

***ATTACHMENT- 1***

**Selection of Borehole Sites**

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### **1. Preliminary Evaluation of Requested Boreholes Sites**

In the earliest period of the Basic Design Study (Study), a preliminary evaluation was done for 100 borehole sites listed on the request by the government of Kenya. As a result, 27 out of 100 were cancelled for the following reasons as shown in Table 1.

- (a) Inaccessibility
- (b) Overlapping with existing drilling plans by other donors
- (c) Problem on land acquisition in private ranch

Other than the originally requested sites, 52 sites were newly identified through the discussions and field reconnaissances jointly conducted by the JICA Study Team and MOWR as listed on Table 2. Accordingly, 125 sites were considered for the basic design study.

In addition, MOWR requested the JICA Study Team Study equipping several borehole sites with motorized pumps and rehabilitating several sites. After the discussions on this matter, eight sites were additionally incorporated including four to be equipped with motorized pumps and four to be rehabilitated. Consequently, the total number of objective sites become 133 for the Study as seen in Table 3.

### **2. Hydrogeological Investigations**

#### **(1) Collection and Analysis of Existing Data**

The inventory of existing boreholes by MOWR, the list of existing boreholes prepared by each district water office, and the previous study reports were collected and analyzed to clarify the hydrogeological characteristics in the Project Area. Analysis was also made for depth of borehole, static water level, groundwater yield, and water quality. Distribution of existing boreholes in the Project Area is shown in Figure 1. The collected data of existing 404 boreholes are presented in Attachment-4. The number of existing boreholes by districts is summarized below.

Item	Laikipia	Samburu	Baringo	Koibatek	Total
No. of Existing Boreholes	258	68	65	13	404

Water quality data are available for 147 boreholes shown below. These locations are shown in **Figure 2**. Water quality data for these boreholes are presented in **Attachment-5**.

Item	Laikipia	Samburu	Baringo	Koibatek	Total
No. of Existing Boreholes with Water Quality Data	79	38	24	6	147

## (2) Field Reconnaissance Survey for Existing Boreholes

A survey including measurements of groundwater level, electric conductivity, pH and water temperature was conducted for 29 of the existing boreholes in the Project Area. These locations are shown in **Figure 3**. However, measurements were not possible at some boreholes already abandoned or completely sealed up by installation of equipment. For such cases, measurements were made at river or spring which may supply groundwater to the borehole. The results of measurements are shown in **Table 4**.

## (3) Hydrogeological Structure and Evaluation of Aquifer

Geological structures of the Project Area consist of Pre-cambrian metamorphic rocks (more than 600 million years ago), Tertiary and Quaternary volcanic rocks (30 million years ago to present), and Quaternary unconsolidated deposits (river and lake deposits at present). The structures show the following hydrogeological characteristics and are evaluated as aquifers respectively. A conceptual figure of hydrogeological structures in the Project Area is shown in **Figure 4**.

### (a) Pre-cambrian Basement Rocks

The basement rocks are metamorphic rocks mainly consisting of granite-gneiss and distributed in Laikipia district in the northeast, Samburu district in the east, and a part of Baringo district.

The basement rocks are generally massive without significant cracks and their fresh parts are evaluated as impermeable layers. Aquifers are found as layers of well-developed cracks along faults and fractured zones or weathered surface layers. Such aquifers are found locally with quite limited extent in the basement rocks.

(b) Volcanics

The volcanics are distributed widely in the Project Area: Laikipia district in the west to south, Samburu district in the southwest, and the whole areas of Baringo and Koibatek districts. These consist of Tertiary and Quaternary volcanic rocks composed of basalt-lavas, phenolites, trachytes, etc., with tuffs and volcanic ash.

These volcanics form lava plateau consisting of multi layers as shown in **Figure 4**. Lava plateau is formed by lava flows with a thickness of 10 to 20 meters overlaying one after another. Confined aquifers exist at contact of layer each other and that of underlying Pre-cambrian basement. The confined aquifers are distributed widely in the Project Area. Static water level and groundwater yield from the confirmed aquifers varies depending on their confined conditions.

In general, static water level is relatively shallow with abundant yield near Mt. Kenya and the Aberdares. As distant from these mountains, a static water level tends to be deep with less yield.

(c) Quaternary Unconsolidated Deposits

Quaternary unconsolidated deposits containing fresh groundwater are locally observed around rivers and lakes in the Project Area. Groundwater, depending on rainfall amount and thickness of the deposits, is subject to seasonal fluctuation. Static water level is recovered during rainy season but is lowering significantly at the end of dry season. The deposits are distributed locally with limited extent. It is, therefore, necessary to confirm hydrogeological conditions on site for evaluation.

#### (4) Possible Pumping Yield

Possible pumping yield from borehole depends on aquifer characteristics and capacity of pump installed at borehole. The analysis was done on the basis of boreholes given in the inventory. The results are shown in **Figure 5**.

#### (5) Static Water Level

From the inventory of existing boreholes, static water levels vary from 10 to 150 meters and many boreholes have levels 40 to 60 meters or deeper. Static water levels at the proposed borehole sites should be carefully examined for application of hand-pumps with their limitation of the maximum pumping head. **Table 5** shows the distributions of unsuccessful boreholes and static water levels of successful boreholes by district.

The table indicates the rates of boreholes unsuccessful and with static water level deeper than 60 m by district are 30% in Laikipia district, 54% in Samburu district and 61% in Baringo and Koibatek districts. Relatively deep static water level is observed around the southern part of Laikipia district near Mt. Kenya and the Aberdares and locations of Quaternary unconsolidated deposits with relatively wide extent. A contour map of static water level in Laikipia district is shown in **Figure 6**.

#### (6) Water Quality

The study on water quality is conducted using the water quality data of existing boreholes. **Attachment-5** gives the results indicating several items of water quality beyond those guidelines in Kenya for many of the existing boreholes. The study mainly pays attention to Fluoride (F) and Nitrate ( $\text{NO}_3$ ) as described below.

- (a) For fluoride, relationships to electric conductivity and aquifer are examined as shown in **Figure 7** and **8**, respectively. Fluoride content for similar electric conductivity varies by region, namely, groundwater indicates high fluoride content in the volcanics areas of Baringo, Koibatek and a part of Samburu districts, especially in the lowland in the Lift Valley.

Fluoride content is less than the guidelines in most aquifers composed of Quaternary unconsolidated deposits and Pre-cambrian basement rocks. Some higher values are observed in aquifers of volcanics.

- (b) Nitrate content is generally less in the whole Project Area, except a part of Samburu district.

Groundwater in Pre-cambrian metamorphic rocks shows poor water quality with high content of dissolved minerals in some places. In general, groundwater quality is good in aquifers of Quaternary unconsolidated deposits and volcanics in Laikipia district. High salt content is observed at a part of Samburu district.

For fluoride content, the Kenyan guidelines accept a content of 3.0 mg/l for exceptional cases like those in the Lift Valley even though the WHO recommended value is 1.0 mg/l.

#### (7) Electric Soundings

Electric soundings were conducted at 102 locations in the Project Area including 50 in Laikipia district, 24 in Samburu district, 24 in Baringo district and 4 in Koibatek district. Locations of electric soundings are shown in **Figure 9**. These locations were selected through hydrogeological field reconnaissances prior to the soundings. The results of field data analysis of electric soundings are given in **Attachment-7**.

#### (8) Water Quality Tests

The samplings for water quality tests were conducted at 16 locations in the Project Area including 12 of groundwater from boreholes, 2 of rivers, 1 of spring, and 1 of lake. Locations of samplings are given in **Table 6** and **Figure 3**. Water quality tests were done for 19 testing items and the results are shown in **Table 7** and a tri-linear diagram shown in **Figure 10**.

Most water samples indicate characteristics of groundwater originating from volcanics. Some of them give similar content to seawater. Samples showing similar content to rain water were taken from basalt lavas near Mt. Kenya.

### 3. Evaluation of Possible Borehole Sites from Hydrogeological Viewpoints

On the bases of the results of the hydrogeological studies described above, 133 sites selected for the basic design study were evaluated as shown in Table 8. The results of the evaluation are summarized below. 86 of the possible borehole sites were screened and their locations are shown in Figure 11.

District	Possible Site for Handpump		Possible Site for Motorized Pump			Omitted Site		Total No. of Site
	Type-1	Type-2	Type-3	Motorized Pump Requested	Rehabilitation Requested	No Aquifer	Poor Water Quality	
Laikipia	28	14	7	1	1	12	1	64
Samburu	14	1	0	1	1	16	0	33
Buringo	12	0	0	1	1	4	10	28
Koibatek	0	2	0	1	1	1	3	8
Total	54	17	7	4	4	33	14	133
	71		15			47		133

Note Type-1: SWL  $\leq$  45 m  
 Type-2: 45 < SWL  $\leq$  55 m  
 Type-3: SWL > 55 m

### 4. Criteria for Successful Rate of Boreholes

For the purpose of the Project, criteria for successful boreholes are prepared on the basis of the guidelines by JICA due to the absence of such criteria in Kenya. The following criteria are applied.

- (a) Groundwater yield : more than 330  $\ell$ /hour
- (b) Water Quality : meeting the Kenya guidelines of potable water quality

Using the criteria above, successful rate of boreholes for the Project is examined in compliance with the results of hydrogeological studies on the condition that drilling points are determined more accurately in the implementation stage.

**Table 5** indicates successful rates of boreholes by region estimated from the data of 321 existing boreholes in the Project Area. On this table, 'Unsuccessful' mean no groundwater is observed or yield is very small at the borehole.

Static water levels at 16% of boreholes are deeper than 55 m that is not suitable to install handpumps. Whereas, all the proposed borehole sites are selected to meet expected static water level up to 55 m depth for installing handpumps. The successful rate of boreholes for the Project is, therefore, obtained from the table as follows.

$$(\text{Successful Rate}) = 1 - (\text{Unsuccessful Rate})$$

The successful rate of boreholes by region is given below.

District	Division	Successful Rate
Laikipia	Mukogodo	78%
	Rumuruti	84%
	Ngarua	76%
	Lamuria	93%
	Central	80%
Samburu	Wamba	30%
	Wamba	30%
Baringo		69%
Koibatek		54%

## 5. Proposed Number of Boreholes

The results of hydrogeological studies give 71 possible borehole sites for installation of handpumps. The number of sites by district and division is shown below.



District	Division	No. of Proposed Sites
Laikipia	Mukogodo	5
	Rumuruti	5
	Ngaria	8
	Lamuria	16
	Central	8
	Sub-total	42
Samburu	Wamba	4
	Lorroki	7
	Kirisia	4
	Sub-total	15
Baringo	Kipsalaman	2
	Tangulbei	3
	Mikutani	1
	Mochongoi	5
	Kolowa	1
	Sub-total	12
Koibatek	Mumberes	1
	Mogotio	1
	Sub-total	2
Total		71

For these 71 sites, proposed number of boreholes was examined taking present supply ratio, population density and successful rate of boreholes into consideration.

#### (1) Population

The latest official population census in Kenya was conducted in 1989 and the population projections to the year 2000 were provided in 1996. Referring this population projections, the population projections in the Project Area were done by sub-location to the year 2000 for the purpose of the Study.

The population projections by district are shown below. Population density in the Project Area is shown in Figure 12.

District	1990	1995	2000	Area (km <sup>2</sup> )	Density (person/km <sup>2</sup> )
Laikipia	245,221	310,440	381,698	9,178	42
Samburu	114,762	136,976	155,056	20,808	7
Baringo	264,754	300,888	329,392	8,567	38
Koibatek	128,935	147,758	168,204	2,387	70

## (2) Present Supply Ratio

Present supply ratio by water supply facility is estimated approximately as described below.

### (a) Piped Water Supplies

Supplied population by piped water supplies were estimated on the basis of available data obtained from Project Status Report, Water Resources Assessment Project, Aftercare Study for NWMP.

### (b) Small Scale Water Supplies

Actual situations of small scale water supplies like point sources were not clarified due to insufficient data. For the purpose of the Study, supplied population by small scale water supplies are estimated approximately from potentials of water sources. The estimation of supply capacity is made on the basis of groundwater yield from the inventory of boreholes prepared by MWR since most of the Project Area covered with ASAL relies on groundwater for domestic use. Supplied population is calculated using estimated supply capacity of water source and unit water consumption assumed at 15  $\ell$ /c/day.

Supplied population and supply ratio are estimated by sub-location and compiled by district as shown below. Distribution of supply ratio in the Project Area is shown in Figure 13.

District	Supplied Population	Population in 2000	Supply Rate
Laikipia	147,723	381,698	38%
Samburu	58,105	155,056	37%
Baringo	79,976	329,392	24%
Koibatek	63,334	168,204	39%
Total	349,318	1,034,350	34%

## (3) Proposed Number of Boreholes

The proposed number of boreholes were determined by:

(a) Proposed borehole is equipped with handpump

(b) Supplied population by one borehole is estimated as follows.

- Unit water consumption : 15  $\ell$ /c/day (from Kenya guidelines)
- Pumping rate : 675  $\ell$ /hour (from JICA guidelines)

When borehole yield is less than 675  $\ell$ /hour, pumping rate is assumed as the same as borehole yield.

- Operation hours : 8 hours/day

For example, supplied population is 360 persons for borehole with pumping rate of 675  $\ell$ /hour.

$$(675 \ell/\text{hour}) \times (8 \text{ hours/day}) / (15 \ell/\text{c/day}) = 360 \text{ persons}$$

(c) First, each borehole is proposed for the selected 71 sites under the following conditions.

- Supply ratio is less than 70% in sub-location where site is located.
- Successful rate of boreholes by region is more than 50%.

As a result, each borehole is proposed at 59 out of 71 sites.

(d) Second, borehole is additionally proposed for the site where supplied population is many and hydrogeological conditions are good. The conditions are as follows.

- Concentration of proposed boreholes to some sub-locations should be avoided. Drilling points at site should also be selected within an area where the same hydrogeological conditions are expected. Number of additional boreholes is, therefore, limited to one per site.
- Population density of sub-location is more than 7 persons/ $\text{km}^2$ , namely, an area within 4 km from borehole point covers more than 360 persons that is equivalent to supplied population per borehole with handpump.

- From the hydrogeological evaluation, it is expected that borehole yield will be more than 1 m<sup>3</sup>/s and static water level is 45 meters depth or less.
- After provision of one borehole, supply ratio of sub-location is still lower than 70%.

As a result, each one borehole is additionally proposed at 31 out of 59 sites.

The number of proposed boreholes are 90 in the Project Area. The results are summarized in Table 9 and the list of proposed boreholes is given in Table 10. The Proposed boreholes in the Project Area are shown in Figure 14.

The number of proposed boreholes by district and division is presented below.

District	Division	No. of Sites	No. of Proposed Boreholes
Laikipia	Mukogodo	5	8
	Rumuruti	5	8
	Ngarua	8	11
	Lamuria	16	14
	Central	8	11
	Sub-total	42	52
Samburu	Wamba	4	0
	Lorroki	7	13
	Kirisia	4	3
	Sub-total	15	16
Baringo	Kipsalaman	2	4
	Tangulbei	3	5
	Mikutani	1	2
	Mochongoi	5	7
	Kolowa	1	2
	Sub-total	12	20
Koibatek	Mumberes	1	1
	Mogotio	1	1
	Sub-total	2	2
Total		71	90

Table 1 Preliminary Evaluation of Requested Borehole Sites

No.	Name of Site	Inaccessibility	Overlapping	Land Acquisition	Evaluation	No.	Name of Site	Inaccessibility	Overlapping	Land Acquisition	Evaluation	
<b>Laikipia District</b>						<b>Lorroki Division</b>						
<b>Mukogoda Division</b>						<b>1 Lonkewan</b>						
1	Kipsing peleta	x	0	0	x	2	Anaiya	0	0	0	0	
2	Anendeguru	0	0	0	0	3	Kisima Town	0	0	0	0	
3	Lorbitosa	0	0	0	0	4	Naueri	0	0	0	0	
4	Muranairusha	0	0	0	0	5	Limisigiyo	0	0	0	0	
5	Ilwotiok	0	0	x	x	6	Baawa	0	0	0	0	
6	Musual	0	0	0	0	7	Mbaringo	0	0	0	0	
7	Sicku	x	0	0	x	sub-total					7	
8	Alijo	0	0	0	0	<b>Kirisia District</b>						
9	Olkiyei	0	0	0	0	<b>1 LParutuk-1</b>						
10	Ewaso-1	0	0	0	0	<b>2 Sirata Oirobi</b>						
11	Ewaso-2	x	0	0	x	<b>3 Nkejemuny</b>						
12	Ilpolei	0	0	0	0	<b>4 Seiya</b>						
13	Murupesi	x	0	0	x	<b>5 Opiroi</b>						
14	Kurikuri-1	0	0	0	0	<b>6 Mabati</b>						
15	Kurikuri-2	x	0	0	x	<b>7 Mbukoi</b>						
16	Saramba	0	0	0	0	<b>8 Malaso</b>						
17	Ngare Ndare	x	0	0	x	sub-total					5	
18	Ingwesi	0	0	0	0	total of Samburu						19
19	Kimaio T.C.	0	0	0	0	<b>Baringo District</b>						
20	Tura	0	0	0	0	<b>Kipsaraman Division</b>						
sub-total					13	<b>1 Kiayach</b>						
<b>Rumuruti Division</b>						<b>sub-total</b>						0
1	Lakija Junction	x	0	0	x	<b>Tangulbei Division</b>						
2	Three Point	0	0	0	0	<b>1 Churo</b>						
sub-total					1	<b>2 Orus</b>						
<b>Ngarua Division</b>						<b>3 Chemukoko-1</b>						
1	Kamigi	0	0	0	0	<b>4 Chemukoko-2</b>						
2	Kiambogo	0	0	0	0	<b>5 Komol-1</b>						
3	Eighteen Rubere	0	0	0	0	<b>6 Komol-2</b>						
4	Ol Ngarua Sec.	0	0	0	0	<b>7 Seroin</b>						
5	Mithiga-1	0	0	0	0	<b>8 Nagarwa-1</b>						
6	Mithiga-2	0	0	0	0	<b>9 Nagarwa-2</b>						
7	Kinamba T.C.	0	0	0	0	<b>10 Kaptua</b>						
8	Marweku	x	0	0	x	sub-total					5	
9	Ngelesha	x	0	0	x	<b>Mukutani Division</b>						
sub-total					7	<b>1 Kiserian</b>						
<b>Lumuria Division</b>						<b>2 Laminong</b>						
1	Kijabe	0	0	0	0	<b>3 Narkwe</b>						
2	Segera	0	0	0	0	sub-total					2	
3	Njoguini	0	0	0	0	<b>Muchogoi Division</b>						
4	Matanya	0	0	0	0	<b>1 Nyimbei</b>						
5	Wamura	0	0	0	0	<b>2 Cheruniny</b>						
6	Imenti-1	0	0	0	0	sub-total					2	
7	Imenti-2	0	0	0	0	<b>Nganyang Division</b>						
8	Kihju Mwiri	x	0	0	x	<b>1 Katikit</b>						
9	Withare	0	0	0	0	<b>2 Seretian</b>						
10	Tigithi-1	0	0	0	0	<b>3 Oro</b>						
11	Tigithi-2	0	0	0	0	sub-total					2	
12	Sweet Waters	0	0	0	0	<b>Kolowa Division</b>						
sub-total					11	<b>1 Kolowa</b>						
<b>Central Division</b>						<b>2 Sukut</b>						
1	Kiniugundura	0	0	x	x	<b>3 Misikist</b>						
2	East Laikipia	0	0	0	0	<b>4 Tiliagwa</b>						
3	Rugutu	0	0	0	0	<b>5 Tiriaka</b>						
4	Ngenia	0	0	0	0	sub-total					2	
5	Muireri	0	0	0	0	total of Baringo						19
6	Muramati	0	0	0	0	<b>Koibatek District</b>						
7	Naibor	0	0	0	0	<b>Ravine Division</b>						
sub-total					6	<b>1 Mumberes</b>						
Total of Laikipia					38	<b>2 Trongo</b>						
<b>Samburu District</b>						<b>sub-total</b>						2
<b>Wamba Division</b>						<b>Mogotio Division</b>						
1	Wamba	0	0	0	0	<b>1 Ararae</b>						
2	Koiting	0	0	0	0	sub-total					1	
3	Matakwen	0	0	0	0	total of Koibatek						3
4	Lkisin	0	0	0	0	<b>For 4 Districts</b>						
5	Ngotim	x	0	0	x	x : cancelled, 0 : screened						73
6	Sesia	0	0	0	0							
7	Lpus	0	0	0	0							
8	Lolkuniyani	0	0	0	0							
sub-total					7							

**Table 2 Additional Borehole Sites Requested**

District	Division	Name of Site	District	Division	Name of Site		
Laikipia	Rumuruti	1 Gatundia	Baringo	Kipsaraman	1 Sibilo		
		2 Machuguru			2 Ngaratuko		
		3 Mifugo			3 Yatya		
		4 Kite			4 Barsemoi		
		5 Salama			5 Lokodowobet		
		6 Muruku		Mukutan	1 Mututani		
		7 Mutara			Muchogoi	1 Kasiela	
	Ngarua	2 Sinoni					
		1 Naigera		3 Kabindasim			
		2 Cheleta		4 Kamailel			
		3 Kiambogo		Nginyang	1 Katugumok		
		4 Mwenje			2 Chepilat		
	5 Kagaa	Lamuria		1 TharuWaichekeheri			
	2 Lamuria T.C		Kolowa	1 Barpelu			
	3 Thome Kiburuti			Sub-total of Baringo	13		
	4 Thome T.C				Koibatek	Eldama Ravine	1 Tolmo
	5 Ngobit T.C						Mogotio
	6 Imenti-2				2 Radat		
	7 Withare				Sub-total of Koibatek	3	
	8 Kihata					Total	52
	Central	1 Nturukuma					
		2 Rugutu					
		3 Endana					
		4 Mukima					
Sub-total of Laikipia		24					
Samburu	Wamba	1 Dikir					
		2 Wamba-3					
	Lorroki	1 Maralal-1					
		2 Maralal-2					
		3 Upper Kisima dam					
		4 Logorate					
		5 Mbaribon school					
		6 Sora adur					
		7 Lepetidet school					
	Kirisia	1 Lpartuk-2					
		2 Ilpartuk					
		3 EastLoikas					
Sub-total of Samburu		12					

Table 3 Selected Borehole Sites for Hydrogeological Investigations (1/3)

**Laikipia District**

**Mukogodo Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
1	Anenduguru	●	1	B
2	Lorbitsa	●	1	B
3	Muranairusha	●	1	B
4	Musual	●	1	B
5	Aljijo	●	1	B
6	Olkinyei	●	1	B
7	Ewaso-1	●	1	B
8	Ilpolei	●	1	B
9	Kurikuri-1	●	1	B
10	Saramba	●	1	B
11	Iingwesi	●	1	B
12	Kimanjo T.C.	●	1	B
13	Tura	●	1	B
14	Doldol		1	C
	Sub-total		14	

**Rumuruti Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
15	Three Point	●	1	B
(Additional)				
16	Gatundia	●	1	B
17	Machuguru	●	1	B
18	Mifugo	●	1	B
19	Kite	●	1	B
20	Salama		1	B
21	Muruku		1	B
22	Mutara		1	B
	Sub-total		8	

**Ngarua Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
23	Kamigi	●	1	B
24	Kiambogo-1	●	1	B
25	Eighteen Rubere	●	1	B
26	Oi Ngarua Sec.	●	1	B
27	Mithiga-1	●	1	B
28	Mithiga-2	●	1	B
29	Kinamba T.C.	●	1	B
(Additional)				
30	Naigera	●	1	B
31	Cheleta	●	1	B
32	Kiambogo-2		1	B
33	Mwenje		1	B
34	Kagaa		1	B
	Sub-total		12	

**Lamuria Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
35	Kijabe	●	1	B
36	Segera	●	1	B
37	Njoguini	●	1	B
38	Matanya	●	1	B
39	Lamuria	●	1	A
40	Wamura	●	1	B
41	Imenti-1	●	1	B
42	Imenti-2	●	1	B
43	Withare	●	1	B
44	Tigithi-1	●	1	B
45	Tigithi-2	●	1	B
46	Sweet Waters	●	1	B
(Additional)				
47	Tharua Waichekeheri	●	1	B
48	Lamuria T.C.	●	1	B
49	Thome Kiburuti	●	1	B
50	Thome T.C.	●	1	B
51	Ngobit T.C.		1	B
52	Imenti-3	●	1	B
53	Withare		1	B
54	Kihata		1	B
	Sub-total		20	

**Central Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
55	East Laikipia	●	1	B
56	Rugutu-1	●	1	B
57	Ngenia	●	1	B
58	Muireri	●	1	B
59	Murarnati	●	1	B
60	Naibor	●	1	B
(Additional)				
61	Nturukuma		1	B
62	Rugutu-2		1	B
63	Endana		1	B
64	Mukima		1	B
	Sub-total		10	

Total of Laikipia

64

Table 3 Selected Borehole Sites for Hydrogeological Investigations (2/3)

Samburu District

Wamba Division

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
65	Wamba-1	●	1	A
66	Wamba-2	●	1	B
67	Koiting	●	1	B
68	Matakwen	●	1	B
69	Ngotim	●	1	B
70	Sesia	●	1	B
71	Ipus	●	1	B
72	Lolkuniyani	●	1	B
(Additional)				
73	Dikir	●	1	B
74	Wamba-3		1	B
	Sub-total		10	

Lorroid division

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
75	Lonkewan	●	1	B
76	Amaiya	●	1	B
77	Kisima Town	●	1	B
78	Nauneri	●	1	B
79	Lmisigiyo	●	1	B
80	Baawa	●	1	B
81	Baawa		1	C
82	Mbarigon	●	1	B
(Additional)				
83	Upper-Kisima Dam		1	B
84	Logorate		1	B
85	Mbaribon school		1	B
86	Sora Adur		1	B
87	Lepetid school		1	B
	Sub-total		13	

Kirsia Division

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
88	LPartuk-1	●	1	B
89	Sirata Oirobi	●	1	B
90	Nkejemuny	●	1	B
91	Seiya	●	1	B
92	Malaso	●	1	B
(Additional)				
93	Lpartuk-2	●	1	B
94	Maralal-1	●	1	B
95	Maralal-2	●	1	B
96	lpartuk		1	B
97	East-Loikas		1	B
	Sub-total		10	

Total of Samburu

33



**Table 3 Selected Borehole Sites for Hydrogeological Investigations (3/3)**

**Baringo District**

**Kipsaraman Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Additional)				
98	Sibilo	●	1	B
99	Ngaratuko	●	1	B
100	Yalya	●	1	B
101	Barsemoi		1	B
102	Lokodowobet		1	B
	Sub-total		5	

**Tangulbei Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
103	Churo-1	●	1	A
104	Churo-2	●	1	B
105	Komol	●	1	B
106	Seronin	●	1	B
107	Nangarwa-1	●	1	B
108	Nangarwa-2	●	1	B
109	Nyaunyau		1	C
	Sub-total		7	

**Mukutani Division**

Site No.	Location	Electric Soundings	No.	Borehole Type
(Original)				
110	Kiserian	●	1	B
111	Narkwe	●	1	B
(Additional)				
112	Mukutani	●	1	B
	Sub-total		3	

**Muchongoi Division**

Site No.	Location	Electric Soundings	No.	Well Type
(Original)				
113	Cheruniny	●	1	B
114	Nyimbei	●	1	B
(Additional)				
115	Kasiela	●	1	B
116	Sinoni	●	1	B
117	Kabindasim	●	1	B
118	Kamailel		1	B
	Sub-total		6	

**Nginyang Division**

Site No.	Location	Electric Soundings	No.	Well Type
(Original)				
119	Seretian	●	1	B
120	Oro	●	1	A
(Additional)				
121	Katugumok	●	1	B
122	Chepilat	●	1	B
	Sub-total		4	

**Kolowa Division**

Site No.	Location	Electric Soundings	No.	Well Type
(Original)				
123	Kolowa	●	1	B
124	Tilingwa	●	1	B
(Additional)				
125	Barpelo	●	1	B
	Sub-total		3	

Total of Baringo

28

**Kolbatek District**

**Eldama Ravine Division**

Site No.	Location	Electric Soundings	No.	Well Type
(Original)				
126	Mumberes	●	1	B
127	Trongo	●	1	B
(Additional)				
128	Tolmo		1	B
	Sub total		3	

**Mogotio Division**

Site No.	Location	Electric Soundings	No.	Well Type
(Original)				
129	Ararae	●	1	B
130	Emening	●	1	A
131	Legetwel		1	C
(Additional)				
132	Kipsogon		1	B
133	Radat		1	B
	Sub total		5	

Total of Kolbatek

8

Note:

A means borehole site to be equipped with motorized pump.

B means borehole site to be equipped with hand pump.

C means rehabilitation site.

● means electric soundings are executed.

Table 4 Water Quality Measurements

No.	Date of measurement	District	Water resources	Division	Location (Village)	Latitude	Longitude	Temp. (°C)	EC ( $\mu$ S/cm)	PH	remarks
M-1	31 Jul. 98	Samburu	River	Lorroki	Kiroriti	36.4808	0.8525	21.1	200	8.3	Antaiya R.
M-2	1 Aug. 98	Samburu	Exist.W	Lorroki	Baawa	36.8014	0.9861	20.0	776	7.9	W-1
M-3	1 Aug. 98	Samburu	Pond	Lorroki	Baawa	36.4810	0.8528	21.0	697	8.1	
M-4	1 Aug. 98	Samburu	Exist.W	Lorroki	Kisima	36.7611	0.9444	21.5	904	9.2	W-2
M-5	3 Aug. 98	Samburu	Exist.W	Wamba	Wamba	37.3250	0.9750	26.5	866	7.3	W-3
M-6	3 Aug. 98	Samburu	Exist.W	Wamba	Wamba	37.3250	0.9625	28.1	3930	7.0	W-4
M-7	4 Aug. 98	Samburu	Exist.W	Kirisia	Maralal	36.7278	1.0583	22.0	1381	7.2	W-5
M-8	5 Aug. 98	Baringo	Pond	Muketani	Narokwe	35.7583	1.2135	32.0	6140	7.8	by rain
M-9	5 Aug. 98	Baringo	River	Muketani	Muketani	36.2417	0.6333	27.5	1680	9.0	W-6
M-10	6 Aug. 98	Baringo	River	Kolowa	Barpelo	35.9027	1.1248	32.0	180	8.6	Barpero R.
M-11	6 Aug. 98	Baringo	Exist.W	Nginyang	Kositei	36.0083	0.9833	37.7	1320	8.1	W-7
M-12	6 Aug. 98	Baringo	Exist.W	Kolowa	Kolowa	36.8083	1.1861	32.0	630	7.6	W-8
M-13	7 Aug. 98	Baringo	River	Kipsaraman	Sibilo	35.9006	0.7017	26.2	593	8.8	W-9
M-14	7 Aug. 98	Baringo	River	Nginyang	Nginyang	36.0139	0.9500	29.9	231	8.7	Nginyang R.
M-15	8 Aug. 98	Baringo	Exist.W	Tangulubei	Tangulubei	36.3083	0.7944	31.1	999	8.0	W-10
M-16	8 Aug. 98	Baringo	Spring	Tangulubei	Churo	36.4067	0.7700	27.1	573	8.7	
M-17	9 Aug. 98	Baringo	Lake	(Lake Baringo Club)		36.0250	0.6167	26.7	635	8.3	W-16
M-18	9 Aug. 98	Baringo	River	Kiserian	Logumukum	36.0861	0.0083	19.2	98	8.0	W-11
M-19	9 Aug. 98	Baringo	Spring	Muchongoi	Chebinyai	36.2103	0.4252	34.5	577	9.1	
M-20	10 Aug. 98	Koibatek	Dug.W	Torongo	Torongo	35.6148	0.1318	16.8	3590	5.6	a bandoned
M-21	12 Aug. 98	Laikipia	Exist.W	Mukogodo	Ildigili	37.0097	0.4875	24.7	1105	5.6	W-12
M-22	13 Aug. 98	Laikipia	Exist.W	Mukogodo	Mukogodo	37.1750	0.3722	22.2	403	7.1	
M-23	13 Aug. 98	Laikipia	River	Mukogodo	Mukogodo	37.1750	0.3722	18.3	865	8.4	
M-24	13 Aug. 98	Laikipia	Spring	Lamuria	Ngogit	36.6508	-0.0658	17.7	605	7.9	
M-25	14 Aug. 98	Laikipia	Exist.W	Lamuria	Sirima	36.6500	-0.0667	20.4	676	7.6	W-13
M-26	14 Aug. 98	Laikipia	Exist.W	Lamuria	Sirima	36.7250	0.0500	22.0	867	9.1	
M-27	15 Aug. 98	Laikipia	Exist.W	Mukogodo	Iingwesi	37.2938	0.3097	19.2	788	7.2	
M-28	15 Aug. 98	Laikipia	Exist.W	Central	Segera	37.0083	0.1542	22.2	697	7.7	W-14
M-29	16 Aug. 98	Laikipia	Exist.W	Ngarua	Kinamba	36.3250	0.4389	20.4	472	7.7	W-15

**Table 5 Unsuccessful Borehole Ratio and Depth Static Water Level**

District	Division	Unsuccessful (Ratio)	Number of Boreholes					Total
			Depth of Static Water Level (D)					
			55m ≤ D	45m ≤ D < 55m	35m ≤ D < 45m	0m ≤ D < 35m	Unknown	
Laikipia	Mukogodo	3 (21.4%)	0 (0.0%)	1 (7.1%)	1 (7.1%)	9 (64.3%)	—	14 (100%)
		11 (15.9%)	19 (27.5%)	17 (24.6%)	8 (11.6%)	14 (20.3%)	—	69 (100%)
	Ngama	4	6	2	1	4	—	17
		23.5%	35.3%	11.8%	5.9%	23.5%	—	100%
	Lamuria	2	4	2	6	18	—	32
		6.3%	12.5%	6.3%	18.8%	56.3%	—	100%
Central	16	11	10	11	34	—	82	
	19.5%	13.4%	12.2%	13.4%	41.5%	—	100%	
Samburu	Wamba	18 (69.2%)	1 (3.8%)	1 (3.8%)	0 (0.0%)	6 (23.1%)	—	26 (100%)
	Kirisia/Lorrolgi	3 (17.6%)	2 (11.8%)	0 (0.0%)	2 (11.8%)	10 (58.8%)	—	17 (100%)
Baringo	10 (30.3%)	3 (9.1%)	2 (6.1%)	1 (3.0%)	10 (30.3%)	7 (21.2%)	33 (100%)	
	Koibatek	14 (45.2%)	4 (12.9%)	3 (9.7%)	0 (0.0%)	1 (3.2%)	9 (29.0%)	31 (100%)

**Table 6 Water Sampling Points for Laboratory Tests**

No.	Date of sampling	District	Division	Location (Village)	Type of water resources	remarks
W-1	1 Aug, 98	Samburu	Lorroki	Kiroriti	Existing well	Chainese team(1998)
W-2	1 Aug, 98	Samburu	Lorroki	Kisima	Existing well	Catholic mission(1992)
W-3	2 Aug, 98	Samburu	Wamba	Wamba	Existing well	C-7910(1976)
W-4	3 Aug, 98	Samburu	Wamba	Wamba	Existing well	Chainese team(1998)
W-5	4 Aug, 98	Samburu	Kirisia	Mararal	Existing well	C-9068(1989)
W-6	5 Aug, 98	Baringo	Mukutan	Mikutani	Seasonal river	Mikutani river
W-7	6 Aug, 98	Baringo	Nginyang	Kositei	Existing well	C-3470(1967)
W-8	7 Aug, 98	Baringo	Koloa	Koloa	Existing well	AIC(1997)
W-9	8 Aug, 98	Baringo	Kipsaraman	Sibilo	Dug well	
W-10	9 Aug, 98	Baringo	Tangulubei	Tangulubei	Existing well	CDN(1997)
W-11	10 Aug, 98	Koibatek	Mogotio	Mogotio	Permanent river	Molo river
W-12	11 Aug, 98	Laikipia	Mukogodo	Iindigiri	Existing well	
W-13	12 Aug, 98	Laikipia	Lamuria	Sirima	Spring	
W-14	13 Aug, 98	Laikipia	Central	Segeera	Existing well	
W-15	14 Aug, 98	Laikipia	Ngarua	Kinamba	Existing well	C-10621
W-16	15 Aug, 98	Baringo			Lake	Lake Baringo

Chainese team: Kenya/China technical co-op borehole drilling project


AIC: African inland church mission

CDN: Catholic diocese of Nakuru water programme

**Table 7 Results of Water Quality Tests**

No.	District	Division	Location (Village)	Water resources	Temp. (°C)	EC (µS/cm)	pH	Color	Turbidity	CO <sub>2</sub> (mg/l)	HCO <sub>3</sub> (mg/l)	Mn (mg/l)	Mg (mg/l)	Fe (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)	TDS (mg/l)	F (mg/l)	NO <sub>3</sub> (mg/l)	SO <sub>4</sub> (mg/l)	Cl (mg/l)	CaCO <sub>3</sub> (mg/l)
W-1	Samburu	Lorroki	Kironi	Well	20.1	848	7.7	>30	1	34.5	189	nil	110	0.8	9.5	45.5	39.8	590	1.1	19.4	nil	180	503
W-2	Samburu	Lorroki	Kisima	Well	20.1	919	9.2	>30	2	24	147	nil	0.5	nil	3.7	141	1.3	645	3.5	0.2	262	175	nil
W-3	Samburu	Wamba	Wamba	Well	20.0	778	7.5	>30	2	18	238	1.2	145	nil	6.3	42.5	50	1380	1.3	0.2	556	130	376
W-4	Samburu	Wamba	Wamba	Well	20.0	3760	6.9	8	17	32	144	4.1	325	2	10.8	370	307.5	1445	0.7	0.1	782	750	454
W-5	Samburu	Kirisia	Mararal	Well	20.1	1419	6.8	16	12	11	162	0.5	140	18	10.5	135	122.5	1130	0.9	0.1	247	160	214
W-6	Baringo	Mukutan	Mukutani	River	20.1	1517	9.1	11	14	62	466	0.1	6.4	9.3	20	430	7.5	1060	1.5	0.1	350	100	nil
W-7	Baringo	Nganyang	Kositei	Well	20.3	1032	8.1	>30	1	33	278	nil	2.3	nil	9.3	95	6.5	835	2.4	1.1	165	90	nil
W-8	Baringo	Kolosa	Kolosa	Well	20.2	525	7.4	27	5	15	161	0.4	nil	18	8.7	27.5	31.8	340	1.5	0.1	1379	40	209
W-9	Baringo	Kipsaraman	Sibilo	Well	20.3	573	8.7	>30	3	15	99	nil	14.9	0.8	4.1	27.5	29.5	420	1.2	0.8	144	60	156
W-10	Baringo	Tangulubei	Tangulubei	Well	20.0	839	7.9	>30	1	24	191	nil	13.4	nil	8.5	31	24.5	400	1.4	0.4	62	140	491
W-11	Kobatek	Mogotio	Mogotio	River	20.4	98	7.9	4	5	128	48	0.1	5	8.8	7.5	12.5	0.8	285	0.2	nil	nil	22.5	nil
W-12	Laikipia	Mukogodo	Indigiri	Well	20.0	1048	7.7	>30	2	107	194	nil	115	0.4	15	62.5	37.6	700	1.3	1.2	308.7	75	434
W-13	Laikipia	Lamuria	Sirima	Spring	20.3	730	7.7	>30	1	171	208	nil	45	0.3	12.5	62.5	17	10	1.5	0.6	144.1	35	197
W-14	Laikipia	Central	Segera	Well	20.1	696	7.8	>30	2	33	187	nil	45	0.3	25	60	19.2	515	0.3	0.2	82.3	37.5	47
W-15	Laikipia	Ngarua	Kinamba	Well	20.2	486	8.2	>30	1	26	170	nil	30	0.1	25	55	10.2	175	1.4	0.1	61.7	17.5	nil
W-16	Baringo		Lake	Lake	20.3	645	7.8	7	4	239	161	0.1	15	8.8	15	6.5	5.2	410	3.5	4.18	102.9	50	nil

Temp.: Temperature of water samples in laboratory test

 : Value exceeding guideline for constituents of health significance


 : Value exceeding guideline for permissible aesthetic quality

Table 8 Evaluation of Sites from Hydrogeological Viewpoints (1/5)

LAIKIPIA DISTRICT

Mukogodo Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
1	Anenduguru	1	B	x					x	
2	Lorbitosa	1	B	○	○	80	40	3.7	⊙	C-3434
3	Muranairosha	1	B	x					x	
4	Musual	1	B	x					x	
5	Ajijo	1	B	x					x	
6	Oikinyei	1	B	x					x	
7	Ewaso-1	1	B	○	○	80	25	1.5	⊙	C-1813
8	Ilpolei	1	B	○	○	90	25	1.8	⊙	C-371
9	Kurikuri-1	1	B	x					x	
10	Saramba	1	B	x					x	
11	Iingwesi	1	B	x					x	
12	Kimanzo T.C.	1	B	○	○	110	25	4.0	⊙	C-3420
13	Tura	1	B	○	○	130	30	0.5	⊙	C-2479
14	Dokdol	1	C							
Total		14								

Rumuruti Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
15	Three Point	1	B	x					x	
16	Gatundia	1	B	x					x	
17	Machuguru	1	B	x					x	
18	Mifugo	1	B	○	○	120	40	4.0	⊙	C-1921
19	Kite	1	B	○	○	130	40	3.0	⊙	C-1899
20	Salama	1	B	○	○	130	45	0.5	⊙	C-1381
21	Muruku	1	B	○	○	120	40	3.0	⊙	C-42
22	Mutara	1	B	○	○	180	45	3.0	⊙	C-1143
Sub total		8								

Ngarua Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
23	Kamigi	1	B	○	○	110	70	8.0	△	C-1977
24	Kiambogo-1	1	B	○	○	130	45	0.5	⊙	C-3916
25	Eighteen Rubere	1	B	○	○	110	20	5.0	⊙	C-10621
26	Oi Ngarua Sec.	1	B	○	○	100	40	0.5	⊙	C-3916
27	Mithiga-1	1	B	○	x				x	
28	Mithiga-2	1	B	○	○	110	70	8.0	△	C-1977
29	Kinamba T.C	1	B	○	○	110	20	5.0	⊙	C-10621
30	Naigera	1	B	○	○	160	50	2.5	●	C-913
31	Cheleta	1	B	○	○	150	50	2.5	●	C-37
32	Kiambogo-2	1	B	○	○	130	50	0.5	●	
33	Mwenje	1	B	○	○	110	20	5.0	⊙	
34	Kagaa	1	B	x					x	
Sub total		12								

Note: Type

Aquifer type

Presence of Aquifer

Water quality

Evaluation

A: Motorized pump, B: Hand pump, C: Rehabilitation

A: Sedimentary deposit, B: Volcanics, C: Basement rocks

○: recognized x: not recognized

○: permissible (F < 3.0 mg/l), x: not suitable (F > 3.0 mg/l)

⊙: Hand pump (Afridif), ●: hand pump (Indian Mark II),

△: Motorized pump, x: not recommendable

Table 8 Evaluation of Sites from Hydrogeological Viewpoints (2/5)

**LAIKIPIA DISTRICT**

**Lamuria Division**

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
35	Kijabe	1	B	○	○	100	30	5.0	⊙	C-1984
36	Segera	1	B	○	○	80	20	2.0	⊙	
37	Njoguini	1	B	×					×	
38	Matanya	1	B	○	○	150	60	3.8	△	C-1563
39	Lamuria	1	A	○	○	130	40	2.5	⊙	C-593
40	Wamura	1	B	○	○	180	50	3.5	△	C-932
41	Imenti-1	1	B	○	○	80	40	6.0	⊙	C-2023
42	Imenti-2	1	B	○	○	100	45	6.0	⊙	
43	Withare	1	B	○	○	120	40	3.0	⊙	C-1984
44	Tigithi-1	1	B	○	○	150	60	3.8	△	C-1563
45	Tigithi-2	1	B	○	○	150	60	4.6	△	C-1015
46	Sweet Waters	1	B	○	○	130	60	3.8	△	C-1563
47	Tharua Waichekeheri	1	B	○	○	120	50	2.0	●	C-1015
48	Lamuria T.C.	1	B	○	○	120	50	2.0	●	C-1015
49	Thome Kiburuti	1	B	○	○	150	50	2.5	●	C-1562
50	Thome T.C.	1	B	○	○	150	50	2.5	●	C-1562
51	Ngobit T.C.	1	B	○	○	80	40	2.0	⊙	
52	Imenti-3	1	B	○	○	120	30	3.0	⊙	C-1791
53	Withare	1	B	○	○	80	20	2.0	⊙	
54	Kihata	1	B	○	○	150	50	2.5	●	C-1562
Sub total		20								

**Central Division**

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
55	East Laikipia	1	B	○	○	100	30	3.0	⊙	C-233
56	Rugutu-1	1	B	○	○	100	40	1.3	⊙	C-2803
57	Ngenia	1	B	○	○	80	50	5.0	●	C-1679
58	Muireri	1	B	○	○	100	55	6.0	●	C-1679
59	Muramati	1	B	○	○	100	55	6.0	●	C-1679
60	Nabor	1	B	○	○	120	50	1.0	●	C-2375
61	Nturukuma	1	B	○	○	100	45	6.0	⊙	C-694
62	Rugutu-2	1	B	○	○	130	60	1.7	△	
63	Endana	1	B	○	○	150	60	4.5	△	
64	Mukima	1	B	○	○	100	45	6.0	⊙	
Sub total		10								

Note: Type

Aquifer type

Presence of Aquifer

Water quality

Evaluation

A: Motorized pump, B: Hand pump, C: Rehabilitation

A: Sedimentary deposit, B: Volcanics, C: Basement rocks

○: recognized x: not recognized

○: permissible (F < 3.0 mg/l), x not suitable (F > 3.0 mg/l)

⊙: Hand pump (Afrides), ●: hand pump (Indian Mark II),

△: Motorized pump, x: not recommendable

Table 8 Evaluation of Sites from Hydrogeological Viewpoints (3/5)

SAMBURU DISTRICT

Wamba Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
65	Wamba-1	1	A	○	○	50	15	1.5	△	C-3827
66	Wamba-2	1	B	○	○	120	30	5.0	⊙	Chinese team
67	Koiting	1	B	×					×	
68	Matakwen	1	B	×					×	
69	Ngotim	1	B	×					×	
70	Sesia	1	B	×					×	
71	Ipus	1	B	×					×	
72	Lolkuniyani	1	B	○	○	100	40	1.0	⊙	
73	Dirkir	1	B	×					×	
74	Wamba-3	1	B	○	○	120	30	5.0	⊙	
	Sub total	10								

Lorroid division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
75	Lonkewan	1	B	×					×	
76	Amaiya	1	B	○	○	100	40	2.0	⊙	
77	Kisima Town	1	B	○	○	100	30	1.0	⊙	C-1806
78	Nauneri	1	B	○	○	100	30	1.0	⊙	C-1806
79	Imisigiyo	1	B	○	○	100	40	2.0	⊙	C-8990
80	Baawa	1	B	○	○	120	40	2.0	⊙	
81	Baawa	1	C							
82	Mbarigon	1	B	×					×	
83	Upper-Kisima Dam	1	B	×					×	
84	Logorate	1	B	×					×	
85	Mbaribon school	1	B	○	○	120	40	3.0	⊙	C-9753
86	Sora Adur	1	B	×					×	
87	Lepetidet school	1	B	○	○	100	30	1.0	⊙	C-1806
	Total	13								

Kirisia Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
88	L Partuk-1	1	B	×					×	
89	Sirata Oirobi	1	B	○	○	130	40	2.5	⊙	C-3833
90	Nkejumuny	1	B	○	○	130	40	2.5	⊙	C-3834
91	Seiya	1	B	×					×	
92	Malaso	1	B	×					×	
93	Lpartuk-2	1	B	○	○	130	50	1.0	●	
94	Maralal-1	1	B	○	○	110	30	1.5	⊙	
95	Maralal-2	1	B	×					×	
96	Lpartuk	1	B	×					×	
97	East-Lolkas	1	B	×					×	
	Sub total	10								

Note: Type

Aquifer type

Presence of Aquifer

Water quality

Evaluation

A: Motorized pump, B: Hand pump, C: Rehabilitation

A: Sedimentary deposit, B: Volcanics, C: Basement rocks

○: recognized x: not recognized

○: permissible (F < 3.0 mg/l), x not suitable (F > 3.0 mg/l)

⊙: Hand pump (Afridef), ●: hand pump (Indian Mark II),

△: Motorized pump, x: not recommendable



Table 8 Evaluation of Sites from Hydrogeological Viewpoints (4/5)

Baringo District

Kipsalaman Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
98	Sibilo	1	B	○	○	50	20	1.5	⊙	
99	Ngaratuko	1	B	○	×				×	
100	Yatya	1	B	○	×				×	
101	Barsemoi	1	B	○	×				×	
Sub total		4								

Tangulbel Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
102	Churo-1	1	A	○	○	110	40	5.0	△	
103	Churo-2	1	B	○	○	130	15	5.0	⊙	
104	Komol	1	B	×					×	
105	Seronin	1	B	×					×	
106	Nangarwa-1	1	B	○	○	130	45	2.5	⊙	
107	Nangarwa-2	1	B	○	○	130	45	2.5	⊙	
108	Nyaunyau	1	C							
Sub total		7								

Mukutan Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
109	Kiserian	1	B	○	○	80	20	1.0	⊙	C-6365
110	Narkwe	1	B	○	○	100	30	1.0	⊙	C-6362
111	Mututani	1	B	○	×				×	
112	Lokodowobet	1	B	○	○	80	20	1.0	⊙	
Sub total		4								

Muchogoi Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
113	Cheruniny	1	B	○	○	50	20	1.5	⊙	
114	Nyimbei	1	B	○	○	100	20	2.0	⊙	
115	Kasiela	1	B	○	○	110	30	2.0	⊙	
116	Sinoni	1	B	○	○	100	30	2.0	⊙	
117	Kabindasim	1	B	○	○	110	30	2.5	⊙	
118	Kamailel	1	B	○	○	110	30	2.5	⊙	
Sub total		6								

Nginyang Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
119	Seretian	1	B	×					×	
120	Oro	1	B	○	×				×	
121	Katugumok	1	B	○	×				×	
122	Chepilat	1	B	○	○	110	40	2.0	⊙	C-6364
Sub total		4								

Kolowa Division

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
123	Kolowa	1	B	○	○	60	15	1.5	⊙	
124	Tilingwa	1	B	×					×	
125	Barpeko	1	B	○	○	100	20	2.0	⊙	
Sub total		3								

Note: Type

Aquifer type

Presence of Aquifer

Water quality

Evaluation

A: Motorized pump, B: Hand pump, C: Rehabilitation

A: Sedimentary deposit, B: Volcanics, C: Basement rocks

○: recognized x: not recognized

○: permissible (F < 3.0 mg/l), × not suitable (F > 3.0 mg/l)

⊙: Hand pump (Afridef), ●: hand pump (Indian Mark II),

△: Motorized pump, x: not recommendable

**Table 8 Evaluation of Sites from Hydrogeological Viewpoints (5/5)**

**KOIBATEK DISTRICT**

**Eldama Ravine Division**

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
126	Mumberes	1	B	○	○	120	50	1.0	●	
127	Trongo	1	B	○	○	200	40	3.0	⊙	
128	Tolmo	1	B	×					×	
Sub total		3								

**Mogotio Division**

No.	Location	No.	Type	Presence of aquifer	Water quality	Depth (m)	SWL (m)	Yield (m <sup>3</sup> /h)	Evaluation	Remarks
129	Ararae	1	B	○	○	120	50	4.0	●	C-285
130	Emening	1	A	○	○	150	70	8.0	△	C-616
131	Kipsogon	1	B	○	×				×	
132	Radat	1	B	○	×				×	
133	Legetwet	1	C							
Sub total		5								

Note: Type

Aquifer type

Presence of Aquifer

Water quqlity

Evaluation

A: Motorized pump, B: Hand pump, C: Rehabilitation

A: Sedimentary deposit, B: Volcanics, C: Basement rocks

○: recognized ×: not recognized

○: permissible (F < 3.0 mg/l), × not suitable (F > 3.0 mg/l)

⊙: Hand pump (Afridef), ●: hand pump (Indian Mark II),

△: Motorized pump, ×: not recomandable





**Figure 1** Distributions of Existing Boreholes

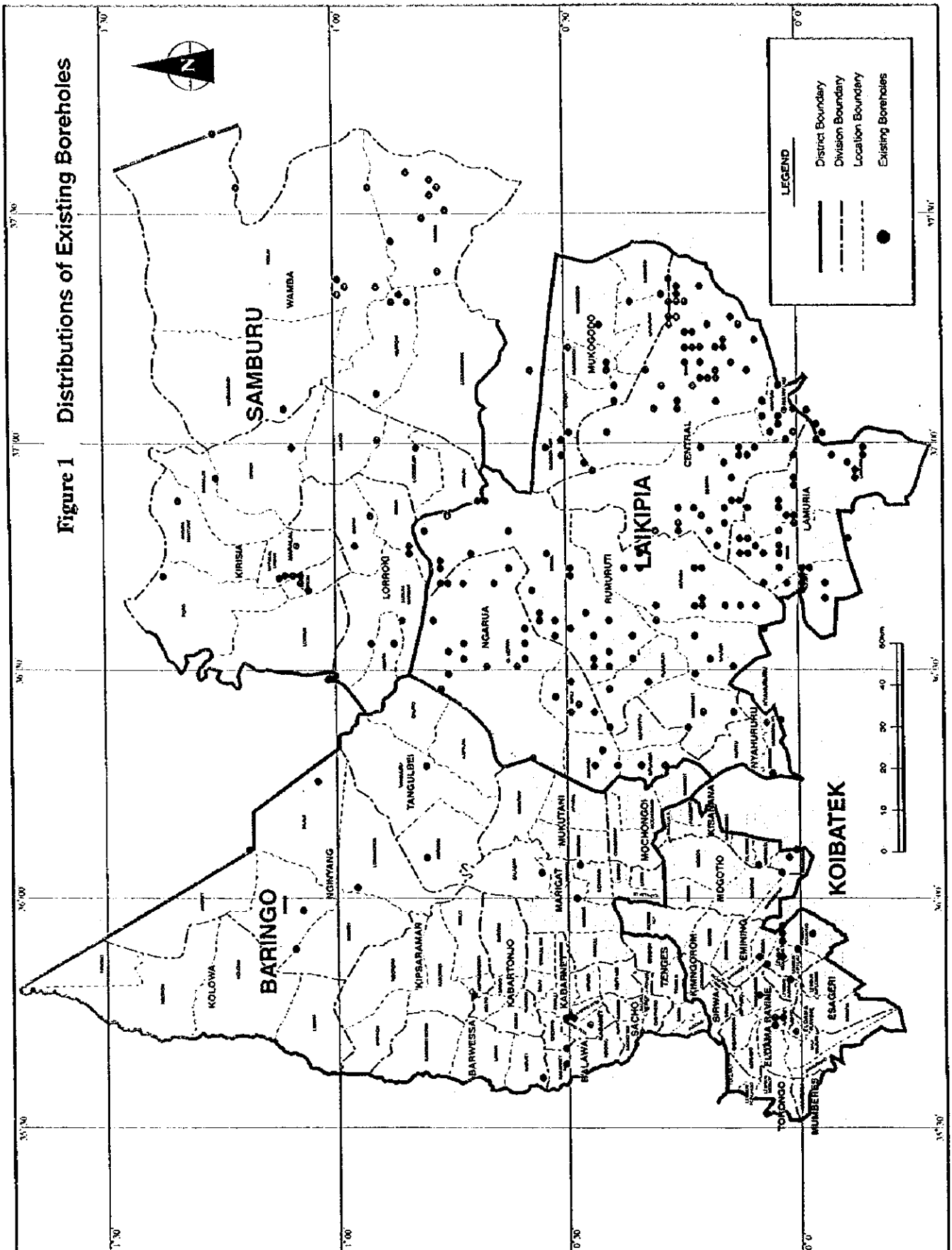
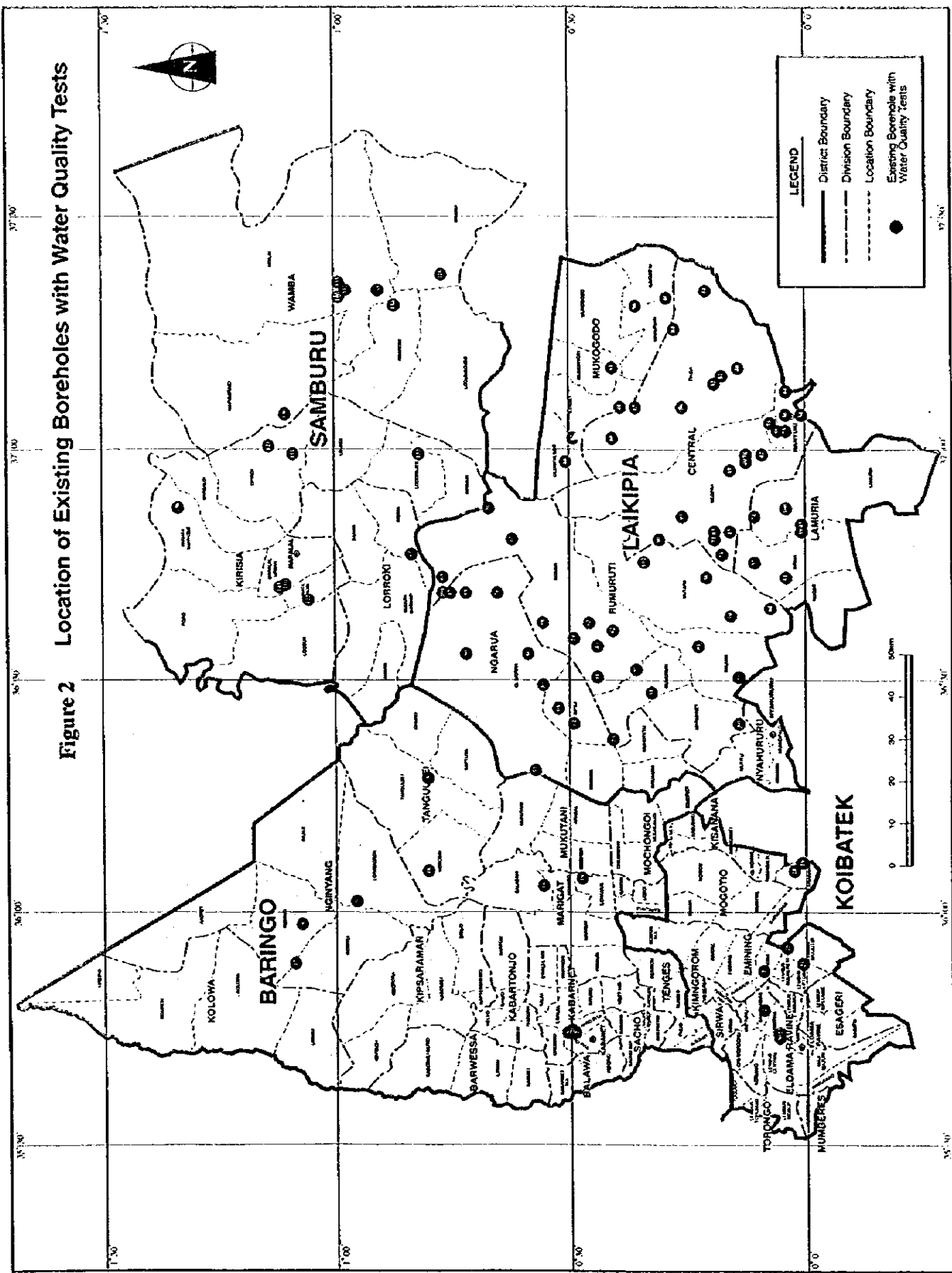


Figure 2 Location of Existing Boreholes with Water Quality Tests



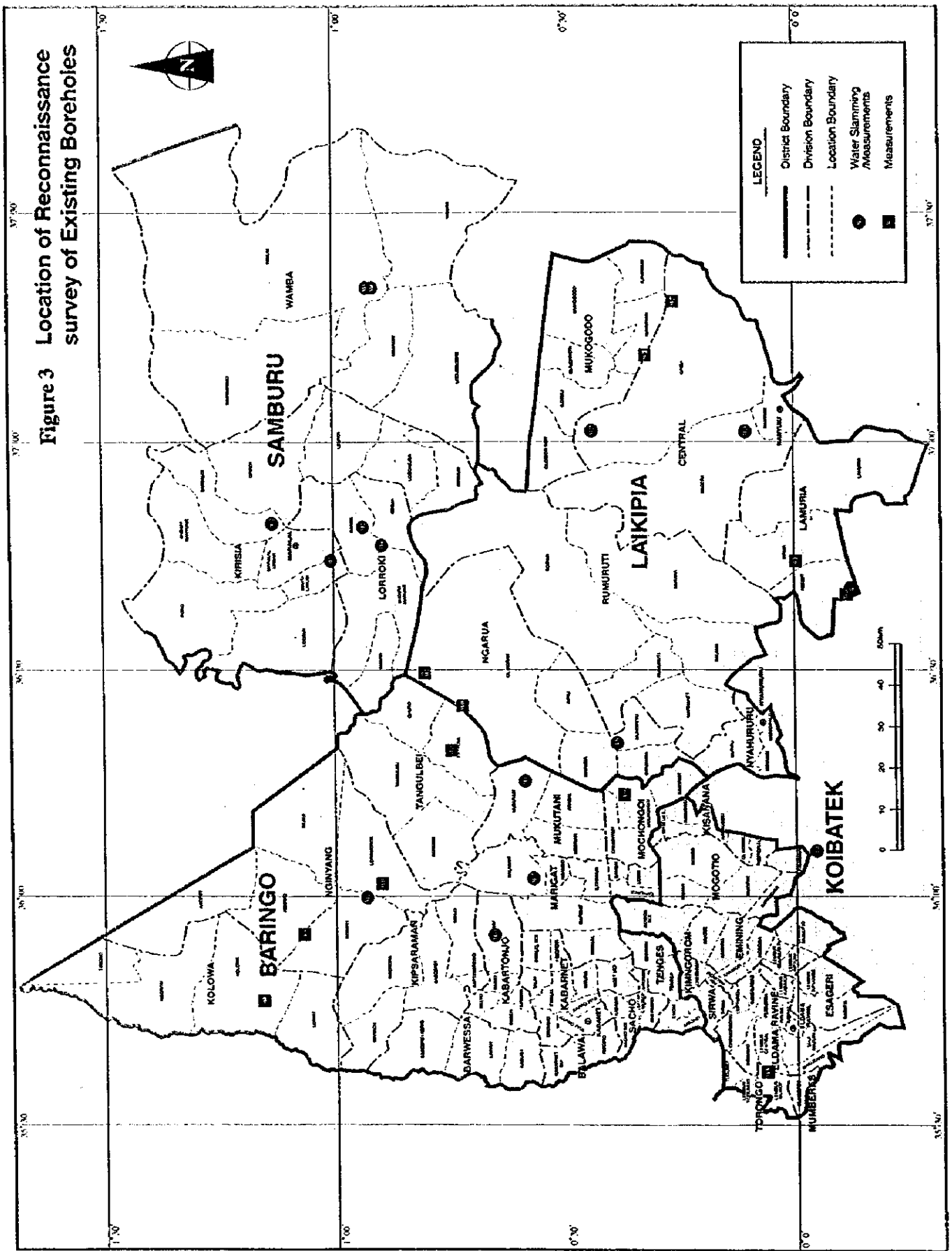
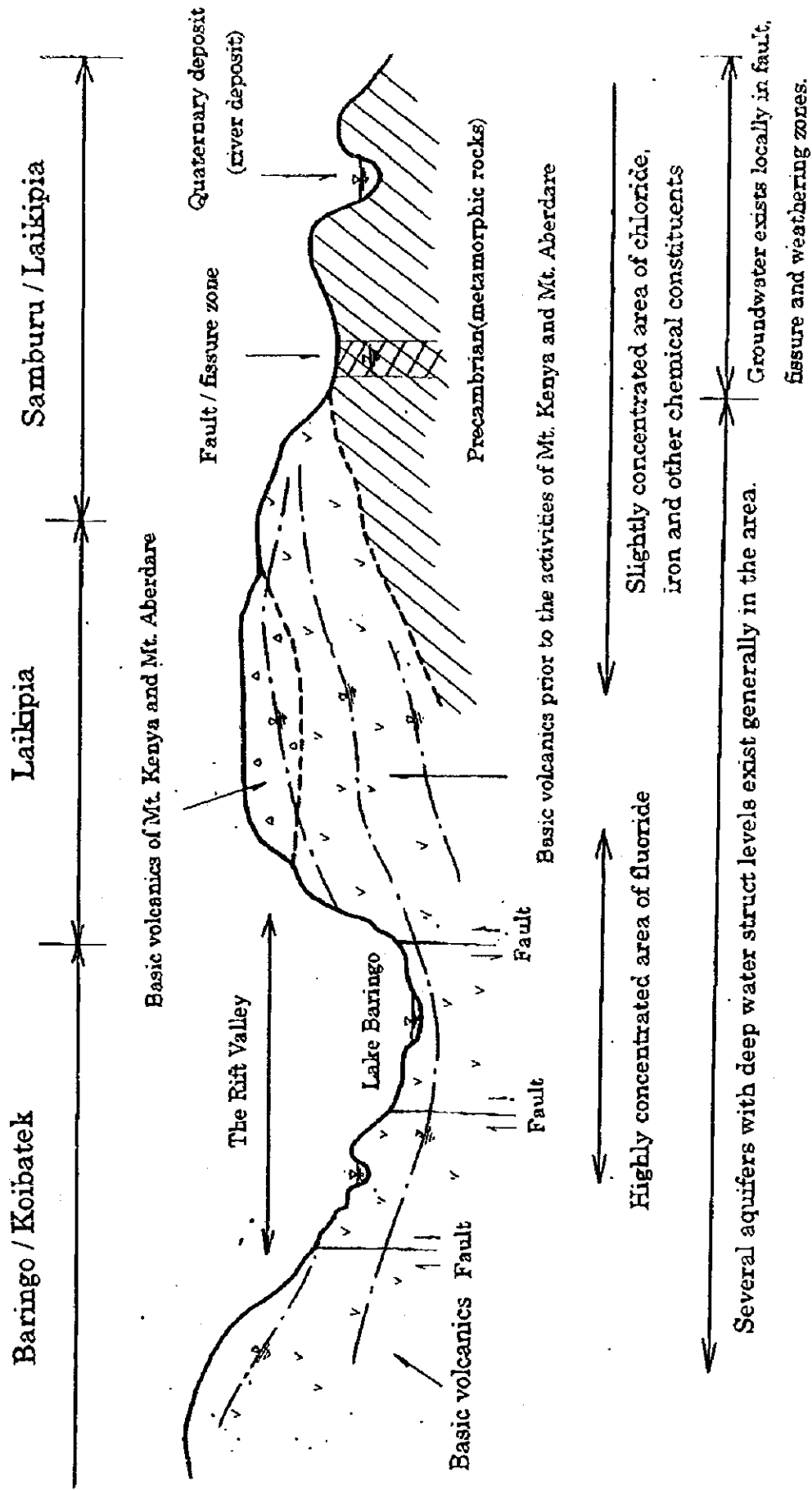
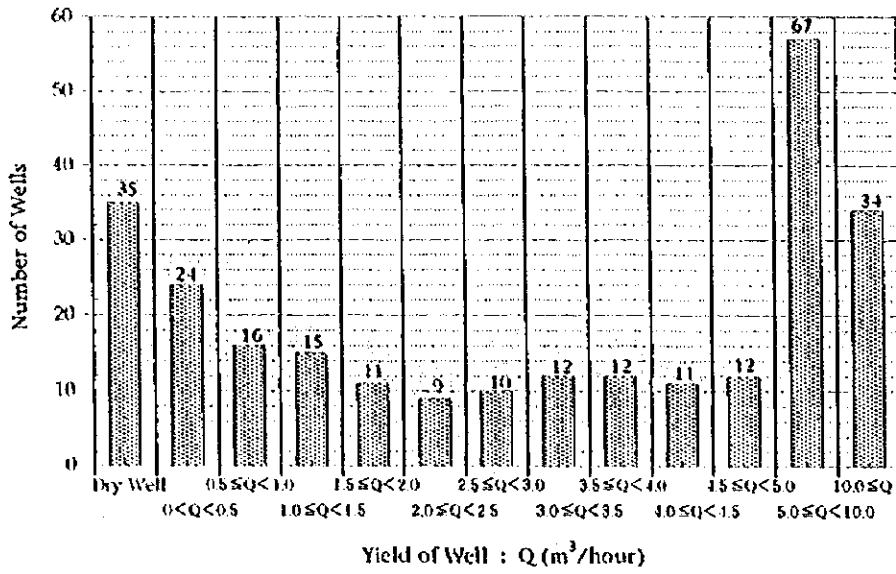


Figure 4 Schematic hydro-geological cross section in the objective area showing groundwater distribution system

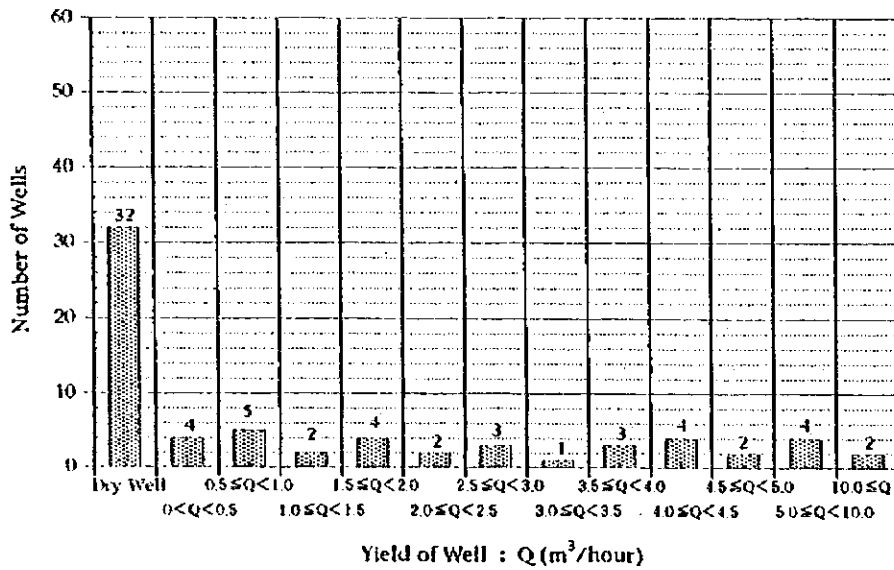




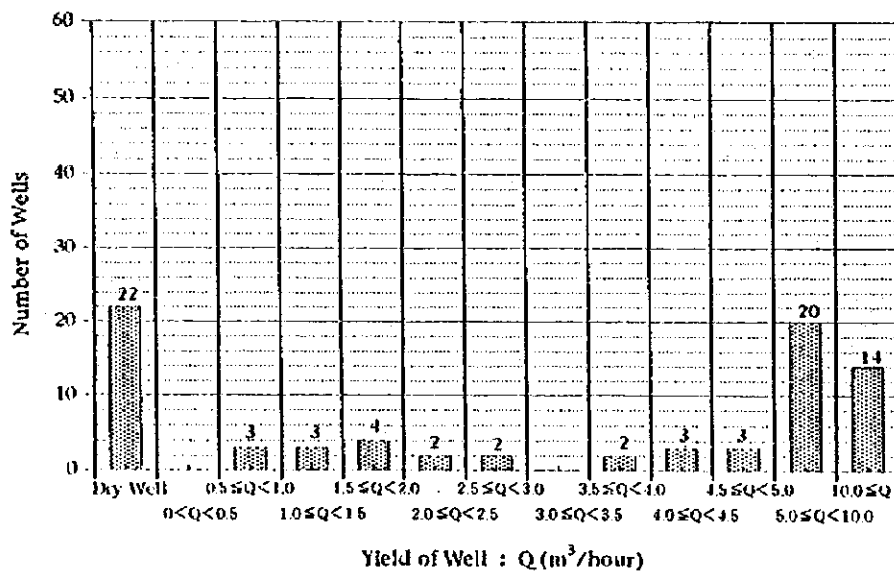
**Figure 5 Yield of Existing Brothels**



**Lalkipla District**

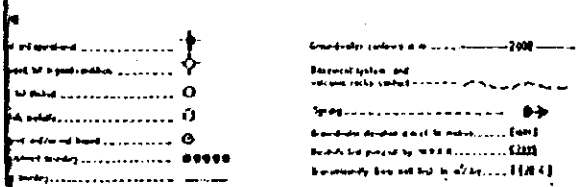
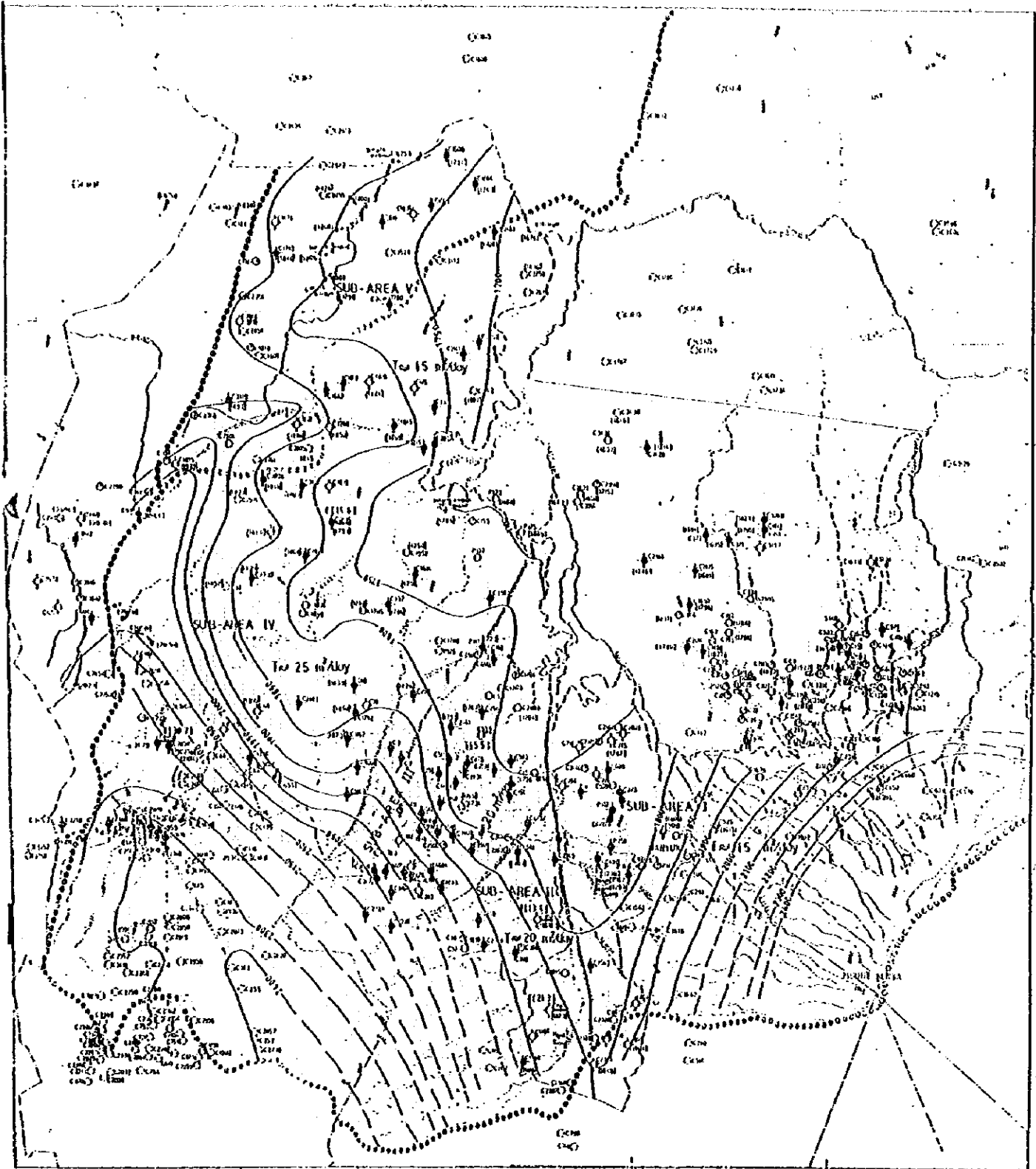


**Samburu District**



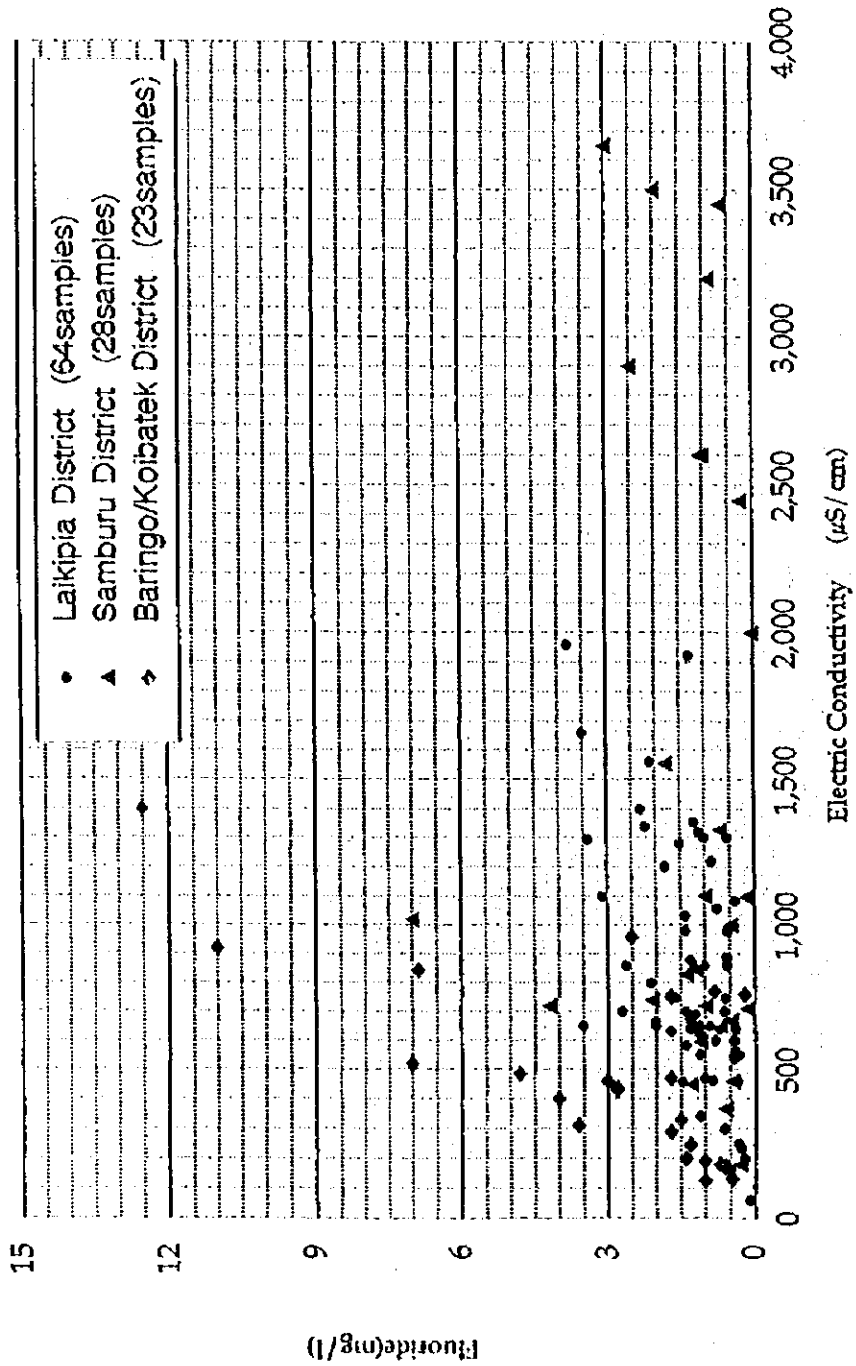
**Baringo/Kolbatck District**

Figure 6 Contour Map of Static Water Level of Groundwater in Laikipia District



出典: DELFT 1987

**Figure 7** Relationship between Fluorine Content and Electric Conductivity



**Figure 8 Fluorine Content by Anger Type**

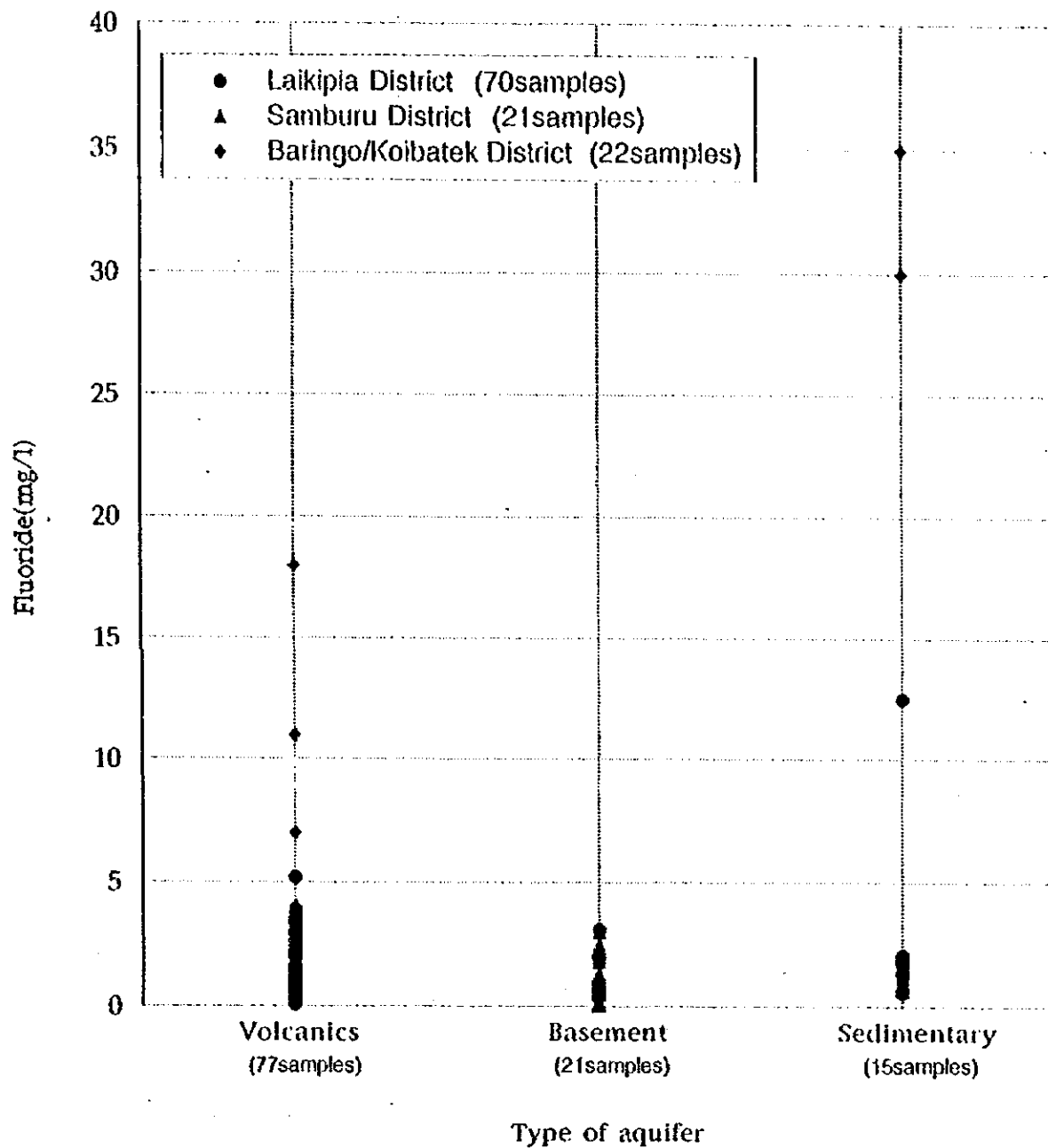


Figure 9 Location of Electric Soundings

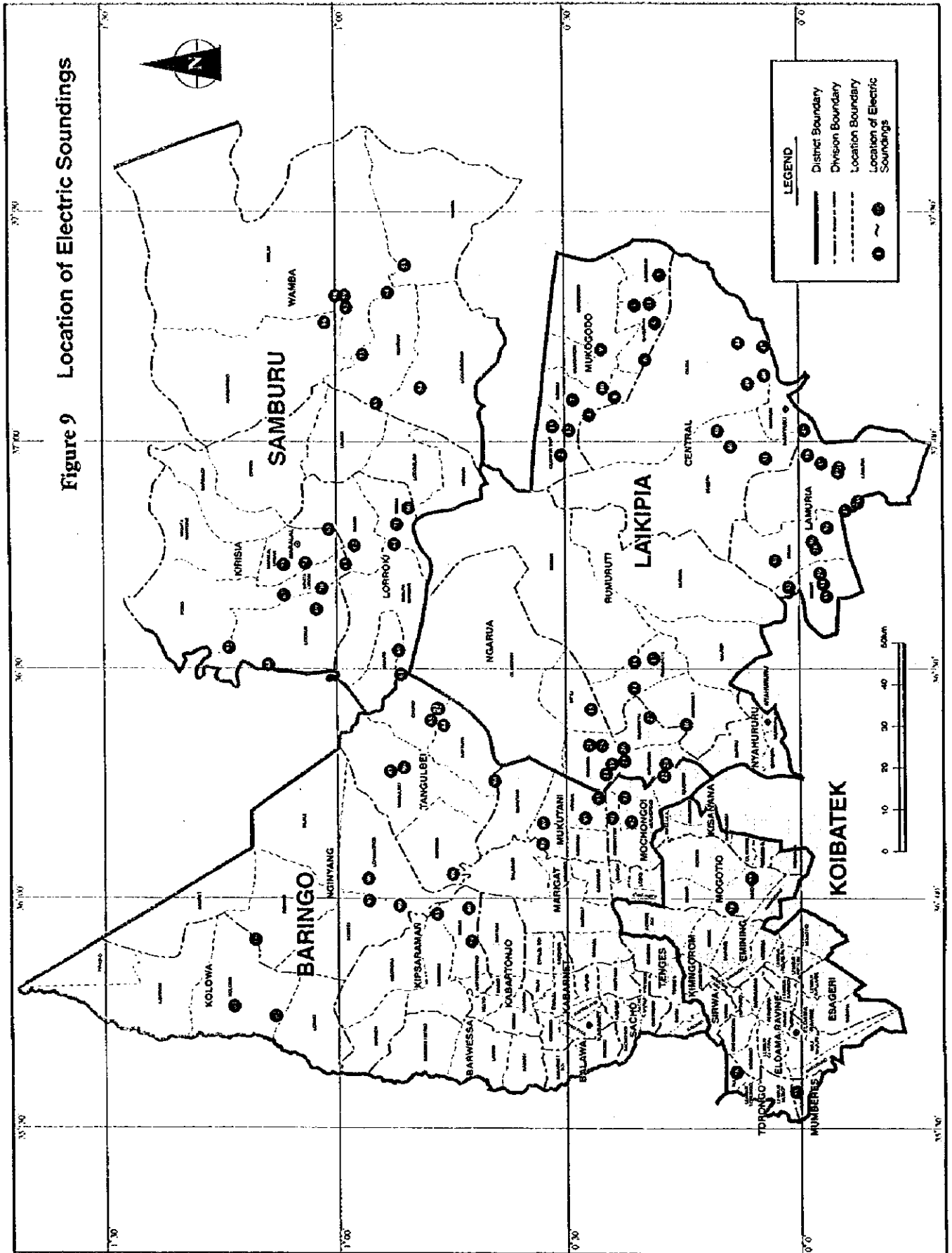
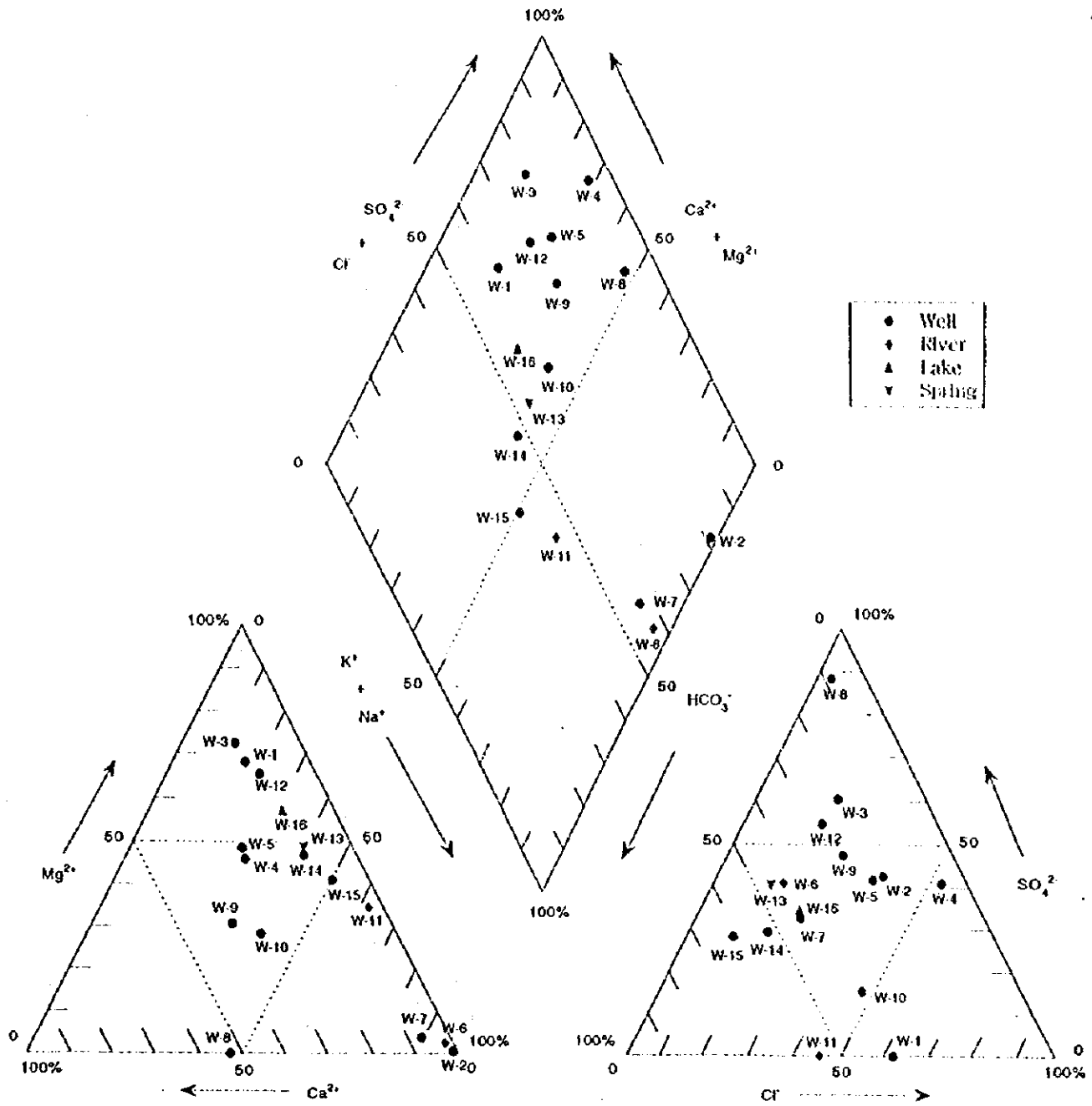


Figure 10 Tri-Linear Diagram



**Figure 11 Possible Boreholes Sites Elongated  
by Hydrated Logical Investigations**

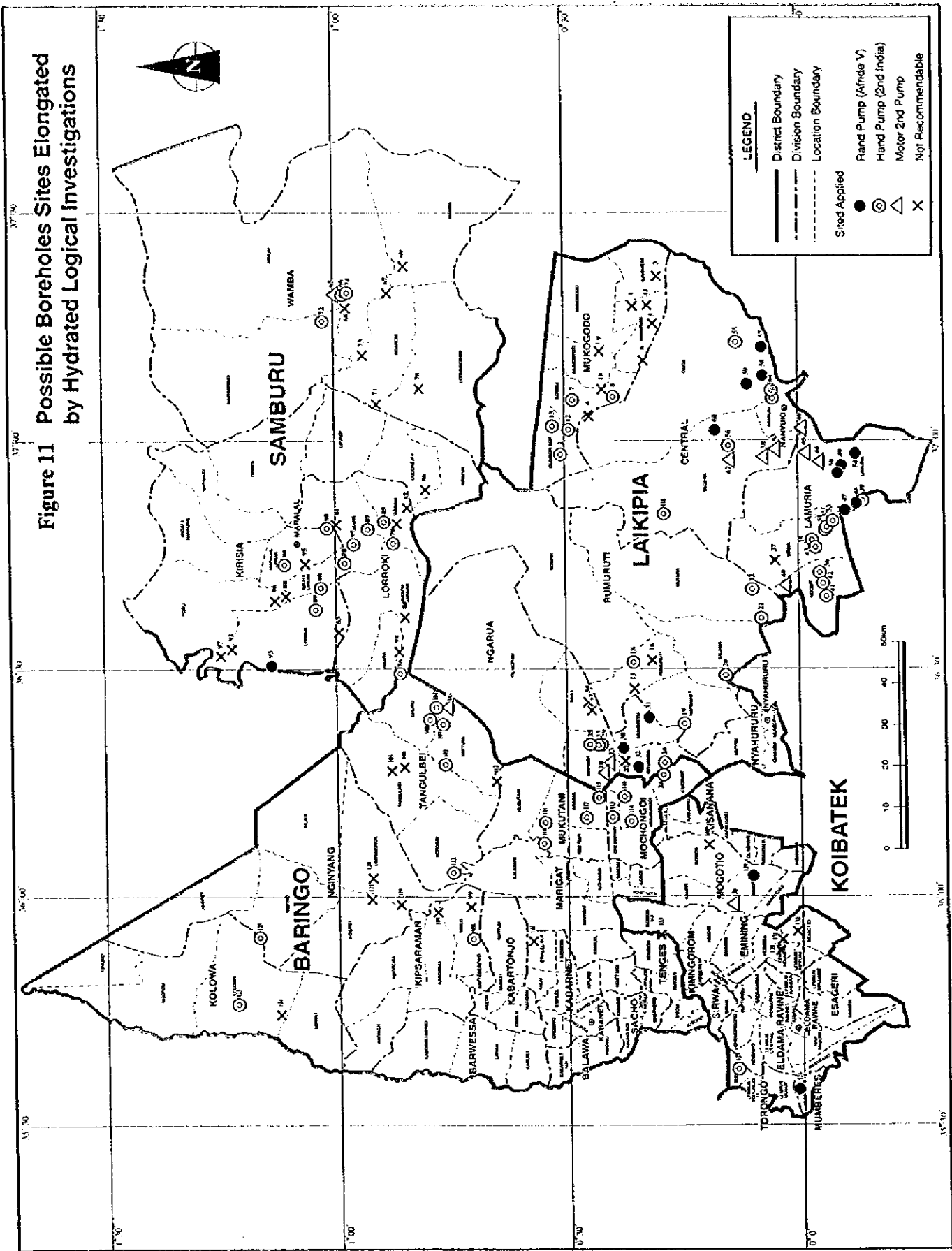


Figure 12 Population Density the Project Area

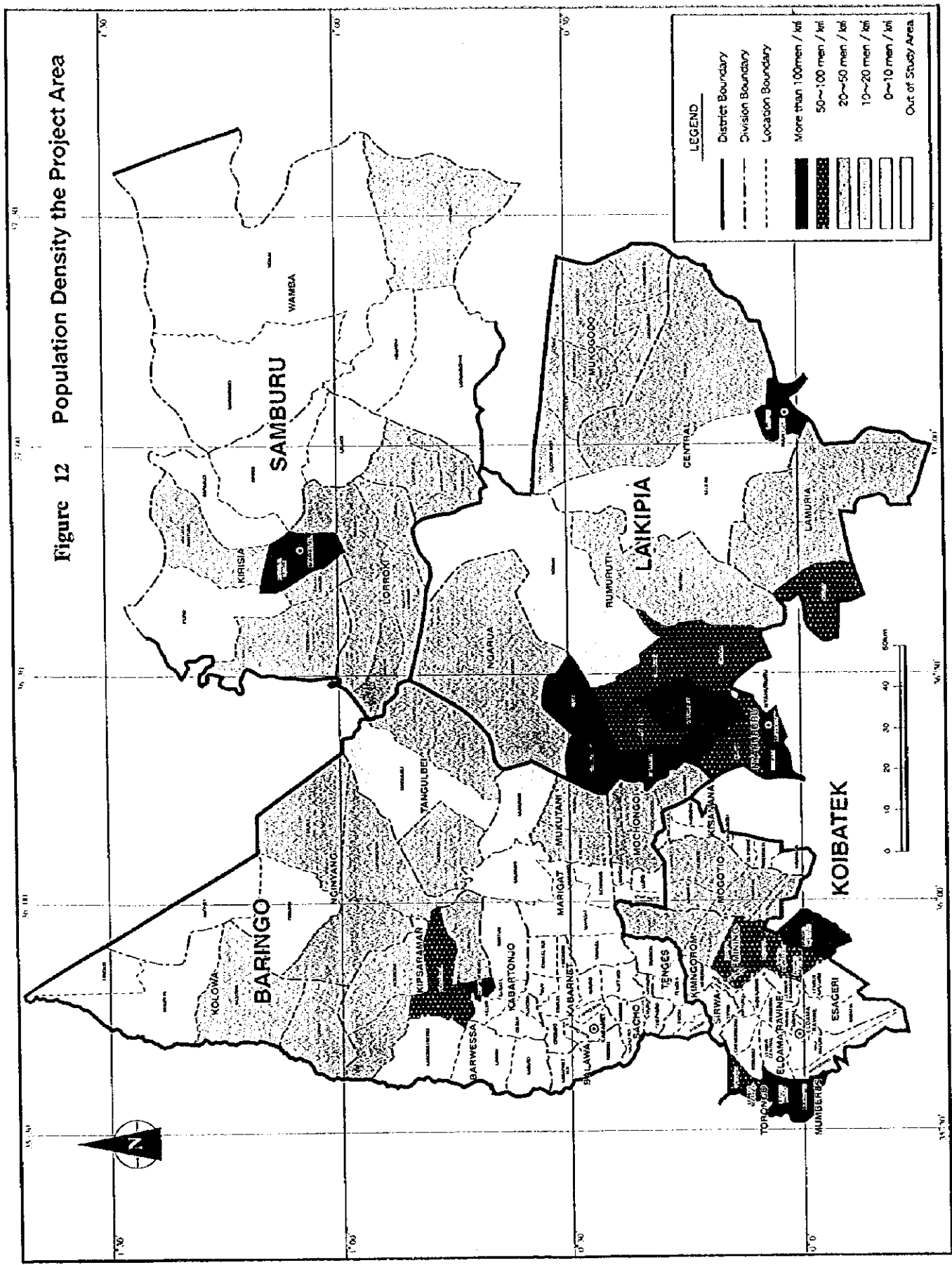




Figure 12 Population Density the Project Area

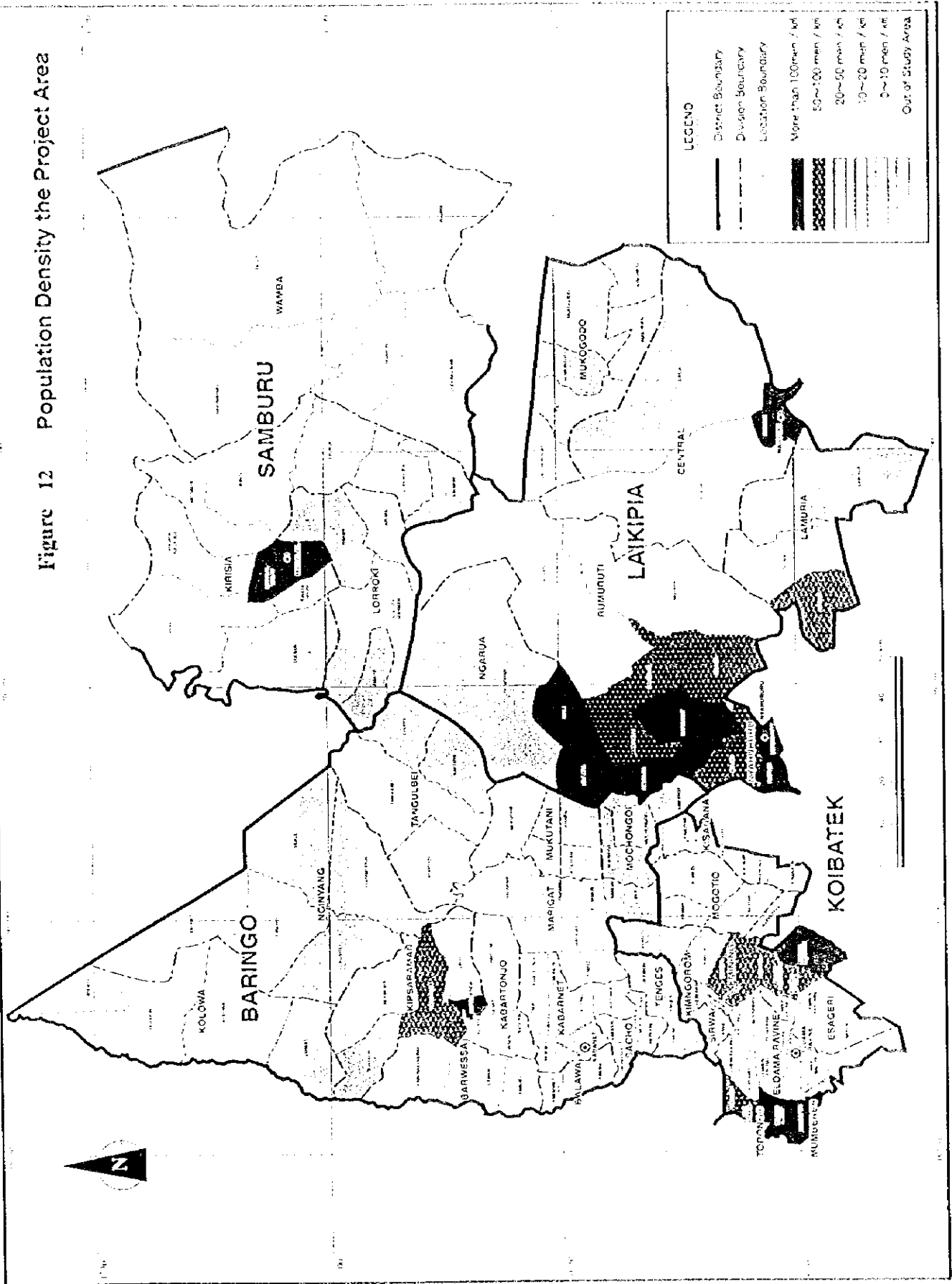


Figure - 13 Supply Ration the Project Area

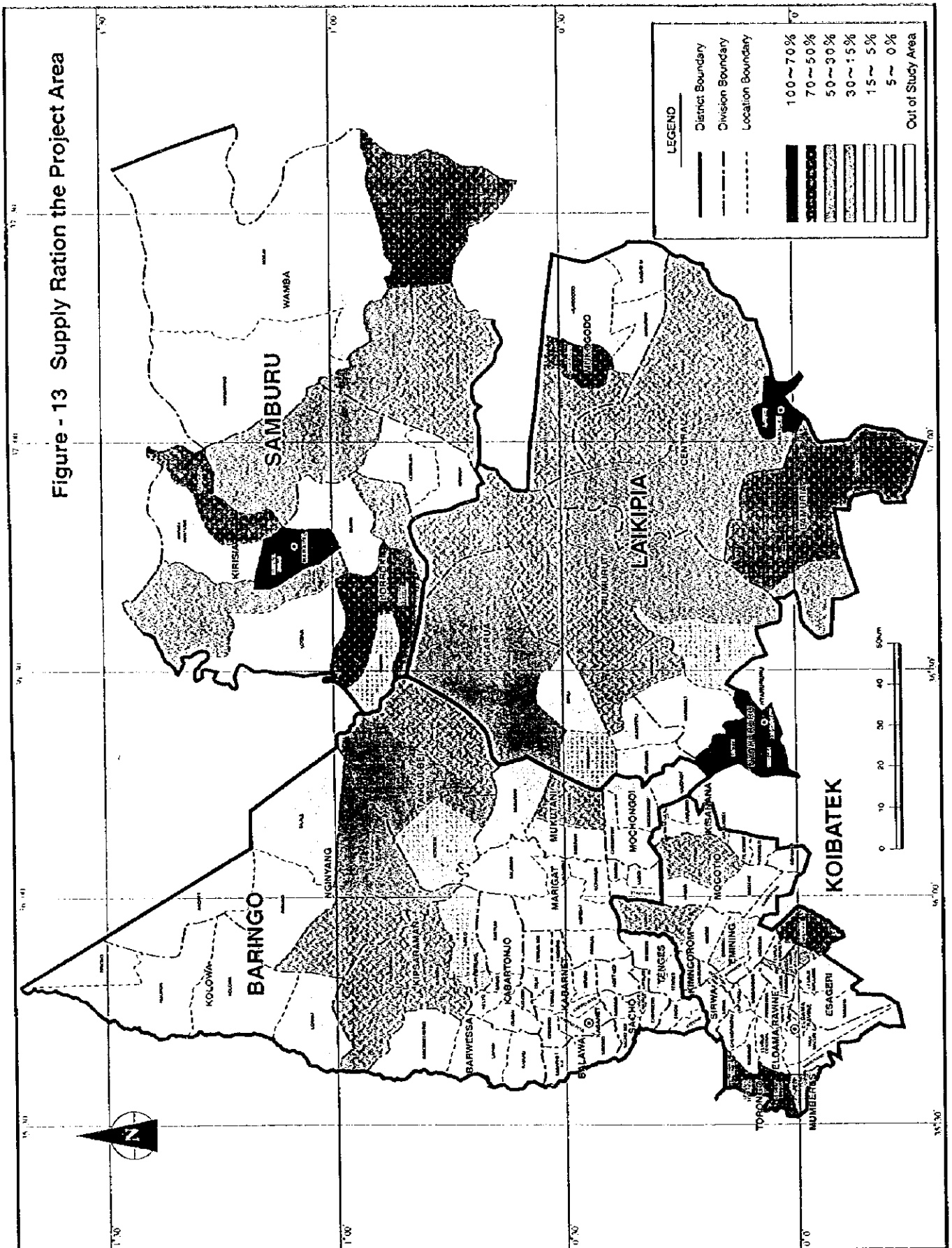
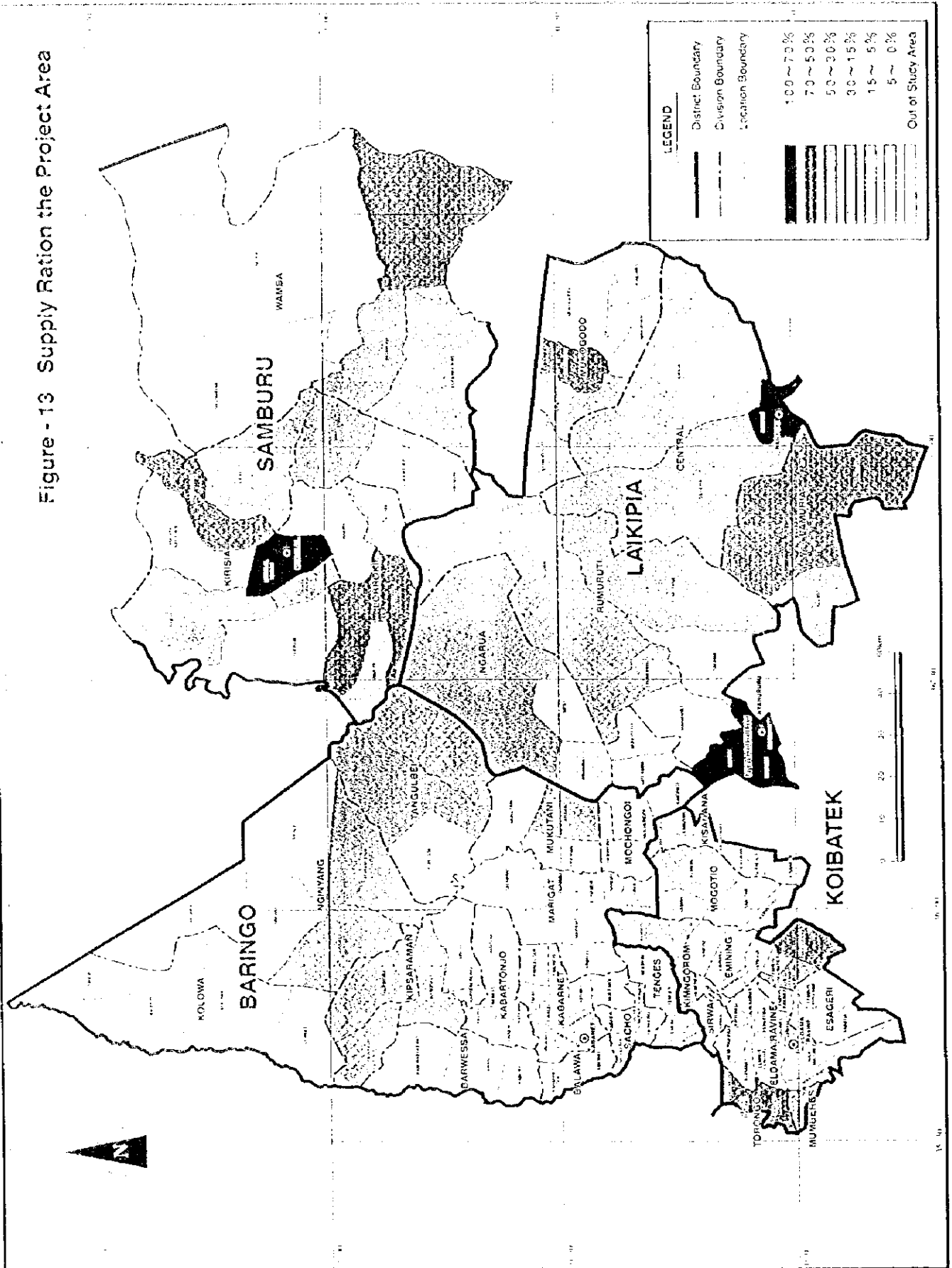
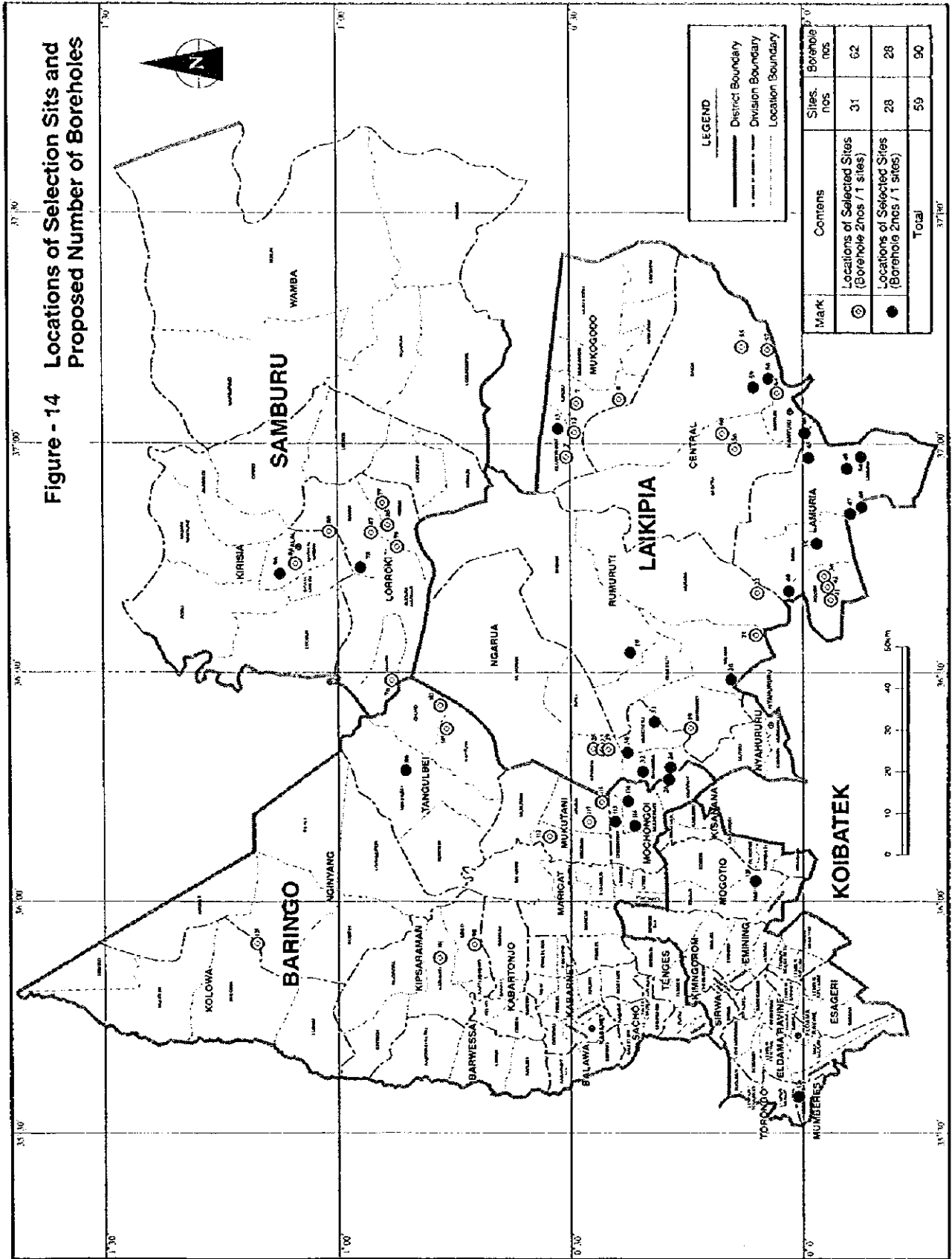


Figure - 13 Supply Ration the Project Area



**Figure - 14** Locations of Selection Sits and Proposed Number of Boreholes



***ATTACHMENT- 2***

**Study on Motorized Pump**

## **Study on Motorized Pump**

### **1. Outline of Motorized Pump**

#### **(1) Present Conditions**

In the Project Area, electricity is not provided except in urban areas. Existing motorized pumps for boreholes are generally operated with a diesel engine and generator. At present, a submergible pump in combination with a diesel engine and generator is popular equipment installed at boreholes in the Project Area.

Other than the submergible pump, motorized pump operated by connecting its drive shaft with a V-belt to a diesel engine is also found in the Project Area. But such pumps are already old and many of them are out of order. This type of pump is suitable for the maximum pumping head of 30 m only.

A solar powered pump is also an alternative but not popular in the Project Area due to its quite high price.

#### **(2) Procurement Conditions**

Motorized pumps are imported. Major suppliers have their branches in the major local cities and service shops near the respective branches. Spare parts and services are supplied through this suppliers network.

### **2. Conditions for Introduction of Motorized Pump**

For introduction of a motorized pump, operation and maintenance aspects in rural areas should be carefully examined. There are problems with operating and maintaining motorized pumps in rural areas in Kenya. GOK, who provides motorized pumps to rural communities, can not look after operation and maintenance due to financial constraints. In many case motorized pumps are handed over to water communities which do not have sufficient technical knowledge or financial sources to operate and maintain them properly.

When water communities are in charge of operation and maintenance of motorized pumps, they need to have technical and mechanical knowledge of operation and maintenance. They also need to have financial resources for fuel, spare parts,

salaries for operators and technicians, etc., which are mainly dependent on water charge collection from beneficiaries.

There is an example of successful introduction of a motorized pump in the Project Area. The following factors for successful operation and maintenance were revealed through interview to the existing water committee established in the community.

- Beneficiaries are many.
- Leaders of water committee have sufficient capability for management.
- Water charge collection is properly done in the community.
- Water communities has other income sources beside water tariffs and deposits such incomes to its bank account to cover operation and maintenance costs and replacements costs in the future.

The basic design study proposes enlightenment activities for establishment of water committee for each proposed facility to enhance proper operation and maintenance by community level. However, the above-mentioned conditions of the existing water community suggest that successful introduction of motorized pump depends on the ability of community and its leaders even though enlightenment activities are provided.

### 3. Application of Motorized Pump in the Project Area

#### (1) Possible Sites

As described in the selection of possible borehole sites, the possible borehole sites for motorized pump are 11 locations including 7 from hydrogeological evaluation and 4 from additional request by MOWR.

#### (2) Conclusions of the Study

At 9 out of 11 sites, except Wamba in Samburu district and Emining in Koibatek district, water communities near the respective sites are not sufficiently organized for operation and maintenance for water supply facility at present. It takes a long time to establish proper water communities having sufficient ability for successful introduction of motorized pump by means of enlightenment and full-scale aftercare. However, the enlightenment activities proposed by the Project do not cover full-scale aftercare due to limitation of the implementation period.

At the other two sites, Wamba and Eming, there are existing water supply facilities managed by MOWR. When proposed boreholes are used for reinforcement of water sources for existing facilities, problems on operation and maintenance of motorized pumps are not expected under management by MOWR. However, their urgencies are not justified since no future facility plans are prepared at present. In addition, it is not recommended to select these two sites in view of successful rate of boreholes for the Project due to low yield in Wamba and poor water quality in Eming evaluated by the hydrogeological studies.

Consequent to the considerations above, the 11 sites for motorized pumps are not proposed for the Project.



***ATTACHMENT- 3***

**Study on Wind Pump**

## Study on Wind Pump

### 1. Outline of Wind Pump

#### (1) Outline

A wind pump is operated by circular motion of rotator transferred to vertical motion of rod. The rotator diameter ranges from 3.7 to 7.4 m and the tower to fix rotator is 7 to 10 m height. The maximum pumping head of a wind pump is around 200 m.

A wind pump is operated using natural energy. The operation cost for a wind pump is, therefore, cheaper than that for motorized pump requiring electricity or fuel. The maintenance of wind pump is also easier because of its simplified mechanics. Wind pumps have been utilized in agricultural farms in Kenya since colonial times. From the late 1970's, a manufacturer in Nairobi has been producing and selling the wind pumps in Kenya, and as well as the neighbouring countries. The manufacturer has supplied 285 units to catholic missions, NGO's, projects by World Bank, UNDP and donor countries for the period from 1979 to 1997.

#### (2) Procurement Conditions

The manufacturer in Nairobi has around 20 staffs and previous supply records suggest that it products one wind pump per month. The manufacture provides training of periodical maintenance of the wind pump for rural people at installation and an intensive training program for 2 weeks in Nairobi. The manufacturer does not have any local branch and needs to despatch staffs for spare parts supplies and services on request.

### 2. Application of Wind Pump

The relationships of rotator diameter, pumping head, and pumping capacity provided by the manufacturer are presented below.

(Unit: m<sup>3</sup>/day)

Dia. of Rotator	3.7 m			4.9 m			6.1 m			7.4 m		
	2-3	3-4	4-5	2-3	3-4	4-5	2-3	3-4	4-5	2-3	3-4	4-5
Wind Velocity (m/s)												
Head 10 m	10	28	59	21	71	150	39	107	227	61	167	354
20 m	5	14	29	10	35	75	19	53	113	30	83	177
40 m		7	15	5	18	37	10	27	57	15	42	89
80 m		3	7	3	9	19	5	13	28	8	21	44
120 m			5		6	12	3	9	19	5	14	29
160 m			4		4	9		7	14	4	10	22
200 m			3			7		5	11		8	17
240 m						6		5	9		7	14

To operate the wind pump requires an average wind velocity of least 2 to 3 m/s.

Operation records of wind pumps in Kenya were reported by the British ODA and the Swedish engineering firm in 1980's. A summary of operation records near Nanyuki is shown below. It seems to correspond with the relationships mentioned above.

Dia. of Rotator (m)	Dia. of Pump (inches)	Head (m)	Average Wind Velocity (m/s)	Average Pumping Volume (m <sup>3</sup> /day)
7.4	3.75	55	3.9	30.4
7.4	3.75	63	4.2	32.6
3.7	3.75	28	3.4	12.1

The following table gives pumping capacity at head of 60 meters for wind velocity of 2.5 to 3.5 m/s.

Average Wind Velocity	Dia. of Rotator			
	3.7 m	4.9 m	6.1 m	7.4 m
2.5 m/s	0 m <sup>3</sup> /day	4 m <sup>3</sup> /day	8 m <sup>3</sup> /day	12 m <sup>3</sup> /day
3.0 m/s	2 m <sup>3</sup> /day	8 m <sup>3</sup> /day	12 m <sup>3</sup> /day	20 m <sup>3</sup> /day
3.5 m/s	4 m <sup>3</sup> /day	12 m <sup>3</sup> /day	20 m <sup>3</sup> /day	32 m <sup>3</sup> /day

According to the Design Manual for Water Supply in Kenya, the average wind velocity is less than 3 m/s in the Project Area except the surroundings mountainous areas such as Nanyuki, Nyahururu and the western part of Baringo and Koibatek districts. Wind pump with rotator more than 4.9 m diameter provides pumping volume equivalent to that of handpump, but it costs around five times that of India

Mark II Extra Deep Type. Wind pump is, therefore, regarded as an alternative to motorized pump but not to handpump.

Under average wind velocity of 3 m/s and 60 meters pumping head, a wind pump with rotator diameter of 3.7 m has a cost per unit pumping volume equivalent to 60% of that of a motorized pump for daily water demand of 4 m<sup>3</sup>/day. Whereas, the ratio becomes 80% for wind pump with rotator diameter of 7.4 meters operated to lift water for daily demand of 14 m<sup>3</sup>/day under the same wind and head conditions.

However, the previous reports indicate that cost effectiveness of wind pump becomes lower than that of motorized pump for average wind velocity less than 3 m/s. So the cost effectiveness of a wind pump is mostly dependent on wind velocity. Precise wind records are, therefore, required for proper design of a wind pump.

### 3. Application of Wind Pump in the Project Area

The available meteorological data show the average wind velocity by month varies from 2.6 to 3.6 m/s at Rumuruti in Laikipia district.

Average Wind Velocity (m/s)														
District	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Laikipia	Rumuruti	3.1	3.3	3.6	3.4	3.2	2.9	2.8	2.6	2.8	3.1	3.1	3.1	3.1

Whereas, it is reported the existing wind pump at Njoguini in Laikipia district does not work efficiently for the period from January to March due to very weak wind. Such wind conditions do not correspond with the wind records at Rumuruti. This suggests wind velocity in the Project Area is quite variable by place.

### 4. Conclusion

To install a wind pump successfully, it is necessary to evaluate operational efficiency of wind pump on the basis of local wind regime at the site prior to installation. However, such local wind regime near the borehole site is not available in the Project Area. Therefore, evaluation of operational efficiency of a wind pump is not possible. Consequently, installation of a wind pump is not proposed for the Project.

***ATTACHMENT- 4***

**The Existing Borehole Data**

















The Existing Borehole Data (8/8)

No.	ID	District	Division	Location	Longitude	Latitude	Altitude (m)	Completion date	USE	Type of aquifer	Total depth (m)	Main water struck level (m)	Other water struck level (m)	Other water struck level (m)	Water table level (m)	Screen length & piling	Screen length & piling	Screen length & piling	Yield (m <sup>3</sup> /hr)	Drawdown (m)	Transmissivity (m <sup>2</sup> /day)	Storage coefficient	REMARKS	BRN.
B-302 C	4254	Samburu	WAMBA	WAMBA	37.317	0.983	1341	12-Jun-76	O	1	208	34		26					0.5				DRY WELL	340
B-343 C	4268	Samburu	WAMBA	WAMBA SEC SCHOOL	37.317	0.983	1360	11-Sep-76	O	2	179	36							0.0				DRY WELL	353
B-304 C	4297	Samburu	WAMBA	D.E.B FRI WAMBA	37.317	0.987	1220	8-Nov-76	O	2	104	35							0.0	79			DRY WELL	364
B-345 C	4315	Samburu	WAMBA	NURIEB SCH WAMBA	37.333	0.920	1594	26-Feb-77	O	2	95	52	40						4.8	26			GOOD WELL	365
B-346 C	7809	Samburu	WAMBA	WAMBA TOWN	37.333	0.927	1500	12-Aug-80	P	2	65	14		0.5					1.0				LOW YIELDING	368
B-308 C	7910	Samburu	WAMBA	WAMBA TOWN	37.333	0.927	1300	21-Apr-83	P	2	120	65	25										NOT TESTED	369
B-301 C	7912	Samburu	WAMBA	WAMBA TOWN	37.330	0.923	1320	28-May-81	P	2	80	52		27.3	17@43								NOT TESTED	370
B-302 C	7913	Samburu	WAMBA	WAMANARABOO	37.300	0.833	1115	2-Jun-81	P	2	100								0.0				DRY WELL	371
B-303 C	7914	Samburu	WAMBA	KIMANIKI	37.300	0.827	1140	17-Jun-80	P	2	92												DRY WELL	372
B-304 C	7916	Samburu	WAMBA	LENGUSUKA	37.300	0.827	1050	12-Jun-80	P	2	70	18											DRY WELL	373
B-305 C	7918	Samburu	WAMBA	SWUARI	37.027	1.100	1120	20-Jul-80	P	2	130	70		63	20@95								NOT TESTED	375
B-306 C	1022	Samburu	WAMBA	WAMBA MISSION	37.317	0.950	1250	30-Jan-84	O		81	45	15	41					0.6	55.5			NOT TESTED	376
																								404