4 Survey on rural-water resources and its potential

4.1 Field reconnaissance survey

Field reconnaissance survey was carried out at about 137 water points and villages in order to collect hydro-geographical information concerning to land forms, soil cover, rock type, spring, existing water points, and present condition of water sources. The information was then used for revising and updating the existing record which had been collected before. Considering both field reconnaissance survey's result and villagers' requirement, the suitable stations to be applied by geophysical survey were determined. As secondary objectives of the field reconnaissance survey, ground truth for photographic information which had been interpreted and extracted from areal photographs were completed for particular villages selecting as subsequent geophysical survey sites. In Table 4-1, summary of field reconnaissance is shown.

4.1.1 Collecting water resource information

In order to re-new and revise the existing record which had been collected as basic information for the evaluation of groundwater resources, most of water points of the Study Area were ensured in field. Water points, including river courses, canals, lakes, springs, gauging stations and wells, were positioned by GPS, and subordinate water facilities, water demands, and condition of water fetching were surveyed. Moreover, the in-situ geologic survey was made with the aim of detecting some indication of groundwater, which might be superimposed on land forms, soil cover, rock types.

4.1.2 Verification of photographic information

Through the interpretation of aerial photographs, surface information such as drainage divides, mountains, terraces, alluvial plain, escarpments and lineaments were delineated adjacent to the proposed villages of subsequent geophysical survey. As the first step of photo-interpretation, an index map was prepared on which every photographic position overlays on to the 1:250,000 map and scanning of aerial photographs was followed in the stereo-scope view. Useful information picked up from each photographs was linked to neighboring scene and are compiled in a photo-interpretation map in a smaller scale. Field reconnaissance survey was carrying out aiming at "Ground truth": the verification of such extracted information form areal photographs. The basic hydrogeological elements were confirmed in field and their results was applied in a selection of possible sites for subsequent geophysical survey.

4.2 In-situ water quality survey

64 water points were visited to check on seven parameters of Iron (Fe), Manganese (Mn), Nitrate (No_3), Ammonium (NH_4), Fluoride (F), EC, pH and Temperature (T) with use of the pack-test kit and portable EC/pH meters. Sampling positions are shown in Figure 4-1 and test results are given in Table 4-2, 4-3 and as below:

Location	Water point	Fe	Mn	NO_3	F	NH_4	EC	pH
River	Max.	2.0	1.0	>5.0	>5.0	>5.0	1,751	7.8
	Min.	0.0	0.0	0.0	0.0	0.0	70	4.9
	Average	0.7	0.2	-	-	-	447	7.7
Number of samples below Kenyan Standard (out of 29 samples)		8	0	0	8	-	-	1
Dam and Pan	Max.	>5.0	>5.0	1.0	>5.0	>5.0	624	9.6
	Min.	0.2	0.0	0.0	0.2	0.0	81	7.3
	Average	-	-	0.1	-	-	250	8.2
Number of samples below Kenyan Standard (out of 11 samples)		7	0	0	2	-	-	1
Borehole, well, spring								
	Max	2.0	0.5	>5.0	>5.0	2.0	990	9.1
	Min	0.0	0.0	0.0	0.2	0.0	336	6.8
	Average	0.5	0.0	-	-	0.2	708	7.7
Number of samples below Kenyan Standard (out of 13 samples)		0	0	0	3	-	-	0
Lake	Lake Baringo	2.0	0.5	0.0	>5.0	0.0	1,278	8.94
	Lake Bogoria (hot spring)	0.5	0.0	0.0	>5.0	0.5	5,490	8.65
	Lake 94 (Kiserian)	2.0	0.0	0.0	>5.0	0.0	618	8.67

Fluoride concentration in some sample is high in excess of the Kenya permissible rate (even over the exceptional case of 3 ppm). This concentration was obtained not only form groundwater but in surface water source. Almost 20 % out of all samples were contaminated with high content of fluoride exceeding 3 ppm. Fluoride is originated from volcanic and fumarolic activity beneath the Rift Valley region. Groundwater source, bearing high content of it, have a relation to a local pocks of high concentration, which are connecting to the deep fractures. In the case of surface water sources, it may be contaminated by soils, as well as seepage water flowing from polluted (hot)springs, and contaminant was further concentrated by evaporation while it was pondered in pans and water holes.

Iron concentration was high in the surface water source particularly in pans, Molo rivers, Mukutani river, seepage water from Perikerra river and Lake Baringo. This concentration may be due to soil erosion from the upper zone of the sounding hills.

As result of this survey, the extent and degree of contamination by Fluoride and Iron were represented as follows:

Locations	Pan		River		Groundwater		Lake	
	(F)	(Fe)	(F)	(Fe)	(F)	(Fe)	(F)	(Fe)
Marigat	-	-	O	△	△	△	-	-
Elude & Ngambo	O	×	O	△	-	-	×	×
Salabani	O	O	-	-	-	-	×	×
Loboi/Sandai/Kupkuikui	-	-	△	△	△	O	×	×
Kimalel	△	O	-	-	×	△	-	-
Kiserian /Mukutani	O	-	△	△	△	O	×	×
Arabal	×	×	O	△	-	-	-	-

O: Most of samples within Kenya Standard (permissible aesthetic quality)
△: Half of samples exceeding Kenya Standard (permissible aesthetic quality)
× : More than half of samples exceeding Kenya Standard (permissible aesthetic quality)
- : no data available

4.3 Water sampling and laboratory water quality test

As stated above, water quality of 64 water points were tested in field. Among these, 22 points were selected for full-analysis with 27 parameters in laboratory. 22 points are all taken form large water sources, which aew using by numbers of villagers, such as major piped water systems and Perkerra river. Following parameters were testing in laboratory water quality test. Sampling positions are shown in Figure 4-1.

No.	Parameters	Unit	Kenya < >desirable aesthetic quality	Kenya ( )permissible aesthetic quality	WHO Guideline
(A) Physical/Chemical Water Analysis					
1	pH	pH scale	<6.5-8.5>	(6.5-9.2)	-
2	Colour	mg pt/l			
3	Turbidity	N.T.U	5		5
4	EC	μ S/cm			
5	Iron(Fe)	mg/l	<0.3>	(0.5)	0.3
6	Manganese(Mn)	mg/l	<0.1>	(1.0)	1
7	Calcium(Ca)	mg/l			-
8	Magnesium(Mg)	mg/l			-
9	Sodium(Na)	mg/l	<200>		200
10	Potassium(K)	mg/l			-
11	Total Hardness (Ca+Mg)	mg/l	<500>		-
12	Total Alkalinity	mg/l			-
13	Chloride(Cl)	mg/l	<250>	(600)	250
14	Fluoride(F)	mg/l	<1.5>/3.0*1		1.5
15	Nitrate(NO3)	mg/l	10		50
16	Hardness (Ca)	mg/l			-
17	Sulfate(SO4)	mg/l	<400>		400
18	TSS(Total Suspended Solids	mg/l			
19	TDS(Total Dissolve Solid)	mg/l	<1000>	(1500)	1000
20	Silica(Si)	mg/l			-
(B) Bacteriological Water Analysis					
21	Total Colonies, spc	CFU/ml	-	-	-
22	Coliform group (24hrs)	/100 ml	not detected	not detected	not detected
23	Coliform group (72hrs)	/100 ml			
24	Faecal Coliform	-	not detected	not detected	not detected
(C) Heavy Minerals Analysis-					
25	Arsenic(As)	mg/l	0.050	-	0.01 ( )
26	Cadmium(Cd)	mg/l	0.005	-	0.003 ( )
27	Mercury(Hg)	mg/l	<0.001>	-	0.001 ( )

Note*1 : in exceptional cases a Fluoride content of 3 mg/l may be accepted in Kenya

Test result is given in Table 4-4. In case that results were compared with "Kenya permissible (or desirable) quality standard", most of water sources were not adopted to drinking water quality due to high concentration of Turbidity, Iron (Fe), Manganese (Mn), Sodium (Na), Fluoride(F), Sulfate (SO4). Even treatment water of Arabal piped water supply W/S was contaminated by coliform and faecal coliform bacteria. Only two samples out of 22 samples, Sesiai UNCEF Well and Marigat W/S were solely meet the Kenian standard.

Paramerter		Turbidity	Iron (Fe)	Manganes e (Mn)	Sodium (Na)	Fluoride (F)	Sulfate (SO4)	Coliform group	Faecal Coliform
Unit		N.T.U	mg/l	mg/l	mg/l	mg/l	mg/l	/100 ml	-
Kenya permissible (or desirable) quality		5	0.5	1.0	200	3.0	400	not detected	not detected
Kimalel	Kipramoi Spring	28	1.1	0.2	51	0.76	28	>2400	>2400
	Kimao Dam	13	1.9	2.2	30	0.66	6.3	>2400	>2400
	Keben spring	2	0.46	0.01	165	5	58	>2400	>2400
	Egerton Unv.B/H	2	0.4	0.01	150	12	50	>2400	>2400
Salabani .	Kanpi ya Samiki W/S	22	0.91	0.05	300	1.8	469	nil	nil
	Chemeron Irrigation Canal	24	0.64	0.12	13	1.0	8	>2400	>2400
Marigat	Perikerra river	166	10.3	0.6	8.5	0.58	6.7	>2400	460
	Marigat W/S	5	0.43	0.1	10	0.35	90	nil	nil
Elude	Molo River	270	3.11	0.3	18	-	28	>2400	1100
Ilng'arua	Sesial UNCEF well	nil	0.38	1	24	1.1	16	nil	nil
Ngambo	Perikerra River	32	1.2	0.05	19	0.94	8	>2400	1100
Sandai	Waseges River	910	17.8	1.2	25	0.68	44	>2400	460
Loboi	Chelaba Spring	2	0.47	0.01	113	4.2	23	>2400	1100
Kapkuikui	Katanin canal	7	0.95	0.4	158	5.3	33	>2400	>2400
Kiserian	Arabal W/S	3	0.47	0.07	123	0.58	226	>2400	>2400
Arabal	Kaseila Spring	2	0.45	0.02	100	0.76	21	>2400	1100
	Arabal River	1900	22	2	48	0.7	40	>2400	>2400
Mukutani	Nosukeita River	83	3.33	0.5	50	1.9	21	>2400	nil
	Mukutani River	73	3.1	1.4	335	5.3	109	>2400	>2400
	Lelerai spring	3	0.47	0.01	172	0.92	54	>2400	>2400
	Ilpirisati hot spring	8	0.75	0.05	182	1.3	52	>2400	nil
	Ilpirisati cool spring	6	0.53	0.02	118	0.9	15	>2400	4

Note: box shaded shows do not to meet the Kenya permissible (or desirable) quality standard.

4.4 Survey on existing water facilities

The survey was carried out at 180 water points aiming at obtaining detail information and up-to-date data on different type of water points (or/and constructed water facilities) in both Marigat and Mukutani Division as shown in Figure 4-2 and Table 4-5. The information on the water source has been used to supplement the present information to which had been collected in WRAP II (1992) study. This result was drawn with regard to the availability and potential of surface and groundwater resources.

The information on the water source was gathered through an inventory field survey. The field survey was comprised of inventory and appraisal of all existing and constructed water points. Information of every existing water points were collected on:

Items of questionnaire forms
General Information: Date Surveyed, Surveyor, Name of Water Point, Co-ordinates, Village name (at water point), Sub-location, Location,
Water Demand: Village name (users), Population, Number of Livestock,
Facility: Type of water points, Facility Name, Organization established, Year, Initial Installation
Facility Maintenance: Facility condition, Maintained by, Maintenance employed, Type of maintenance, Re-renovation, Type of re-renovation.
Pump Condition : Type of pump installed, Yield, Water level
Sanitary and Hygiene Education : Present activity: Comments on present activity and future plan:
Comments on water facility and its future plan

All the identified water points were plotted on the topographical map scaled 1:50,000 and were further confirmed by GPS positioning. Water points covered were all types, consisting of piped water supplies, dams, pans, springs, wells, boreholes, waterholes, every withdrawal spots on rivers, canals and lakes. All the data recorded in the survey was recorded on the Inventory.

4.4.1 Water points of Study Area

The type of water points which are in use in the Study Area and number of users for every types are given as follows.

Sub Location	Type of Water points										Total
	River	Pan	Spring	Water Hole	Bore hole	Well	Dam	Canal	W/S	Lake	
Arabal	9	5	6		2						22
Eldume	2				1			1	1		5
Endao	0	6			2		1	6			15
Ilngarua	1										1
Kaptombes		2						4			6
Kapkuikui		1						2			3
Kimalel	1	5	4	3			1		2		16
Logumgum	1										1
Kiserian	6								1	3	10
Koriema			4	2	1	1	1		2		11
Chelaba		2	2								4
Maji Ndege	1		1								2
Meisori		2		1					2	3	8
Mukutani	6	3	1	2							12
Ngambo	2	2				2	1			1	8
Perkerra	1							16			17
Salabani				1						3	4
Sandai	4							7			11
Yatoi	15	3			2		1	1	2		24
Total	*50*	*31*	*18*	*8*	*8*	*3*	*5*	*37*	*10*	*10*	180

Note: Numbers of facility may includes double-count because of some water sources are accessed by several Sub-Locations

In the Study area, common type of water points are river (canal) and pan, which are not treated and are known as contaminated water sources.

4.4.2 River

As stated above, river are most accessible water sources, as well as important sources in the communities. A lot of water points are aligned along several perennial rivers and canals, and villagers fetch water to the nearest water-withdrawal spots on river courses from their villages. Major perennial rivers and their water usage are summarized as below:

Watershed	Main Water Points	Condition of Water Points and Facilities
Perkerra	Main Course(R..perikerra) Tributary (R.Maol) Tributary (R.Alopno)	Villages in a part of Marigat, Kimalel Locations fetch river water as main water source in all purposes. Perennial streams
	Marigat W/S in-take	1,750 people in Marigat Location are supplied.
	Perkerra Irrigation Canal	A lot of Villages locating in Marigat, Eludme, Ilngarua, Ngambo and a part of Kimalel Locations use irrigation water for all domestic purposes including drinking water as main water sources for villages. Villagers taken water from directly from irrigation canal. Irrigation water is flowing much and perennial
Molo	Main Course(R.Molo) Tributary (R.Merumbe) Tributary (R.Embakong)	A part of Eludme Location uses river water. It is muddy water, but commonly used as all domestic purposes.
	Molo Irrigation Canal	A part of Eludme Locations uses,
Waseges	Main Course (R. Waseges)	Sandai Location uses water source.
	Sandai Irrigation Canal	Villages in Eludme/Sandai Locations use irrigation water diverted at Sandai village for domestic purpose and cattle watering. In dry season, villages take 2 hrs for fetching water to main river course and even to Loboi spring
Ol Arabal	River Course (R.Arabal) Tributary (R.Ngusero)	Most of Arabal villages uses river water as main source for all purposes. Villagers living in surroundings are taken water from water-hole on the river bed or directly from river stream for the use of drinking, cattle feeding and other domestic use.
	Ol Arabal W/S in-take	Facility is under construction, 11,837 people in Kiselian, Eludme, Sandai Loboi Locations will be supplied in 2001
Mukutani	Main Course (R. mukutani)	Mainly, northern part of Mukutani Location uses this source. Water containing a bit of suspended material. Villagers living in Mukutani center and surrounding villages use this water in all domestic purposes and irrigation. Villagers dig water-hole on river-bed for collecting clean water.
	Tributary (R.Nosikweta & R. Akule)	Mainly, eastern part of Mukutani Location uses this source. Tributary of Mukutani river, but seasonal stream. In dry season, villagers have to fetch water to Mukutani river
Endao	River Course (R. Endao) Tributary (R.Kinyo) Tributary (R.Nasagum)	It is seasonal flow at the lower reach of main stream so that perennial source is only available at the upper stream. Villages living in northern part of Kimalel use this stream as main water source in all purposes.

4.4.3 Lake

Lake are important water points except Lake Bogoria. Salabini, Kiselian, and Ngambo Location are used lake water for all the domestic purposes. Condition of water use at these water points are described as below:

Lake	Location	Water facility	Condition of Water Use
Lake Baringo	Salabani (Kampi Ya Samaki)	Kampi Ya Samaki W/S	W/S was constructed by MENR in 1989, but water tank have been not completed yet. Accordingly, treated water is pumping directly to the distribution lines and taps every morning. About 3000 villagers are provided by the W/S. A part of operational cost of W/S is shared by village user.
	Salabani (Meinsori)/ Ngambo	no water facility	Villagers use lake water as all domestic purposes by fetching water from/to 5 km as maximum distance. It is generally treated with Alum (KAl(SO4)2・12H2O) if it uses for drinking purpose.
	Kiserian (Center)	- do-	Lake (1.5km far, 1hrs on lap) is main water source for Kiselian center. Village is consisting of 200 households, 2000 people, 250 caws, 1500 gouts, 600 sheep and 30 donkeys
Lake 94	Kiserian (Loitip/Lasaburbur)	- do -	Villages located south of Kiserian center use the lake 94's water. It is wide and shallow pond which is spreading south of lake Baringo. It was initially formed by flood caused 1994, thus it is called as "lake 94" by local people. It was sometimes died especially in the severe drought such as that of 1999. This water is used as alternative water source for surrounding villages (Loitip / Lasaburbur villages: population 1000). When stream near villages are dried, people gathered to lake from 3km far, with 2hrs on lap. Water is used for all the domestic use, including cattle watering, bathing, washing and even drinking purpose.

4.4.4 Pan and Waterhole

31 pan were found in the Study Area, and most of pans are located in Arabal, Marigat(Endao), Kimalel Locations. Their water usage of major pan facilities is summarized as below:

Site Name	Location	Year of Construction	Constructed by	No. of Users (Pop.)	Water Use					Walking Distance (km)	
					Dr Fo	Wa Ba	Li	Ag	In Co	Wet Season Min-Max	Dry Season Min-Max
Arusin	Arabal	1989	MOARD	2000	y	y	y			<1-10	<1-12
Ramacha	Arabal	1972	Community	100	y	y	y			<1-3	<1-4
Sirata	Kiserian		Community	500	y	y	y			<1-3	<1-4
Enkutoto	Kiserian	1958	Government	500	y	y	y			<1-2	<1-4
Lorrok	Kiserian	1984	Community	200	y	y	y			<1-1	<1-2
Lorrok	Kiserian	1990	NGO	250	y	y	y			<1-3	<1-3
Lotiyeki	Kiserian	1990	NGO	200	y	y	y			<1-2	<1-2
Kimalel	Kimalel	1982	MENR	700	y	y	y			<1-4	<1-4
Kapkun pan	Kimalel	1985	MENR	1000	y	y	y			<1-2	<1-3
Ketikibiet pan	Kimalel	1984	MENR	3000	y	y	y			<1-3	<1-5
Kapngetung pan	Kimalel	1985	MENR	3000	y	y	y			<1-3	<1-6
Chepkoimet pan	Loboi	1984	MENR	600	y	y	y			<1-5	<1-7
Chelaba pan	Loboi	1984	MENR	200	y	y	y			<1-2	<1-4
Chemalane pan	Loboi	1984	MENR	200	y	y	y			<1-1	<1-2
Kaptombes pan	Loboi	1985	MENR	1000	y	y	y			<1-4	<1-6
Chaule pan	Loboi	1984	MENR	200	y	y	y			<1-4	<1-6
Kipchebii pan	Loboi	1986	MENR	200	y	y	y			<1-4	<1-5
Ngusui pan	Marigat	1984	HZ Co.	300			y			<1-4	<1-5
Sirinyo pan	Marigat	1985	MENR	500	y	y	y			<1-3	<1-4
Loberer pan	Marigat	1972	Community	100	y	y	y			<1-1	<1-2
Koilel pan	Marigat	1974	Community	400	y	y	y			<1-1	<1-2
Parkibi pan	Marigat	1978	MENR	500	y	y	y			<1-2	<1-5
Samburi	Marigat	1972	MENR	100	y	y	y			<1-1	<1-3
Chemangaa pan	Marigat	1978	Community	200	y	y	y			<1-1	<1-3
Akule	Mukutani	1972	Community	200	y	y	y			<4-1	<1-6
Losokoni	Mukutani	1960	Government	500	y	y	y			<1-4	<1-6
Karau (A)	Mukutani	1960	Government	400	y	y	y			<1-3	<1-4
Karau (B)	Mukutani	1989	MENR	400	y	y	y			<1-3	<1-4
Lekiricha	Mukutani	1986	NGO	120	y	y	y			<1-2	<1-2
Rugus	Mukutani	1985	NGO	300	y	y	y			<1-3	<1-4
Lamalok pan	Salabani	1984	MENR	60	y	y	y			<1-1	<1-1
Endebe pan	Salabani	1984	MENR	200	y	y	y			<1-1	<1-1

Note: Data are referred from WRAP(1992). Some differences from the Survey result (2000) are found in their belonging Locations.

Due to the limited water sources, there are hardly not difference in use of different type of water points: muddy water in the pan is even used for all domestic purposes of drinking, cooking, washing, bathing and cattle watering.

4.4.5 Dam

Dams found in the Study Area are as below:

General Information				Location	Water Use Pattern		Operational Status	Ownership and Maintenance	
No.	Site Name	Constructed by	Year of Construc-tion	Sub-Location	Users	No. of Users (pop)	Present Status	Owner	Maintenance by
D002	Chemeron	KVDA/HZ	1983	Endao	Community	4500	In use	Government	Nobody
kimao dam	kimao	KVDA	-	Koriema	Community	-	under construction	Government	Nobody
Arabal W/S	Arabal W/S	NWC&PC	-	Kiseian	Community	-	under construction	Government	Nobody
D018*1	Tikaluk	Local Community	1979	Arabal	Community	100	In use	Community	Nobody

Note *1: Data of "Tikaluk" dam is referred from WRAP(1992). It was not included in the Survey (2000).

Most of them are not functioned much due to following reasons:

Name	Location	Facility Installed by	Used with	Condition of Water Use
Kamio Dam	kimalel	Kerio valley water development authority	not used	Kimao dam is gravity type dam, and total capacity of reservoir is 288,000 m^3. Effective storage is 142,000, height 25m, length 35m and catchment area is 7.8 km^2. This dam was planed for domestic and irrigation purpose for Koriema, Kimalel and Kimorock. But, reservoir have been only constructed in 1998 as phase I. The phase II, comprising of treatment system and distribution system, is not commenced up to the present.
Chemeron Dam	Marigat	Kerio valley water development authority	used	Earth dam, 380 m long with 31m high, was constructed by Kerio Valley Water Development Authority with contract by H.Z. co.ltd in 1983. Dam storage is of 4600,000 m^3, but has been suffered by siltation in reservoir and crack of embankment. Villagers use canal water, which is conveyed from dam reservoir. About 4500 villagers utilize this water for all the domestic purposes and irrigation water, as well.
Arabal W/S	Kiserian	NWCPC	not used	In 1994 during heavy rains the intake reservoir was filled with silt and boulders and some part of intake structures were washed away rendering in-take useless. New, the sub-surface dam with storage capacity of about 4000 m^3, is under construction. By summer 2000, it will be completed. At present, It provides water surrounding villages.

4.4.6 Spring

In the Study Area, springs are not many. There are 18 springs. Summary of eight major springs as below:

Name	Location	Facility Installed by	Used with	Condition of Water Use
Keben spring	kimalel	MENR/village community	taps	Water source of Sabor W/S with 22 taps. In-take is of small barrage and 2" pipe. Flow rate is about 30 l/min. Fluoride content is high.
Kipramoi spring			taps	Water source of Koriema W/S. In-take is with small barrage and 2" pipe. Flow rate is about 200-300 l/min. Drinkable, but protection of spring required.
Lorwai hot spring	Loboi	not improved	bucket	Hot spring, flowing (2-3 m3/sec) form Bogoria hotel. Water is only used for cattle watering, and car wash due to high and F, Fe contents.
Chelaba spring		do	bucket	Measure water source of Loboi village, villagers use this source as main water source. The yield is high as about 0.7m3/sec. Village has new plan to provide water to upper part of village by W/S. Drinkable.
Ilpirisati hot spring	Mukutani	do	bucket	Hot spring. Flow rate can not be measured due to extent range of seepage (300 m x 150m), but may be not much. To the down-stream, seepage water is merging into the ground. Water is only used for cattle watering and bath du to high content of Fe.
ilpirisati spring (cool)		do	bucket	Spring-eye is of 5 x 5m. Flow rate is about 150 l/min. Streams pouring out from spring are to flowing to both Murat river and neighboring depression for cattle watering. Flow rate is not changed through a year. Users of spring are of 100 households, 1000 people, 1000 cattle and 4000 gouts, 100 sheep and 60 donkeys by villagers' declaration.
Lelerai spring		do	bucket	Clean water. Discharge is about 10 l/min, villagers constructed barrage to trap water, and use in all domestic purpose. EL.1370m which can be obtained 250 m head form Mukutani center.
Kasie spring	Kasie (Muchongoi Loc.)	Christian Church	taps	Hot spring locating at the foot of Kapkosom ridge, and is yielding over 80 l/min. Spring-eye is 40m x 30m, and providing water to glassy land extending down stream. From spring-eye, three outlets are settled for bathing, cattle watering and drinking. respectively. The improvement of spring, fencing around spring and taps, was made with assistance of Christian Church. Villagers have further plan to extend the survive area.

Almost springs are perennial. When other water points dry up in the dry season, people are gathering from far a way to fetch water to spring. Abstraction from spring is made manually using small containers. Maintenance of them is poor.

4.4.7 Well

In the Study Area, there are seven(7) wells locating along river courses at Eldume, Mukutani, Koriema and Ngambo Location but half of them are breakdown. Present condition of wells are given as below:

Name	Location	Facility Installed by	Used with	Condition of Water Use
Lekerati well	Mukutani	Gospel Church	not used	Well was build with the assistance of Gospel Church in 1991. But, hand pump was stolen in 1998. Up to now, well is not in used, like as abandoned wells due to plugging by woods, stones and soils. No of well curved on basement is "KA-97".
Eldume primary school well	Eldume	Inter AID	break down	Hand dug-well was constructed at 1993, 9 classes with 425 pupils were used. But it was breakdown due to the lowering of groundwater level at recent drought. Water contains high fluoride.
Sesiai UNICEF well	Ngambo	UNICEF	used	Hand dug well, installed by UNICEF in 1994. At same times, UNICEF made 4 wells in Ngambo Location, but 2 were already breakdown now. Water community is not organized.

Pump installed are to be Afridev. Water committee are not organized, so that handpump maintenance is not carrying out, Water abstraction of form well is mainly for domestic use.

4.4.8 Borehole

In the Study Area, there are 17 wells as shown below:

General Information				Location	Water Use Pattern		Operational Status	Ownership and Maintenance	
B/Hole No.	Site Name	Constructed by	Year of Construction	Sub-Location	Users	No. of Users (pop)	Present Status	Owner	Maintenance by
BH030(1)	Eldume	MOENR	1987	Eldume	Nobody		Abandoned	Government	Nobody
BH030(2)	Eldume	MOENR	1987	Eldume	Nobody		Abandoned	Government	Nobody
BH032	Loboi	MOENR	1986	Maji ndege	Others	30	In use	Others	Government
BH032	Loboi	MOENR	1986	Maji ndege	Others		In use	Others	Government
BH033	Sandai	MOENR	1990	Sandai	Nobody		Abandoned	Others	
BH034	Ngambo	MOENR	1985	Ngambo	Nobody		Abandoned	Government	Nobody
BH035	Kimalel 1	MOENR	1987	Koriema	Nobody		Dry	Others	Nobody
BH036	Kimalel 2	MOENR	1987	Koriema	Nobody	100	Dry	Others	Nobody
BH037	Egerton Univ.	MOENR	1982	Koriema Chemeron	Others		In use	Others	Others
BH038	Salabani Center	MOENR	1985	Salabani	Nobody		Abandoned	Government	
BH039	BSAAP Staff Q.	MOENR	1987	Marigat	Nobody		Dry	Others	Nobody
Maoi well	Maoi	MOENR	-	Marigat	Perkerra		In use	Others	Government
DRICO well	DRICO	DRICO	2000	Marigat	Yatoi		In use	Other	Others
JICA Well 86	Kabairwok	JICA/MONR	2000	Arabal	Kabairwok		under construction	MOENR	Nobody
JICA Well 85	Chemerongwon	JICA/monr	2000	Arabal	Chemerongwon		under construction	MOENR	Nobody
EnDow no.1	Endow	CCF	2000	Endow	Endow		under construction	Others	Nobody
EnDow no.2	Endow	CCF	2000	Endow	Endow		under construction	Others	Nobody

Among 17 boreholes, eight(8) boreholes were being dry or abandoned due to unacceptable water quality for domestic purpose, four(4) boreholes are still under construction. Remaining five(5) boreholes are solely using in the Study Area. Information in relation to usage of them are as below.

Name	Location	Facility Installed by	Used with	Condition of Water Use
Egerton Univesity, Chemeron Field	kimarel	personal	Submersible pump 2"	In use. borehole build in 1982 in Egerton University, Chemeron Field station. Water is warm and saline. Domestic use for cattle and 36 workers and neighboring villagers. Yield is little and 6 hr/day pumping is required to maintain the demand of farm.
Bogoria hotel borehole	Sandai	MENR	Submersible pump with solar system	Constructed in 1999 with depth of about 20 m, installed solar pump (50WX6=300W), only used for irrigation purpose.
EnDow Borehole (CCF well no.2)	Marigat	CCF	Submersible pump (under construction)	Constructed in 2000. Pump is not yet installed. CCF drilled it on August 2000. Yield is high, so the W/S (level 2; consisting of submersible pump, water tank and pipe line with gravity system) is now constructing.
Endow Borehole(CCF well no.1)	Marigat	CCF	-do-	Constructed in 2000, Pump is not yet installed. CCF drilled it on September 2000. Yield is as high as 300 l/min.
Eldume borehole(1),(2)	Eldume	private	not in use	Borehole was construed in 1987 aiming at use of Bogoria hotel's, but not have been used with the reason of high fluorine content. Location is 50 m far from river

4.4.9 Piped Water Supply

Piped water supply systems offering higher service level than other water points. There are eight(8) systems locating at Marigat, Salabaini, Kiseian, and Kimarel Locations, as follows:

Name of pipe supply	Source	Status	Managing Agency	Area Served (km2)	Pop. in Supply	Safe yield (Storage Capacity)	year constructed
Marigat	Perkerra river	in use	MLPR&WD	25.00	1750	240(135)	1957
Kampi Ya Samaki	Baringo Lake	in use	MLPR&WD	4.00	2305	280(135)	1989
Loruk	Baringo Lake	in use	Community	4.00	300	60(50)	1991
Arabal W/S	Arabal river	under construction	NWCPC	25.6 591	11,837 21,378	341(500) 436(500)	2001 2015
Koriema	Spring	in use	Community	-	-	- (-)	-
Sabor	Spring	in use	Community	-	-	- (-)	-
Maoi	Borehole	in use	Community	-	-	- (-)	-
Endao	Borehole	under construction	Community	-	-	- (230)	-

All the piped water supply system are covered limited area and population, and are not fully functioned due to the shortage of chemical, power supply, fuel, leaking water and breaking down of pumps and pipelines. Community based-systems are not routinely maintained.

4.5 Geophysical investigation

A geophysical survey of the Marigat and Mukutani Division, covering about 1200 square kilometers, was begun in late September and concluded in early November of 2000. Primary objectives of this survey were to determine the aquifer availability of target villages and to locate the suitable borehole-drilling sites nearby the village center. Secondary objectives of the study were to evaluate aquifer potential, and detect layered structure of overlying sedimentary facies, fault and fracture zones, consequently to clarify the groundwater resources potential of the Marigat and Mukutani Division. The measurements of Geophysical Survey cover whole selected villages stated above and is placed at where the results obtained from existing works (WRAP II, 1987-1992) can be applied for analysis of this survey. The resistivity survey was completed at three stations of which the vertical structure is drawn-out in resistivity profiles from TEM Result.

4.5.1 Transient Electromagnetic Sounding

The transient, or time-domain, electromagnetic method, often referred to as TEM, is a method in which the ground is energized by a man-made magnetic field and its response is measured as a function of time to determine the resistivity of the earth beneath the observation point as a function of depth.

1) The Transient Electromagnetic Method

In this method, a steady current is passed through a loop of wire situated on the surface of the earth, which is inductively linked to the earth. The fact that loop sources, which have no direct contact with the earth, can be used, makes this method suitable in areas where high surface resistivities prohibit the use of conventional direct current methods. This would include regions covered by dry sand and silt flats or extrusive volcanics.

In practice, the direct loop current is abruptly interrupted and the secondary field, which arises due to eddy currents induced in the earth, can be measured in the absence of the primary field. The eddy currents migrate from the transmitter loop into the earth and the pattern resembles the propagation of a 'smoke ring'. The rate of change of the magnetic field depends upon the underground resistivity structure. Given a poorly conductive medium, the receiver coil output voltage, which is proportional to the time rate of change of the secondary magnetic field, is initially large but decays rapidly. The response of a good conductor is initially lower but the voltage decays slowly. The time derivative of the transient magnetic field which results from these currents can be measured by a coil sensor.

The decay of the secondary field measured at surface can be analyzed to determine the resistivity of the earth at depth. The resistivities of geological materials are highly dependent upon porosity, water saturation, and pore fluid resistivity. Resistivity sounding, therefore, yields information about water content and quality, and TEM resistivity measurements are a valuable structural mapping tool for groundwater studies.

The TEM method was selected for this survey for the following reasons; (1) stability of the transmitter signal, (2) lack of static shift, (3) no near field phenomena, (4) uniqueness of the results, (5) high production rate and (6) suitability of the ungrounded source in rock desert.

2) TEM Equipment

The TEM system which was used in this survey was manufactured by Geonics Ltd., of Canada. The primary components of the system are a transmitter, a sensor coil and a receiver.

Two transmitters, an EM-47 and an EM-57, were used in this survey. The EM-47 is a battery powered transmitter which is capable of operating at high frequencies. It can be used to resolve shallow resistive units such as dry alluvium. It is a low power transmitter, however, and has a limited depth of penetration. The EM-57 operates at lower frequencies and is powered by a gasoline motor generatoror 24 volts battery providing a higher output current, leading to a greater depth of penetration. By combining measurements made from both sources, both the shallow and deep sections can be adequately resolved.

A responsive high frequency receiver coil with an effective area of 31.4 square meters and an internal signal preamplifier was used for EM-47 measurements and a more sensitive low frequency coil with an area of 100 square meters was used in the EM-57 measurements.

The receiver, a PROTEM 57(C) unit, samples the coil response at a series of time intervals that are delayed by a prescribed amount from each turn-off of the loop current. There are 20 geometrically spaced gates or channel positions in each time range. Decay voltages were recorded at two EM-47 transmitter base frequencies (uh-237.5,vh-62.5 and h-25Hz) and at three EM-57 base frequencies (H-25, M-6.25 and L-2.5 Hz) during the course of this survey.

A reference cable is used to establish precise timing between the transmitter and receiver.

3) Measurement configuration

Survey parameter tests were conducted at the beginning of the survey to aid in determination of the optimum measurement configuration for this survey. These tests were performed at a station near the Rugus area where the thickest alluvial section was expected, so that the penetration of the measurements could be assessed. The test site was also chosen to be near a power line so that the effect of electromagnetic noise upon the measurements could be considered.

During these tests, measurements were made at the center of square loop,several lengths of loops varying 50 m to 150 m meters in widthwere tested. In the testing, the loop was typically energized with a current of one(1) ampere for high frequency EM-47 measurements and a current of about 13 amperes for lower frequency EM-57 soundings. While large loop yield higher signal and have a greater depth of penetration, they can be difficult and time consuming to deploy and retrieve. With use of 100 m x 100m in size of loop, the depth of penetrationis reaching to 150 m deep As result, The 100 x 100 m `central loop` sounding configuration was selected as standard configuration of the Survey.

4) Station Positioning

TEM measurement stations were positioned byGPS. GPS was placed at the receiver coil site and an accurate position "fix" was obtained by averaging hundreds of GPS measurements.The survey points were converted toUniversal Transmercator (UTM) coordinates. This data was entered into the header of each sounding record as measurements were recorded. UTM coordinates were used during all field operations and the datum which was used throughout this survey isARC 1960 mean V.

5) Station Locations

TEM measurements were made at a total of 42 villages including 479 stations as shown in Appendix-B and Table 3.-1 and Figure 4-3.

6) Noise

Electromagnetic noise is induced in the receiver coil by power lines and from movement of the receiver coil in the earth's magnetic field by wind. Repetitive voltage measurements were made and averaged or 'stacked' to minimize these effects. The electromagnetic noise level was very low in the majority of the survey area but noise from power lines was appreciable in the vicinity of Marigat, Eldume and Loboi.

Data can also be distorted by man made conductive objects such as wells, pipelines or metal fences. Initial measurements produced transient data with polarity reversals at several stations near fences and water-pipelines. These stations were moved a few ten meters and usable data was obtained.

7) Data processing

The data which has been recorded in the field is first transferred from the PROTEM receiver to a personal computer, using the Geonics program. This data is stored in ASCII data files which are then read by a data inversion program.

In the first phase of data processing, the decay voltages for each gate are transformed into late-time apparent resistivity values, by normalization with respect to field data measurement parameters such as loop dimensions, receiver gain, current and sounding geometry.

The voltages, V_o (in units of mV), which are measured by the PROTEM receiver are converted to magnetic field decay rate, *dB/dt* (nV/m^2), by the following formula (Geonics, 1992).

$$\frac{dB}{dt} = \frac{V_0 \cdot 19200}{E \cdot 2^n}$$

where E is the receiver coil moment (m^2), and n is the amplifier gain setting. Apparent resistivities r_a (ohm-m) are then given as a function of time *(t)* by,

$$\rho_a(t) \cong \frac{\mu}{4 p t_c}\left(\frac{2 \mu M}{5 t_c \, dB/dt}\right)^{2/3}$$

in which, m is magnetic permeability (*4p*10^{-7} H/m), t_c is measurement time or the gate center time in seconds, and M is transmitter moment which is the product of loop area (m^2) and current (A).

An automatic one dimensional inversion technique was used to generate resistivity models composed up to 19 layers. In this process, the resistivities of the layers of a candidate model, which is chosen by the inversion program, are gradually changed and response curves are computed to determine the model whose response best fits the observed data. The model is not restricted by the condition that the resistivities of the layers change smoothly with depth, as they are with the Occam or 'smooth' inversion method. Models derived by this technique, without artificial parameterization, can be used to produce images which aid in visualization of underground structures. The imaging results were also used to estimate initial model parameters for the interactive one-dimensional inversions which followed.

4.5.2 TEM Sounding Results

Automatic one-dimensional data inversion was performed to generate 19-layer resistivity models for each of the data sets. The thickness of the layers increase with depth and these models extend to a depth of 150m from the surface. These results were used to determine the aquifer availability of target villages and to locate the suitable borehole-drilling sites nearby the village center.

As shown in analytical summary given below, 19 villages were represented as indicating some potential out of 42 villages surveyed. However, half of them (7 sites among 19 villages) were through to be underlain by saline water due to its low resistivity less than 5 ohm-m. Remaining 12 were judged as possible sites to develop groundwater by borehole drilling.

Location (Sub-location)	village	Loop No	Point No	Loop Size	Tem 47/57	Potential Level	Estimated Depth (m)	Resistivity (ohm-m)
Arabaru	Kapindas	2	18	100x100	47/57	Low	10-20	10-12
	Arabaru Pr School	2	18	100x100	47	High	40-70	4-8
	Ramacha	2	18	100x100	47	Low	40-60	20-30
	Karuma	1	11	100x100	47	Middle	30-50	5
	Katilomwo	2	18	100x100	47	Middle	30-60	10
	Parotaro	1	9	100x100	47	Low	40-50	70
	Kipkoibetu	1	9	100x100	47	Low	30-40	10
	Negrecha	1	9	100x100	47	-	-	-
	Losokoni	1	9	100x100	47	High	80-120	3
Eldume	Eldume Pr School	1	8	100x100	47/57	Low	90-100	0.5
	Lororo Center	2	16	100x100	47/57	Low	60-90	5-10
Ilngarua	Ilngarua	1	9	100x100	47			
	Ntepes	1	9	100x100	47			
Kapkuikui	Toborweche	1	9	100x100	47	-	-	-
Kimalel	Keniyach	1	8	100x100	47	-	-	-
	Kimorok Pr School	1	8	100x100	47	-	-	-
	Bartulgel	2	18	100x100	47	-	-	-
(Koriema)	Ranut	1	9	100x100	47			
(Sabor)	Kapkun	1	9	100x100	47	-	-	-
Kiseria	Loitip	2	18	100x100	47	-	-	-
	Losaburbur	1	9	100x100	47	Low	30-60	1
	Mosuro	1	9	100x100	47	-	-	-
	Sokotei	2	18	100x100	47	-	-	-
Loboi	Kapronguno	1	9	100x100	47	Low	60-80	20
Mukutani	Rugus	2	12	100x100	47/57	-	-	-
	Ilmuvet	1	10	100x100	47	Low	10-20	7
	Akure	1	9	100x100	47	High	80-100	10
	Mukutani Center	1	9	100x100	47	-	-	-
	Karau	1	9	100x100	47	-	-	-
	Murat	1	9	100x100	47	-	-	-
	Iberesati	2	18	100x100	47	-	-	-
	Lakerati	1	9	100x100	47	High	90-100	10
Ngambo	Masai	2	18	100x100	47	-	-	-
	Sintan	1	9	100x100	47	-	-	-
	Lolopiri	1	9	100x100	47	-	-	-
Sandai	Sandai Pr School	2	18	100x100	47/57	High	30-50	5
	Kairel	1	9	100x100	47	-	-	-
	Chepkotoiyan	2	18	100x100	47	High	40-60	2
Sarabani	Londeyani	2	19	100x100	47	High	20-40	1
(Yatoi)	Sirinyo	1	9	100x100	47	-	-	-
(Perikera)	Ndambul	1	9	100x100	47	Low	40-80	2
(Endao)	Barkibi	2	18	100x100	47	-	-	-
Total		57	506					

5 Major findings on existing water facility and resources

Most of existing water points and facilities in the Study Area were visited, and their performance and improved potential were evaluated, as summarized below:

-Water Holes: A water hole is a natural depression or digging hole on river-bed that contains water usually from groundwater and surface water run-off. Most natural depressions emerge immediately after the rain and last for a few weeks up to three months before they dry up. Natural depressions are often found in remote area of Neglecha Sub-Location, and Kimarel Sub-Locations, where are locating far form of village center. Digging holes are temporarily made on river bed for scooping underneath seepage water. They exit many at villagers' withdrawal spots along Molo and Perikerra rivers. Water are in general used for domestic purpose, live stock watering and minimal agriculture activity. Villagers draw off water manually. But water were almost contaminated.

- Natural Spring: Most of spring occur at the fringe of eastern and western slopes except the nearby Lake Bogoria. The spring found around Lake Bogoria can not be used because of too hot, salty, much Fluoride and sulfur. Another types of springs found in Arabal, Mukutani, Kimarel, Koriema, and Loboi Sub-locations are mostly used for domestic consumption and live stock watering and even for irrigation. Ilpirisati spring (cool) locating in Mukutani is yielding as much as 150 lit/min. And, a bit of contamination with faecal coliform, however other parameters show a drinkable water quality. It is needed to be improved with fencing and capping the spring-eye.

- Spring Protection: This type of improved springs are used as gravity supply sources. Most spring protection were made by community with supervision and funded by government/donor. These springs were found in Sobor and Koriema (user is in Koriema, but spring itself is locating outside of Koriema; Kituro Location) Sub Locations. However, two of them were imperfect facilities in particular its size of protection and capping. Extent of protection was tend to be small so that the volume of water available to user was restricted, and contamination by animals was caused. They were recommended that:

- Protection of the source with fencing, clean drainage of them;
- Protection boxes should always be covered
- Protection of the pipe line for flooding, vehicles and collapsing on hill slops;
- Cattle troughs should be build to keep away domestic animals form the points (at least 20 m downstream) and that way control pollution, and
- Concrete slabs and fitting draw-off pipes are to be settled above the natural level of streams.

In order to reduce on the working distance to the spring source, it is recommended that gravity pipe line are constructed wherever possible.

- Shallow Well/Hand-dug Well: Shallow well is a about 1.5 m wide and less than 10 m deep, hand dug hole, constructed for abstracting water from a shallow groundwater aquifer. Water is usually using by mean of a hand pump. As stated above, there were seven(7) wells along river courses at Koriema, Eldume, Mukutani and Ngambo Sub-Locations. One (1) well in Koriema was made by community. Two(2) in Eldume and Mukutani Sub-Locations were installed by Inter AID and Catholic M. and other four(4) in Ngambo Sub-Locations were constructed by UNICEF. Three(3) wells out of seven(7) were

breakdown.
UNICEF wells are all shallow as less than 10 m deep, and were constructed within a period of two to three months during dry season, so that they were nearly dried-up in drought year. In dry season, villagers used them very hard and frequent, and was apt to give serious damages to the pump piston and snider, which were resulting in breakdown. But, the villagers in Ngambo Location had none of knowledge how to maintain pumps and also how to organize water committee.
Community well in Koriema Location was quite lacking of well protection to prevent the contamination by entering of surface water. These wells must be repaired.

- **Boreholes:** Boreholes are small diameter, deep, machine drilled holes, constructed to abstract water from medium to deep aquifers. Borehole diameters, as found in Study Area are normally 150 mm; borehole depths found were deeper than 50 m. As mentioned above Among 17 boreholes drilled in the Study Area, five(5) boreholes were only used in the Study Area.

Reason to be abandoned of boreholes were being dry or saline water, however success boreholea are almost maintained well up to now. For example, Maoi well in Yatoi Sub Location, it was built by Government in 1993. The operation and maintenance practice of boreholes is already shifted to users, and users contribute to the operation cost. About 60 community members pay an agreed amount of money, as quantitative rate (2 KSh / 20 lit) to the water committee. This money is then used to pay for fuel and maintenance The Government provides the technical staff and meet the maintenance cost.
Privately owned boreholes and those of institutions and organizations such as Egerton University's are operated and maintained by the owners.
It is known as that the groundwater potential in the Study area is not much. In the groundwater potential survey, 42 villages centered by Mukutani, Arabal and Kiserian Locations were survey up to 150 m deep by TEM method. However, only 19 villages were detected a significance of deep aquifer. Further, half of them (7 sites among 19 villages) were supposed to be have high saline water. Finally, only 12 are judged as possible sites to develop groundwater by borehole drilling.

-**Dams:** As stated above, three major surface dams and one sub-surface dam are located in the Study Area. Chemeron, Tikaluk and Kimao dam are surface dams. In-take facility in Arabal piped water supply is sub-surface dam.

Chemeron dam are earth dam with 380 m long, 31 m high and 4600,000 m^3 of storage capacity. It was constructed by Kerio Valley Development Authority with the contract by H.Z. co.ltd in 1983. Although it was large capacity, half of reservoir has been filled by sediment. Likewise, dam body have been not maintained until now, so that embankment cracks in parts. The useful span of dam must be shortened unless proper erosion control measures would be taken in catchment areas of the dams.
Kimao dam is gravity type dam with 25 m high and 35 m long, and total capacity of reservoir is 288,000 m^3. Its effective storage estimated as 142,000 m^3, and catchment area is 7.8 km^2. This dam was planed for domestic and irrigation purpose for Koriema, Kimalel Sub-Location and far beyond for Kimorock area. Dam body itself and reservoir was solely constructed up to1998 as phase I construction. However, The phase II construction comprising of treatment and distribution system is not commenced due to financial

difficulty up to the present.

The source of Arabal pipied water supply is sub-surface dam, and are under construction. This sub-surface reservoir is located below the bottom of gravelly Arabal river, an is created by restraining the sub-surface runoff of that gravely river via an under ground embankment.

In-take of Arabal piped water supply was once destroyed by heavy flood took place in 1994 and 1997 caused from world-wide effect of El-nino. Its supply system including dam and pipelines are re-constructing by Nation Water Supply and Co-operation. The construction commenced at summer 2000, then will be terminated within one year. Finance was made with assistance of world bank.

Major problems of dams in the Study Area are a heavy siltation and pollution of reservoir. Siltation was observed over all dam reservoirs. Almost half of Chemaron dam capacity were already filled by silt. Cattle and other animals are easily enter dam reservoir, therefore, pollution is manifested. Water leakage, cracking of dam body and spillway are needed to be repaired. Eventually, proper catchment management is required to reduce sediment into dam reservoir in order to extend the their life span.

-Pan: Pan is the frequent water facility, and more than 30 pans were built in the Study Area. In villages like as Ramacha locating in hilly area, pan is sole water source to surrounding villages. In these areas, villagers and cattle have to walk over up 5 km to reach a pan for fetching water. Generally, pans are owned on the basis of land own ship. Where land has not been demarcated pans are considered to be public facility.

The two major problems related to the usage of pan are founded, which are:

-Polluted water, and

-Drying up during part of the year (Most of pan dried up for a period ranging one to four months).

For example, Losokoni pan in Arabal Location was newly renovated in June 2000, however, it was suffered by serious pollution with high content of iron, manganese, ammonium (indicating over 5 ppm which are far exceeding Kenyan standard). The pollution of pan is caused in many ways of:

- pollution of the surface runoff feeding the pan;
- cattle and the human beings entering the pan for getting water. Most consumers are aware that the water is polluted, but have no alternative then to the use pan for their domestic needs. Besides, most of pan dried up for a period ranging one to four months. For instance, Londaini pan located in Salabani Location is no longer functioning due to its high percolation and thick silt sediments. It is even drying up just after rainy season. Likewise,
- most pan are shallow while located in area with limited rainfall and high evaporation;
- most pan loose their effectiveness water storage capacity due to siltation. Most of the pans are silted, and
- losses of water trough the bottom of pan. Proper compaction of bottom is needed.

Both the quality of the water abstracted from the pan and water storage capacity can be improved through:

- proper siting;

- proper design;
- erosion control measures ,and
- proper implementation of the pan construction works.

- **Roof Catchment:** These system are mainly still at an introductory phase and have been recently implemented to schools and health centers by NGO and Public Health Department. A Few individual system were found in Marigat township. Size of the roof varies in respective case, and its design of institution system were mainly done by NGO. Construction in most cases was executed by local contractor or skilled local artisan with an assistance of users. In the case of Kimorok Primary school which is constructing roof catchment now, students and teachers are conveying necessary water for construction.

The Roof catchment in school and other institution such as health center and dispensary where extensive roof cover exist, and which include guttering and ground storage tanks, may offset the water supply problem considerably. Length of dry period must be considered in the design of tank. First water from each rain shower should be prevented from entering the storage reduced pollution by dust, leaves and birds droppings on the roof.

- **Piped Water Supply:**Water treatment system is always needed if surface water is used as a source of water supply; surface water is not clear enough and always contaminated. Four piped water supplies at Marigat, Kampi Ya Samaki, Arabal and Loruk stations have "Partial Treatment System" which are not with filtration unit. If groundwater, which shows less turbid and contaminated than surface water, is used, pied water supply system is rather simple than that of surface water system. Groundwater based piped water supply system often do not have any water treatment system. In the Study Area, Sabor, Maoi, and Endao water supply are used spring water or groundwater, and are not have any treatment system.

The success of water supply depends on various factors, of which the organization of the operation and maintenance is probably important. Although water supply systems governed by water sector of divisions, a kind of operation and maintenance system was found, but community based systems were almost not maintained. The metered individual connection was not installed ever in the Study Area. The number of user per connection was extremely high owing to flat rates per connection. In fact, Koriema water supply, they were only three connections serves as many as whole shopping canter. It was noticed that because of the flat rate payment beneficiaries tend to use more water. Likewise, Marigat water supply system served much amount of water exceeding the proper amount estimated by water tariff because of improperly use even by outsider form neighboring villages.