Report C for breakdowns by Location). Figure 2.4.5 shows the geographical distribution of safe abstraction rates by Location.

<u>Shallow wells</u>:

No substantial data have been available for the Study with regard to present yield nor potential yield of shallow wells. Therefore, the Study had to take a rather short-cut approach for the estimate of potential yield of shallow wells.

Reviewing all the available information, though scarce and mostly piece-mill, collected from various sources, the following safe yield rates were estimated for each type of rocks:

- Quaternary sediments	:	10 m^3/day/well (alluvial)
		5 m^3/day/well (colluvial)
- Older sedimentary rocks	:	5 m^3/day/well
- Pre-cambrian metamorphic basement rocks	:	5 m^3/day/well
- Pre-cambrian granites	:	5 m^3/day/well
- Volcanic rocks	:	no shallow well

Shallow well yield was calculated for each Location applying the above yield rates and assuming the well density of a well per 2 km^2 in area. The summary of results by District is shown in Table 2.4.4 (see Sectoral Report C for breakdown by Location).

The estimated shall well yield is 426 million cubic meter per year. Geographical distribution of the yield is shown in Figure 2.4.6.

It is noted that the estimate of safe groundwater yields given above is based on a broad assumption. Therefore, the use of figures should be treated with caution.

2.4.5 Groundwater quality

Groundwater constitutes one portion of the earth's water circulation system known as the hydrologic cycle. Groundwater dissolves parts of soils and rocks as groundwater infiltrates and percolates through the soils and rocks. The cations occurring in groundwater are commonly calcium, magnesium, sodium, iron, manganese and potassium. The anions are mostly carbonate, bicarbonate, sulphate, chloride and nitrate.

Whether groundwater of a given quality is suitable for a particular purpose depends on the criteria or standards of acceptable quality for that use.

(1) Guidelines of water quality

1) Drinking

The basic requirements for drinking water are as follows:

-- Free from disease causing organisms.
-- Containing no compounds that would adversely effect on human health.
-- Fairly clear (low turbidity and little colour).
-- Not saline
-- Containing no compounds that cause an offensive taste or smell.
-- Not causing corrosion or incrustation of the water supply.
-- Not staining clothes washed in it.

The permissible level for each ion may be a function of water availability and socioeconomic factors. In general the guidelines most accepted are set out by the World Health Organization.

2) Livestock use

In general no definitive water quality criteria exist for livestock use. There is a wide range of ions, bacteria and viruses affecting water quality. A guideline for evaluating water quality for livestock use is shown in Sectoral Report C.

3) Irrigation

Good water has the potential to allow maximum economical returns. Poor water causes soil and cropping problems which will reduce yields. Water considered "unsuitable" under the prior concept of quality may really be "usable" under certain conditions. In fact, poor water is often better than no water. Some guidelines on classification of irrigation water are shown in Sectoral Report C and Subsection 5.5.2 hereinafter.

(2) Geographical distribution of water quality

The Study attempted to prepare regional maps showing the geographical distribution of water quality features of the country. They are shown in Figures 2.4.7 through 2.4.20.

Regional maps are very useful for understanding of overall features. However, regional mapping involves interpolation and extrapolation of available data to predict the expectations in places where data are absent. It must be emphasized that the regional maps prepared in this Study are based on limited data and hence should be used with caution just as a guide to the likely condition.

1) Electrical conductivity and total dissolved solids

Electrical conductivity is often expressed as an index to represent total dissolved solids (TDS) content. The relation between electrical conductivity and TDS depends on the ions in the water. For example, for irrigation purpose, 1000 micro S/cm is equivalent to 600 or 700 mg/l in TDS.

The recommended maximum limit for human consumption is believed to be 750 micro S/cm. In places where no other water is available, water with double or triple of this limit is used. The limits for irrigation and livestock are believed to be 2000 and 8000 micro S/cm, respectively.

In the ASAL area, electrical conductivity is more than 1000 micro S/cm (Figures 2.4.8 and 2.4.9). A serious problem in groundwater development in the ASAL is that of saline water, which has resulted in the failure of several boreholes.

2) Fluoride (F)

Fluoride is naturally present in some foods and water. There is no evidence of harmful effects associated with the relatively low levels. At levels above 1.5 mg/l, the maximum limit guided by WHO, mottling of teeth has been reported very occasionally, and at 3.0 to 6.0 mg/l, skeletal fluorosis is observed. When exceeding a concentration of 10 mg/l, crippling fluorosis can follow.

High fluoride content is believed to be related to geology, particularly volcanic rocks in the Rift Valley area and the Central part of Kenya (Figures 2.4.9 and 2.4.10). It is believed that the fluoride content has an origin in the volcanic and fumarolic gases. In the ASAL areas, high content of fluoride may be related to the degradation of fluorite.

3) Iron (Fe)

Although iron is an essential element in human nutrition, drinking water is not considered to be an important source for nutrition. At levels of 0.3 mg/l, maximum limit of WHO guidelines, iron stains laundry and plumbing fixtures and causes an undesirable taste. The presence of iron may lead to deposits in pipes and at levels higher than 0.3 mg/l there may be increased maintenance costs.

In the western and south-eastern parts of the country, high contents of iron higher than 0.3 mg/l are common (see Figures. 2.4.11 and 2.4.12).

4) *Sodium (Na), calcium (Ca) and magnesium (Mg)*

The taste threshold for sodium is about 200 mg/l, guideline value of WHO. The threshold value for livestock is 1,000 mg/l and the limiting concentration is 2,000 mg/l. In the ASAL area, high contents of sodium more than 200 mg/l are predominant (see Figures. 2.4.13 and 2.4.14).

The hardness of water is caused by calcium and to a lesser extent magnesium. The taste threshold for calcium is in the range of 100 to 300 mg/l depending on the associated anion. The limiting value for livestock is 1000 mg/l. The taste threshold for magnesium is less than that for calcium. The limiting concentration for livestock is 500 mg/l. In the ASAL, high contents of calcium and magnesium higher than 100 mg/l are common (see Figure 2.4.15 through Figure 2.4.18).

5) Sodium absorption ratio (SAR)

The sodium absorption ratio (SAR) is the property of soil extracts and irrigation water used to express the relative activity of sodium ions in an exchange reaction with soil. Effects from sodium are to some extent negated by calcium and magnesium.

Irrigation water is classified on the basis of their electrical conductivity and SAR. According to this classification, groundwater is classified as high or very high salinity and high or very high sodium specially in the ASAL areas (see Figures 2.4.19 and 2.4.20).

Drinking water risk map was prepared as shown in Figures 2.4.21 through 2.4.23 for three selected parameters - electrical conductivity, fluoride, and iron. It is to be noted that the maps are based on a limited number of data and hence are of limited use only for providing a broad information of geographical distribution of groundwater quality features. There will be a great deal of potential of good quality aquifers even in the areas evaluated as "unfavourable" on these maps.

2.5 Present Socioeconomic Condition

2.5.1 Population

(1) Census population

When the current master plan study was being carried out, the latest available and reliable information regarding present population and its distribution by "Location" was the 1979 population census. In May 1991, the provisional results of the 1989 census was released in "Economic Survey 1991". However, the final results of the 1989 census will still not available until the time this current study is finalized. Thus, although the study is formulated on the basis of as much available data of the

1989 census as possible, the detailed information such as population distribution by "Location" and family size is based on the 1979 census results, as discussed in the Steering Committee.

(2) Population distribution and growth

Table 2.5.1 shows the intercensal comparison of the 1979 census with the 1989 census provisional results. According to the table the national population was 15,327 thousand in the 1979 census and 21,397 thousand in the 1989 census. The intercensal average growth rate was 3.4% per annum in the country. This growth rate was fairly lower than the rate (3.7% on average between 1984 and 2000) projected in the Sessional Paper (Ref.11), although it was a desirable trend for the country. The Districts which appear to have appreciably gained more than 4% per annum on average are: Nairobi, Nyandarua, Isiolo, Kajiado, Nakuru, Narok, Trans Nzoia and Samburu. The major losing Districts, the growth rate of which are less than the national average growth rate of 3.4% per annum, are Districts in Central Province (excluding Nyandarua); Districts in Coast Province (excluding Kilifi); District in Eastern Province (excluding Isiolo); all Districts in North-Eastern Province; Districts in Nyanza Province (excluding Kisumu); Kericho and Turkana in Rift Valley Province; and Kakamega/Vihiga in Western Province. In particular, the Districts of Garissa and Wajir have lost a lot of population and grown at negative rate as seen in the table.

The Districts having a population more than one million in the 1989 census were Machakos/Makueni, Kakamega/Vihiga, Nairobi, Kisii/Nyamira, Meru and South Nyanza. In terms of population density, on the other hand, Mombasa was the most densely inhabited District of 2,348 persons/sq.km. Nairobi was the second, having a density of 2,285 persons/sq.km. Subsequently to them, Kisii District had a density of 522 persons/sq.km., about a quarter of Nairobi's density.

(3) Urban population

The provisional results of the 1989 census show urban population by status of urban centre. The District total of urban population is summarized in Table 2.5.1. The Districts which appear to have appreciably gained more than 10% per annum on average are: Siaya, Nandi, Murang'a, Taita Taveta, and South Nyanza.

Characteristics of the urbanization process in Kenya are analyzed by studying population and employment changes in some of the major urban centres. Table 2.5.2 shows the major centres having more than 10 thousand people at the 1979 or 1989 census. Although these data are not conclusive because of the distortion due to the boundary extension of some centres, it shows that about a half of the total urban population at the 1989 census occurred in Nairobi and Mombasa with 36% in Nairobi alone, as shown in the table. Besides these two cities, the following towns had large increment (more than 50 thousand) of urban population between the two censuses: Nakuru, Eldoret and Nyeri.

Some towns have grown at high rates of more than 15% per annum, such as Ruiru (21%) in Kiambu District, Taveta (19%) in Taita Taveta District, Maragwa (16%) in Murang'a District and Siaya (15%) in Siaya District, as shown in Table 2.5.2. On the other hand, the following six towns have slowly grown at a less than half of the average growth rate (4.9%) of urban population: Nyeri, Embu, Kisumu, Nyahururu, Marsabit, and Nyamira. In particular, Mandera has decreased at 6.2% per annum during the two censuses.

(4) Family size

An average family size in the 1979 census was 5.2 persons in the country. In District averages, the largest size was 6.4 persons of Bungoma and the smallest was 4.1 of Nairobi and Mombasa. The Districts having more than 6 family members on average were West Pokot, Kisii and South Nyanza as well as Bungoma. Besides Nairobi and Mombasa Districts, the following three Districts recorded less than 4.5 family members on average: Isiolo, Laikipia and Elgeyo Marakwet.

2.5.2 GDP and GRDP

(1) GDP

The national economy has shown relatively good performance during the recent years. In 1989, the economic growth recorded 5.5% in real term, which exceeded that (5.2%) in 1988. Sectoral contributions of various components of GDP are given in Table 2.5.3. The leading sector in the national economy was still agricultural sector which accounted for around 30% of GDP. Next to agriculture, (a) manufacturing sector and (b) trade, restaurants and hotels sector contribute to the national economy, accounting for approximately 12% and 11%, respectively. Besides these private sectors, government services contribute about 15% to GDP.

(2) GRDP

The GRDPs by District in 1989 are estimated on the basis of the following data: District output of agricultural and manufacturing sectors through "Socioeconomic survey, 1991" by the JICA Study Team and wage earnings by District (Ref.12). Table 2.5.4 tabulates them. Among 41 Districts, Nairobi occupies the biggest share of GRDP, namely K£2,224 thousand or 30% of GDP. On the other hand, Tana River and Mandera Districts occupy the smallest shares (about 0.15%) in GDP. Applying the 1989 census population, GRDP per capita of Nairobi attained the largest of K£1,653. Kitui District was the smallest among 41 Districts, amounted to K£63.

(3) Inter-industrial relationship

The latest input-output table was prepared in October 1979, which was based on reference year 1976 (Ref.13). No input-output tables were officially published afterward. The MOPND, however, has prepared some tables as inner references. The latest series of tables refer to the year 1986 (Ref.14). Referring to this table, Leontief inverse matrix is calculated as shown in Table 2.5.5. This matrix indicates induced effects of investment. Supposing one point of investment is done in the construction sector, 2.18 points of investment effects would be induced in the national economy. Those comprise one point for the construction sector as direct effect and 1.18 point through the other sectors as indirect effects. Thus, these components show direct and indirect positive economic effects on respective production sectors. On the contrary, if the relative sectors do not reserve production power to support the new investment, it would be feared that the investment simply raises prices of construction materials.

2.5.3 Service centres

The concept of "Service Centre" was originally formulated as a classification of urbanized areas for planning purposes. Depending on the degree of urban agglomeration, an area is classified into a certain level of urban hierarchy, and a certain level of infrastructure is provided for the area. Therefore, each service centre is expected to install some urban facilities and infrastructure suitable for urban agglomeration. In the third "National Development Plan 1974-1978" (Ref.15), the service center "policy" was adopted for urban development. In the latest "District Development Plan 1989-1993" (Ref.16) as well, this system is reflected for capture of urbanization in Districts. The service centres are classified into the following five levels: (1) growth centre, (2) urban centre, (3) rural centre, (4) market centre and (5) local centre.

"District Development Plans 1989-1993" of 40 Districts give an inventory of service centres. Every plan, however, does not give service centre inventories completely. Therefore, to accomplish the exhaustive inventories in the country, the following four references were used for filling-up lacking information: (1) District Development Plans 1989-1993 (Ref.16); (2) National Development Plan 1974-1978 (Ref.15); (3) Human Settlement in Kenya (Ref.17); and (4) Socioeconomic Survey, 1991, the JICA Study Team. Table 2.5.6 shows the inventory of service centres, which is compiled through the said references. The total number of service centres is 1,758 and classified as follows: 15 growth centres, 89 urban centres 176 rural centres, 475 market centres, and 1,003 local centres.

2.5.4 Household income and expenditure

Table 2.5.7 is a part of analytical results from "Urban Household Budget Survey" by CBS. Data in the table are based on the price level in 1983, so the value itself is not eloquent of household economy at present. However, relative relationship such as (a) balance between income and expenditure and (b) composition of expenditure items is interpreted through this table. In particular, water expenditure, which is a part of a regular expenditure, accounted for 0.8% to 2.3% of the total urban household income. This is similar to an approximate value of the recommended range (1 - 2%) of the World Bank.

2.5.5 Prices and exchange rates

Consumer price indices in Nairobi are presented in Table 2.5.8. Through these indices, an inflation rate is measured by means of comparison with respective indices. In 1990, it was recorded as 11.8% in upper income group, 12.9% in middle and 13.2% in lower. According to the information brought by the time this study report was finalized, in the same year the inflation rate abruptly jumped to 15.8%. It further increased to 19.6% in 1991. These increases were caused by the adverse effects of the following backgrounds: (a) the Gulf Crisis, (b) the depreciation of the Kenya shillings, (c) the introduction of the value added tax (VAT) on various commodities, and (d) decontrol of prices. As a result, real average earnings declined by 8.3%.

Besides Nairobi, price indices for the three urban centres of Mombasa, Kisumu and Nakuru are presented in the same table. Inflation rates in 1990 recorded increases of 15.6%, 13.5% and 13.8% for Mombasa, Kisumu and Nakuru, respectively. In the table, cost indices regarding construction works are listed as well as consumer price indices.

Construction and O&M (operation and maintenance) costs of proposed projects as well as benefit are estimated under the pricing conditions in February 1991. At that time, a foreign exchange rate of Kenya Shilling to US$ was 25.205, as shown in Table 2.5.9. Incidentally, an exchange rate to Japanese Yen was 132 at the same time. Table shows the trend of foreign exchange rates from 1979 to 1991 as of the end of respective periods.

2.5.6 Public expenditure

In the fiscal year 1989/90, the public expenditure by the central government was approximately K£3.5 billion, corresponding to 48% of GDP in 1989. This percentage has steadily expanded from 37% in 1985/86 to 48% for recent five years, as seen in Table 2.5.10, in spite of the curtailment efforts by the government. Of the total expenditure, the development expenditure accounted for around a quarter, of which more than half was procured through appropriations-in-aid by foreign countries in recent two years particularly. In 1989, K£666 million or 66% of the total expenditure was distributed for capital expenditure. On average for recent ten years, however, the capital expenditure was around 50% of the total development expenditure, of which 90% was invested by the central government directly as gross fixed capital formation.

Development expenditure by Ministry of Water Development accounted for between 6% and 9% of the total development expenditure for the latest five years. Though it occupied about 7.5% of the total in 1989/90, its trend does not seem to have increased in spite of the fact that water development is expected to be encouraged as much as possible. Although the expenditure for development projects related to water exceeded 20% of the development expenditure in the fiscal years 1986 and 1989, it has been less than 20% for the recent 10 years as seen in the table. Of this total, 37% was disbursed by MOWD on average for the recent years.

CHAPTER 3 PRESENT CONDITION OF WATER RESOURCES DEVELOPMENT AND USE

3.1 Domestic and Industrial Water

3.1.1 Water use in general

In general, human population has been concentrated on high lands, often on ridges far from perennial water source. In the past when population density was low, peoples living on high lands took water from small streams or springs nearby. Small water supply systems were developed relying on such water sources. Nowadays, population has grown and water demands exceed by far the supply capacity of such sources.

Perennial water sources with large quantity (perennial rivers) are often located far from the demand centers of water or in the lower elevation. Such a relationship between water sources and demand centres makes water supply development in Kenya difficult and expensive.

The water supply coverage in Kenya is a very difficult figure to obtain. Table 3.1.1 shows results of the Demographic and Health Survey carried out in 1988 (Ref.18). From this table, the proportion of women who have access to the protected water sources (piped into house, public tap, well with pump and well without pump) accounts for 46.7%. Then, more than a half of the women in Kenya still depend on the unprotected water sources.

The present water abstraction of surface water can be estimated based on the water permit data in the database of the MOWD. The data is classified into two categories; that is, (i) under normal flow condition and (ii) under flood flow condition. According to the information from the MOWD, in case that the river water level at water abstraction point is lower than 80% of the annual mean water level, the water permit on flood flow condition is not effective. The water permits on normal flow condition have been issued with a priority for domestic/industrial water use, but also for perennial agriculture and power generation uses, while those on flood flow condition mainly for seasonal irrigation water supply and also for power generation as the case may be.

The study attempted to enumerate the water permits which were supposed to have been issued for domestic, public and industrial water uses, by sorting out the data as much as possible. The result is given below.

Surface water abstraction rates by drainage area
(normal flow condition)

(Unit: MCM/year)

Drainage Area	1	2	3	4	5	Total
Water Permit	254.3	46.8	133.1	595.4	42.1	1,071.7

The calculated figure is, however, relatively large as compared with the potential water demand at present level (some 500 MCM/year). The difference is supposed to be due to the reasons that, notwithstanding the sorting of the data, the calculated figure has counted in other water uses or partly due to the inclusion of obsolete water permit data.

Nevertheless, the figure is indicative in respect that the water permits on normal flow issued so far for domestic/industrial uses, though on a nominal basis, accounts for 5% of the perennial surface water resources.

3.1.2 Water undertakers

The Water Act stipulates as follows:

124.(1) For the purpose of the distribution of water supplies in any area, the Minister, after consultation with the Water Resources Authority*1, may appoint water undertakers who shall be responsible for the provision of an adequate supply of water for the area within their limits of supply, and who shall comply with the provision of this Act.

124.(3) The area of the limits of supply of a water undertaker shall be determined by the Minister, after consultation with the Water Resources Authority*1, and water shall not be supplied by the water undertaker to any person outside such limits of supply without the prior consent of the Minister.

Water undertakers are;

- Ministry of Water Development
- National Water Conservation and Pipeline Corporation
- Municipal Councils
- County Councils
- Institutions such as schools and prisons
- Kenya Railway Corporation
- Religious Organizations
- Water supply associations (self-help)
- Privates

Exact number of the water undertakers is not known, although the Water Act stipulates as mentioned above. The number of the limit of supply so far gazetted is around 400 as given in Table 3.1.2, far smaller than the existing water supply systems.

3.1.3 Water supply systems

It is believed that there are more than 1,000 water supply systems, but exact number is yet unknown. According to the Socio-economic Survey carried out under this Study, out of

*1 The Water Resources Authority was defunct. The MOWD has been performed its function.

1,783 centres, 1,570 centres reported to have water supply systems as shown below (Table 3.1.3):

MOWD systems	:	579	
NWCPC systems	:	188	
Community systems	:	339	
Self-help systems	:	243	
Local authority systems	:	164	
NGO systems	:	53	
Donor systems	:	4	Total : 1,570
No information	:	213	Total : 1,783

The total amount of domestic and industrial water actually supplied and consumed in entire Kenya is not known, since almost all the private systems have no measuring devices and some public water supply system also have none or broken measuring devices. The water abstraction permits give a very rough figures of 2.9 million m^3 per day or 130 litre per capita per day. It is noted however that this represents a nominal figure as explained in Subsection 3.1.1.

3.2 Irrigation

3.2.1 Irrigation projects

In Kenya three major types of irrigation are practiced, i.e. private irrigation, smallholder irrigation and Government managed irrigation. The total area of irrigation performed by these three types is about 65,000 ha as shown in the table below.

Irrigation in Kenya

Private	25,800 ha
Smallholder	27,200 ha
Managed by Government	12,000 ha
Total	65,000 ha

Ref. E.23, 37, 45

As seen in the table, the non Government managed irrigation takes the largest share of hectarage, mainly in coffee plantations. Smallholder and Government managed irrigation areas are planted mainly for food crops and vegetables.

Table 3.2.1 shows the district wise distribution of above irrigation schemes in numbers and irrigation area. The size of these schemes varies from 1 ha to more than 20,000 ha. About 60% of the total number of scheme have an area of less than 100 ha. The name and area of each scheme are given in Appendix E5 of Sectoral Report E.

3.2.2 Water use

Monthly irrigation water requirement for both existing and proposed schemes were determined in three modes:

Mode A : For schemes with available documents or information, the data presented in those reports/paper are used

Mode B : For schemes with no documents, information on water requirements presented in "Water Requirement for Irrigation in Kenya" (Ref.19) are used. This document was prepared by MOWD in 1985, for estimation of irrigation requirement in the whole of Kenya.

Mode C : For private commercial schemes, water abstraction amounts registered at Water Apportionment Board (WAB) are used

Table 3.2.2 presents an estimate of the total irrigation water demand in 1990 by basin and is summarized below :

Water Use by Existing Irrigation Schemes

Unit m^3/sec

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	annual
23.7	26.9	45.2	53.1	57.2	48.2	39.7	40.4	50.4	54.1	57.3	54.5	45.9

3.3 Livestock

3.3.1 Livestock population

Livestock population in each District was estimated by using available information obtained from following documents:

1. District Development Plan (DDP)
2. Livestock and Wildlife Data Summary 1987-1988 for Kenya Rangelands
3. Annual Report prepared by Ministry of Livestock Development

Present livestock population is summarized in Table 3.3.1.

3.3.2 Livestock water demand

A unit water requirement of 50 litre/day/LU which is the MOWD standard, was used to estimate water demand for cattle, sheep, goat and camel. Water consumption by other stocks like poultry, donkey, pigs etc. was assumed to be small. To convert livestock population into livestock unit, average live-weight of each livestock and unit weight of 1 LU of 450 kg were used. Average live-weight is estimated from MOLD information of herd composition and standard weight. Table 3.3.2 presents the calculation and the results. Table 3.3.3 shows water demand for each sub-basin in 1990 and summarized below.

Livestock Water Demand in 1990

Unit : litre/sec

Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
1,257	770	412	616	708	3,763

3.4 Wildlife and Fishery

3.4.1 Wildlife watering

There are many varieties of animal species in the country; for some of which their distribution and population are monitored and assessed by DRSRS. DRSRS has conducted a detailed survey of livestock/wildlife population over rangelands of 15 Districts. Total surveyed area assessed in 1987 - 1988 is about 439,700 km^2 which is about 75% of total national land. The estimated numbers and distributions of the major species are mentioned in Table F2.1 of Sectoral Report F. The major species were grouped into (i) Group-A with daily water consumption of 5.0 litre/100 kg-weight and (ii) Group-B of 2.5 litre/100 kg-weight.

On the basis of the above estimated water consumption and the estimated numbers, water demands for the major 20 species were calculated for 15 Districts. Total daily water demand for 20 major species in the 15 Districts was estimated at about 7,700 m^3. Taking the coverage of surveyed area (75% of total national land) and many other species of wildlife into consideration, total daily water demand for wildlife over the country would be more than 21,000 m^3 of fresh water.

3.4.2 Inland fishery

There is no information available at all about water consumption amount or rate for fish farming. Hence, the following assumptions were made to estimate present water use:

- water will be changed once a year
- average water depth is 1 m
- water will be supplied with compensation at rates of 5 mm for evaporation and 1 mm for percolation.

Based on these assumptions, total amount of water use is estimated at about 16 million tons in the whole of Kenya.

Fish Farming Water Use in Kenya

Unit : million tons

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Amount	3.4	0.3	0.8	8.1	3.6	16.2

3.5 Hydropower

(1) Power Supply System

KPLC is operating a national power grid. The system has been divided into six regions since 1989/90 - they are, (i) Nairobi region, (ii) Coast region,(iii) Central Rift Valley region, (iv) Western region, (v) Mt.Kenya region and (vi) North Rift Valley region. Figure 3.5.1 shows the supply region boundaries as well as the existing power systems and sites of the potential indigenous energy sources.

(2) Power Generation

Generating facilities in Kenya consist of hydroelectric, conventional thermal and geothermal power plants. Total installed capacity of these facilities as of January 1991 in the interconnected power system was 705 MW. Composition of generating facilities is summarized as follows:

Plant	Installed Capacity		Effective Output	
	(MW)	(%)	(MW)	(%)
Hydropower*	495.3	70.3	477.8	74.5
Conventional thermal	145.9	20.7	112.8	17.6
Geothermal	45.0	6.4	43.0	6.7
Diesel	18.3	2.6	8.0	1.2
Total	704.5	100.0	641.6	100.0

* excluding Turkwel (106 MW) and supply from Owen Falls (Uganda)

Historical records of generation by plant type are outlined as below:

	1979 (GWh)	1984 (GWh)	1988/89 (GWh)	Share (%)	Growth* (%)
Supply (GWh)					
Hydropower	1,288	1,471	2,449	83.5	7.00
Geothermal	-	233	322	11.0	-
Oil Thermal	205	174	25	0.9	-
Diesel & G.T.	2	1	23	0.8	-
Import	160	215	112	3.8	-
Total Supply	1,655	2,094	2,931	100.0	6.20
Station Use	22	28	27		
Net Supply	1,633	2,066	2,904		6.25
System Losses	220	276	466		8.22

Note: * Growth rate during 9.5 years from 1979 to 1988/89.

As seen in the above tables, hydroelectric generation plays a major role in the supply of power and energy in the country; 75% in effective power output and 84% in energy generation (excluding hydropower from Uganda).

3.6 River and Flood

3.6.1 Issues related to rivers

Several issues on rivers were observed through interview survey and field reconnaissance conducted under the Study. The major items are cited here:

(1) Erosion and deforestation in watersheds

A prominent problem observed almost everywhere is soil erosion in watershed area. It occurs usually in the form of gully, rill and sheet erosions. The erosion is bringing about a number of problems, particularly;

(a) Decrease of fertile soils in agricultural lands, such as;
  - soil degradation due to direct exposure especially when gulleys run parallel to the contours
  - change of soil structures due to aggravation of stability and porosity
  - decline of organic matter content causing decrease in nutrient storing capacity of soil due to percolation

(b) Deterioration of water retaining and infiltration capacity in soils,

(c) Infilling of reservoirs and irrigation canals,

(d) Turbidity of river water, creating extra burden to water treatment works.

To prevent the erosion hazards, some types of countermeasures such as terracing, cut off drains and check dams have been provided at many places. The works are contributing to the reduction of erosion, though they are mostly protection at local places.

Extensive deforestation has been progressing in parts of mountainous areas on account of encroachment of agricultural activities and production of logs and fuelwoods. It tends to bring about crucial problems on the environments of watersheds.

(2) Flood and bank erosion

There are a number of places where flood and bank erosion are causing problems of varying extent. This issue is discussed in Subsection 3.6.2 below.

(3) Urban inundation

Flood also takes place in urban areas. Among others, those in Nairobi and Mombasa are noteworthy. The inundation usually lasts a couple of hours and causes damages to urban infrastructures and traffic interruption, thus hampering the city's economic activities. The inundation is due chiefly to inadequate drainage facilities and maintenance thereof.

(4) River water use

In terms of river water use, most rivers in Kenya are characterized by some negative features, such as;

(a) Relatively large imbalance of discharges between the dry and rainy seasons, which makes steady water abstraction difficult.

(b) Low water level in the dry season which requires pumping for water abstraction.

(c) Instability of river channels due to excessive meandering and/or braiding, which requires careful implementation/maintenance of riverine structures such as bridges and water offtake structures.

(d) Steep riverbed gradient, except in the Lower Tana, which impedes navigation in the river.

(e) Large sediment yield causing the devastation of river courses and siltation of reservoirs, while on the other hand excessive sand/gravel extraction at some places.

(f) Turbid river water causing the costly maintenance of intake facilities and treatment works.

3.6.2 Flood problem

In general, flood is not a very serious problem in Kenya compared with some of other tropical countries. Nevertheless, the problems in varying extent already exist and/or are arising in many rivers. Table 3.6.1 shows the chronology of major flood events since 1961.

The Study attempted to look into major issues about rivers in each district (see Table 3.6.2) and identified 59 places to have some sorts of problems (Table 3.6.3). Location of the rivers are shown in Figure 3.6.1.

Of those 59 places, the Study noted that 9 places would need specific attention in terms of their damage potential and sizes of flood area. The others are mostly spot problem with relatively small damage. Table 3.6.4 summarizes the main features of these 9 selected problem areas. All have flood problems, except the Lower Tana where the bank erosion is serious.

The relevant agencies such as MOWD , LBDA and TARDA have already launched undertaking of major flood control works in the Nzoia, Yala, Nyando, and Tana rivers. Plans have been formulated for the Kuja River and Nairobi city.

3.7 Water Quality

3.7.1 Water quality monitoring programme

(1) *Surface water*

To maintain acceptable water quality in the rivers and lakes in the face of rapid population growth and agricultural/industrial development, the Water Quality and Pollution Control Section of the MOWD is responsible for the implementation of a nationwide water quality monitoring programme. This monitoring network covers all major rivers, lakes and aquifers (springs) and incorporates 120 sampling points (see Figure 2.3.2). These are located at hydrological gauging stations to allow mass load to be estimated.

The network is comprised of two basic types of stations;

(i) "Reference stations" are sited in the upper catchment of the major rivers and designed to provide baseline data on natural water quality.

(ii) "Impact stations" are sited near to known point sources of pollution and are specifically for pollution control purpose. Similar sampling stations are located further downstream of such point sources to assess the self-cleaning capacity of the river.

The programme calls for each station to be sampled four times a year in January - February; April - May; June - July; and October-November. Additional samples are collected and analyzed on an irregular basis as the need arises.

In practice, however, the water quality monitoring programme described above falls far short of the desired level of surveillance. The main reasons are;

(a) Financial constraints
(b) Lack of transport
(c) Lack of suitable equipment and maintenance services thereof
(d) Shortage of skilled staff, especially at the District level

(2) Water supplies

Urban water supplies are monitored at various intervals depending on the population sizes as follows:

Population Size	Sampling Frequency
10,000 over	Daily
5,000 - 10,000	Weekly
1,000 - 5,000	Monthly
50 - 1,000	Every 6 months

(3) Groundwater

Of the nearly 10,000 boreholes in the country, only 15% have some water quality data logged on the MOWD database. Most of the data represent the ones tested at time of initial drilling, and no regular testing has been undertaken for most of the boreholes since then. The scarcity of existing data makes it quite difficult to meaningfully assess the groundwater water quality of the country. More intensive sampling surveys will be required in the future.

3.7.2 Overview of water quality in Kenya

(1) River water

Overall, surface water quality in Kenya remains good with regard to pollution aspect compared with some other industrialized countries. There have been relatively few examples of persistent or widespread gross pollution of river, lake and spring sources in the past. Nevertheless, some intermittent local pollution incidents have already occurred and become more serious year by year at some places.

All the rivers for which water quality data are available are freshwater with an electrical conductivity usually between 100 and 250 uS/cm, but occasionally 350 - 500 uS/cm. The water is generally neutral to slightly alkaline, except for some rivers which have slightly more acidic headwaters. Overall, concentration of cations (metals) is low, but some rivers have iron and magnese levels in excess of the WHO drinking-water guideline values, which should be subject to reduction by treatment. Fluoride remains a problem in some areas, eg. Lower Turkwel. The physico-chemical characteristics of principal rivers are summarized in Tables 3.7.1 to 3.7.12, as the representative data. It is noted that the data shown in the tables covers only a few to several years period, mostly in 1980s. Continuous updating of the information is important.

Because of soil erosion problems in many river catchments, the total suspended load carried by most rivers is very high, especially in the middle and lower reaches. This has direct impacts on the efficiency of chlorination at treatment plant and the infilling of reservoirs/irrigation channels.

Overall the country, only limited information on the bacteriological quality of river water is available, but the data has been accumulated recently in some regions. Because of the intimate use of rivers by people, livestock and wildlife populations, the total and faecal coliform counts are inevitably high and all river waters require filtration and disinfection as a minimum treatment prior to distribution. Treatment of most river waters can be by conventional methods of sand filtration and chlorination.

(2) Lake water

Kenyan lakes are either highly saline and of no importance from a water supply viewpoint, or fresh and have water supply potential. The alkaline-saline lakes, however, have economic and ecological importance as tourist attractions or sources of raw materials. The general physical and chemical characteristics of the lakes are summarized in Tables 3.7.13 through 3.7.15.

Alkaline-saline lakes:

Four lakes; Elementeita, Nakuru, Magadi and Bogoria, fall in this category. All these lakes are in closed basins and no water or dissolved material is lost via outflows. The long term chemical composition is thus much affected by inputs from the catchment and once chemicals and sediments have been transported into the basin, there are not sufficient mechanisms for their physical removal.

Consequently, these lakes are very susceptible to pollution and since their ecology is very simple, it is also fragile and easily damaged. The impacts of extensive land and water use changes in the catchment of these lakes on their ecology can be very serious and irreversible.

Freshwater lakes:

The other lakes; Naivasha, Victoria, Baringo and Turkana, fall in this category, of which the Lake Turkana is technically brackish. All lakes except Lake Victoria are closed-basin lakes and in consequence subject to evaporative concentration of solutes which enter them via river inflows, wind-blown dust and rainfall. Although no hard evidence is available, Lake Naivasha is said to have underground outflows.

Three lakes, excepting Lake Turkana, are moderately alkaline but have soft waters with sodium as the dominant cation. The concentration of iron in the Lake Naivasha and Lake Baringo is high but does not seem to impair water use for irrigation. Fluoride levels in Lake Baringo are too high for safe human domestic consumption. Lake Turkana is highly brackish and undrinkable, but it supports a large commercial fishery within the catchment.

The lakes appear to have or may have potential water quality problems peculiar to each lake in connection with future water development around there. These aspects are described in Section 3.7.3.

(3) Groundwater

Groundwater is extremely variable in chemical composition and this variation occurs both spatially and seasonaly. A general summary of groundwater quality on a provincial basis is given in Table 3.7.16.

Essentially, the quality of groundwater is affected by the chemistry of geological formation in which the water is retained. In hard granitic areas or sand reservoirs the water will be little changed, whilst in sedimentary and evaporate deposits the water may become mineralized or saline as is the case in areas of North Eastern and Coast Provinces.

Most groundwater supplies in Western, Central and Nyanza Provinces contain little dissolved matter and consequently have little conductivity. They are generally soft waters of moderate alkalinity and satisfactory for all domestic purposes from a chemical point of view. Groundwater in other areas is not always favourable. Especially, in Coast and North Eastern Provinces, the water is more saline due to sea water intrusion along the coast and evaporate deposits inland.

Overall, these two provinces plus Eastern Province have generally poor to very poor quality groundwater resources. Further, in these areas, most of the unprotected shallow wells tend to have low bacteriological quality because of contamination by animal droppings and poor drainage/sanitary practices.

Fluoride content far exceeds the recommended WHO drinking-water guideline value of 1.5 mg/l in many areas. The mean value in Rift Valley, North Eastern and Nairobi Provinces are 3.3, 5.7 and 6.6 mg/l respectively. This factor represents one of the more intractable problems with groundwater utilization since fluoride removal is not technically feasible under the prevailing circumstances (see Sectoral Report C for some descriptions).

3.7.3 Locational specific aspects

The following specific locational aspects are noteworthy for taking into account in the subsequent water development studies:

(1) River water

Rivers suffer from pollution by effluent from both point and non-point sources. Most significant non-point source inputs are;

(a) Sediment from soil erosion
(b) Runoff of agricultural chemicals, mainly fertilizers, pesticides and herbicides
(c) Runoff from populated urban areas including discharge of sewage inadequately treated at households

These inputs occur everywhere. Yet, the sources (a) and (b) occur particularly in the high production agricultural areas since in these areas, land use changes, leading to soil erosion and the greatest application of agro-chemicals are dominant. In the ASAL regions, river pollution is predominantly in the form of sediment deposition from soil erosion.

Point source pollution occurs mainly in rivers used as effluent receiving waters in the vicinity of urban centre and industrial complexes and rural factories. Although the number of these locations would be many, noteworthy examples include, but not limited to;

(a) Municipal and industrial effluents:
- Nairobi (Nairobi and Athi rivers)
- Eldoret (Sosiani River)
- Kisumu (Lake Victoria)
- Nakuru (Lake Nakuru)

(b) Factory effluents in non-urban areas:
- Pan African Paper Mill (Wabuye, Nzoia River)
- Chemical and heavy metal pollutants (Sosiani River)
- Several sugar factories on various rivers in western Kenya (Nzoia, Nyando rivers)
- Almost 1,800 coffee factories scattered around the country

One of the major sources of municipal effluents may be outflow from sewage treatment plants if the treatment is inadequate due to insufficiency of treatment capacity (e.g. Nakuru). Pollution by factories' effluents is an increasingly serious issue at many places. Coupled with a large number of the factories, coffee waste is a long standing problem.

It is almost impractical for this master plan study to examine these incidents on individual basis. The matter is therefore taken into account in terms of the preservation of minimum flow to be retained in the river.

(2) Lakes

Water quality problem foreseen for the lakes is variant by each lake;

Lake Turkana:

For several years now, evaporation has exceeded inflows, and the lake water level and area have been reducing. If this is accelerated due to increased water consumption in the upper catchment, the concentration of dissolved matter in the lake water will be increased. If it reaches a level where the existing fauna and flora cannot survive, the existing fishery will collapse followed by the crocodile population. Continuous monitoring of water quality and fauna/flora ecology is important.

Lake Baringo:

A concern has been expressed over many years about the increasing silt load entering the lake from its immediate catchment. Increasing turbidity may have an impact on artisanal lake fishery, though not quantitatively assessed so far. However, this lake is of no use as a domestic water source in view of the high fluoride content.

Lake Naivasha:

Careful attention should be paid as to the possibility of eutrophication of the lake waters due to inflows of nutrient rich water from surrounding irrigation areas. A further source of pollution is domestic waste from Naivasha township. Under these circumstances, diversion of the Malewa River upstream may have some additional impacts.

Lake Nakuru:

Lake Nakuru is receiving the entire volume of insufficiently treated domestic and industrial effluent emanating from Nakuru Municipality. A fear expressed among various agencies is that further increase of the effluent may cause the existing saline-water environment to collapse.

Lake Victoria (Winam Gulf):

It is reported that the open waters of Lake Victoria and the Winam Gulf in general have not been affected to any great extent by human activities. Nevertheless, an increase in some chemical parameters has been noted in the Winam Gulf. Future monitoring is important.

The situation in the Kisumu Bay area is somewhat worse than in the rest of the Winam Gulf and the water quality is greatly reduced in three specific areas; one is off the mouth of Kisat River which receives treated effluent from Kisumu conventional sewage works, another in Yacht Club Bay which receives polluted runoff from two squatter settlements and Nyamasaria sewage lagoons, and the third is car wash bay which receives oil waste and other wastes from numerous water-side eating houses.

It is also reported that the lake water quality is being degraded due to effluents discharged from many other rivers; particularly Nzoia River (Webuye Pan paper mills) and Kuja River (Kisii Municipality, agricultural nutrients from Kisii highlands).

(3) Groundwater

The following are specific aspects to be noted in the groundwater development plan:

(a) In general, relatively low water quality in most part of the country; particularly in the Coast, North Eastern, and Eastern Provinces

(b) High fluoride concentration in some parts of the country; eg. Rift Valley, Nairobi and Eastern Provinces; the water in particular areas cannot be used for human domestic consumption

(c) Bacteriological contamination of shallow well waters, particularly in ASAL areas (e.g. Wajir).

CHAPTER 4 FUTURE WATER DEMAND AND ASSOCIATED ISSUES

4.1 Projected Socioeconomic Condition

4.1.1 Population projection

(1) Population distribution

As noted in Section 2.5, the Study prepared two different population projections;

(i) Original projection principally based on 1979 census data (see Part 1 of Sectoral Report A)
(ii) Revised projection incorporating the provisional results of 1989 census data (see Part 2 of Sectoral Report A)

The revised projection of (ii) above was finally adopted for preparation of this master plan study.

The report on "Population Projections for Kenya 1980-2000" (Ref.20) by CBS officially presents the future populations up to the year 2000. Among three scenarios for projection in the report, Scenario 1 was adopted in the original projection since this has been officially applied in both "Sessional Paper No.1 of 1986 on Economic Management for Renewed Growth" (Ref.11) and "District Development Plans 1989-1993" (Ref.21). Beyond 2000, the total population up to the year 2010 was projected through a quadratic regression method on the basis of the above projection. This was the principal approach adopted in the original projection.

Population distribution by administrative unit is a prerequisite to consideration of water demand and supply distribution in this study. Population distribution by District and by urban centre is based on both population censuses in 1979 and 1989. However, the distribution by Location is assumed by means of the 1979 census, because the detailed results of the 1989 census were not available, as mentioned in Section 2.5. Thus, the future population is projected on the basis of the latest available census data and information presented by the agencies concerned while the study was being implemented. The projection procedure and the applied data are discussed in the Sectoral Report A.

Table 4.1.1 shows the projected District population in the country. The national population is summarized as follows:

(Unit : thousand,%)

Area	1989(Census)*1		1990		2000		2010	
	No.	%	No.	%	No.	%	No.	%
Urban	3,736	17	3,965	17	7,933	26	12,698	32
Rural	17,661	83	18,784	83	22,779	74	27,607	68
Total	21,397	100	22,749	100	30,712	100	40,305	100

Remark : *1 Provisional results in Ref.A08 (Sectoral Report A)
The reason why the population difference between 1989 and 1990 looks large is that the final 1989 census figure of the total population will be revised to nearly 22 million, according to the agency concerned.

(2) Urban population

It was identified in the 1989 census that urban population has not grown as expected in the Sessional Paper (Ref.11), even if the total national population was pondered on why it grew at a lower average rate of 3.4% per annum between the two censuses. The growth rate of urban population was 4.9% per annum, which was fairly lower than the rate expected at 7.1% (the rate of Projection A) in the Paper. In this projection, however, the growth rate up to the year 2000 is assumed to recover to the expected rate of 7.1% per annum, because the urbanization should be accelerated to absorb the coming young labour force in the near future.

In the future, urban areas will extend not only to suburban areas around present urban areas but also to newly organized areas for urbanization. Thus, urban population is projected to be classified into three ranked groups for the sake of identification of newly urbanized areas in addition to existing urban centres. They are: Group 1, comprising populations in urban centres which are enumerated in the 1979 census report (Ref.22) and which are authorized as District headquarters; Group 2, consisting of Local Authorities which are established by the Local Government Act (Ref.23) as of 1990; and Group 3, which is made up of population within Rural Centres, the third ranked Service Centre.

The projection methodology to estimate urban population was also mentioned in the Sectoral Report A. Table 4.1.2 shows the projected urban population by town between 1990 and 2010. The total urban population is estimated at 7,933 thousand by the year 2000 and 12,698 thousand in 2010, as shown in Table 4.1.1. There are 278 towns in the country as shown in Table 4.1.2. However, if the definition of urban centre - settlement with 2,000 persons or more - is applied to the enumerated towns in the table, only 171 towns are counted as urban centres in 2010. In that case, the total urban population is estimated as 12,594 thousand in 2010 or 1.0% less than the originally estimated urban population.

4.1.2 GDP projection

Projection of GDP is fundamentally based on the target growth of the long-range national economic development plan, which is stated in the Sessional Paper No.1 of 1986

(Ref. 11). In the Paper, the economic development policy and strategies are proposed over all economic sectors up to the target year 2000.

Beyond the year 2000, however, the Paper does not refer to national economic growth. Regarding this issue, the Long-Range Planning Unit in MOPND provides a projection programme, though it is not published for official use. According to the core model solution of this programme, the economic growth (GDP) is assumed to be around 4% per annum between 2000 and 2010, if the present economic development policy is maintained continuously. Following suit in this current study, the GDP growth rate beyond 2000 is also assumed to be 4% per annum in the light of economic successiveness.

The GDPs in the years 2000 and 2010 are projected to aggregate K£13.8 billion and K£20.4 billion at 1989 constant prices, respectively. The agriculture sector will remain the leading economic activity in the country, but its share will decrease from 29% in 1989 to 27% in 2000 and to 25% in 2010. On the other hand, the manufacturing sector is expected to grow from 12% in 1989 to 14% in 2000 and to 15% in 2010. Furthermore, of the GDPs in 2000 and 2010, the urban sector will product about K£8.6 billion or 63% in 2000 and K£13.1 billion or 64% in 2010. The details of the respective sectors are shown in Table 4.1.3.

Through these GDP estimation and population projection, Per capita GDP in 2000 and 2010 is estimated to be K£448 (equivalent to US$415) and K£506 (US$468), respectively. Since it was K£333 (US$309) in 1989, it will have grown by nearly 35% by 2000 and by almost 52% up in 2010. Per capita GDP by urban/rural sector is also estimated as follows: (a) urban sector: K£1,089 (US$1,008) in 2000 and K£1,034 (US$957) in 2010; and (b) rural sector: K£228 (US$228) in 2000 and K£265 (US$245) in 2010. Thus, the per capita GDP ratio between urban sector and rural sector will be expected to reduce from 6.3:1 in 1988 to 4.8:1 in 2000 and to 3.9:1 in 2010.

4.1.3 Demand projection of agricultural and livestock products

The Ministry of Agriculture (MOA) is the leading agency for agricultural production in the country. The per capita consumption rates of food commodities are presented by the Crop Development Division of the MOA. According to these rates, diet of urban people is different from that of rural people. Urban people seem to have a growing tendency toward Europeanization in diet. This food preference is reflected in the per capita consumption rates (see Table 4.1.4).

Food demand is calculated as a product of the per capita consumption rates and the projected population. Table 4.1.4 shows food demand in 1990, 2000, and 2010. Domestic production and/or imports of the four major agricultural products below are expected to achieve the following targets for food security in 1990, 2000, and 2010:

(Unit: 1000mt)

Products	1990	2000	2010
Maize	2,744	3,631	4,700
Wheat	286	424	590
Beef	175	249	339
Milk	1,706	2,345	3,116

Future production of cash crops is estimated through interpolation or extrapolation method on the basis of the target projection in the Sessional Paper. Thus, the target production in 2010 is summarized as follows: 603 thousand metric tonnes of coffee; and 366 thousand tonnes of tea.

4.1.4 Industrial production projection

According to "Statistical Abstract 1990, CBS" (Ref.24), the latest industrial production and value added in 1988 are given as K£6,103 million and K£798 million, respectively. Among the various manufacturing industrial types, the food, beverages and tobacco industry contributed the biggest share of 40% in industrial production, which also listed the largest number of establishments. It is also anticipated that this agro-based industry will continue to lead the manufacturing industry in the national economy in the future.

The total value added of manufacturing sector in 2000 and 2010 is projected to be KShs.38 billion and KShs.62 billion at 1988 constant prices, respectively. District distribution of the projected value added is shown in Table 4.1.5. Among the Districts, Nairobi will attain the largest value added of KShs.18 billion in 2000 and KShs 29 billion in 2010. The top five Districts regarding value added attainment are Mombasa, Nakuru, Kiambu and Kisumu as well as Nairobi, which account for KShs.44 billion in 2010 or 71% of the national total.

4.1.5 Public expenditure projection for development

Inadequate public finance is one of the most serious constraints for project implementation in developing countries. In formulation of projects in the current study, this is also considered to play a serious role. Investment ceiling of public finance for projects is laid out by the government policy. In this context, the policy is the most important decisive factor for project formulation, which is declared in the development plans and is usually piled on top of the accumulation of the past capital formation. From this point of view, a principle case of public development expenditure will be estimated in the following procedure:

1) The total expenditure by the central government is estimated in proportion to GDP. Its rate is expected to be 44%. The development expenditure accounts for a quarter of the total expenditure.

2) Capital expenditure is assumed to be 52% of the development expenditure.

3) 20% of the development expenditure will be spent on projects related to water development, 37% of which will be disbursed by the MOWD.

Table 4.1.6 shows the trend projection of public expenditure estimated based on the above assumptions. The public expenditure for development projects related to water schemes is expected to amount to K£476 million in the fiscal year 2010 at 1989 constant prices. Its total amount cumulated from 1992 to 2010 will be K£6.8 billion, equivalent to US$6.3 billion at 1989 prices.

4.2 Domestic and Industrial Water

4.2.1 Domestic water demand projection

In terms of water demand projection, the Design Manual for Water Supply in Kenya stipulates standards and criteria. (Details are shown in Design Manual)

- Planning horizon:

present	1990
future	2000
ultimate	2010

- Residential demand

population projection:	as explained in Section 4.1
service type:	
potential in rural area:	high, medium and low potential areas measured by overlaying administration map on agro-climatic map by GIS
urban housing class:	The following figures were adopted: high class 5 % medium class 70 % low class 25 %
individual connection rate:	See Table 4.2.1

- Livestock demand

livestock population:	as explained in Section 4.4 below

The distribution of livestock population is assumed to be proportional to population distribution. In urban areas, per capita livestock holding is assumed to be one forth of that in rural areas.

- Institutional demand

	Rural	Urban
boarding schools (pupil/pop.)	2 %	2 %
day schools (pupil/pop.)	28 %	28 %
Inpatient hospital (bed/1,000pop.)	0	29.9
outpatient (pop./1,000pop.)	2.5	2.5
administration officer (pop./1,000pop.)	0	83.6

- Commercial demand

hotels	High (bed/1,000pop.)	0	4
	Medium	0	8.7
	Low	5	4.5
shops (no./1,000 pop.)		0	23.6

- Industrial water demand

Separately estimated as explained in Subsection 4.2.2 below.

Unit water consumption rates: as shown in Table 4.2.2

Domestic water demand projection was made on a Location basis. The results are presented in Sectoral Report D.

4.2.2 Industrial water demand projection

As discussed in Section 4.1 before, industrial water requirement was estimated as a product of three components : 1) the number of manufacturing establishments by industrial type; 2) value added (VA) of respective industrial types; and 3) unit water consumption rates (cubic meter per value added (KShs.billion)) by industrial type.

The former two components were already combined and estimated as "District" distribution of VA which aggregated for all industrial types into a manufacturing sector in Table 4.1.5 in Section 4.1. The distribution is broken down to the "Location" level up to the target year 2010.

Since information on unit water consumption rates by industrial type in Kenya is not made public, consumption rates which were surveyed in Japan in 1986 as indicative of industrialized conditions, were applied for estimation of water requirement with the following modification:

1) Monetary values such as production and value added are transferred by following foreign exchange rates: KShs16.2/US$ and J¥160/US$ (year 1986).

2) Water recirculation system was not taken into consideration in estimation of the industrial water consumption in 1988. It was assumed that water recovery would reach the level of half of the recovery rate achieved by industrialized countries. For instance, the food, beverages and tobacco industry consumes 8,330 cu.m./day/KShs. billion of value added in 1988, but it would reduce net water consumption to 6,610 cu.m./day/KShs. billion in 2010, as shown in Table 4.2.3.

3) Industrial water requirement by "Location" was estimated by distributing the value added to each location.

Table 4.2.4 shows the water requirement of manufacturing industry by District to the year 2010. In 2010, water demand in Nairobi was estimated at 282 thousand cu.m./day, accounting for 57% of the national total requirement. Secondly, Mombasa accounts for 14% or 67,000 m^3/day. Manufacturing establishments in Nakuru, Machakos Kiambu, Kilifi, Uashin Gishu and Kisumu Districts would also consume plenty of water.

4.2.3 Total domestic and industrial water demand

Total domestic and industrial water demand for the whole of Kenya is estimated below and the breakdowns by District are shown in Tables 4.2.5 through 4.2.7.

Total domestic and industrial Water Demand in Kenya

unit : Thousand m^3/day

		1990	2000	2010
Urban	Residential	491.2	1,004.5	1,642.9
	Non-residential	82.2	164.4	263.2
	Sub-total	573.4	1,168.9	1,906.1
Rural	Residential	376.2	560.2	932.6
	Non-residential	155.9	189.1	229.1
	Sub-total	532.1	749.3	1,161.7
Livestock		326.7	426.5	621.4
Industry		218.7	377.5	494.0
Total		1,650.9	2,722.2	4,183.2
Overall per capita (l/c/d)		73	89	104

Livestock water demand is also shown as a part of domestic water.

As shown above, the potential demand for residential water in the urban areas and industrial water is projected to grow rapidly due to rapid urbanization and industrialization. Per capita levels of water consumption including livestock consumption seem moderate when taking into account the large livestock population in the country.

4.3 Irrigation Water Demand

(1) Irrigation Development Projects

About 160 irrigation schemes with total area of about 118,000 ha have been proposed by various agencies. Table 4.3.1 shows the area and numbers of these irrigation schemes in each District. Water demand calculations were made only for those schemes which have enough information for estimation, such as the area and location of the schemes.

(2) Water Demand

The calculation method described in Section 3.3 was applied to estimate the future irrigation water demand. For estimation of water use by private small schemes (Mode C in Subsection 3.2.2), an attempt was made to assess the past trend of water abstractions appearing on the water abstraction permit data for each drainage basin as shown in Figure 4.3.1. As can be seen in the figure, it was not possible to establish a trend for all basins. Thus, it was assumed that future increment of water use by private small schemes would be almost equal to the average annual increase rate of water permit amount issued in the past.

Aggregating all irrigation water uses, monthly water demand in 2010 was estimated as shown in Table 4.3.2 (by sub-basin) and as summarized below (country total).

Water Demand in 2010

Unit m^3/sec

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	annual
93.4	100.4	126.1	133.9	143.9	130.4	110.2	128.6	158.6	184.3	162.5	146.4	134.9

4.4 Livestock Water Demand

4.4.1 Livestock population

Estimation of future livestock population was based on a rather simple projection method that the livestock population would grow to meet the increase in demand of milk and meat. The growth of milk and beef consumption was determined by applying per capita consumption rates and estimated human population as shown below :

Calculation of Milk and Beef Growth Rate

	1988 Production (million ton)	Per capita consumption (kg)		Population in 2010 (million)		2010 Production (million ton)	Annual Growth Rate %
		Urban	Rural	Urban	Rural		
				12.698	27.607		
Milk	2.163	88.6	72.1			3.116	1.67
Beef	0.227	11.9	6.8			0.339	1.84

Assuming that dairy cattle and camel populations will increase at the same rate as the milk production trend and beef cattle and sheep/goat populations will increase with the beef production trend, then livestock population by district was estimated for 1990, 2000 and 2010 as shown in Table 4.4.1. The present livestock population of 11.5 million Cattle, 15 million Sheep/Goat and 0.7 million Camel will increase to about 17 million Cattle, 22.5 million Sheep/Goat and one million Camel in 2010.

4.4.2 Livestock water demand

By applying unit water requirement of 50 l/day/LU and the estimated livestock unit (see Table 4.4.2), future livestock water demand was estimated at about 142 million tons per year in 2000 and 170 million in 2010(*1). Table 4.4.3 presents livestock water demand by sub-basin and Table 4.4.4 shows the water demand by District

4.5 Wildlife and Fishery

4.5.1 Wildlife watering

No accurate information could be obtained with regards to the population of wildlife nor water demand for the wildlife species as described in Section 3.4.1. The future population of wildlife is also not known. The Study assumed that the future water demand would not be significantly different from the present level of 21,000 m^3/day as estimated in Section 3.4.1.

4.5.2 Inland fishery

Future fish production demand was estimated at 222,000 tons(*2) in the year 2010, however it was not possible to allocate this demand projection to the three fishery activities, i.e. marine fishery, lake fishery and fish farming. The future fish farming activity was therefore based on the trend of fish farming production. The production of fish farming was estimated at about 2,240 tons(*3) in the year 2010.

(*1) In the final estimate of the demand in Sectoral Report D, the larger figures were derived through the calculation on each location basis. Those larger figures were final adopted in subsequent water balance/supply planning studies.

(*2) 40,305,000 person x 5.5 kg/person = 222,000 tons

(*3) Trend projection of fish farming activities from past 10 years. See Figure F3.7 of Sectoral Report F.

Assuming it is possible to achieve a national production of 2.5 t/ha in future, 896 ha of ponds would be required to produce 2,240 tons of fish. Taking into account the above assumption, the total fish farming water use in the year 2010 was estimated at about 28.6 MCM or 0.906 m^3/sec. Required 896 ha ponds will be absorbed by newly constructed reservoir which will be implemented under the dam development plan towards 2010. This dam development plan will bear about 23,000 ha of reservoir.

4.6 Hydropower Development

KPLC has prepared power and electrical energy demand projections in two studies; one is in "National Power Development Plan (1987)" and the other in "Feasibility Study for A Geothermal Power Station at East Olkaria (1990). Both projections set out three forecast scenarios - low, median, and high forecasts. The results of the two studies are shown in Table 4.6.1 and 4.6.2 respectively. The former forecast has recently been updated by adding available data to 1989 in a report "1990 Interim Update of National Power Development Plan 1991 to 2010", and its results are shown in Table 4.6.3.

Power demand will continue to increase at 5.5% per year towards the year 2000 and beyond that at 6.0% to 2010. The most prospective source developments to meet future demand would be geothermal and hydropower, according to the report.

4.7 Balance between Demands and Available Water

4.7.1 Balance for surface water

(1) Perennial River Model

Perennial river model for surface water balance calculation was established according to the following procedures;

(a) Catchment

Subbasins with a perennial main river were further divided into sub-basins taking the location of potential damsites and the confluence of tributaries into considerations.

(b) Point of water balance calculation

Water balance was calculated at the following points;

(i) downstream end of catchment,
(ii) confluence, and
(iii) immediate downstream of potential damsite

(c) Naturalized discharge

Naturalized discharge, defined herein as the natural discharge before any water abstraction, was estimated for each subbasins with a perennial river. In the Study, the objectives of the estimation of naturalized discharge were to (i) clarify the water deficit by subbasin during low flow discharge with 10-year probability and (ii) to specify subbasins where a water deficit will occur in the year 2010.

The generation of naturalized discharge was carried out on a monthly basis for 30 years by either of the following 3 methods; namely, (i) preliminary water balance model for Drainage Area 1, (ii) discharge correlation for major rivers, and (iii) runoff ratio in semi-arid areas on the basis of that analyzed for the Tsavo River. (See Appendix B6 of Sectoral Report B.)

Table 4.7.1 shows the run-off ratio of perennial rivers in Kenya. The annual runoff in the Table is the naturalized discharge at the downstream end of the river basin. Table shows that about 9.5 % of annual rainfall depth flows down through main river channels. The isohyetal map of annual average runoff depth is shown in Figure 4.7.1 and that of minimum monthly runoff depth is also shown in Figure 4.7.2.

(d) Demand

Water balances in the years 1990, 2000, and 2010 were calculated by subtracting the future demand from the naturalized monthly discharge for 30 years. The future demand was first organized into domestic, industrial and livestock demands (First Trial). However irrigation demand was not calculated on the premise that the irrigation water would not be abstracted at such a critical drought period as occurring once in 10 years.

Secondly, after ensuring the water sources for domestic, industrial and livestock demands, the irrigation demand on monthly basis in 2010 was examined in the surface water balance calculation (Second Trial). The monthly irrigation demand was then subtracted in case that the simulated monthly discharge ensures the 80% dependability.

(e) Flow regulation by existing dam

Flow regulation of existing dams was considered in the generation of naturalized discharge in the upper reach of the Tana River. Therefore, the naturalized discharge estimated for the Tana river basin represents the flow regime with-dam condition.

While, in the remaining subbasins, the naturalized discharge was estimated without-dam condition.

(2) Water Balance between Demand and Available Surface Water

Perennial river model and its results of water balance calculation of the First Trial were given in Appendix M.3 of Sectoral Report M. The water balance calculation for the years 1990, 2000, and 2010 was carried out taking the increase of domestic and industrial demands into considerations. The subbasin having a deficit of surface water on regional basis has already been identified in 1990, especially where urbanized areas are located. Such an area will expand gradually in proportion to the increase of domestic and industrial demands toward the year 2010 as shown in Figure 4.7.3.

4.7.2 Balance for groundwater

As analyzed in Subsection 2.4.4, the total groundwater yield (in terms of safe abstraction rate) of the country was estimated as 193 million m^3/year for boreholes and 426 million m^3/year for shallow wells.

Similar to the case of surface water, the water balance expressed as maximum exploitable groundwater volume above vs. total water demand was examined by subbasin as shown in Figure 4.7.4.

4.7.3 Balance between water demand and potential available water

Similarly, the water balance between the total demand and the total available water sources (surface water & groundwater) was assessed on regional basis for each subbasin. The results are shown in Figure 4.7.5.

To clarify the potential of surface water and groundwater is the one of indexes defining the subbasins which requires the construction of storage dams or water transfer scheme. Table 4.7.2 shows the subbasins having deficit in the years 1990, 2000, and 2010 and major demand centers in the respective areas. Many urban centers are located astride a few subbasins, so the same urban area is mentioned as the major demand center in a few subbasins.

CHAPTER 5 STRATEGIES FOR WATER RESOURCES DEVELOPMENT AND USE

5.1 Problem Areas

In Kenya, readily available surface water has already been consumed in subbasins with major water demand centres as described in Section 4.7 (Figure 4.7.5). Although groundwater use has been exploited in the whole country, the estimated groundwater abstraction rates show a rather small volume of groundwater use of 57.2 MCM/year comparing it with surface water use of 1,071.7 MCM/year during low flow seasons (Subsection 3.1.1). Water harvesting, which has been practiced for many years in ASAL regions, is particularly suited for small domestic and livestock demand. Therefore, surface water flow is predominantly utilized in Kenya.

The provision of piped water to a community has grown considerably. For example, less than 7% of the population had access to clean water in 1963 while 15% of the population had accessed to piped water in 1978. The situation continues to improve with the current government policy.

There are relatively more abundant water sources in the high potential land areas than in the medium and low potential land areas, and this is reflected in the distribution of population and the level of economic development. In pace with rapid socio-economic development in the high potential areas, subbasins with surface water deficit are expanding gradually. On the basis of the results of water balance calculation (see Table 4.7.2), relatively large deficits will occur in the year 2010 in many places particularly in the subbasins where Nairobi, Mombasa, Nakuru, Machakos, Eldoret, Kitui, Nyahururu and Kakamaga are located.

In subbasins with a seasonal river, no surface water is available during 10-year drought. The combination of groundwater development and rainwater harvesting is necessary for securing permanent and reliable water sources in these areas. For the development of groundwater, it is cheaper to supply water from a shallow well than from boreholes.

5.2 Hydrological Planning Criteria

5.2.1 Safe yield

The concept of safe yield is defined in the "Design Manual for Water Supply in Kenya (MOWD)" as follows;

(1) For principal towns and urban centers:

The 96% - probable daily low flow shall be regarded as the safe yield of a river. The flow - frequency analysis shall be made by using the lowest recorded daily flow of each calendar year for which records are available for the dry season.

(2) For rural areas and local centers:

The 96% - probable monthly low flow shall be regarded as the safe yield of a river. The flow-frequency analysis shall be made by using the recorded lowest average flow during one calendar month for each year for which records are available for the dry season.

Since rivers having daily discharge records with long duration sufficient for probability analysis are limited in number, long-term river discharges over the country had to be generated on the monthly basis.

An attempt was made to analyze the relationships between the probability of daily discharges and that of monthly discharges. Incorpolated in this analysis were the discharge records at 15 water level gauging stations having daily discharge records for more than 15 years with a few missing data. The data, however, are not for 15 consecutive years. At first, the flow - frequency analysis was made by using the lowest recorded daily flow of each calendar year and the probable low daily discharges were estimated for the recurrence intervals of 2, 5 and 10 years. Secondly, the flow duration curves by station were developed by sorting all the monthly data in descending order.

Table 5.2.1 shows that the relationship between the probable daily low flow discharges and flow duration curve on monthly basis. The probability of daily low flow discharges is equivalent to the following duration on a monthly basis.

Recurrence interval (years)	Duration on monthly basis (%)
2	95.6
5	99.2
10	99.8

Therefore, the recorded minimum monthly discharge can be regarded to be almost equivalent to the daily discharge with the probability of once in 10-year. In case that a water supply system is designed on the basis of recorded minimum monthly discharge, the supply failure would occur for 20 days on an average in 10 years. While, in case that the design discharge having 96 % - probable monthly low flow discharge is adopted at rural areas as mentioned in the "Design Manual for Water Supply in Kenya", its probability of daily low flow discharge is equivalent to the recurrence interval of once in about 2 years on average.

5.2.2 Maintenance of minimum flow

Maintenance of the minimum flow in perennial rivers is not mentioned in the "Design Manual for Water Supply in Kenya". However, it was deemed necessary to maintain certain amount of water for conservation of natural river environment, groundwater resources, people's amenity, etc. The minimum flow of perennial river is also an indicator of the allowable limit of water withdrawal from the river. The concept of minimum flow is schematically illustrated in Figure 5.2.1.

In the water balance calculation in the Study, the recorded lowest daily discharge was assumed as minimum flow to be maintained. It is noted that this is a tentative assumption used in the Study. In actuality, the required minimum flow is variant by river and hence should be assessed separately for each river.

The ratio of recorded lowest daily discharge to annual average discharge was roughly estimated at 6.2% on an average on the basis of the discharge record at the aforementioned 15 stations.

5.3 Domestic and Industrial Water Supply

5.3.1 Domestic water supply policy

The latest statement on the water supply policy is shown in the current Five-Year National Development Plan for the period from 1989 to 1993 as "During 1974, Government promulgated the National Water Plan with the express aim of ensuring the availability of potable water to within 4 kilometers of every household by the year 2000.". The earlier documents made statements ensuring of piped water by the year 2000.

Targets during the current five-year development plan period are to increase the proportion of the population having access to water in the rural areas from 26% (4.91 million people in 1987) to 50% (11 million people) by 1993 and in the urban areas from 75 % to 95% by 1993.

Taking into account the Government policy on the water supply sector, this Study assumes provision of safe and sustainable water supply to all the population by the year 2010.

5.3.2 Urban and rural centres

Surface water for urban water supply has been predominantly utilized among water resources in Kenya. The demand for surface water is constantly increasing due to expansion of urban centres. In selecting towns to which urban water supply systems is to be provided, two criteria were taken;

- towns nominated as urban centre, or
- towns to have a population of more than 5,000 by the year 2000

Then, 158 urban areas were selected.

5.3.3 Supply measures

Long Term Guideline of Infrastructure Facilities in Various Level of Centres (source :PPD's Chart for Urban and Rural Organization) in the Design Manual stipulates the following guideline for the water supply:

Centre	Population Served	Population Resident	Water Supply
Principal	>1,000,000	>100,000	Piped Grid Water Supply
Urban Centre	>100,000	>5,000	Piped Grid Water Supply
Rural Centre	>50,000	>2,000	Piped Grid Water Supply
Market Centre	>15,000	Negligible	Communal Points Water Supply
Local Centre	>5,000	Negligible	Communal Points Water Supply

In this Study, bulk water supply systems were planned for the above 158 service centres including Principal Towns and Urban Centres, and other service centres were considered to be covered by area/rural water supply. In principle, rural water supply in the high potential areas and part of the medium potential areas where permanent surface water is available, will be covered by piped water supplies from surface water sources. The remainder of the medium potential areas and low potential areas will be covered by spot supply mainly from groundwater, water harvesting or others.

As for the distribution of the water, piped water supply with treatment is essential for the surface water while groundwater is supplied by piped water system basically without treatment.

5.3.4 Urban water supply development

(1) Water Availability

In Kenya, meteorological and hydrological conditions differ largely from Location to Location, and there are few or no reliable surface water sources in ASAL areas.

Demand for water supply is almost constant throughout the year and therefore unregulated seasonal rivers can not be relied on as water sources, while safe yield of perennial rivers are to be set at reasonable occurrence of supply failure.

Safe yield of the surface water development is based on the 10-year drought which is almost equivalent to the recorded minimum monthly discharge for 10-year period as discussed in previous Section.

Availability of groundwater resources both in terms of quantity and quality is as explained in Section 2.4. The groundwater sources, if its quality is suitable for drinking, require least cost for treatment. However, uncertainty of successfully exploiting the planned quantity of groundwater, the often shortening of the lifetime of boreholes owing to screen trouble ,etc. and the high exploitation, operation and maintenance costs of boreholes give rather low priority to groundwater development. Hence, groundwater development for the urban domestic water supply might be limited to the following Locations;

- Locations having no reliable surface water sources
- Locations with low demand density which will result in a high cost of surface water supply

In the two types of Location mentioned above, rain water harvesting was also taken into account. Details on the availability of water by Location are shown in Sectoral Report M.

Springs, in general, provide good quality water at low cost. However, most of the spring sources are already utilized, excepting several springs like Mzima. Therefore, spring source utilization in future is considered as continuation of the present use with improvement (spring protection).

(2) Supply areas

The supply area of the water supply system was estimated assuming population density of three income classes and their shares as follows:

Income class	Density (Persons/ha)	Ratio (%)
High income - low density	40	5
Medium income - medium density	130	70
Low income - high density	300	25

(3) Urban sewerage

Urban sewerage is necessary for protection of urban environment and human health when the potential water demands are met by water supply development. It was considered that the urban sewerage system development be made in such a way as to keep pace with the urban water supply development.

5.3.5 Rural water supply development

The rural areas have wide varieties in their land potentials, population densities, etc. In some Locations, there are more than two service centres, but there also are Locations having no service centres. Therefore, uniform approach to the rural water supplies may mislead the Study. So the following approaches were taken in this Study:

(1) Land potential

According to the agro-climatic zoning, Locations are classified into high, medium, and low potentials (same as demand estimate).

(2) Water source

According to assessment of accessibility to the surface water sources (rivers and streams - PR index), sources of the rural water supplies were allocated to surface water and/or non-surface water as follows:

PR index - 1	:	100% surface water
PR index - 2	:	75% surface water
PR index - 3	:	50% surface water
PR index - 4	:	25% surface water
PR index - 5	:	100% non-surface water

As the representative of non-surface water sources, groundwater (boreholes or shallow wells) was assumed. In evaluating groundwater resources in each Location, the following four parameters were introduced (see Sectoral Report M for details):

GA	:	existing groundwater development activity
GQ	:	groundwater quality
GS	:	share between borehole/shallow well developments
GC	:	groundwater exploitation cost

Other potential water sources, such as roof catchment, small dams, subsurface dams and rock catchment, were also examined.

5.4 Livestock Water Supply

Waters to support livestock industries should be conserved (surface water) or exploited (groundwater) everywhere as required.

(1) Urban area

Livestock water needed in urban areas, though not much in quantity, will be supplied by piped water supply system in conjunction with domestic and industrial water supply.

(2) Rural area

The Study assumes that livestock will be supplied with water basically at water source points (rivers, small dams, boreholes, etc.). Source development for livestock watering was evaluated by Location as well as that for rural domestic water supply.

Another target may be the expansion of nomadic pasturage activities in semi-arid and arid areas in the wet period when the pastures grow there. Such areas cover approximately 349,000 km^2 in total. The Study proposes to provide watering points (boreholes or shallow wells with windmill pump) in nomadic pasturage areas in arid lands.

5.5 Development of Irrigation Systems

5.5.1 National policy

According to the Sixth Five-Year Development Plan 1989-1993, the Government set up irrigation development targets for the period to be as follows:

Irrigation Target (1989 - 1993)

Unit : ha

Targets	1989	1990	1991	1992	1993
Present	33,000	34,380	35,760	38,440	41,880
Increment	1,380	1,380	2,680	3,440	3,670
Total	34,380	35,760	38,440	41,880	45,550

This Development Plan emphasizes a low cost approach in the implementation, and the small scale irrigation projects and utilization of gravity flow are given preference.

5.5.2 Irrigation potential

Potential of irrigation development in the whole of Kenya has been assessed at about 540,000 ha by the study of National Master Water Plan Stage I (NMWP-I) in 1980, while a recent study carried out by Euroconsult (Options and Investment Priorities in Irrigation Development (SOIPID)) in 1987 estimated total potential area for irrigation to be about 244,000 ha. The table below gives a comparison of these two estimates for five river basins with inclusion of existing irrigation area.

Estimated Irrigation Potential

(Unit : ha)

Basin	Existing	Study in 1980	Study in 1987
Tana	25,900	205,000	90,900
Athi	28,200	40,000	49,500
Lake Victoria	5,600	200,000	57,400
Kerio Valley	4,000	64,500	31,200
Ewaso Ng'iro(N)	1,300	30,000	15,700
Total	65,000	539,500	244,700

In this Study re-assessment of irrigation potential in Kenya was carried out by comparing water availability with irrigation water requirements and with area of land expected to be good for irrigation development. Development of groundwater would be accorded a higher priority for domestic and livestock water usage, however irrigation potential by groundwater was also examined. The details of the derivation of irrigation potential is included in Sectoral Report E. The findings are summarized as follows:

(1) Irrigation potential by surface water

Land resources

Information on soil and topography was evaluated to estimate the extent of land potentially suited to irrigated agriculture by applying GIS technology. Figure 5.5.1 and Figure 5.5.2 shows the distribution of the land suitable for upland crops and lowland crops, respectively. The total area suitable for irrigation in Kenya was assessed to be about 13 million ha for upland crops and about 11 million ha for lowland crops if water availability is disregarded.

Crop Land Potential in Kenya

Unit : million ha

Crop	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Upland Crops	2.57	1.77	2.05	3.86	2.99	13.23
Lowland Crops	0.74	1.68	1.46	3.25	3.64	10.77

Irrigation potential

Estimation of the irrigation potential for each subbasin were derived through matching monthly flow (mean flow; see Table 5.5.1) and irrigation demand (see Table 5.5.2) and including the following assumptions:

1 Domestic and livestock water usage takes priority over irrigation
2 Return flows are disregarded
3 Surplus water is allocated to downstream requirements following river system as illustrated in Figure 5.5.3
4 No storage facilities are considered
5 Irrigable area is limited to be the area accorded to have land potential as assessed above

Calculation of the water balance between water demand and available water indicates that about 470,000 ha of land is available for upland crop irrigation and 340,000 ha is available for lowland crop irrigation. A basin-wise breakdown of the irrigation potential is indicated below and Table 5.5.3 shows irrigation potential area of each subbasin.

In addition, irrigation potential under 80% dependable flow was also estimated in the same way. The results are shown also in Table 5.5.3.

Irrigation Potential Area by Surface Water

Unit : 1000 ha

Crop	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Upland Crops	214.2	84.3	22.4	132.7	16.0	469.6
	(178.5)	(52.0)	(21.0)	(89.2)	(9.3)	(350.0)
Paddy	136.6	47.9	21.9	117.3	14.6	338.3
	(114.7)	(33.1)	(20.3)	(85.0)	(8.5)	(261.6)

Note : Parenthesized figures shows the results for applying 80% dependable monthly flow.

(2) Irrigation Potential by groundwater

Groundwater quality

Water quality is one of the important factors to evaluate irrigation water. The quality of groundwater was evaluated for 1,169 boreholes which have water quality data (see Sectoral Report C for detail). Based on the FAO's evaluation guideline, the criteria for this evaluation was set out as shown in Figure 5.5.4.

Based on the isoquality map presented in Figures 2.4.8 through 2.4.20 and the criteria (see Figure 5.5.4), Figure 5.5.5 was prepared to clarify the distribution of good quality ground water area for irrigation

Land resources

Estimation procedure is almost the same as that for surface water. Areas reduced from agricultural potential land are township,forest & park, road and poor water quality areas. Remoteness of agricultural potential land is not considered for estimating crop land potential

Figure 5.5.6 and Figure 5.5.7 shows the distribution of the land suitable for upland crops and lowland crops respectively. The total area suitable for ground water irrigation in Kenya is about 9 million ha for upland crops and about 7 million ha for lowland crops.

Crop Land Potential in Kenya (Groundwater)

Unit : million ha

Crop	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Upland Crops	1.88	2.12	1.29	1.80	2.08	9.17
Lowland Crops	0.41	2.43	0.65	1.33	1.90	6.72

Irrigation potential

Irrigation potential for each subbasin were derived through matching groundwater availability (see Table 5.5.4) and irrigation water demand (see Table 5.5.2) and including the following assumptions :

1 Available groundwater is calculated by multiplying land potential area with unit groundwater yield,
2 Return flows are disregarded, and
3 No transfer of waters between subbasins

Calculation of the water balance between water demand and available water indicates that about 1,500 ha of land is available for upland crop irrigation and 1,000 ha is available for lowland crops irrigation. A basin-wise breakdown of the groundwater irrigation potential is indicated below.

Irrigation Potential Area by Groundwater

Unit : ha

Crop	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Upland Crops	598	544	372	0	0	1,514
Lowland Crops	155	660	210	9	4	1,038

(3) *Comparison of estimated irrigation potential*

The irrigation potential in Kenya has been estimated in two previous studies, namely, NMWP-I in 1980 and SOIPID in 1987. The table below shows their estimated figures for each river basin together with the estimate by this Study.

Estimated Irrigation Potential

Unit : ha

		NMWP-I	SOIPID	this Study		
		Surface Water*	Surface Water*	Surface Water*	Surface Water**	Ground Water
1	Lake Victoria	200,000	57,400	214,000	178,500	600
2	Kerio Valley	64,500	31,200	84,300	52,000	540
3	Athi River	40,000	49,500	22,400	21,000	370
4	Tana River	205,000	90,900	132,700	89,200	0
5	Ewaso N'giro (N)	30,000	15,700	16,000	9,300	0
	Total	539,500	244,700	469,600	350,000	1,510

Note * monthly mean flow was applied.
** 80% dependable monthly flow was applied.

5.5.3 Irrigation development

As mentioned in the previous section, Kenya seems to have a fairly large potential for irrigation. At present, only 14 % of the potential area is irrigated. Priorities of further development of irrigation would be given to the following:

- small scale irrigation scheme (low cost development)
- irrigation area adjoining densely populated District or Location (many beneficiaries)
- the area where the agriculture would only be possible by provision of irrigation water (food security in strategic area)

5.6 Wildlife Watering

Wildlife is one of the most important tourism resources in Kenya. The National Park or Game Reserve areas need to be conserved for this purpose. According to information from the Kenya Wildlife Services (KWS), the present condition and issues in each National Park/Game Reserve in terms of water development are summarized in Table F2.4 of Sectoral Report F.

About half of the National Park/Reserve will require artificial water facilities; such as rehabilitation of existing water sources, new boreholes, and new small dams.

Nevertheless, the major water sources for livestock will remain to be rivers and other natural surface waters, which should be conserved with utmost care. The rivers which would call for careful attention for wildlife conservation are:

Rivers closely relevant to wildlife conservation

Amboni	Kimakia	Mathioya	Ongorit
Bisanadi	Kindani	Mderit	Rojewaro
Bwatheroagi	Kinna	Mulika	Rombo
Chania	Kiolu	Murubara	Rupingazi
Dawa	Kipsonoi	Mwatate	Sandai
Ewaso N'giro	Kirtiget	Mzima	Saoumua
Hembe	Kogou	Naishi	Seiya
Irati	Kurera	Narok	Syapei
Isiolo	Lamuriak	Ngare Karoh	Tsavo
Itake	Loolturesh	Ngare Mars	Tana
Kakungu	Magura	Ngeny	Thiba
Kanjoo	Makalia	Ngosorr	Turkwell
Karmar	Malewa	Njangiri	Tuthu
Katundu	Mara	Njoro	Wanjohi
Kerio	Maragwa	Nyamindi	Wei Wei
Kesup	Maringato	Olambwe	

Source: Kenya Wildlife Service

5.7 Fishery Development

Although the current national development plans contain no specific goals for aquaculture development, it can be presumed that the strategies set forth for agriculture be applied to this sector. The sector is important in terms of both foreign exchange earnings and contribution to national economic growth. Likewise fish is one of the major commodities to be supplied to domestic market.

In the wake of the Government strategies to exploit the fisheries potential in both marine and inland fisheries, many projects have been carried out by many agencies including the Department of Fisheries, LBDA, TARDA and KVDA.

5.8 Source Development

Balancing water demand and supply is the requisite for water resources development and use. In balancing, the level of supply reliability to be selected is one of the key factors of development planning. If a high level is selected, water resources development facilities will become expensive. If a lower level is selected, facilities will be cheap, but supply failures will often take place.

In Kenya, many water supply systems depend on unreliable water sources, and such systems have been subject to frequent supply failures for long periods. Such supply failure is one of the reasons that inhabitants in the service area are reluctant to support the water supply systems. It is a fact that some systems having received less support have been poorly maintained to the extent of breaking down.

The water holding capacity of the watershed areas in Kenya is generally low and river flows reach their minimum flow almost every two years or so. Also a low level of supply reliability, for example 80 % dependability, causes supply failure almost every two years or so. Therefore, a rather high supply reliability is to be selected not only for the benefit of water users but also for the sustainability of water resources development facilities themselves.

Water source development shall proceed from less expensive sources to expensive ones, in principle. Development of clean and perennial flow (river or spring) by gravity transmission is the cheapest. However, most such sources have already been utilized. In this Study, every development measures are to be sought in order to balance water demand and supply.

Source development such as interbasin water transfer to closed river basins may become environmental issues. If environmental issues are to be considered on priority basis, it may cause other social and economic issues. Hence source development for balancing water demand and supply is examined first and related issues are examined separately.

5.9 Hydropower Development

At present, hydroelectric generation plays a key role in the supply of electric power in the country. The importance of hydropower will not change in the future. One of the major aspects in the energy policy of the country is the continued rapid development of hydro and geothermal potentials for electricity generation. As a result, power generation in the country will take an exceptional position compared to that of other countries in that a significant proportion of the base load will be supplied from geothermal and hydroelectric services.

In the Update of National Power Development Plan drafted in 1991, the following generating facilities were recommended for development by 2010 after completion of the Kiambere project. The recommended generation plan is organized into;

384 MW of hydroelectric plant (including Turkwel)

394 MW of geothermal
400 MW of low speed diesel
90 MW of medium speed diesel
60 MW of gas turbine

As a result of the above expansion of the power generating facilities, the share of power plants by type in the year 2010 will be as follows:

Power Plant	1989	2010
Hydropower	71.3%	47.1%
Geothermal	6.5%	23.5%
Steam thermal	12.7%	0%
Gas turbine	6.9%	3.2%
Diesel	2.6%	26.2%
Total	100%	100%

The above table shows that the share of hydropower plants in 2010 will still be the highest. In such circumstances, the primary reservoir operating policy may be to maximize the production of firm energy. This may tend to draw down the reservoir water level only when necessary.

Another aspect is that the stacking position of hydroelectric power plants on the load duration curve will gradually change from base load portion to peak load portion in progress of the development of base load generating plants like geothermal plants. Increase in peak load may require the addition of new peak power supply station(s) to the future system, which may be hydropower or gas turbine.

One of the measures for meeting the increasing peak load will be the capacity addition to existing hydropower stations. In fact, installation of the third unit at Gitaru is scheduled in the Update of National Power Development Plan (draft).

5.10 Flood Mitigation

5.10.1 Basis for setting the target and strategy

As noted in Chapter 3, floods appear to be still a less serious problem in Kenya compared with needs for development in other sectors (eg. domestic water supply, agricultures, livestock, etc.). The extent of damage to lands/properties and loss of human lives is still at a relatively small level, though it is foreseen to increase in future as the development and production activities expand year by year.

An important aspect to consider is that there would be a limit in financial resources. This leads to setting a criterion that only economically viable projects would be justified for implementation for a foreseeable future until the resources constraint is removed.

Floods have two different consequences; one is negative effect causing damages and losses, and the other beneficial effect in terms of transporting nourishments to lands and river shores which contributes to agriculture, other types of vegetation growths (particularly useful for livestock), and riverine fishery; In some instances, occasional floods are a factor of equilibrating the existing natural environments. Quantitative assessment of the latter is quite difficult, but this beneficial effect should not be disregarded. Examples may be the Middle/Lower Turkwel, Lower Kerio, Lower Tana and Middle/Lower Ewaso N'giro North (Lorian Swamp). In the areas where flooding occurs on natural floodplains, the reduction in flood intensity and/or frequency will have detrimental impacts on local use of the floodplain. Seasonal floodplain agriculture and riverine fisheries in particular will be adversely affected. A guideline proposed here is "the rivers are used as they are as far as the damage and/or nuisance is still within an extent tolerable to people' lives". This leads to setting a criterion that flood protection is not always an immediate requirement in the presently "damage tolerable" areas.

Flood in urban areas has a different aspect. Other than economic losses, it often causes unwholesome situations in highly populated area. Further, rivers create an important open space in urban areas, giving good scenic and/or amenity opportunities in some places. A special priority criterion can be given to urban drainage works including the improvement of urban rivers.

5.10.2 Target and strategy of flood protection works

On the basis of these considerations, this Study proposes to set out the following targets and/or strategies:

(a) Implementation of only economically viable projects for a foreseeable future; say, towards year 2010.

(b) No immediate proposal of measures for presently "damage-tolerable" areas, placing a preference to using the beneficial effects which the flood brings about.

(c) A specific priority will be placed on urban drainage works. Adhoc river improvement work will also be required for major urban rivers where problems and improvement needs are foreseen to arise.

5.11 Water Quality Aspects

5.11.1 Water quality monitoring programme

The MOWD is maintaining a nationwide water quality monitoring programme. The programme itself is a well prepared system. However, the actual achievement to date was far less than originally intended. The reasons being that there have been significant resources constraints in both financial and manpower aspects. (see Section 3.7).

Although it is a fact that water quality monitoring programmes are relatively expensive to run in terms of both capital and recurrent costs, the benefits derived from protection of the nations water resources outweigh these costs. The programme must be operated on a continuous long term basis.

On one hand, the programme is obliged to assume that some extent of resources constraint would continue for the foreseeable period. Under this circumstance, the following improvement approaches are proposed:

(1) Re-evaluation of monitoring method to conform with budgetary constraints

The number of stations (presently 120 stations) and the range of parameters monitored should be re-evaluated and reduced to conform with budget constraints. It is not recommended that the frequency of sampling be reduced to lower the monitoring cost. Water quality exhibits considerable seasonal variation especially in rivers and streams, and this variation would be missed by infrequent sampling.

(2) Scrutinization of the data

Some of the existing data is erroneous and in some cases unlikely or impossible values encountered. As a general principle, it is more worthwhile having good reliable data from a lesser number of water sources than unreliable data from many sources. Further, the data should be well scrutinized before entry into the database. This improvement could be achieved without significant increase of operational costs.

(3) Collection and collation of additional data

Other than the data logged on the MOWD database, a considerable additional volume of water quality data exists in published documents, consultants reports, aid organization studies, university theses, NGO documents and in many other places. It is recommended that a concerted effort is made by the MOWD to collect and collate this material and to enter it on the database and to update the information at regular intervals. This effort could also be achieved at a moderate cost.

(4) Groundwater quality monitoring

A noteworthy aspect is that the water quality data of groundwater is available only for 15% of the boreholes in the country. This situation should be rectified by more intensive monitoring at a regular interval, say 2 times a year, each in the dry and rainy seasons. This will cause some cost burden to the MOWD and other relevant agencies for monitoring the government owned and other public boreholes/wells. The monitoring of private boreholes may be left at the owners' obligation by setting forth a relevant regulation, but to be limitedly applied to major water users.

5.11.2 Water pollution control

(1) Effluent quality standards:

Effluent discharge standards have been formulated and are enforced by the Pollution Control Unit of the MOWD (Omwenga 1990). The standards include a generalized effluent quality standard (see Table 5.11.1) and some specific standards for industrial sources (Table 5.11.2). In this context, the following are noteworthy:

(a) It is recommended to establish more specific standards to be applied to other types of industrial, domestic and agricultural effluent sources.

(b) The principal components of the generalized standards are the biochemical oxygen demand (BOD) and total suspend solids (TSS) contents. These standards are derived from the British Royal Commission on Sewage Disposal Report in 1898. The present criteria; BOD test for oxygen demand for a period of 5 days at an incubation temperature of 20°C and TSS standard arbitrarily set at 30 mg/l, do not always have relevance to conditions in Kenya. A re-evaluation of these standards is worthy of consideration in the future.

(c) There is no complete form of standards for bacteriological quality of treated effluents, except that the standard for coliform has been established. This standard should be established.

(d) Similarly, standards for receiving waters (river and lake) should also be established.

(2) Enforcement of Water Pollution Control

Overall waters in Kenya have not been polluted so seriously. Nevertheless, local and intermittent pollution incidents have been rising and doubtless will become more frequent in the future as the population and economic growth continue. What is essential now is firm action by the regulating authorities to contain the present level of pollution and prevent further problems arising. By establishing good management and administrative practices, the threat of pollution spread in the future can be mitigated and the mistakes made in industrialized countries of the world can be avoided. Without doubt, where pollution control is concerned, prevention is far better and more economical than cure.

Legal provisions for the control have been clearly set forth in the Water Act. What is needed now is the positive enforcement of the regulations by the relevant authorities with provision of necessary resources. Some recommendations are given in Sectoral Report P.

5.11.3 Water quality criteria in water development

Overviewing the considerations described in Section 3.7 and Subsections 5.11.1 and 5.11.2 above, the following criteria are taken into account in the water development planning:

(1) River water

(a) All sources of groundwater springs will be protected (spring protection).

(b) All river water is subject to treatment before delivering for human domestic purposes. A conventional method comprising sand filtration and chlorination would meet the requirement for most sources.

(c) River water having excessive Fluoride concentration (more than the recommended WHO drinking-water standards) will have to be out of the planning; e.g. Lower Turkwel, though subject to further survey in-situ.

(2) Lake water

(a) As fresh water source, only waters of the Lake Victoria, Lake Naivasha, Lake Chala and Lake Jipe will be the objects of consideration for water supply.

(b) Of more importance for the lakes is not to disturb the existing equilibrium of natural environments. The lakes needing specific attention are Lake Nakuru, Lake Naivasha, Winam Gulf and Lake Turkana. Attention sholud also be paid to Lakes Baringo and Bogoria.

(3) Groundwater

(a) In some areas, particularly in the North Eastern, Eastern and Coast Provinces, there may be a possibility of the occurrence of only low quality groundwater sources. At such locations, the development criteria below may have to apply:

Plan towards year 2000:
Securing the minimum amount of water required for drinking and cooking by rain water harvesting, and low quality groundwater for other uses. In some areas, however, sub-standard supplies may have to apply.

Plan towards year 2010:
Introduction of water treatment facilities for supply systems where the water quality is less than the desired level, and/or introduction of long-distance water transfer.

(b) Groundwater containing excessive Fluoride (eg. more than 3.0 mg/l) will not be exploited for human domestic use.

(c) All groundwater supply points shall be protected from entry of foreign effluents, especially shallow wells in the ASAL area.

(d) High levels of sodium would require the examination of sodium absorption ratios (SAR) in any supplies for irrigation purposes.

CHAPTER 6 DEVELOPMENT PLAN TOWARDS YEAR 2010

6.1 Development Plan for Domestic and Industrial Water Supply

6.1.1 Urban water supply

An inventory study was made for each urban area with regard to (i) present supply capacity and (ii) present and future water sources, referring to project reports, information from answers to questionnaires, information from MOWD, NWCPC and Provincial and District Water Engineers, etc.

Possible water sources were checked on the 1:50,000 topographic maps. However, water source study based on the 1:50,000 topographic maps remains at a macroscopic study level, and water source for a specific urban area is to be looked into on a project basis in the future. Since the urban water demands are bulky, surface water sources were given priority. The water source of each urban area is presented in Table 6.1.1.

Due to insufficient river runoff with the required dependability, several urban areas will have to rely on water from storage reservoirs and/or interbasin water transfer.

6.1.2 Urban sewerage

(1) Requirement of Sewerage Development

In order to protect the environment, effluent from water supply systems should be treated to the extent permissible for the environment. The requirement for effluent from sewerage treatment plants is as follows:

BOD concentration	≤20 mg/l
Suspended solid loading	≤30 mg/l
Coliform content	≤1,000/100 ml

For industrial waste water, pre-treatment is the responsibility of such industries, and hence pre-treatment cost was not considered.

(2) Method of Treatment

There are various methods in waste water treatment. However, they can be classified into two types: one relies solely on natural contributions such as sunshine and temperature for promotion of the biological purification process, and the other employs mechanical equipment to aid and accelerate the biological purification process.

The two methods have distinct differences in cost implications as follows: (advantage to other: +, disadvantage: -)

First Method

+ less capital cost requirement
+ less foreign exchange requirement
+ less O & M cost requirement
+ less skilled manpower requirement
- large land requirement

Second Method

- large capital cost requirement
- more foreign exchange requirement
- large O & M cost requirement
- large requirement for skilled manpower
+ less land requirement

Except in some areas, land for the treatment plant is not a serious constraint in Kenya, provided that land use planning is made properly. However, constraints of fund availability both for capital cost and O & M cost and manpower are recognized to be remarkable. So the first method (waste stabilization pond) was assumed in this Study.

(3) Land Requirement for Waste Water Treatment Plant

Land requirement for waste stabilization ponds was estimated in order to present only indicative figures based on the following assumptions:

Influent standards
BOD loading : 500 mg/l
Effluent standards
BOD loading : ≤ 20 mg/l
Suspended solid loading : ≤ 30 mg/l
Coliform count : ≤ 1000/100ml of discharge
Rate of BOD removal Kt=0.22

6.1.3 Rural water supply

This study assumed that the development of water sources in rural areas will be undertaken in the following two (2) stages:

Stage 1: Provision of water sources within walking distance, i.e. within 1 km in high potential area and within 4 km in semi-arid/arid areas, wherein the water available is not always potable quality.

Stage 2: Provision of piped water supply systems with water treatment, wherein the water would be "potable".

For each of the water sources, the development sequence would be;

	Stage 1	Stage 2
Surface water	Water as available on the site (abstraction of water by people themselves)	Piped water supply, with treatment (except for spring water)
Groundwater	Spot supply at the borehole/well sites	Piped water supply, with treatment where necessary from water quality aspect
Roof catchment	Rainwater as stored	As Stage 1. No water treatment is deemed necessary.
Small dam	Water as impounded, with protection from contamination sources (e.g. livestock)	Piped water supply, with treatment
Subsurface dam	Water as stored and supplied at pipe outlet (sand dam) or well (subsurface dam)	Piped water supply, with treatment
Rock catchment	Water as stored, with protection of catchment	As Stage 1. No water treatment is deemed necessary.
Pipeline (built for urban supply and passing in rural areas)	Supply of water at water stands provided on the pipeline route. Water is treated.	Extension of branch pipeline system. Water is treated.

6.2 Development Plan for Livestock Water Supply

Livestock water development is similar to that applied to rural water supply. However, livestock could have more dependence on surface waters than the case of domestic supplies.

(a) Livestock can move over longer distance than human in seeking water, and

(b) Livestock can have more number of watering points whenever water sources are available

In this context, the Study assumed that the utilization of surface water sources by livestock would be more than that for domestic water supply. The use of groundwater would be lesser by the corresponding quantity.

It is noted that neither piped water supply nor water treatment is required for livestock watering, i.e. livestock water supply is planned at "Stage 1" level as mentioned in Subsection 6.1.3 above.

In addition, the Study proposed to provide watering points (boreholes or shallow wells with windmill pump) in normadic pasturage areas in arid lands. The objective is to promote nomadic production activities in such areas where pastures grow in the wet season but no watering points are available. The proposed plan envisages providing a watering point every 25 km.

6.3 Development Plan for Agriculture

6.3.1 Government agricultural policy

Agricultural development policy in Kenya is formally defined in the Development Plan and Food Policy paper. In those documents, the Kenya government has set the objectives of agricultural development to comprise;

growth of agricultural GDP
increasing foreign exchange earnings
food security
increasing employment
generation of revenue
regional equity
increasing farm incomes
national resource conservation

To achieve the above objectives, the Government set many programs and targets such as coffee and tea expansion programs, food and horticultural crop production target, etc.

6.3.2 Present land use

Kenya has about 581,000 km^2 of land and 11,300 km^2 of water surface, giving a total of 592,300 km^2. According to the information obtained from a 1989' landsat image, socio-economic surveys and publications, the territory of 592,300 km^2 was categorized as follows.

Present Land Use in Kenya

Unit : 1000 km^2

Forest/Park	Swamp	Waters	Town ship	Barren land	Agricultural land	Other land	Total land
65.7	6.7	11.3	9.9	75.2	46.6	376.9	592.3

Table 6.3.1 shows the estimated present land use in each District.

6.3.3 Food demand in 2010

Food demand in future is estimated by production of per capita consumption and projected population.

Per capita consumption

The MOA projected per capita consumption in the year 2000 is as shown in the table below, which assumes that people's diet preference is different between the urban and rural areas. The Study assumed that these people's dietary preference will not change within the Plan period.

Unit Per Capita Consumption

(Unit:kg/p/year)

Foods	Urban	Rural
Maize	97.1	125.6
Millet	0	19.8
Wheat	24.7	10
Rice	13.1	1.4
Potatoes	14.8	26.2
Other roots	3	30.5
Sugar	30	15
Pulses	13.8	14.2
Milk	88.6	72.1
Beef	11.9	6.8
Fat	6.5	1.7
Vegetable	36.9	20.4
Fish	1.9	1.7

Source: MOA

Food Demand

The results of the calculation of food demand in the future are presented in Table 6.3.2 and summarized below together with the present production of major crops.

Food Demand Projection

Unit: 1000 ton

	Present Production*	1990	1995	2000	2005	2010
Population (million)		22.749	26.389	30.712	35.209	40.305
Maize	2762	2744.3	3157.3	3631.4	4135.2	4700.4
Sorghum/Millet	219	371.9	413.3	451.0	497.7	546.6
Wheat	298	285.7	344.9	423.7	500.2	589.8
Rice	44	78.2	101.4	135.8	167.2	204.9
Potatoes	849	550.8	628.5	714.2	807.6	911.2

* Average production of recent five years(see Table E1.22 of Sectoral Report E)

As can be seen in the table, the present production of maize, wheat and potatoes is more than the self-sufficiency rate of 100%. However, the country will require double to five times the amount of foods in the year 2010 compared with the present food production.

6.3.4 Land requirement and potential

Land requirement

Agricultural land requirement was calculated by dividing food demands by projected unit yields as shown below. The unit anticipated yields were estimated form trend projection as shown in Figure 6.3.1. But average unit yield was applied for rice, since it shows a negative trend. The table below shows the unit yield and land requirement in 2000 and 2010.

Land Requirement in 2000 and 2010

	2000			2010		
	Food Demand (1000ton)	Target Yield (ton/ha)	Required Land (1000ha)	Food Demand (1000ton)	Target Yield (ton/ha)	Required Land (1000ha)
Maize	3,631.4	2.4	1,513	4,700.4	2.8	1,679
Wheat	423.7	2.8	151	589.8	3.4	173
Millet/Sorghum	451.0	1.2	376	546.6	1.5	364
Rice	135.8	3.0	45	204.9	3.0	68
Total			2,085			2,284

Land potential

Agriculture land potential in Kenya was estimated at a master plan level by applying GIS technology and based on available information of soil, climate, present land use and topographic conditions. The results showed that there is enough agriculture potential land for future expansion (see Table below).

Comparison between Crop Land Requirement and Potential

Unit: 1000ha

	Maize	Wheat	Rice	Sorghum/Millet
Requirement	1,679	173	68	364
Potential	5,000	1,350	1,300	7,200

6.3.5 Future land use

Future land use in Kenya was preliminarily examined taking into account the above land requirements and national agriculture expansion programmes. Table 6.3.3 presents a preliminary projection of future land use for each district and Figure 6.3.2 illustrates a general feature of the present and future land use in the whole country. The assumption made in preparing these tables and figures are:

- Forest and National Reserve will remain unchanged
- National Park and Game reserve will remain unchanged
- Barrenland and swamp are not developed for agriculture and livestock
- Township area is not available for agriculture and livestock
- Present crop intensity of 80% will increase to 90%

6.3.6 Irrigation development

In line with the strategy set forth in Section 5.5, the Study proposes the following irrigation development plans:

a) Small scale irrigation project

About 140 schemes under contemplation by various agencies are proposed for development towards the year 2010. The total area of the proposed scheme is about 7,000 ha. In line with government policy for irrigation development, these small irrigation deployment have top priority in implementation. These small scale schemes would be implemented by farmers themselves with the assistance of MOA or other government agencies concerned.

b) Large scale irrigation project

About 160 irrigation schemes have been proposed by various agencies. From those irrigation schemes, 18 large scale schemes were selected for further analysis to formulate water development plan in Kenya using the following criteria.

1) Schemes having more than 500 ha in area
2) Schemes having technical information revealed in previous studies
3) Schemes proposed as the government undertaking

List of Large Scale Irrigation Schemes

Name	Area (ha)	Name	Area (ha)
Arror	1,340	Lower Rupingazi	1,800
Kano Plain	25,640	Mwea Extension	2,900
Kanzalu	4,055	Sabaki Extension	3,000
Kibwezi Extension	13,200	Tana Delta	12,000
Kimira	2,000	Taveta	3,780
Kunati	1,050	Thanantu	2,520
Lower E.'Ngiro	10,000	Turkwel	600
Lower Kuja	1,900	Upper Nzoia	7,550
Lower Nzoia/Bunyala	10,480	Yala Swamp	7,540

Detailed information of selected projects are described in Sectoral Report E and Appendix E4, Irrigation Project Sheets (DB.5). Figure 6.3.3 shows the location of these 18 schemes.

Out of the 18 schemes, construction of Tana Delta schemes has commenced and implementation of Mwea Extension scheme was committed in 1991. These two schemes will produce mainly paddy of about 45,000 ton per annum. With regard to rice production, existing schemes and these two schemes will achieve rice production sufficient for meeting the demand up to the year 2005 as shown in Figure 6.3.4.

6.4 Source Development Plan

6.4.1 Source development plan by basin - urban water supply

Either surface water (natural river flow, springs and lakes) or groundwater was considered to be the most conventional water source, and possibly the least costly, for urban water supply schemes. However, as the water balance assessment defines, some towns need the exploitation of water by storage dam scheme or the transfer of water from another river basin.

Dam Schemes:

In total, 28 dam schemes were selected for source development for various purposes towards the year 2010 as enumerated below;

Purpose	Damsite (nos.)
Single purpose	
- water supply	19
- irrigation	2
- hydropower	2
Multi-purpose	
- water supply and irrigation	2
- water supply, irrigation and hydropower	1
- irrigation and hydropower	2
Total	28

The locations of damsites are shown in Figure 6.4.1 and the list of dam for source development including hydropower generation and irrigation is given in Table 6.4.1. Of the total 28 dams, 22 dams are relevant to urban water supply schemes.

Water Transfer Schemes:

In case that no potential damsite is available in the subbasin, it is necessary to transfer water firstly from another subbasin in the same river basin (intra-basin water transfer) and secondly from another river basin (inter-basin water transfer). The list of intra-basin and inter-basin water transfer schemes are enumerated in Tables 6.4.2 and 6.4.3. Locations of the water transfer schemes are shown on Figure 6.4.2.

Sources Development Plan by Basin:

The urban centers which would need the augmentation of available surface water by construction of storage dam and water transfer pipeline are described below with their water sources.

(1) Drainage Area 1 (Lake Victoria Basin)

(a) Tributaries of Malaba River and Sio River Basin (1A)

Sio river basin (subbasins 1AH and 1AG) shows the deficit of present surface water balance. Although the volume of domestic water demand at **Busia** and **Nambale** is rather small compared with other urban centres, the surface water deficit will increase by the year 2010. Since no potential damsite is in the basin and the volume of groundwater is limited, the intra-basin water transfer scheme having a capacity of 48,400 cmd (0.56 cms) in total is required to augment the capacity of existing water supply pipeline from the Sio River .

(b) Nzoia River Basin (1B to 1E)

No water deficit in the upper reach of Nzoia river basin (1B) occurs by 2010. **Moiben dam** is, however, required to be constructed to supply 51,000 cmd (0.59 cms) of water to meet the domestic water demand at **Eldoret** (1CB). The Eldoret water supply scheme from the Nzoia River is proposed as an alternative.

Moiben dam also to supply 3,500 cmd (0.04 cms) of water to **Iten** in Kerio river basin (2CB) to meet the domestic water demand..

The surface water deficit of 49,300 cmd (0.57 cms) in total also will occur at **Kakamega** (subbasins 1EA and 1EB) in the year 2010. **Mukulusi Dam** is proposed to supply water to Kakamega to offset the deficit.

(c) Nyando River Basin (1G)

In the upper reach of the Nyando River, **Londiani dam** is proposed to supply 20,800 cmd (0.24 cms) of water to **Londiani** to meet the domestic water demand.

(d) Shore of Lake Victoria (1H)

Surface water deficit will occur at **Kisumu** (1HA) in the year 2000 and at **Maseno** (1HB) in the year 2010. The volume of deficit is estimated at 40,000 cmd (0.46 cms) at Kisumu and 30,200 cmd (0.35 cms) at Maseno. **Kibos Dam** is proposed for the Kisumu water supply. The construction of a small dam on the Edzawa River, will be required for Maseno water supply.

(e) Sondu River Basin (1J)

No surface water deficit will occur in the Sondu river basin. Upstream of Itare River, **Itare dam** is proposed to supply 127,000 cmd (1.47 cms) of water to drainage area 2 (2E and 2F) to meet domestic water demand in **Elburgon, Molo, Njoro** and **Nakuru.**

(f) Kuja River Basin (1K)

Surface water deficit of 8,700 cmd (0.10 cms) will occur at **Kisii, Manga** and **Keroka** (1KA) in 2010. **Bunyunyu dam** is proposed to offset this deficit.

(2) Drainage Area 2

(a) Kerio River Basin (2C)

In 2010, surface water deficit of 1,700 cmd (0.02 cms) will occur at **Kabarnet** which is located astride the basin boundary between subbasin 2CB and 2EH. **Kirandich Dam** is proposed to offset this deficit.

(b) Lake Baringo basin (2E)

In the subbasin 2ED, **Chemususu dam** has been planned up to detailed design level. The dam is designed to supply 6,000 cmd (0.07 cms) of water to **Eldama Ravine** and **Mogotio.**

Surface water deficit in the basin will occur at **Molo** and **Elburgon** (subbasins 2EC and 2EG1) in the year 2010. The available groundwater is quite limited and none of potential damsite with a relatively large scale reservoir was identified in the basin so that the inter-basin water transfer scheme is therefore required. An inter-basin water transfer pipeline from **Itare dam** to supply 40,000 cmd (0.47 cms) of water to **Molo** and **Elburgon** areas is proposed.

(c) Lake Nakuru, Elementaita and Naivasha (2F and 2G)

Surface water deficit has already occurred in the urban centres in the basin, especially in the towns of **Nakuru, Gilgil** and **Naivasha.** In these basins, the volume of groundwater is also limited and only **Malewa dam** is the potential damsite of reservoir type. Although the water transfer scheme, the Greater Nakuru Water Supply Project (Phase I), is under construction, the transferred water will not meet the demand in 2010.

After the construction of Malewa dam for the supply of 51,000 cmd (0.59 cms) to Gilgil and Nakuru, the inter-basin water supply scheme with **Itare dam** is proposed to cover surface water deficit at **Nakuru** and **Njoro.**

(d) Lake Magadi Basin (2H)

Surface water deficit of 10,400 cmd (0.12 cms) will occur at **Magadi** in the year 2010. To cover this deficit construction of another water pipeline along the existing one is proposed. Water pipeline from Ewaso N'giro River is proposed as an alternative scheme.

(e) Ewaso N'giro River Basin (2K)

Narok town suffers from a surface water deficit at the present and this deficit is estimated to reach 53,600 cmd (0.62 cms) of water in the year 2010. To cover this deficit, **Upper Narok dam** is proposed.

(3) Drainage Area 3 (Athi River and Coast)

(a) Athi River Basin (3A to 3H)

The largest surface water deficit in Kenya will occur in and around **Nairobi** in the year 2010. To cope with such a large deficit, **Thika dam** which is located in the upstream of Chania River is under construction. When completed it will supply 224,700 cmd (2.60 cms) of water to Nairobi. However, Thika dam will not meet the increasing demand of Nairobi towards the year 2010. **Ruiru A dam** and **Chania B dam** are therefore proposed to supply 26,000 cmd (0.30 cms) and 65,700 cmd (0.76 cms) of water to Nairobi. To cover the remaining surface water deficit at Nairobi, construction of **Ndarugu dam** is proposed. However, the volume of inflow into Ndarugu reservoir from subbasin (3CB) is not adequate to the demand in the year 2010. The additional inflow required, having a monthly fluctuation with the maximum of 8.0 cms is proposed to be transferred from Chania River intake; that is, **Komu Transfer** scheme. Munyu dam may be the alternative to Ndarugu dam.

Kiambaa Dam proceeds to construction stage for the water supply to **Kiambu** and **Karuri** towns.

Kiserian dam which proceeds to construction stage in the uppermost subbasin (3AA) of Athi River will supply 0.70 cms of water to **Kajiado**. **Upper Athi dam** is planned for the domestic water supply to **Athi River** town.

Another large deficit in the upper Athi river basin will occur in the upstream reaches of the Thwake River where Machakos town is located. Although a few potential damsites were identified in the basin, the development yields of dams do not meet the demand of **Machakos** in the year 2010. It is proposed to supply 80,400 cmd (0.93 cms) of water through pipeline from the main Athi River channel.

In the Tsavo river basin, the present water supply volume through **Mzima pipeline** of 0.43 cms will be increased to 0.83 cms in the year 2010 coping with the surface water deficit at **Voi** and **Mombasa**. Also, possible alternative plan for Mombasa water supply will be water transfer from Njoro Springs and/or Lake Jipe (subbasin 3J).

The extension of existing **Sabaki water supply system** in the lower reach of the Sabaki River is also proposed as an alternative to Mwachi and Pemba dams which supply domestic water to **Mombasa** and **Malindi** areas.

(b) Rare River Basins (3L)

Voi River is the uppermost river in the basin. The surface water of the river, however, dries up in the ASAL area which is located between Voi and the coastal area. The main channel of Voi River is not clearly identifiable in the ASAL area and appears again as Rare River in the mountainous region of the coastal area. The drainage system between Voi and Rare rivers is therefore discontinuous, especially in dry months.

The surface water deficit of **Voi** town of 8,700 cmd (0.10 cms) will be supplied by the **second Mzima pipeline system**. **Rare dam** will supply 32,900 cmd (0.38 cms) of water through a pipeline to **Malindi** areas.

(c) Mwachi River Basin (3M)

The largest surface water deficit in the coast area will occur in subbasin 3MD. The present water supply volume of 37,000 cmd (0.43 cms) through Mzima pipeline will be increased to 71,700 cmd (0.83 cms) coping with part of the water demand of 157,200 cmd (1.82 cms) at **Mombasa** in the year 2010. **Mwachi dam** is planned to supply the remaining part of the water demand.

(d) Pemba River Basin (3M)

Small surface water deficit of 2,400 cmd (0.03 cms) will occur in the coast area. **Pemba dam** is proposed to supply water to the coastal area at **Mombasa**.

(4) Drainage Area 4 (Tana River Basin)

In the upper reach of the Tana River, the amount of surface water is abundant comparing with the other drainage areas. **Thika dam** and **Chania B dam** are proposed to supply the domestic water to the urban centers in and around **Nairobi** (Drainage area 3). **Komu transfer** which is designed as run-of-river type development with open channel with a maximum capacity of 8.0 cms is proposed to augment inflow volume into Ndarugu dam or alternatively Munyu dam.

In the lower reach, both abundant surface water in upstream reach and the storage control by existing dams make an inter-basin water transfer schemes to the other drainage areas possible even in the dry months; that is, water supply scheme to

Lamu. However, the first effort may be the maximum exploitation of groundwater resources in the Lamu Island.

(5) Drainage Area 5 (Ewaso N'giro River and North)

In the dry months, surface water along the Ewaso N'giro River decreases to an extent that surface water flow at the lower reaches of the rivers is not available for a few months per year. Two potential damsites; namely, **Nyahururu and Rumuruti damsites**, were identified in the upstream reaches of the river. Both these damsites, however, have a relatively small catchment and the inflows into reservoirs are not sufficient to store and regulate their development yield throughout the year. However, there were no other potential damsites identified for the purpose of providing stable domestic water supply to **Nyahururu** and **Rumuruti**. These two storage dams are proposed for the seasonal supply of domestic water use for the above urban centres. Since these two dams could not meet the whole demand, the development of boreholes is tentatively proposed to supply about a half of domestic water demand in the towns.

About a half of water deficit of **Wajir** town of 6,235 cmd (0.07 cms) will be supplied by the inter-basin water transfer pipeline from **Ewaso N'giro River**. The remaining deficit will be supplied by the development of boreholes.

Groundwater Development:

A primary assumption for the above allocation of water sources is that surface water will take precedence over groundwater sources in the development for urban water supply because of easy accessibility and cheaper abstraction cost in most cases. In the case that surface water can not meet water development requirement of urban water supply, groundwater will be utilized instead of surface water or a combination of the both.. There are some cases when surface water sources are not available and groundwater can not match the water development requirement due to water quality constraint. In these cases, maximum affordable development of roof catchment and subsurface dams may be considered instead of groundwater but this is particularly suited to peri-urban and rural areas.

According to the results of the domestic and industrial water supply study (Sectoral Report (D)), the following urban centres have to utilize groundwater as a major water source. Water balance expressed as available groundwater volume vs. required water demand was calculated for 22 urban centres as enumerated below, on the assumption that groundwater can be extracted within the location where the urban centres are situated or from the surrounding locations. Table 6.4.4 shows water balance calculation for 22 urban centers. Proposed numbers of boreholes and shallow wells were calculated as shown in the following table, on the assumption that 10 % of total water demand will be utilized from shallow wells for livestock and the remaining will be extracted from boreholes except for urban centres. Outer radii of groundwater development were estimated in consideration of the groundwater availability ratio.

Urban water supply mainly by groundwater for the year 2010

Urban center	Location	Water demand (m3/day)	Number of boreholes	Number of shallow wells	Outer radius of development (km)
Msambweni	Msambweni	2,671	50	54	32
Isiolo	Isiolo	9,343	167	187	58
Garbatula	Garbatula	1,417	22	28	22
North Horr	North Horr	1,218	29	23	24
Korr	Korr	3,366	76	68	39
Kargi	Kargi	3,241	90	61	42
Marsabit	Mountain	8,971	214	0	65
Sololo	Sololo	2,787	99	56	44
Moyale	Moyale	5,885	78	589	39
Mudo Gashe	Madogashe	1,121	27	22	23
Ijara	Ijara	584	13	11	16
Kotile	Kotile	534	26	11	23
Elwak	Elwak	4,170	100	84	45
Wajir	Wajir Town	6,148	188	224	61
Buna	Buna	3,047	162	61	57
Bute	Bute	989	24	20	22
Nyabikaye	Bugembe	1,370	32	28	25
Wamba	Wamba	2,604	124	51	50
Barogoi	Elbarta	2,252	205	45	64
Lodwar	Lodwar	7,792	179	155	60
Nyahururu*	Nyahururu	4,282	172	10	60
Rumuruti*	Rumuruti	780	32	16	23

Note : * Tentatively listed. Development of surface water resources is to precede.

As indicated in the table above, both the number of boreholes/shallow wells and the anticipated area of well field are quite large, if an ordinary range of safe yield per borehole (30-80 cmd) is assumed. The calculated figures are almost impractical for most of the towns. High yielding aquifer(s) must be found in each area, and for this purpose the primary action would be to carry out a detailed groundwater resources study accompanied with insitu physical prospecting.

It is highly possible that the groundwater resources available in the area will not meet the demands foreseen. In this case, an alternative source of water exploitation will be either inter-basin transfer of surface water from an other basin or provision of water harvesting measures (eg. subsurface dam), as appropriate to each area. The alternative source plans for several towns are described in Sectoral Report C and also in the project sheets contained in the Databook (DB-6).

Nevertheless, the first action to be taken is to launch the maximum development of groundwater sources, particularly for 20 towns other than Nyahururu and Rumuruti.

6.4.2 Source development plan by basin - rural and livestock water supply

In view of the vastness of the study area and varying type of water sources envisaged, it was thought impractical to formulate definite water supply plans specific to each rural area. The study therefore attempted to evaluate potential water sources available in each area and to estimate the conceptual costs of the development. The study adopted the following approaches for this purpose:

Step-1 : Listing of potential water sources and their combinations by Subbasin/Location

Several water sources were examined for evaluating the potential development of perennial water sources; they are, surface water, groundwater, roof catchment, small dam, subsurface dam, rock catchment and pipeline built for urban water supply. Other type of seasonal water sources are dealt with separately only as supplemental measures which would be effective to shorten the access distance in the rainy season.

Step-2 : Setting-up of source potential evaluation criteria

The study assumed that the development of water sources in rural areas is undertaken in two stages; namely, (i) Stage-1 : provision of water sources within walking distance, wherein the water available is not always a grade of "potable water" and (ii) Stage-2 : provision of piped water supply systems with water treatment, wherein the water would be "potable". The evaluation was based on relative comparison indices.

Step-3 : Setting-up of source allocation criteria

The study had to adopt a simplified approach to evaluating the source allocation plans just sufficient for formulation of a framework of future water development for both domestic and livestock water supplies because of the varieties of water sources and demand area characteristics. The basic concepts are (i) main water supply sources would be surface water and groundwater and (ii) other water harvesting measures are planned as subordinate measures to supplement and/or substitute the surface water/groundwater sources. The criteria adopted for this assessment are described in Sectoral Report M.

Step-4 : Assessing water sources development by Subbasin/Location

Data used for assessment of source development for rural water supply (domestic and livestock uses) are organized into (i) water demand towards 2010, (ii) demographic data, (iii) source potential parameters evaluated in Step-3, and (iv) water yield and cost data.

The rural water demand in 2010 was estimated at 1.719 MCM/day which is comprised of into 1.160 MCM/day for domestic water demand and 0.559 MCM/day for livestock water demand as given in Table 6.4.5. Source allocation plan for rural water supply over Kenya is summarized in Figure 6.4.3. Source allocation plan by drainage area is summarized in Figures 6.4.4 and 6.4.5.

In addition, the watering points in normadic pasturage areas were proposed to promote nomadic production activities. The proposed water sources are boreholes or shallow wells with windmill pumps. Assuming that a watering point is provided every 25 km, 559 watering points in 21 Districts within the arid lands are required (Table 6.4.6), although a further study is needed with regard to the availability of rainy season pastures in each area.

6.4.3 Source development plan by basin - Irrigation water supply

The water source for selected 18 large irrigation schemes are described hereinafter.

1. Arror

   This project is located at Kerio valley along the left bank of the Kerio River. The irrigable lands have been grouped into four Blocks with a net area of 1,340 ha and requires a peak flow of 2.0 m^3/sec. **Two pipelines** will convey the irrigation water from the Arror River, one is for Blocks 1 & 2 while the other one is for Blocks 3 & 4. Sprinkler systems are recommended for this area mainly due to the soil and topographic conditions.

2. Kano Plain

   Project area extends southeast of Kisumu town and lies on the flat terrain - so called Kano Plain. At present (1991), a feasibility study is being undertaken by JICA to formulate optimal development plan on the Kano Plain Irrigation Project.

   The total Project area of 73,000 ha consists of 13,000 ha of swamp, 50,000 ha of arable/natural vegetation, and 10,000 ha of other area. About 25,000 ha of paddy and upland field would be irrigated by transferring the Sondu river water after generating about 60MW of electricity at **Sondu/Miriu Dam**. Peak irrigation water requirement is about 29 m^3/sec occurring in October.

3. Kanzalu

   The Kanzalu irrigable area is located between the Kanzalu Range and the Athi River about 60 km east from Nairobi. From a potential of 12,000 ha of irrigable area, about 5,000 ha was investigated which consists of three irrigable areas.:

   Block A : covering a net irrigable area of 1,750 ha between Nditha and Athi Rivers;

Block B : covering a net irrigable area of 2,560 ha situated on the peneplain between the Kanzalu Range and the Nditha River; and

The valley bottoms located between irrigation blocks A and B.

The water source for the scheme is the regulated flow from **Ndarugu Dam** or **Munyu Dam.** Headworks would be constructed at downstream of Fourteen Falls in order to divert the required water of about 1.1 m^3/sec into a 21km main canal.

4. Kibwezi extension

The Kibwezi scheme is located on the right bank of Athi River, between the Yatta Gap and the Mtito Andei River with an area of around 30,000 ha. The area is divided into four Blocks:

Block A: 1,920 ha
Block B: 4,050 ha
Block C : 5,980 ha
Block D : 8,970 ha

The water sources for the scheme is the regulated flow from **Yatta Dam** in the Athi River.

Headworks would be constructed 8km downstream of Yatta Bridge on the Athi River. Diverted irrigation water will be conveyed to the proposed nightstorage reservoir by a 26 km long main canal. The location of the nightstorage reservoir will be within the Masongaleni River Valley. After the nightstorage reservoir, lined secondary and tertiary canals will convey the water to each irrigation block and fields.

In the scheme, the peak irrigation water of 17.0 m^3/sec is required in September. However, the maximum development of Yatta Dam would regulate 13.0 m^3/sec in September taking into consideration the water resource development and conservation in the downstream reach of the Sabaki River. The other water source should be further studied for full development of the scheme.

5. Kimira

The Kimira scheme is located west of Kendu Bay town in South Nyanza District. This area has very flat topography with an average elevation of 1,140m. Due to poor drainage condition and low topography level, part of the area is submerged during the rainy season. At present, the area is used as grazing land.

Irrigation water of about 2.2 m^3/sec will be diverted from the **Awach Kibuon River** and conveyed through about 3 km of unlined canal to the area.

6. Kunati

Kunati scheme is located east of Meru town in Meru District. Estimated peak irrigation water requirement is about 0.4 m^3/sec and annual mean requirement is 0.33 m^3/sec. The **Thanantu River** is the expected water source.

7. Lower Ewaso N'giro

The area is located to the west of Lake Magadi. It is suitable for large scale irrigation development due to favorable topography, soils and climate. The TARDA planned the following activities required for the implementation of this scheme;

- establishment of a pilot irrigation project
- aerial photography and topographical surveys of the project area
- semi detailed soil survey
- irrigation planning

Peak irrigation water requirement is about 13 m^3/sec occurring in November. Headworks would be constructed at the tailrace of **Oldorko Dam** which is proposed for hydropower development.

8. Lower Kuja

Project area is located at about 110 km southwest of Kisumu town in South Nyanza District. Stage wise development plan, namely Phase I and Phase II will develop the 1,900 ha of total irrigation potential area. The irrigation water would be pumped from **Kuja River** by six engine pumps into a lined canal which will convey the water to the project area. Estimated peak discharge is 1.3 l/sec/ha.

9. Lower Nzoia/Bunyala Extension

These two irrigation schemes are located along both side of the Nzoia River near its Lake Victoria outlet in Busia and Siaya District. The area is about 125 km^2 with an average elevation of 1,180 m. This area includes the existing Bunyala irrigation scheme. Two main canals, one on each bank convey the irrigation water from the intake weir on the **Nzoia River**. An experimental farm is proposed to seek high value added crops under irrigated agriculture.

10. Lower Rupingazi

This scheme is located about 10 km south of Embu town. The area extends on both sides of Rupingazi River, having a net area of 1,800 ha. The land within the project area comprises slopes of less than 5% except along the existing streams. Sprinkler irrigation systems is recommended in this area due to the soil and social conditions.

The peak water requirement is estimated at about 1.1 m^3/sec occurring in November. The **Rupingazi River** is the source of irrigation water.

11. Mwea extension

Mwea irrigation project is located near Sagana town about 80km northwest of Nairobi in Kirinyaga District with a total area of 16,000 ha. It extends over the flat land on the outskirts of Mt. Kenya with an elevation of 1,100 m. This irrigation project comprises the existing Mwea Irrigation Settlement Scheme of 12,000 ha and the Extension area of 4,000 ha. The following works are on going for existing Settlement Scheme:

Rehabilitation of headworks
Rehabilitation of main canal
Rehabilitation of link canal
Construction of a Pilot Farm

Extension area has 2,470 ha of paddy field and 430 ha of horticulture land. **Thiba Dam** with storage capacity of 18 MCM is proposed on the Thiba River for the whole Mwea irrigation project.

12. Sabaki Extension

The Sabaki irrigation area is located on the left bank of the Sabaki River on the flood plains of the Dagmra Area . For the purpose of costing , a 150 ha pilot scheme is proposed. Irrigation water for this pilot area will be extracted from the **Sabaki River** by means of boreholes along the river banks. During a two years pilot operation period, the following investigations or study are proposed:

- method of water conveyance
- method of water intake
- test drilling
- feasibility study for the full development of this project

Detail design and nine years construction works will follow this pilot scheme.

13. Tana Delta

The Tana Delta is a vast lowland located in the most downstream basin of the Tana River with an area of about 2,000 km^2. This project is situated in this Delta at about 9 km east of Garsen town with 12,000 ha, which is comprised of three empoldered areas - Polder-1 (4,500 ha), Polder-2 (3,850 ha) and Polder-3 (3,650 ha). Rice cultivation is proposed.

The Polder-1 area is now under construction. The TARDA is the execution agency for this project.

Irrigation water of about 24 m^3/sec at peak requirement in December will be diverted from the **Tana River**.

14. Taita Taveta

The area is situated near Taveta town in Taita Taveta District extending along the Lumi River. Existing small scale irrigation schemes, in total covering about 550 ha have some physical and organizational problems, namely:

- a part of the area is underlain by a caliche at a shallow depth
- lack of drainage systems
- saline groundwater
- regular flooding
- inadequate extension services and lack of a farmers organization

The water sources for those irrigation schemes are the **Lumi River** and **Njoro Springs**. A resources survey carried out by TARDA identified about 3,800 ha of irrigation potentials in this area. It is noted that about 70% of project area is in private land.The following detailed investigation are required for development of the whole area;

- detailed surface and groundwater resources assessment (including the present water abstraction rate for private land)
- aerial photograph and mapping of the project area
- semi detailed soil surveys
- irrigation planning

15. Thanantu

The scheme is located at about 20 km east of Meru town in Meru District. The Thanantu River forms the northern boundary while Kuuru River forms the southern boundary. A sprinkler system has been recommended due to the high permeability of the volcanic soils. Irrigation water will be diverted from **Thanantu River**.

16. Turkwel

The area is located at about 50 km downstream of **Turkwel Dam**. Total area of 600 ha, which comprise five small cluster of 120 ha each are scattered on both sides of Turkwel River. If ecological and institutional problems are disregarded, more than 7,000 ha can be irrigated around this area after the completion of Turkwel Dam.

17. Upper Nzoia

The area is located at about 20 km south of Kitale town in Bungoma District. This area covers a total area of 176 km^2 with altitudes of 1,700 m. The landform is hilly with occasional steep slopes. A Pilot scheme is proposed to obtain information on a series of agricultural, economic and social problems and to train an initial nucleus of technicians and farmers. This Pilot scheme will have an area of 300 ha and will need an investment of Kshs 36 million. Sprinkler irrigation is proposed to irrigate hilly area. The peak irrigation water of 4.4 m^3/sec is required in December. To irrigate the whole area of 9,400 ha in gross, **Hemsted Bridge Dam** having a capacity of 75 million m^3 is required after 2010.

18. Yala Swamp

The Yala Swamp is located in Siaya and Busia Districts of Nyanza and Western Provinces. The swamp itself was formed by the deposition of silt from the Yala at the point where the river flows into Lake Victoria. In addition to the Yala River, the Hwiro River (seasonal river) also flows into the Yala swamp.

The Swamp has been divided into three areas. The 2,300 ha Area I is the name given to the area which was reclaimed in 1970 and is now being cultivated. The 9,200 ha Area II forms the main body of the swamp and is the area which would be reclaimed by gravity drainage. The 6,000 ha Area III is the swamp which is generally below the level of Lake Victoria and is considered to be only reclaimable by the construction of polders and pumping out of the water.

The reclamation of the Yala swamp was first proposed in the Kenya Nile Basin Water Resources Study 1956. After this proposal various studies have been undertaken on the reclamation of the Yala Swamp.

As early as the 1960's a start was made with the reclamation of the Yala Swamp resulting in the drying out of Area I. Detailed designs and tender documents for Area II were prepared in 1982. Latest proposal is reclamation and development of Area II by extension and expansion of the existing **Yala River diversion canal,** diversion of the Hwiro River and reconstruction of existing dyke. A peak irrigation water of 12 m^3/sec is required in October.

6.5 Hydropower Development

The National Power Development Plan (1987) had listed 11 hydropower schemes worthy of further consideration, but recently its updated plan (1991) reexamined 8 hydropower schemes. These hydropower schemes are listed in Table 6.5.1.

Comparing the 8 schemes, the updated plan recommended the implementation of five hydropower scheme towards year 2010, i.e. Miriu, Low Grand Falls, Oldorko, Mutonga and additional installation of Gitaru No.3 unit. The updated plan also suggested a recommended commissioning schedule of the above five (5) schemes as given in Table 6.5.2.

Magwagwa was also evaluated favourably in Table 6.5.1, but it was left out in the updated plan because it will be developed in conjunction with a large irrigation development which will be late in the planning period (Draft final report of Update of National Power Development Plan). Subsequently, the feasibility study of the Magwagwa project was completed in December 1991. The study revealed that the project would be technically and economically feasible for commissioning towards year 2003. This project is also included in the implementation programme of this master plan.

The principal features of selected hydropower development schemes are described below.

(1) Sondu/Miriu

The annual mean discharge of the Sondu River was estimated at 41.0 m^3/s at the damsite. The layout of intake facilities consist of gated concrete weir type. The reservoir has a storage of 1.1 MCM with FSL at EL. 1,402.5 and the minimum operating level of EL. 1,400.0 m. The gross head is 196.6 m and installed capacity is 60 MW at FSL with a maximum plant discharge of 39.9 m^3/s.

The schemes has a plan of providing an additional powerplant (No.2 powerhouse). The proposed installed capacity is 20.6 MW.

(2) Magwagwa

The annual mean discharge of the Sondu River was estimated at 40.0 m^3/s at damsite. The layout of dam consists of concrete facing rockfill type embankment of 4.4 million m^3. The reservoir FSL is at EL. 1,665 m and the minimum operating level is at EL. 1,609 m with active storage capacity of 701 MCM which corresponds to 55.6% of annual inflow volume. The gross head is 180 m and installed capacity is 120 MW at FSL with a maximum plant discharge of 82 m^3/s.

(3) Oldorko

The annual mean discharge of the Ewaso N'giro (south) River was estimated at 8.0 m^3/s at the damsite. The layout of dam consists of a fill type embankment of 4.48 million m^3. The reservoir FSL is at EL. 1,300 m and the minimum operating level is at EL. 1,272 m with active storage of 885 MCM which corresponds to 351% of the mean annual inflow volume. The gross head is 480 m, installed capacity is 76 MW at FSL with a design discharge of 18.0 m^3/s.

(4) Mutonga

The annual mean discharge of the Tana River was estimated at 132.1 m^3/s at the damsite. The layout consists of a fill type embankment of 0.87 million m^3 across the Tana River. The reservoir FSL is at EL. 550 m and the minimum operating level is at EL. 542 m with active storage of 87.8 MCM which corresponds to 2.1%

of annual inflow volume. The gross head is 37 m and installed capacity is 60 MW at FSL with a design discharge of 195.5 m^3/s.

(5) Low Grand Falls

The annual mean discharge of the Tana River was estimated at 146.2 m^3/s at the damsite. The reservoir FSL is at 512 m and the minimum operating level is at 500 m. The active storage is 857 MCM which is 18.6% of the annual inflow volume. The gross head is 68.2 m and installed capacity is 120 MW at FSL with a design discharge of 212 m^3/s.

At this site, an alternative development plan is High Grand Falls scheme. The merit of this multipurpose scheme should be assessed in a subsequent study.

As a factor supporting the future water development, provision of qualified transmission and distribution systems is an important component of undertakings by the power sector. Most of water supply schemes require firm and stable supply of power.

6.6 Flood Mitigation Plan

6.6.1 Flood protection projects

After reviewing the present conditions (Ref. Section 3.6), the Study examined in more detail 9 selected flood prone areas where the extent of flooding and damage is relatively large. The location of the 9 areas is shown in Figure 6.6.1.

Protection level (in terms of recurrence probability of design discharge) for the proposed flood protection plans was examined with two indices in consideration; (i) protection method (dyke embankment or non-embankment) and (ii) land use intensity (urban area or rural area). The protection level varies from 5 to 100-year recurrence probability, being classified by damage potential and implementation staging.

The Study prepared a preliminary design of all 9 schemes; river improvement work for 8 flood protection schemes and groin construction for bank erosion protection in the Lower Tana. Several flood control dam plans were also examined, but found to be more costly.

Flood control benefit was assumed to accrue from the reduction in damages to agricultures, housing and public facilities, including indirect damages thereto. Benefit from bank protection work was assessed to be the value of productions in the lands otherwise lost in case of absence of the work. The estimate of benefits was made for two time horizons; i.e. at year 1990 and year 2010 where the latter assumed the increase of damage potential as the population increases and the economic activity expands.

The Study then compared the relative attractiveness of the schemes in terms of B-C and B/C. The results of the overall evaluation of 9 schemes were classified into 3 separate groups by priority order:

Priority A : A fair economic viability even under 1990 condition and an increasing viability under 2010 condition, and high social needs assessed.

Priority B : A high to moderate economic viability under 2010 conditions, though low under 1990 condition,s and high to mid social needs.

Priority C : Relatively low economic return even under 2010 conditions, and relatively low social needs.

Schemes classified into each group are summarized below.

Priority Group	Scheme	B/C 1990 Condition	B/C 2010 Condition	Implementation Cost (US$ mil.)
A	Kano plain	0.84	2.40	31.4
	Nairobi city	0.75	1.85	
B	Yala swamp	0.34	2.33	31.0
	Kuja river mouth	0.17	1.20	
	Lumi river mouth	0.39	1.01	
C	Sondu river mouth	0.09	0.76	24.7
	Lower Tana	0.23	0.62	
	Middle Turkwel	0.00	0.24	
	Downmost Athi	0.00	0.20	
	Total			87.1

On the basis of the findings above, the Study proposes to implement the schemes under the following programmes:

(a) Schemes accorded Priority-A be implemented towards year 2000

(b) Schemes accorded Priority-B be implemented towards year 2010

(c) Schemes accorded Priority-C would be realized thenceforth, seeing additional needs which may be otherwise arising

(d) Preservation of budgetary resources equivalent to some 50% of (a) + (b) above, to cover other adhoc works including improvement of selected urban rivers

Preliminary plans of schemes categorized into (a) and (b) are shown in Sectoral Report G.

6.6.2 Urban drainage and minor river improvement projects

(1) Urban drainage project

Issues relating to urban drainage are occurring in many cities and urban centers, causing standing waters sometimes in unhealthful condition and inundation in local areas. Problems in Nairobi and Mombasa in particular appear to be worsening.

The Study presumes that the priorities of urban drainage works would be given to major cities which are listed in Table 6.6.1.

(2) Minor Ad-hoc River Improvement Projects

Other than specific flood control projects proposed in Section 6.6.1, there will also be many needs for improvement of river channels on ad-hoc basis, such as the improvement associated with urban drainage works, local bank protection work, removal of excessively accumulated silt, channel clearing work, canalization, etc. particularly in urban areas.

The identification of individual schemes is almost beyond the capability of this Study in view of limited information available at present. The work would be proposed from each regional office as and when the problem and need would arise in the future.

(3) Long-term Improvement of Lower Tana River

There are two major existing constraints in the Lower Tana reaches. One is the flood problem and the other the unstable river courses. The former, though not an acute problem at present, can ultimately be solved possibly by constructing flood control dams in the upstream reaches (there are several potential damsites) and levee construction in the downstream reaches. The latter is already causing a lot of inconveniences to riverine people and also to some major irrigation schemes (Bura and Hola irrigation schemes). It is deemed that the stabilization of river channel is a primary step toward the overall improvement of the Lower Tana River including flood protection objectives, which is proposed to be undertaken in advance of the levee construction there.

In line with this concept, the Study proposes to launch the pilot project of the channel stabilization works (chiefly rectification of meandering and protection of bank erosion) towards the year 2000. Based on the experience gained in the pilot project, the long-term improvement plan would be formulated.

6.7 Cost Estimate

The construction costs of the proposed schemes were estimated at the construction price in February 1990. The costs at this stage are only preliminary to indicate the order of magnitude. The construction costs consist of direct construction cost, engineering and administration, land acquisition and physical contingency. The direct construction costs were estimated based on the actual costs and estimates for similar projects in Kenya. When cost curves were available, such cost curves were utilized in the estimate. The construction costs are expressed in US$ at this time assuming exchange rates of Kshs25.2/US$.

(1) Urban water supply

Development cost of each system includes costs of intake, pipeline, raw water pumps, storage tanks having capacity equivalent to one-day demand, grid distribution system and allowance of 25%, but excludes costs of water source works of dams.

Unit costs of several works in the above were referred to those presented in Design Manual after due up-dating. The estimated costs are as given in Table 6.7.1. Unit development cost (development cost / daily supply volume) was compared with those of already planned or designed water supply schemes and found to be within the range of those schemes (See Sectoral Report D). The total development cost was estimated at US$4,372 million excluding dam cost.

(2) Urban sewerage

In estimating the required cost for urban sewerage development, it was assumed that the waste water from the manufacturing industries would be pre-treated by the industries before discharging into the sewerage system.

Ratio of waste water to water supplied was preliminarily assumed at 1:1. Sewer system was assumed to cover 50% of the total area of the urban centres with a population more than 100,000 persons and 25% for the remaining urban centres. The total cost of urban sewerage development was estimated at US$705 million as given in Table 6.7.2.

It was considered that the urban sewerage system development be made in such a way as to keep pace with the urban water supply development.

(3) Rural water supply

Unit water exploitation cost for the above water sources was estimated for each subbasin. The average unit water exploitation cost was estimated as follows (See Sectoral Report M):

Unit Water Exploitation Cost

(Unit:US$/$m^3$)

	Water Source	Cost
1.	Groundwater	
	- Borehole	0.53
	- Shallow well	0.12
2.	Small Dam	0.18
3.	Roof Catchment	2.92
4.	Subsurface Dam	0.53
5.	Sand Dam	0.39
6.	Rock Catchment	0.39

Cost of water supplied to rural areas from the urban water supply pipeline was incorporated into the construction cost for urban water supply. The total water exploitation cost (source development cost) was estimated at US$1,414 million.

Water supply cost for rural water supply was estimated by Location on the basis of the cost curves which includes the costs of intake facilities, 5-km raw water main, full treatment, storage with capacity equivalent to one-day demand and distribution.

The cost was estimated by applying the cost curves with treatment for surface water source and that without treatment for groundwater source. The total cost for rural water supply was estimated at US$1,213 million as given in Table 6.7.3.

(4) Livestock water supply

Water source for livestock water supply is organized into five sources: they are, surface water, groundwater, small dam, subsurface/sand dam and existing pipeline

The cost of water supply through existing urban water pipeline was included in the construction cost for urban water supply. The total livestock water exploitation cost was estimated at US$670 million as given in Table 6.7.4.

The cost for the development of watering points in nomadic pasturage areas was estimated at US$73 million as given in Table 6.4.6.

(5) Irrigation water supply

About 140 small irrigation schemes are proposed and total area of proposed scheme is about 7,000 ha. The cost for implementation was estimated at US$11.4 million applying unit cost of 1,630 US$/ha (41,000 Kshs/ha).

For the large irrigation schemes, 18 schemes were selected for the formulation of water development plan. The construction cost was estimated at US$861.9 million as summarized below.

Development Cost of Large Irrigation Schemes

Name	Cost(million US$)	Name	Cost(million US$)	
Arror	6.3	Lower Rupingazi	6.0	
Kano Plain	232.5	Mwea Extension	63.7	*1
Kanzalu	29.7	Sabaki Extension	19.8	
Kibwezi Extension	81.9	Tana Delta	141.4	
Kimira	18.1	Taveta	11.9	
Kunati	3.5	Thanantu	17.3	
Lower E.'Ngiro	57.0	Turkwel	1.8	
Lower Kuja	5.6	Upper Nzoia	88.0	
Lower Nzoia/Bunyala	12.4	Yala Swamp	65.0	
Total			861.9	

Note : *1 includes the development cost of Thiba Dam.

(6) Hydropower development

The recommended plan includes 5 new hydroelectric power development projects after Turkwel. The construction cost of the 5 hydropower development projects including the Gitaru #3 extension was estimated at US$1,034 million including the dam construction cost.

Construction Cost for Hydropower Development

	Plan	Installed Capacity (MW)	Construction Cost (million US$)	
1	Sondu/Miriu (No.1)	60.0	133	(119)
	" (No.2)	20.6	36	(-)
2	Low Grand Falls	120.0	291	(291)
3	Oldorko	72.0	71	(71)
4	Magwagwa	120.0	329	(340)
5	Mutonga	60.0	149	(149)
6	Gitaru #3	72.5	25	(25)
	Total	525.1	1,034	

Note : *Figure in ( ) show the cost estimated in NPDP, 1991.*

(7) Allocation of dam cost

In total, 28 damsites were selected for source development towards the year 2010. The cost of dam was estimated on the basis of embankment volume and unit cost of dam embankment (see Sectoral Report H).

The construction cost was allocated tentatively in proportion to water use quantity by purpose; they are, (i) hydropower, (ii) irrigation water and (iii) water supply developments. The cost of water supply development was further allocated in proportion to domestic water use quantity by major demand center. However, in case of dam schemes involving hydropower development, the whole dam cost was allocated to hydropower development.

Table 6.7.5 shows the results of allocation of dam construction cost. The dam cost so allocated is US$656.7 million for hydropower development, US$175.6 million for irrigation and US$577.3 million for urban water supply. The total development cost is US$1,409.6 million.

(8) Flood protection and drainage works

(i) Major flood protection projects

Five schemes are proposed for implementation towards the year 2010. The total development cost was estimated at US$62.5 million as summarized below.

Development Cost of Major Flood Protection Projects

(Unit: million US$)

	Plan	Construction Cost
1.	Kano plain	20.7
2.	Nairobi city	10.8
3.	Yala swamp	17.7
4.	Kuja rivermouth	5.0
5.	Lumi rivermouth	8.3
	Total	62.5

(ii) Urban drainage works

Table 6.6.1 shows very preliminarily estimated cost of the drainage works comprising of gravity drains. It is to be noted that drainage work involves in some cases major associated works such as pumping station, retarding basin, and improvement of receiving river channels., which should be planned in detail for each city. The development cost was estimated at US$874 million.

(iii) Minor ad-hoc river improvement projects

The estimates of these works on an individual scheme basis are beyond the capability of this Study, and hence a rule-of-thumb estimate made herein that a budget resource of about 1.5 times the amount appropriated for major flood control projects (US$90 million) should be preserved to cover the expenditures for these minor river improvement works.

(iv) Long-term improvement of Lower Tana River

The work will involve sophisticated planning of river morphological aspects and step-wise works on a do-and-see basis, and hence require a long period until the channel is in a stable regime. The Study presumes that an annual budget of the order of US$5 million/year (US$40 million in total) will be worthy of appropriation for the coming years towards 2000 as the budget for undertaking the proposed pilot project.

(9) Total development cost

The undiscounted total construction cost of water resource development was estimated at US$ 12,133 million equivalent for implementation of all the schemes required up to the year 2010 as enumerated below.

(Unit:million US$)

	Purpose	Development Cost
(1)	Urban Water Supply	
	– Water supply system	4,949*1
	– Sewerage system	705
(2)	Rural Water Supply	
	- Source dvelopment cost	1,414
	- Water supply facilities cost	1,213
(3)	Livestock Water Supply	
	– Domestic water supply system	670
	– Watering points in nomadic pasturage activities	85
(4)	Irrigation Water Supply	
	– Small irrigation scheme	11
	– Large irrigation scheme	1,015*2
(5)	Hydropower Development	1,034*3
(6)	Flood Protection and Drainage	
	- Flood protection projects	63
	- Urban drainage and minor river improvement	1,004
	TOTAL	12,163

Note *1 includes dam cost of USS 577 million
*2 includes dam cost of USS 176 million All the cost for large irrigation schemes were counted without considering construction schedule.
*3 includes dam cost of USS 657 million

6.8 Socioeconomic Effects and Impacts

6.8.1 Basic viewpoints of effect estimation

The beneficial and adverse effects of proposed plans are estimated as the annual equivalent of economic benefits and costs for an evaluation period.

The prices of internationally tradable goods and services are basically estimated on the basis of the World Bank projection to 2000, or the international market price in February, 1991. The prices of local goods and services are the normalized price in February, 1991. The