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Kenya Water Resources Infrastructure Gaps

Final Report

May 2003

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Kenya Water Resources Infrastructure Gaps

Final Report **Contents** **May 2003**

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Executive Summary

E.1 Introduction and background

This report forms part of the socio-economic assessment of water resources issues and challenges in Kenya supported by the World Bank Netherlands Water Partnership Program Water Resources and Livelihoods of the Poor

The report reviews at a national level water security issues in four components:

i. The natural resources of Kenya in terms of available water
ii. An update of the water demand requirements to the year 2030
iii. A review of the effective storage from the viewpoint of vulnerability, reliability, safety and sedimentation.
iv. An estimate of water resources investment needs for the multi sectoral uses to meet short, medium and long term demands.

E.2 Sources of information

Relevant reports were collected on a national and regional level from many government authorities and institutions within Kenya from 27 April to 15 May 2003. Field visits were completed to Embu, Nyeri, Nanyuki and Isiolo between 2nd to 6th May 2003 visiting hydropower schemes, water storage dams, irrigation schemes, local water user groups, provincial offices, research stations and Development Authorities.

E.3 Water resources availability

A groundwater comparison of the year 2000 abstraction rates with the recharge concluded there was considerable scope for additional abstraction (Tuinhof 2001). The year 2000 groundwater abstraction is approximately 182 Mm^3/year and the potential is 1,051Mm^3/year.

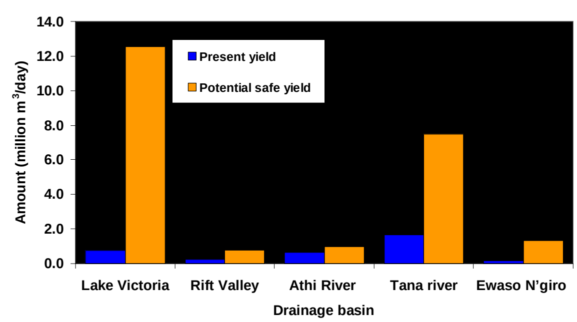
The year 1992 abstraction of surface water for the normal flow condition was estimated based and on the water permit data (JICA[2] 1992) and is approximately 1,072 Mm^3/year, whereas the safe abstraction is 7,396 Mm^3/year.

Accurate information on the surface water abstraction rates is not available and there are many illegal surface water abstractions, which are not recorded. Estimation of the an accurate present surface water abstraction rate by river basin is outside the timeframe of this study therefore the year 1992 values from the NWMP have been used.

For a very approximate assumption, if the surface water abstraction rates have increased at the same rate as groundwater abstraction (44%) since 1990 then the current surface water abstraction would be 1,544 Mm^3/year.

The combination of adding the year 2000 abstraction rates of both the groundwater and the year 1992 surface water sources with the potential yields is shown in Figure E.1

Figure E.1 Comparison of potential safe water abstraction by drainage basin.



The results show that the biggest potential for additional water abstraction is on the Lake Victoria and the River Tana basins.

The total safe yield combining surface and groundwater is approximately 8,447 Mm^3/year and the current abstraction is likely to be in the range of minimum 1,200 Mm^3/year (1992 value) to a possible 1,725 Mm^3/year for the whole of Kenya.

E.4 Water demand projections

The National Water Masterplan (NWMP) 1992 and the AfterCare Study 1998 use the 1989 Central Bureau of Statistics (CBS) for demand projections to the year 2010.

In the Year 2001 the CBS published the 1999 provincial population statistics. Based on the CBS 2001 findings the population and demand projections have been updated to the year 2030 to take into account the long term water needs of Kenya.

The updated demand projections for the various sub-sectors are shown below in Table E.1.

Table E.1 Summary of projected water demand requirements (unit 1000 m^3/day)

Year	1990	2000	2010	2020	2030
domestic water urban	557	1,105	1,721	2,430	3,019
domestic water rural	516	708	1,049	1,333	1,671
domestic water total	1,073	1,813	2,770	3,763	4,691
Irrigation	3,965	6,052	8,138	10,225	12,311
livestock	335	312	390	492	623
Industry	220	366	491	606	714
Other (fishery and wildlife)	65	82	99	116	133
Total (1000 m^3/day)	5,659	8,624	11,889	15,202	18,471
Total (Mm^3/year)	2,067	3,150	4,343	5,552	6,747

The results show that the total water demand requirement in the year 2010 (not including irrigation) is approximately 3.79 Mm^3/day, which matches closely with the Aftercare study value of 3.66 Mm^3/day.

The projected water demand requirement for Kenya in the year 2030 is 18.5 Mm^3/day or 6,750 Mm^3/year.

E.5 Vulnerability, safety and reliability of groundwater

E.5.1 Groundwater Reliability

- If pumping rates are controlled and recharge is monitored then the boreholes are likely to be reliable.
- Good for storage during drought periods
- Operation and maintenance issues of the boreholes should be addressed

E.5.2 Groundwater Vulnerability

- Vulnerability for groundwater sources is variable and depends on the natural protection.
- Salinity increases in the North East province and the Coast province due to evaporate deposits and seawater intrusion respectively.
- Bacterial quality of water is of concern where groundwater is pumped from shallow wells.

E.5.3 Groundwater Safety

The groundwater safety factors are as follows:

- Ineffective groundwater management may lead to uncontrolled development and result in over pumping of the aquifer and on the groundwater pollution.
- Groundwater monitoring is important

E.6 Vulnerability, safety and reliability of surface water

E.6.1 Surface water Reliability

- Dependant on good water resource management practices. Kenyan forests play an important role in providing a sustainable and reliable water supply.
- Restricted to the size of dam and climate conditions (e.g. evaporation can be high).
- Interbasin transfer schemes can reduce risk and improve reliability of a river / dam.

E.6.2 Surface Water Vulnerability

Surface water vulnerability factors include the following:

- Susceptible to pollution/contamination since the rivers/ dams are largely unprotected.
- Reducing the water supply requirement from a single source reduces the vulnerability.
- Monitoring the off takes/ pumping / abstraction from the rivers during normal to low flow conditions.

E.6.3 Safety

Surface water safety factors include the following:

- It is Important to have regular dam, weir and river embankment safety checks to prevent walls/ embankments collapsing during flood events.
- Good operating procedures should be in place to help ensure management of flood flows and optimal storage for drought conditions.

E.7 Water resources demand balance

The annual volume of potential safe water resources (Groundwater and surface water) was estimated to be as follows:

Total (safe yield) 8,447 Mm^3/year

Given that Table E.1shows the national projected water demand in 2030 to be 6,747 Mm^3/year, the national potential water resources in Kenya is sufficient for the water demand requirement to the year 2030.

However due to the water resources water availability variation between the five drainage zones there are areas that will suffer from water deficit.

Comparison of the updated year 2020 water demands requirements as shown in section 3 for the various sectors has similarity with the NWMP findings for the year 2010 since growth of human population, livestock population and irrigation potential has not increased at the rate envisaged in the NWMP.

Therefore many of the groundwater and surface water schemes proposed in the NWMP could be phased at a later date between the years 2010 to 2030.

The lack of investment in water infrastructure and poor water resources management means that the national water demand currently outstrips available water by approximately 4.8 Mm^3/day based on water demand figure calculated during the mission. This deficit occurs in all river basins except the Tana River basin. The deficit could rise to approximately 7.6 Mm^3/day depending on surface and groundwater abstraction/ interbasin transfers and whether new surface water storage in terms of dams is implemented.

E.8 Infrastructure gaps recommendations

Recommendations for Kenya's water resources needs are as follows:

i. Water resource feasibility studies and economic assessments are required for each of the potential dam sites that are published in the NWMP before embarking on dam construction projects in the medium term.

ii. Water resource feasibility studies and economic assessments should be carried out for each of the practical NWMP proposed interbasin and intrabasin transfer schemes.

iii. Irrigation is by far the largest sector user of water. Refurbishment of the existing large scale irrigation and small scale schemes is crucial for ensuring optimal allocation of water for maximum crop yield in the short term.

iv. An accurate assessment of the surface water abstraction licence daily allowable flows from the Ministry of Water Resources database is required in the short term.

v. Safety and vulnerability of surface water sources needs addressing. All the main dams and pumped abstractions require safety inspections to prevent dam failure/ water loss in the short term. Failure of the Sasumua Dam wall on 4 May 2003 during the flood events had the impact that one million people with in the City of Nairobi were without water.

vi. Vulnerability of the groundwater sources is a major issue. An accurate database is required of all the borehole abstraction rates in the country and an investigation into the actual abstraction rates in the short term.

vii. Sedimentation effects on the large dams require investigation. Improved data monitoring, regular dam volumes surveys are crucial in finding methods of reducing sedimentation and extending the dam life.

viii. It is a necessity to improve the hydrological data collection within the Ministry of Water Resource Management with other Government authorities. Accurate timeous data collection and digitisation is necessary to allow rapid response to flood events and effective water resources management. By linking data to GIS systems etc it can be effectively used for many of the required hydrological studies in Kenya in the medium term.

ix. Storing the large event peak flows during flood events for use during the dry season requires weirs, canals and addition surface water storage dams. Flood Alleviation/ water resources studies are essential to understanding how best to reduce flooding and increase water storage across the river basins within Kenya in the medium short to medium term.

Section 1
Background and Introduction

1.1 Introduction and background

This report forms part of the socio-economic assessment of water resources issues and challenges in Kenya supported by the World Bank Netherlands Water Partnership Program Water Resources and Livelihoods of the Poor.

This report forms part of a review at a national level water security and poverty and growth. To address the impacts of climate variability in Kenya it is necessary to improve the water security for poverty alleviation and economic growth.

This report addresses water security issues and is divided into four sections, which are summarised below:

i. Background review of present physical conditions in the study area
ii. A review and analysis of the short, medium and long term of the sub sector water demand requirements for now and the future
iii. A review of the effective storage from the viewpoint of vulnerability, reliability, safety and sedimentation.
iv. An estimate of water resources investment needs for the multi sectoral uses to meet short, medium and long term demands.

1.2 Sources of Information

Relevant reports were collected on a national and regional level from the following authorities and institutions within Kenya from 27 April to 15 May 2003.

- Ministry of Water Resources Management and Development
- Ministry of Energy
- Ministry of Agriculture and Rural Development
- Tana and Athi River Development Authority
- Ewaso Ngiro North Development Authority
- Kengen
- World Bank

The reports used are detailed in the References section.

3 May 2003 Masinga Dam

1.3 Liaison

Liaison has been an important aspect of this study;

- Regular contact with Directors and Assistant Directors from the Department of Water Resources Management and Development
- Meetings were arranged with the various authorities involved in the study as shown in Section 1.2.
- Field visits to Embu, Nyeri, Nanyuki and Isiolo between 2nd to 6th May 2003 visiting hydropower schemes, water storage dams, irrigation schemes, local water user groups, provincial offices, research stations and Development authorities.

The full list of meetings/ contacts and field visits are given in Appendix A.

Section 2

Natural Resources

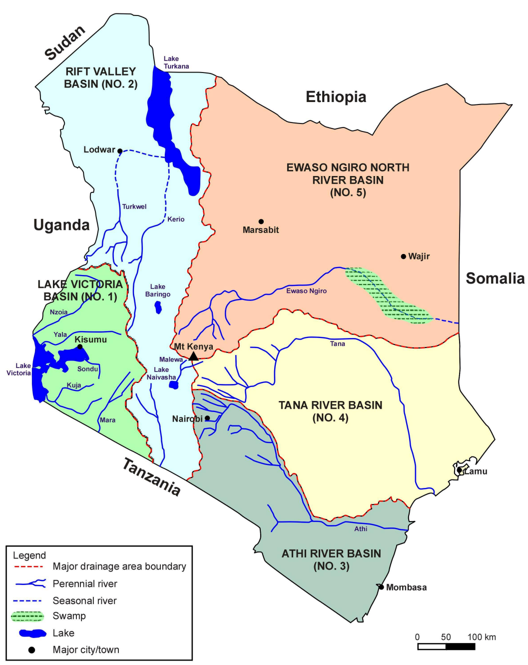
2.1 Physical characteristics of Kenya

Kenya has a territorial area of approximately 583,000 km^2 and a water area of nearly 11,230 km^2. Kenya's topography has much diversity ranging from a sea level elevation to the highest point at Mount Kenya of 5,199m. 86% of the land area is classified as arid to semi-arid (ASAL) which has few soil or water resources but supports over 25% of the human population and over 50% of livestock production in the country (JICA[2] 1992).

2.1.1 Drainage Basins

Kenya is divided into five drainage basins as shown in Figure 2.1.

Figure 2.1 Kenya drainage basins



Ref (JICA[2], 1992)

The catchment parameters for each of the basins are given in Table 2.1.

Table 2.1 Surface water catchment characteristics by drainage basin

Drainage area name	Drainage Area (km^2)	% of total area	Mean Annual Rainfall (mm)	Mean annual runoff (Mm^3)
Lake Victoria	46,229	8%	1,368	11,672
Rift Valley	130,452	23%	562	2,784
Athi River	66,837	12%	739	1,152
Tana river	126,026	22%	697	3,744
Ewaso N'giro	210,226	36%	411	339
Total	579,770	100%		19,691

Ref (JICA[2] 1992), (JICA[2] 1998)

2.1.2 Evaporation

Mean annual evaporation depths are recorded at the Dept. of Meteorology. The evaporation figures vary from between 1,215mm to 3,945mm/ year (JICA[1] 1992).

2.1.3 Rainfall

The mean annual rainfall is 621mm and this ranges from 411mm in the Ewaso Ngiro area to 1368 mm in Lake Victoria (JICA[2] 1992).

Figure 2.2 Drainage areas and annual rainfall

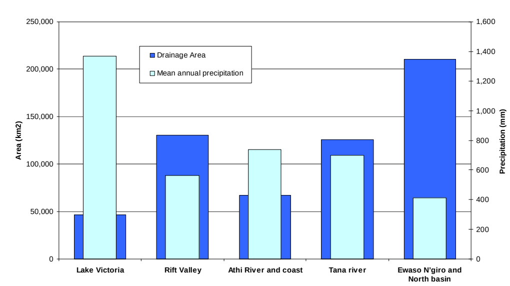


Figure 2.2 shows the rainfall variability within Kenya for each drainage zone. The highest average annual rainfall occurs in the Lake Victoria drainage basin, which has the smallest area, whilst the Ewaso Ngiro drainage basin has the least average yearly rainfall with the largest area.

2.2 Present groundwater abstraction

The groundwater is recharged by rainfall and is dependant on rainfall total, evaporation rates, topography etc. From analysis of the abstraction rainfall estimates it was determined that 0.65% of the rainfall can safely be abstracted within Kenya (Tuinhof, 2001).

The estimated groundwater recharge for the Kenya drainage basins is given in Table 2.2.

Table 2.2 Groundwater recharge rates

Drainage area name	Average rainfall	Groundwater recharge	
	Mm^3/year	Mm^3/year	mm/year
Lake Victoria	13800	394	9
Rift Valley	3260	428	3
Athi River and coast	1310	296	4
Tana river	3700	500	4
Ewaso Ngiro	340	484	2
Total	22410	2102	

Ref (Tuinhof 2001)

A comparison of the year 2000 abstraction rates with the ground water recharge concluded there was considerable scope for additional abstraction (Tuinhof 2001). Table 2.3 summarises this with the no. of wells, current abstraction and potential abstraction for each of the drainage basins. The year 2000 groundwater abstraction is approximately 190 Mm^3/year.

Table 2.3 Year 2000 groundwater abstraction characteristics by drainage basin

Drainage area name	No. Wells	year 2000 Abstraction (Mm^3/year)	Potential recharge (Mm^3/year)	Additional abstraction (Mm^3/year)
Lake Victoria	1344	17	197	180
Rift Valley	2241	38	214	176
Athi River	6720	102	148	46
Tana river	987	10	250	240
Ewaso Ngiro	1708	15	242	227
Total	13000	182	1051	869

Ref (Tuinhof 2001)

Approximately 5 times more water can be safely abstracted from the groundwater sources.

The number of boreholes in the Year 1990 was estimated to be approximately 9,000 and there is approximately 13,000 in the year 2000 (Tuinhof 2001). This accounts for a 44% increase since 1990.

2.3 Surface water abstraction

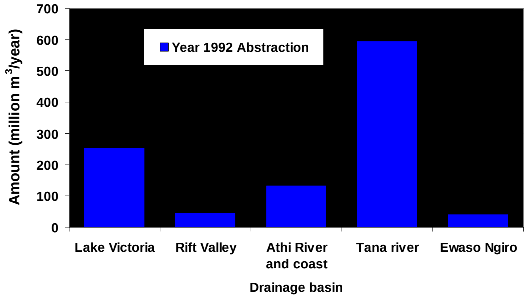
The year 1992 abstraction of surface water for the normal flow condition was estimated based and on the water permit data and is shown in Table 2.3 and Figure 2.3 (JICA2 1992).

Table 2.4 Year 1992 Surface water abstraction data

	Year 1992 Abstraction	Safe yield abstraction
	(Mm^3/year)	(Mm^3/year)
Lake Victoria	254	4380
Rift Valley	47	77
Athi River and coast	133	213
Tana river	595	2480
Ewaso Ngiro	42	246
Total	1,072	7396

Ref (JICA[1], 1992)

Figure 2.3 Year 1992 Surface water abstraction data



Most of the permits are in the Lake Victoria and River Tana basin.

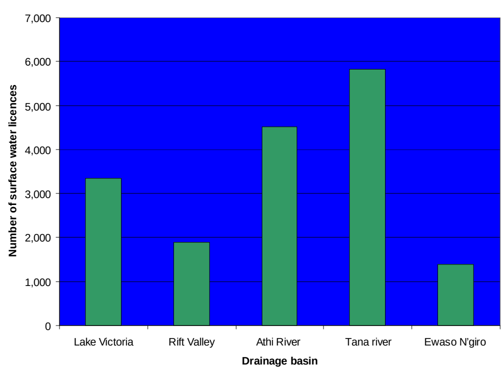
The magnitudes of annual renewable water from surface means that approximately 6 times more water can safely be extracted from the surface water.

Electronic data was collected from the Ministry of Water Resources on water surface abstraction licences up to the end of year 2002 from their database system. Analysis of the data showed there are over 16,000 licences as displayed in Figure 2.4.

Analysis of the water permit information in terms of the average daily abstraction rates was not possible within the timeframe of the project since thorough checking of the data base is required.

For a very approximate assumption, if the surface water abstraction rates have increased at the same rate as groundwater abstraction (44%) since 1990 then the current surface water abstraction would be 1,544 Mm^3/year.

Figure 2.4 No. of surface water abstraction licences to the Year 2002



The main surface water dams in Kenya are presented below in Table 2.5.

Table 2.5 Main surface water dams of Kenya

Dam name	Type	Drainage basin
Masinga	Hydropower storage	Tana River
Kamburu	hydropower	Tana River
Gitaru	hydropower	Tana River
Kindaruma	hydropower	Tana River
Sasumaru	domestic : Nairobi	Tana River
Bathi	domestic : Nairobi	Tana River
Ruiri	domestic : Nairobi	Athi River
Turkwell	hydropower	Rift Valley
Twin Rivers	domestic	Lake Victoria
Thika	domestic	Tana River

Masinga Dam is the large dam with 1,560 Mm^3 of storage volume available. Most of the other dams have between 2 to 10 Mm^3 of storage capacity and Thika dam has 56 Mm^3.

2 May 2003 Gitaru hydropower dam looking downstream from the spillway gates

2.4 Energy structures and storage facilities

Generating facilities in Kenya consist of hydroelectric, conventional thermal and geothermal and wind. The total installed capacity for Kenya 1,162 MW (Ministry of Energy 2003) and this is detailed in Table 2.6.

Table 2.6 Summary of power generating facilities in Kenya

Type	Energy (MW)
Hydro	677.2
Thermal	398.0
Geothermal	57.0
Wind	0.35
Total	1162.0

Ref (Ministry of Energy 2003)

Imports from Uganda Electricity Transmission company (UETCL) range from 0 to 30 MW. Hydro generation sources make up 62.2% of the effective capacity. The details of the hydropower generated from the dams in Kenya are detailed in Table 2.7 below.

Table 2.7 Specific energy data on hydropower sources in Kenya

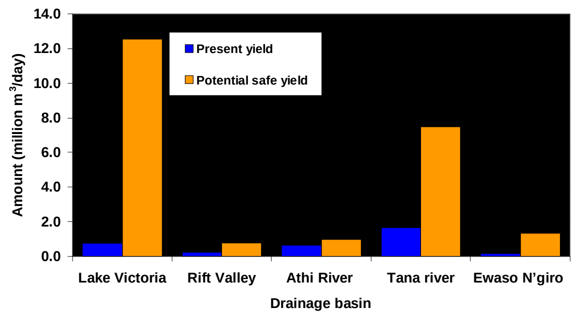
Dam	Capacity (MW)	
	Installed	Effective
Tana	14.4	12.4
Wanji	7.4	7.4
Kamburu	94.2	84.0
Gitaru	225	215
Kindaruma	40	40
Masinga	40	40
Kiambere	144	144
Small stations	6.2	5.4
Turkwell	106	106
UETCL	30	0
Total	707.2	654.2

2.5 Water resources availability

The combination of adding the year 2000 abstraction rates of both the groundwater and the year 1992 surface water sources with the potential yields is shown in Figure 2.5

Accurate information on the surface water abstraction rates is not available and there are also many illegal surface water abstractions, which are not recorded. The work required to estimate a present surface water abstraction rate by river basin is outside the timeframe of this study therefore the Year 1992 value has been used.

Figure 2.5 Comparison of surface (Year 1992) and groundwater abstraction (Year 2000) and potential safe abstraction by drainage basin.



The results show that the biggest potential for additional water abstraction is on the Lake Victoria and the River Tana basins.

The total safe yield combining surface and groundwater is approx 8,447 Mm^3/year and the current abstraction is likely to be in the range of minimum 1,200 Mm^3/year (1992 value) to a possible 1,725 Mm^3/year for the whole of Kenya.

Section 3

Present and future water demands

3.1 Domestic Water Demands

The Central Bureau of Statistics (CBS) published the population census in 2001 for the year 1999.

The National Water Master Plan (NWMP) of Kenya (JICA[1], 1992) used the year 1989 CBS population projections and the Aftercare Study on the NWMP (JICA[2], 1998) analysed data from the CBS 1989, and the Eight National Development Plan 1997 to 2001.

3.1.1 Year 1999 Population by Drainage Area

The human population distribution for each of the drainage basins was calculated using the year 1999 provincial population statistics (CBS 2001). This information was spacially referenced from the districts to the equivalent drainage basins to obtain a percentage population per drainage basin and is summarised in Table 3.1.

Table 3.1 Year 1999 Population distribution by drainage basin

Drainage basin	1999 Population	% total population
Lake Victoria	11,600,615	40
Rift valley	2,768,616	10
Athi River	7,034,739	25
Tana River	4,716,386	16
Ewaso Ngiro	2,566,250	9
Total	28,686,607	

Ref (CBS, 2001)

A comparison was made of the population for each drainage basin and the average annual runoff, which is shown in Figure 3.1.

Figure 3.1 1999 percentage population and average surface water runoff by drainage basin

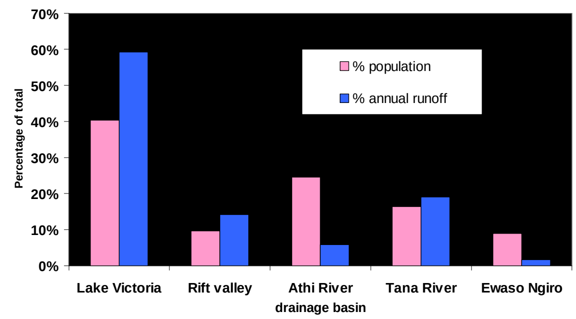
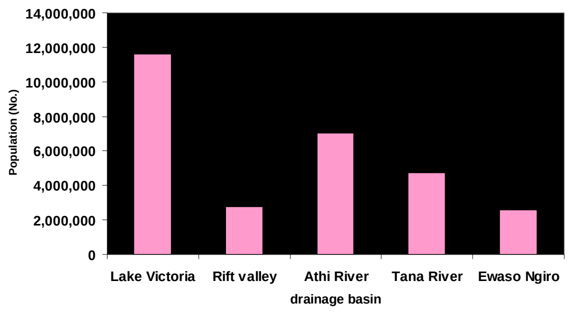


Figure 3.1 shows that 40% of the population and over 60% of the average river flow occurs in the Lake Victoria basin. This clearly demonstrates that the percentage of river basin flow and percentage population is highly variable over Kenya.

3.1.2 Population projections

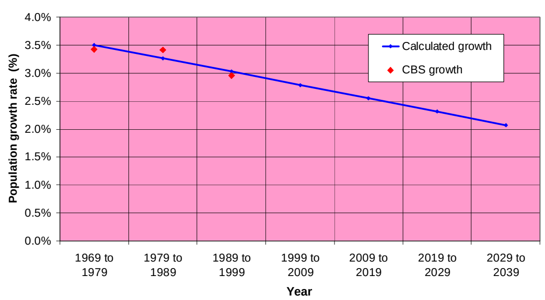
The 1999 population for Kenya was enumerated to be approximately 28.6 million. Figure 3.2 shows the equivalent population for each drainage basin.

Figure 3.2 Year 1999 population by drainage area



The Population growth rates in the last three decades have been decreasing (CBS, 2001) and this is summarised with a linearly projected growth rate to the year 2039 as shown in Figure 3.3.

Figure 3.3 Estimated population growth rates from 1969 to 2039



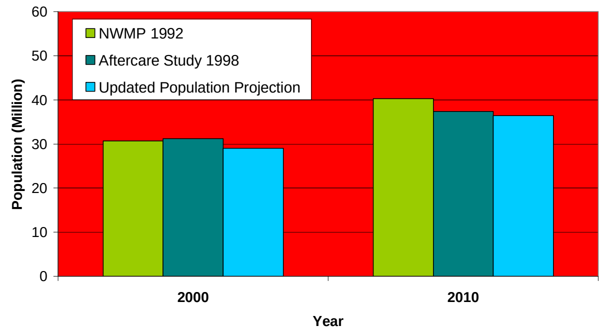
The results show that the population growth rate between 1999 and 2009 is likely to decrease to 2.75 %.

A comparison of the NWMP 1992, The Aftercare Study on the NMWP 1998 and the estimated population projections are shown in Figure 3.4.

The results show that both the NWMP 1992 and The Aftercare study 1998 have similar estimates for the year 2000 population projections. For the year 2010 a much higher population is projected with the NWMP 1992 than the Aftercare Study and the population projection in this report. The Aftercare Study year 2000 population projections are similar to the estimated population projections given in this report thereby giving confidence in using the extrapolated growth rates shown in Figure 3.3.

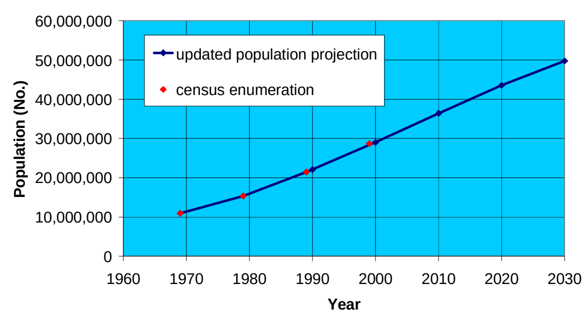
Figure 3.4 shows the updated population projections based on the growth rates from Figure 3.3.

Figure 3.4 Adopted population projections for Kenya



Due to the declining growth rate from the 1999 census when compared with the 1989 census we feel it prudent to consider a more likely population growth rates as given in Figure 3.3. The total population is likely to reach 36.4 million by 2010 and 43.6 million by 2020 and this is shown in Figure 3.5.

Figure 3.5 Updated population projections to 2030



Population growth rates for both the rural and urban areas were extrapolated using logarithmic regression from the NWMP 1992 report. The urban growth rate is expected to be approximately 4.1% and the rural growth rate will drop to 1.3% by 2030. The summary of population projections for both rural and urban areas is given in Table 3.2.

Table 3.2 Updated population projections for rural and urban components (Million)

	1990	2000	2010	2020	2030
urban	3.849	7.497	11.467	15.900	19.404
rural	18.233	21.528	24.930	27.661	30.351
total	22.082	29.026	36.396	43.561	49.755

The total population in 2030 is estimated to be approximately 49.7 Million.

3.1.3 Domestic water consumption

The domestic water consumption rates are given in the 1986 Design Manual.

The Aftercare Study 1998 and NWMP 1992 has estimated the rural and domestic consumption projections from 1990 to 2010 using the ideal situation; the water consumption rates from the 1986 design manual.

Within the scope of this study it was outside the timeframe to calculate population demands by district. The consumption rates for the years 2020 to 2030 were calculated approximately for the country using linear extrapolation of the averaged year 1990 to 2010 estimates from the NWMP 1992. The results of the Aftercare 1998 and the NWMP 1992 are similar.

The summary of domestic water consumptions used is given in Table 3.3.

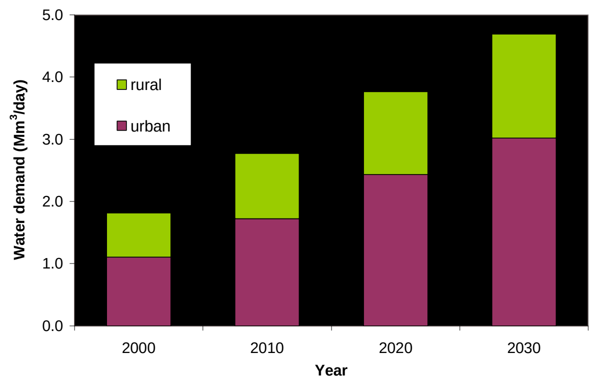
Table 3.3: Domestic demand per capita (l/c/d)

	1990	2000	2010	2020	2030
urban	145	147	150	153	156
rural	28	33	42	48	55
total	74	87	102	113	123

3.1.4 Domestic water demands

The domestic demands for rural and urban areas to the year 2030 are shown below in Figure 3.6 and are taken as the product of Table 3.2 and Table 3.3.

Figure 3.6 Domestic water demand projections to the year 2030

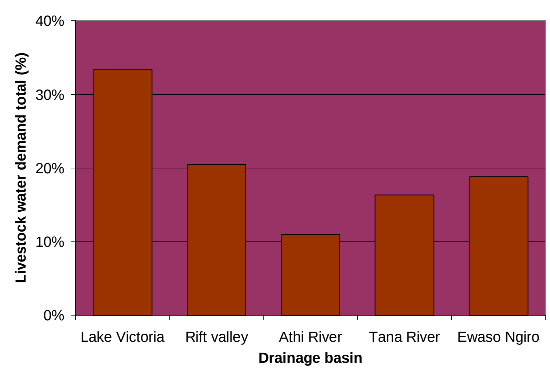


By the year 2030 the estimated water demand is anticipated to be 4.7 Mm^3/day. The results are similar to the Aftercare study year 2010 estimated water demands of 2.38 Mm^3/day.

3.2 Livestock water demands

The NWMP distribution of livestock population demands for each drainage basin is given below in Figure 3.7.

Figure 3.7 Livestock distribution in Kenya by basin



(Ref JICA[2], 1992)

The results show that most of the livestock is in the Lake Victoria basin with 33%.

According to the NWMP the livestock population projection for the year 2000 was as follows:

Table 3.4 NWMP Year 2000 projected livestock population

	2000
cattle	14,261,320
sheep/goat	18,751,300
camel	848,660

The livestock population given in the NWMP required updating due to the effects of the La Nina event from October 1998 and November 2000 where millions of livestock died due to the drought conditions.

The Year 2000 livestock population after La Nina is given in Table 3.4 (Ref UNEP 2000).

Table 3.5 Effects of La Nina on Livestock, Year 2000

	Population	Numbers died	total
cattle	8,900,000	1,725,000	10,625,000
sheep/goat	13,600,000	2,184,000	15,784,000
camel	800,000	8,000	808,000

Ref (UNEP, 2000)

The total livestock populations from Table 3.4 and Table 3.5 have a high variation. The assumed year 2000 livestock population projection used in this report was the average of Table 3.4 and Table 3.5 minus the number of livestock that died. This method was chosen since it was not possible within this report timeframe to check the accuracy of either of the livestock population figures in more detail.

The livestock water demand projection was calculated using the same methodology as in the NWMP report, where livestock population would grow to meet the increase in the demand of milk and meat and applying the average unit water requirement of 50l/day per livestock unit. The demand calculations are detailed in Appendix B and the future livestock water demands are shown in Figure 3.8.

Figure 3.8 Livestock demand projection

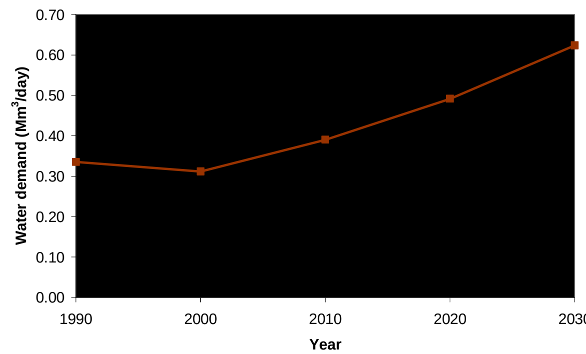


Figure 3.8 shows the water demand drop from the year 1990 to the year 2000 due to the drought impact of La Nina, but with regular growth until year 2030 with a water demand of 0.62 Mm^3/year.

The NWMP estimated the livestock demand in 2010 to be approximately 0.62 Mm^3/day whereas Figure 3.8 shows the demand to be 0.39 Mm^3/day. The lower water demands are mainly due to the impacts of El Nino and La Nina between the years 1996 to 2000.

3.3 Irrigation water demands

The potential of irrigation development in the whole of Kenya has been estimated to be 351,500 Ha (JICA[1]). The distribution of this in size by drainage basin is given in Figure 3.9 below.

Figure 3.9 Irrigation potential in Kenya

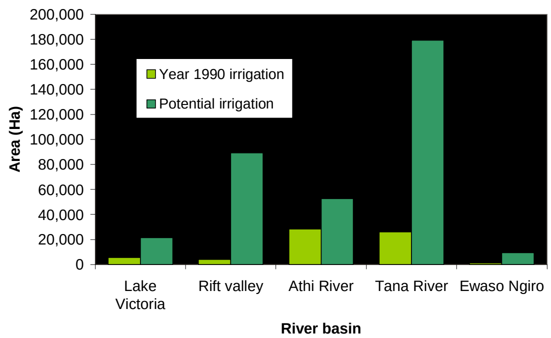


Figure 3.9 shows that in the year 1990 only 23% of the irrigation potential in Kenya was being utilised.

Irrigation water demands from the NWMP in the year 1990 were estimated to be 3.97 Mm^3/day.

Table 3.6 Irrigation developments in Ha

Irrigation type	Area (Ha)	
	1990	1995
Private	25,800	33000
Small holder	27,200	37000
Managed by government	12,000	12000
Total	65,000	82,000

Ref JICA[1], Republic of Kenya 2000

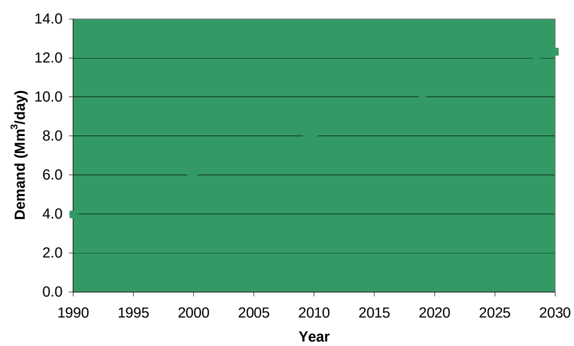
It was assumed that the average irrigation water demand per hectare was 61.1m^3/day based on the above information.

Table 3.6 shows the irrigation developments for both 1990 in the NWMP and in the year 1995 from updated information.

From discussions with the National Irrigation Board, many schemes are presently damaged and not operational, therefore the irrigation developments managed by government have decreased substantially since 1995. However this has been offset by an increase in the number of smallholder irrigation schemes in the vicinity of the large government irrigation schemes. No recent total irrigation area information was available from the relevant government departments during the publication of this report.

Assuming linear extrapolation of the data in Table 3.6, the irrigation water demand projection to the year 2030 was estimated to be 12.3 Mm^3/day and is shown in Figure 3.10.

Figure 3.10 Irrigation demand projection



The irrigation projections assume that the Government irrigation schemes will be refurbished and all will be fully operational in the near future. Figure 3.10 shows that irrigation demands are estimated to be 8.1 Mm^3/day in the year 2010 compared with the 11.7 Mm^3/day for the year 2010 in the NWMP 1992. The reason for this is that irrigation development for agriculture has not progressed as rapidly as forecast in the NWMP due to the effect of El Nino, La Nina and other economic factors.

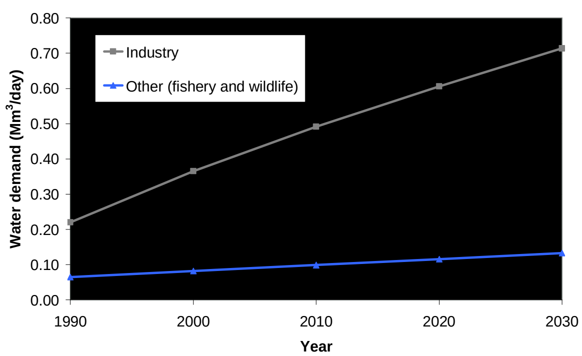
3.4 Industry and other water demands

The industrial demand and other demands (fishery and wildlife) were estimated by extrapolating the NWMP demands estimates until the year 2030.

The industrial and other users account for the smallest component of the water demand sector calculations, therefore the projections analysis has not been analysed in detail since this has less of an impact on the total demand.

The NWMP presents a conservative approach to the water demand requirement for industry and this has been used in the report.

Figure 3.11 Industry, fishery and wildlife water demands projections



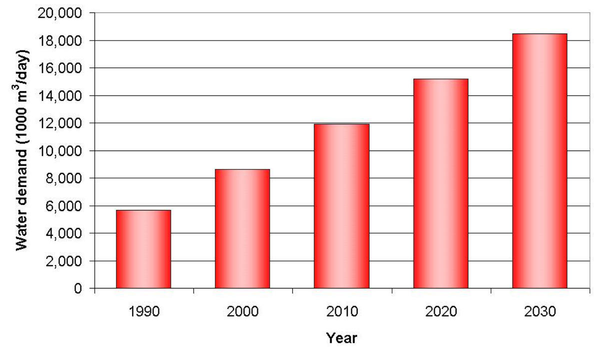
3.5 Summary of water demands

The main water demand requirements for Kenya within the various subsectors are summarised below in Table 3.7 and Figure 3.12.

Table 3.7 Summary of projected water demand requirements (unit 1000 m^3/day)

Year	1990	2000	2010	2020	2030
domestic water urban	557	1,105	1,721	2,430	3,019
domestic water rural	516	708	1,049	1,333	1,671
domestic water total	1,073	1,813	2,770	3,763	4,691
Irrigation	3,965	6,052	8,138	10,225	12,311
livestock	335	312	390	492	623
Industry	220	366	491	606	714
Other (fishery and wildlife)	65	82	99	116	133
Total (1000 m^3/day)	5,659	8,624	11,889	15,202	18,471
Total (Mm^3/year)	2,067	3,150	4,343	5,552	6,747

Figure 3.12 Water demand requirements



The results show that the total water demand requirement in the year 2010 (not including irrigation) is approximately 3.79 Mm^3/day, which matches closely with the Aftercare study value of 3.66 Mm^3/day.

The projected water demand requirement for Kenya in the year 2030 is 18.5 Mm^3/day or 6,750 Mm^3/year.

Section 4

Vulnerability, Safety and Reliability of Effective storage

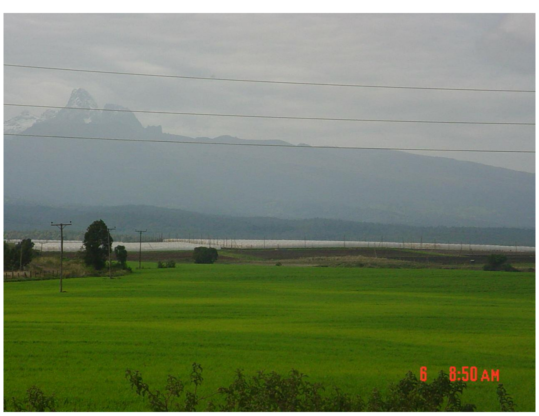
4.1 Introduction

This section of the report reviews the vulnerability, reliability and safety of water resources schemes in terms of surface water yield and the potential effects on groundwater.

The Groundwater and surface water impacts are discussed under separate headings.

4.2 Groundwater

Groundwater does occur everywhere in Kenya, but reliability and successful drilling sites requires a good understanding of the local/ regional hydro-geological characteristics. Exploitation of this resource has considerable potential for boosting water supplies, but has a relatively expensive due to the small capacities. The average pumping rate is 8 m^3/hr and the percentage of national productive boreholes is 55% (Tuinhof 2001). Groundwater is suitable in the Arid and Semi Arid Lands of Kenya where availability of surface water is marginal since in the predominantly semi arid regions where rural areas are scattered, surface water supply systems with large scale pipes are unlikely to be economically viable (Tuinhof, 2001).



6 May Horticultural farms near Mount Kenya

Ground water has a very high water resource value in the semi-arid areas that are sparsely populated. Groundwater sources are used for irrigation, domestic water supply, livestock and industries.

4.2.1 Groundwater Reliability

The reliability factors for groundwater are as follows:

- Groundwater generally represents a considerable source of good quality water.
- Average recharge is 0.65% of the rainfall and is realistic for semi-arid areas.
- If pumping rates are controlled and recharge is monitored then the borehole is likely to be reliable.
- Good for storage during drought periods
- Spacing should be a minimum of 800m between each borehole
- Dependent on climate and rock type for recharge rates
- Groundwater is dependent on sustainability (this includes the hydrological connection between groundwater and surface water).
- Operation and maintenance issues of the boreholes should be addressed

In summary groundwater does have high reliability if maintained and operated well and pumping rates are controlled.

4.2.2 Groundwater Vulnerability

The vulnerability factors for groundwater are as follows:

- Vulnerability for groundwater sources is variable and depends on the natural protection.
- Quality of the groundwater is generally good in the Western central, Nyanza and Nairobi provinces.
- Salinity increases in the North east province and the Coast province due to evaporate deposits and seawater intrusion respectively.
- Bacterial quality of water is of concern where groundwater is pumped from shallow wells.

4.2.3 Groundwater Safety

The groundwater safety factors are as follows:

- Ineffective groundwater management may lead to uncontrolled development and result in over pumping of the aquifer and on the groundwater pollution.
- Groundwater monitoring is important
- New wells should not be drilled closer than 800m of existing wells

4.3 Surface water

More surface water is available than in the ground therefore management and protection of the surface water is important, but groundwater should not be underestimated. Currently there are approximately 12 main dams within Kenya that are used for either domestic water supply or power generation. Surface water used for irrigation schemes is mostly abstracted from the river by pumps or by weirs to gravity irrigation canals.

4.3.1 Surface water Reliability

Surface water reliability factors are as follows:

- Dependant on good water resource management practices. Kenyan forests play an important role in providing a sustainable and reliable water supply.
- Restricted to the size of dam and climate conditions (e.g. evaporation can be high)
- Water demand requirements imposed on surface water since there is limited storage capacity
- Interbasin transfer schemes can reduce risk and improve reliability of a river / dam

Surface water sources in Kenya are likely to be less reliable than the groundwater sources, however surface water does usually have much higher storage volumes.

4 May Irrigation canal and gate near Embu

4.3.2 Surface Water Vulnerability

Surface water vulnerability factors include the following:

- Susceptible to pollution/contamination since the rivers/ dams are largely unprotected
- Reducing the water supply requirement from a single source reduces the vulnerability
- Interbasin transfers can reduce the vulnerability of a dam
- Monitor the off takes/ pumping / abstraction from the rivers during normal to low flow conditions
- Dependent on the average annual river flows and the short to long term water demand requirements

4.3.3 Safety

Surface water safety factors include the following:

- It is Important to have regular dam, weir and river embankment safety checks to prevent walls/ embankments collapsing during flood events.
- Good operating procedures should be in place to help ensure management of flood flows and optimal storage for drought conditions

Examples of recent failure are given below:

Failure of the Sasumua Dam wall on 4 May 2003 during the flood events with the impact of 1 million people without water.

Failure of the Perkerra irrigation scheme weir during flooding on 3-5 May, which contributes to a total area of 350 Ha.

The flooding impacts on dam safety are proving to be a critical factor within Kenya.

2- 6 May 2003 National Kenya Newspapers highlighting flooding and safety factors

4.3.4 Sedimentation

The potential sedimentation effects on surface water sources are as follows

- Deforestation can result in increased land erosion and higher sediment loads in rivers.
- Increased sediment load in rivers deposits in the dams, thereby reducing the capacity of facilities.
- Increased dam sedimentation requires building additional and larger facilities to ensure the reliability of the water supply.
- Failure of river intakes can occur with increased sedimentation as the fluvial geomorphologic behaviour is affected (Annandale 2002)

3 May Gitaru dam looking upstream

Examples of impacts of sedimentation/ siltation on pans and small to large scale reservoirs.

Table 4.1 summarises the Ministry of Water Resources and Development (MWR) work in surveying the existing pans and small dams in Kenya

Over 90% of the dams sites have been surveyed. MWR is currently completing a survey for the remaining 10% of the dams. The results show that from the 2115 small dams, 31% of the capacity is available. The main use of the dams is for domestic supply and livestock. The dam capacities range from 3000m^3 to 150,000 m^3.

Table 4.1: Summary of small dams in Kenya

Province	Total No.	Original capacity (Mm^3/day)	1999 Siltation (%)	Available capacity (Mm^3/day)
Central	85	28.1	28	8.0
Coast	90	3.9	10	0.4
Eastern	725	20.8	35	7.2
Nairobi	-	-	-	-
North East	100	3.0	25	0.8
Nyanza	290	26.0	41	10.8
Rift valley	825	16.2	41	6.7
Western	-	-	34	-
Total	2115	98.1	31	33.7

Rehabilitation of the pans/ dams is possible by either raising the retaining wall or by dredging where appropriate.

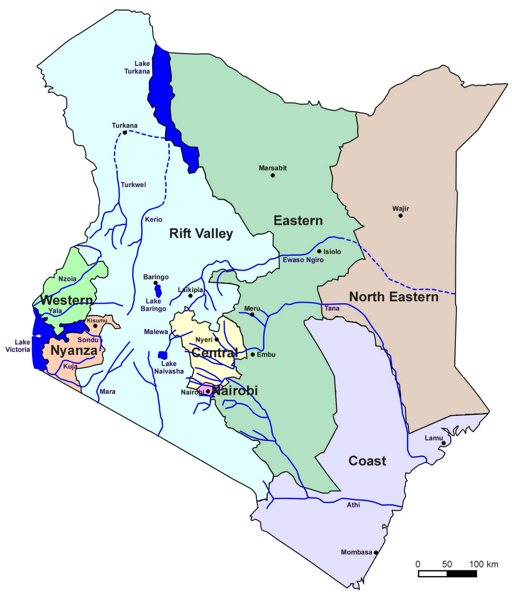


Figure 4.1 Kenya Provinces

An assessment of reservoir and intake sedimentation at selected sites in Kenya using GPS and echo sounding was completed in 2002 (Annandale 2002) and the report concluded that it was difficult to quantify and interpret the accuracy of sediment yield on the existing information.

It was determined that it is of extreme importance that collection of adequate and accurate water resource data is required to manage the water resources of Kenya (Annandale 2002).

Section 5

Water Resources Development Investment Needs

5.1 Water resources and water balance

On the basis of the CBS 2001 population projections and other relevant information collected from 27 April to 15 May 2003, the analysis of water requirements to the year 2030 is given below in Table 5.1.

Table 5.1 Summary of projected water demand requirements (unit 1000 m^3/day)

Year	1990	2000	2010	2020	2030
domestic water urban	557	1,105	1,721	2,430	3,019
domestic water rural	516	708	1,049	1,333	1,671
domestic water total	1,073	1,813	2,770	3,763	4,691
Irrigation	3,965	6,052	8,138	10,225	12,311
livestock	335	312	390	492	623
Industry	220	366	491	606	714
Other (fishery and wildlife)	65	82	99	116	133
Total (1000 m^3/day)	5,659	8,624	11,889	15,202	18,471
Total (Mm^3/year)	2,067	3,150	4,343	5,552	6,747

The annual volume of potential water resources was estimated as follows:

Surface water potential	19,590 Mm^3/year
Surface water safe yield	7,396 Mm^3/year
Groundwater safe yield	1,051 Mm^3/year
Total (safe yield)	8,447 Mm^3/year

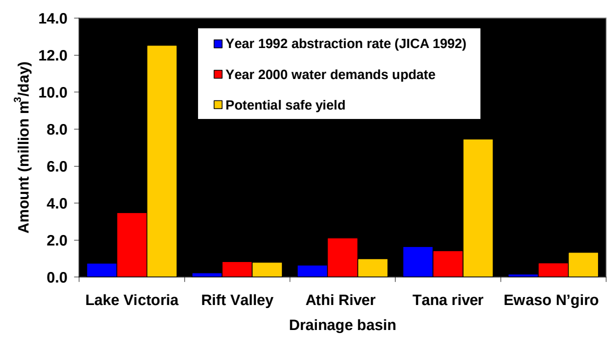
Given that the above projections show that the national projected water demand in 2030 will be 6,747 Mm^3/year, the national potential water resources are sufficient for the water requirement to the year 2030.

However due to the water resource water availability variation between the five drainage zones there are areas that will suffer from water deficit.

Comparison of the calculated Year 2020 water demands requirements as shown in section 3 for the various sectors has similarity with the NWMP findings for the year 2010 since growth of human population, livestock population and irrigation potential has not increased at the rate envisaged in the NWMP.

Therefore many of the groundwater and surface water schemes proposed in the NWMP could be phased at a later date between the years 2010 to 2030.

Figure 5.1 Potential water demand deficits



The lack of investment in water infrastructure and poor water resources management means that the national water demand currently outstrips available water by approximately 4.8 Mm^3/day based on water demand figure calculated during the mission. This deficit occurs in all river basins except the Tana River basin. The deficit could rise to approximately 7.6 Mm^3/day depending on surface and groundwater abstraction/ interbasin transfers and whether new surface water storage in terms of dams is implemented.

It should be noted that reliable surface water abstraction data is not available therefore the NWMP 1992 surface water abstraction values have been used.

5.2 Hydrometric station upgrading

Presently out of the 903 registered hydrometric stations in Kenya owned by the Ministry of Water Resources Management only 204 stations are working and provide data. This is summarised below in Table 5.2.

Table 5.2 Registered hydrometric stations in Kenya

Drainage basin	Stations			
	No. Listed	Year 1990	Year 2001	Drop (%)
Lake Victoria	229	114	45	80
Rift Valley	153	50	33	78
Athi	223	74	31	86
Tana	205	116	66	67
Ewaso Ngiro	113	45	29	74
Total	923	339	204	78

Ref (JICA[5] 1992)

The hydrometric station gauges are mainly water level staff meters where local MWR personnel take daily readings, which are sent to the head office monthly.

Upgrading of the hydrometric stations is required to enable accurate and timeous data collection to reach the WRM for digitisation, and analysis to allow rapid response to flood events and effective water resource management.

The three commonly used methods for data collection with average implementation costs and with a short description are given in Table 5.3.

Table 5.3 hydrometric station types

Station type	Capital cost and installation expense ($)	Description
Water level staff meter	$120 per meter of gauge	Time consuming, manual labour required daily, potential for errors and consistency
Chart recorder/data logger	$15000 per data logger	Automatic water level recordings. Requires personnel monthly to download data and send to head office.
Satellite transmission systems	$80,000 to $112,000 per systemı	Instant water level information can be transmitted to head office, no personnel required to read data

Telemetry systems are probably not appropriate within Kenya since some of the distances to be covered are too large. Therefore satellite transmission systems are the most appropriate method and this could be used in conjunction with the World Meteorological Organisation (WMO) satellite system, which is free of charge and available for Kenya. The main disadvantage with using satellite transmission systems is the very expensive installation costs. Since there is a relatively small market for water level recorders in the world, the equipment is specialised and the prices are relatively expensive.

A summary of approximate upgrading installation costs for the 719 non-functioning hydrometric stations are given in Table 5.4 for options A to C.

Table 5.4 Approximate hydrometric station refurbishment costs

Option	Type	Approximate cost ($)
A	Staff meters	258,840
B	Data loggers	10,785,000
C	Satellite transmission systems	69,024,000

Table 5.4 shows the wide range in prices for water level recorders. It is recommended that at the most critical (in terms of flood / water resource management information) and inaccessible locations for river gauging within the country, satellite transmission systems are used (option C) and most of the other gauging stations either data loggers or staff meters are installed (options A or B).

Due to the high siltation levels within the country it is recommended that at most of the river gauging locations a cross section survey is completed with re-rating analysis.

Assuming survey rates of $100 per river cross-section, the cost of surveying all the river gauging station cross sections would be in the order of $923,000. It is assumed that the re rating of rating curves would be analysed in house within the MWR. It would be recommended that due to the high siltation rates, the river cross sections should be resurveyed every 5 to 10 years depending on siltation loads.

5.3 Groundwater monitoring network

Inventories on boreholes characteristics and total groundwater uses have been the subject of national studies and the total number of boreholes has increased from the first 190 boreholes in the period 1928 – 1934 till approximately 13,000 today (Tuinhof, 2001).

The status of the wells indicates that more than 50% of the Northern districts are not in production (Tuinhof, 2001).

Many of the boreholes are not productive due to various reasons including:

- Old wells that have been abandoned
- Mechanical breakdown and lack of O&M funds
- Low yield or completely dry

Effective groundwater management requires the human resources, technical means and regulatory framework needed to maintain a sustainable and secure supply. Observed constraints in the present groundwater practises include (Tuinhof, 2001):

- Detailed analyses of the groundwater recharge systems and groundwater flow in specific aquifer systems is often inadequate
- Main information sources are scattered and not shared.
- The absence of regular monitoring is a crucial missing link
- Over-pumping and pollution have serious risks
- The regulatory system is not effective
- Groundwater development is expensive

It is therefore recommended that an assessment of the groundwater monitoring network is a key priority. Recommended actions and initiatives that should be key priorities are as follows (Tuinhoff, 2001):

- Data collection and sharing, setup monitoring networks and procedures for data handling, retrieval and dissemination. Involve other stakeholders to provide their information and data in return for access to data
- Dissemination of good practises in water resources management and development. Increase the success rate of borehole drilling and improve the quality of boreholes. This requires not only better siting skills, but also communication with the private sector about tender procedures and selection criteria.
- New technologies and applications (bank infiltration, artificial recharge,

borehole siting techniques, seawater intrusion, recharge estimation techniques, borehole registration using GPS and others).

5.4 Flood control facilities

Based on the flooding in April and May 2003 it appears that the extent of flooding and the damage to lands/properties and loss of life is having a major impact as development and production activities expand.

An important aspect to consider in flood mitigation is that there would be a limit on financial resources (JICA[5], 1992).

Flood have two different consequences :

- Negative effect of causing damages and losses
- Beneficial effect in terms of transporting nourishments to lands and river shores which can contribute to agriculture and riverine fishery

Quantative assessment of the latter is quite difficult to define.

Flood in urban areas has a different aspect since other than economic losses detrimental situations include potential loss of life and sanitation impacts in highly populated areas.

The NWMP reviewed a flood mitigation plan and examined in more detail 11 selected flood prone areas where the extent of flooding and damage is relatively large. The areas are given in Table 5.5 below:

Table 5.5 NWMP flood areas

Ref No.	Flood area
1	Yala swamp
2	Kano plain
3	Sonu Rivermouth
4	Kuja rivermouth
5	Middle/lower Turkwell
6	Lower Kerio
7	Downmost Athi
8	Lumi Rivermouth
9	Lower Tana
10	Middle/ Lower Ewaso Ngiro north
11	Nairobi city

Ref (JICA[5], 1992)

The NWMP produced an overall evaluation in terms of relative attractiveness and the results of the overall evaluation of the 9 schemes were classified into 3 separate groups in order of priority

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

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

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

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

The classified schemes are grouped and shown in Table 5.6 below.

Table 5.6 flood mitigation priorities

Group	Scheme	Implementation cost ($ Million) Year 1990
A	Kano plain Nairobi city	31.4
B	Yala swamp Kuja river mouth Lumi river mouth	31.0
C	Sondu river mouth Lower Tana Middle Turkwel Downmost Athi	24.7
Total		87.1

Ref (JICA[5],1992)

The NWMP also investigated dam development plans and the possibility of multipurpose dams for hydropower, irrigation, domestic water supply, flood protection etc. Out of the 28 dam schemes in the water master plan Table 5.7 below shows the potential of multipurpose development at a pre-feasibility level.

Table 5.7 potential multipurpose dam sites

Dam	Purpose	Size (Mm^3)
Nyando – 5km u/s of Muhoroni	Domestic, industrial, irrigation and flood control	250.0
Nandi Forest dam down stream of confluence with Yala river, Kimondi rivers	Hydropower, irrigation and water supply	Unknown
Kimwarer- upper part of Kerio valley	Hydropower, rural water, irrigation	unknown
Sererwa Dam located on the Arror river	Hydropower, irrigation	58.0
Munyu dam- main stream of Athi river	Water supply, hydropower generation and irrigation	190.0
High grand falls dam – Tana river	Hydropower generation, irrigation and flood control	5,325.0
Adamson's falls and Kora dams – Tana main stream	Hydropower, irrigation and flood control	1.172.0

Ref (JICA[5], 1992)

It must be noted that extensive studies including water resources, environmental and ecological would need to be completed before embarking on a dam project,

5.5 Recommendations

The main recommendations within the water resources infrastructure gaps are given below.

i. Water resource feasibility studies and economic assessments are required for each of the potential dam sites that are published in the JICA 1992 reports before embarking on dam construction projects.

ii. Water resource feasibility studies and economic assessments should be carried out for each of the practical NWMP proposed interbasin and intrabasin transfer schemes

iii. Irrigation is by far the largest sector user of water. Refurbishment of the existing large scale irrigation and small scale schemes is crucial for ensuring optimal allocation of water for maximum crop yield. Optimal allocation of water to the crops will reduce river abstractions. Currently only two of the six main government irrigation schemes are in operation.

May 5 Rice fields near Meru

iv. An accurate assessment of the surface water abstraction licence daily allowable flows from the Ministry of Water Resources database. Presently there are over 16,000 licences on the database and in some cases the data base values of the total licensed abstraction rates are higher than the yield of some of the drainage basins. It is vital to complete a study into the actual abstraction flow rates for a full understanding of the reduction in river flows in recent years and to manage the water resources of the rivers effectively.

v. Vulnerability of surface water sources needs addressing. All the main dams require safety inspections to prevent dam failure. Failure of the Sasumua Dam wall on 4 May 2003 during the flood events had the impact that one million people with in the City of Nairobi were without water.

May 4Tributary of the Tana River during flooding

vi. Vulnerability of the groundwater sources is a major issue. Over abstraction of groundwater by borehole pumps decreases the groundwater level resulting in a reduction of the daily abstraction rates. An accurate database is required of all the borehole abstraction rates in the country and an investigation into the actual abstraction rates. Boreholes should not be close than 800m between each other.

vii. Sedimentation effects on the large dams require investigation. Improved data monitoring, regular dam volumes surveys are crucial in finding methods of reducing sedimentation and extending the dam life.

viii. It is a necessity to improve the hydrological data collection within the Ministry of Water Resource Management (WRM) and provide linkages with Centre for Training and Integrated Research for ASAL Development (CETRAD), Dept. of Meteorology and the River Basin Development Authorities. Presently only about 300 of the 900 gauging stations are functioning at present. The process of data collection can take over one month from the river station to reach the WRM for digitisation. Accurate timeous data collection and digitisation is necessary to allow rapid response to flood events and effective water resources management. By linking this to the Geographical Information system at ENNDA, CETRAD and other organisations, data can be used effectively for many of the required hydrological analysis.

May 6 Tributary of the Tana River

ix. Storing the large event peak flows during flood events for use during the dry season requires weirs, canals and addition surface water storage dams. The recent flood events across Kenya in April/ May 2003 caused large loss of life and immense damage to road infrastructure, homes etc. Flood Alleviation/ water resources studies are essential to understanding how best to reduce flooding and increase water storage across the river basins within Kenya.

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Appendix A

Present Situation

A1 Mission meeting record with summary of findings

Below is the list of meetings attended during the project from 26 April until 16 May 2003.

Date	Time	Description
27 Apr Sun	18:00 – 23:00	Introduction meeting World Bank team
28 Apr	09:00	Meeting : Water Minister Martha Karua
	10:30	Meeting : MWR Engineer D N Stower Groundwater issues, amnesty for illegal abstractions, new data required
	12:00	Meeting : MWR discussion on international water boundaries
	14:00	Arrangements for the fieldtrip
30 Apr	09:00	Meeting : MWR Patrick Oloo : discuss hydrological data
	10:30	Meeting : Moses Chongwany Managing Director, Tana and Athi River Development Authority (TARDA) Discuss ownership of dams, irrigation projects/crops
	14:00	Meeting National Irrigation Board (NIB) John Olum Main policy is for provision of hydraulic infrastructure and management. Restructuring taking place. Irrigation schemes have doubled in size due to smallholders Water use efficiency not increased since 1992 NIB irrigation areas have decreased in size since much of the infrastructure is currently in disrepair, with little budget for refurbishment.
	16:30	Meeting : MWR hydrology department Discuss of domestic water/ hydropower dams
2 May	10:00	Library MWR, WRAP reports
	11:00	Meeting MWR: Dams department Information on small dams in Kenya, siltation effects
	12:00	Meeting MWR hydrology dept Operation gauges 400-500 out of 900. Data collected, not all digitised, takes one month to send to main office
	14:00	Meeting MWR Groundwater Mr Mwango Discussion on groundwater abstractions, lack of accurate records of abstractions, many illegal abstractions take place, groundwater depletion in some areas. Difficult to assess current abstractions amounts.
	16:00	Meeting : Irrigation and Drainage Dept. Mr Kamau Decline in coffee/ rice, increase in horticulture, fruit and vegetables. Impression is that there is not a large increase in irrigation needs The water demand requirements are similar between 1992 and 2002, less coffee crops, but more horticulture crops. No new investment in the small

Date	Time	Description
		schemes. The available water resources have decreased in the last change years, possibly due to climate change, lower river flows etc. Most irrigation schemes are pumped directly and do not have storage. The reliability of the water for small irrigation schemes has decreased in the last 10 years.
3 May Sat	10:00	Commence field trip Visit Masinga Dam, Tana and Athi River Development Authority, visit farms
	14:00	Visit Gitaru Dam : Kengen : Kiio Kawa Chief Engineer In general reliability of the dams is good, storage water from Masinga Dam. Sedimentation of the hydropower dams along the Tana River is not an issue for KenGen.
	16:00	Mango/ Apple farm visit in the Tana river basin near Embu through TARDA
4 May	09:00	Visit Yatta irrigation canal
	14:00	Meeting: Mwea irrigation office : George Ndede senior irrigation officer, Raphael Wanjogu, senior research officer Rice area has doubled, two rice crops per year. French beans, tomato production, and high activity of horticultural farming. Farmers/ National Irrigation Board- conflict, irrigation infrastructure damaged, e.g. gates broken, this has reduced income by 50% Monitoring of permits/ abstractions are important to solve low water availability problems Canal system is vulnerable to illegal off takes Total area paddy 5860ha, Horticulture 800Ha, approx 3300 farmers
5 May Mon	09:30	Nyeri Provincial Water Office : Meeting Mr Maitima Need to ensure only users with licences are allowed to abstract Water users associations help the way forward in changing users perceptions about the availability of water
6 May Tue	12:00	Nairobi Rivers water users association 6 projects from the water users association, has taken over 15 years to complete Appears river flows are decreasing and abstract conflict upstream and downstream, minimal flows for irrigation/ raw water supply and livestock much of the year.
	15:30	Meeting Centre for Training an Integrated Research for ASAL Development (CETRAD), Nanyuki, formerly Liakipia research station, Boniface Kiteme Regional coordinator The GIS research is mainly based on five districts in the area and two ASAL areas in the North East. Horticulture reduces water availability Linkages with other organisations include UNEP, UNDP, Africover, DRSRS, IGAD, IGADRS
	17:00	Meeting Rural Focus, Nanyuki, Nancy Balford and Mike Thomas directors Work completed in the area with downstream users, discussed technical and communication issues, appropriate representation of groups Water vulnerability high for the small holder. Avoiding conflict requires operating rules
7 May Wed	10:00	Meeting Ewaso Ngiro North River Basin Development Authority (ENNDA), Isiolo. Eng. Ali Managing director

Date	Time	Description
		Heavy abstraction of water upstream, land degradation, approximately 4x more abstraction occurring than permitted. Policing is critically required with equipment to meter abstraction amounts. Fuel wood an issue in the lower catchment Programs needed include afforestation programs for soil conservation includes indigenous gum Arabic and raisin trees Rural water resource programs to harness flood waters 3 months of the year Monitoring of groundwater recharge Land conflict, livestock demand increasing Small scale irrigation exists beans/ horticulture 1,100 Ha ENNDA have a GIS system, which they wish to expand, possibly include CENTRAD as a subset.
8 May Thu	15:00	Meeting: Ministry of Energy : Bernadette M Nzioki Senior Deputy Secretary Existing hydropower generation Tana, Wanjii, Kamburu, Gitaru, Kindaruma, Masinga, Kiambere, Small stations, Turkwel, imports from Uganda Electricity Transmission Company (UETCL). No studies on sedimentation carried out, viewpoint is this should be carried out by MWR. Dam safety issues are checked . Water flows of dams are monitored hourly. All flows downstream of Masinga dam are only 24 hours, therefore storage is minimal. Hydropower in general does meet its required demands. Currently completing a strategy examining new sources for power generation.
12 May		Water resources seminar
13 May		Water resources seminar
15 May Thu	09:00	Meeting MWR Godwin Namenya : Water bailiff assistant Discussed and analysed the surface water abstraction database.
16 May	14:00	Aide Me moiré meeting

Appendix B
Water demand tables

B1 Water demand tables

Overleaf are the summary tables for the Figures used in Section 3, water demand calculations.

Population projections using CBS Year 2001 data and calculated growth projections : Figure 3.3

Province	1969	1979	1989	1990	2000	2010	2020	2030
Nairobi	509,286	827,775	1,324,570	1,363,649	1,792,496	2,247,659	2,690,117	3,072,625
Central	1,675,647	2,345,833	3,111,255	3,203,047	4,210,356	5,279,480	6,318,761	7,217,225
coast	944,082	1,342,794	1,825,761	1,879,627	2,470,740	3,098,129	3,708,004	4,235,245
Eastern	1,907,301	2,719,851	3,768,689	3,879,877	5,100,039	6,395,078	7,653,967	8,742,285
N/Eastern	245,757	373,787	371,391	382,348	502,591	630,212	754,271	861,521
Nyanza	2,122,045	2,643,956	3,507,160	3,610,632	4,746,120	5,951,290	7,122,818	8,135,612
Rift valley	2,210,289	3,240,402	4,917,551	5,062,634	6,654,754	8,344,579	9,987,233	11,407,317
Western	1,328,298	1,832,663	2,622,397	2,699,766	3,548,801	4,449,938	5,325,921	6,083,214
Total	10,942,705	15,327,061	21,448,774	22,081,580	29,025,896	36,396,365	43,561,093	49,755,045
Growth rate	0.0343	0.0342	0.0295	0.0295	0.0279	0.0255	0.0231	0.0207

Updated rural and urban population projections : Table 3.2, Figure 3.6

			1990	2000	2010	2020	2030
Population	urban	No.	3,848,673	7,497,474	11,466,593	15,899,799	19,404,468
Population	rural	No.	18,232,907	21,528,422	24,929,772	27,661,294	30,350,578
Population	total	No.	22,081,580	29,025,896	36,396,365	43,561,093	49,755,045
Water requirements	urban	(l/c/d)	145	147	150	153	156
Water requirements	rural	(l/c/d)	28	33	42	48	55
Water requirements	urban	(m^3/day)	556,577	1,104,727	1,721,253	2,430,320	3,019,329
Water requirements	rural	(m^3/day)	516,489	708,163	1,049,042	1,332,900	1,671,187
Water requirements	total	(m^3/day)	1,073,066	1,812,890	2,770,296	3,763,220	4,690,516

Livestock population projection (post La Nina)

				trendline	trendline	trendline
Livestock trend	1988	1990	2000	2010	2020	2030
cattle	11,512,526	11,930,575	10,718,160	12,804,895	15,297,901	18,276,273
sheep/goat	15,066,600	15,066,600	15,083,650	21,461,879	30,537,188	43,450,056
camel	695,699	719,128	820,330	1,167,212	1,660,777	2,363,048
Ref JICA2 Table 4.4.1 and UNEP 2000 Table 4.1			26,622,140			

Livestock demand projection (post La Nina) (m3/day) assuming growth from milk, meat trend : Figure 3.8

		1988	1990	2000	2010	2020	2030
cattle	(m^3/day)	251,715	260,855	234,347	279,972	334,480	399,601
sheep/goat	(m^3/day)	50,222	50,222	50,279	71,540	101,791	144,834
camel	(m^3/day)	23,190	23,971	27,344	38,907	55,359	78,768
Total	(m^3/day)		335,048	311,970	390,419	491,630	623,202

Irrigation demand calculation : Figure 3.10

		1990	2000	2010	2020	2030
Irrigation demand (JICA 1992)	(m^3/day)	3,965,040	6,051,575	8,138,111	10,224,646	12,311,182

Industry and other (fishery and wildlife) demand projections : Figure 3.11

		1990	2000	2010	2020	2030
Industry	(m^3/day)	220,378	365,528	491,436	606,278	713,537
Other (fishery and wildlife)	(m^3/day)	65,000	82,000	99,000	116,000	133,000