
- vegetable garden watering
- livestock watering
- local brewing
- other uses including waste disposal.

Rainwater can be used to supply the water for all the above needs. Very clean water, for welfare, social and educational institutions like schools and hospitals within the community will be needed for drinking, washing and cooking. Such clean water can be obtained from the roof catchments. However less clean water which can be used for livestock watering, poultry, and gardening can be obtained from ground or compound catchments. This will reduce rainwater harvesting and storage costs for clean water. Of course where sufficient water can be collected from roofs and where storage facilities are adequate clean water can be used for all purposes.

2.1 Water Consumption Rates

As an aid to designing a water supply for a small rural community, the following tables have been suggested. (Nissen - Petersen 1982).

Table 1: Typical Domestic Water Consumption Rates

Type of Supply	Consumption in litres/ capita/day
Living 15 km from a water source	2 - 3
Living 1 km from a water source	3 - 6
Having water next to house	10 - 20
Having a tap, a shower and adjusted WC	60 - 80
Having full sanitary installation	175 - 250

Proper rainwater harvesting practice will place clean water next to the house, and with some arrangements, taps and showers can be installed in the houses. This is the one advantage that rainwater harvesting has over other types of external supply.

Table 2: Typical Livestock Water Consumption Rates

Type of Animal	Consumption in litres/animal/day
Small stock (sheep, goats)	3
Local cattle	20
Grade cattle	75

Table 3: Water Requirements for Irrigation and Small Scale Farming. (Rommi, K.J. 1977)

Crop Type	Applied water factor in m^3/m^2/year
Tree and vine	0.52
Field/pasture	0.71
Row	0.92

The crop water requirements will also vary with climate, soil type, method of irrigation and locality. The above figures have been taken from Santa Clara Valley in U.S.A. Crop water requirements for locally irrigated crops could not be obtained.

Due to high amounts of rainfall, irrigation is not at the moment practised in Kisii, but could be tried in some areas during the dry months.

2.2 Estimation of Water Requirements

In order to estimate the total water requirements for a small family or large community, an inventory of all the water consumers must be made. Their daily consumptions must be known, and the number of dry days if rainwater is to be used as a source of supply. The following relationships may be used for the estimation.

(i) For Persons

Volume of water required to last through the dry period = Number of persons x daily consumption x number of dry days.

(ii) For Livestock

Volume of water to last through the dry period = Type and number of Livestock x rate per animal x number of dry days.

It should be noted that only the water for drinking purposes needs to be of high quality, while water for other uses like livestock watering, garden watering and waste disposal need not be so clean.

2.3 Estimation of Total Roof-runoff

The following relationship should be used when calculating total runoff from a roof.

Roof Area (m^2) x Annual Rainfall (m) x Run-off factor (ROF) = Total Run-off in m^3/year (m^3/a).

The run-off factor is to correct for losses due to evaporation and splashing from roofs and gutters and is a function of type of roof catchment.
It may also be affected by rainfall intensity and duration, as well as the design of the roof catchment. Table 4 gives some values of run-off factors from different catchments.

Table 4: Run-off Coefficient factors

(World Water, October 1981)

Catchment	Run-off factor (ROF)
Uncovered catchment surface	
- completely flat terrain	0.3
- sloping 5 - 10%	0.5
Covered catchment surface	
- roof tiles	0.8 - 0.9
- concreted bitumen	0.7 - 0.8
Brick pavement	0.5 - 0.6
Compacted soil	0.4 - 0.5

3. DESIGN OF RAINWATER CISTERN SYSTEMS

3.1 General

In the design of rainwater cistern systems, the capacity of the cistern will depend on the following factors: - (Winarto, 1982).

1. Rainfall
2. Daily water needs
3. Number of consumers
4. Catchment area (roof surface)
5. Length of wet and dry seasons.

Of these, the only design variable that is uncontrollable and unpredictable is rainfall. For this reason the critical rainfall figure is used for design purposes, otherwise normally the mean annual figure for a period of 50 years or more is used. In the design of gutters, knowledge of the water surface profile and flow hydrographs is necessary, but details of these will not be covered in this report.

Whereas all the above factors have to be considered in the design of cistern systems, the availability of funds and the adequacy of the existing catchment area are also two deterministic factors.

Most of the rainwater cistern systems in the study area have been constructed without full consideration of all the variables mentioned above. Many of them are underdesigned, hence their failure to satisfy the needs for which they were constructed.

3.2 Estimation of Reservoir Volume

The following step by step method can be used to estimate the volume of the storage reservoir. (Pompe, 1982).

STEP 1. Daily consumption (litres/day x number of users

a. Drinking and cooking = ... x ... = ...

b. Washing and bathing = ... x ... = ...

c. Livestock water = ... x ... = ...

d. Irrigation = ... x ... = ...

Total daily consumption =

STEP 2. Monthly consumption, MC (litres/month)

MC = total daily consumption x 30.5 days = ...

STEP 3. Catchment area, A (M^2)

Determine available catchment area, A = ...

STEP 4. Runoff factor, ROF

Determine ROF: for vegetative cover ROF = 0.5

for hard paved areas ROF = 0.9

Run off factor, ROF = ...

STEP 5. Critical rainfall, CRF (MM/month)

$$\text{Calculate CRF} = \frac{MC}{ROF \times A} = \frac{\quad}{\ldots \times \ldots} = \ldots$$

STEP 6. Assuming no leakage and evaporation from the reservoir, the volume of the reservoir may be estimated by the following relations

(i) Storage Volume, SV m^3 = Total Daily Consumption, m^3/d x No. of dry days

(ii) Storage Volume, SV m^3 = CRF m/month x Catchment Area m^2 x ROF x Number of dry days in months.

Relation (i) gives the actual storage volume required to last through the dry period. To take care of any eventualities like extended drought, this volume should be increased by 30 - 50% to give extra security storage. This then should be the amount of rainwater in storage at the start of the dry period.

Relation (ii) gives an indication of the size of storage required to store rainwater assumed to fall during a period corresponding to the drought months. It gives an indication of the total amount of water that can be harvested and kept in storage.

In practice rain will fall during the rainy months. Much or all of this rainwater will have to be collected and held in storage, and withdrawals for consumption monitored so that there is enough in storage to carry through the dry months. In general rainfall regimes follow certain annual patterns. Storage volumes may best be designed considering total annual rainfall for a critical year or a mean annual rainfall figure instead of considering monthly rainfalls.

The water demand will thus dictate the size of storage required, while the rainfall, and size and type of catchment will show whether this demand can be satisfied.

3.3 Design Considerations

The following design considerations are suggested.

1. Arrange for flushing out or by-passing waters from the first rains so that it does not directly

go into the reservoir. This water is usually not clean.

2. Storage tanks should be covered to reduce evaporation, keep off sunlight and contamination from dust. Cement covers may be used or roofs erected.

3. The inflow should be filtered at the entrance to the reservoir to remove any foreign materials and to trap any small animals like lizards that may drown and decompose in the tanks.

4. Where sub-surface storage is used, the floor should be covered with an impervious lining like plastic or polythene sheets instead of cementing with plaster.

5. The tanks should be constructed in such manner to facilitate easy cleaning.

6. The tank floor should be gently sloped away from the tap, so that any sediments will settle away from the tap and thus keep it free from clogging.

7. The drawing point or tap area should be cemented with concrete plaster and drained to keep it dry and clean from spilled waters.

8. The tank should be placed well raised so that the tap is easily accessible when drawing water.

9. Corrugated galvanized iron tanks should be laid on wooden supports placed on raised cement platforms to ensure that the outer bottom surface is kept dry all the time to reduce corrosion risk.

10. The walls of buildings should be of reasonable height as this will limit the size and shape of the storage tank.

11. The houses from which the rainwater is to be harvested should be carefully planned so that savings in guttering and pipelines can be realised, and drawpoints possible under gravity.

3.4 Minimum Catchment Area

If the daily demand is fixed and is defined in litres per day. Then for a given area of known average annual rainfall, the following relationship can be written to define the minimum catchment area:- (Perrens, 1982)

$$A = \frac{365D}{R} \qquad (1)$$

where A = Catchment area (m^2)

D = Daily demand (1)

R = Average annual rainfall (mm)

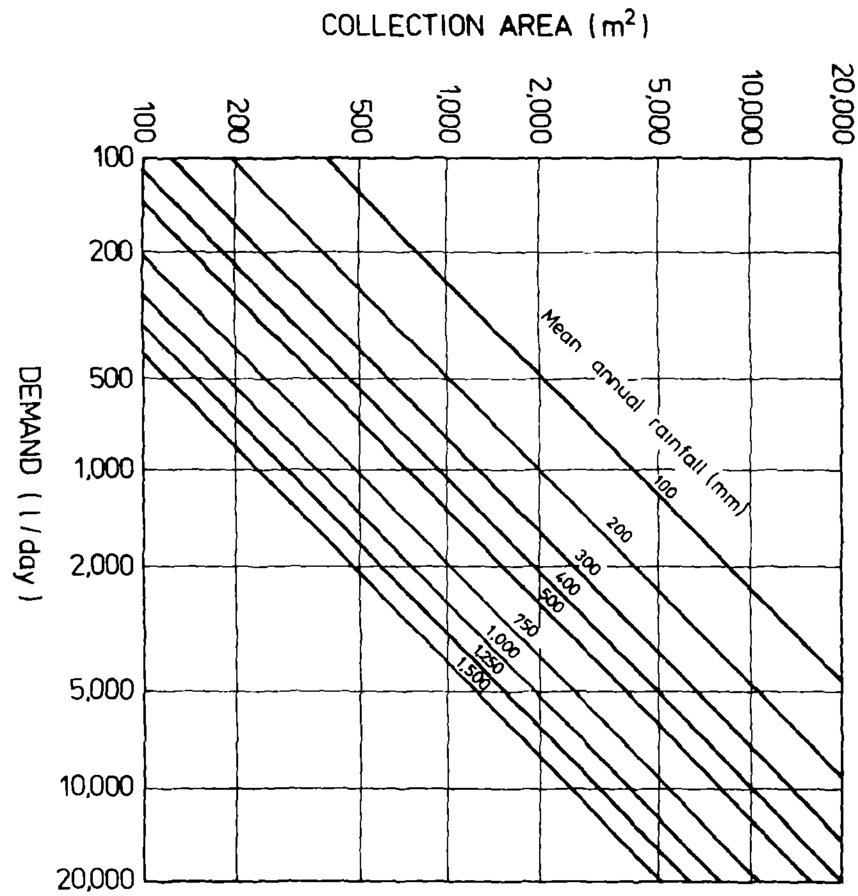
This minimum catchment area is also termed the 'basic' area.

If the consumption is taken as 15 litres/person/day, then the minimum catchment area in the study area, with average annual rainfall 2000 mm, for a family of 6 persons would be $16.4m^2$. However it was observed that most individual galvanized iron sheet roofed houses have a roof area in excess of $20m^2$. This means that all individuals living in Kisii can at least harvest enough water from their roofs for drinking purposes all year round.

From the above relation denoted (1), it is clear, that if the rainfall is assumed to be constant, then the minimum catchment area will vary directly with demand. However if the demand is fixed then the catchment area will vary inversely with average annual rainfall. The conclusions following from the above relationship are quite useful.

Nomographs can be plotted showing what minimum area is required to meet specified demand for given mean annual rainfalls. These can be very useful for rapid design purposes. Fig. 1 shows an example of such nomographs designed for New South Wales, Australia, but similar nomographs could be made for the study area.

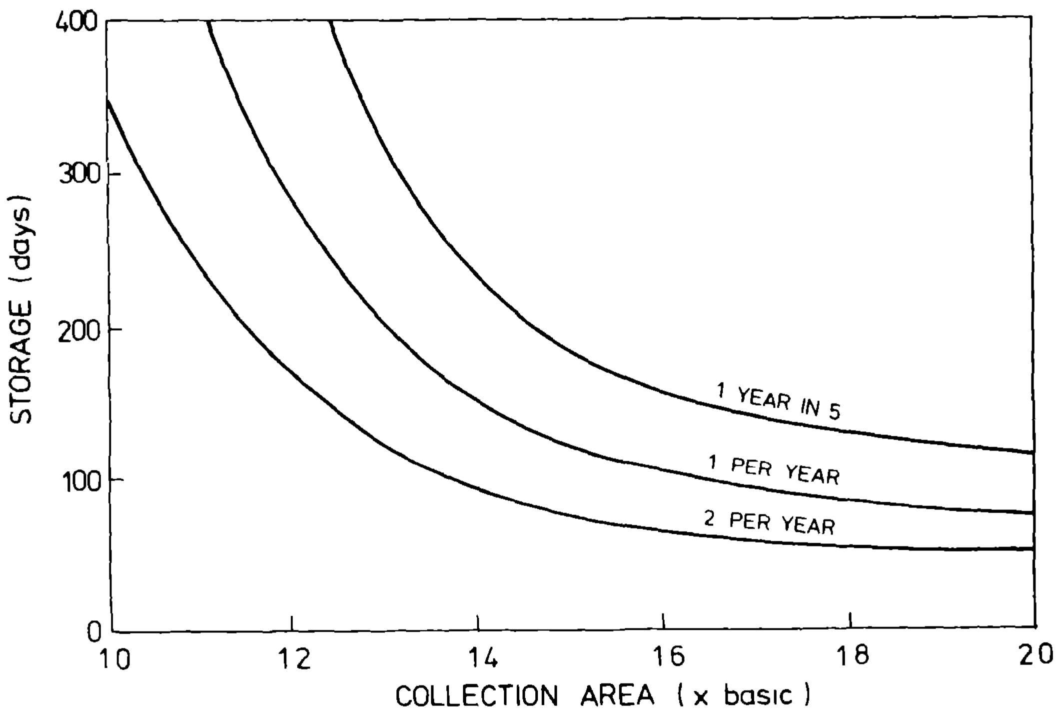
Fig. 1. Minimum Catchment Area, required to meet a specified demand for given'mean annual rainfall. (Perrens, S.J., 1982).



3.5 Catchment Area and Storage

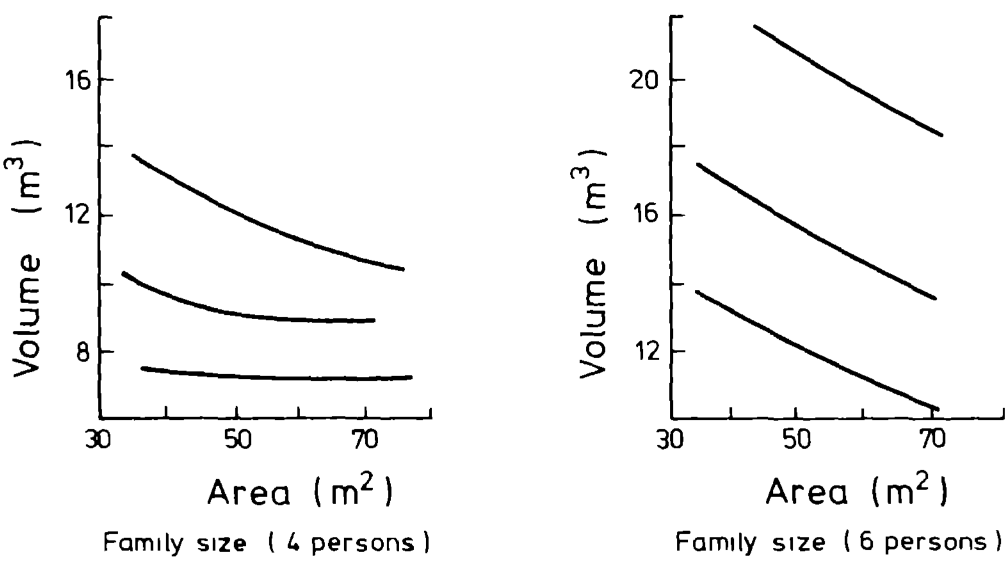
A relationship between catchment area and storage for a given demand situation can be established for a given area. Nomographs can also be drawn incorporating various probabilities of failure of supplies. This storage to area relationship is very useful and such an analysis can account for big savings in design costs especially when funds are scarce. Figure 2, below has been reproduced for a rainwater station in New South Wales, Australia. It is intended that similar nomographs be prepared for the study area.

Figure 2: Relationship between collection area and storage for Coff's Habour for a given demand for various probabilities of "failure" (Perrens S.J., 1982).



Nomographs also relating cistern volumes, roof area and family size can be drawn, for a given mean annual rainfall. Such nomographs have the shapes shown in Figure 3 drawn for an area in Indonesia.

Figure 3: Cistern Volume nomographs based on roof area and family size (Doelhomid, 1982)



4. WATER RESOURCES AND WATER SUPPLY IN KISII

4.1 The Study Area

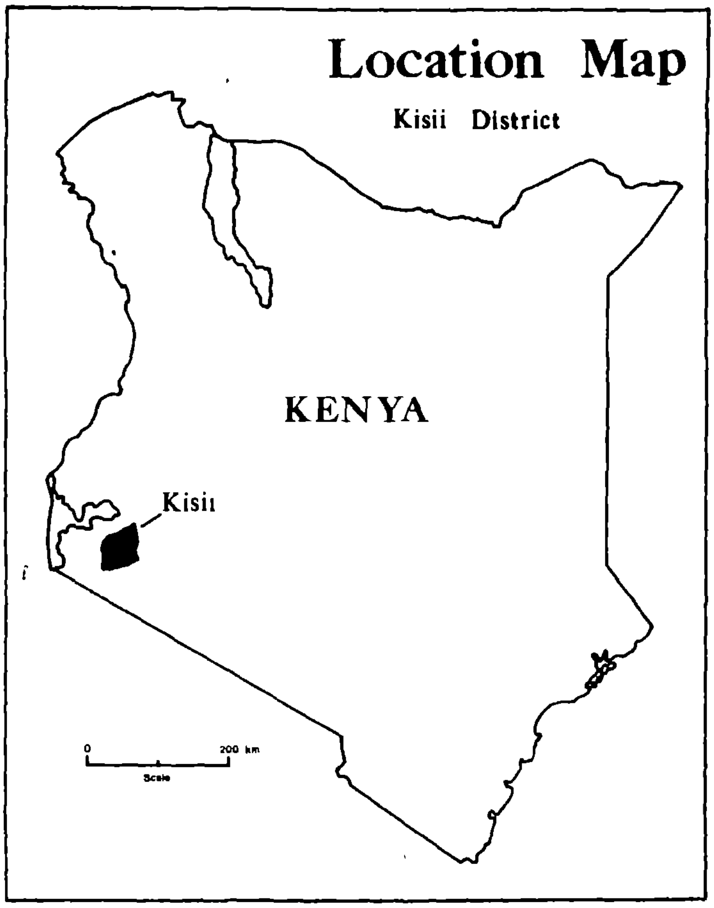
Kisii is a hilly district with few level areas. Much of the western area is between 1500 and 1800 metres above sea level. The eastern part is over 1800 metres in elevation and some areas are as high as 2300 metres. The area covers an area of 2196 km^2.

The district's population in 1980 was 1,007,000 persons, and has an estimated annual population growth of 3.63% (Statistical Abstracts 1982). Most of the people are small scale farmers, but, few large farms exist where cash crops like coffee, tea, pyrethrum and many subsistence ones are grown. The land tenure is such that individual ownership of plots is very much exercised.

The climate may be described as highland equatorial, a zone characterized by high altitude and high rainfall. There are no pronounced climatic variations as found in other parts of Kenya because the topography is not very varied. The temperatures may be described as mild.

Figure 4 shows the location of the area.

Figure 4 : Location Map of Study Area



4.2 Surface Waters

The district is well drained by many rivers and streams. Some of the major rivers are the Kuja, Omogusi, Chiri Chiro, Mogonga and Riana. The district has no natural or man-made lakes, so there is no surface water storage. However, the major rivers flow all year round and serve as regular sources of domestic water supply.

4.3 Ground Waters

Judging from the large number of shallow wells that have been dug by local inhabitants, the district has great ground water potential. Most of these wells are only 4 - 10 metres deep indicating that the ground water table is generally high. Deep boreholes sunk in some areas by the Ministry of Water Development and others have given very good yields.

4.4 Rainfall

The district receives a mean annual rainfall of over 2000 mm., with more than 1500 mm expected every year. This rainfall is well distributed over the whole area. Two distinct rainfall maxima exist. The long rains start in March and end in June while

the short rains start in October and end in December. During these months rain is falling almost every day. At the moment there are 22 rainfall recording stations in the district. Many of these stations have records extending over a period of over 50 years.
Figure 5 shows rainfall and temperature distribution in the district (National Environment Secretariat DP-3). The area around Kisii town receives over 2000 mm of rain annually, but the rainfall dwindles outwards from the township to about 1524 mm/year in both the northern and south-eastern sections of the district.

Data is lacking on rainfall variability, intensity and on potential evaporation and evapotranspiration on earlier records, but recent stations are now recording these parameters. In the period between 1957 and 1970, a measuring station at Coffee Research Centre in Kisii recorded a mean annual rainfall of 1957 mm with a maximum of 2281 mm and a minimum of 1690 mm. The maximum rainfall recorded in 24 hours in this period was 108 mm.

Table 5 shows the average monthly rainfall figures for Kisii town in the years 1980 and 1981 (Statistical Abstracts, 1982).

Fig. 5: Rainfall and temperature distribution (National Environmental Secretariat DP-3, August 1981).

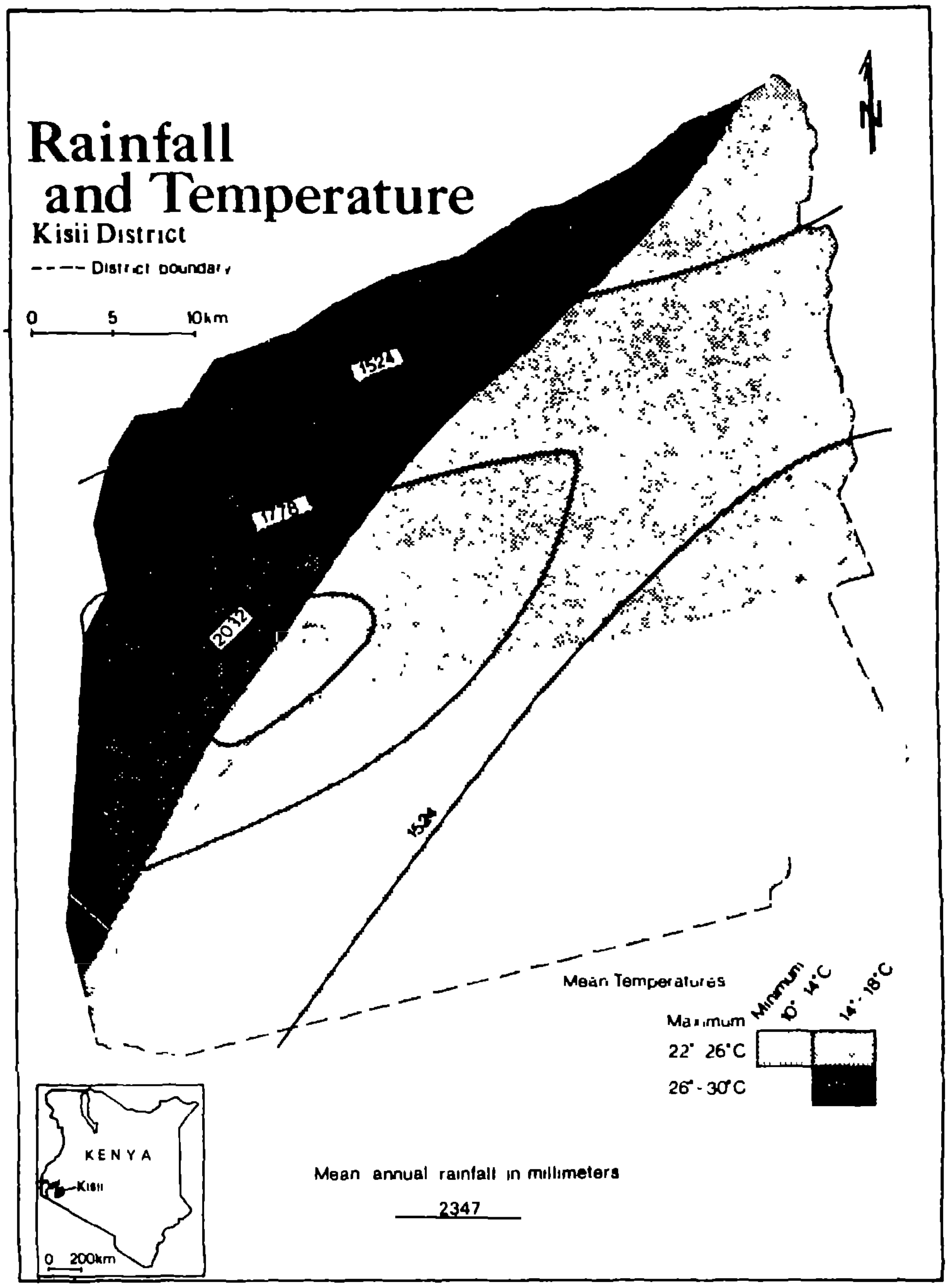


Table 5: Kisii Town Monthly Rainfall for 1980 and 1981 (in mm).

(Statistical Abstracts 1982).

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTALS
1980	70.4	89.5	179.2	166.2	288.7	131.6	129.8	189.7	131.7	95.6	176.7	67.5	1,716.6
1981	31.6	93.8	188.7	294.3	226.3	71.9	123.5	203.7	212.8	78.8	137.9	88.7	1,752.0

4.5 Water Quantity and Quality

The district has sufficient water which may be utilised for many purposes. Extensive agriculture and livestock farming have been possible because of the available water resources. Except for a few boreholes which contain slightly saline water all the other waters are fresh and non-saline. Most of the surface waters are not fit for drinking due to contamination and pollution especially during the rainy season. The waters are generally highly coloured turbid and show high bacterial counts. Some rivers also show high concentrations of iron.

Most of the shallow wells that have been dug, are not properly protected and show high bacterial colony counts. They cannot be used as source of drinking water without causing health problems. In fact most of them are used for livestock watering only.

Protected springs, serve at the moment as the only recognised and accepted source of good drinking water. Wells with proper protection can also provide good drinking water. Rainwater which is in abundance in the district remains another potential source of good drinking water. However this has to be collected and stored properly to preserve its purity. Where this has been done, people seem to prefer to use it for most of their needs.

Table 6 shows the water quality characteristics of the rivers Kuja and Omogusi. and a shallow well. (Ministry of Water Development).

Table 6: Water Quality Characteristics of Rivers, Kuja Omogusi and a Shallow Well

Sample Source and Marks / Parameter (1)		Omogusi River Date: 13/10/83 (2)	Kuja River Date: 3/9/76 (3)	Orina's Well Date: 13/10/83 (4)
pH		7.3	8.8	6.0
Colour	TCU	200	150	10
Turbidity	NTU	34	290	2.0
Permanganate value	ppm	21	9.4	2.2
Conductivity	μs/cm	68	66	10
Iron	ppm	7.0	-	<0.01
Manganese	ppm	<0.01	<0.01	<0.01
Calcium	"	5.6	-	1.6
Magnesium	"	13	-	1.4
Sodium	"	14	-	7.0
Potassium	"	13	-	3.6
Zinc	"	1.3	-	1.5
Total hardness as $CaCo_3$	"	40	20	12
Total Alkalinity as $CaCo_3$	"	28	104	4
Chloride	"	2.5	8.5	0.75
Fluoride	"	-	0.27	-

Table 6 ....Continued

Table 6 ...... Continuation

1	2	3	4
Sulphate ppm	2.4	-	0.31
Lead	<0.01	-	<0.01
Total colony count/100ml	1200	-	1200
Total Dissolved solids ppm	41	46	6

4.6 Water Supplies

Only 13 - 15 per cent of the population in the district has access to good clean treated water supplies (Jacobi 1983). This is mainly in the town of Kisii and the other smaller but upcoming towns of Keroka, Ogembo, Nyamira, Manga and Kebirigo. Most of these water supplies have been sponsored and maintained by the Ministry of Water Development in their rural water supply programmes. A few have been set up by the Kisii Town Council, some missions, Ministry of Health, self-help and through donor agencies in collaboration with the government.

In general the water supplies include piped or unpiped waters from boreholes, protected springs and shallow wells. In figure 6 which shows current and proposed water supplies in the District non is utilising rain water harvesting as a sole or supplementary source of water supply despite its abundance in Kisii.

A field survey revealed that there is at least one galvanized iron sheet house to every village. This means that every village can collect good rain-water for drinking purposes. It was observed that where good understanding prevails within the village members, the people share the rainwater collected for drinking purposes. However it was observed that in some cases, rainwater was not being used mainly due to ignorance and partly due to lack of funds for the purchase or construction of storage facilities.

The questionnaire revealed, that there are no sociological and psychological factors that would affect the use of rainwater for drinking and other domestic purposes. Of the 30 individual homes visited, it was found that all of them use rainwater when collected and only revert to springs and streams during the dry seasons. Well water is normally used for washing and livestock watering but never for drinking unless boiled.

Fig. 6: Proposed water projects in Kisii District. (Ministry of Water Development, Departmental Records, 1980).

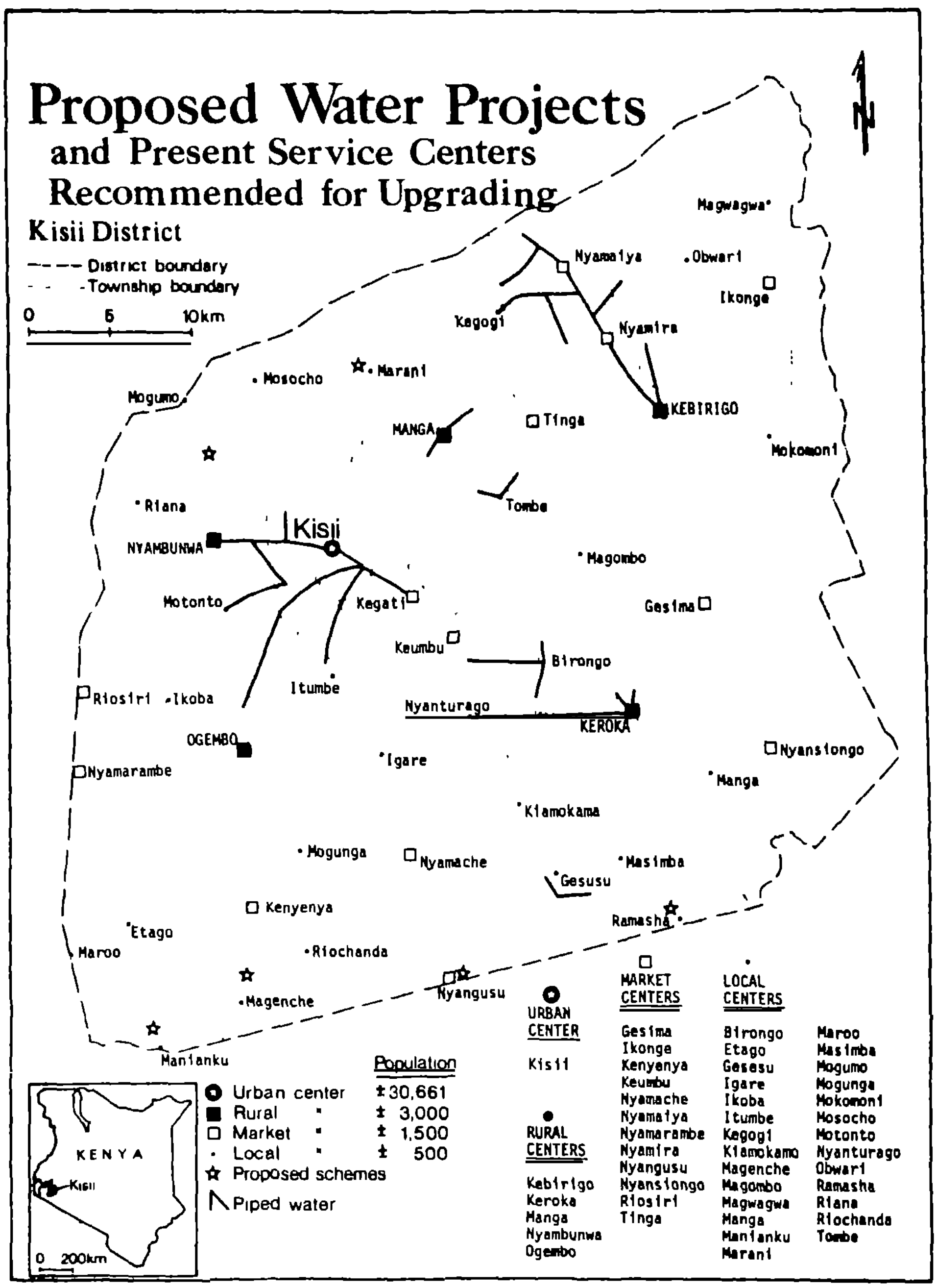


Table 7 also shows the water projects sponsored and maintained by the Central and Local Government in Kisii. (Ministry of Water Development, 1980). What is however surprising is that none of the above projects is using rainwater harvesting in whole or in part for water supply.

Table 7: Water Projects Sponsored and Maintained by Central and Local Government in Kisii

Name and Location (1)	Type of Facility (2)	Sponsoring Agency (3)	Maintaining Agency (4)	People of Area Served (5)	Level of Completion/Operation (6)
Gusii Urban Water Supply Nyaribari Chache Loc. Irianyi Div.	Fully treated piped supply	Ministry of Water Development	Ministry of Water Development	Kisii Township 25,000 people	Complete and in full operation
Sameta Rural Water Supply Nyaribari Chache Loc. Irianyi Div. S. Mugirango Chache Loc. Bosongo Div.	-do-	-do-	-do-	c. 87,000 people	Not operational, about 80% complete
Keroka Rural Water Supply Nyaribari Chache Loc. Irianyi Div.	-do-	-do-	-do-	6,000 (1973)	Completed and fully operational
Manga Rural Water Supply Central Kitutu Loc. Manga Div.	Untreated spring water	Gusii County Council	-do-	c. 3,000 people	Complete and in operation

.... continued

Table 7: ---------------- Continuation

(1)	(2)	(3)	(4)	(5)	(6)
Nyamira Rural/Urban W/S West Mugirango Loc. Nyamira Div.	Fully treated piped water	Min. of Water Dev.	Min. of Water Dev.	c. 1,000 people	Complete and in full operation
Tombe Rural Water Supply East Kitutu Loc. Manga Div.	Untreated spring water	Gusii County Council	-do-	c. 1,000 people	Complete and in operation
Gesusu Rural W.S. Nyaribari Masaba Loc. Irianyi Div.	-do-	-do-	-do-	c. 1,000 people	-do-
Tabaka Water Supply S. Mugirango, Chache Loc. Bosongo Div.	-do-	-do-	*Catholic Mission*	c. 2,000 people	-do-
Rangenyo Water Supply W. Mugirango Loc. Nyamira Div.	-do-	-do-	--	--	Not in operation
Keumbu Water Supply Nyaribari Chache Loc. Irianyi Div.	-do-	-do-	Amasago Sec. School	over 400 people	In operation

Table 7 -------------- Continuation

(1)	(2)	(3)	(4)	(5)	(6)
Nduru Water Supply S. Mugirango Chache Loc. Bosongo Div.	Untreated spring water	Min. of Health	Nduru Secondary School	c. 1,000 people	In operation
Marani Water Supply West Kitutu Loc. Manga Div.	-do-	Gusii County Council	Gusii County Council	c. 2,000 people	--
Kiabonyoru Water Supply N. Mugirango Loc. Nyamira Div.	-do-	-do-	Kiabonyoru Sec. School	c. 200 people	--
Sengera Water Supply Majoge Chache Loc. Ogembo Div.	-do-	Min. of Health Sengera Sec. School	--	--	Not complete
Ogembo Water Supply Majoge Chache Loc. Ogembo Division	Untreated piped water	Gusii County Council	Gusii County Council	c. 1,500 people	In operation

.............Continued

Table 7 Continuation

(1)	(2)	(3)	(4)	(5)	(6)
Nyatieko Water Supply Kitutu West Loc. Manga Div.	Untreated spring water	Min. of Health	Nyatieko Sec. School	c. 1,000 people	In operation
Gakero Water Supply Majoge Chache Loc. Ogembo Div.	-do-	Gusii County Council	Gusii County Council	c. 1,000 people	Not in operation
Birongo Water Supply Nyaribari Chache Loc. Irianyi Div.	-do-	Min. of Health	----	---	Not in operation

Source: Ministry of Water Development, 1980.

5. RAINWATER HARVESTING SYSTEMS IN KISII

5.1 The State of the Art

Rainwater collection from roofs for domestic purposes has been practiced in the district for many years. However the practice is at a rather poor stage of development in many homes and communities. In many cases the rainwater is collected on a daily consumption basis, with no storage facilities for longer periods. It is normal to see villagers carrying water from polluted rivers, streams and wells even when it is raining. This may be due to lack of knowledge on good water quality guidelines. Also most people fail to appreciate the fact that their once pollution free traditional sources (streams, rivers), are now laden with pollutants from industrial and agricultural activities and domestic wastes from the increased population.

Thirty individual households taken as representative of the whole area were visited, and the people questioned about their water supply situation. A questionnaire was used. (See Appendix 1). Also ten rural centres: schools, missions, health centres that are using rainwater cistern systems were examined. In general many schools and social institutions in the district use some kind of roof-catchment system as part of their water supply.

Some of the more interesting systems observed are described here.

5.1.1 Viongozi Centre

This is a Christian Centre that trains young Christians. The centre is almost always occupied by groups of students of about 100 at a time who come to attend short courses. The layout of the centre is as shown in Figure 7.

The centre has 15 building blocks of which 12 are tapped for rainwater which is all collected and stored in an underground tank of estimated volume of 1,000 m^3. The tank was excavated by tractor, the soil compacted and then lined with a polythene/canvas sheet. The tank is covered with galvanized iron sheet roof. This roof is also tapped for rainwater. About half of the buildings in the centre have galvanized iron sheet roofs; the chapel roof is of tiles while the rest are of asbestos roofs. The system seemed to be well maintained. The water is pumped out of the storage tank to smaller tanks for immediate use. Samples were taken for chemical and bacteriological examination and the results are as shown in table 8. The analysis results show that this water is of good chemical and bacteriological quality.

Fig. 7: Viongozi Centre Roof-Catchment System Layout

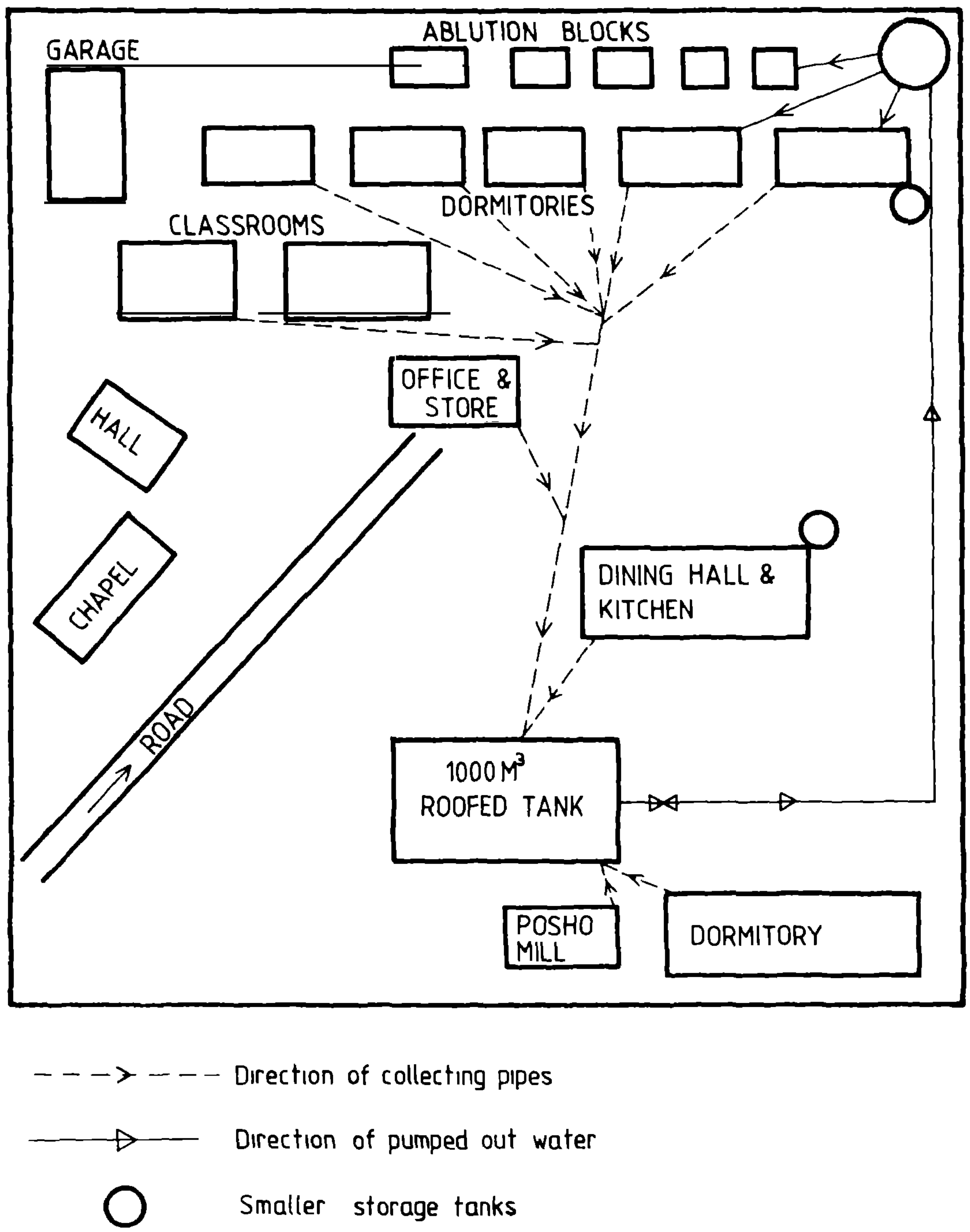
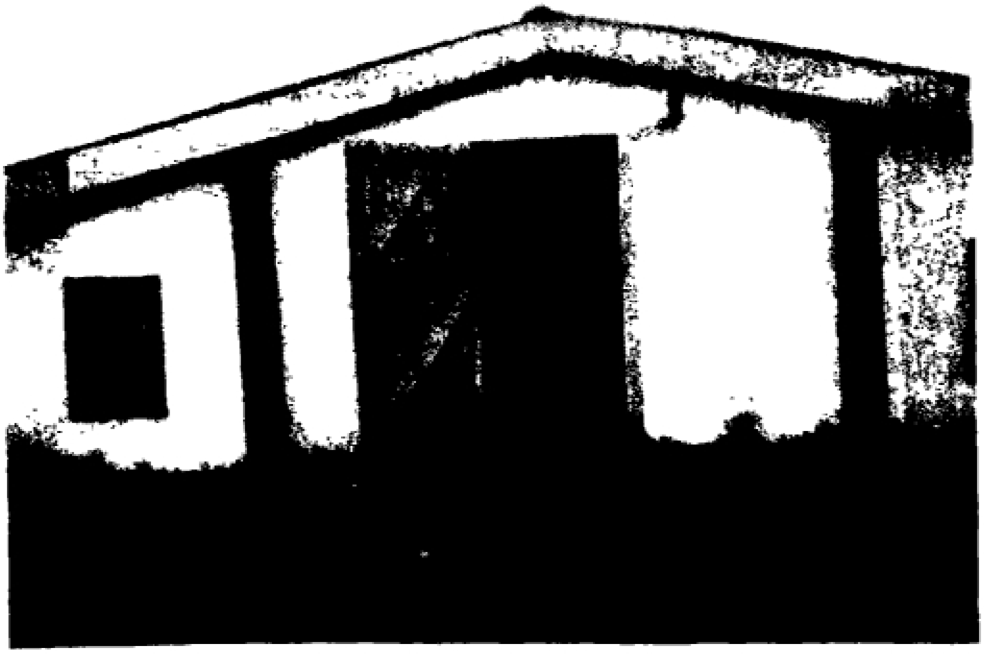


Table 8: Water Quality Characteristics of Viongozi Centre Rainwater

Date of Sampling 10/11/83

Parameters		Results
pH		5.7
Colour	TCU	<5
Turbidity	JTU	1.0
Permanganate value (20 min)	mg/L	6.95
Conductivity at $25^{o}C$	μS/cm	18
Iron	mg/L	<0.05
Manganese	"	<0.01
Calcium	"	2.4
Magnesium	"	1.0
Zinc	"	0.3
Total Hardness as $CaCo_3$	"	10
Total Alkalinity as $CaCo_3$	"	4
Chloride	"	1.0
Fluoride	"	0.1
Sulphate	"	0.5
Total Dissolved Solids	"	11
Total colony count/100 ml		<100
MPN of Coliforms/100 ml		8
E. Coli/100 ml		0

Fig. 8: Viongozi Centre Sub-Surface Storage Tank



The water is chlorinated regularly before use (every 6 months). The centre has never experienced any water shortages since the system was set up in 1975. The water is used for all domestic purposes, but as an extra precaution the water is boiled before use.

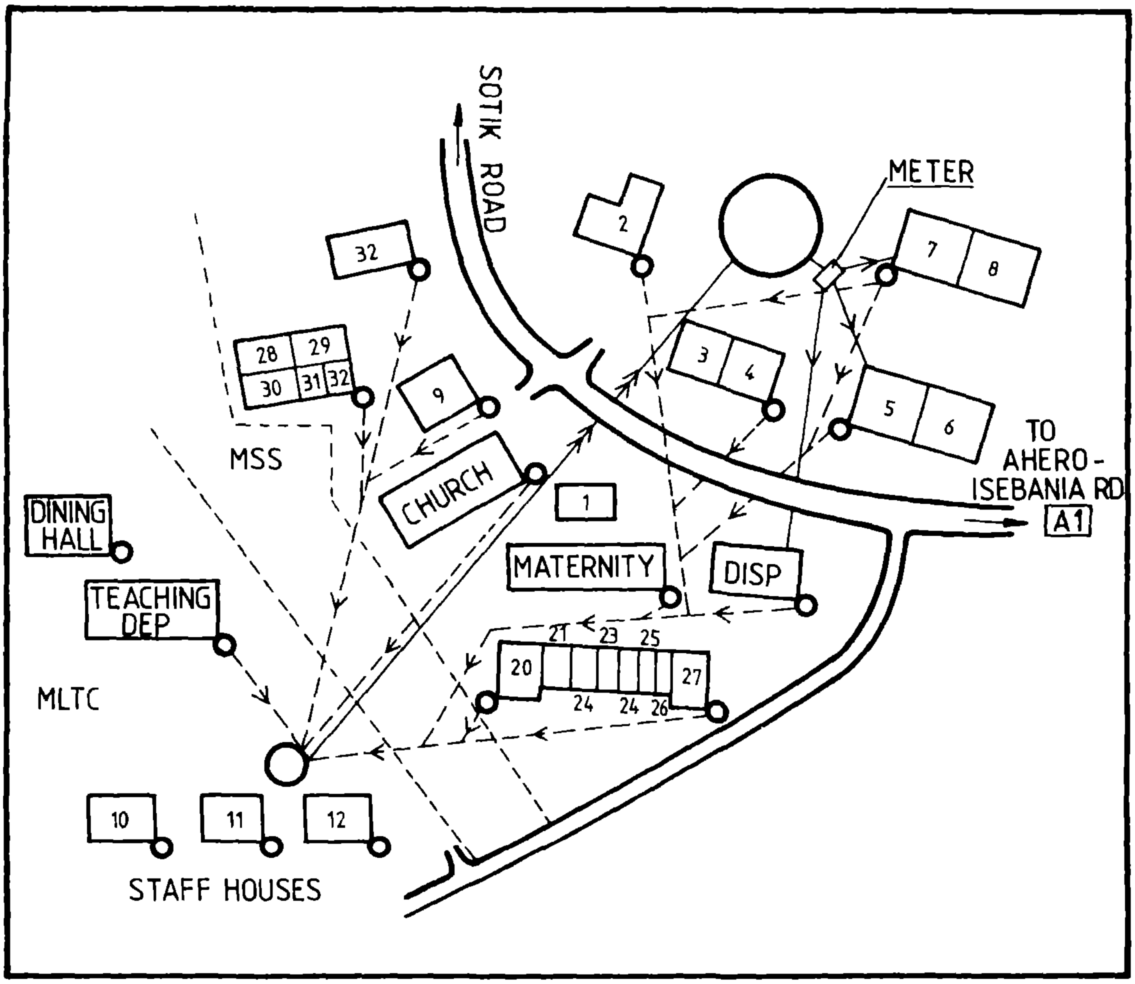
It was observed that no arrangement had been provided to waste the first foul flush at the start of the rains. (See Appendix 4). No individual sieves were placed at the end of the gutters from each building but only one main one at entry into the large tank. The underground pipes are plastic material. The water drains under gravity to the storage tank because it is placed at a lower elevation than the rest of the buildings. The centre has a total estimated roof area of 2500 m^2. The mean annual rainfall recorded by a nearby measuring station at Kenyenya chief's camp between 1968 - 1977 is 1628 mm (Ministry of Power and Communications, 1983). If this is used in calculating total roof/runoff, then the centre can collect over 4000 m^3 of water in a year (assuming ROF = 1 or no other losses). In fact the storage tank overflows most of the time since consumption is not very large. It was not possible to obtain figures for the cost of the system but from the topography of the area it seems to be a most appropriate system. Fig. 8 shows a section of the storage tank of the centre.

5.1.2 Matongo Mission

This place comprises a boy's secondary school, a nursing home, a mission and a village polytechnic. It has a total population of about 1,000 persons. This social centre is served by two major sources of water supply, well water and rainwater cistern system. The idea to start collecting rainwater came about after several dry years when the well water proved inadequate and water had to be transported from a nearby polluted river, Sondu, by trucks. On several occasions, the secondary school and the nursing home had to close down due to a shortage of water.

The present rainwater harvesting system is fairly extensive. The total roof catchment area is estimated to be 4000 m^2. The catchment is a mixture of galvanized iron roofs, asbestos roofs, and painted galvanized iron roofs. All the water from the roofs is collected by a system of gutters and down pipes into a large cement reservoir, placed lower down in elevation than most of the buildings, from which it is continuously pumped by wind pump into an even larger concrete tank of capacity 700 m^3. This water is then slowly released into the different compounds through a water meter as and when required. Many smaller tanks have been installed beside each building to cater for extra storage. Thus, there are five, $50m^3$ capacity

Figure 9: Matongo Roof Catchment System Layout



KEY

- - -> - - Direction of collecting pipes

——>—— Direction of pumped and outgoing water

o Small storage tanks

O Lowers collecting tank fitted with wind pump

◯ Upper storage reservoir supplying whole compound by gravity

MSS - Matongo secondary school

MLTC - Matongo lutherian theological centre

Fig. 10: Matongo Main Rainwater Storage Reservoir

concrete tanks, one 20m^3 concrete tank, another 15m^3 tank; six 5m^3 concrete tanks and ten corrugated sheet iron tanks of capacity 5m^3 each. The total storage capacity of this centre is 1065m^3. The per capita consumption is very high, so that the demand is always higher than the supply. In fact it was reported that since the big storage tank was constructed it had never filled up with water. However, if the mean annual rainfall for the area is taken as 1,500 mm, they should be able to collect a total volume of about 6000 m^3 from their roofs. This water cannot meet their requirements at a consumption rate of 20 l/c/day. The needs for the supplementary sources - well water is justified and they have plans to use the river Sondu water in future. As it is, they require more storage volume facilities to collect all the water and the system should be checked for leaks.

It was noted that precautions to prevent contamination from dust and bird droppings had not been considered during the design of the system. Also no facility for wasting the first foul flush had been included. The water collecting in the main reservoir therefore looked turbid and had some suspended matter. It was suggested that small modifications be made to include mesh wire to sieve out dirt and other animals that may find their way into the reservoirs, and that the water should be chlorinated before use. Several samples were taken from various points in the system for chemical and bacteriological testing.

Table 9, gives the breakdown of the construction costs of the system.

Table 9: Construction Costs of Matongo Rainwater System (Jaakko Lounela & Zephania Ombeta)

Item	Cost in Kenya shillings
Gutters and downpipes	42,400
Pipes in the soil	12,000
Storage tanks	31,400
Worker salaries	15,580
Total	101,380

This breakdown gives a per capita sum of about KShs.200/- assuming that it is serving half the population at Matongo while the other water comes from the well. The values refer to the cost of the system as at 1978. The present worth value of the system and the capita costs should be much higher.

Table 10: Rainwater Quality at Matongo (Mixed Roof Catchment)

Date of Sampling 13/10/83

Parameters		Results
pH		7.3
Colour	TCU	10
Turbidity	NTU	7.0
Permanganate value (20 min)	mg/l $KMnO_4$	7.9
Conductivity	µS/CM	120
Iron	mg/l	<0.05
Manganese	"	<0.01
Calcium	"	14
Magnesium	"	6.0
Sodium	"	14
Potassium	"	13
Zinc	"	0.7
Total Hardness as $CaCo_3$	"	44
Total Alkalinity as $CaCo_3$	"	48
Chloride	"	3.7
Fluoride	"	<0.10
Sulphate	"	0.88
Lead	"	<0.01
Total dissolved solids	"	72
Total colony count/100 ml	"	less than 100

N.B. These analysis results show that this water is of good chemical and bacteriological quality.

Table 11: Quality of Matongo Well Water
Date of Sampling 13/10/83

Parameters		Results
pH		6.7
Colour	TCU	70
Turbidity	NTU	18
Permanganate value (20 min)	$KMnO_4$/L	35
Conductivity	µS/cm	90
Iron	mg/L	<0.05
Manganese	Mg/L	<0.01
Calcium	"	8
Magnesium	"	4.4
Sodium	"	15
Potassium	"	15
Zinc	"	0.2
Total Hardness as $CaCo_3$	"	28
Total alkalinity as $CaCo_3$	mg/L	28
Chloride	"	5.0
Fluoride	"	0.13
Sulphate	"	0.74
Lead	"	<0.01
Total Dissolved solids	"	54
Total colony count/100 ml	"	2,000
MPN of coliforms per 100 ml		100

These results show that this well water is coloured and turbid. There is some organic pollution as well as slight bacterial contamination. This water is of a poorer quality than that of the rainwater collected at the same place. (Table 10). This water should be filtered through a fine sand and charcoal device, and then chlorinated to improve its quality.

5.1.3 Kioge Secondary School

This school has a total population of about 600 students, whose water consumption is estimated at 20 litres per student per day. The school has at the moment two sources of water supply:- stream water and rainwater system. The rainwater system is being used as a supplementary source and only half of the buildings in the compound are harvested. The school at the moment spends about KShs.4,000 per year on diesel oil for pumping water from the stream to the school compound. These charges would be reduced if all the roofs were harvested. In addition the stream water looks bad (turbid and coloured) during the rains and rainwater should be collected especially at this time to avoid drinking contaminated water.

The total roof area is estimated at 2000 m^2. The mean annual rainfall recorded by a measuring station at Nyakoe Farmers Co-Operative Society (operating since 1950) shows a value of 1792 mm up to 1982. The lowest rainfall recorded for the station is 1420 mm recorded in 1955. Other rainfall recordings below 1500 mm are 1432 mm in 1959 and 1482 mm in 1971. The highest rainfall recorded in the station was in 1977 a total of 2454 mm. For design purposes 1420 mm can be taken as the critical rainfall. This gives a possible collectable volume of 2556 m^3 assuming no leaks and a runoff factor of 0.9. Assuming that the students stay in the school for 3 terms (270 days). Then total water consumption would be 3240 m^3. This means that during the dry years the water from the roofs would be insufficient at these times. Alternative sources could be used to satisfy the water demand.

At the moment only part of the roofs are harvested and rainwater only contributes 1/5 of the total water supply. The rest of the water being supplied from a nearby stream. It is quite evident that during wet years tapping all the roofs will provide enough water for everyone; and there will also be a substantial saving in pumping costs.

5.1.4 Gesusu Secondary School

This school is situated on a slope, an ideal site for a roof catchment system utilising gravity flow. The school has a population of 300 students. The estimated consumption per student per day is 20 litres. This would require a total annual storage of approximately 2000 m^3. The estimated roof catchment area is approximately 1500 m^2. At a mean annual rainfall of 2000mm this catchment area is more than enough to meet the school's annual water requirements.

It was observed that the present rainwater harvesting system is underdesigned. Only two large storage tanks of $50m^3$ each and two smaller tanks of $10m^3$ each have been constructed. It is therefore not surprising that the school does experience water shortage problems and students have to obtain water from a spring about 1 km away. More or larger storage facilities should be added. It was also observed that the present rainwater system was not well maintained. The gutters were leaking, and the concrete tanks were badly finished. Pumps installed to pump water to overhead tanks are broken down. At the time of the visit several students were seen drawing water from one of the tanks by means of a bucket and a rope.

Figure 11 shows a layout of the Gesusu rainwater harvesting system while Figure 12 shows students at the school withdrawing water. Figure 13 also shows water being withdrawn from a tank by means of a bucket and a rope.

Fig. 11 Layout of Gesusu Rainwater System

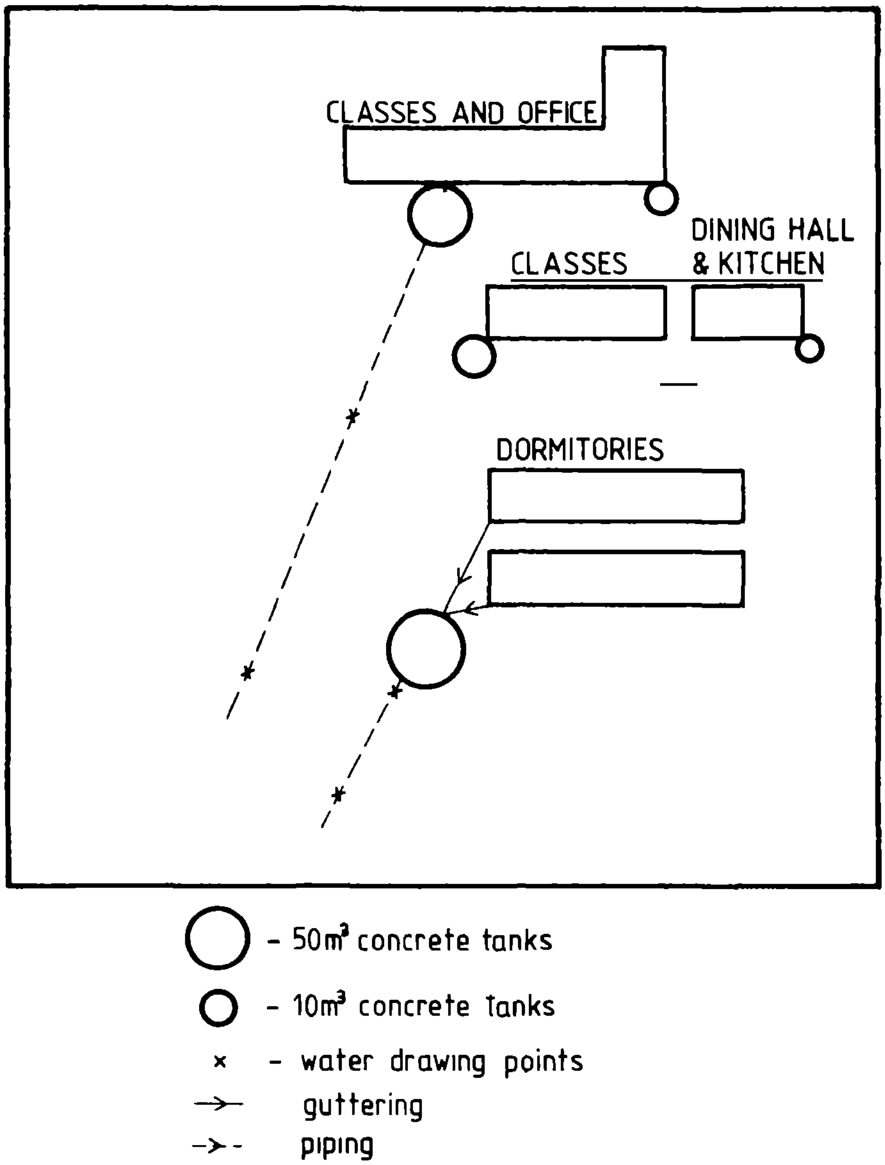
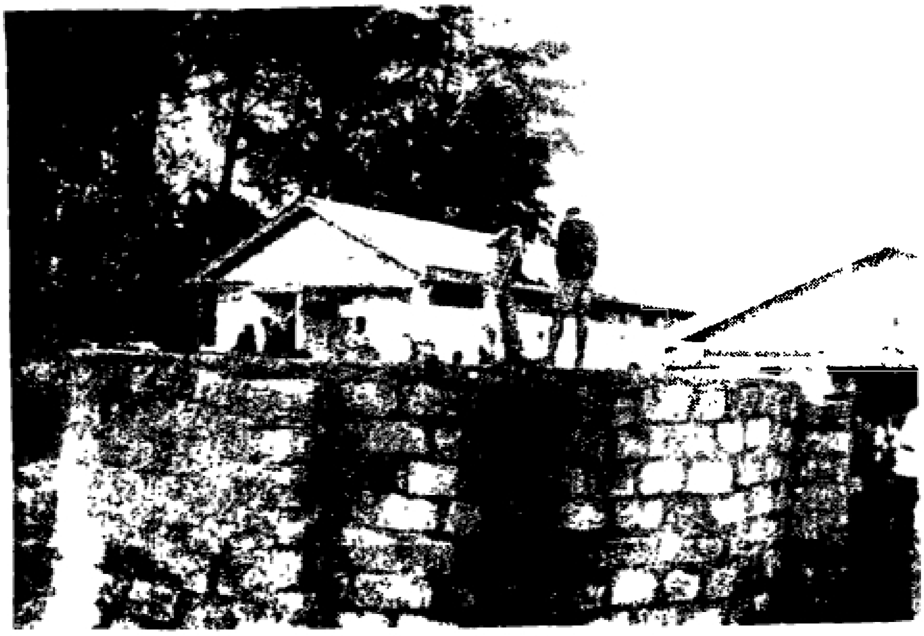


Fig. 12 Students of Gesusu Secondary School withdrawing rainwater from one of the storage tanks.



The picture also shows the badly finished outer-wall of the tank.

Fig. 13. Water withdrawal from Mr. Osoro's water tank.

Such withdrawal practices should be discouraged as they contaminate the water. In this case the tap has been blocked due to bad design. The tank has never been cleaned for 10 years. A climbing ladder can be seen and the area around the tank is covered with shrubs.

Fig. 14. Downpipes at St. Mary's School Mosocho

The figure shows down pipes from one of the classrooms taking water to an underground storage from which it is pumped to an elevated tank before use.

Fig. 15. Elevated water tank at St. Mary's School Mosocho. The tank is calibrated to monitor consumption.

Table 12: Water Quality Characteristics of Gesusu Rainwater

Parameter \ Sample Source and Marks		R2 - Well maintained concrete tank Date 13/10/83	R3 - Badly maintained concrete tank Date 13/10/83
pH		6.3	5.1
Colour	TCU	<5	<5
Turbidity	NTU	1.0	1.0
Permanganate value 20 min	mg/L	7.9	0.63
Conductivity	μs/cm	32	20
Iron	mg/L	<0.05	<0.05
Manganese	"	<0.01	<0.01
Calcium	"	5.6	2.4
Magnesium	"	1.2	1.0
Sodium	"	1.6	1.2
Potassium	"	3.6	3.0
Zinc	"	1.5	1.5
Total Hardness as $CaCo_3$	mg/L	24	10
Total Alkalinity as $CaCo_3$	"	14	5
Chloride	"	1.0	1.5
Flouride	"	<0.10	<0.10
Sulphate	"	1.2	0.5
Lead	"	<0.01	<0.01
Total Dissolved solids	"	19	12
Total colony count/100ml		less than 100	1000

These results show that water samples in the same compound can have different quality characteristics.

In this case the samples were taken from different tanks and different roofs. The high bacterial count in sample R3 may be due to the bad maintenance of the tank. This was because the water was very low in the tank, and could not come through the tap, hence the bucket and rope; a dangerous practice which should be discouraged. The water appeared contaminated with suspended matter and micro-organisms.

Table 12 gives the analysis results of two samples taken from Gesusu. Apart from slight organic and bacterial contamination, the waters are of good quality.

5.1.5 Iterio Secondary School

In this compound are also a primary school, and a mission hospital. Though water is pumped from a nearby spring, roof catchment system would reduce pumping costs as the roof areas are adequate for supplying the water for the population of about 1000. Rainwater harvesting is being practiced in the primary school and there are plans to have a similar system in the secondary school.

5.1.6 St. Mary's School Mosocho

Rainwater harvesting is practiced and supplies about 50 per cent of the school's water needs. All the classrooms and dormitories are tapped. The water is led to a central large tank underground by a system of pipelines. The water is then pumped to an elevated medium capacity tank $30m^3$ from which it flows to the kitchen, bathrooms and other waterpoints under gravity. The other supplementary water source is borehole water and pumping costs have been largely offset by the rainwater harvesting system. The school has a total population of about 200 inhabitants.

5.1.7 Ichuni Secondary School

For a long time this school with a total population of about 700 persons suffered from water shortages during the drought months. The main problem then used to be inadequate rainwater harvesting and storage facilities. A few years ago an extensive rainwater harvesting system was installed tapping all the new buildings in the school, and collecting the water into a central underground tank of capacity $150m^3$. The water is then pumped into an elavated tank before being distributed for use. Now the school has enough water. It also uses treated water from a nearby small town supply of Keroka. Previously the students used to travel about two kilometres to a protected spring to obtain bathing water and trucks were used to transport water for other uses.

5.1.8 Individual Household Systems

Thirty individual household systems were visited. These were made up as follows: 5 well kept galvanised iron sheet - concrete tank systems; 10 galvanised iron sheet; and semi-permanent storage systems, and 15 poorly maintained grass-roof earthenware systems that can only store rainwater on a daily basis. In general it was observed that some of the catchment systems were neglected. No follow up maintenance had been done to the gutters, or tanks since installation in some cases. Gutters were leaking, there were leaves and lots of dust on them, and a substantial amount of water that could otherwise have been collected was lost.

The reservoir floor was in some cases not properly designed (sloping away from the tap) outlet pipes were therefore either fully or partially blocked by leaves and other foreign matter. In other cases the reservoirs had been completely neglected, and, the tanks were outgrown by tall grass and shrubs. Spilling waters from leaking gutters had made the areas around the reservoir wet and swampy during the rains. Also observed was the poor positioning of the tanks and taps making them not readily accessible to use. A number of tanks were not lying on raised wooden supports and the taps were just a few centimetres from the ground making it extremely difficult to draw out water. Many of the taps did not have locks and wasting by children could not be avoided.

5.2 Roofs

The ideal catchment is perhaps an aluminium sheet roof but since this is likely to be too expensive, it is recommended that galvanized iron sheet roofing be used. The sheets should be sloped in a gentle manner to enable the rainwater to flow to the gutters quickly but with little splashing on impact at the gutters.

Of the houses within the study area, about 40 per cent have galvanized iron sheet roofs. About 55 per cent have grass thatched roofs, and a 5 per cent have tile or asbestos roofs. From the point of view of efficient rainwater collection, grass roofing will have to be replaced by galvanized iron sheets. The roof catchment device has, a double advantage:- it provides good means of collecting safe drinking water, and also imparts good outlook to the house. In view of the relatively small roof areas of individual houses, the construction of the roof is recommended to be a single slope. This will result in a considerable saving in the gutters and the ridge. The slope should be directed, towards the entrance of the house so that the reservoir can be easily available at the front of the house. The roof should be of reasonable height to leave room for the tank. The roofs should not be painted. If they have to be painted, the paint should be non-toxic.

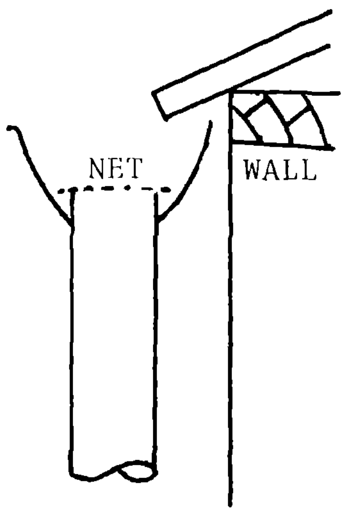
5.3 Guttering

Gutters have the same significance that pipelines have in modern water supply piped systems. The type of gutters used and their arrangement will affect the yield from the roof catchment. The best gutters in use are of galvanized iron, but they are also most expensive. Cheap local materials can be used as an initial alternative especially at household level. Such alternatives may be timber, bamboo, PVC pipes or banana coat.

It was noticed that one of the major handicaps to rainwater harvesting practices in the district is the lack of good durable gutters; as well as lack of storage facilities. When it rains people try to use all kinds of gutters to collect the rain. Precautions to prevent splashing by a good choice of slope was not considered in a number of households visited. It is recommended that where good quality gutters cannot be purchased ridges may be used since they are about four times cheaper than gutters. The current price of a six foot ridge is KShs.18; while that of gutter of about the same dimensions is KShs.60.

In the one-slope roof system, only one gutter will be enough for the system. The pipe leading from the gutter to the reservoir should be slightly raised and capped with a wire net as shown in Figure 16. This is to prevent sediments and other animals and birds from entering the reservoir. The pipe in the gutter should not be raised more than 1 cm to prevent mosquitoes breeding in the accumilated water in the gutter.

Fig. 16: Recommended Terminal Guttering



5.4 Pipelines

Pipelines will be unnecessary for individual supplies. However for community supplies where water is collected from several buildings into one central reservoir pipelines are needed. Though there are several pipeline alternatives, such as stainless steel, lead pipes; plastic pipes are the cheapest and the ones less likely to affect the water quality.

Where rainwater harvesting is envisaged as a source of water supply for a community, the planning should be such that houses are placed conveniently close by to reduce on lengths of collecting pipelines. Mostly the piping used in the systems visited were of PVC and stainless steel.

5.5 Operation and Maintenance

Like other sources of water supply, a rainwater harvesting system should be properly operated and maintained. This means that all the necessary precautions to prevent wastage through leaks and vandalism should be taken. The taps should be provided with locks where necessary and the consumption rates should be monitored.

As was observed in the study area, rainwater harvesting systems are never maintained at all after they have been installed. However, roofing should be checked for corrosion, gutters and pipelines should be checked for leaks, while reservoirs should be cleaned and disinfected periodically.

Though operation and maintenance data and costs are lacking in all the systems visited, it is strongly recommended that such information be made available in order to access the worthiness of the systems. In rural water supply schemes and in large town supplies, annual operation and maintenance costs are usually about 10 per cent of the initial investment cost. Operation and maintenance costs for rainwater harvesting should be much lower.

5.6 Contribution to Total Water Supply

At the moment, no data exists on what percentage rainwater from roofs contributes to total water supply in the study area. From the observation that people still collect water from their polluted traditional sources even during the rains; it may be said that the significance of rainwater collecting as a source of water supply has not been understood by many people. If the little rainwater that is collected on a daily basis by individuals and that which is collected and used in missions and schools is taken together and considered as a percentage of the total water supply it will only be about 10 per cent. A survey on what sources of water supply are used in the district for domestic consumption revealed the following distribution as shown in Table 13.

Table 13: Water Use Distribution

Water Source	% of Users
Rivers and streams	50
Unprotected springs	20
Protected springs	10
Shallow wells	5
Rain water	10
Treated piped water	5

6. RAINWATER STORAGE

6.1 General

Lack of adequate rainwater storage facilities is a common feature in the district. Some villagers have good roof catchments but no storage tanks. In many cases the people use only simple containers like earthenware, tins and used oildrums for their water storage.

If rainwater is to be utilised as a source of water supply in the district, then the people should be encouraged to buy or construct tanks that can store sufficient water all year round, especially during the dry months, when water is likely to be in short supply.

The storage facilities should be constructed above or below the ground. Whatever storage is selected, adequate enclosure should be provided to prevent contamination from humans and animals, leaves, dust and other pollutants. A tight cover should be provided to ensure dark storage conditions so as to prevent algal growth and the breeding of mosquitoes. Open storage tanks should never be used to store water intended for drinking purposes. Such waters will be contaminated and in addition water will be lost through evaporation.

The storage facilities observed in the schools and missions visited were of the permanent or immovable type. The storage facilities in the thirty individual households visited varied from portable movable containers to permanent immovable containers.

Table 14 shows the distribution of storage facilities in the individual homes.

Table 14: Types of Rainwater Storage Facilities

Type of Storage	No. of Houses	Frequency of occurence as a percentage
No device	2	7
Portable containers (Pots, earthenware, pails, plastic buckets)	13	43
Semi-permanent containers (mainly oil drum and gutter)	10	33
Permanent containers (Storage tank and gutter)	5	17

6.2 Permanent Storage Containers

A wide choice of materials exist for the construction of permanent water storage containers. Tanks may be made of concrete, corrugated steel sheeting, wood, clay or waterproofed frameworks. Each storage tank should however be well designed to meet the requirements of volume and tensile strength. The tanks should be calibrated before use so that withdrawals can be monitored.

6.2.1 Concrete Block Tanks

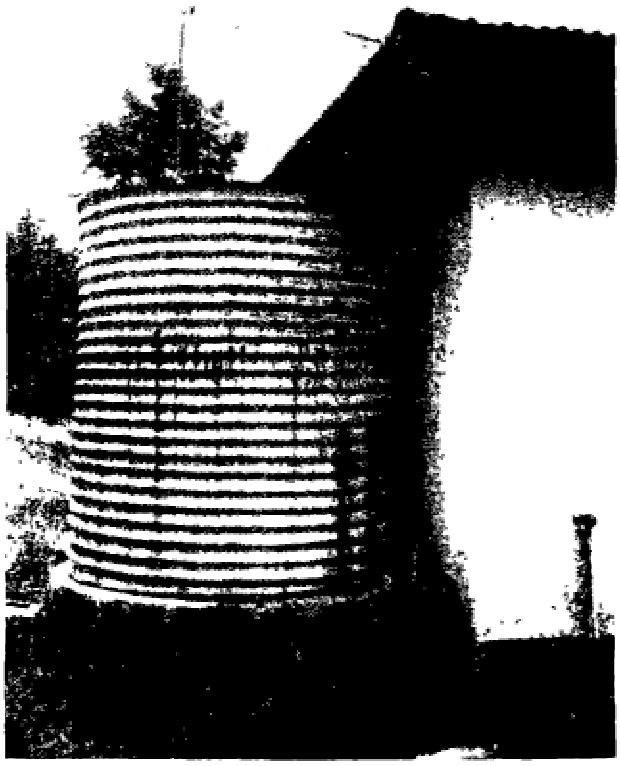
These tanks are strong and are easy to build. However because a lot of cement is used in their construction they are very expensive. The more common shape for the tank is cylindrical but rectangular forms are possible especially when the tank forms part of the wall of a building. The tanks are usually build out of bricks, but concrete rings can also be used.

Due to their being expensive to construct, only very few of them have been constructed in individual homes. They have a life time in excess of thirty years and because of their great tensile strength, and the fact that they can be built to any size, they have been constructed in many social and communal centres. The main storage reservoir at Matongo is an example of a large concrete block tank (Fig. 10). Where large storage volumes have to be stored such tanks should be encouraged.

6.2.2 Corrugated Galvanized Iron Sheet Tanks

These tanks are the quickest and easiest ones to install, but they have to be purchased. Currently a 2.25 m^3 capacity tank which is adequate for holding drinking water for a small family costs KShs.1450/= in Nairobi. The price will vary with locality and transport charges may be quite high. Though these tanks are cheap, they have some serious drawbacks:- They can only be purchased in standard sizes, they are affected by rough handling and corrode easily. Coating the tank with bitumen paint will reduce corrosion. The tank should also be placed on a reinforced concrete foundation. Better still the tank should be placed on a wooden stand on the concrete foundation to ensure that the tank is kept dry to reduce corrosion risk. With care these tanks can last a maximum of about ten years. With careless handling they can last only a few months. Figure 17 shows a rusty corrugated galvanized iron sheet tank. The tank has undergone serious corrosion despite the fact that it is painted with bitumen paint, lower part,and standson concrete foundation.

Fig. 17: Rusty Corrugated Galvanized Iron Sheet Tank



It was learnt that bleaching poweder had been added into the tank to disinfect the water. The corrosion may be due to the reactive nature of bleaching powder and also due to the age of the tank which is 10 years. It is suggested that other simple disinfection methods e.g. silver nitrate, potassium permanganate, iodine be used as these are non-reactive to the tank material. The dosages used should also be well calculated. However despite the visible corrosion, samples of water taken from this tank showed no iron in the water, a factor which may be explained by the low solubility of ferric ions in water.

6.2.3 Granary - Basket Tanks

Bamboo-reinforced concrete and ferrocement tanks have been constructed in areas like China, Thailand and Indonesia (IRC 1981). Similar technology has now been introduced in the study area. The granary basket tank also called the ghala tank is made from a ghala wooden framework. The framework is then cemented with or without a wire mesh as reinforcement. Other modifications of the granary basket tank are the small and large cement jar designed and introduced into the country by UNICEF.

It is estimated that to construct a granary basket tank of capacity $2.0m^3$ would cost half the cost of galvanised iron tank and about one quarter the cost of a concrete block tank of similar capacity. For this reason granary basket tanks should be encouraged as they can be constructed using locally available materials.

Figure 18 shows one form of a granary basket tank as used at Matongo Mission.

Fig. 18: Granary Basket Tank

6.3 Semi-Permanent Storage Containers

6.3.1 Used Oil-Drums

Many individuals in the study area have good roof catchments but cannot afford to purchase or construct permanent storage facilities. It is common to see rainwater in their homes being collected in semi-permanent containers mainly used oil drums. These containers themselves do not look clean, but are used for lack of better alternatives. Figure 19 shows one such form of rainwater collection.

Fig. 19: Used Oil-drum Container

6.3.2 Other-Portable Containers

The majority of individuals cannot afford any form of permanent or semi-permanent storage, and this will be the biggest handicap in trying to encourage rainwater harvesting among individuals. It is a common observation to see people throwing out all possible containers (pails, sufurias, pans, pots etc) to catch water from their roofs when it rains.

Earthernwares are very common containers used for water collecting but they are very fragile. They are locally obtained. They are used together with plastic containers. However these are slightly more expensive than earthenwares. In all respects these type of containers should be discouraged as rainwater storage containers. They can only be used for short term water holding. Fig. 20 shows an assortment of different portable containers as used in one household. These containers now stand, where a galvanised iron tank used to stand. The pegs that formed the platform for the tank can also be seen. Figure 21 shows the leaky and rusty tank that had been removed from the position indicated on Fig. 20. This tank had started to leak. Repairs of such tanks are difficult to implement.

Fig. 20: An Assortment of Portable Containers

The figure shows all sorts of portable containers, standing where a galvanized iron sheet tank used to sit.

Fig. 21: Discarded Rusty and Leaky Galvanized Iron Sheet Tank

This tank started to leak and was removed. The former position is now occupied by an assortment of portable containers (see figure 20). Such tanks are difficult to weld in the countryside.

6.4 Surface and Sub-Surface Storage

Where large volumes of water are to be stored, large reservoirs or dams will be needed. These reservoirs may be on the surface or below the ground.

The storage reservoir at Viongozi Centre in the study area is a good example of sub-surface storage (Figure 8). This reservoir was excavated by tractor, the bottom covered with a water-tight plastic lining and then covered with a galvanized iron roof. The reservoir has an external appearance of a house, the roof keeps the water cool, reduces evaporation, and prevents aerial contamination. The main storage tank at St. Mary's School, Mosocho is also sub-surface storage tank.

Sub-surface storage saves on space and other construction costs e.g. walls in the case of concrete-block tanks. One disadvantage with this type of storage is that the water has to be pumped out to the surface or to an elevated tank before use.

Other forms of sub-surface storages are:- storage wells used in China and bee-hive storage structures which have been constructed in Sudan, Botswana, Swaziland, Brazil and Jamaica (IRC, 1981). Such technology could be introduced into the study area when rainwater harvesting is taken seriously as a source of water supply.

7. RAINWATER QUALITY

7.1 Sampling and Analytical Programme

A scheme intending to monitor how rainwater quality changes during the various stages of collection as well as the general rainwater quality in the study area was devised.

The sampling was timed to coincide with the start of the rains, in order to pick the first rainfall samples. Other samples were then later collected from various combinations of roof catchment and storage reservoirs and subjected to both physico-chemical and bacteriological analysis. Biological analysis, though intended was not carried out due to lack of facilities.

Samples were taken from new and old roofs and tanks to determine the effect of roof age on water quality. For a comparative water quality assessment samples were also taken from rivers, streams, wells and other traditional sources.

In all 30 samples were collected and analysed. No attempt was made to check the effect of storage on water quality in view of the short project time.

7.2 Laboratory Analysis

The sampling and analysis was carried out according to the procedures in APHA's Standard Method for the Examination of Water and Wastewater 15th edition.

The metal analysis was carried out by atomic absorption spectrophotometry. Analysis for pesticide residues and asbestos fibres could not be done due to the limitations of the laboratory facilities. Biological analysis, though intended, was also not carried out. Nevertheless from the physico-chemical and bacteriological analysis carried out, it is possible to draw out some water quality conclusions.

7.3 Drinking Water Quality Guidelines

The following water quality guidelines have been proposed by the WHO (Galal-Gorcher H. et. al.). They are divided into three parts:- Aesthetic quality, Inorganic constituents of Health significance and Bacteriological quality. These are presented in tables 15, 16 and 17 respectively.

Table 15: Aesthetic Quality

Parameter	Concentration mg/L
Aluminium	0.2
Chloride	250
Copper	1.0
Hardness as $CaCo_3$	500
Iron	0.3
Manganese	0.1
Sodium	200
Sulphate	400
TDS	1000
Zinc	5
Colour	15 TCU
Taste and Odour	Not offensive for most consumers
Turbidity	5 NTU
pH	6.5-8.5

Table 16: Inorganic Constituents of Health Significance

Constituent	Concentration mg/L
Arsenic	0.05
Cadmium	0.005
Chromium	0.05
Cyanide	0.1
Fluoride	1.5
Lead	0.05
Mercury	0.001
Nitrate as N	10
Selenium	0.01

Table 17: Bacteriological Quality

Piped Supplies	Number per 100 ml
(i) Treated water entering distribution system	Feacal coliforms 0 Coliform organisms 0
(ii) Untreated water entering distribution system	Feacal califorms 0 Coliform organisms 3 in anyone 0 in 2 consecutive samples 0 in 98% of yearly samples.
(iii) Water in distribution system	Feacal coliforms 0 3 coliform organisms in anyone or 0 in 2 consecutive samples 0 in 95% of yearly samples.
Unpiped Supplies	Feacal Coliforms 0 Coliform organisms 10.
Bottled drinking water	Feacal coliforms 0 Coliform organisms 0
Emergency supplies of Drinking water	Feacal coliforms 0 Coliform organisms 0

Table 18: Sample Sources

Sample Marked	Origin/Source	Roof Type	Storage Tank Type	Other Remarks
R1	Ichuni	Galvanized iron	Galvanized iron tank	3 years old system
R2	Gesusu	Galvanized iron	Concrete tank	10 yrs old system
R3	Gesusu	" "	" "	10 " " "
R4	Gichana's house	Painted galvanized iron	Used oil drums	10 yrs old roof
R5	Osoro's Hse	Galvani ed iron	Concrete tank	10 " " system
R6	Morira's Hse	Grass roof	Earthern ware	1 yr old system
R7	Osoro's Hse	Grass roof	Earthen ware	30 yrs old
R8	Kisii town	Rusty galvanized iron	Rusty galvanized iron	8 yrs old
R9	Kisii town	-	-	well water
R10	Kisii town	Galvanized iron	concrete tank	20 yrs old
R11	Kisii town	Galvanized iron	Galvanized iron tank	1 yr old
R12	Matongo	Asbestos, painted roofi Galvanized iron	Concrete tank	5 yrs old
R13	Matongo	-	-	well water
R14	Matongo	Asbestos	Galvanized iron tank	10 yrs old
R15	Matongo	Asbestos	Galvanized iron tank	" " "
R16	Matongo	Painted galvanized iron	Galvanized iron tank	" " "
R17	Nyakoe	-	-	O ogusi river
R18	Kioge	-	-	Spring water
R19	Kioge	galvanized iron	Galvanized iron tank	10 yrs old
R20	Kisii town	Painted galvanized iron	galvanized iron tank	10 yrs old

......./continued

Table 18 .... continuation

Sample Marked	Origin Source	Roof Type	Storage Tank Type	Other remarks
R21	Orina's well	-	-	well water
R22	Kisii town	Tiles	galvanized iron tank	7 yrs old
R23	Matongo	-	-	Pond water
R24	Nyakoe	-	-	Omogusi river
R25	Gesima	-	-	Unprotected spring water
R26	Viongozi Centre	Galvanized iron, Asbestos	plastic lined sub-surface tank	8 years old
R27	Riakworo	-	-	Unprotected spring water
R28	Matongo	-	-	Ground catchment
R29	Kereri	-	-	Unprotected Spring water
R30	Nyakoe	-	-	Background rainwater

7.4 Analysis Results and Their Discussion

The sources of the samples is shown in table 18. The table shows in addition to the source of the sample, the type of roof catchment and storage system used. The age of the rainwater system has also been included.

The results are discussed with special reference to selected key parameters. The possible effects of roof type tank type and roof and tank age on water quality is also considered under the individual key parameters.

For ease of reference, the analytical results have been tabulated under four separate groups. These are as follows:- Table 19a, water quality characteristics of rainwater samples from galvanized iron roof-galvanised iron tank and galvanised iron roof-concrete tank systems. Table 19b, water quality characteristics of rainwater samples from grass, asbestos, tile and painted roofs. Table 19c, water quality characteristics of samples drawn from wells and springs. Table 19d, water quality characteristics of samples drawn from rivers and ponds.

It should be noted that the interval between sampling time and analysis was about five days. The samples had to be transported a distance of 500 km to the city of Nairobi for analysis. Precautions were taken to preserve the samples in order to reduce both chemical and biochemical deterioration. Except for very slight changes that may have occurred during the transit period, the analytical results obtained can be taken as being reasonably reliable.

Table 19a. Water Quality Characteristics of rainwater Samples from Galvanised Iron Roof Galvanised Iron tank; and galvanised iron roof-concrete tank systems

Sample Source and Marks / Parameter	R1-Galvanized iron roof galvanised iron tank Date: 10/10/83	R2-Galvanized iron roof contrete tank system Date 10/10/83	R3 Galvanised iron roof-concrete tank system Date: 10/10/83	R5-Galvanised iron roof-concrete tank system Date: 10/10/83	R8-Galvanised iron roof and tank (Rusty) Date: 11/10/83	R10- Galvanised iron roof concrete tank system Date:11/10/83	R11 - New galvanised iron roof and tank Date: 11/10/83	R19-Galvanised iron roof and tank. Date: 12/10/83
pH	6.0	6.3	5.1	6.7	6.5	6.4	6.5	5.8
Colour, TCU	<5	5	<5	<5	<5	10	5	5
Turbidity, NTU	0.7	0.9	1.0	0.5	0.9	0.9	0.8	0.9
Total dissolved solids ppm	8.4	19	12	17	9	14	16	7.2
Conductivity μs/cm	14	32	20	28	15	23	27	12
Total alkalinity $CaCo_3$ ppm	4	14	1.0	18	7	9	14	12
Total Hardness, $CaCo_3$ ppm	12	12	10	16	16	20	32	12
Calcium ppm	2.4	3.6	2.4	4.0	2.0	4.8	2.4	1.0
Magnesium "	1.5	1.2	1.0	1.6	1.2	2.4	2.7	1.1
Iron "	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Manganese "	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc "	2.0	1.6	1.5	1.0	2.7	0.9	3.6	3.0
Sodium "	1.9	1.6	1.2	2.3	1.9	5.5	8.5	2.2
Potassium "	2.2	3.6	3.0	2.8	2.2	7.9	12	2.5
Chloride "	1.0	1.0	1.5	1.0	1.0	1.0	2.0	0.8
Sulphate "	1.0	1.2	0.50	0.60	0.5	0.63	0.70	0.30
Fluoride "	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Permanganate value"	1.0	7.9	0.60	0.60	2.8	6.9	11	2.8
Lead "	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Standard plate count /100ml	<100	<100	1000	<100	14500	<100	3200	<100
MPN of coliforms/ 100 ml	2	2	8	2	-	2	-	2
E. coli per 100 ml	0	0	0	0	-	0	-	0

N.B. For other details of sample marks please refer to table 18. The pH value of a background water sample, R30, was 5.0

Table 19b. Water quality characteristics of rainwater samples from grass, asbestos, tile and painted roofs

Sample Source and marks / Parameter	R6-New grass roof Date: 10/10/83	R7-Old grass roof Date: 10/10/83	R4-Painted roof Date: 10/10/83	R16-Painted roof Date: 12/10/83	R20-Painted roof Date:12/10/83	R15-Asbestos roof Date:12/10/83	R22- Tiled roof Date: 10/11/83	R14- Asbestos roof Date: 11/10/83	R12-Mixed roofs Date 11/10/83	R26- Mixed roofs Date: 10/11/83
pH	7.6	6.3	5.9	6.8	5.4	7.1	7.0	6.5	7.3	5.7
Colour TCU	85	150	10	<5	15	5	<5	5	10	<5
Turbidity NTU	2.0	3.0	2	0.9	8.0	0.6	2.0	1.0	7.9	1.0
Total dissolved solids ppm	18	27	8	9.6	29	22	54	20	72	11
Conductivity µs/cm	30	45	13	16	48	36	90	33	120	18
Total alkalinity, $CaCo_3$ ppm	28	12	4	12	10	12	36	14	48	4
Total Hardness, $CaCo_3$ ppm	12	14	10	18	16	22	45	16	44	10
Calcium ppm	2.7	2.0	1.6	4.8	2.4	6.4	14	5.0	14	2.4
Magnesium "	1.3	2.2	1.2	1.9	2.8	1.4	2.4	1.0	6.0	1.0
Iron "	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-	-	<0.05	<0.05
Manganese "	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	<0.01	<0.01
Zinc "	0.2	0.1	2.4	1.4	0.14	1.0	-	-	0.7	0.3
Sodium "	2.0	2.0	2.1	6.3	6.5	7.0	-	-	14	-
Potassium "	3.8	9.3	2.4	11	11	8.6	-	-	13	-
Chloride "	1.5	2.5	1.5	1.5	1.5	1.0	3.0	0.60	3.7	1.0
Sulphate "	0.60	1.2	0.29	1.8	0.63	1.3	1.7	0.67	0.90	0.50
Fluoride "	0.11	<0.10	<0.10	<0.10	0.16	<0.10	0.15	-	<0.10	<0.10
Permanganate value ppm	56	57	4.7	1.3	1.3	2.8	4.4	2.8	7.9	7.0
Lead	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-	-	<0.01	<0.01
Standard Plate count/100ml	100	200	4700	1600	-	2300	-	<100	<100	<100
MPN of coliforms /100ml	32	-	-	-	-	-	-	2	8	8
E. coli/100ml	-	-	-	-	-	-	-	0	0	0

NB: For other details of sample marks please refer to table 18.

Table 19c. Water quality characteristics of Samples drawn from wells and springs in the study area

Sample Source and Marks / Parameter	R9-Well water at Kisii town. Date: 11/10/83	R13-Well water at Matongo Date: 11/10/83	R18-Spring water at Kioge. Date:12/10/83	R21- Well water from Orina's home Date:12/10/83	R25-Unprotected spring at Gesima. Date:10/11/83	R27-Unprotected spring at Riakworo Date:10/11/83	R29- Unprotected spring water at Kereri Date:10/11/83
pH	6.2	6.7	7.8	6.0	5.3	5.4	5.7
Colour TCU	<5	70	175	10	10	15	<5
Turbidity, NTU	0.8	18	30	2.0	7.0	6.0	2.0
Total dissolved solids ppm	7	54	84	6	49	51	68
Conductivity μs/cm	12	90	140	10	82	84	115
Total alkalinity, $CaCo_3$ ppm	8	28	56	4	12	12	34
Total Hardness, $CaCo_3$ ppm	14	28	64	10	10	12	36
Calcium ppm	3.0	8.0	14	1.6	3	4	8.0
Magnesium "	1.5	4.4	7.0	1.4	0.6	0.6	4.0
Iron "	<0.05	<0.05	<0.05	<0.05	-	-	-
Manganese "	<0.01	<0.01	<0.01	<0.01	-	-	-
Zinc "	2.0	0.2	1.7	1.5	-	-	-
Sodium "	6.0	15	12	7.0	-	-	-
Potassium "	6.4	15	11	3.6	-	-	-
Chloride "	1.0	5.0	2.0	0.80	2.0	2.5	3.0
Sulphate "	1.3	0.80	0.29	0.31	0.33	0.33	1.3
Fluoride "	<0.10	0.13	<0.10	0.10	0.25	0.26	0.19
Permanganate value ppm	4.4	35	7.1	2.2	5.7	27	6.0
Lead "	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Standard Plate count /100 ml	20000	2000	200	500	1900	4000	3000
MPN of Coliforms/ 100ml	-	100	-	-	35	-	-
E. coli /100ml	-	-	-	-	12	-	-

Table 19d. Water quality, characteristics of samples drawn from rivers and ponds in the study area

Sample Source and Marks / Parameter	R17 - Omogusi river Date: 12-10-83	R23- Pond water at Matongo Date: 10-11-83	R24 - Omogusi river Date: 10-11-83	R28 - Ground Catchment at Matongo Date: 10-11-83
pH	7.3	7.1	6.5	6.5
Colour, TCU	200	300	250	20
Turbidity NTU	34	240	190	23
Total dissolved solids ppm	41	99	42	26
Conductivity μs/cm	68	165	70	44
Total alkalinity, $CaCo_3$ ppm	28	64	22	18
Total hardness, $CaCo_3$ ppm	40	28	30	12
Calcium ppm	5.6	8.0	5.0	3.2
Magnesium ppm	13	2.0	4.2	1.0
Iron ppm	7.0	-	6.5	-
Manganese "	<0.01	-	<0.01	-
Zinc "	1.3	-	1.2	-
Sodium "	13	-	12	-
Potassium "	13	-	10	-
Chloride "	2.4	7	2.0	2.0
Sulphate "	2.4	<1.0	2.1	<1.0
Fluoride "	-	0.9	-	0.30
Permanganate value ppm	21	38	31	27
Standard plate count, colonies/ 100ml	1200	1000	16000	5000
MPN of coliforms/ 100ml	-	170	1800^+	-
E. coli per 100 ml	-	170	1800^+	

7.4.1 pH

The World Health Organisation guidelines for water quality recommend a pH range of 6.5 - 8.5 for waters to be used for domestic consumption. In general most of rain water samples from galvanised iron roof catchments and a combination of either galvanized iron tank or cement tanks had pH values below 6.5. The lowest pH of 5.0 was recorded for a background sample. The results show that the pH value seems to increase slightly as the rainwater runs down the roof catchment and into the storage tanks.

In contrast to the low pH values of samples from galvanised iron roofs, the pH values from other roof catchments (table 19b) are generally much higher, with the highest pH of 7.6 being recorded for water from new grass roofs. High pH values are recorded for rivers and ponds (table 19d) while some wells and springs indicate rather low pH values; (see table 19c).

It may be concluded therefore that most of the waters in the project area are of acidic nature. This means that this water will be corrosive to storage facilities like galvanised iron tanks and pipelines. This corrosive nature of the waters will very much reduce the lifetimes of such devices.

These waters should not be condemned as unfit for drinking purposes because of the low pH values. There are many more acidic drinks being consumed by people everyday. However, if one really wants to raise the pH of these waters, lime or soda ash should be added in calculated doses to the water.

7.4.2 Taste and Odour

It was observed that first rains samples had a rather flat and unacceptable taste while those from new galvanised iron tanks and cement tanks had a slight metallic or tank taste which may be offensive to some users. It has been recommended that such waters be flushed out initially before usingthe systems to store rainwaters. Only grossly polluted waters from alternative sources of water supply (rivers, ponds, streams and springs) had an earthy or marshy odour. Generally waters from these sources had acceptable taste and odour characteristics.

7.4.3 Colour and Turbidity

Except for the first rains samples which are characterised by high colour and turbidity, most of the samples from the roof catchments had colour and turbidity below the WHO guidelines of 15 TCU and 5 NTU.

The only exceptions are samples from grass roofs which had a very high colour. The waters from rivers and ponds, and some wells and springs had colour and turbidity units in excess of the WHO guidelines. Filtration through a fine sand filter or in combination with powdered charcoal is recommended to reduce the colour of such waters. Alum may be added to reduce turbidity, or the waters just allowed to settle out on their own.

7.4.4 Organic Matter

It was noticed that the water samples from sources other than rainwater catchments had generally higher permanganate values indicative of pollution of organic origin. Though most samples from rainwater catchments showed very little organic contamination e.g. sample R3, R5 and R20 some showed incidences of organic contaimination e.g. R11. The samples from grass roofs showed very high organic contamination, the permanganate value of the results show that samples collected from new roofs and tanks and from grass roofs are polluted with organic matter. The permanganate value used in these analysis was the 20 minute test.

7.4.5 Total Dissolved Solids/Conductivity

None of the waters collected from the study area had a conductivity of over 200 μs/cm. In fact all the waters are fresh and non-saline in the area. The highest recorded conductivity was 140 μs/cm for spring water at Kioge Secondary School. The water from mixed roof catchments (asbestos, painted galvanised and galvanised iron roofs) all discharging into one reservoir at Matongo showed a high conductivity of 120 μs/cm. This high conductivity may be attributed to the leaching of salts from pipelines, gutters and intermediate tanks. The ratio between conductivity and total dissolved solids was found to be between 0.5 and 0.7 for most of the waters in the area. The TDS values are well below the maximum stipulated by the WHO of 1000 mg/L. It may be argued here that rainwater may therefore be too clean to drink, due to its low mineral content. However, as man eats and drinks other liquids, the deficit in mineral content in the rainwater can be compensated for from other foods eaten like vegetables and meat.

7.4.6 Hardness

All the samples collected in the study area have total hardness values expressed as mg/L $CaCo_3$ of between 10 - 50 mg/L. This indicates that the water may be classified as soft to very soft. The WHO guidelines for drinking water regarding this parameter is that samples should have less than 500 mg/L. These waters are good for washing, laundry and other industrial activities that require soft waters. The only danger is that they may be corrosive to pipes and storage tanks, as has been mentioned already under pH consideration.

7.4.7 Zinc

All the rainwater samples collected had some Zinc ions, so had the samples from alternative sources of water supply. One of the rainwater samples from a new roof and tank had Zinc concentration of 3.6 mg/L, (sample R11). This is still much lower than the WHO guideline maximum of 5 ppm. In general samples from galvanized iron roofs and tanks have higher zinc contents than those from other catchment - storage combinations. This must be due to the dissolution effect of the acidic water on the zinc coating on the roofs and tanks. However, galvanised iron roofs have been recommended as the best roof-catchment, since they are cheap to put up, runoff is good and improves appearance of the house.

7.4.8 Iron

All the samples analysed showed little or no iron at all in the water except the sample from river Omogusi, R17 which had a concentration of 7 mg/L. This high iron concentration results from leaching the soils of the area which are said to be very rich in iron. The surprisingly low iron in waters from rusty galvanised iron tanks and roofs may be explained by the fact that the rust which is an oxide of iron is insoluble in water. Rusty roofs and tanks do not seem to be a threat to rain water quality. The iron may be present as an insoluble sediment at the bottom of the tank, but of course the tanks and roofs don't look good.

7.4.9 Lead

All the samples analysed showed no presence of lead. This may be due to the fact that no lead sources could be identified in the study area.

7.4.10 Fluoride

All the samples in the study area showed very low fluoride values. Generally rainwater has little or no fluoride. In areas where fluoride levels prohibit the use of other sources of water supply, rainwater could be a good substitute, or at least a good supplement even for drinking purposes only. The deficits in fluoride found in rainwaters can be compensated for by eating vegetables or drinking tea, a thing done by most people.

7.4.11 Bacteriological Quality

Only waters collected at the start of the rains, and those from badly maintained tanks like the one at Gesusu (Fig. 12) and the samples from grass-roof earthernware combinations had high bacterial colony counts. However none of the coliforms was of feacal origin when this confirmatory test was carried out.

The samples drawn from other sources of supply (R17, R20, R23, R24, R25, R27) showed very high bacterial colony counts, as well as the presence of feacal coliforms. It therefore looks reasonable to recommend the use of rainwater for drinking; but it has to be collected properly, to ensure good bacteriological quality.

7.4.12 Biological Analysis

Although this analysis was not done, bottom sediment samples have been shown to contain larvae of the chironomidae (fly) family, the water flea (cyclops spp.), the segmented worm (Nais spp), and the larvae of the midge. (Gerardi, H.M.). These micro-organisms are not harmful and can be eliminated by simple chlorination and proper design, maintenance and operation of the storage systems. However, many more and more harmful biological species can be expected in the ponds, rivers and the unprotected springs currently used as sources of drinking water. In this regard rainwater harvesting should be encouraged since its biological quality can be easily assured.

7.5 Simple Water Treatment Methods

If design considerations are adhered to, and the rainwater system is operated and maintained properly, clean good quality rainwater will be collected. However, where contamination has occurred, the following simple treatments may be applied (Wagner E.G. et. al., 1959).

* Use of a pot chlorinator with chlorine tablets.
* Use tincture of iodine (2 drops/litre for 3 minutes).
* Use silver ions (0.05 mg/litre dose).
* Use potassium permanganate (0.5 g/litre).
* Use filtration by a small sand filter or ceramic filter.
* Use filtration by a mixture of very fine sand and powdered charcoal.

* Boil the water before use.
* Coagulate by suspending a bag containing a coagulant e.g. alum in the storage reservoir. This helps in clarifying the water.
* Store the water indefinitely (say 90 days). This may require an extra storage reservoir. This may help in destroying any pathogenic bacteria in the water.

8 COST OF RAINWATER HARVESTING SYSTEMS

In discussing the cost of rainwater harvesting systems, the total costs incurred in putting up a complete house will not be considered. It is an accepted fact that people will always put up houses to live in, and the houses will in most cases have usable roofs. Therefore, only the costs of the roof catchment, gutters, pipelines and storage tanks will be discussed.

8.1 Cost of Roof Catchment

It should be stressed that if people intend to harvest rainwater from their roofs then they should select a suitable roofing material. Galvanized iron sheet roofing has been recommended as a practical roofing since it gives good runoff and does not affect the water quality. The people should also be asked to build permanent or semi-permanent houses as this also ensures that a suitable roof catchment will be available.

The general trend in Kisii District is that people are moving from semi-permanent grass-thatched houses to semi-permanent and permanent galvanized iron roofed houses. It is estimated that at the moment about 40 per cent of the houses in Kisii District have galvanized iron roofs which can be used for rainwater harvesting.

To estimate the cost of a roof catchment we will consider the housing requirements of a family of six to ten persons. Such a household will have several houses out of which one or two will be permanent or semi-permanent with galvanized iron roofs. The total usable roof area of such houses will be 50 - 100 m^2, depending on the shape and size of the houses. It has been estimated that such a roof catchment will require about thirty galvanized iron sheets. According to the current prices these will cost between KShs.2,000 - 3,000.

A small household will therefore only be required to invest a maximum of KShs.3,000 to put up a suitable roof catchment. This works out to a per capita roof catchment cost of about KShs.300. The same argument as above will hold when considering water supplies for large communities like schools, missions and hospitals. In general the roof area will be quite extensive in such cases, but it will again be important to remember that whenever possible and if rainwater harvesting is intended galvanized iron roofing should be used.

8.2 Cost of Gutters and Pipelines

Whereas good gutters are a must for individual water supplies, both gutters and pipelines are necessary for large community supplies. If we consider the guttering requirements of a small household of six to ten persons, this will be 20 - 30 metres for one house or about 50 metres for two houses. At the current prices of KShs.60 a gutter of two metres this gives a total cost estimate of KShs.1250. If ridges are used as gutters, as most people do, then at the current price of KShs.18 per ridge of two metres the total cost estimate gives a cost of KShs.450. When local materials like bamboo and wood are shaped and used for guttering the costs will be very much reduced.

When considering large communities, the costs of laying downpipes and pipelines in the soil will have to be considered along with the costs of guttering. As has been shown in the total cost of the Matongo rainwater system, table 9, gutters, downpipes and pipes in the soil account for up to 50 per cent of the total cost of the system. They are expensive. The costs of good gutters and pipelines continues to be a big problem for those who intend to harvest rainwater from their roofs, because of their big costs.

They also have the added disadvantage that they can be easily damaged or pulled away by vandals if not layed properly.

For purposes of discussion the costs of good gutters will be taken at the current estimated cost of KShs.1,250 for a small household, giving a per capita cost of KShs.125. For large communal supplies, the cost of the pipelines will be taken as 40 - 50 per cent of the total cost of the rainwater harvesting system.

8.3 Cost of Storage Tanks

It was observed that the biggest obstacle to collecting rainwater for domestic purposes is the unavailability of suitable storage facilities. It has already been observed in the survey that only a small fraction of the people can afford to build permanent storage facilities for themselves, the rest being unable to purchase even semi-permanent storage facilities. We will consider here the costs of galvanised iron tanks, granary basket tanks and concrete block tanks.

8.3.1 Corrugated Galvanized Iron Tanks

A survey of current prices of corrugated galvanized iron tanks for water from a prominent dealer in the city indicated the following prices as shown in table 20.

Table 20. Cost of Corrugated Galvanized Iron Tanks

Tank Size/Capacity		Price in Kenya Shillings
Gallons	Litres	
200	900	890
500	2250	1450
1000	4500	1920
1500	6750	2950
2000	9000	3540

These prices will fluctuate, depending on the area where the purchase is made, and do not include transportation which can sometimes be high. A storage tank of capacity 4.5 m^3 could suffice for holding water for drinking purposes only for a small household of six to ten persons. However, if larger water consumptions are envisaged say 20 l/per capita/day for normal domestic consumption, then the larger tank of capacity $9m^3$ can be used. This storage tank in conjuction with other storage facilities can supply sufficient water for a small household (10 persons) for a period of drought of two months. This tank costs KShs.3,540.

8.3.2 Granary Basket Tank

A visit to the centre for Research Training for Village Technology at Karen, Nairobi gave the following cost breakdown (Table 21), for the easy to build granary basket or ghala tank.

Table 21. Cost of a Granary Basket Tank

Tank Size/Capacity	Price estimate in Kenya Shillings
1500 litres	
Basket & framework	300
Pipe and tap	100
3 bags of cement	250
½ ton of sand	100
Wire mesh	100
Labour	100
Total Cost	950

For adequate storage for drinking water, two such tanks will have to be constructed. This will bring the total cost to KShs.1900. These tanks therefore provide one form of a cheap storage facility, which can be exploited to good benefit. Moreover the estimated lifetime of such tanks is about 20 years as compared to less than 10 years for the galvanized iron tanks.

A modification of this Ghala basket tank is the cement water jar. This requires reinforcement bars, chicken wire, plane sheet metal, saw-dust or sand, cement and americano sheeting. All these are totally estimated at KShs.1,250, with a lifetime of 10 years. This is yet another cheap alternative storage reservoir.

8.3.3 Concrete-Block Tanks

A cost estimate for a small concrete-block tank for a small family of 6 - 10 persons at current prices revealed the following breakdown (Table 22).

Table 22: Cost of Concrete Block Tanks

Tank Size Capacity

5000 litres

Item	Quantity	Estimated cost in KShs.
Ordinary cement	6 bags	500
Waterproof cement	2 kg	200
Coarse sand	1 ton	250
Aggregate small size	1 ton	150
Ballast (large aggregate)	½ ton	100
Barbed wire	50 m	200
Pipe and tap	1	100
Nails and Timber		400
Galvanized iron sheets	4	400
Labour		500
Reinforcement bars		1500
Total		4300
Transport cost and other sale conditions @ 100%		4300
Total cost		8600

Constructing up this kind of tank is indeed expensive. However one consoling factor is that the tank once constructed may last as long as the lifetime of the house itself. This has been estimated to be 50 years. This indicates a long term saving in maintenance and replacement costs that may have to be incurred with other storage reservoirs. The initial investment costs are high and may be higher than estimated due to the sale conditions of some items like sand, ballast, and barbed wire.

8.4 Comparative Cost Analysis

In order to evaluate the feasibility of utilising rainwater roof catchment as a source of domestic supply in Kisii District, a comparative cost analysis of the different water supply alternatives is considered.

From the foregoing cost analysis the following cost estimates can be presented for a rainwater roof catchment system. However since the cost of the system will depend on the type of reservoir being used and on the type of catchment and also on the size of community to be supplied, the figures presented here should only be treated as realistic estimates.

Let us consider the cost of putting up a rainwater harvesting system that could supply a small household of 6 - 10 persons. The cost of the system will be considered under three separate cases depending on a combination of catchment and storage facility as shown in tables 23a, 23b, and 23c.

Table 23a. Cost of a rainwater harvesting system - Case 1 - Galvanized iron sheet catchment Granary basket reservoir, capacity $3m^3$.

	Estimated cost in Kenya Shillings
Roof catchment	3,000
Pipelines	-
Good Gutters	1,000
2 Ghala tanks	1,900
Water treatment	-
Operation and maintenance	200
Total cost	6,100

Pipeline costs are not included here as they will not be required for a small household.

If precautions are taken in the design and operation of the system, the water will be quite clean and will require no treatment. Operation and maintenance will not feature prominently for a single household supply.

The estimate therefore yields a per capita cost of KShs.610. However if the cost of catchment is excluded from the total cost, we obtain a per capita cost of KShs.310 . This case gives the cheapest cost estimate for a rainwater harvesting system.

Table 23b. Cost of a rainwater harvesting system - Case 2 - Galvanized iron sheet catchment and tank capacity 4.5m^3

	Estimated cost in KShs.
Roof catchment	3,000
Pipelines	-
Good gutters	1,000
Corrugated Galvanized iron tank	2,000
Transportation of tank	500
Maintenance and treatment	200
Total cost	6,700

This total estimate gives a per capita cost of KShs.670. Again if the cost of the roof catchment is not included in the total cost from the assumption that people will always build houses, then we have a redued per capita cost of KShs. 370. This case gives the second cheapest cost estimate for a rainwater harvesting system.

Table 23c. Cost of Rainwater harvesting system - Case 3 - Galvanized iron sheet catchment with a concrete block tank of capacity 2.5 - 5m^3

	Estimated cost in KShs.
Roof catchment	3,000
Pipelines	-
Good gutters	1,000
Concrete block-tank	8,600
Maintenance and treatment costs	200
Total	12,800

This estimate yields a per capita cost of KShs.980-1280. This is the most expensive cost estimate for this system.

The following tables 24, 25, 26 and 27 give cost estimates for alternative sources of water supply for hand pump well, borehole; well lined with concrete rings, shallow well lined with bricks, and protected spring. The estimated figures have been extracted from a consultancy report prepared by Kefinco, for an area in the same region.

Table 24: Construction Costs for a Hand-Pump well, (Borehole) 35 m deep produced with a drilling machine

		Estimated cost in K.Shs.
1.	Capital cost of drilling equipment	4,200
2.	Service and repairs of drilling equipment	2,900
3.	Drilling bit	300
4.	Survey of a well site	
	- capital costs	700
	- direct costs	1,600
5.	Fuel	2,500
6.	Salaries including watchmen	1,700
7.	Transportation of drillers	1,200
8.	Construction materials	
	- casing (22m)	4,400
	- drive shoe	300
	- PVC pipe 35 m, including slotting	1,900
	- Filter material	200
	- Handpump including installing	5,000
	- Concrete apron, chipping including transportation	1,500
9.	Transportation of the rig	1,000
10.	Test pumping	1,000
	Total cost	30,400

If other general costs, like initial investigation, design and planning, workshop services and other project costs are considered, this will bring the total well costs to KShs.50,000. As each well can supply up to 200 people, the cost per capita comes to KShs.250. This cost is quite comparable with case 1 of the rainwater catchment system per capita cost of KShs.290. The latter has definite advantages in that the water will be next to one's house and no time will be wasted walking to the well and may be queuing to draw the water. In the case of handpump wells, maintenance costs and dangers of vandalism and breakdowns make them less suitable alternatives.

Table 25. Construction costs for a handpump well lined with concrete rings

	Estimate in KShs.
1. Capital costs of tractor, lorry, landrover and test pump	5,700
2. Service and repairs of above equipment	2,700
3. Survey of well sites	2,000
4. Fuel, transportation and excavating	1,300
5. Salaries	2,000
6. Construction materials	
- sand and balast	400
- cement rings	3,000
- flexo band	300
- plastic membrane	100
- handpump	3,500
- concrete slab, chipping including transportation	1,500
7. Test pumping	500
Total cost	22,300

Taking into account other project costs as before, the total cost may rise to about KShs.40,000 giving a comparable per capita cost as before of KShs.200. This water supply system has the same disadvantages as those mentioned before, for the borehole case.

Table 26. Construction Costs of a Shallow Well Lined with Bricks (depth 6 metres)

	Estimate in KShs.
1. Capital costs of lorry, landrover, pump and tools	1,800
2. Service and repair of above equipment	400
3. Survey of well sites	200
4. Fuel, transportation and dewatering	500
5. Salaries	4,300
6. Construction materials	
- bricks	600
- cement	800
- handpump	3,500
- concrete apron, chipping including transportation	1,500
Total cost	13,600

This alternative may be considered much cheaper than the rainwater catchment system, only if the construction costs are shared between many families. However other related costs and problems, like finding good sites on neutral ground e.g. on roadsides, etc., time wasted when going to collect the water, and occasional breakdown of handpump, all make it a doubtful good alternative choice over the rainwater collection system.

Table 27. Construction Costs of a Protected Spring

		Estimated in KShs.
1.	Capital costs of lorry, land-rover and tools	1,200
2.	Service and repair of above equipment	100
3.	Survey of spring sites	200
4.	Fuel transportation	300
5.	Labour	850
6.	Construction materials	
	- sand and ballast	95
	- cement	510
	- stones	100
	- concrete blocks	270
	- GS pipes 20"	300
	- plastic membrane	40
	- wire mesh	45
	- iron bar	15
	Total cost	4,025

Depending on the yield of the spring, it has been estimated that a protected spring can serve 50 - 100 people. Thus the direct construction costs would be KShs.40 - 80 per capita. But taking into account other project costs an approximate figure of KShs.100-150 per capita may be acceptable.

Like the other alternatives considered here, protected springs although likely to offer very clean water may have other problems, like being inaccessible during rains, and the fact that they may be as far as several kilometres away. This contrasts poorly with the rainwater harvesting system which places clean water next to one's house.

All the alternatives considered here although appearing to have comparable per capita costs with rainwater harvesting costs, and sometimes apparently cheaper than it, have other serious problems associated with them as discussed. They may be used as sources of water supply where rainwater harvesting is impracticable. Otherwise all the possible sources of water supply including rainwater harvesting should be considered when decision making.

Information extracted from the Ministry of Water Development concerning thecost of on-going surface water schemes revealed average investment costs of approximately KShs.1,200 per capita. When utilising groundwater supplies, savings through limited treatment and a compact distribution area result in an investment cost of KShs.900 per capita. This shows how expensive it is to provide clean treated water supplies when this is compared with all the alternatives suggested above as well as rainwater harvesting. Despite the advantages of treated water supply systems, it seems indeed unlikely and unrealistic to supply such water to each individual home in the rural areas. The piping costs in themselves will be quite prohibitive.

Treated water supplies from surface water or groundwater can of course be considered as a possible choice for supplying small rural communities. However, this choice should be made in the light of all the other alternatives including rainwater harvesting. If this is done huge investment savings may be made in some cases which may be used for other developments.

From the foregoing discussions it is quite evident that rainwater harvesting from roofs especially for drinking purposes holds a lot of promise and should be encouraged in the rural areas, and in the small and large urban areas, where rainfall is adequate.

9. CONCLUSIONS AND RECOMMENDATIONS

About 90 per cent of the population in the study area are rural dwellers. It has been shown that it is impractical and unrealistic to supply piped treated water to every individual household, because of the very high costs. Rainwater harvesting from roofs for drinking and other domestic purposes will offer a cheap and practical solution to the water needs of these people. It has the following distinct advantages and benefits over the sources currently being used and those that have been proposed.

- The catchments are easy to design construct and maintain.
- Very high purity water can be collected, making treatment unnecessary, and ensuring good health of the people.
- The water is easy to tap and can be collected next to one's door-making the need for long expensive pipelines unnecessary.
- The quantity in the study area is adequate for collection.
- The supply is readily acceptable by the community because the water is of good quality characteristics and is of traditional origin.

- No elaborate machinery is required and in many cases even pumps will not be required.
- Collecting rain from roofs may prevent soil erosion around the house unless proper drainage gutters have been provided.
- The supply can be effected by individuals themselves with little external assistance. This will instill a personal sense of water supply ethics in the populace, and generate a sense of responsibility which can be exploited in other development activities.
- Large savings can be realised which can be utilised in other monetary developments.
- The better health resulting from the use of this system, will assure more productivity in other activities.
- The walking time saved by the womenfolk and children, since the supply will be next to their house, can be used for other activities.
- The per capita costs are reasonable and are comparatively more realistic than those from other sources, in view of the many advantages that rainwater harvesting has over other sources.

The following recommendations are suggested:

- Educate the people on the need to use rainwater for drinking and other domestic purposes. Most people do not realise that it is better quality water than that from other sources like rivers. This should be done through the mass media and through the local administrators and community workers.

- Assist the people financially in constructing rainwater harvesting systems. Credit facilities should be availed either for constructing catchment systems or for the purchase of storage tanks or for the whole system. This will be a very good incentive.

- Urge people to put up more galvanized iron roof houses as this has been found to be the best roof catchment. However painting of such roofs should be discouraged, unless the paints are certified as being non-toxic.

- Provide free design or similar advice when needed.

- Set up a district reservoir management and maintenance board that will provide free advice on construction and maintenance of the rainwater systems.

- Open up district water testing centres and incorporate testing of water samples from reservoirs into the routine rivers, stream and lake monitoring programmes currently existing.

- The Ministry of Housing and Social Services to make it imperative to include reservoirs as an essential and necessary component in the design drawings of all houses. This will then dispel the myth currently held that the construction of storage reservoirs is a thing belonging only to the elite of the society.

- On a countrywide basis, the government to discourage the use of polluted traditional sources e.g. rivers as sources of drinking water and to encourage rainwater harvesting. More so to encourage rainwater harvesting in areas with bad water quality. Such areas could be those with high fluoride and high salinity.

- The meteorological department to open up more rainfall measurement stations, to provide precipitation data necessary for the design of reliable reservoir volumes.

- The Ministry of Environment and Natural Resources to enact environmental protection laws, since rainwater harvesting is very sensitive to aerial environmental pollution.

- Proper records of construction costs as well as operation and maintenance to facilitate easy follow up and checking on performance, to be kept.

- Feasibility studies on the possible use of rainwater harvesting as a source of water supply for urban centres, in whole or in part to be carried out.

From the foregoing conclusions and recommendations, it is hoped that rainwater harvesting can be seriously taken up as a source of domestic water supply in Kisii. It may also be said generally that although it may not be suitable technology in every case, it is important to note that it is another suitable alternative that should be considered when analysing water supply alternatives.

If a rainwater harvesting campaign is launched in Kisii, a new source of clean water supply will be ensured at household level, and pressure on current clean water supplies resulting from the fast growing population and the even faster-growing socio-economic development will be eased.

It is hoped that the success of similar systems reported in other countries will serve as a source of inspiration and an incentive to launch the same in this densely populated district and elsewhere in the country.

REFERENCES

APHA, Standard Methods for the Examination of Water and Wastewater. 15th Edition, American Public Health Association, Washington D.C. 1980.

Boers Th. M and Ben-Asher. A Review of Rainwater Harvesting. International Institute for Land Reclamation and Improvement, ILRI, Wageningen (The Netherlands), December 1981.

Breth, A.S. and Stelly M., Pesticides and their Effects on Soils and Water. ASA Special Publication No. 8, Soil Science Society of America Inc. Madison Wisconsin, November 1966.

Cooley K.R. et. al. 1975, Water Harvesting. "The State of the Art". Reprinted from Watershed Management Symposium ASCE Irr. Drain. Div. Logan, UT 20pp.

Doelhomid S. Rainwater Cistern Systems in Indonesia Proceedings of the International Conference on Rainwater Cistern Systems, June 1982. Water Resources Research Center, University of Hawaii at Manoa, Honolulu, Hawaii.

Galal-Gorchev H., et. al. WHO, Guidelines for Drinking Water Quality. WHO, Geneva, September 1982.

Gerardi H.M., et. al. Aquatic Invaders. WATER/Engineering & Management. October 1982.

Hollick M. "The Design of Roaded Catchments for Maximum Runoff". Proceedings of the Water Harvesting Symposium. US. Department of Agri. and Agri. Research Service, Western Region, ARS W-22, February 1975, pp. 201-220.

Ikebuchi S., et. al. Feasibility Analysis of Rainwater Cistern Systems as an Urban Water Supply Source. Proceedings of the International Conference on Rainwater Cistern Systems, June 1982, Water Resources Research Centre, University of Hawaii at Manoa, Honolulu Hawaii.

IRC., Small Community Water Supplies. Technical Paper Series No. 18. August 1981. The Hague, the Netherlands.

Jacobi, Overview of the Rural Domestic Water Supply Situation in the Lake Basin Area, Ministry of Water Development, Republic of Kenya, September 1983.

Kefinco. Lake Basin Development Authority. Shallow Wells Workshop Kisumu 10-12 October 1983 Rural Water Supply Development Project in Western Province, Kefinco Kakamega.

Krüger, I. A/S. Water Quality in Water Supply Reservoirs. Danish Isotope Research Centre. Academy of Technical Sciences. Department of Environmental Engineering. Technical University of Denmark. October 1982.

Ministry of Health, Kisii Hospital Records, 1981, Republic of Kenya.

Ministry of Water Development, Departmental Records, 1983, Republic of Kenya.

Ministry of Power and Communications Rainfall Records, Meteorological Department, 1983, Republic of Kenya.

National Academy of Sciences. More Water for Arid Lands. Washington, D.C. 1974.

National Environment Secretariat DP-3. Kisii District Environment Assessment Report. Ministry of Environment and Natural Resources, Kenya, August 1981.

Nissen-Petersen, E. Rain Catchment and Water Supply in Rural Africa. Hodder and Stoughton. London 1982.

Perrens S.J. Rainwater Cistern Systems. Proceedings of an International Conference on Rainwater Cistern Systems June 1982. Water Resources Research Center, University of Hawaii at Manoa, Honolulu Hawaii.

Pompe, C.L.P.M. Design and Calculation of Rainwater Collection Systems. Proceedings of the International Conference on Rainwater Cistern Systems June 1982. Water Resources Research Centre, University of Hawaii at Manoa, Honolulu, Hawaii.

Rommi, K.J. Water Supply, Land use and Urban Growth. Journal of the Water Resources Planning and Management Division. November 1977.

Statistical Abstracts, Republic of Kenya, 1982.

Stern P. Rainwater Harvesting, Waterlines, July 1982.

Vadhanavikkit, C., et. al. Roof Catchment (Thailand) Progress and Financial Reports for July - December 1981 and January - December 1982. Faculty of Engineering, Khon Kaen University, Khon Kaen, Thailand.

Wagner, E.G. and Lainore J.N., Water Supply for Rural Areas and Small Communities. Monograph Series No. 42. WHO, Geneva 1959.

Winarto, Y.D.D., Rural Rainwater Cistern Design in Indonesia. Proceedings of the International Conference on Rainwater Cistern Systems. June 1982. Water Resources Research Centre, University of Hawaii at Manoa, Honolulu, Hawaii.

World Water, October 1981.

APPENDIX 1 - WORKING QUESTIONNAIRE

DATE:

RAINWATER STUDIES

Project Area

Assessment of present status

1. What are your current sources of domestic water supply?
   (a)
   (b)
   (c)
2. Is rain water harvesting practised?
3. How is rain water harvesting practised? What kind of catchments are used?
4. How many animals are served by rainwater?
5. How many people are served by rainwater?
6. How is the water collected?
7. How is the water stored?
8. Is the water enough?
9. What is the estimated specific consumption?
10. What is the volume of the reservoirs used?
11. What type of reservoirs are used?
12. Are the reservoirs well maintained?
13. What is the area of the roof catchment?
14. How much rain falls in the area?
15. How much is collected/lost?
16. How many rainfall months? How many drought months?

17. What material is used for roofing?

18. What are the other uses of the collected water?

19. What is the water quality like?

    Physical: - Colour

    Turbidity

    Odour

    Taste

    Chemical:-

    Bacteriological:-

    Biological:-

20. How often is the water tested?

21. What is the cost of the water supply system?

22. What problems have been experienced?

    Leaks?

    Rusting?

    Lack of storage?

    Quality ?

23. What are the other alternative sources of supply?

24. How reliable are they in quantity and quality?

    Shallow wells?

    Borehole?

    River?

    Treated supply?

25. What is the occupation of the people in the community?

26. What industries exist in the area?

27. Is aerial spraying of pesticides practised?

28. What is the general layout of the present system?

29. Is there any data on operation and maintenance costs?

APPENDIX 2: DETAILED RAINWATER STUDIES QUESTIONNAIRE

1. How does the quality and quantity of the water compare with that from other sources?

2. How can the quality be improved?
   - Preservation
   - Collection
   - Disinfection
   - Filtration
   - Liming
   - Fluoridation
   - Proper roofing materials.

3. How can the quantity collected be increased?
   - Proper guttering
   - Proper roofing
   - Proper storage
   - Proper pumping

4. What is the minimum roof catchment and minimum storage required to meet the needs of a small family of 10 persons?

5. What is the effect of type of roofing on water quality?

   (i) Galvanized corrugated iron sheets

   (ii) Painted galvanized corrugated iron sheets

   (iii) Lead roofs

   (iv) Polyethylene roofs

   (v) Grass roofs

(vi) Other catchments:-

(i) Cement roofs

(ii) Asbestos roofs

(iii) (sisal + cement + polythene sheet)

6. What is the effect of type of storage and storage period on water quality?

7. What is the effect of harvesting time on water quality?

8. What is the effect of reservoir age on water quality?

9. What is the effect of roof age on water quality?

10. How can daily and monthly consumption be monitored?

11. Are there any sociological and psychological factors that may affect the supply?

12. What cheap treatment method can be used at household and community level?

13. What other benefits may be derived from rainwater harvesting studies?

14. What does it cost to put up a simple rainwater harvesting system?
    How does it compare with other sources?

15. Which could be the best design for reservoirs and why?

16. What roofing materials should be avoided?

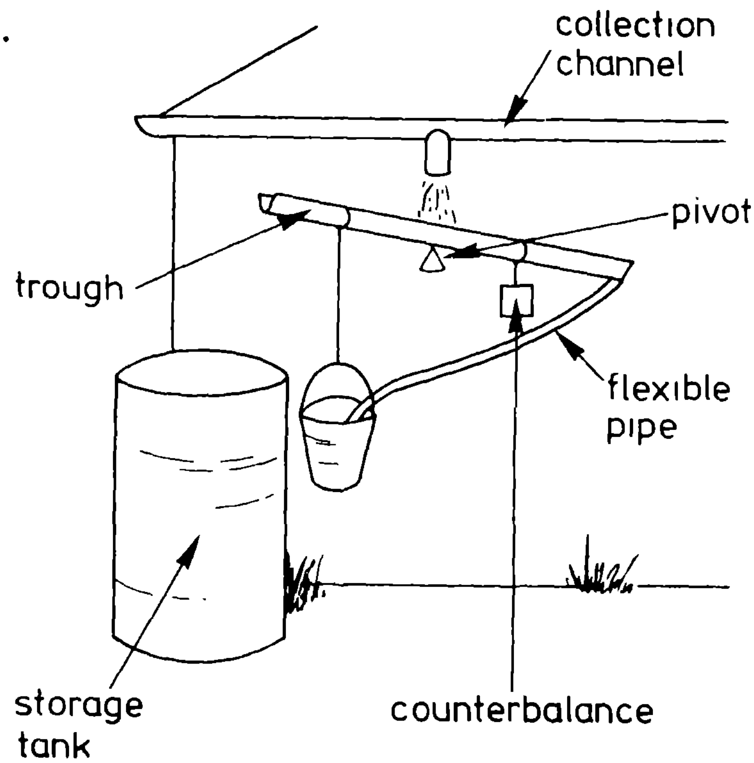
17. What is the life-time of different storage tanks?

APPENDIX 3 CONVERSION TABLES

1 US$	= 13.9 Kenya Shillings (K.Shs.)
1 Finnish Markka	= 2.34 Kenya shillings
1 gallon	= 4.5 litres.

APPENDIX 4. AN ARRANGEMENT FOR WASTING THE FIRST FOUL FLUSH

Fig.



The figure above, gives one form of arrangement for wasting the first foul flush. The terminal gutter is pivoted in such a manner, so that it can be swang to waste the first foul flush. Such a devise is useful, in areas where there are long dry periods, when dust and leaves can build up on roofs and in the gutters. These can be washed into the storage tank in the absence of such a devise.