PART IV

WATER RESOURCE DEVELOPMENT PLAN

THE AFTERCARE STUDY ON THE NATIONAL WATER MASTER PLAN

SUPPORTING REPORT

PART IV : WATER RESOURCE DEVELOPMENT PLAN

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

1.1 Background to Water Resources Development Planning

Planning water resources development is an important and integral part of the Aftercare Study on the National Water Master Plan in the Republic of Kenya (the Study). The National Water Master Plan (NWMP) was established in July 1992 under technical cooperation programme of the Japan International Cooperation Agency (JICA) and includes a nationwide framework for orderly planning and development of water resources in the country for various purposes such as urban, rural and livestock water supplies, irrigation and hydropower development, sewerage, and wildlife water supply.

The objectives of the Study are:

(1) To review the water supply and sewerage sector development plan in NWMP and establish new implementation programmes,
(2) To make recommendation on strengthening law, organisation and institution for project implementation, and improvement of management, operation and maintenance of the project, and
(3) To transfer the technology on the planning of water supply and sewerage development.

The water supply projects develop of various water resources with various magnitudes. Kenya is blessed with fair water resources but they are distributed unevenly throughout the country and fluctuate throughout the year and from year to year owing to climatic and geographic conditions. NWMP had assessed and evaluated all water resources in Kenya and addressed comprehensively the water resources development to meet the required water demand at the target year 2010. It planned to develop various types of water resources such as surface water, groundwater, springs, rainwater harvesting, etc.

The Study was programmed to be completed within a period of 12 months from October 1997 to September 1998, of which only a four month period was allowed for work in Kenya. The study area covers the entire territorial area of Kenya so it is hardly possible to obtain accurate planning data from all corners of the study area.

The water resources development plan presented here was elaborated by deploying the previous study results to the maximum extent, as mutually agreed with the Technical Committee of the Study. Note, this is a preliminary plan and is subject to further detailed planning prior to actual implementation.

1.2 Previous Studies

1.2.1 National Water Master Plan

In NWMP, various and great volume of data and information on water resources in Kenya were collected and processed and finally built up a National Water Resources Database (NAWARD) which is explained in Section 1.3. It also elaborated qualitatively and quantitatively potentials of various water resources and their development plan towards the year 2010. Such analytical results and development plan are presented in the following reports:

1)	Volume 1	Water Resources Development and Use Plan towards 2010
2)	Sectoral Report B	Hydrology
3)	Sectoral Report C	Groundwater Resources
4)	Sectoral Report D	Domestic and Industrial Water Supply
5)	Sectoral Report H	Dam Development Plan
6)	Sectoral Report M	Integrated Water Resources Development Planning
7)	Data Book DB.1	Hydrological Data (Study Supporting Data)
8)	Data Book DB.2	Groundwater Data (Aquifer Test and Well Survey)
9)	Data Book DB.3	Groundwater Data (Study Supporting Data)
10)	Data Book DB.6	Project Sheet for Urban Water Supply

The water resources development plan presented here refers to various analytical results and development plans which are contained in those reports.

1.2.2 Water Resources Assessment and Planning

The Water Resources Assessment Planning (WRAP) aimed at developing capabilities and methodologies for: (1) systematic and regular water resources assessment at regional or catchment level, (2) rational development and effective management of water resources in the country, and (3) facilitating rural water supply in selected districts; by providing basic water resources data. WRAP was initiated in 1981 and is continuing in phases under the assistance of the Government of Netherlands. To date, WRAP has been completed for 14 districts in 4 phases as shown in **Table - 1.2.1**.

Under WRAP IV, detailed field inventory surveys of water resources were done and the survey results have included various information relating to water usage in digitised forms. Also under WRAP IV, studies were made to establish effective water development plans for each district.

Although some of information has been left blank, the information covered by the field inventory survey is comprehensive and considered to be reliable. However, the descriptive method of UTM (Universal Traverse Mercator) coordinates is not unified properly. The complete set of coordinates has been reviewed and modifications were made where necessary.

1.2.3 Western Water Supply Programme, Water Supply Development Plan 1990 - 2005

This plan presented the results of assessment of water resources potential in Bungoma, Busia, and Kakamega districts in the Western Province and it was completed in the late 1980's under the assistance of the Government of Finland. According to the report, the study area is classified into three categories, namely, "good", "fair", and "poor" in terms of groundwater potential.

1.3 Water Resources Database

1.3.1 Water Resources Database Section

The Water Resources Database Section in MWR was established in 1993 with the following objectives:

(1) To implement the recommendations on development and updating of the National Water Resources Database (NAWARD)

(2) To further develop the Water Resources Database and to speed decisions taking on all policy matters with regards to collection, storage, analysis and release of water resources data and information

(3) To coordinate the establishment of Catchment and District Water Resources Data and Information Centres

The Water Resources Database Section is divided into three units: (i) The Water Resources Documentation Centre, (ii) NAWARD, and (iii) Geographical Information Systems (GIS) & Digital Cartography Centre

1.3.2 Water Resources Documentation Centre

The centre promotes useful information on water resources and other related issues in water sector for the purpose of planning for example water supply and sanitation, community participation, health, environment, and engineering projects. The centre has about 700 documents, covering such specialised subjects as (i) groundwater and geology, (ii) surface and hydrology, (iii) water quality, (iv) sanitation data on water resources, (v) water supply, (vi) WRAP reports, and (vii) district development plans.

1.3.3 National Water Resources Database

NAWARD was established under NWMP with assistance of JICA in 1992. NAWARD was developed to handle various types of data related to water resources management. Initially the data stored in the system included those which were collected and processed by the JICA study team in the course of NWMP and those which were transferred from the previous database installed by SIDA.

The database covers not only groundwater but surface water, water quality and water rights and assessment. Current status of NAWARD is as given below.

Current Status of NAWARD

Section	Type of data	Number of Data
Surface Water	Water Level	16,703 stations
	Current meter gauging	27,812 samples
	Rating curves	1,175 samples
Water Quality	Pollution	1,155 samples
	Water supplies	1,817 samples
	Monitoring	3,266 samples
	Borehole	2,353 samples
Ground Water	Boreholes	10,724 samples
Water Rights and Assessment	Water permits and Authorities	8,448

Source: "Water Resources Information," Water Rights & Assessment Section, Water Resources Database Unit, MWR, September 1996
As of December 1997, water quality data of borehole and borehole data amount to 2,545 and 10,778 respectively.

During the data processing, the Study Team identified the following facts:

1) Coordinates, water struck level, water rest etc. of boreholes are not properly recorded for a considerable number of data;
2) Units for various parameters seem not to be unified;
3) The boreholes in the field are not necessarily recorded;
4) Current status as to "operational" or "abandoned" appears not to have been updated.

NAWARD is important and precious tool for water resources development planning in Kenya and, therefore, needs to provide data and information as accurate as possible. It is recommended that data input into made with utmost care and database itself be updated from time to time.

1.3.4 Geographical Information System and Digital Cartography Centre

The centre prepares maps of various types and sizes for WRAP V districts. Maps include, meteorology, hydrology, geology, existing groundwater sources, existing surface water sources, hydrogeology, surface water development potential, medium - deep groundwater potential, etc.

CHAPTER 2 PRESENT NATURAL CONDITIONS IN THE STUDY AREA

2.1 Land, Topography and Physiography

Kenya lies approximately between latitudes 50°20' N and 4°40'S and between longitudes 33°50'E and 41°45'E, and has a territorial area of 582,646 km^2, according to "Statistical Abstract, May 1996, CBS".

The territorial area is divided into water area of 11,230 km^2 and land area of 571,416 km^2. Of the land area, approximately 490,000 km^2 (86% of the land area) is classified as arid and semi-arid, which are hardly blessed with soil and water resources. However, the arid and semi-arid lands support over 25% of the human population and over half of the livestock production in the country at the present. The remaining area of about 81,000 km^2 is classified as profitably usable lands, sustaining substantial portion of Kenyan economy and human population.

As shown in Location Map in frontispiece, Kenya is characterised by tremendous topographical diversity, practically every land form type ranging from glaciated mountain to a true desert landscape. According to "National Atlas of Kenya, Fourth Edition, 1991, SOK" elevations varies greatly from sea level at the Indian Ocean to 5,199 m at the Batian Peak of Mt. Kenya, but the entire landscape is dominated by a flight of plateaux which somewhat conveys the impression of extensive upland plains rather than mountainous environments.

There are six distinct physiographic provinces in the country: the Nyanza Low Plateau, the Central Highlands which are bisected by the Great Rift Valley, the vast Northern Plain lands, the Foreland Plateau which includes the Duruma - Wajir Low Belt, and the poorly developed Coastal Plains.

2.2 General Geology

Kenya is underline by the four major geological Eras' units ranging from Pre-Cambrian to Cenozoic as shown in **Figure - 2.2.1**. A summary of the geological units and succession are as shown in **Table - 2.2.1**.

The Pre-Cambrian system is represented by volcanic rocks, igneous rocks, and metamorphic complexes and covers mainly western area and central area of the country.

The Palaeozoic - Mesozoic system consists of mainly sedimentary rocks including limestone underlain by basalt at the lowest part of the succession. The system covers the north-east area bordering Ethiopia and Somalia, and southeast coastal area. A succession of Palaeozoic - Mesozoic sediments is shown in **Table - 2.2.2**.

The Cenozoic system is divided into three sub-systems: (i) Tertiary sedimentary and large volume of volcanic rock, (ii) Pleistocene coral reefs, sandstone intercalated by pyroclastic lava, and

(iii) Recent alluvial deposit, evaporate and volcanic ash. The volcanic rock of the system covers the major part of the Rift Valley and Recent (Quaternary) deposit does mainly in the vast area of the eastern area of the country as shown in **Figure - 2.2.1**. A geological succession of Cenozoic sediments is summarised as shown in **Table - 2.2.3** and Quaternary sediments in north-east Kenya is as shown in **Table -2.2.4**. The chronology of volcanic eruptions in Kenya is summarised in **Table - 2.2.5**.

2.3 Hydrogeology

2.3.1 General

Characteristics (capability) of aquifers principally result from hydrogeological characteristics that are of dependence on lithological conditions; e.g. sandstone of Tertiary and Quaternary ages with almost the same granular properties would occur in similar aquifers.

The hydrogeological conditions in Kenya are as shown in **Figure - 2.3.1** and as summarised in **Table - 2.3.1**. There are major three hydrogeological areas in Kenya: (i) volcanic rocks (Patterns 3 and 4), (ii) Pre-Cambrian metamorphic basement rocks (Pattern 5) and Pre-Cambrian intrusive rocks (Pattern 9), and (iii) Sedimentary rocks (Patterns 1, 2, 6, 7, 8 of **Figure - 2.3.1**).

2.3.2 Volcanic Rock Area

The volcanic rocks cover about 26% of the country, more widely in Western Kenya, where the volcanic rocks manifest a linear alignment along with the Rift Valley System. Generally the volcanic rocks distribute from Tanzania into Sudan and Ethiopia, showing north-south trend alignment.

The lithology is variable considerably and includes phonolites, trachytes, tuffs and basalts. Groundwater is mostly stored in the old weathered surfaces of older formations (mainly the metamorphic basement rocks) below lava flows and in layers between successive lava flows. Fractures, faults, fissures, and joints are also suitable sites for groundwater storage. The thickness of the volcanic overburden varies from nil to several hundred meters and hence groundwater occurs at greatly varying depths. This also means that several aquifers are stuck in a borehole.

The aquifers in the volcanic areas are confined. Yield, depth to aquifers, and static water level vary considerably within the volcanic rocks. According to the database of MWR the average yield of a well is about 7.5 m^3/hr with a standard deviation of about 6.5 m^3/hr; average depth to the main aquifer is about 94 m with a standard deviation of about 58 m, and average artesian pressure is about 45 m.

The groundwater in the volcanic area is generally of bi-carbonate type with low total dissolved solids (TDS) or low electric conductivity. There are local pockets with high fluoride content that are believed to be of volcanic and fumarolic origin.

2.3.3 Pre-Cambrian Metamorphic Basement Rock and Intrusive Rock Area

The Pre-Cambrian rocks are widely distributed in the central, western and northwestern parts of Kenya and cover about 17% of the country.

Granites, gneisses, schists and sediments dominate the lithology. These rocks are deeply weathered in places although the extent of weathering differs. Groundwater occurs in rather deep level in locations where faults and fractures are distributed.

The aquifers in the basement area are rather confined. Yield, depth to aquifers, and static water level vary within rocks. The average yield is about 4.5 m^3/hr with a standard deviation of about 5.2 m^3/hr, the average depth to main aquifer is about 55 m with a standard deviation of about 40 m, and the average artesian pressure is about 31 m.

Quality of the confined groundwater is generally hard at moderate electric conductivity.

In the upper parts of the basement rocks, unconfined groundwater occurs locally at depths varying from a few to several tens of meters where the basement rocks are weathered and fractured. The water level fluctuates considerably and may dry up in the dry season.

2.3.4 Sedimentary Rock Area

The sedimentary rock area accounts for about 55% of Kenya, predominantly in its eastern and northwestern parts and around Lake Victoria. The rocks range in age from Palaeozoic to Cenozoic and are composed of sands, clays, sandstones, shales, and limestones.

The average depth to aquifers is about 54 m with a standard deviation of about 48 m. The artesian pressure is lowest (about 20 m), but the specific capacity is highest at about 0.32 m^3/hr/m among aquifers in Kenya.

(1) Quaternary Sediments

The Quaternary sediments area accounts for almost one-third of the country, ranging essentially from the Tanzanian border to the Ethiopian border, and as far east as longitude 38°E.

Alluvial, lake and beach sands, coral reefs, and limestones dominate the lithology. The sediments are loose and permeable.

The aquifers are generally shallow and unconfined. The success ratio of boreholes is very high.

A serious problem in groundwater development in Quaternary sediment area is occurrence of salt water, which has resulted in failure of development of a number of boreholes so far. The groundwater is generally of a chloride type. The origin of the saline water is believed to be due to accumulation of solute evaporate minerals within the sediments which have not been removed by groundwater circulation. However, salty groundwater in the coastal parts is believed to be due to the seawater intrusion.

(2) Older Sedimentary Rock Area

The older sediments are distributed in the southeastern and northeastern corners of the country. The three major sedimentary rocks, sandstones, limestones and shales dominate the lithology.

The aquifers are mostly confined and deep. Considerable faulting and folding are believed to have occurred and the groundwater occurs in syncline parts of the folds, and fractured parts of faults. The groundwater is generally of a chloride type.

2.4 River System

As shown in Location Map, Kenya's drainage system is relatively simple. All the main rivers are consequent on the great dome formed by the Central Highlands or on the southern foothills of the Ethiopian highlands. The main rivers originate from these highlands in a radial pattern and the country could be divided into five drainage areas as shown in **Figure - 2.4.1** and as summarised below :

Drainage System in Kenya

Drainage Areas	Area (km^2)	Proportion (%)
Lake Victoria Basin	46,229	8.0
Rift Valley Basin	130,452	22.5
Athi River and Coastal Basin	66,837	11.5
Tana River Basin	126,026	21.7
Ewaso N'giro River and Northern Basin	210,226	36.3
Total	579,770	100.0

Source: The Study on the National Water Master Plan, Sectoral Report (B), Hydrology, July 1992

Schematic diagrams of the major rivers and basic basin information of the major rivers are compiled in the Data Book. The followings are the principal characteristics of the major rivers in the country.

Major Rivers in Kenya

Rivers	Classified Drainage Area	Drainage Area (km^2)	River Length (km)
Tana	1	88,754	979
Athi-Galana-Sabaki	3	37,689	688
Mara	1	8,967	270
Nzoia	1	12,709	334
Suam-Turkwell	2	20,468	390
Ewaso N'giro (North)	5	74,365	752
Ewaso N'giro (South)	2	8,722	287
Kerio	2	13,816	559
Yala	1	3,280	219
Sondu	1	3,481	170
Kuja	1	6,919	221
Malewa	2	1,716	75
Rare	3	8,176	243

Source: The Study on the National Water Master Plan, Sectoral Report (B), Hydrology, July 1992

These major rivers are mostly blessed with perennial flow on their main streams. Their tributaries and other rivers than the above are in general seasonal. It is to be noted that all the rivers in the Rift Valley debauch into the lakes which have no outlet and sensitively fluctuate as a balance among amounts of inflow evaporation, and seepage through their bottom.

2.5 Lakes and Springs

2.5.1 Lakes

Kenya has a number of lakes of different water types as shown below and in Location Map :

Major Lakes in Kenya

Lakes	Altitude (El. m)	Area (km^2)	Type of Water
Victoria (Kenyan part)	1,133	3,755	Fresh
Turkana	375	6,405	Fresh
Naivasha	1,884	210	Fresh
Baringo	975	129	Fresh
Bogoria	991	34	Saline
Nakuru	1,758	52	Saline
Elementaita	1,776	21	Saline
Jipe	701	39	Fresh
Magadi	579	104	Saline
Total		10,749	

Source : Statistical Abstract, 1996, CBS

All the lakes excluding Lakes Victoria and Jipe are located in the Rift Valley, and only Lake Victoria has an outlet. The other lakes have no outlet.

Lake Nakuru and a part of Lake Turkana are designated as the National Park. It is noteworthy that Lake Nakuru is the first registered area under Ramsar Convention in Kenya and world famous habitat area of flamingos. Lake Magadi is used for industrial purpose, production of soda.

The lakes are one of the precious water resources in Kenya, especially in the ASAL areas. There are however increasing concerns about water quality and hydrologic phenomena on some lakes as described in Section 3.5 hereof.

2.5.2 Springs

It is believed that there are a large number of springs in the country and they are the important source of water supply for various sectors. According to "Welfare Monitoring Survey II, 1994, Basic Report, CBS", protected and unprotected springs sustain 4.5% and 10.2% of the total households in terms of safe water supply. In general springs are the predominant source of safe water supply in Nyanza and Western Provinces, sustaining 32.3% and 31.1% respectively. In particular, springs bear as much as 75% of total safe water supply in Kisii District.

Unfortunately there is no inventory presenting exactly the locations of and discharges from the springs. According to NWMP, major springs are Mzima, Njoro Kubwa, Noltresh and Kikuyu. Their natures and present water use are reported as follows :

Mzima springs : They are located at the south-eastern rim of the lava field of the Chyulu Hill and are the main water supply source to the Mombasa Municipality and its surrounding areas. These springs yield 3.0 m^3/s on the average, of which 0.43 m^3/s is transmitted to Mombasa through a 240 - km long pipeline for the urban water supply only with disinfection.

Njoro Kubwa springs : These springs emerge in a pool on the right bank of the Lumi River, about 3 km southeast of Taveta Township. It appears that these springs and Lake Chula have a close hydrological linkage each other. The spring water is used for irrigation supply to sisal estate and domestic purpose of Taveta Town and its surrounding areas.

Noltresh springs : These are located on the slope of Mt. Kilimanjaro and discharge 0.25 - 0.33 m^3/s. The spring water is the main water supply source to Mtitu Andi, Machakos and Kajiado and conveyed into such areas through the Noltresh Pipeline.

Kikuyu springs : The outflow is transmitted to the Kabete waterworks which is one of the water source for Nairobi.

2.6 Climate

2.6.1 General Climate

The climate in Kenya is primarily controlled by the movement of the Inter Tropical Converges Zone (ITCZ) and by topographic relief, especially elevation.

The ITCZ normally stays nears the Equator during the period from April to June and from October to December, whereas it moves to the southern-most position (around Zambia, Malawi) during the period from January to April and to the northern-most position (Northern Kenya, Uganda, Ethiopia, Northern Somalia) from July to October. Consequently the south monsoon is the predominant during the period from April to May or to June in the low altitude areas east of 38°. The northeast monsoon contrary becomes dominant from October to December.

Figure -2.6.1 shows the climatic regions in Kenya. The country is basically divided into three climatic regions: Equatorial and Monsoon Variety, Northern and Southern Tropical and Continental and Monsoon Variety, and Northern and Southern Tropical Continental Semi-Desert and Desert. Each region is further divided into a number of sub-regions as also depicted in **Figure - 2.6.1**.

2.6.2 Air Temperature and Relative Humidity

Air temperature varies largely from below the freezing point at snow-capped peak in Mt. Kenya to over 40°C in low altitude arid areas in the north and northeast. **Figure - 2.6.2** presents the annual mean maximum and minimum temperature patterns throughout the country and monthly temperature variation at the representative locations in the country.

Relative humidity is almost constant throughout the country and the year. It is in a range of 60 - 80% at 06:00 GMT and in a range of 40 - 70% at 12:00 GMT.

2.6.3 Evaporation

The evaporation largely varies from location to location. The annual evaporation is only 1,215 mm at Kimakia but amounts to as much as 3,846 mm at Lokori.

2.6.4 Rainfall

Rainfall over Kenya is dominated by three distinct air masses : (i) northeast monsoon dominates the western part of Kenya from November to March, (ii) the southeast monsoon conquers substantial part of the central, southern and eastern regions of the country from April to September, and (iii) the southwest trade wind influences the western parts of the country in July. Thus there are two rainy periods for the most parts of the country in a year. In general "Long Rain" period lasts from March to May and "Short Rain" remains from October to November.

Although the annual rainfall is about 620 mm on the average over the country, it is uneven throughout the country and the year and varies largely from year to year. As shown in isohyetal map in **Figure - 2.6.3**, the annual rainfall is the lowest in Lake Turkana area, being less than 200 mm and the highest in Kakamega area in Western Kenya, being more than 1,800 mm. Nearly a half of the territorial area receives the annual rainfall less than 400 mm, while there are three areas being blessed with the annual rainfall more than 1,000 mm: one is the central highlands area, the second is a part of the Rift Valley around Nakuru and the third is the area along the coast facing Indian Ocean.

As shown in **Figure - 2.6.4**, seasonal distribution also differs largely from area to area being influenced by three air masses. The rainfall occurs continuously throughout the year in a part of the Western Kenya with double maxima in April and October. A double maxima is also observed in Central Kenya, whereas in the coastal area, a remarkable single maximum is the predominant. The northern and northeastern parts of the country is continuously dry throughout the year.

2.6.5 Drought and Flooding

The country experienced severe drought and contrary serious flooding throughout the country during the period between 1996 and 1998.

It was reported that there was very scarce rainfall in the Short Rain Period in 1996 and "Long Rain Period" in 1997, especially over the Central, Northern and North Eastern Provinces.

Soon after the long spell of the drought period, the unusual rains caused by the El Nino weather phenomenon started from September 1997 and lasted until end of April 1998. It resulted in flooding various part of the country, including Nairobi and Mombasa. Raging floods have caused loss of human lives and livestock, displacement of thousands of people, damage on infrastructure, and outbreak of killer diseases. Unfortunately, no complete statistics on flood havoc are made available so far. The flood havoc by middle of January 1998 is outlined herein on the basis of information abstracted from the local newspapers:

1) It is quite clear that given the magnitude and extent of the destruction, it is the biggest national calamity that Kenya has ever faced. The Government say it will spend over Kshs 8 billion over the next five years on the infrastructures. The damage to infrastructure will be felt by all sectors of the economy for many years to come.

2) In December 1997 more than 2,000 people have been displaced and another 8,000 people have been adversely affected in Kano - Nyakach in Kisumu District. Also at the same time it was reported that raging floods have made an estimated 48,000 people homeless and rice fields of 2,000 ha have been damaged in Tana River District.

3) It is reported that 33 people and 2,360 livestock have died during the period from October 1996 to middle of January 1998.

4) Outbreak of killer diseases particularly cholera and Rift Valley Fever were also recorded in the North Eastern Province and killed people and livestock.

5) Damage to the infrastructure is serious. The road network has been cut off, causing many areas isolated and residents in such areas imminent starvation. The closure of the Mombasa - Nairobi Road had devastating effect on the economy since the road is the artery supplying the interior with much needed supplies.

6) Most critical for Kenya is the threat of hunger following destruction of crops that were ready for harvesting and those that were still in the fields. It is reported that, according to Famine Early Warning Section of USAID and the Regional Economic Services Office, the national long rains maize production was expected to drop from a 1991-1996 average of 2.22 million tonnes to 1.83 million tonnes.

CHAPTER 3 SURFACE WATER RESOURCES

3.1 Data Sources

The previous two studies, NWMP and WRAP present extensive and valuable data and information regarding the surface water resources in the country. It is therefore pre-determined upon consultation to the Technical Committee that the surface water resources sector of the Study refers to such data, information and analytical results of the previous studies as far as they are adaptable in order to proceed with the Study rationally and efficiently and to maintain the consistency in nature and accuracy of the studies.

3.2 Existing Stream Flow Gauging Network

The stream flow gauging is under the responsibility of the Hydrology Section of MWR. As of 1991, there are 399 stream flow gauging stations under operation. Their distribution by the drainage area is as shown below :

Number of Stream Flow Gauging Stations in Kenya

Drainage Area	Stream Flow Gauge Station		
	In-operation	Abandoned	Total
Lake Victoria Basin	114	115	229
Rift Valley Basin	50	103	153
Athi River and Coastal Basin	74	149	223
Tana River Basin	116	89	205
Ewaso N'giro and Northern Basin	45	68	113
Total	339	524	923

Source: The Study on the National Water Master Plan, Sectoral Report (B), Hydrology, July 1992

A systematic code number is put to each stream gauging station to facilitate the database operation. As shown in the above, a large number of stream gauging station was abandoned in the past, reason of which is not clear. It is strongly recommended that stream gauge station be sited at strategic points of the river for efficient and rational management of water resources and stream gauging be continued as larger as possible. The surface water of the river is one of the precious natural resources in Kenya.

3.3 Low Flows of Perennial Rivers

3.3.1 Annual Mean Runoff

Among the various hydrological data and analytical results presented in NWMP, the Aftercare Study Team particularly regarded two different analytical results. One is the dimensionless flow duration curves and the other is the quantity of surface runoffs of the perennial rivers.

The later broadly reveals the potentiality of the surface water resources in the country and, when compared to the existing water abstraction, its further development potential in future. The mean annual runoffs of the perennial rivers are estimated at 19,691× 10^6 m^3/year as shown in **Table - 3.3.1** and as summarised below :

Average Annual Mean Runoff of Perennial Rivers

Drainage Area	Catchment Area of Perennial River (km^2)	Annual Mean Runoff	
		Total (10^6 m^3/year)	Per Unit Area (m^3/year/km^2)
Lake Victoria	41,306	11,672	282,570
Rift Valley	51,062	2,784	54,510
Athi River and Coast	53,955	1,152	21,340
Tana River	95,989	3,744	39,000
Ewaso N'giro and North	12,107	339	28,000
Total	254,419	19,691	77,390

Source: The Study on the National Water Master Plan, Sectoral Report (B), July 1992

As shown in the above, surface water resources largely vary throughout the country. This characteristic is more clearly seen in **Figure - 3.3.1** which shows the contour lines of annual mean runoff over the country. The pattern of contour lines is almost identical to the isohyetal map in **Figure - 2.6.3.**

3.3.2 Dimensionless Flow Duration Curves of Representative Stream Gauge Stations

The dimensionless flow duration curves are the important tool in order to evaluate the available runoff of the river with variable dependability. Especially in Kenya, a run-of-river intake is the most predominant type of the intake facilities for potable water supply scheme. There is only few reservoir/dam exclusively used for water supply project in the country.

In the dimensionless flow duration curve, vertical coordinate is expressed as a percentage of daily runoff against the annual mean runoff and horizontal coordinate shows a time scale of the year. Thus, by knowing only the annual mean runoff of the river under consideration , daily runoff at any dependability can be obtainable.

According to NWMP, the dimensionless flow duration curves were developed by using daily runoffs for such stream gauge stations that :

1) at least daily runoffs were recorded for over 300 days in a year,

2) daily runoffs were recorded for more than 3 years, and
3) there are no missing data seasonally.

Under the above criteria, 174 stream gauge stations were finally selected and the dimensionless flow duration curve was constructed for each of them.

Table - 3.3.2 presents the list of stream gauge stations with the dimensionless flow duration curve. Data Book compiles all the dimensionless flow curves.

3.4 Flood Flows of Perennial Rivers

NWMP has elaborated the analysis of flood flow characteristics for every drainage areas and particularly worked out the following :

1) Relationship between the ratio of probable floods of various return periods to the mean annual flood and the return period
2) Relationship between the catchment area and the mean annual flood.

It is reported that the above relationships were developed based on the recorded annual maximum floods over 20 years. Among a number of stream gauging stations, the actual number eligible for the above criterion was 39 for Drainage Area 1, 9 for Drainage Area 2, 7 for Drainage Area 3, 15 for Drainage Area 4, and 8 for Drainage Area 5.

Figures -3.4.1 and **3.4.2** presents a relationship between the return period and the ratio of probable flood to mean annual flood and a relationship between magnitude of mean annual flood and catchment area respectively. By using those two charts, magnitude of flood flow at any probability at any location of river can be obtainable by giving only the catchment area of the river under consideration.

3.5 Water Quality

The Water Quality and Pollution Control Section of MWR is responsible for implementation of a nation wide water quality monitoring programme and its monitoring network consists of 120 monitoring points over all the major rivers, lakes and springs. The existing monitoring points are classified into two groups as follows :

1) "Reference points": They are located in the upper catchment of the major rivers to provide baseline data on natural water quality.
2) "Impact points": These are sited near to pollutant load discharge point. Similar stations are located at the downstream reach of such impact point to assess the self-dilution capability of the rivers.

The programme calls for sampling at the respective location, four times a year: January - February, April - May, June - July, and October - November.

In general, the surface water quality is judged good with regard to pollution compared to industrialised countries. However, there have been identified local pollution incidents in a certain rivers and serious concerns about water pollution and deterioration of water environment with increasing population and rapidly expanding human activities in the catchment area. A general water quality of rivers and lakes is reported in "The Study on the National Water Master Plan, Main Report, Volume 1, July 1992" as follows :

(1) Rivers

Physical-chemical characteristics of waters of the major rivers are as presented in **Table - 3.5.1.**

In general, electric conductivity is 100 - 250 micro S/cm, but occasionally reaches 350 - 500 micro S/cm. Alkalinity is generally in a range of neutral to slightly alkaline. Caution concentration is low, but some rivers show higher concentration of iron and manganese than those set forth in Kenyan Drinking Water Guideline.

In view of water treatment process for drinking water, conventional sand filtration and chlorinating will be adaptable. However, in some rivers, a relatively high concentration of fluoride has been detected which will be the major problem in view of drinking water supply.

(2) Lake

Physical - chemical characteristics of the lake waters are given in **Table -3.5.2.** The lakes in the country are grouped into alkaline - saline lakes (Elementaita, Nakuru, Magadi and Bogoria) and freshwater lakes (Naivasha, Victoria, Baringo and Turkana).

The alkaline - saline lakes are impossible to be used as source of potable water supply. Of the freshwater lakes, Lake Victoria is currently the main source of potable water supply to Kisumu. NWMP has pointed out the following concerns about the major lakes :

Lake Turkana: For several years now, evaporation has exceeded inflows, resulting in reduction of lake level and surface area. If this is accelerated due to further increased water consumption in the upper catchment area, the concentration of dissolved matters in the lake water will naturally be increased. If it reaches a level where the existing fauna and flora can not survive, fishery activity will be forced to be ceased followed by the crocodile population. It is very important to keep attention to monitor the water quality and ecology of fauna and flora.

Lake Baringo: A concern has been expressed over many years about increasing sediment loads into the lake from its catchment area. The increase in turbidity may have an impact on artisanal fishery, but it is not assessed yet quantitatively. The lake water is however not suitable for drinking owing to high concentration of fluoride.

Lake Naivasha : Attention must be drawn to the possibility of eutrophication due to inflows of nutrient rich drainage water from irrigated lands surrounding the lake shore and wastewater from

Naivasha Town. The increased water abstraction in the upper catchment of the Malewa River, a major water source of the lake, would result in the same problem as those of Lake Turkana.

Lake Nakuru : It acts as receptacle of the wastewater from the catchment area including Nakuru Town, which is identified to be the major source of pollutant loads. Although sewage treatment works have been renovated recently with increased treatment capacity, a continuous effort is essential to reduce the pollution load generation in and sediment loads from the catchment area and to monitor the lake water quality and ecology.

Lake Victoria (Winam Gulf) : The open water of the lake and gulf have not been affected to a great extent by human activities. Nevertheless an increase of some chemical parameters has been noted in the gulf.

The situation in the Kisumu Bay is somewhat worse than in the rest of the Winam Gulf and water quality has been greatly deteriorated especially in three specific areas; one is the vicinity of the mouth of the Kisat River which receives treated effluent from Kisumu sewage treatment works, the second is Yacht Bay receiving wastewater from two squatter settlements and Nyamasaria sewage lagoons, and the third is car wash bays being subjected to discharge of oil waste and other wastewater. Also, the lake water quality has been showing a degrading tendency due to inflows of wastewaters from urban areas and nutrients from agricultural lands through the Nzoia and Kuja Rivers.

3.6 Sediment Loads

MWR has been making a suspended load measurements on an ad-hoc basis at the representative stream gauging stations. NWMP established a preliminary relationship between the suspended load concentration and the discharge based on the measurement records so far made available. The relationship is expressed by the following mathematical equation :

$$Qs = aQ^b$$

where,
- Qs : suspended load concentration (ppm)
- Q : river discharge (m^3/sec)
- a, b : constant

The relationship was developed for 36 stream gauging stations as given in **Table - 3.6.1**. NWMP finally recommended that the measurement be carried out continuously and periodically to analyse more accurately the amount and long-term tendency of the suspended loads to effect the watershed management and conservation of the lakes.

3.7 Estimate of Available Surface Water Resources by District

The surface water resources are practically the runoffs of the perennial rivers, although a number of lakes and springs contribute to great extent to the water supply. The Study envisages to establish appropriate water supply plans for urban centres, rural areas and livestock production respectively. As far as rural areas and livestock production are concerned, the unregulated surface runoffs of the rivers and groundwater are the main source of the water supply and a run-of-river intake is the predominant type of source facilities in using the surface runoffs of the rivers. The rural and livestock production water supplies are to be planned on a basis of district unit. In the context of water supply planning criteria, features of existing source facilities and availability of hydrological data, the following method was deployed for estimate of the available surface water resources for the respective district:

(1) Definition of available surface water resources

It is supposed that the prevailing run-of-river intake will continuously and widely be employed even in future, if the runoffs of the river needs to be developed. In case of the unregulated runoffs of the river is to be used, reliable flow at a given site of a given river is defined to be a 90% dependable flow deducted by river maintenance flow.

The administrative area varies largely from district to district, ranging from 282 km^2 of Mombasa district to 72,290 km^2 of Marsabit district. There is a case that one district extends over a couple of river basins. In such case the available water resources of the district under consideration is the summation of the reliable flows of the rivers in the district.

(2) 90% dependable flow

A 90% dependable flow is obtainable from flow duration curve of the nearest stream gauging station of the river or from dimensionless flow duration curve of river with a similar hydrologic characteristics.

(3) River maintenance flow

The river maintenance flow is to preserve aqua-ecology of river and assumed to correspond to the recorded daily minimum runoff of the river.

(4) Surface water resources of seasonal rivers

As explained in Section 3.3, total drainage area of the perennial rivers is only 254,419 m^2 out of the entire territorial area of 582,646 m^2. The rest of area is classified as ASAL areas where rivers run out seasonally when there is a heavy storm rainfall. According to the definition mentioned above, no reliable surface runoff is practically available from the seasonal rivers.

The available unregulated surface runoff is estimated based on the concepts and criteria mentioned above as presented in **Table - 3.7.1**. It amounts to 21.2×10^6 m^3/day for the entire country.

CHAPTER 4 GROUNDWATER RESOURCES

4.1 Features of Existing Boreholes

4.1.1 Number of Existing Boreholes

There were 10,778 boreholes recorded in NAWARD as of December 1997, out of which 8,448 boreholes are registered for water right. Number and density of the boreholes by district are shown in **Table - 4.1.1**. Note, some of the boreholes in the table are not always used; some are abandoned, some are un-operationable.

The largest number of boreholes were drilled in Kiambu district (1,212 nos.) followed by Nairobi (986 nos.), Nakuru (920 nos.), Kwale (647 nos.) and Masaku (621 nos.) districts. About 46% of boreholes were drilled in the above four (4) districts that cover a total area of only 5% of the whole nation. On the other hand, less than 20 boreholes were drilled in Tana River and Nandi districts.

The highest density of boreholes occurred in Nairobi district (1.42 nos./km^2) followed by Kiambu (0.47 nos./km^2) and Mombasa (0.37 nos./km^2), whereas density less than 0.01 nos./km^2 occurred in 16 districts. Boreholes were no evenly drilled in the country.

4.1.2 Diameter of Casing

According to NAWARD, the diameters of the existing casing pipe are as follows.

Diameter of Existing Boreholes

	Diameter of the Existing Casing (mm)								
	d<100	100 ≤d< 120	120 ≤d< 140	140 ≤d< 160	160 ≤d< 180	180 ≤d< 200	200 ≤d< 220	220≤d	Total
Nos.	1,394	489	169	4,546	100	8	1,497	244	8,447
Percent	16.5%	5.8%	2%	53.8%	1.2%	0.1%	18%	2.9%	

Source: NAWARD

It is noted that casing pipe with a diameter of 140 - 160 mm is widely used in the country, followed by the casing pipe with diameter of 200 - 240 mm. In particular, casing pipes with diameters of 152 mm (6 inch) and 203 mm (8 inch) amount to 50.3% and 17.2% respectively. As no significant technical problems, it is recommended that casing pipes of diameters of 152 mm (6-inch) or 203 mm (8-inch) should be used for well construction unless otherwise required.

4.1.3 Depth of Boreholes

Depth of existing boreholes varies considerably depending on the hydrogeological conditions. The average and range of the existing well depth are summarised in **Table - 4.3.2**.

4.1.4 Borehole Productions

From NAWARD, statistic of well production is obtained for two different casing diameters, 152 mm and 203 mm.

Casing Diameter (mm)	Borehole Nos.	Borehole Production (m^3/hour)		
		Average	Range	Standard Deviation
152	3,889	6.13	0 - 56.7	5.4
203	1,266	9.12	0 - 98.7	9.1

Source: NAWARD

Note, the larger casing the diameter is, the more the well production will be.

4.1.5 Operation and Maintenance Issues of Boreholes

It has been recognised that a considerable number of existing boreholes were abandoned. The Study considered it essential to highlight operation and maintenance matters of existing boreholes for a future sustainable development of groundwater resources.

The database of the WRAP field inventory surveys include the various information on operation and maintenance of existing boreholes in Baringo, Kilifi, Kajiado, West Pokot and Marsabit Districts, and some of WRAP reports have reported the current operation status of facilities for each district concerned. As the above 5 districts are considered to well represent the various parts of the country, the Study has attempted a statistic analysis to clarify the actual status such as operation status and mode and ownership of boreholes.

(1) Operation Status

Operation status of the existing boreholes is presented in detail in **Table - 4.1.2** and is summarised below:

Present Status of Boreholes

	In Use	Dry	Unknown	Abandoned	Total
Nos.	302	48	42	405	797
Percent	38%	6%	5%	51%	100%

Source: WRAP database, compiled and summarised by the aftercare study.
Information for Baringo, Kilifi, Kajiado, West Pokot and Marsabit Districts

It is remarkable that operation of 51% of the existing boreholes have been abandoned. The reasons of the above abandonment are as summarised below.

Reasons of Abandonment

	Low Yield	Poor Water Quality	Mechanical Breakdown	Lack of Fund for O/M	Local/ Political Bickering	Unknown
Nos.	40	53	113	75	1	123
Percent	10%	13%	28%	19%	0%	30%

Source: WRAP database, compiled and summarised by the Aftercare Study.

Information for Baringo, Kilifi, Kajiado, West Pokot and Marsabit Districts

O/M: Operation and Maintenance

The above table shows that main reasons are improper operation and maintenance (Mechanical Breakdown 28% and Lack of Fund for O/M 19%).

(2) Operation-Maintenance Status and Ownership

The operational mode was broken down into ownership of facilities as shown in **Table - 4.1.3**. The table shows that reasons for abandonment of facility appear to have less dependency on ownership. This is because that the owners such as the government do not use or maintain facilities.

(3) Mode of Owner - User - Maintainer

To assess sustainability of existing boreholes in use, the aftercare study analysed operation mode of boreholes for the possible four - (4) combinations. The result is as shown the table below.

The table shows that owner - user - maintainer is the predominant mode of borehole maintenance followed by owner - maintainer.

Maintenance Mode of the Existing Boreholes in Use

(Unit : Number)

User	Owner	Owner	User	User	Total
Maintainer	Owner	User	Owner	User	
Balingo	6	4	18	0	28
Kilifi	2	0	0	0	2
Kajiado	95	7	48	0	150
West Pokot	2	7	7	0	16
Total	105	18	73	0	196
Percentage	53.6%	9.2%	37.2%	0	100%

Source: WRAP database, compiled and analysed by the Aftercare Study.

From the above assessment, it may be concluded that:

1) the owner should directly maintain boreholes for sustainable groundwater development
2) arrangement have to be made to allocate a sufficient budget for maintenance of boreholes to ensure sustainability.

In along with the above recommendation, boreholes to be implemented by the Government should be handed over to the users so that they will turn to be the owners.

4.2 Features of Existing Dug Wells

4.2.1 Share of Dug Wells in Water Supply

As reported in Section 3.3, in Kenya dug wells (protected and unprotected) are one of the important sources of water supply. Dependence on the unprotected wells varies from 0.5% to 38.2% and that on the protected wells is in the range of 0.4% to 29.8%. According WRAP inventory survey, a large number of dug wells are used in the surveyed five districts; 145 wells in Baringo, 1,172 wells in Kilifi, 289 wells in Kajiado, 71 wells in West Pokot and 49 Wells in Marsabit district as shown in **Table - 4.1.2**.

4.2.2 Operation and Maintenance Issues of Dug Wells

WRAP provides some information on existing dug wells in the Baringo, Kilifi, Kajiado, West Pokot, and Marsabit districts. Similar to the assessment made for boreholes, operation status is analysed as follows:

(1) Operation Status

Operation status of dug wells is summarised in **Table - 4.1.2**. Contrary to boreholes, 80% of dug wells are in operational. In contrast to the other districts, slightly high numbers of dug wells are abandoned in Kilifi. It is therefore considered that dug wells are a sustainable option for groundwater usage.

Reasons of abandonment of dug wells are also summarised in **Table - 4.1.2**. Although data sample may not be sufficient for a statistic analysis, water quality is the major reason for the abandonment of dug wells. It is not clear now which components of water quality are responsible for the abandonment of the dug well, but salinity may be one of the reasons. However, as shown in the table, dug wells of low salinity (represented by EC) are also abandoned in coastal areas of Kilifi district. It is understood pollution by human activities may be a reason of abandonment.

Dug Wells and Electric Conductivity in Kilifi District

Electric Conductivity (micro S/cm)	Abandoned Wells (nos.)	Wells in Use (nos.)
> 10,000	10	95
5,000 - 10,000	5	96
2,000 - 5,000	16	275
1,000 - 2,000	12	220
< 1,000	17	237

Source: WRAP inventory survey. Analysed by the Aftercare Study.

(2) Operation & Maintenance Status and Ownership

Operation status and ownership of wells are summarised in **Table - 4.2.1**.

(3) Mode of Owner - User - Maintainer of Dug Wells

Similarly to the case of boreholes, the Study analysed operation mode of boreholes for the possible four - (4) combinations to assess sustainability of existing dug-wells in use. The result is as shown below.

Operation Mode of the Existing Dug Wells in Use

(Unit : Number)

User	Owner	Owner	User	User	Total
Maintainer	Owner	User	Owner	User	
Balingo	119	1	6	0	126
Kilifi	201	3	244	17	465
Kajiado	46	0	25	3	74
West Pokot	2	0	1	2	5
Total	368	4	276	22	670
Percentage	54.9%	0.6%	41.2%	3.3%	100%

Source: Wrap database, compiled and analysed by the Aftercare Study.

Same as the case of the boreholes, owner - user - maintainer is the predominant mode of dug wells maintenance followed by owner - maintainer. It may be concluded that the dug wells maintained by owners are one of better options for sustainable groundwater development.

(3) Water Bailing Method from Dug Wells

Water bailing methods in the said 5 districts is as summarised below:

Water Bailing Method from Dug Well

District	Total	No Pump	Type of Pump			
			Hand Pump	Engine Powered Pump	Electric Powered Pump	Wind Powered Pump
	(nos.)	(nos.)	(nos.)	(nos.)	(nos.)	(nos.)
Balingo	128	104	0	24	0	0
Kilifi	1024	804	194	24	2	0
Kajiado	90	61	27	2	0	0
West Pokot	63	69	4	0	0	0
Marsabit	199	167	32			

Source: WRAP Inventory Survey. Data compiled and analysed by the Aftercare Study.
For Marsabit, type of pump is not available in WRAP inventory.

Of the dug wells in use, 80% are not equipped with pumping facilities. Mechanical pumping is exercised at the rest of wells.

The reliance of households on the protected dug wells are 0.7, 2.2, 0.4, and 15.5% for the Baringo, Kilifi, Kajiado and Marsabit districts, respectively. In the Marsabit district, one well sustains 0.8% of the total households. Reliance on the dug well is very high.

4.3 Reassessment of Groundwater Safe Production

4.3.1 Review of Previous Studies

As reported in Section 1.2, there are two different and fundamental studies in assessment of groundwater resources in Kenya. Upon completion of NWMP, NAWARD was strengthened with additional information and data with assistance by WRAP Team. The Study Team therefore made review of the concerned section of the previous two studies in the light of the data and information available from NAWARD and attempted to update the safe groundwater production. The results of the reviewal study are summarised below and a summary of safe yield by the previous studies is shown in **Table - 4.3.1.**

(1) Survey Area

NWMP covers the entire area of Kenya, whereas WRAP resulted in groundwater exploitable potential only for 6 districts (Isiolo, Meru, Kajiado, Laikipia, Baringo, Samburu) out of 50 districts under study.

(2) Safe Yield

NWMP defines "safe yield of borehole" as yield that can be continuously abstracted from a borehole for a period of 20 years at constant abstraction rate with a drawdown within 10 m from the static water level. The constant abstraction rate equals to the yield that is either recorded in NAWARD or adopted for a field pumping test by NWMP. NWMP names the yield as "initial yield" and calculated transmissivity and storage capacity on the basis of Cooper and Jacob's equation.

WRAP adopts terminology "exploitable groundwater" which corresponds to 5 to 30% of the total groundwater flow in the area under study.

(3) Calculation of Safe Yield (Borehole)

1) NWMP

NWMP introduced a concept of "the ratio of safe-yielding of borehole" to estimate area-wide groundwater safe yield that is defined by the following mathematical model:

$$R = (B / A) \times 100\ (\%)$$
$$SY = R \times IY$$

Where;

- R : Ratio of number of safe yielding borehole against total number of boreholes in the area under study
- A : Total number of boreholes with data of Transmissivity and Storage Capacity.
- B : Among boreholes "A", the number of boreholes that is able to produce "safe yield" as defined above.
- SY : Total safe yield of a given area
- IY : Sum of initial yield of existing boreholes in the area
- Initial yield : Yield that is either recorded in NAWARD or adopted for a field pumping test by NWMP.

At the time of NWMP, transmissivity and storage capacity parameters were available only for 927 boreholes out of the existing 9,462 boreholes. Those data were actually employed for the above mathematical model.

2) WRAP

The groundwater developing potential of a district concerned were estimated principally by applying an orthodox hydrogeological method after the clarification the natural conditions such as hydrology and hydrogeology. The applied equations are as follows:

$$Q = W \times T \times i$$

Where;

- Q : Total groundwater flow
- W : Width of groundwater flow
- T : Transmissivity
- i : Hydraulic gradient

Exploitable groundwater was estimated by multiplying the total groundwater flow by a factor ranging from 5% to 30%.

(4) Transmissivity

Transmissivity is the predominant parameter in estimating safe yield of borehole as far as the above mathematical models are concerned.

In general WRAP's approach is considered to be more appropriate for a narrower area than that of NWMP. However, it is to be noted all WRAP estimation of groundwater potential are greater than that of NWMP as shown in **Table - 4.3.1.** In particular, WRAP used transmissivity values of 100 m^2/day to 1,000 m^2/day and 140 m^2/day to 450 m^2/day for the Meru and Isiolo Districts respectively, whereas, according to NAWARD, they are only 13 m^2/day and 9 m^2/day.

(5) Summary

The review of the two previous studies could be summarised as follows:

1) "Safe yield" obtained by NWMP appears to be the "safe yield" from the existing boreholes that are not always fully utilised in the country from various reasons. It seems that the results do not always reflect the hydro-geological conditions.
2) Hydrogeological factors appear to be inconsistent between WRAP and NAWARD.

As a result of the reviewal study, it is considered essential to make re-assessment of groundwater safe production over the entire Study Area.

4.3.2 Methodology Adopted for Re-Assessment (Borehole)

The objective area of the Study is as same as that of NWMP, covering the entire territorial area of Kenya. Therefore it is deemed to be appropriate to apply the same assessment method as that of NWMP for re-assessment of the groundwater safe production under the Study. The re-assessment was elaborated on the basis of the following premises and conditions:

1) Under the Study, the safe yield is defined as yield that can be ensured for a period of 20 years with resulting drawdowns of wells not exceeding 15 m from the original static level.
2) In order to facilitate the subsequent water supply plan, safe groundwater production is to be estimated on a basis of district.
3) The same mathematical model as that adopted in NWMP is applicable to the present re-assessment. The hydro-geological parameters such as transmissivity and storage capacity in NAWARD were averaged for each district, assuming the averaged hydrogeological factors represent the average hydrogeological **Table - 4.3.2.**
4) Initial yields in NAWARD were averaged for each district, assuming the initial yield is the optimum yield to an average borehole in a district.

5) A borehole should be apart from other adjacent boreholes so that drawdown of the concerned borehole least influences the other adjacent boreholes. A distance was calculated from a borehole to a point where the resulting drawdown is not more than 0.1 m after 20 years operation. The averaged initial yield was used for this drawdown calculation.
6) The calculation was carried out for six (6) different pumping hours: 4, 6, 10, 12, 18 and 24 hours per day.
7) The calculated pumping volumes from a unit area (km^2) vary as a function of daily pumping hours and well density. Maximum pumping potential from a unit area was selected as the safe yielding potential.
8) The maximum pumping potential was multiplied by "Safe yield factor"; the ratio of safe yielding boreholes against all boreholes to be considered.

4.3.3 Estimated Safe Groundwater Production

(1) Borehole

The calculated results are shown in **Table - 4.3.3.** It is noted that the total potential of this estimation is similar to the estimation of NWMP, though estimation for districts varies considerably.

It is considered that the estimation by this study reflects hydro-geological conditions represented by a set of data (initial yield, transmissivity, and storage capacity) in the database; and therefore to be utilised for the planning purpose.

As can be seen in **Table -4.3.4**, Total "safe Yield" estimated by the Study amounts to 184 million cubic meters per year, whereas safe yield of 193 million cubic meters was estimated by NWMP.

Relatively high 'safe yield' occurs in Muranga (916 $m^3/year/km^2$), Kajiado (834 $m^3/year/km^2$), Kipsigis (923 $m^3/year/km^2$) and Bomet (923 $m^3/year/km^2$) Districts. On the other hand very low "safe yield" occurs in Kwale (64 $m^3/year/km^2$), Tana River (48 $m^3/year/km^2$), Nandi (68 $m^3/year/km^2$) and Samburu (69 $m^3/year/km^2$) Districts.

(2) Shallow Well

The NWMP defined 'a shallow well' to be a groundwater-producing-well fulfilling the following conditions:

1) Hand dug well
2) Hand-drilled or machine drilled well not exceeding 50 m in depth

It is understood from the text of NWMP that 'a shallow well' is a well that belongs to the above category and abstract unconfined water.

The NWMP estimated the safe yield of shallow well as summarised in **Table - 4.3.5.**

Although the potential appears to be larger than that of borehole, there are possible problem involved in the use of shallow wells such as:

1) Water quality may not be satisfactory due to contamination from domestic wastage in populated areas, pollution form agricultural chemicals and fertilisers in farmlands, saline water intrusion in coastal areas, etc.
2) Shallow water may dry up in dry seasons.

It may be concluded that shallow-well-option should be less prioritised for planning purpose and used only when alternative water sources should not be available.

(3) Gross Safe Groundwater Production

The gross safe groundwater production is the sum of boreholes and dug wells. It is estimated at approximately 610.6 × 10^6 m^3/year, consisting of 184.5 × 10^6 m^3/year by boreholes and 426.1 × 10^6 m^3/year by dug wells, as shown in **Table - 4.3.5**.

As reported in the succeeding Section 5.1 of this report, the groundwater has been developed widely at many locations within the country and the present abstraction is estimated at 57.2 × 10^6 m^3/year. It is therefore estimated that it is theoretically possible to top additionally 553.4 × 10^6 m^3 annually. A district-wide development potential is as estimated in **Table - 4.3.6**.

4.4 Groundwater Chemical Quality

4.4.1 Review of Existing Data

The information on water quality recorded in NAWARD has increased from 1,435 in 1992 to 2,545 in 1997. Among all those data, each data of three parameters recorded with coordinates are 1,590, and complete data sets with all the three parameters and coordinates are only 628 as shown in the table below.

Water Quality Data Recorded in NAWARD

Item	Total data in NAWARD	Total of each data	Each data with coordinates	Three data with coordinates
EC	2,545	2,430	1,590	628
Fluoride		2,402	1,594	
Iron		2,088	1,427	

NWMP presented three maps of water quality under the title of "Drinking Water Risk" for the above three parameters and one map showing "Integrated Drinking Water Risk". These maps were produced by using 1,435 water quality data recorded in NAWARD.

According to these maps, majority of the country is subject to saline groundwater with electric conductivity more than 2,000 micro S/cm. Owing mainly to the salinity, the map of 'Integrated Drinking Water Risk' shows that groundwater is unfavourable for drinking purpose in most part of Kenya. This result appears to contradict the reality that groundwater is the major drinking water source in most of the rural area in the country.

The Study produced similar maps to ones of NWMP by using the updated water quality information recorded in the database (NAWARD) as shown in **Figure - 4.4.1**, **Figure - 4.4.2** and **Figure - 4.4.3**.

These maps produced by the Study Team resemble those of NWMP as a matter of course, showing wide areas of high electric conductivity more than 2,000 micro S/cm as shown in **Figure - 4.4.1**. The integration of the three maps will obviously result in the wide areas of groundwater unsuitable for drinking.

However, areas encompassed by contours showing high values appear not to be supported by actual data points. In other words, areas with sparse data sets tend to show the area of unsuitable groundwater. It seems that the contour maps may be misleading.

4.4.2 Water Quality

Instead, data points only are plotted as shown in **Figure - 4.4.4**, **Figure - 4.4.5** and **Figure - 4.4.6**. From these figures the following points are noticeable.

(1) EC (Electric conductivity)

High EC is densely observed in the coastal area. In northeastern area such as Mandera and Wajir districts, majority of boreholes yields high EC groundwater; whereas permissible groundwater is available in Garissa district. In other areas, majority of borehole appears to yield permissible groundwater though some yield saline water. No noticeable distribution pattern is recognised.

(2) Fluoride (F)

Borehole with high concentration of fluoride in groundwater is densely observed in and around Nairobi and Nakuru Districts. Some boreholes yield high fluoride groundwater in the districts around Mt. Kenya. In other areas, boreholes yielding high fluoride groundwater are sparsely observed, particularly in ASAL of the northeast of the country.

(3) Iron (Fe)

Borehole with high concentration of Iron is densely observed in the Western Province, Meru District, and in/around Nairobi and Nakuru Districts. In other area, similar to the case of fluoride, boreholes yielding high Iron groundwater are sparsely observed, particularly in ASAL of the northeast of the country.

Among the parameters considered above, fluoride solely is harmful to human health. Iron and salinity are factors that cause inconvenience or adverse aesthetic effect if the concentrations exceed certain levels. Hence, groundwater with a higher concentration of iron (Fe) or high salinity could be used if alternative water source is not available. In fact, such groundwater is being utilised in Kenya: - e.g. groundwater with EC higher than 5,000 micro S/cm is used for drinking purpose in Kilifi district, groundwater with Fe higher than 3 mg/l is used for drinking purpose in Baringo district.

Although further detail investigation will be required on the distribution of water quality, the Study Team is of the opinion that opportunity of groundwater development for human life could still be high in whole area of the country.

4.5 Groundwater Resources Development Concepts

4.5.1 General Criterion

The National Water Policy clearly points out that "The common bottlenecks in the choice of technology have been brought about by the use of conventional technology influenced by training, use of modern sources of energy which are not renewable and sophisticated equipment. These problems have resulted in costly maintenance and in many instances failure of the services. Therefore, use of traditional technologies will be encouraged with modification if necessary".

In line with the National Water Policy, a report on "Community Management of Water Supply Project" was issued by MWR in October 1997. The Study Team fully agrees with the approach set forth in the report, in particular with regard to the selection of the optimal technology for a certain rural or small scale community water supply and expects that such approach should be brought into effect as earlier as possible to as many as water supply schemes.

4.5.2 Groundwater Depth

Water Struck Level (WSL) is defined as a water level that is first encountered in a borehole during a drilling operation. In most cases, a WSL is either a parched water level of phreatic water level, though it can be an water level of a confined aquifer.

On the other hand, "Water Rest Level (WRL)" is defined as a water level that finally rests in a hole after completion of drilling. WRL could either be a parched water level, or a phreatic water level or a water level of a confined aquifer, depending on the hydrogeological conditions in place.

Although WSL is a groundwater level encountered in a shallow depth of a hole and therefore can be reached by shallow holes, groundwater forming a WSL is susceptible to drying up and contamination; and hence unreliable. Therefore, WRL should be considered as a more reliable water source.

4.5.3 Selection of Pumping Facilities

According to the National Water Policy, pumping schemes can be prioritised as follows:

Priority 1	:	Hand pumps
Priority 2	:	Wind powered pumps
Priority 3	:	Electrical power driven pumps
Priority 4	:	Diesel engine driven pumps
Priority 5	:	Solar energy using pumps

Groundwater level is a key factor for a selection of pumping facilities from the hydrogeological point of view. NWMP states that:

1) Hand pumps can pump water from a maximum pumping head of 60 m. However generally the pumping head should be less to assure a reasonable abstraction and reduce the exhaustion of pump. Abstraction rate of hand pump is assumed to be 10 m^3/day.
2) The windmills can pump water from a maximum pumping head of 100 m, but pumping head is assumed to be 60 m to assure a reasonable abstraction.

On the other hand, the Design Manual shows the maximum head for comfortable operation of a deep well hand pump of plunger type as follows: -

Head for Hand Pump

Cylinder Diameter (mm)	Head (m)
50	Up to 25
65	Up to 20
75	Up to 15
100	Up to 10

Source: Design Manual of Kenya

It is understood that hand pumps of local-made could bail water from some 25 meter depth at the maximum, while imported hand pumps are able to bail water from deeper zones, say deeper than 60 meters.

With a consideration that hand pump option is most sustainable as discussed above, the Study Team considers that hand pump should be utilised to bail water from say-60 meters, although such pumps should be imported. Accordingly, wind powered pumps for WRL deeper than 60 m, and other alternative such as electric power or diesel power for WRL deeper than 100 m.

4.5.4 Application Ratio of Pumping Facilities by Districts

WRL varies from place to place in the country according to hydro-geological conditions. For a planning purpose, percentages of WRL to be expected in a district is analysed for the cases of (1) WRL≤25 m, (2) 25 m<WRL≤60, (3) 60<WRL≤100 and (4) 100 m<WRL as shown in **Table - 4.5.1**.

If a hand pump is used for a well of WRL<60 m, 51% to 100% of wells can be equipped with hand pumps except in Garrissa (21%), Tana River (17%) and Wajir (45%) districts

As the average of the country, it may be concluded that:

1) Hand pumps may be installed to 82% of boreholes
2) Wind powered pumps may be preferable to 10% of boreholes, and
3) Powered pumps, such as electric powered or diesel powered pump, may be required to 8% of boreholes.

From the above assessment, hand pump option is promising to be implemented for most of districts in the country.

4.5.5 Recommended Well Production

NWMP recommended that 10 m^3/day (0.42 m^3/hour) should be assumed for a future planning purpose, which the Study agrees with. As for the other pumping method such as engine pump option, initial yield as shown in **Table - 4.3.3** is recommended as production rate.

In **Table - 4.3.3**, 'area needed for a well' is calculated with an assumption that water is pumped at initial yield rate. If hand pumps are applied in an area, well spacing may be narrowed to some 0.5 km^2 that results in 0.8 km^2 of area for a well.

4.5.6 Water Quality Criteria

NWMP commented on water chemical quality for electric conductivity, total dissolved solids, fluoride, iron, sodium, calcium, magnesium and sodium absorption ratio (SAR). Among those, three parameters (electric conductivity, fluoride and iron) are focused on to be most significant parameters for rural and small community water supply as shown in the table below.

Water Quality Criteria for Rural and Small Community Water Supply

Parameter	Unit	Permissible	Limit	Significance
		Maximum Recommended by WHO	Maximum permissible by the Design Manual of Kenya	
Electric conductivity	micro S/cm	750 (*)	2,000 (*)	Aesthetic
Iron	mg/l	0.3	1.0	Aesthetic
Fluoride	mg/l	1.5	3.0	health

Note: * Recommended by the NWMP. A firm value is not identified in WHO standard.

The Study Team is of the same opinion as NWMP that these parameters will be the least necessary parameters though recommendation of WHO and Design Manual of Kenya include the other parameters.

CHAPTER 5 PRESENT WATER RESOURCES DEVELOPMENT SITUATION

5.1 Existing Water Abstraction

The surface waters of the rivers and lakes, the groundwater and springs water are used for various purposes such as potable water for both urban and rural areas, irrigation/agriculture, livestock production, hydropower generation, etc. In Kenya, the water abstraction from the rivers, lakes, springs and groundwater is under jurisdiction of the Water Apportionment Board (WAB) of MWR. WAB authorises water permits for every water abstraction.

As far as the surface water resources of the rivers are concerned, the water permit is issued under two different conditions: (i) rate of abstraction under normal flow condition and (ii) rate of abstraction under flood flow condition. The water permit under the normal flow condition is significant and is issued with a high priority for domestic/ industrial water supply as well as year-round irrigation and hydropower generation, while that under flood condition is normally applicable for seasonal irrigation supply and hydropower generation as the case may be.

According to NWMP, the annual abstractions from the surface water and groundwater resources are reported as summarise below :

Present Surface Water Abstraction

Drainage Area	Drainage Area (km^2)	Total Abstraction (10^6 m^3/year)	Abstraction per Unit Area (m^3/km^2/year)	Ratio to Annual Mean Runoff (%)
Lake Victoria Basin	41,306	254.3	6,156	2.2
Rift Valley Basin	51,062	46.8	917	1.7
Athi River and Coastal Basin	53,955	133.1	2,467	11.6
Tana River Basin	95,989	595.4	6,203	15.9
Ewaso Ngiro and Northern Basin	12,107	42.1	3,477	12.4
Total	254,419	1,071.7	4,212	5.4

Source : The Study on the National Water Master Plan, Main Report, Volume 1, July 1992

Present Groundwater Abstraction

Drainage Area	Drainage Area (km^2)	Total Abstraction (10^6 m^3/year)	Abstraction per Unit Area (m^3/km^2/year)	Ratio to Annual Mean Runoff (10^{-2}%)
Lake Victoria Basin	46,229	9.34	202.0	1.5
Rift Valley Basin	130,452	11.67	89.5	1.6
Athi River and Coastal Basin	66,837	27.76	415.3	5.6
Tana River Basin	126,026	4.79	38.0	0.5
Ewaso Ngiro and Northern Basin	210,226	3.65	17.3	0.4
Total	579,770	57.21	98.7	1.6

Source : The Study on the National Water Master Plan, Sectoral Report (C), July 1992

The surface water abstraction volume is of under normal flow condition and based on the water permits available from NAWARD. The total abstraction quantity corresponds to only 5.4% of the annual mean runoff, ranging from 1.7% in the Rift Valley river basin to 15.9% in the Tana river basin. It is no exaggeration to say that the surface water resource in the country remains almost untapped, excepting the Tana and Turkwell river basins. In the Tana river basin a series of dams/reservoirs has been developed mainly for hydropower generation and its runoff has been controlled to a great extent throughout the year and over a number of years. The Turkwell river basin is under the similar conditions as that of the Tana river basin.

The groundwater resources are widely developed in the Athi and Coast, Lake Victoria and Ewaso Ngiro and Northern basin. The present abstraction is only about 9% of the safe groundwater production quantity. According to the NWMP estimate, the groundwater abstraction by water use category is as follows:

Present Groundwater Use by Category

Water Use Category	Annual Abstraction (m^3/year)	Ratio (%)
Public water supply	11.13	19.5
Agriculture	11.75	20.5
Domestic	3.46	6.0
Irrigation	2.08	3.6
Livestock	1.07	1.9
Exploratory	0.10	0.2
Observation	0.08	0.1
Others	7.89	13.8
Unknown	19.65	34.4
Total	57.21	100.0

Source: The Study on the National Water Master Plan, Sectoral Report (C), July 1992

The water supply is the predominant water use with a total share of 25.5.%, although others and unknown categories account for 48.2% of the gross abstraction. It is supposed that the others and unknown categories may include private water uses.

5.2 Prevailing Sources of Water Supply under Present Conditions

5.2.1 Prevailing Sources of Water Supply

The contemplated Study aims at formulating water supply plan at a master plan level. Target sector of water supply is residential, industrial, commercial, institutional and livestock.

Characterised by climatic, hydrologic and geographic conditions, Kenyan people depend on various types of water sources for their water consumption. "Welfare Monitoring Survey II, 1994, Basic Report, CBS" provides a valuable data on existing water supply situation. **Table - 5.2.1** shows the percentage distribution of households with access to safe water and main water sources at present by district, which is quoted from the above report. Its summary is given below:

Access to Safe Water under Existing Conditions

(Unit :% of household)

Area	Access to Safe Water	Piped water	River	Lake/ Pond/ Dam	Roof Catch.	Protect. Spring	Unprot. Spring	Protect. Well	Unprot. Well	Borehole	Other
Rural Area	32.5	17.3	30.5	6.6	3.9	5.6	12.6	5.8	8.2	7.7	1.9
Urban Area	93.3	90.2	3.1	0.0	0.3	0.4	0.7	2.3	0.7	0.7	1.4
Total	44.9	32.1	24.9	5.3	3.2	4.5	10.2	5.1	6.7	6.3	1.8

Source : Welfare Monitoring Survey II, 1994, Basic Report, CBS

According to the report, safe water includes treated surface water, untreated and uncontaminated water sources such as protected springs/well, pipe water and roof catchment.

The table shows that 44.9% of the total households has access to safe water, comprising 32.5% in rural areas and 93.3% in urban areas. Piped water supply is the predominant in urban areas in safe water supply, while the untreated river water far exceeds the piped water supply in rural areas.

Springs, both protected and unprotected sustains more than 30% of the total households in the Nyanza and Western Provinces. The protected and unprotected wells bears more than 15% of the households in the North Eastern, Nyanza, Western provinces. It is important to improve the unprotected springs and wells to the protected so that the safe water could be ensured.

Characterised by the water resources, there are also various type of water source facilities and the Design Manual provides design criteria for the respective source facilities. Outlines of existing water source facilities are explained in the succeeding subsections.

5.2.2 Surface Water Source Facilities

For the surface water resources development, there are four typical source facilities.

(1) Dam with seasonal regulating reservoir

A large dam is constructed to create a reservoir with a large storage capacity capable of regulating the runoff of the river throughout the year. This type of source facilities is rarely developed with a single purpose for water supply because of a large initial investment. In Kenya, only Nairobi and Eldoret are provided with this type of source facilities.

(2) Small dam/weir

There are 1,779 water supply systems in Kenya in 1994, according to the "National Development Plan, 1997 - 2001". Substantial portions of these system depend on the unregulated surface runoff of the river for their raw water source and a run-of-river intake is the predominant method in the surface water resources development. There are two types of intake facilities : one is a gravity intake scheme and the other is pumping scheme. Baricho and Kisumu water supply systems are of typical one in pumping scheme. Many of the pumping scheme are reported to be encountered with operation and maintenance problems.

MWR promotes the construction of small dams in order to provide water for various purposes especially in ASAL areas. According to "Inventory of Dams and Pans in the Country, July 1997, MWR" there are 1,359 dams in the country as shown in **Table - 5.2.2**, and of these 551 and 375 dams are located in the Rift Valley and Eastern province, respectively.

Small dam/weir has very small storage capacity, not capable of controlling the runoff of the river throughout the year. The water stored exhausts in a relatively short period, being accelerated by evaporation and is in some places used for domestic consumption without any treatment. It is, however, an important water resources especially in ASAL areas for both human and livestock consumption. Dam is normally of earth fill type and weir is of concrete or masonry structure.

5.2.3 Groundwater Source Facilities

The groundwater source facilities are basically grouped into two. One is dug well and the other is borehole. The features of boreholes and dug wells are reported in detail in Sections 4.1 and 4.2, respectively.

5.2.4 Springs Source Facilities

Most typical spring source facilities are that of Mombasa water supply system. An intake is constructed in water pool and water is conveyed in a gravity flow to service reservoir through a long transmission pipeline only after disinfecting. In some small springs, surrounding area is protected with masonry to protect the springs from contamination and spring water is led directly into small tank for distribution.

According to NWMP, it is supposed that all identified springs have been used for water supply and there may be no more development potential in this type of source.

5.2.5 Rainwater Harvesting

(1) Roof Catchment

Roof catchment is typical facilities in rainwater harvesting and about 3% of the total households in Kenya depends on this facility for their safe water supply. It is commonly used especially in ASAL areas for domestic consumption, where are scarcely blessed with water resources and annual rainfall.

Rainwater collected from roof is led into water tank for storage. For effective rainwater harvesting solid and waterproof material such as corrugate iron or galvanised steel sheet is used as roof material. Nowadays very portable water tanks with a long durability are available easily from local market. The Design Manual recommends that roof catchment facilities be designed on a basis of 90% dependable rainfall.

(2) Water Pans

This is normally constructed taking advantage of topographic condition and stores seasonal rainwater. This is one of important source facilities especially for livestock water supply but its usable period is limited to a short period after rainy season because of shallow water depth, small storage capacity, seepage through bottom, and evaporation from the pond surface. As shown in **Table - 5.2.2** there are 825 water pans in the country, of which 33 and 201 pans are located in the Rift Valley and Coast provinces, respectively.

5.2.6 Other Source Facilities

Such other water source facilities as sub-surface/sand dams and rock catchment are considered to be appropriate technology especially for the areas remote from more conventional water resources. Under the present conditions it appears that there is little such water source facilities in Kenya.

5.3 Estimate of Present Water Supply Quantity

5.3.1 General Description

There are no accurate statistics available to comprehensively indicate the safe water supply quantity in Kenya. This is attributed to such facts that there are a number of water undertakers in Kenya, many systems are operated without master meter, self-help and community systems keep no record, etc. MWR and SIDA conducted "Economic and Financial Analysis of Operation and Maintenance of Urban and Rural Water Supply Scheme" in 1988. According to this survey the total amount of water produced by gazetted urban and rural schemes was 83.3 million m^3 in 1985/86. It is, however, supposed that this figure is of the public water supply systems, not inclusive those of NGOs, self-help, and community schemes.

In order to estimate the water resources development requirement to meet the water demand in the target year 2010, it is indispensable to estimate the latest safe water supply quantity for respective urban centre and district. An attempt was made by deploying all available data and by the methods as described in the succeeding sub-sections.

The Study Team, however, strongly recommends that a complete inventory and status of all water supply schemes in Kenya be installed in NAWARD as earlier as possible. This will greatly contribute to rational and efficient administration and planning in water supply sector.

5.3.2 Data Source

The following material is utilised to obtain water supply capacity of existing, on-going and planned/designed projects:

1) Survey on Existing Urban and Rural Water Supply Systems by the Aftercare Study in 1998
2) Survey for rehabilitation of existing water supply system by MWR, 1997
3) Project Status Report 1996, MWR, December 1997
4) Brief of National Water Conservation and Pipeline Corporation's Activities and Present Status, NWCPC, September 1997
5) District Water Development Plan, Water Resources Assessment and Planning (WRAP)
6) Information from MOLA
7) Annual and Monthly Report by Provincial Water Offices, MWR
8) The Study on the National Water Master Plan, July 1992

5.3.3 Approach to Estimate

The existing water supply system can be grouped into four groups in view of water consumption and service areas : (1) urban water supply, (2) large scale rural water supply, (3) small scale water supply, and (4) livestock water supply. The estimate of water supply capacity is attempted to be estimated for each group.

(1) Urban Water Supply (UWS)

Water supply capacity of existing UWS has been surveyed by the Study Team. However, design capacity of 49 urban centres out of 141 objective urban centres were obtained data from the material mentioned in the sub-section 5.3.2.

For the on-going and planned/designed projects, the water supply capacity is referred to the MWR Project Status Report 1996.

(2) Large Scale Rural Water Supply (LSRWS)

There are 295 LSRWS in Kenya and their water supply capacity is obtained by the same method as the UWS.

(3) Small Scale Rural Water Supply (SSRWS)

Rural water supply schemes other than large scale water supply schemes are defined as small scale rural water supply schemes (SSRWS). The existing data source such as the MWR Project Status Report 1996 does not list up all SSRWS schemes. It is therefore assumed that the total water supply capacity of SSRWS is in a similar level to the estimated water demand because of the following:

1) Registered members are major customers in case of SSRWS. A sudden increase of the customers is very rare.
2) Normal water supply schemes apply safety side of design values to cope with future population growth.

3) Population growth rate in rural areas is generally lower than that of urban centre population.

For the on-going and planned/designed SSRWS, the water supply capacity is mainly derived from the MWR Project Status Report 1996.

Roof catchment is one of the major water supply methods, especially rural area, and it is included in small scale rural water supply. Although the water supply capacity is subject to the amount of rainfall and water tank capacity, it is estimated based on the number of households resorted to the roof catchment and water consumption per capita. The water consumption per capita is assumed to be 5 litter per day. The water supply capability by roof catchment is assumed to remain constant throughout the planning horizon.

(4) Livestock Water Supply

The present situation of water supply for livestock is assumed that 80% of the water demand is being fed from the existing facilities as stated in Supporting Report II, Water Supply Planning. According to this assumption, water supply capacity for livestock is estimated 410,000 m^3/day in 1995.

5.3.4 Estimated Quantity of Present Water Supply

In accordance with the method stated in Section 5.3.3, water supply capacity of existing, on-going and planned/designed water supply schemes is estimated. The inventory of the existing, on-going, and planned/designed water supply projects for UWS, LSRWS, and SSRWS are as presented in **Tables - 5.3.1** to **5.3.3**, respectively, and the summary is shown below:

Water Supply Capacity

(Unit: 1,000 m^3/day)

Category	Existing Schemes	Ongoing Schemes	Planned/Designed Schemes	Total
UWS	708.8	83.7	759.6	1,552.1
LSRWS	448.6	657.9	375.9	1,482.4
SSRWS	205.2	37.2	60.9	303.3
Roof Catchment	(4.2)	(0.0)	(0.0)	(4.2)
Total	1,362.6	778.8	1,196.4	3,337.8

Source : The Aftercare Study Team

Note: Water supply capacity of roof catchment is included in SSWS.

Water supply capacity will increase 53% upon the completion of on-going projects. Furthermore, upon completion of the planning and designed projects, the total water supply capacity reach 3.5 x 10^3/day, almost 233% of the present water supply.

CHAPTER 6 ASSESSMENT OF FUTURE WATER RESOURCES DEVELOPMENT REQUIREMENT FOR SAFE WATER SUPPLY

6.1 Forecast Safe Water Demand

The water balance analysis between the future source water demand and the water supply capacity is to ascertain the magnitude of the water resources development. The source water demand is forecast as presented in Supporting Report II, Water Supply Planning and is summarised in the table below:

Forecast Water Demand

(Unit : 1,000 m^3/day)

Province	Urban Water Supply		Rural Water Supply		Livestock		Total	
	1995	2010	1995	2010	1995	2010	1995	2010
Nairobi	331.8	721.7	0.0	0.0	1.2	1.4	333.0	723.1
Central	56.6	176.2	116.1	176.5	19.9	22.5	192.6	375.2
Coast	106.1	187.2	46.8	82.5	22.1	24.9	174.9	294.6
Eastern	44.9	154.8	77.4	184.6	117.5	132.4	239.8	471.8
North Eastern	8.4	37.4	13.4	20.1	89.9	101.3	111.8	158.7
Nyanza	72.0	155.1	68.8	221.3	40.6	45.8	181.5	422.1
Rift Valley	135.1	407.6	91.1	251.3	201.4	226.9	427.6	885.8
Western	45.5	165.9	73.4	136.8	24.9	28.1	143.8	330.7
Total	800.5	2,005.9	486.9	1,072.9	517.5	583.2	1,805.0	3,662.0

Source : The Aftercare Study Team

6.2 Assessment of Future Water Resources Development Requirement

6.2.1 Purpose of Assessment

The water supply capability of the whole existing water supply facilities is estimated at 1.9 million m^3/day, whereas the overall safe water demand is forecast to amount to as large as 3.7 million m^3/day in the target year 2010. It is evident that there is serious need for development of new water supply projects, though magnitude of development in need may varies largely from area to area. The availability of water resources also varies largely frame one area to another as discussed in Sections 3.7 and 4.3 hereof.

Purpose of assessment is to formulate at preliminary level of future water resources development plan to meet the increased water demand.

6.2.2 Assessment Unit

There are many types of water supply schemes developed in the country. Although it is considered more practical to work out water supply development plans based on supply areas of the existing water supply schemes, as the limited study period and availability of reliable information for each scheme, the assessment of future water resources development for safe water supply is carried out for the following three categories:

(1) Urban Water Supply (UWS)

In the Study, target area of urban water supply is defined at 141 urban centres. The assessment is done on a basis of urban centre.

(2) Rural Water Supply (RWS)

The target area of rural water supply is defined as the all area except urban water supply target areas. Rural water supply is divided into LSRWS and SSRWS. The assessment is done on a basis of district.

(3) Water Supply for Livestock

Livestock water demand will account 35% of total demand for rural water supply area in 2010, and it is more than residential water demand in several districts such as Garissa, Wajir, Makueni, etc. Since it is not necessary to supply potable quality water for livestock, future water resources development for livestock is considered to be planned separately from the other water consumers.

6.3 Water Balance between Water Demand and Water Supply Capacity

6.3.1 Method of Water Balance Calculation

In order to formulate the future water supply plan, it is significant to ascertain quantitatively a relationship between the future water demand and the water supply capacity. If the demand is exceeding the supply capacity, there needs to develop of new water resources and water supply facilities. A flow chart of water balance calculation is as presented in **Figure - 6.3.1.** In order to facilitate the planning of future water supply projects, the water balance calculation was worked out for four steps as follows:

(1) Step 1: Under the Existing Condition

The 2010 water demand is compared to the water supply capability of the existing facilities. The water deficit (1) occurs if the demand exceeds the supply capability.

(2) Step 2: Step 1 + Completion of the Ongoing Projects

The resultant water deficit (1), if any, is compared to the water supply capacity of the on-going projects in the area concerned. The existing data such as the MWR Status Report do not indicate the water supply capacity of the on-going projects but design population. It is therefore estimated based on the design population and assumed per capita water consumption (75 litres/day for rural water supply scheme and 150 litres/day for urban water supply scheme).

The water deficit (2) occurs if the on-going projects capacity fell short of the water deficit (1). There is no need of development of new project if the resultant is vice versa.

(3) Step 3: Step 2 + Completion of the Planned/Designed Projects

In the same manner as the Step 2, the water deficit (2) is again compared to the water supply capacity of the planned/designed projects in the area concerned. The deficit, if any, is defined as deficit (3). The water supply capacity of the planned/designed projects is mainly referred to the MWR Status Report and the NWCPC Status Report.

(4) Step 4: Step 3 + Completion of the Proposed Rehabilitation Works of Existing Facilities

MWR has been placing great emphasis on rehabilitation of existing facilities to restore them to their original functions. The Aftercare Study Team quite agrees with this approach and recommends MWR to implement the rehabilitation works as promptly as possible.

It is evident that the rehabilitation works will results in augmentation of production capacity, which is taking into consideration under Step 4. The eventual water deficit (4) must be covered by development of new projects.

6.3.2 Result of Water Balance Calculation

(1) Urban Water Supply (UWS)

The result of water balance calculation is as shown in **Table - 6.3.1**. Since the augmentation of water demand is quite huge, water deficit still occur in the target year 2010 at 109 urban centres out of 141 urban centres even after the completion of rehabilitation works of existing projects, on-going projects and planned/designed projects. A summary of the water balance calculation is given below:

Water Deficit in 1995

Description	Step 1	Step 2	Step 3	Step 4
No. of Urban Centres Facing Water Deficit	86	70	56	51
No. of Urban Centres Without Water Deficit	55	71	85	90
Shortage of Raw Water (1,000 m^3/day)	184.2	162.3	140.9	119.0

Water Deficit in 2010

Description	Step 1	Step 2	Step 3	Step 4
No. of Urban Centres Facing Water Deficit	133	121	111	109
No. of Urban Centres Without Water Deficit	8	20	30	32
Shortage of Raw Water (1,000 m^3/day)	1,313.7	1,253.6	1,152.6	1,111.6

Source : The Aftercare Study Team.

Figures - 6.3.2 and **6.3.3** illustrate the urban centres subject to water deficit in 2010 under conditions of Steps 1 and 4 respectively.

(2) Rural Water Supply (RWS)

The result of water balance calculation is as shown in **Tables - 6.3.2** and **6.3.3**. Water deficit will occur at 13 districts in the target year 2010 even after the completion of proposed water supply projects as summarised below:

Water Deficit in 1995

Water Supply System	Descriptioo	Step 1	Step 2	Step 3	Step 4
LSRWS	No. of Districts Faciog Water Deficit	24	7	3	2
	No. of Districts Without Water Deficit	25	42	46	47
	Shortage of Raw Water (1,000 m³/day)	62.7	13.3	5.7	4.8
SSRWS	No. of Districts Facing Water Deficit	0	0	0	0
	No. of Districts Without Water Deficit	49	49	49	49
	Shortage of Raw Water (1,000 m³/day)	0.0	0.0	0.0	0.0

Water Deficit in 2010

Water Supply System	Description	Step 1	Step 2	Step 3	Step 4
LSRWS	No. of Districts Facing Water Deficit	36	15	11	9
	No. of Districts Without Water Deficit	13	34	38	40
	Shortage of Raw Water (1,000 m³/day)	233.4	65.7	42.3	35.9
SSRWS	No. of Districts Faciog Water Deficit	46	42	34	34
	No. of Districts Without Water Deficit	3	7	15	15
	Shortage of Raw Water (1,000 m³/day)	355.0	324.9	292.0	292.0

Source : The Aftercare Study Team. Number of district is 49 as Nairobi in excluded.

Figures - 6.3.4 and **6.3.5** show the water balance situation in LSRWS in 2010 under conditions of Steps 1 and 4 respectively. **Figures - 6.3.6** and **6.3.7** also indicate the water balance situation is SSRWS for the same conditions as LSRWS.

(3) Water Supply for Livestock

The result of water balance calculation is as shown in **Table - 6.3.4**. Required water resources development is estimated 169,000 m³/day to meet the increased demand in 2010.

6.3.4 Required Water Resources Development

It is clarified that, even under condition of Step 4, water deficit will occur over a large number of urban centres and district. The water deficit, resultant of the Step 4 calculation stated above varies largely depending on the present water supply capacity and capacities of the newly proposed projects.

Table - 6.3.5 shows the required water resources development by district that is calculated by subtracting the present water supply capacity from the water demand in the target year 2010. The summary is as shown below:

Future Water Resources Development

Province	Present Water Supply Capacity (Step 1) (1,000 m³/day)	Water Demand in 2010 (1,000 m³/day)	Required Water Resources Development (1,000 m³/day)
Nairobi	319.0	721.7	402.7
Central	338.4	352.7	67.0
Coast	158.7	269.7	111.0
Eastern	149.5	339.4	191.6
North Eastern	8.1	57.4	49.4
Nyanza	88.9	376.4	287.4
Rift Valley	218.9	658.9	440.0
Western	85.4	302.6	217.3
Total	1,366.8	3,078.8	1,766.4

Source : The Aftercare Study Team

It is concluded that it is necessary to develop water resources to cover for water deficit of 1,766 $\times 10^3$ m^3/day in 2010.

CHAPTER 7 PRELIMINARY WATER RESOURCES DEVELOPMENT PLAN

7.1 Water Resources Development Concepts

7.1.1 Urban and Rural Water Supply

Under the present conditions, the surface waters and rivers and groundwater are the main water source for water supply and, as analysed in Chapters 3 and 4, these resources still remain almost untapped, though their availability is widely different from area to area. In view of the natures of water resources, the following water resources development concepts are introduced for the urban and rural water supply systems:

(1) Urban Water Supply (UWS)

The surface water of the rivers is the predominant source of raw water for the large urban centres, and accordingly is given the first order of development. As much as the unregulated runoff of the river is available, a run-of-river intake method is considered to be best suited. When the unregulated runoff of the river is insufficient to meet the water deficit, a large scale dam with seasonal flow regulating capacity or inter-basin transfer scheme as identified by NWMP will be considered.

Depending on the magnitude of the water deficit, the groundwater, particularly boreholes will be proposed in place of the surface waters as is available in the vicinity of the urban area concerned and more economical than the surface water.

(2) Large Scale Rural Water Supply (LSRWS)

The same development concepts as the urban water supply schemes are basically adaptable. However, the groundwater development will be given the first order of development when the area concerned is located in ASAL area.

(3) Small Scale Rural Water Supply (SSRWS)

The groundwater development will be considered to be the predominant source. It is evident that there are no perennial surface water resources available in the ASAL areas as reported in the Chapter 3 of this report. In general for small community water supply, construction of boreholes or dug wells are more advantageous than the surface water in view of initial investment, operation and maintenance cost.

7.1.2 Water Resources Development Concept for Livestock

It is not absolute requirement to supply the livestock with water in potable quality. It is simply assumed that all the water deficit will be secured by means of construction of water pans. NWMP assumed that the average storage capacity of small dams and water pans for water supply is 50,000 m^3 and about 77,600 m^3 of gross storage is estimated including sediment and evaporation loss in reservoir. The required number of water pans by province is as summarised below and shown in **Table - 7.1.1.**

Development of Water Pans

Province	Water Deficit in 2010 (1,000 m³/day)	Number of Water Pans Required by 2010
Nairobi	0.4	1
Central	6.5	16
Coast	7.2	29
Eastern	38.4	150
North Eastern	29.4	160
Nyanza	13.3	27
Rift Valley	65.8	198
Western	8.2	16
Total	169.2	597

Source : The Aftercare Study Team

7.2 Comparison of Water Resources Development Potential and Development Requirement

The development potentials of the unregulated surface water of rivers and groundwater resources are assessed at 21.2×10^6 m³/day and 1.5×10^6 m³/day, respectively, as explained in Sections 3.7 and 4.3. The distribution of such water resources is, however, not uniform or even throughout the country.

The water resources development requirement is estimated at 1.7×10^6 m³/day, only 7.4% of the total potential of the surface water and groundwater. However, since the availability of water resources is widely different from area to area, it is essential to take into account such effect in future water resources development planning. The table below presents the relationship between the water resources potential and the resources development requirement by province.

Province	Water Resources Development Potential			Required Development Requirement (B) (1,000 m³/day)	(B) / (A) (%)
	Surface Water (1,000 m³/day)	Ground Water (1,000 m³/day)	Total (A) (1,000 m³/day)		
Nairobi	11	0	11	403	3,663.6
Central	2,329	18	2,347	110	4.7
Coast	3,850	224	4,074	66	1.6
Eastern	6,896	358	7,254	138	1.9
North Eastern	161	468	629	24	3.8
Nyanza	886	33	920	186	20.2
Rift Valley	5,722	398	6,119	347	5.7
Western	1,363	18	1,380	165	12.0
Total	21,218	1,517	22,735	1,439	6.3

Source : The Aftercare Study Team

7.3 Preliminary Water Resources Development Plan

7.3.1 Preliminary Water Resources Development Plan for UWS

The water resources development plan is basically resorted to the ones water was proposed by NWMP. Its summary is given as follows:

1) NWMP has selected water sources for 118 urban centres out of 141 target urban centres. These are also adopted in the present study.
2) For the remaining 23 target urban centres not listed in NWMP, it is proposed to develop the surface water first. If water deficit is still occurring after the allocation of available surface water resources, groundwater is planned to make up. In ASAL area, groundwater is, however, given the first priority.

Table - 7.3.1 shows the proposed water resources development plan for each urban water supply. The table below summarises the surface and groundwater resources development to meet the water demand in 2010 in the respective province:

Water Resources Development for UWS by 2010

Province	Number of Urban Centres				Water Development Quantity (10^3 m^3/day)		
	S.W.	G.W.	SW+GW	Total	S.W.	G.W.	Total
Nairobi	1	0	0	1	403	0	403
Central	11	0	1	12	91	2	93
Coast	12	0	1	13	35	1	36
Eastern	14	7	0	21	80	19	99
North Eastern	3	4	0	7	7	13	20
Nyanza	13	1	0	14	106	1	107
Rift Valley	25	3	3	31	230	9	239
Western	10	0	0	10	116	0	116
TOTAL	89	15	5	109	1,066	46	1,112

Source : The Aftercare Study Team
Note: S.W.: Surface Water G.W.: Ground Water

The surface water resources are planned to bear 96% of the total development. The unregulated run off of rivers or groundwater or combination of both of them are not sufficient enough to meet future water demand in a number of the urban centres. For these, a large dam or inter-basin transfer or combination of them are proposed.

Fourteen prospective dams, five existing dams, and five inter-basin transfer sources are proposed by NWMP as future water sources as summarised in the table below:

Newly Proposed Large Scale Dam

Prospective Dam	River (Dam site)	Demand Urban Centre
Moiben	Moiben	U-166 Eldoret
Mukulusi	Mukulusi	U-210 Kakamega
Kibos	Kibos	U-120 Kisumu
Itare	Itare	U-155 Elburgon, U-157 Molo, U-159 Nakuru, U-160 Njoro
Bunyunyu	Kuja	U-117 Kisii, U-139 Keroka
Malewa	Malewa	U-156 Gilgil, U-158 Naivasha, U-159 Nakuru
Upper Narok	Ewaso Narok	U-163 Narok
Upper Athi	Athi	U-69 Athi River
Kikuyu	Nairobi	U-5 Kikuyu
Rare	Rare	U-38 Kilifi, U-40 Malindi
Rumuruti	Ewaso Narok	U-154 Rumuruti
Nyahururu	Nyahururu	U-28 Nyahururu
Chemususu	Perkerra	U-182 Mogotio
Kirandich	Kirandich	U-179 Karbarnet

Existing Large Scale Dam

Existing Dam	Demand Urban Centre
Thika	U-1 Nairobi
Kiambere	U-91 Mwingi
Edzawa	U-121 Maseno
Dimilitch	U-148 Kericho
Kimugung	U-148 Kericho

Inter-basin Transfer Scheme

Water Source by Inter-basin Water Transfer	Demand Urban Centre
Oloibortoto River	U-142 Nairobi
Second Mzima	U-55 Voi
Tana River	U-47 Lamu
Sio River	U-206 Busia
Athi River	U-71 Machakos, U-77 Kangundo/Tala, U-98 Mtito Andei

Source : NWMP Sectoral Report (M), Integrated Water Resources Development Planning

7.3.1 Preliminary Water Resources Development Plan for LSRWS

Since the location and covering area of the respective LSRWS are not precisely inventoried, water resources planning was attempted on a basis of district. The development concept is as stated in sub-section 7.1.2.

Table - 7.3.2 is water resources development plan for LSRWS and its summary is given in the table below:

Water Resources Development for LSRWS by 2010

Province	Number of Districts				Water Development Quantity (10^3 m³/day)		
	S.W.	G.W.	SW+GW	Total	S.W.	G.W.	Total
Nairobi	0	0	0	0	0	0	0
Central	0	0	0	0	0	0	0
Coast	1	0	0	1	3	0	3
Eastern	1	0	0	1	7	0	7
North Eastern	1	1	0	2	3	1	3
Nyanza	0	0	0	0	0	0	0
Rift Valley	3	0	0	3	16	0	16
Western	2	0	0	2	7	0	7
TOTAL	8	1	0	9	35	1	36

Source : The Aftercare Study Team
Note: S.W.: Surface Water G.W.: Ground Water

98% of the future water requirement would depend on the unregulated surface runoffs of rivers.

7.3.2 Preliminary Water Resources Development Plan for SSRWS

Table - 7.3.3 is water resources development plan SSWRS. 45% and 55% of required water development would resort to the unregulated surface runoffs of the rivers and groundwater respectively. The summary is shown below:

Water Resources Development for SSRWS by 2010

Province	Number of Districts				Water Development Quantity (10^3 m³/day)		
	S.W.	G.W.	SW+GW	Total	S.W.	G.W.	Total
Nairobi	0	0	0	0	0.0	0.0	0.0
Central	1	1	0	2	6.7	10.5	17.1
Coast	0	4	0	4	0.0	26.6	26.6
Eastern	0	6	1	7	0.5	31.7	32.2
North Eastern	0	2	1	3	0.3	1.1	1.4
Nyanza	0	3	2	5	46.0	33.0	79.0
Rift Valley	0	4	5	7	55.4	37.3	92.7
Western	0	1	3	4	25.6	17.2	72.9
TOTAL	1	19	8	28	134.5	157.4	292.0

Source : The Aftercare Study Team
Note: S.W.: Surface Water G.W.: Ground Water

- PART IV : WATER RESOURCE DEVELOPMENT PLAN -

TABLES

Table - 1.2.1 WRAP Studies

Stage	Wrap I - III	Wrap IV		Wrap V	
District	Water Resources Assessment	Water Resources Assessment with detailed inventory survey	District Water Development Plan	Water Resources Assessment & District Water Development Plan	
Marsabit	-	1997	-		-
West Pokot	1985	1994	1995		-
Elgeyo Marakwet & Baringo	1984	-	-	Keiyo	1999*
				Marakwet	1999*
Baringo	1987	1993	1995		-
Samburu	1991	-	-		-
Laikipia	1987	-	-		1999*
Meru	1991	-	-		-
Isiolo	1991	-	-		-
Machakos	1986	-	-		-
Kajiado	1991	1995	nearly completed		-
Kilifi	-	1996	-		-
Lamu	1988	-	-		-
Nakuru	-	-	-		1999*
Turkana	-	-	-		1999*

*: Years of completion or expected completion
Datasource: MWR

Table - 2.2.1 Summary of the Geology in Kenya

	Systems	Representative Rocks	Tectonic Events	Main Economic Uses (after Pulfrey,1960)
Cainozoic	Recent	Soils, alluvials, sands. Hot springs-trona and other evaporites. Volcanic	Rise to present sea level. Minor volcanicity and grid faulting.	Trona, salt, sands, brickearths, meerschaum, guano.
	Pleistocene	Moraines on highest peaks. Coral reefs andsandstones at coast.Interior sediments, alkaline and pyroclastic lavas.	Grid faulting, major volcanic eruptions in rift south of Nakuru, Nyambeni and Marsabit areas.3rd major faulting of Rift Valley and Kano Rift, alkaline dyke	Limestones, cement, diatomite, gypsum, bentonitic clays, kaolin.
	Tertiaty	Coastal sediments. Large quantities of volcanic rocks of the highlands.Interior	1st and 2nd major faulting of Rift Valley. Warpings, major regional uplift in central Kenya alkaline and	Limestones, building stones, carbon dioxide, ballast, lead, batytes.
Mesozoic - Paleozoic	Cretaceous	Danissa Beds, Maheran Sandstones, Freretown limestones and siltstones.	Stability. Probable commencement of carbonatite intrusions.	
	Jurassic	Limestones and shale in coastal areas. Daua Limestone Series and Mandera Series.	Slight uparching and tilting: Faulting in N.E. Kenya.	Limestones and shales, shales, gypsum.
	Triassic Permian Carboniferous (Karroo)	Duruma Sandstones, Mansa Guda Formation.	Gentle tilting, warping and tilting of mesozoic rocks. Erosion.	Ballast
Pre-Cambrian	Bukoban	Kisii Series-Acid and basic volcanics, quartzites and other sediments.	Gentle warping faulting. Dolerites and pegmatites intruded.	Soapstone, cassiterite
	Basement (The Mozambique Belt)	Quartzites, crystalline limestones schists, gneisses including Kusae, Kasigau Series, Turoka and other formations.	3rd period of N.E. trend folds in north Kenya. Early recumbent folds. Major period of orogenesis. Granites, granodiorites, pyroxenites, eclogites etc. intruded.	Asbestos, Kyanite marble, limestones, vermiculite, garnet.
	Kavirondian	Arenaceous and argillaceous sediments. Conglomerates, hornblende andesites etc.	Metamorphism with isoclinal folding with N.E. and S.E. trending axes. Granites, syenites and dolerites intruded.	Gold, silver
	Nyanzian	Sandstones, conglomerates, quartzites, phyllites, limestones, pelites volcanics and ironstones.	Slight metamorphism of Ablum and Embu Series. Granites, epidiorites, Gabbros.	Gold, copper, zinc, chromite, cobalt, silver, corundum and other minior minerals.

Source : Ojany, F.F. and R.B. Ogendo, Kenya: A Study in Physical and Human Geography,1988

Table - 2.2.2 Succession of Paleozoic-Mesozoic Sediments

System	Stage	North-east Kenya		Coastal Kenya
Cretaceous	Neocomian	Marehan Sandstones, Marehan Danissa Beds Series		Freretown Limestone
Jurassic	Tithonian	Mandera Series Dakacha Limestones Hereri Shales		
	Kimmeridgian	Seir Limestones Muddo Erri Limestone Rahman Shales	Daua Limestone Series	Rabai Shales
	Oxfordian			
	Callorian	Rukesa Shales		Miritini shales
	Bathonian	Murri Limestones		Kibiongoni beds
	Bajocian			Kambe Limestone
	Lias?	Didimtu Beds		-----
Trias	-----	Mansa Guda Formation -----		Mazeras Sandstones/ Shimba Grits Mariakani Sandstones Duruma Maji ya Chumvi Beds Sandstones
Permian-Carboniferous ?				Taru Grits
Pre-Cambrian		Matamorphosed Sediments of the Basement System		

Note: Dashed lines (-----) denote unconformities.
Source : Ojany, F.F. and R.B. Ogendo, Kenya: A Study in Physical and Human Geography, 1988

Table - 2.2.3 Succession of Cenozoic Units

Period	Interior and West Kenya	North-east Kenya	Coastal Kenya
Recent	Soils including laterites. Alluvium, spring deposits and evaporites in interior lakes e.g. Magaditrona	River soils including Kankar limestones, laterites and surface sands	Alluvium and beach sands
Upper Pleistocene	Loams, sheet limestone, mudstones, siltstones,tuffs, pumice lavas, fluviatile sediments	Red and brown clays having nodules	Windblown sands, Raised alluvial deposits
Middle Pleistocene	Lake beds in floor of Rift,Kanjeran Beds.Rawe Fish Beds	Thin laminated limestones, sandstones, conglomerates and ironstones. El Wak Beds	Kilindini sands, Mombasa Crag, coral reefs
Lower Pleistocene	Miriu Gravel.Lower Rawe Beds.Kanam Beds	Gypsum, limestones, sand-stones and clays. Wajir Beds	Magarini sands?

Source : Ojany, F.F. and R.B. Ogendo, Kenya: A Study in Physical and Human Geography, 1988

Table - 2.2.4 Quaternary Sediments in North East Kenya

Recent	River Soils and Windblown Sands		
Upper Pleistocene	Red and brown clays with calcareous nodules		
Middle	Thin laminate limestones		Partly contemporaneous with El Wak Beds
	Ferruginous sandstones and conglomerates		
	Gypsite and gypsum	Wajir Beds	
	Impure limestones		
Lower	Sandstones	Wajir Beds	
	Clays and sands		

Source : Ojany, F.F. and R.B. Ogendo, Kenya: A Study in Physical and Human Geography, 1988

Table - 2.2.5 Chronology of Volcanic Eruptions in Kenya

Period	Volcanic Events
Recent	Teleki and Andrew cones in Northern Kenya, geothermal activities-hot springs. Upper Menengai volcanics. Basalts in Rift Valley, Simbi Crater. Olivine basalts of Chulu Hills.
Upper Pleistocene	Eruption of the main cones in Rift Valley floor-Longonot, Suswa. Early eruptions in Chulu Hills. Eruption of tuffs, pumice showers, Kijabe basalts and Eburu volcanics and comendites. Parasitic vents of Mt. Kenya.
Middle Pleistocene	Extensive eruption of pyroclastics in Naivasha area. Aberdare tuffs and trachytes. 2nd major eruption of Mt. Kenya.
Lower Pleistocene	Homa basalts. 1st major eruption of Mt. Kenya. Olivine basanites, basalts and trachytes in Limuru, Kijabe and Simba areas. Initial activities in Homa area.
Pliocene	Main eruption of Lower Menengai volcanic series. Nephelinites, trachytes, pyroclastics, phonolites and tuffs in Rift Valley and Naivasha. Londiani agglomerates, Kedowa, Mau, Kinangop and Bahati tuffs. Beginnings of Sattima series-Laikipia and Aberdare eruption. Main eruption of Mt. Elgon.
Middle Miocene	Londiani and Rumuruti phonolites, Simbara Series. Gwasi and Samburu volcanics. Extensive fissure eruptions-Kapiti, Yatta and Kericho

Source : Ojany, F.F. and R.B. Ogendo, Kenya: A Study in Physical and Human Geography, 1988

Table - 2.3.1 Summary of Hydrogeology in Kenya

Era	Period	System	Representative Rocks	Hydrogeological Division	Groundwater Resources	
					Aquifer	Water Quality
Cainozoic	Quaternary	Recent	Soils, alluvials, sands. Hot springs-trona and other evaporates. Volcanic ashes.	Eastern and Western Quaternary Sediment	Eastern Area: Aquifers are generally shallow and unconfined.	Deeper water is saline while shallower fresh. Shallow water is subjected to pollution.
		Pleistocene	Moraines on highest peaks. Coral reefs and sandstones at coast. Interior sediments, alkaline and pyroclastic lavas.		Western Area: Aquifers are shallow near the Equater, but deep in the other areas.	Shallow water is moderately saline but potable.
	Tertiary		Coastal sediments. Large quantities of volcanic rocks of the highlands. Interior Miocene Beds.	Vocanic Rock Area outside the Rift Valley	West to Rift Valley: aquifers are either in the weathered zone of Basement below the volcanic rocks or volcanic rocks, depth to aquifer varies significantly. East of Rift Valley: aquifers are in volcanic rocks, usually artesian, depth to the aquifer varies significantly.	Water is generally bicarbonate type with low total dissolved solid. High fluoride content exists as local pockets.
				Vocanic Rock Area in the Rift Valley	Aquifers are displaced by faults and the occurrence is unpredictable. Either cool or hot (including steam) water is available in deeper ground.	Water is generally bicarbonate type. High fluoride content exists as local pockets.
Mesozoic - Paleozoic	Cretaceous		Danissa Beds, Maheran Sandstones, Freretown limestones and siltstones.	Old Sedimet Rock Areas	Numerous aquifers in the systems, most are deep and confined.	Water quality is generally good though occasional occurrence of water with high electrical conductivity.
	Jurassic		Limestones and shale in coastal areas. Daua Limestone Series and Mandera Series.			
	Triassic Permian Carboniferous (Karroo)		Duruma Sandstones, Mansa Guda Formation.			
Pre-Cambrian		Bukoban	Kisii Series-Acid and basic volcanics, quartzites and other	Basement Complex Area	Aquifers are in weathered zones, shallow and more less unconfined; discontinuous (isolated aquifers).	Water Quality is good in origine, but subject to pollution by human activity.
		Basement (The Mozambique Belt)	Quartzites, crystalline limestones schists, gneisses including Kusae, Kasigau Series, Turoka and other formations.			
		Kavirondian	Arenaceous and argillaceous sediments. Conglomerates, hornblende andesites etc.			
		Nyanzian	Sandstones, conglomerates, quartzites, phyllites, limestones, pelites volcanics and ironstones.			

Source : Hydrogeology mainly from Groundwater Resources in Kenya WHO (1973)

Table - 3.3.1 Runoff Ratio of Perennial Rivers in Kenya

River Name	Catchment Area (sq.km)	Annual Rainfall (mm)	Annual Runoff (mm)	Runoff Ratio (%)
DRAINAGE AREA 1				
Sio	1,338	1,683	269	16.0
Nzoia	12,903	1,424	310	21.7
Yala	3,240	1,565	163	10.4
Nyando	3,356	1,298	222	17.1
Kibos	833	1,327	414	31.2
Awach Seme	717	1,191	373	31.4
Sondu	3,487	1,497	500	33.4
Gucha	6,824	1,444	266	18.5
Mara	8,608	1,037	217	20.9
DRAINAGE AREA 2				
Turkwel	19,906	532	22	4.1
Kerio	13,460	696	50	7.2
Lake Baringo	5,770	933	147	15.8
Lake Bogoria	1,220	747	121	16.2
Lake Nakuru	1,503	1,048	131	12.5
Lake Elementaita	551	789	133	16.9
Ewaso N'giro	8,652	832	47	5.7
DRAINAGE AREA 3				
Athi	37,836	733	17	2.3
Pemba	1,028	915	77	8.4
Mwachi	7,362	638	31	4.9
Rare	7,729	733	26	3.6
DRAINAGE AREA 4				
Tana	95,989	712	39	5.4
DRAINAGE AREA 5				
Ewaso N'giro (*)	12,107	707	28	3.9
Weighted Average	254,419	815	77	9.5

Note : (*) Archer's Post water level gauging station
Source: The Study on the National Water Master Plan, Sectoral Report (B), July 1992

Table - 3.3.2 (1/3) List of Stream Gauging Station with Dimensionless Flow Duration Curve

Code	River	Location		Type	Station		Rated	Catchment	Annual Mean
		Latitude	Longitude		Open	Closed		Area (km²)	Runoff (m³/s)
1AD02	MALAKISI	N 00°37'30" E	34°20'31"	S	02/40/46		Y	473	2.9
1AH01	SIO RIVER	N 00°23'15" E	34°08'30"	SA	01/99/14	31/12/67	Y	1450	11.5
1BA01	MOIBEN	N 00°48'15" E	35°26'35"	S	20/05/53		Y	262	1.1
1BB02	LOSURUA	N 00°57'15" E	35°14'15"	S	31/10/61		Y	140	1.4
1BB03	CHEPKOITET (TR OF KIBOYOAN	N 01°02'25" E	35°19'50"	S	15/09/76		Y	1940	0.9
1BC01	NOIGAMEGET	N 00°55'40" E	35°08'00	S	01/61/03		Y	681	5.4
1BD01	LITTLE NZOIA	N 00°49'10" E	35°07'30"	S	2/8/60		Y	254	0.9
1BD02	NZOIA	N 00°45'40" E	35°03'40"	S	2/26/46				14.9
1BE01	KWOITTOBOS	N 01°04'28" E	35°01'40"	SW	1/27/86	30/06/73	Y	715	3.2
1BE05	KWOITTOBOS	N 01°04'35" E	34°50'00"	SW	17/03/49		Y	78	1.0
1BG06	EWASO RONGAI	N 00°53'00" E	34°57'00"	S	2/4/86		N	531	3.4
1CA02	SERGOIT	N 00°38'00" E	35°04'00"	S	02/01/00		Y	717	2.8
1CB01	SOSIANI	N 00°30'05" E	35°17'40"	SW	1/4/82	31/08/63	Y	298	1.9
1CB03	ELLEGERINI	N 00°27'05" E	35°28'30"	SW	1/2/27	31/07/68	Y	52	0.5
1CB04	SOSIANI	N 00°33'00" E	35°10'35"	S	24/09/57	30/11/70	Y	421	1.9
1CB05	SOSIANI	N 00°37'35" E	35°05'25"	S	02/00/99		Y	697	3.6
1CB08	NUNDOROTO	N 00°26'45" E	35°22'00"	S	2/20/67		Y	167	1.5
1CB09	KIPWEN	N 00°27'25" E	35°23'00"	S	2/19/48		Y	80	0.8
1DB01	KUYWA	N 00°37'25" E	34°42'00"	S	2/15/89	31/01/72	Y	446	4.2
1EB02	ISUKHU RIVER	N 00°15'15" E	34°45'00"	S	17/03/63		Y	359	9.0
1ED01	LUSUMU	N 00°18'33" E	34°28'50"	S	20/01/51	30/09/68	Y	1207	20.8
1EF02	GAULA	N 00°10'50" E	34°10'15"	S	02/69/17		Y	81	0.4
1EG03	WAROYA RIVER	N 00°09'45" E	34°19'10"	S	02/55/78		Y	283	3.1
1FE02	YALA	N 00°11'00" E	34°56'10"	S	28/06/61		Y	1577	16.6
1FF01	EDZAWA	N 00°06'25" E	34°43'30"	S	01/91/55	31/12/62	Y	49	0.9
1FF02	ZAABA	N 00°03'30" E	34°37'40"	S	02/00/89		Y	47	0.6
1FG01	YALA	N 00°05'10" E	34°32'25"	SA	01/60/13		Y	2388	25.5
1FG02	YALA	N 00°02'35" E	34°15'55"	SA	02/00/35		Y	2864	33.7
1GB05	AINAMATUA	S 00°38'65" E	35°10'30"	S	01/68/37		N	606	2.8
1GC06	NYANDO	S 00°28'00" E	35°28'00"	S	02/32/26		Y	546	1.3
1GD02	NYANDO	S 00°29'90" E	35°09'25"	S	01/86/60	18/01/62	Y	1375	6.2
1GG02	NAMUTUNG	S 00°28'45" E	35°15'25"	S	01/95/71	30/11/61	Y	386	1.2
1HA04	KIBOS	S 00°60'30" E	35°48'15"	SW	00/91/32		Y	117	1.6
1HA14	AWACH	S 00°37'50" E	34°48'15"	S	2/8/56		Y	248	1.3
1HB05	AWACH	S 00°34'80" E	34°28'25"	S	15/01/65		Y	101	0.5
1HD01	AWACH	S 00°15'90" E	34°40'10"	S	27/04/50	30/04/73	Y	508	6.3
1HD02	AWACH	S 00°13'00" E	34°53'00"	S	2/2/81	30/06/71	Y	119	1.8
1HD03	AWACH	S 00°13'45" E	34°53'00"	S	2/26/54		Y	119	2.0
1JA02	KIPTIGET	S 00°06'95" E	35°15'25"	S	01/91/77		Y	179	3.5
1JC02	JANJI	S 00°12'55" E	35°10'45"	S	01/71/44	31/12/58	Y	330	5.7
1JC03	KIMUGU	S 00°18'00" E	35°17'30"	S	14/05/51	31/12/63	Y	146	1.1
1JC04	SOASA	S 00°14'75" E	35°17'45"	S	29/01/55	30/11/58	Y	112	0.6
1JC10	SOASA	S 00°14'75" E	35°18'20"	S	01/92/99	30/11/71	N	39	0.5
1JC14	LAGAN	S 00°15'90" E	35°20'00"	SAW	01/93/68		N	5	0.5
1JD01	LESSER AINABKOI	S 00°13'70" E	35°08'30"	S	01/89/32	2/11/35	Y	107	1.3
1JD03	YURITH	S 00°11'65" E	35°04'45"	SA	02/37/44		Y	3600	25.9
1JF02	KIPSONOI	S 00°01'55" E	35°07'20"	SW	01/89/70	31/08/63	Y	476	7.9
1JF06	KIPSONOI	S 00°02'30" E	35°13'15"	S	18/02/63		Y	394	7.3
1JG01	SONDU	S 00°16'65" E	35°00'30"	SA	23/03/46		Y	3287	36.4
1JG02	MIRIU	S 00°19'50" E	34°48'45"	S	01/84/76	15/02/73	Y	3450	65.8
1KA09	RIANA	S 00°02'50" E	34°31'00"	S	22/02/67		Y	398	6.3
1KB01	GUCHA	S 00°16'55" E	34°16'20"	S	22/05/50	31/05/64	Y	3103	24.3
1KB01A	GUCHA	S 00°17'15" E	34°16'30"	SA	2/19/51		Y	3115	27.0
1KB03	GUCHA	S 00°08'30" E	34°34'15"	S	2/24/94		Y	1114	14.9
1KB04	GUCHA	S 00°05'30" E	34°48'45"	S	01/91/53	30/06/62	N	371	3.6
1KB05	GUCHA	S 00°16'50" E	34°12'25"	SA	02/37/44		N	6600	47.2
1KB07	GUCHA	S 00°02'30" E	34°49'15"	S	2/4/28	30/06/75	Y	342	6.6
1KC03	MIGORI	S 00°16'50" E	34°28'15"	S	16/01/51		Y	3046	17.1
1LA01	NYANGORIS	S 00°04'20" E	35°21'30"	S	14/01/51	22/02/64	Y	635	10.0
1LA03	NYANGORIS	S 00°07'10" E	35°20'50"	S	23/10/63		Y	679	9.8
1LB02	AMALA	S 00°13'50" E	35°26'15"	S	21/09/55		Y	697	5.6
2B 01	KAPTEGA	N 01°13'15" E	34°45'30"	W	14/06/49		Y	13510	1.0
2B 07	SUAM (SWAM)	N 01°28'55" E	35°00'30"	SA	25/01/55		Y	1350	8.4
2B 08	WEI WEI	N 01°23'35" E	35°27'55"	S	25/01/55		Y	190	3.3
2B 09	MORUN	N 01°32'05" E	35°28'20"	S	26/03/55	29/03/80	N	1343	5.9
2B 15	WEI WEI	N 01°25'15" E	35°28'05"	S					3.9
2B 27	TURKELL	N 01°55'45" E	35°22'30"	SA	02/70/34		Y	5924	24.6
2B 30	MALMALTE	N 01°50'20" E	35°28'20"	S	02/84/94		N	2974	8.2
2C 05	ARROR	N 01°00'06" E	35°29'54"	S	16/02/61		Y	185	2.1
2C 07	NDOO	N 00°27'03" E	35°38'48"	SA	2/15/28		Y	893	15.9
2C 12	EMBOBUT	N 01°14'00" E	35°40'00"	S	02/55/78		N	133	5.0
2D 01	SUGUTA	N 01°10'55" E	36°06'20"	S	24/09/68		Y	3497	15.7

Table - 3.3.2 (2/3) List of Stream Gauging Station with Dimensionless Flow Duration Curve

Code	River	Location		Type	Station		Rated	Catchment Area (km²)	Annual Mean Runoff (m³/s)
		Latitude	Longitude		Open	Closed			
2EE07	PEKEKERA	N 00°27'27" E	35°57'57"	S	2/14/95		Y		4.6
2EE08	PEKEKERA	N 00°09'54" E	35°49'10"	S	18/10/63		Y	500	2.4
2FC05	NJORO	S 00°17'80" E	35°55'30"	SW	01/35/25	31/12/55	Y	125	1.0
2GB01	MELAWA	S 00°06'80" E	36°24'10"	SWA	23/06/31		Y	1428	4.1
2GC04	TURASHA	S 00°11'55" E	36°25'00"	SWA	01/61/70	31/12/67	Y	695	3.2
2GC07	TURASHA	S 00°01'60" E	36°38'12"	SW	01/69/30		Y	18	0.2
2K 01	GUASO	S 00°10'98" E	35°45'28"	S	14/03/59		Y	688	3.7
2K 03	NAROK	S 00°15'50" E	35°51'40"	S	19/03/59		Y	869	4.4
2K 06	SEBEYAI	S 00°14'75" E	35°57'07"	S	24/07/62		Y	581	2.4
3AA04	MBAGATHI	S 00°03'00" E	36°37'40"	WA	17/07/63		Y	272	1.1
3BA29	NAIROBI	S 00°03'73" E	36°48'37"	SA	17/04/53		Y	75	0.3
3BA32	NAIROBI	S 00°08'60" E	37°07'10"	SA	01/90/90		Y		14.6
3BD05	THERERIKA	S 00°10'84" E	37°02'28"	WA					1.6
3CB05	NDARUGU	S 00°12'50" E	37°09'40"	S					4.8
3DA02	ATHI	S 00°14'70" E	37°11'40"	SA			Y	5724	23.2
3F 02	ATHI	S 00°27'25" E	37°50'45"	S			N	4521	31.0
3G 02	TSAVO	S 00°59'45" E	38°28'28"	S	01/66/52		Y	7252	6.1
3G 03	MZIMA	S 00°20'50" E	38°01'40"	S	01/71/68		Y	306	3.3
3HA12	ATHI	S 00°22'50" E	38°41'00"	AS	26/11/80		Y	25203	35.7
3KC04	MWACHEMA	S 00°55'00" E	39°32'00"	S	19/09/75		Y	145	1.0
3KG01	UMBA	S 00°74'10" E	39°06'40"	S	01/64/46		Y	2388	5.7
3LA05	VOI	S 00°43'35" E	38°35'35"	S	02/40/23			496	4.5
3MA03	MWACHI	S 00°77'00" E	39°39'30"	S	17/09/71		Y	8619	6.0
4AA01	SAGANA RIVER	S 00°18'00" E	37°04'00"	ASW	01/57/14		Y	96	1.0
4AA07	SAGANA RIVER	S 00°21'70" E	37°09'00"	SW	01/68/08		Y		1.1
4AB05	AMBONI RIVER	S 00°19'00" E	36°59'20"	SW	01/64/38		Y	420	1.8
4AC03	SAGANA RIVER	S 00°13'43" E	37°02'35"	S	01/60/74			1440	11.2
4AC04	CHANIA RIVER	S 00°14'85" E	36°57'30"	S	01/71/69			210	4.8
4AD01	GURA	S 00°08'98" E	37°04'35"	S				430	12.7
4AD03	THUTI	S 00°07'00" E	36°54'30"	S				37	1.4
4BB01	RAGATI RIVER	S 00°01'88" E	37°11'35"	S	26/10/48	31/12/60	Y	254	3.8
4BC02	TANA	S 00°00'20" E	37°12'25"	SA	17/01/48		Y	2365	29.5
4BC04	RWAMUTHAMBI	S 00°00'20" E	37°14'30"	S	19/11/73		N	158	2.0
4BC05	RWAMUTHAMBI	S 00°04'93" E	37°14'30"	S	10/3/72		N	86	1.6
4BC06	KANDERE STREAM	S 00°14'55" E	37°13'15"	S	14/08/81		N	6	3.1
4BE02	TANA	S 00°07'15" E	37°16'05"	S	01/71/77	02/81/31	N	3672	84.3
4BE09	MARAGUA RIVER	S 00°01'45" E	36°50'30"	S				43	3.3
4BF01	THABATHABA	S 00°11'50" E	37°15'52"	S				252	22.0
4CA02	CHANIA RIVER	S 00°38'68" E	37°03'47"	SWA				518	9.3
4CA03	CHANIA RIVER	S 00°10'45" E	36°47'30"	S				73	6.4
4CA16	KIMAKIA	S 00°06'55" E	36°44'50"	S				28	1.3
4CB04	THIKA RIVER	S 00°18'85" E	37°03'57"	WA	01/49/80			316	6.3
4CC03	YATTA FURROW	S 00°14'60" E	37°21'40"	S				1321	0.7
4CC03A	YATTA FURROW	S 00°14'60" E	37°21'40"	S					96.6
4CC05	THIKA RIVER	S 00°18'49" E	37°27'21"	A				1700	92.4
4CC06	YATTA FURROW	S 00°11'00" E	37°34'35"	S					0.1
4DA02	THIBA RIVER	S 00°15'50" E	37°18'35"	W	21/03/61	17/02/82		32	1.7
4DA07	THIBA RIVER	S 00°03'55" E	37°28'37"	S	2/4/69	23/04/70		658	9.4
4DA10	THIBA RIVER	S 00°02'85" E	37°19'00"	SA	1/10/73			358	10.4
4DA11	THIBA RIVER	S 00°07'85" E	37°20'05"	S	22/09/78			180	7.3
4DA13	KIRINGA	S 00°09'98" E	37°15'05"	S	23/09/78				2.7
4DB01	NYAMINDI	S 00°06'75" E	37°23'00"	S				215	10.5
4DC02	RUPINGAZI RIVER	S 00°03'30" E	37°29'40"	S	2/11/73			347	11.7
4DC03	RUPINGAZI RIVER	S 00°08'00" E	37°26'15"	SA				197	2.6
4DD01	THIBA RIVER	S 00°09'15" E	37°38'30"	S				2616	25.0
4DD02	THIBA RIVER	S 00°03'54" E	37°30'22"	SA				1500	50.5
4EA03	KITHENU	S 00°33'94" E	37°40'50"	S	01/75/40			44	2.8
4EB01	NITHI	S 00°22'85" E	37°38'45"	S				120	4.0
4EB04	THUCHI	S 00°16'70" E	37°35'55"	S				111	3.6
4EB06A	RUGUTI	S 00°18'96" E	37°51'30"	S				368	5.1
4F 01	TANA	N 00°16'00" E	38°01'00"	S					135.7
4F 02	KAZITA RIVER	N 00°16'00" E	38°01'00"	S					14.5
4F 03	KAZITA RIVER	N 00°02'36" E	37°38'30"	SW					2.2
4F 04	THINGISHU	N 00°03'30" E	37°39'35"	S					2.1
4F 05	MARIARA	N 01°02'30" E	37°39'30"	S					1.3
4F 10	KAZITA RIVER	S 00°34'55" E	37°58'40"	S					11.1
4F 13	TANA GRAND FALLS	S 01°22'95" E	38°01'05"	SA					233.8
4F 19	KAZITA RIVER	S 00°25'80" E	38°00'20"	SA					31.5
4F 29	KAZITA RIVER	S 00°60'38" E	37°02'47"	S					8.0
4F 31	KAZITA RIVER	N 00°01'33" E	37°35'14"	S					1.7
4G 01	TANA	S 00°13'00" E	39°42'00"	SA	01/06/02		Y	32692	151.0
4G 02	TANA	S 00°16'30" E	40°07'00"	S					127.8

Table - 3.3.2 (3/3) List of Stream Gauging Station with Dimensionless Flow Duration Curve

Code	River	Location		Type	Station		Rated	Catchment	Annual Mean
		Latitude	Longitude		Open	Closed		Area (km²)	Runoff (m³/s)
4G 04	TANA	S 00°10'00" E	40°02'00"	S					129.4
4G 08	TANA	S 00°11'23" E	39°51'15"	S					176.6
5AA01	UASO NAROK (UASO NARO)	N 00°02'20" E	36°22'30"	SWA	15/01/45			577	5.0
5AA02	EQUATOR	N 00°01'26" E	36°22'09"	SW	01/68/05		Y	251	15.1
5AA04		N 00°01'21" E	36°21'00"	S	02/00/69		N	60	0.2
5AA05		N 00°01'12" E	36°21'48"	S	02/00/69		Y	157	41.2
5AB01		N 00°08'06" E	36°36'19"	SW	23/02/45	01/97/32	Y	380	0.3
5AB02		N 00°12'01" E	36°31'00"	S	18/11/58		Y	412	0.7
5AB03		N 00°05'43" E	36°34'53"	S	02/00/68			319	1.7
5AB04	PESI EAST	N 00°03'47" E	36°31'37"	S	02/00/68		Y	135	6.1
5AC03	UASO NAROK (UASO NARO)	N 00°16'00" E	36°32'48"	SW	01/51/57		Y	878	0.4
5AC04		N 00°22'39" E	36°38'50"	SW	01/49/78		Y	2403	0.3
5AC06	UASO NAROK (UASO NARO)	N 00°16'42" E	36°35'28"	SW	01/52/51		Y	448	0.2
5AC08	UASO NAROK (UASO NARO)	N 00°30'30" E	36°51'45"	SWA	01/71/70		Y	3290	3.7
5AC10	UASO NAROK (UASO NARO)	N 00°26'15" E	36°43'26"	S	29/10/58		N	2590	2.8
5AC11		N 00°15'29" E	36°32'23"	S	18/11/58		Y	868	2.1
5BB02	UASO NYIRO (UASO NGIRO)	N 00°08'00" E	36°52'00"	SW	01/57/17		Y	405	1.1
5BC04	UASO NYIRO (UASO NGIRO)	N 00°05'23" E	36°54'18"	SA	22/05/44		Y	1870	69.4
5BC06	BUGARET	N 00°06'34" E	37°02'15"	SW	01/60/71		Y	98	0.8
5BC08	NGOBIT	N 00°03'00" E	36°47'00"	SWA	01/57/75		Y	256	0.8
5BE01	NANYUKI	N 00°01'15" E	37°04'38"	SW	00/95/03		Y	68	0.6
5BE04		N 00°03'40" E	37°12'00"	SWA	00/98/68		Y	62	0.4
5BE05	TELESWAN	N 00°04'57" E	37°13'49"	SW	01/47/92		Y	36	0.2
5BE06	TIMAU	N 00°05'18" E	37°14'30"	SW	13/12/43		Y	64	0.1
5BE07	LIKI	N 00°01'15" E	37°05'13"	S	01/46/10		Y	176	1.4
5BE20	NANYUKI	N 00°08'50" E	37°01'47"	SA	2/2/81		Y	860	19.0
5D 05	EAST UASO NYIRO	N 00°31'45" E	36°52'00"	SA	21/08/49		Y	4561	8.7
5E 03	UASO NYIRO (UASO NGIRO)	N 00°38'30" E	37°40'40"	SWA	01/67/12		Y	15300	21.6
5E 03	UASO NYIRO (UASO NGIRO)	N 00°38'30" E	37°40'40"	SWA	01/67/12		Y	15300	21.6

Table - 3.5.1 (1/8) Water Quality of Major Rivers

Nzoia River

Parameter	Unit	Upper zone (Kipkareen)	Middle zone (Siranga))	Lower zone (L.Victoria)
pH	---	7.4	7.0	7.7
Colour	mg Pt/l	50	150	30
Turbidity	NTU	12	65	10
Oxygen absorbed	mg/l	28.0	30.0	23.0
Conductivity	uS/cm	125	83	162
Iron	mg/l	---	---	2.5
Manganese	mg/l	0.20	0.10	0.03
Calcium	mg/l	9.4	3.7	12.0
Magnesium	mg/l	4.4	1.8	4.2
Sodium	mg/l	---	---	---
Potassium	mg/l	---	---	---
Total hardness	mg/l CaCO3	37	27	48
Total alkalinity	mg/l CaCO3	56	36	77
Chloride	mg/l	4.0	3.0	12.0
Fluoride	mg/l	0.20	0.17	0.15
Sulphate	mg/l	---	---	2.2
Orthophosphate	mg/l	0.02	0.03	0.03
TDS	mg/l	73	48	97

Source: Ministry of Water Development
Values given are mean values (1983 - 1984)

Sondu River

Parameter	Unit	Upper zone	Middle zone
pH	---	7.0	7.1
Colour	mg Pt/l	20	10
Turbidity	NTU	8	7
Oxygen absorbed	mg/l	15	12
Conductivity	uS/cm	58	69
Iron	mg/l	0.9	1.2
Manganese	mg/l	0.01	0.01
Calcium	mg/l	3.2	4.0
Magnesium	mg/l	1.0	1.3
Sodium	mg/l	---	---
Potassium	mg/l	---	---
Total hardness	mg/l CaCO3	12	15
Total alkalinity	mg/l CaCO3	21	32
Chloride	mg/l	6.3	7.0
Fluoride	mg/l	0.58	0.45
Sulphate	mg/l	0.8	6.0
Orthophosphate	mg/l	0.03	0.02
TDS	mg/l	35	42

Source: Ministry of Water Development
Values given are mean values (1983 - 1984)

Table - 3.5.1 (2/8) Water Quality of Major Rivers

Nyando River

		Upper zone		Middle zone		Lower zone	
Parameter	Units	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
pH	–	8.7	7.1	8.3	6.6	8.6	7.1
Turbidity	NTU	900	5	320	53	2700	10
Colour	mg Pt/l	1000	5	660	15	1000	5
Conductivity	uS/cm	3900	100	1180	140	315	140
Iron	mg/l	6.0	0.1	16.0	0.1	8.0	0.1
Manganese	mg/l	11.0	0.0	5.0	0.2	1.1	0.1
Calcium	mg/l	32.0	6.8	35.0	7.6	36.8	12.6
Magnesium	mg/l	18.0	3.0	50.0	4.0	49.0	3.0
Sodium	mg/l	25.0	16.0	30.0	15.0	27.0	11.8
Total Hardness	mg/l	436	38	242	20	234	4
Tot. alkalinity	mg/l	202	26	164	30	136	66
Chloride	mg/l	60.0	2.0	12.0	1.0	25.0	3.0
Fluoride	mg/l	0.0	4.0	1.5	0.3	0.0	1.0
Nitrate	mg/l	2.7	0.1	2.8	0.1	1.7	0.0
Sulphate	mg/l	119.0	0.3	18.7	0.2	24.0	1.3
Phosphate	mg/l	0.7	0.2	2.0	0.1	0.4	0.1
TDS	mg/l	280	145	270	19	320	84

Source: MOWD data; various dates from 1974-1988.

Parameter	Unit	Upper zone	Middle zone	Lower zone
pH	---	7.8	7.8	7.7
Colour	mg Pt/l	360	45	25
Turbidity	NTU	46	25	15
Oxygen absorbed	mg/l	40	27	18
Conductivity	uS/cm	297	215	255
Iron	mg/l	0.87	2.10	2.10
Manganese	mg/l	0.02	0.10	0.02
Total hardness	mg/l CaCO3	103	178	88
Total alkalinity	mg/l CaCO3	132	93	114
Chloride	mg/l	6.4	5.3	7.9
Fluoride	mg/l	0.46	0.32	0.52
Sulphate	mg/l	3.0	2.3	0.9
Orthophosphate	mg/l	0.56	0.13	0.14
TDS	mg/l	172	129	120

Source: Ministry of Water Development, NES 1987.
Values given are mean values (1983 - 1984)

Table - 3.5.1 (3/8) Water Quality of Major Rivers

Arror River

Parameter	Units	Mean	Max	Min
pH	--	7.4	7.9	6.9
Colour	mg Pt/l	17.5	70.0	5.0
Turbidity	NTU	14.2	29.0	1.5
Conductivity	uS/cm	238	420	132
Iron	mg/l	2.1	8.5	0.2
Manganese	mg/l	0.2	0.4	0.1
Calcium	mg/l	17.6	38.0	6.6
Magnesium	mg/l	6.6	11.0	0.4
Sodium	mg/l	8.7	17.0	4.0
Total Hardness	mg/l	79.5	158.0	2.4
Tot. alkalinity	mg/l	88.3	150.0	52.0
Chloride	mg/l	10.8	80.0	2.0
Fluoride	mg/l	0.4	4.0	0.1
Sulphate	mg/l	1.9	6.5	0.1
Phosphate	mg/l	0.02	0.10	0.01
TDS	mg/l	142	252	79

Source: Feasibility Study on the Integrated Development of the Arror River Basin (1990)

Kerio River

Parameter	Unit	Upper zone	Middle zone
pH	---	7.6	8.0
Colour	mg Pt/l	---	---
Turbidity	NTU	104	76
Oxygen absorbed	mg/l	27	28
Conductivity	uS/cm	145	230
Iron	mg/l	---	---
Manganese	mg/l	---	0.06
Calcium	mg/l	13.0	23.0
Magnesium	mg/l	15.0	5.9
Sodium	mg/l	---	---
Potassium	mg/l	---	---
Total hardness	mg/l CaCO3	81	86
Total alkalinity	mg/l CaCO3	114	102
Chloride	mg/l	3.0	6.0
Fluoride	mg/l	0.50	0.50
Sulphate	mg/l	2.5	---
Orthophosphate	mg/l	0.13	0.23
TDS	mg/l	100	120

Source: Ministry of Water Development
Values given are mean values (1983 - 1984)

Table - 3.5.1 (4/8) Water Quality of Major Rivers

Yala River

Parameter	Unit	DAMSITE MEAN	DAMSITE MAX	DAMSITE MIN	KIMONDI MEAN	KIMONDI MAX	KIMONDI MIN	MOKONG MEAN	MOKONG MAX	MOKONG MIN
Temperature	oC	18.7	20.1	17.2	18.0	20.0	17.5	18.4	20.1	16.5
Conductivity	uS/cm	107	130	90	79	99	55	144	160	130
pH	--	7.8	8.8	7.0	7.4	8.3	6.8	7.4	8.5	6.7
Colour	mg Pt/l	79	110	40	40	78	10	59	112	10
Turbidity	NTU	49	88	22	17	24	12	54	90	28
Dissolved oxygen	mg/l	8.9	10.8	7.3	8.3	9.9	7.1	7.6	8.9	7.1
DO % saturation	%	119	140	100	113	130	96	102	115	96
Carbon dioxide	mg/l	2.8	2.9	ND	3.5	4.0	ND	6.9	9.0	4.5
Alkalinity-total	mg/l	47.3	52.0	35.0	38.1	52.0	21.0	72.3	89.0	66.0
Harness-total	mg/l	41.4	58.0	34.0	24.2	34.0	14.3	57.5	103.6	36.0
Chloride	mg/l	3.4	7.2	<1.0	3.3	8.3	ND	3.4	7.7	1.0
Fluoride	mg/l	0.34	0.62	ND	0.27	0.53	ND	0.43	0.67	0.15
Manganese	mg/l	0.047	0.090	0.020	0.055	0.120	0.020	0.064	0.135	0.030
Iron	mg/l	1.430	2.500	0.700	1.320	2.200	0.680	1.020	2.360	0.560
Ammonia-N	mg/l	0.096	0.280	0.001	0.099	0.220	ND	0.108	0.230	0.022
T.S.S.	mg/l	41.0	76.0	11.0	13.3	31.2	6.1	62.8	149.0	14.2

Source: Ministry of Water Development.
Data : 1985-1986

Turkwell River

		Upper zone	Middle zone	Lower zone
pH	---	7.4	7.7	7.7
Colour	mg Pt/l	13	250	500
Turbidity	NTU	4	22	600
Oxygen absorbed	mg/l	4.0	5.5	0.4
Conductivity	uS/cm	78	100	208
Iron	mg/l	0.4	0.9	0.0
Manganese	mg/l	0.10	0.06	0.01
Calcium	mg/l	9.4	14.5	23.0
Magnesium	mg/l	4.4	4.3	0.5
Sodium	mg/l	4.8	5.4	7.5
Potassium	mg/l	2.4	2.7	3.5
Total hardness	mg/l CaCO3	42	53	60
Total alkalinity	mg/l CaCO3	53	76	96
Chloride	mg/l	1.0	1.0	2.0
Fluoride	mg/l	0.21	0.19	2.00
Sulphate	mg/l	4.1	1.0	2.5
Orthophosphate	mg/l	0.53	0.63	0.05
Nitrate	mg/l	0.67	0.75	0.44
TDS	mg/l	40	68	120

Source: Ministry of Water Development
Values given are mean values (1983 - 1984)

Table - 3.5.1 (5/8) Water Quality of Major Rivers

Malewa River

Parameter	Units	R.Malewa tributaries above dam: River Kimuru	R.Malewa tributaries above dam: River Olkalou	River Malewa: 15 km above damsite	River Malewa: Malewa damsite	River Malewa: 13 km below damsite	River Malewa: 28 km below damsite
Temperature	oC	14.3	18.0	16.5	15.7	17.0	18.5
pH	-	8.01	7.78	7.95	8.24	8.09	8.08
Colour	mg Pt/l	16	16	16	17	18	18
Turbidity	NTU	14	40	24	25	70	28
Suspended solids	mg/l	13	39	35	25	27	35
Conductivity	uS/cm	110	160	130	130	240	200
Dissolved oxygen	mg/l	8.4	6.8	6.8	7.4	7.2	7.2
COD	mg/l	8	15	4	8	7	10
Total nitrogen	mg/l	2.260	3.391	3.166	2.700	-	3.577
Kjeldhal-N	mg/l	1.05	2.25	2.25	2.70	-	2.55
Ammonia-N	mg/l	-	-	-	-	-	-
Nitrate-N	mg/l	1.20	1.10	0.90	<0.01	0.90	1.00
Nitrite-N	mg/l	0.010	0.041	0.016	<0.001	0.018	0.027
Phosphate-P	mg/l	0.13	0.09	0.04	0.12	0.09	0.10

ND = not detectable
Source: JICA 1990.

Malewa River at Damsite

Parameter	Units	June 15	July 5	July 11	July 17	July 25	MEAN
Temperature	oC	15.7	-	-	-	-	15.7
pH	-	8.24	-	8.27	7.88	8.08	8.08
Colour	mg Pt/l	17	16	-	19	19	18
Turbidity	NTU	25	-	-	-	-	25
Conductivity	uS/cm	130	104	65	71	74	89
Dissolved oxygen	mg/l	7.4	-	-	-	-	7.4
COD	mg/l	8	16	18	65	13	24
Total nitrogen	mg/l	2.700	-	-	-	-	2.7
Kjeldhal-N	mg/l	2.70	-	-	-	-	2.7
Ammonia-N	mg/l	-	0.04	0.05	0.26	0.06	0.10
Nitrate-N	mg/l	<0.01	1.00	0.60	2.00	0.50	0.84
Nitrite-N	mg/l	<0.001	0.017	0.026	0.154	0.005	0.041
Total phosphorus	mg/l	-	0.49	ND	1.54	0.63	0.89
Phosphate-P	mg/l	0.12	0.12	0.21	0.16	0.17	0.16
Suspended solids	mg/l	25	23	36	323	62	94

ND = not detectable
Source: JICA 1990.

Table - 3.5.1 (6/8) Water Quality of Major Rivers

Tana River

Parameter	Unit	Upper zone (Masinga dam)	Middle zone (Garsen)	Lower zone (Coast)
pH	---	7.1	8.0	7.7
Colour	mg Pt/l	55	---	---
Turbidity	NTU	28	---	80
Oxygen absorbed	mg/l	25	0	42
Conductivity	uS/cm	77	170	151
Iron	mg/l	2.2	---	---
Manganese	mg/l	0.13	---	0.07
Calcium	mg/l	5.0	20.0	18.0
Magnesium	mg/l	2.5	9.6	10.0
Sodium	mg/l	7.0	---	---
Potassium	mg/l	---	15.0	---
Total hardness	mg/l CaCO3	33.0	90.0	87.0
Total alkalinity	mg/l CaCO3	20.0	216.0	90
Chloride	mg/l	6.6	14.0	6.9
Fluoride	mg/l	0.25	0.25	0.50
Sulphate	mg/l	5.8	5.0	---
Orthophosphate	mg/l	0.04	---	0.07
TDS	mg/l	44	285	91

Source: Ministry of Water Development
Values given are mean values (1983 - 1984)

Tana River, Tributaries

Parameter	Unit	River Mutonga (4EA6)	Mutonga River (4EA7)	Thanantu River (4F20)	Kazita River (4F18)	Kithenu River	Thingithu River at Mitungu	Thanantu River at Mukothima
pH	---	6.9	6.7	7.8	7.5	8.2	7.7	7.9
Colour	mg Pt/l	brown	brown	brownish	brownish	<5	10	<5
Turbidity	NTU	25	140	50	45	0	10	<5
Conductivity	uS/cm	95	82	180	150	100	100	240
Iron	mg/l	2.6	2.0	1.6	2.0	0.8	0.3	trace
Manganese	mg/l	0.10	0.10	0.20	0.3	0.0	0.0	0.0
Calcium	mg/l	2.2	2.2	11.0	14.0	10.0	6.4	2.4
Ammonia-N	mg/l	0.01	0.00	0.80	0.00	0.00	0.04	0.00
Nitrate-N	mg/l	<0.01	trace	0.0	<0.01	0.0	0.0	0.0
Nitrite-N	mg/l	<0.01	trace	0.0	<0.01	0.0	---	0.0
Total hardness	mg/l CaCO3	40	19	35	46	28	20	112
Total alkalinity	mg/l CaCO3	34	28	80	65	50	44	156
Chloride	mg/l	5.0	6.0	7.0	6.0	30.0	15.0	2.0
Fluoride	mg/l	0.25	0.25	0.50	0.35	0.00	0.20	0.40
Sulphate	mg/l	<0.3	<0.3	51.0	4.0	0.0	4.0	0.0
Total phosphorus	mg/l	0.01	<0.03	0.05	0.05	---	---	---
TDS	mg/l	57	49	108	90	70	80	170
Suspended solids	mg/l	20	512	30	510	---	---	---

Source: MOWD/SIDA; Greater Tharaka Water & Sanitation Project, June 1990.
Data: 1990

Table - 3.5.1 (7/8) Water Quality of Major Rivers

Athi River

Parameter	Unit	Upper zone (14 Falls)	Middle zone (Kibwezi)	Lower zone (Coast)
pH	---	6.8	7.8	8.0
Colour	mg Pt/l	70	---	90
Turbidity	NTU	20	90	65
Oxygen absorbed	mg/l	35	47	42
Conductivity	uS/cm	245	305	594
Iron	mg/l	2.0	---	---
Manganese	mg/l	0.60	---	---
Calcium	mg/l	8.2	16.0	26.0
Magnesium	mg/l	3.5	8.5	19.0
Sodium	mg/l	58.0	---	---
Potassium	mg/l	9.0	---	---
Total hardness	mg/l CaCO3	45	76	161
Total alkalinity	mg/l CaCO3	64	123	193
Chloride	mg/l	22.0	14.0	63.0
Fluoride	mg/l	0.72	0.53	1.10
Sulphate	mg/l	7.3	6.8	42.0
Orthophosphate	mg/l	0.36	0.23	0.06
TDS	mg/l	147	183	371

Source: Ministry of Water Development
Values given are mean values (1983 - 1984)

Tsavo River and Mzima Springs

Parameter	Unit	Tsavo River Upper	Tsavo River Middle	Tsavo River Lower	Mzima Springs Upper	Mzima Springs Lower
pH	--	8.7	8.8	8.2	8.6	8.4
Turbidity	NTU	250	64	2000	0.5	1.6
PV (*)	mg/l	235	391	94	Nil	Nil
Conductivity	uS/cm	820	610	600	600	550
Manganese	mg/l	0.6	0.6	1.6	0.1	0.1
Total hardness	mg/l	174	162	360	105	100
Total alkalinity	mg/l	281	238	259	202	216
Chloride	mg/l	95.9	32.0	22.5	8.5	12.9

(*) = permanganate value
Source: Ref:C36.
Data : April 1980

Table - 3.5.1 (8/8) Water Quality of Major Rivers

Ewaso N'giro (North) River

Parameter	Unit	Upper zone	Middle zone
pH	---	7.5	8.0
Colour	mg Pt/l	245	40
Turbidity	NTU	30	28
Oxygen absorbed	mg/l	24	53
Conductivity	uS/cm	198	313
Iron	mg/l	---	2.2
Manganese	mg/l	---	0.20
Calcium	mg/l	13.0	21.0
Magnesium	mg/l	8.8	13.0
Sodium	mg/l	---	---
Potassium	mg/l	---	---
Total hardness	mg/l CaCO3	67	96
Total alkalinity	mg/l CaCO3	79	57
Chloride	mg/l	9.0	14.0
Fluoride	mg/l	0.30	0.40
Sulphate	mg/l	1.7	1.2
Orthophosphate	mg/l	0.08	0.27
TDS	mg/l	119	188

Source: Ministry of Water Development
Values given are mean values (1983 - 1984)

Table - 3.5.2 (1/2) Water Quality of Lakes

Saline Lakes

Parameter	Unit	Lake Elmenteita	Lake Nakuru	Lake Magadi	Lake Bogoria
pH	---	10.2	9.5	9.7	9.7
Turbidity	NTU	6	21	--	253
Oxygen absorbed	mg/l	172	197	200	115
Conductivity	uS/cm	21,000	9,158	58,500	41,380
Iron	mg/l	--	1.2	--	0.6
Manganese	mg/l	--	0.7	--	0.2
Calcium	mg/l	1.5	5.7	13.0	1.1
Magnesium	mg/l	2.0	2.4	16.0	0.3
Sodium	mg/l	--	--	--	15,400
Total hardness	mg/l CaCO3	4	16	88	130
Total alkalinity	mg/l CaCO3	7,384	5,747	23,500	38,920
Chloride	mg/l	2,432	1,049	6,325	2,818
Fluoride	mg/l	598	167	112	899
Sulphate	mg/l	369	55	140	142
Orthophosphate	mg/l	--	0.30	--	--
TDS	mg/l	12,900	5,494	32,100	24,830

Note: closed basin saline lakes fluctuate substantially in water level and chemical concentration; the data shown here are mean values.

Source: Ministry of Water Development; NES 1987.

Data : 1983-1984

Table - 3.5.2 (2/2) Water Quality of Lakes

Freshwater Lakes

Parameter	Unit	Lake Naivasha	Lake Victoria	Lake Baringo	Lake Turkana
pH	---	8.3	8.0	8.6	9.3
Turbidity	NTU	25	4	70	21
Oxygen absorbed	mg/l	38	20	21	35
Conductivity	uS/cm	429	140	838	2730
Iron	mg/l	16.0	--	10.0	--
Manganese	mg/l	0.60	--	0.15	--
Calcium	mg/l	16.0	5.7	8.1	4.3
Magnesium	mg/l	8.4	5.5	4.5	2.6
Sodium	mg/l	32.7	--	--	189.3
Total hardness	mg/l CaCO3	96	37	50	22
Total alkalinity	mg/l CaCO3	125	53	360	914
Chloride	mg/l	20.0	9.3	48.0	400.0
Fluoride	mg/l	1.80	0.35	55.00	8.80
Sulphate	mg/l	1.3	2.6	7.1	28.0
Orthophosphate	mg/l	0.88	0.01	0.35	1.30
TDS	mg/l	259	86	510	2138

Source: Ministry of Water Development
Values given are mean values.
* Lake Turkana is virtually semi-saline;brackish and undrinkable.
Herein included in this table in view of low salinity compared with the lakes listed in Table 3.7.13.

Lake Victoria, Kisumu Bay

Parameter	Unit	Study mean	SD as % of mean	WHO guide-line value
Temperature	oC	26.2	3.1	ngs
Conductivity	uS/cm	160	21	ngs
pH	---	7.9	2.5	6.5-8.5
Secchi depth	cm	50	20	ngs
Turbidity	NTU	15	40	5
Dissolved oxygen	mg/l	6	14	ngs
DO % saturation	%	89.5	14.7	ngs
Total hardness	mg/l CaCO3	24	26	500
Total alkalinity	mg/l CaCO3	71	16	ngs
Chloride	mg/l	7.5	42.7	250
Chlorophyll a	um/l	16.7	33.5	ngs
Phytoplankton	no/ml	1238	36	ngs
Zoolplankton	no/l	822	84	ngs

ngs = no guideline set
Source: Ministry of Water Development.
Data : 1985-1986

Table - 3.6.1 Rating Equation of Suspended Load and Its Volume

No.	Code	River Name	Catchment Area (sq. km)	Annual Mean Discharge (cms)	Rating Equation		Suspended Load	
					a	b	Mean (ppm)	Annual (ton/year)
1	1DA02	Nzoia	8,417	56.6	18.531	0.446	112	212,298
2	1ED01	Lusumu	1,207	27.9	22.686	0.552	142	128,239
3	1GB05	Ainamotua	606	5.2	44.653	0.675	136	28,954
4	1GB07	Kapchure	129	1.1	68.831	0.328	71	2,555
5	1GD01	Nyando	2,598	17.6	136.508	0.623	815	566,362
6	1HA10	Luando	234	3.0	227.405	0.255	301	26,561
7	1JG01	Sondu	3,287	50.0	13.314	0.409	66	107,160
8	2ED02	Leigel	108	0.5	79.223	1.115	37	799
9	2EE04	Perkerra	1,334	2.8	1197.201	1.010	3,387	390,033
10	2GB01	Malewa	1,430	3.3	19.302	0.736	46	5,637
11	3AA04	Mbagathi	272	1.6	139.713	0.685	193	4,456
12	3BA09	Karyra	44	0.8	368.177	0.737	312	9,124
13	3BA10	Ruaraka	65	1.1	31.142	0.225	32	989
14	3BA22	Nairobi	75	1.3	51.216	0.392	57	2,231
15	3BB10	Riara	41	0.4	144.554	0.219	118	1,474
16	3CB05	Ndarugu	312	4.4	95.369	0.505	202	29,356
17	3DA02	Athi	5,724	23.6	8.220	0.924	153	131,089
18	3F 02	Athi	10,272	33.6	39.338	0.750	549	753,627
19	3HA12	Athi (L. Falls)	25,203	33.2	48.079	0.823	859	2,057,487
20	3J 06	Lumi	451	1.2	210.044	1.663	284	9,020
21	4AA01	Sagana	96	1.1	40.572	0.739	44	1,659
22	4AA05	Sagana	505	5.6	31.183	0.676	100	18,845
23	4AC03	Sagana	282	4.1	21.177	0.763	62	8,405
24	4BC02	Tana-Sagana	2,365	21.0	2.084	1.924	729	999,721
25	4BD01	Mathioya	500	6.6	1.833	1.875	63	20,107
26	4BE01	Maragua	414	11.3	13.671	1.128	211	70,797
27	4CA02	Chania	518	8.2	8.591	0.967	66	22,132
28	4CB04	Thika	316	6.9	23.957	1.020	172	53,063
29	4DD01	Thiba	2,616	33.4	5.181	0.736	69	75,167
30	4F 01	Tana (G. Falls)	16,972	184.4	2.358	1.134	875	6,098,075
31	4F 19	Kazita	1,702	17.9	4.918	1.117	123	82,057
32	4G 01	Tana (Garissa)	32,892	166.0	134.316	0.447	1,320	6,907,451
33	5BC02	Naromoru	83	0.8	21.242	0.422	19	486
34	5BC06	Burgret	98	1.0	36.569	0.588	37	1,130
35	5BE20	Nanyuki	860	1.8	16.823	0.936	29	2,072
36	5E 03	Ewaso N'giro	15,300	21.6	230.284	0.618	1,538	1,045,035

Note: Annual suspended volume was calculated on daily basis by using dimensionless flow duration curve.

Table-3.7.1 (1/2) Surface Water Resources Development Potential by District

Province	Code	District	Catchment Area Code	Area (km²)	Area of Perennial River Basin (km²)	New Surface Water Development Potential (m³/day)
Nairobi	110	Nairobi	3	693	578	10,978
Central	210	Kiambu	2	393	393	18,095
			3	1,923	1,602	30,457
			4	271	271	37,349
			Total	2,587	2,267	85,901
	220	Kirinyaga	4	1,485	1,485	521,814
	230	Murang'a	4	2,525	2,525	681,144
	240	Nyandarua	2	1,912	1,912	39,848
			4	143	143	19,687
			5	1,318	1,318	49,348
			Total	3,373	3,373	108,883
	250	Nyeri	4	2,231	2,231	134,951
			5	1,035	1,035	796,245
			Total	3,266	3,266	931,195
Coast	310	Kilifi	3	10,336	8,613	479,328
			4	2,670	2,670	720,283
			Total	13,006	11,283	1,199,611
	320	Kwale	3	8,260	6,883	97,950
	330	Lamu	4	6,818	6,818	351,536
	340	Mombasa	3	282	235	623
	350	Taita	3	16,697	13,914	323,509
			4	268	268	72,233
			Total	16,965	14,182	395,742
	360	Tana River	4	38,782	35,000	1,804,600
Eastern	410	Embu	4	2,805	2,805	734,321
	420	Isiolo	4	2,894	2,894	149,213
			5	22,710	0	0
			Total	25,604	2,894	149,213
	430	Kitui	3	958	799	18,565
			4	18,934	17,489	998,960
			Total	19,892	18,287	1,017,525
	440	Masaku	3	4,005	3,338	79,100
			4	2,244	2,244	605,318
			Total	6,249	5,581	684,419
	450	Marsabit	2	10,821	0	0
			5	61,469	0	0
			Total	72,290	0	0
	460	Meru	4	1,758	1,758	354,448
			5	1,765	1,765	17,454
			Total	3,523	3,523	371,902
	470	Nyambene	4	2,201	2,201	593,660
			5	1,865	1,865	10,520
			Total	4,066	4,066	604,180
	480	Thraka Nithi	4	2,295	2,295	462,672
	490	Mwingi	4	9,911	9,911	2,673,591
	4A0	Makueni	3	7,719	6,433	198,250
North-Eastern	510	Garissa	4	27,981	2,981	153,700
			5	15,411	0	0
			Total	43,392	2,981	153,700
	520	Mandera	5	25,871	2,000	7,320
	530	Wajir	5	56,923	0	0

Table-3.7.1 (2/2) Surface Water Resources Development Potential by District

Province	Code	District	Catchment Area Code	Area (km^2)	Area of Perennial River Basin (km^2)	New Surface Water Development Potential (m^3/day)
Nyanza	610	Gusii	1	1,252	1,112	77,127
	620	Kisumu	1	2,077	1,845	158,894
	630	Siaya	1	2,524	2,242	273,568
	640	Homa Bay	1	3,105	2,759	295,577
	650	Migori	1	2,603	2,313	44,863
	660	Nyamira	1	946	840	36,349
Rift Valley	710	Kajiado	2	7,883	7,883	362,616
			3	13,873	11,561	356,306
			Total	21,756	19,444	718,922
	720	Kipsigis	1	2,569	2,282	62,239
	730	Laikipia	2	1,009	1,009	38,073
			5	8,153	4,124	428,749
			Total	9,162	5,133	466,822
	740	Nakuru	1	1,001	890	24,262
			2	6,189	6,189	233,557
			Total	7,190	7,078	257,818
	750	Narok	1	7,189	6,387	608,313
			2	7,939	7,939	138,926
			Total	15,128	14,326	747,239
	760	Trans Nzoia	1	2,261	2,009	267,047
			2	206	206	3,316
			Total	2,467	2,215	270,363
	770	Uasin Gishu	1	3,144	2,793	138,483
			2	74	74	2,795
			Total	3,218	2,867	141,278
	780	Bomet	1	2,371	2,106	271,856
	790	Transmara	1	2,874	2,553	243,177
	810	Baringo	1	34	30	971
			2	10,920	10,800	1,478,599
			Total	10,954	10,830	1,479,570
	820	Elgeyo Marakwet	1	1,153	1,024	13,380
			2	1,896	1,896	259,562
			Total	3,049	2,920	272,942
	830	Nandi	1	2,784	2,473	301,749
	840	Samburu	2	5,183	0	0
			5	15,625	0	0
			Total	20,808	0	0
	850	Turkana	2	69,146	4,146	37,190
	860	West Pokot	1	321	285	15,610
			2	8,616	8,616	434,958
			Total	8,937	8,901	450,567
Western	910	Bungoma	1	3,072	2,729	362,767
	920	Busia	1	1,652	1,468	69,978
	930	Kakamega	1	3,020	2,683	871,712
	940	Vihiga	1	541	481	58,315
	TOTAL			581,787	254,419	21,217,952

Note: Development potential of unregulated surface run offs of rivers

Source : The Aftercare Study Team

Table - 4.1.1 Existing Boreholes by the District

District			Number of Borehole	Borehole Density
Code	Name	Area (km^2)	(nos.)	($nos./km^2$)
110	Nairobi	693	986	1.42
210	Kiambu	2,587	1,212	0.47
220	Kirinyaga	1,485	29	0.02
230	Muranga	2,525	67	0.03
240	Nyandarua	3,373	201	0.06
250	Nyeri	3,266	73	0.02
310	Kilifi	13,006	275	0.02
320	Kwale	8,260	647	0.08
330	Lamu	6,818	45	0.01
340	Mombasa	282	104	0.37
350	Taita	16,965	92	0.01
360	TanaRiver	38,782	16	0.00
410	Embu	2,805	277	0.10
420	Isiolo	25,604	123	0.00
430	Kitui	19,892	116	0.01
440	Masaku	9,911	621	0.06
450	Marsabit	6,249	133	0.02
460	Meru	7,719	69	0.01
470	Nyambe	72,290	-	-
480	Tharaka Nithi	3,523	-	-
490	Mwingi	4,066	-	-
4A0	Makueni	2,295	-	-
510	Garissa	43,392	120	0.00
520	Mandera	25,871	95	0.00
530	Wajir	56,923	141	0.00
610	Gusii	1,252	39	0.03
620	Kisumu	946	193	0.20
630	Siaya	2,077	259	0.12
640	Homa Bay	2,524	296	0.12
650	Migori	3,105	-	-
660	Nyamira	2,603	-	-
710	Kajiado	21,756	520	0.02
720	Kipsigis	2,569	59	0.02
730	Laikipia	9,162	275	0.03
740	Nakuru	7,190	920	0.13
750	Narok	15,128	58	0.00
760	Trans Nzoia	2,467	76	0.03
770	Uasin Gishu	3,218	183	0.06
780	Bomet	2,371	-	-
790	Transmara	2,874	-	-
810	Baringo	10,954	74	0.01
820	Elgeyo Marakwet	3,049	27	0.01
830	Nandi	2,784	12	0.00
840	Samburu	20,808	92	0.00
850	Turukana	69,146	488	0.01
860	West Pokot	8,937	90	0.01
910	Bungoma	3,072	262	0.09
920	Busia	1,652	386	0.23
930	Kakamega	3,020	461	0.15
940	Vihiga	541	-	-
Uncertain			566	-
Total		581,787	10,778	average= 0.02

Source: NAWARD (National Water Resources Database)
Note: Shaded District Name ... New District

Table - 4.1.2 Status of Boreholes and Wells

Borehole

District	Total No.	Status: In Use	Status: Dry	Status: Unknown	Status: Abandoned	Reasons of Abandon: Low Yield (a)	Poor Water Quality (b)	Mechanical Breakdown (c)	Lack of Funds for O/M (d)	Local/Political Bickering (e)	Unknown (f)
Baringo	89	29	10	0	50	6	5	8	7	0	24
Kilifi	195	43	4	17	131	4	39	23	3	0	62
Kajiado	372	176	18	24	154	25	3	40	58	1	27
West Pokot	92	36	10	0	46	2	2	28	4	0	10
Marsabit	49	18	6	1	24	3	4	14	3	0	0
Total	797	302	48	42	405	40	53	113	75	1	123
(%)	100%	38%	6%	5%	51%						
					100%	10%	13%	28%	19%	0%	30%

Well

District	Total No.	Status: In Use	Status: Dry	Status: Unknown	Status: Abandoned	Reasons of Abandon: Low Yield (a)	Poor Water Quality (b)	Mechanical Breakdown (c)	Lack of Funds for O/M (d)	Local/Political Bickering (e)	Unknown (f)
Baringo	145	128	7	0	10	1	3	0	0	0	6
Kilifi	1,172	1,024	25	57	66	2	32	8	2	0	22
Kajiado	289	90	0	198	1	0	0	0	0	0	1
West Pokot	71	63	2	0	6	0	1	2	0	1	2
Marsabit	204	199	5	0	0	0	0	0	0	0	0
Total	1,881	1,504	39	255	83	3	36	10	2	1	31
(%)	100%	80%	2%	14%	4%						
					100%	4%	43%	12%	2%	1%	37%

Source: WRAP Inventory Database, compiled and summerized by the Aftercare Study

Table - 4.1.3 Status and Ownership of Boreholes

		Community	Family	Farm	Government	NGO	Others	Nobody	Unknown	Total
Baringo	Owner	Community	Family	Farm	Government	NGO	Others	Nobody	Unknown	Total
	(a) In Use	3	1	0	15	0	10	0	0	29
	(b) Abandoned	10	12	0	21	0	7	0	0	50
	(c) b/(a+b) %	77%	92%		58%		41%			63%
Kajiado	Owner	Community	Family	Farm	Government	NGO	Others	Nobody	Unknown	Total
	(a) In Use	26	70	3	54	15	8	0	0	176
	(b) Abandoned	29	68	1	38	5	5	1	7	154
	(c) b/(a+b) %	53%	49%	25%	41%	25%	38%	100%	100%	47%
Kilfi	(a) Owner	Community	Family	Farm	Government	NGO	Others	Nobody	Unknown	Total
	(b) In Use	2	12	17	10	1	1	0	0	43
	(c) Abandoned	1	30	15	80	3	2	0	0	131
	(c) b/(a+b) %	33%	71%	47%	89%	75%	67%			75%
West Pokot	Owner	Community	Family	Farm	Government	NGO	Others	Nobody	Unknown	Total
	(a) In Use	10	0	1	13	5	1	0	6	36
	(b) Abandoned	10	1	0	24	10	1	0	0	46
	(c) b/(a+b) %	50%	100%	0%	65%	67%	50%		0%	56%
4 Districts	Owner	Community	Family	Farm	Government	NGO	Others	Nobody	Unknown	Total
	(a) In Use	41	83	21	92	21	20	0	6	284
	(b) Abandoned	50	111	16	163	18	15	1	7	381
	(c) b/(a+b) %	55%	57%	43%	64%	46%	43%	100%	54%	57%

Source: WRAP Inventory Database, Compiled and summarized by the Aftercare Study

Table - 4.2.1 Status and Owenrship of Wells

District	Owner	Community	Family	Farm	Government	NGO	Others	Nobady	Unknown	Total
Baringo	(a) In Use	8	111	0	0	0	9	0	0	128
	(b) Abandoned	0	5	0	0	0	5	0	0	10
	(c) b/(a+b) %	0%	4%				36%			7%
Kajiado	(a) In Use	1	89	0	0	0	0	0	0	90
	(b) Abandoned	0	1	0	0	0	0	0	0	1
	(c) b/(a+b) %	0%	1%							1%
Kilfi	(a) In Use	78	785	83	16	16	45	1	3	1,027
	(b) Abandoned	13	43	6	2	1	0	0	1	66
	(c) b/(a+b) %	14%	5%	7%	11%	6%	0%	0%	25%	6%
West Pokot	(a) In Use	0	57	0	2	2	0	0	1	62
	(b) Abandoned	2	0	0	2	0	0	0	1	5
	(c) b/(a+b) %	100%	0%		50%	0%			50%	7%
4 Districts	(a) In Use	87	1042	83	18	18	54	0	4	1,306
	(b) Abandoned	15	49	6	4	1	5	0	2	82
	(c) b/(a+b) %	15%	4%	7%	18%	5%	8%		33%	6%

Source: WRAP Inventory Database, Compiled and summarized by the Aftercare Study