JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF ENERGY
THE REPUBLIC OF KENYA

FEASIBILITY STUDY
ON
MUTONGA/GRAND FALLS HYDROPOWER PROJECT

FINAL REPORT

VOLUME I
MAIN REPORT

MARCH 1998

NIPPON KOEI CO., LTD.
PASCO INTERNATIONAL INC.
TOKYO,JAPAN

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This Report consists of

Executive Summary

Executive Summary for Environmental Assessment

Volume I Main Report

Volume II Supporting Report (1)
(Engineering Study)

Volume III Supporting Report (2)
(Environmental Assessment)

Volume IV Supporting Report (3)
(Workshop Proceedings)

The cost estimate is based on the price level of June 1997 and the monthly mean exchange rates in June 1997. The monthly mean exchange rates in June 1997 are:

US$ 1.00 = KShs. 54.0 = J. Yen 120

PREFACE

In response to a request from the Government of the Republic of Kenya, the Government of Japan decided to conduct the Technical Cooperation for Feasibility Study on Mutonga/Grand Falls Hydropower Project in the Republic of Kenya and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a study team led by Mr. Keisuke Sumikawa of Nippon Koei Co. Ltd., to the Republic of Kenya eight times from February 1994 to February 1998.

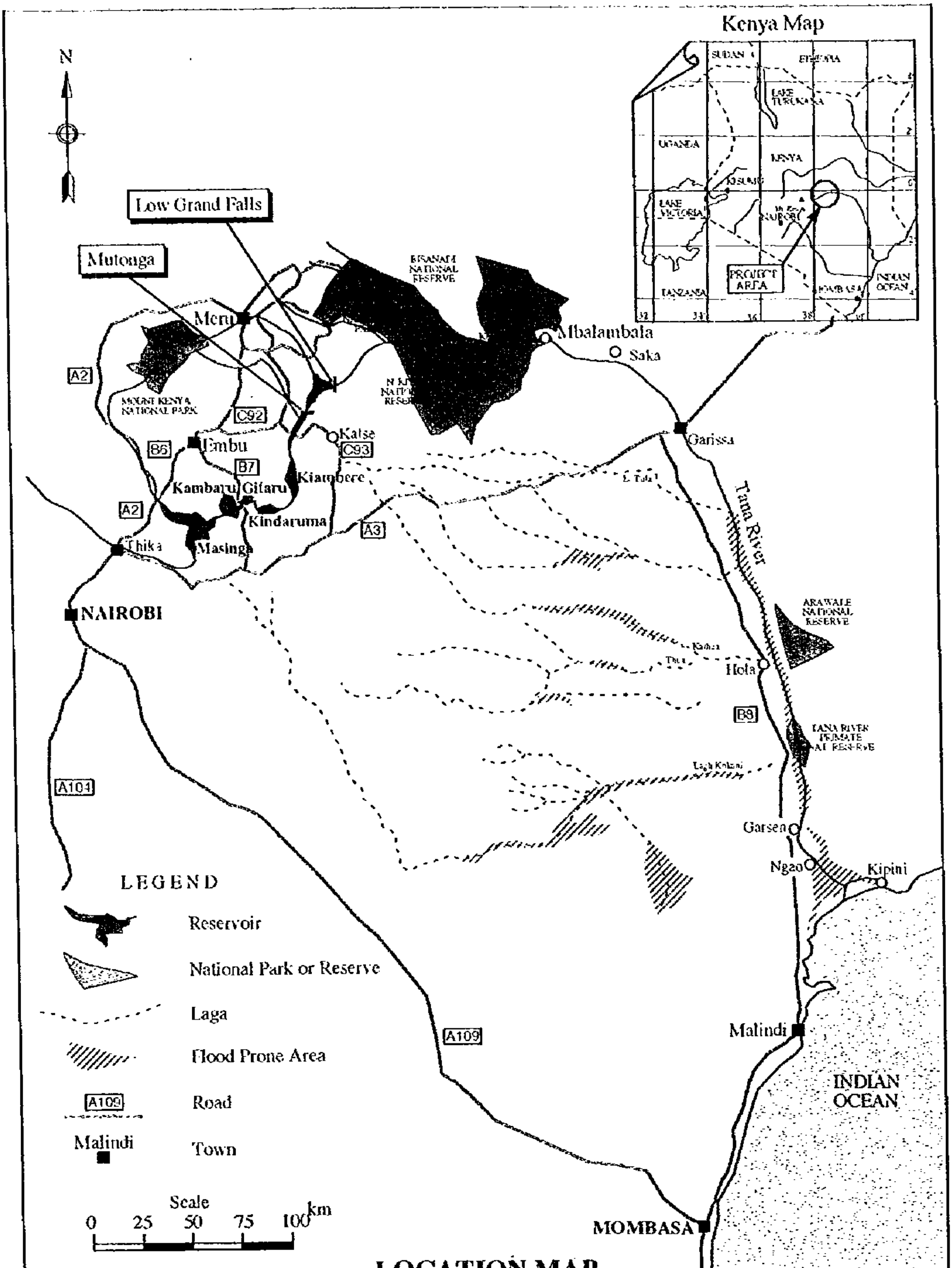
The team held discussions with the officials concerned of the Government of the Republic of Kenya, and conducted related field surveys. After returning to Japan, the team conducted further studies and complied the final results in this report.

I hope this report will contribute to the promotion of the plan and to enhancement of friendly relations between our two countries.

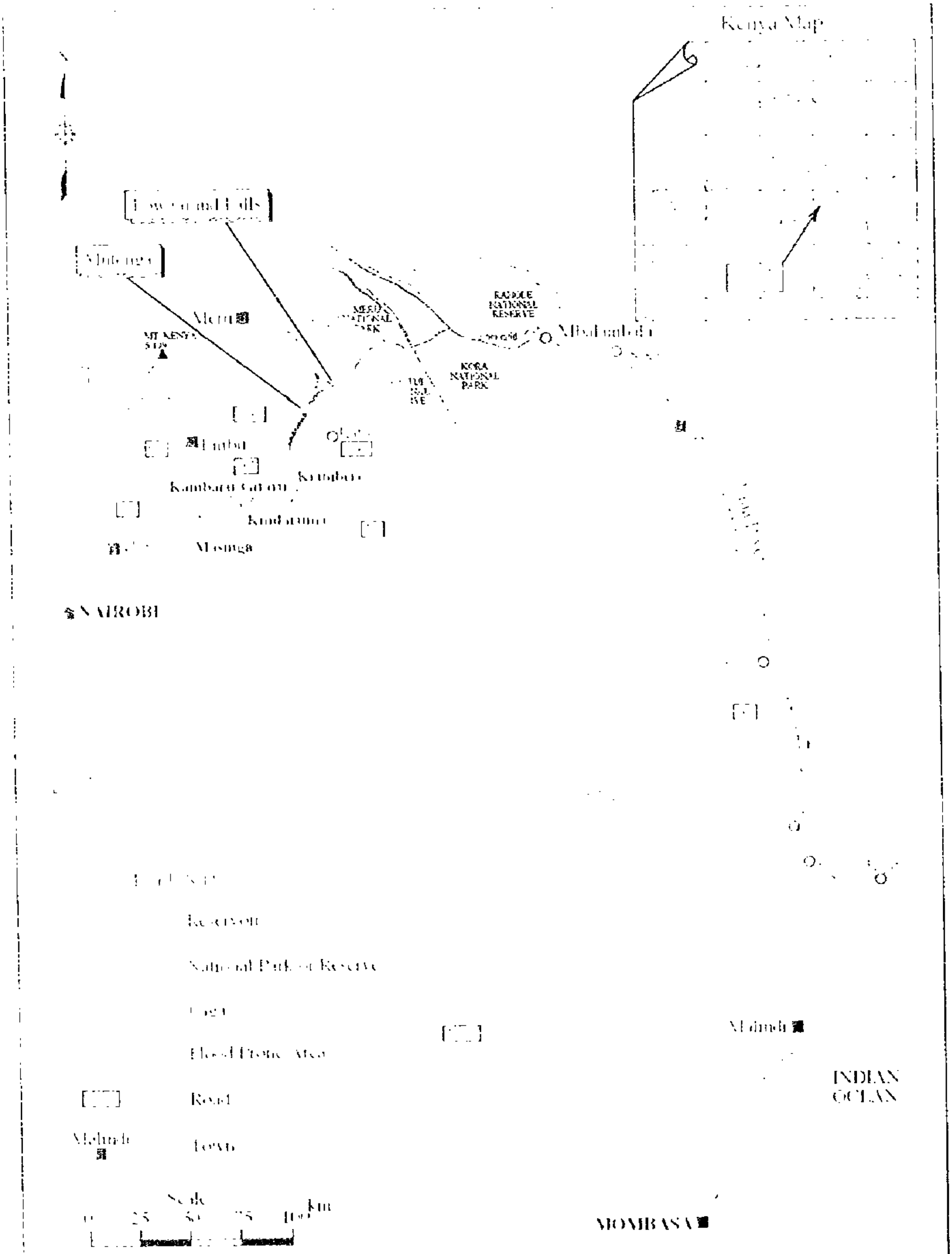
I wish to express my sincere appreciation to the officials concerned of the Republic of Kenya for their close cooperation throughout the study.

March 1998

Kimio FUJITA
President
Japan International Cooperation Agency



LOCATION MAP



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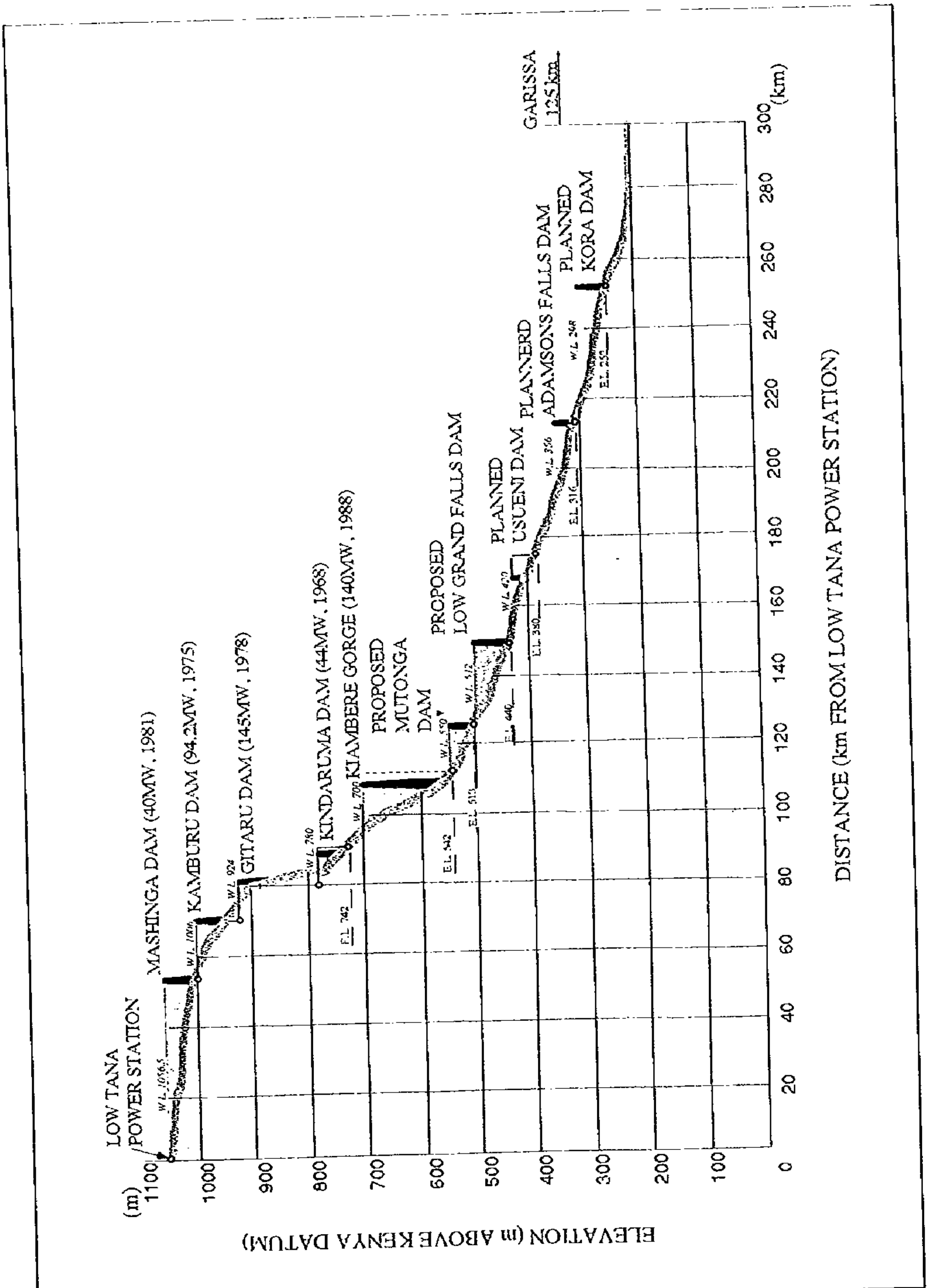


JAPAN INTERNATIONAL COOPERATION AGENCY	Tana River Cascade Hydropower	Fig. No.
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		

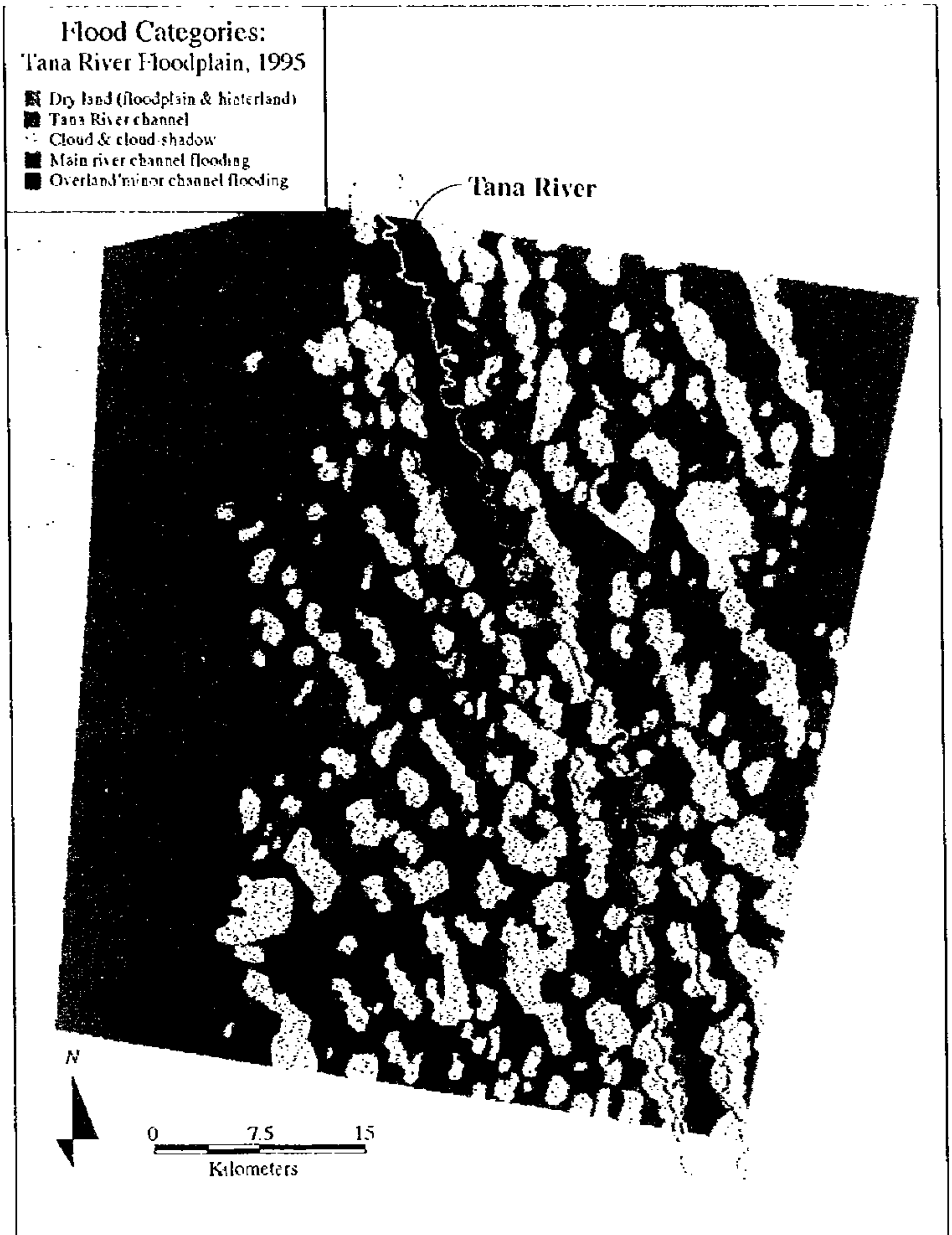
JAPAN INTERNATIONAL COOPERATION AGENCY	Waterfall of 4km Upstream from Grand Falls Dam Site	Photo 1
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		

Riverine Forest, Hewani East

Mangrove Swamps at Kipini

JAPAN INTERNATIONAL COOPERATION AGENCY REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT	Riverine Forest along Tana River and Mangrove Swamps in Tana Delta	Photo 2

Interpreted Spot satellite image : Tana River Floodplain near Hola, 6 May 1995



JAPAN INTERNATIONAL COOPERATION AGENCY	Interpreted SPOT Satellite Image (Tana River Flood Plain near Hola on May 6, 1995)	
REPUBLIC OF KENYA MUTONGA/GRAND FALLS HYDROPOWER PROJECT		

PRINCIPAL FEATURE OF THE PROJECT

	Low Grand Falls	Mutonga
1. Hydrology and Reservoir		
- Catchment area	17,234 km^2	15,365 km^2
- Annual mean discharge	173 m^3/sec	157 m^3/sec
- Full supply level (FSL):	EL. 512.0 m	EL. 550.0 m
- Minimum operation level (MOL)	EL. 491.4 m	EL. 538.5 m
- Gross storage capacity	1,261 MCM	132 MCM
- Effective storage capacity	955 MCM	85 MCM
- Dead storage capacity	306 MCM	47 MCM
- Design flood of dam	5,400 m^3/sec (1.2 x 200-year probable flood)	4,000 m^3/sec (200-year probable flood)
- Extreme flood of dam	12,800 m^3/sec (10,000-year probable flood)	10,900 m^3/sec (10,000-year probable flood)
- Design flood of river diversion	2,800 m^3/sec (50-year probable flood)	1,600 m^3/sec (5-year probable flood)
2. Power Output		
- Installed capacity	140 MW (70 MW x 2 units)	60 MW (30 MW x 2 units)
- Maximum plant discharge	227.6 m^3/sec	175.0 m^3/sec
- Rated head	69 m	38.9 m
- Firm output	134 MW	58 MW
- Annual average energy	715 GWh/year	337 GWh/year
3. Structures		
(1) River diversion		
- Lane of diversion tunnel	Two lanes	One lane
- Diameter of diversion tunnel	10.5 m	11.0 m
- Total length of diversion tunnel	630m and 760 m	660 m
- Crest elevation of cofferdam	EL. 466.0 m	EL. 539.0 m
(2) Main dam		
- Type of dam	Combined type with concrete and rockfill dam	Concrete dam type
- Dam crest elevation	EL. 516.5 m	EL. 555.0 m
- Dam height	90 m	60 m
- Dam volume		
Concrete	1,175,000 m^3	416,000 m^3
Rockfill	2,885,000 m^3	-

	Low Grand Falls	Mutonga
(3) Spillway		
- Type	Gated type	Gated type
- Type of gate	Radial gate	Radial gate
- Number of gate	Six	Four
- Dimensions	15.0 m wide x 15.5 m high	17.5 m wide x 16.0 m high
- Energy dissipation	Roller Bucket	Stilling basin
- Dimension	20 m radius	80 m long
(4) Artificial flood and sediment release facility		
- Lane	Two lanes	Two lanes
- Type	Steel conduit with gates	Steel conduit with gates
- Dimensions	5.0m wide x 5.0 m high	5.0m wide x 5.0 m high
- Gates	A high pressure roller gate with a stoplog gate for one lane	A high pressure roller gate with a stoplog gate and a radial gate for one lane
(5) Waterway		
- Elevation of intake invert	EL. 477.8 m	EL. 526.5 m
- Type of intake gate	Selected water intake gates	Sluice gate
- Diameter of penstock	5.4 m	4.7 m
- Length of penstock	90 m	59 m
(6) Powerhouse		
- Type	Open-air type	Open-air type
- Dimensions	32m wide, 60m long and 50m high	30m wide, 49m long and 44m high
(7) Generating equipment		
- Maximum plant discharge	227.6 m^3/sec	175.0 m^3/sec
- Rated head	69.0 m	38.9 m
- Type of turbine	Francis type	Francis type
- Type of generator	3-phase synchronous alternator of Vertical shaft with grushless excitor	3-phase synchronous alternator of Vertical shaft with grushless excitor
- Number of units	Two	Two
- Rated output	2 x 70,000 kW	2 x 30,000 kW
(8) Transmission line		
- Voltage	220 kV double-circuit	220 kV double-circuit
- Conductor size	Canary (ACSR 460 mm^2)	Canary (ACSR 460 mm^2)

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ABBREVIATIONS

(1) Domestic organization

GOK	:	Government of Kenya
MOE	:	Ministry of Energy
TARDA	:	Tana and Athi Rivers Development Authority
KPC	:	Kenya Power Co., Ltd.
KPLC		Kenya Power & Lighting Co., Ltd.
MOWD	:	Ministry of Water Development
MOALD	:	Ministry of Agriculture and Livestock Development
NWCPC	:	National Water Conservation & Pipeline Corporation
TRDC	:	Tana River Development Co., Ltd.
WWF	:	World Wide Fund for Nature
KWS	:	Kenya Wildlife Service
NIB	:	National Irrigation Board

(2) Foreign organization

GOJ	:	Government of Japan
JICA	:	Japan International Cooperation Agency
WB	:	World Bank
UNDP	:	United Nation Development Program
IUCN	:	International Environmental Organizations

(3) Measurement

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer

Electrical Measures

V	=	Volt
kW	=	kilowatt
MW	=	Megawatt
kWh	=	kilowatt hour
MWh	=	Megawatt hour
GWh	=	Gigawatt hour

Area

km^2	=	square kilometer

Money

KShs.	=	Kenya Shilling
K.£	=	Kenya Pound
US$	=	US dollar
US¢	=	US cent
¥	=	Japanese Yen

Volume

MCM	=	million cubic meter
m^3	=	cubic meter

Weight			Other Measures		
kg	=	kilogram	%	=	per cent
ton	=	metric ton	°	=	degree
			'	=	minute
Time			"	=	second
sec, s	=	second	m^3/s	=	cubic meter per second
min	=	minute	ppm	=	parts per million
hr	=	hour	℃	=	degree centigrade
yr	=	year	BOD	=	biochemical oxygen demand
			COD	=	chemical oxygen demand
			DO	=	dissolved oxygen
			pH	=	exponent of hydrogen ion concentration
			TDS	=	total dissolved solids
			SS	=	suspended solids

(4) Economy and finance

EIRR	:	Economic Internal Rate of Return
FIRR	:	Financial Internal Rate of Return
FC	:	Foreign Currency
LC	:	Local Currency
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GRDP	:	Gross Regional Domestic Product
OMR	:	Operation, Maintenance and Replacement
LS	:	Lump Sum

(5) Elevation

EL.	:	Elevation above mean sea level
FWL	:	Flood water level
HWL	:	High water level
LWL	:	Low water level

(6) Exchange rates (as of June 1997)

US$ 1.00 = KShs. 54 = J. Yen 120

K.£ = KShs. 20

CHAPTER 1 INTRODUCTION

1.1 The Project

The Tana river is the largest and most important river in Kenya. Its catchment covers some 100,000 km^2 (18% of the land area of Kenya) and stretches for about 1,000 km between the Kenya Highlands with the peak of Mt. Ol-dolinyo at EL. 3,999 m and the Indian Ocean. The Mutonga/Grand Falls Hydropower Project (the Project) is located 25 - 50 km downstream of the existing Kiambere project and about 150 km north-east of Nairobi, Capital of Kenya, in air-distance (See Location Map).

The Tana river basin covers areas of the four provinces, namely Central, Coast, Eastern and North-Eastern provinces, of the total eight provinces in Kenya. According to the census in 1989, total population in the four provinces was recorded at 9,086,000 which was about 42.4 % of the total population in Kenya. The upstream area of the river basin touches the Nairobi province. The population including Nairobi reaches to 10,411,000 persons, or 48.5% of the total population of Kenya.

The Tana river drains annual water of 3,740 million m^3, which is equivalent to about 19.1 % of total perennial river flow in Kenya. The basin is supplying water for municipal and irrigation uses, the annual amount at present being estimated at 175 million m^3 for municipal water supply in the upstream districts and at 2,300 million m^3 for irrigation, which are 29 % and 19 % of the total demands in Kenya, respectively. Hydropower development of the river began in 1968 with completion of Kindaruma dam with an installed capacity of 44 MW. Thereafter, the other four dams with power plants have been built, at Kamburu (94.2 MW in 1975), Gitaru (145 MW in 1978), Masinga (40 MW in 1981) and Kiambere Gorge (144 MW in 1988). In addition, relatively small hydropowers stations such as Wanjii (7.4 MW) and Tana (14.4 MW) have been in operation in the upper tributaries. Total installed capacity on the Tana river is then 489 MW which is 60 % of the total installed capacity in the interconnected system in Kenya in 1996, and annual energy output at minimum level is estimated at 2,800 GWh to be compared to the annual total supply of 2,977 GWh in 1996.

The Project was studied in the past as follows:

- Feasibility Study for Kiambere Development in 1980 (EPDC); at the time of the feasibility study for the Kiambere project, studies were also carried out for Mutonga and Grand Falls hydropower development projects. The project dimensions drawn in the study gave the basis for the following studies.
- National Power Development Plan in 1987 and 1992 (UNDP/World Bank); by focusing project function on power generation, three alternative schemes are depicted, Mutonga (60 MW with FSL 550 m), Low Grand Falls (120 MW with FSL at 512 m) and High Grand Falls (180 MW with FSL at 550 m); the first, second and/or combination of the both two are mutually exclusive with the third.
- National Water Master Plan in 1992 (JICA); The Mutonga and Low Grand Falls Projects are reported to be promising. Irrigation schemes of about 25,000 ha in total are proposed in the downstream areas of the Projects.

Main features of the alternative development plans reported in the previous studies are as listed below:

Items	Unit	Mutonga	Low Grandfalls	High Grandfalls
Reservoir				
FSL	m	550	512	550
MOL	m	535	500	535
Live storage	10^6m^3	62.6	701	1,925
Tailwater				
LWL	m	511.7	443.0	443.0
Average	m	513.0	443.8	443.8
Head				
Gross	m	37.0	68.2	106.2
Net	m	35.2	64.8	101.0
Installed Capacity	MW	2x30	2x60	3x60
Output				
Firm power at LWL	MW	40.8	88.3	141.4
Firm energy	GWh	219	535	692
Average energy	GWh	285	620	802

Source : Kiambere Feasibility Study (EPDC, 1980), Kenya National Power Development Plan (Acres,1986)

1.2 Study Objective

The Government of Kenya envisaged to develop the Mutonga/Grand Falls hydropower project in light of her energy and water supply development policy, i.e. exploration of indigenous energy resources and achievement of self-sufficiency on staple food, and requested the Government of Japan to provide the technical cooperation to carry out the feasibility study.

In response to the request of the Government of Kenya, the Government of Japan dispatched a mission consisting of officials of Japan International Cooperation Agency (JICA), the official agency for the implementation of technical cooperation programs of the Japanese Government, to Kenya for discussing the scope of works of the Study with its counterpart agency, the Tana and Athi Rivers Development Authority (TARDA), in August 1993.

The scope of work envisaged four alternative development plans as listed below, which would contribute to production of hydroelectric power as well as to water supplies to agriculture and municipalities, further to floods regulation:

- Mutonga dam only
- Low Grand Falls dam only (with a case of heightening in the future)
- Low Grand Falls dam + Mutonga dam
- High Grand Falls dam only

The Study was divided into three stages as follow:

Stage 1 : Initial Environmental Impact Study
Stage 2 : Definite Plan/Pre-feasibility Study
Stage 3 : Feasibility Study

The objective of the Study is to formulate an optimal plan for the Mutonga/Grand Falls Hydropower Project and to assess its technical and economic feasibility. Another implicit objective of the Study is environmental assessment which considers a wide range of environmental aspects, including not only, the impact of dam construction on the reservoir area, but also that on the downstream river corridor.

1.3 Work Progress

Figure 1.1 shows the overall flow of the Study. The Stage 1 study was commenced in February 1994 by dispatching a JICA Study Team to Kenya, with the objective of initial environmental assessment and completed by preparing the report on the Initial Environmental Assessment in August 1994 and by holding the Workshop No.1 on the report in September 13 to 16, 1994 at Embu with the attendance of TARDA, KPLC, JICA, WB, concerned Kenyan Government Organisations, DEC (Embu, Tharaka-Nithi, Tana-River, Mwingi), International Environmental Organisations (IUCN, WWF) and the JICA Study Team.

The Stage 2 study started in September 1994 immediately after the completion of the Stage 1 study, with the objective to select definitive plan of the Project among the alternatives, through studies on:

- environmental assessment as quantitatively as possible, by paying due considerations to the results of the Workshop No.1 discussions, including resettlement in the reservoir area, water quality and fishery potential, farming systems, riverine forests, mangroves and flow regime in the downstream reach.
- survey and investigations including socio-economic surveys, geological investigations of alternative plans and power surveys.
- techno-economical studies for comparing economic viability of the alternative plans.
- selection of the most preferred alternative plan on the basis of the results of the techno-economical studies and the environmental assessment.

The Progress Report (1) concluded and recommended the option of Low Grand Falls and Mutonga as the optimum development scheme from a technical, economical and environmental viewpoint. The Workshop No. 2 was held in ICIPE/Duduville, Nairobi, from 20 to 22 March 1995 with an attendance of invited organisations who attended the Workshop-1. The study results were reported at the Workshop to discuss the results among the attendants.

The Stage 3 study was divided into two parts: Part 1 consisting of topographic mapping, geological investigation and transmission line system survey for the feasibility design and the study on the optimization of plant scale, and Part 2, the preliminary design, construction cost estimate and plan, and the project evaluation.

In the Part-1 of the Stage 2, the field investigations such as topographical mapping, boring investigation, seismic prospecting test and construction material test were carried out from June to September 1995. Hydrological analysis was reviewed at a level of the feasibility study. All the study results were presented in the Interim Report and Progress Report (2) submitted in November 1995 and March 1996, and discussed and accepted by the Steering Committee (the Ministry of Energy, TARDA and KPC) on June 13 to 17, 1997.

The Part 2 of the Stage 3 was commenced in July 1997 for preparing preliminary design at the feasibility study level and construction plan and cost estimates, and for assessing economic and financial viability. An overall evaluation of the Project was finally made including the environmental assessment. Draft Final Report was submitted in October 1997 by dealing with all the results achieved in this study.

The Workshop No. 3 was held in KCCT/Mbagathis (Kenya College of Communications Technology), Nairobi, from 26 to 29 January 1998 with attendance of officially invited organizations and public applicants, total 188 participants. The study results of the Stage 3 in the Draft Final Report were presented by the JICA Study Team at the Workshop, followed by three group discussions concerning the engineering study, the upstream environmental assessment and the downstream environmental assessment. The results of general and group discussions and recommendations of the Workshop No.3 were complied in the Workshop proceedings.

The Steering Committee meeting was held on January 20 and 21 1998 and February 2 and 3 1998 to explain and discuss the study results of the Part 2 of the Stage 3 in the Draft Final Report by the JICA Study Team. Minutes of Meeting was singed between the Steering Committee and the JICA Study Team on February 4, 1998.

CHAPTER 2 SOCIO-ECONOMIC SCENES

2.1 Present Conditions of Socio-Economy

2.1.1 Geographical Features

The total area of Kenya is 581,787 km² consisting of 467,875 km² of livable area (80% of the total area), 102,682 km² of unlivable area (18% sharing) and 11,230 km² of water area (2%). Among the livable area, the area of townships is only 1% sharing with 4,574 km² to the total livable area in the nation.

The Tana river basin is situated in eastern part of Kenya, consisting of a part of the Central province, Coast province, Eastern province and North-Eastern province. The basin is under or close to the equator, stretching between 36°18' E and 40°42'E in longitude, and between 0°32'N and 3°20'S in latitude. The basin area includes Mt. Kenya with 5,199 m high above sea level, the second highest mountain in Africa, from which the Tana river originates. The basin occupies are area of around 100,000 km² in total that is about 19.5% of the total area of Kenya.

2.1.2 Administration Situation

Kenya comprises 8 provinces, namely the Nairobi, Central, Eastern, North-Eastern, Nyanza, Rift Valley, Western and Coast provinces. These provinces are divided into 41 districts as of 1990. Several districts among them are now planned to be separated so as to establish new districts but not gazetted yet as of 1994. The districts are further divided into divisions which are the smallest administrative units. The present situation on administrative boundaries of the districts is shown in Figure 2.1.1.

2.1.3 Population

According to the result of population census in 1989, the total population of Kenya was 21 million with its population density of 37 persons per km² at 4,353,000 families, and that of the Tana river basin was 5 million with its population density of 44 persons per km² at 970,000 families according to the Census as illustrated in Figure 2.1.2 and summarized below with their average family sizes:

Whole area of Kenya

Item	Unit	Nairobi	Central	Coast	Eastern	N.Eastern	Nyanza	Rift Valley	Westren	Total
Population	1,000psns	1,325	3,117	1,829	3,769	371	3,507	4,982	2,544	21,444
Density	persons/km²	1,911	235	22	24	3	280	27	307	37
Family size	persons/fmly	3.46	4.69	5.07	5.56	5.30	5.00	4.88	5.35	4.93

Source : Population Census 1989

Item	Unit	Central	Coast	Eastern	N.Eastern	Total
Population	1,000psns	2,379	162	2,344	60	4,945
Density	persons/km^2	241	4	47	5	44
Family size	persons/fmly	4.73	5.59	5.51	4.93	5.10

Source : Population Census 1989

2.1.4 Labor Force and Employment

Economically active population, namely the population of 15 years old and over, in 1969, 1979 and 1989 in the whole area of Kenya are indicated in the following table by province:

Province	Economically active population (persons)			Annual average growth ratio (%)		
	1969-census	1979-census	1989-census	1969-1979	1979-1989	1969-1989
Nairobi	332,866	546,696	909,185	5.09	5.22	5.15
Central	819,290	1,141,936	1,653,297	3.38	3.77	3.57
Coast	539,277	752,487	1,011,109	3.39	3.00	3.19
Eastern	972,598	1,376,135	1,911,125	3.53	3.34	3.44
North-Eastern	132,750	202,615	194,700	4.32	-0.40	1.93
Nyanza	1,063,926	1,348,396	1,752,937	2.40	2.66	2.53
Rift Valley	1,155,204	1,652,161	2,509,881	3.64	4.27	3.96
Western	633,839	896,628	1,240,517	3.53	3.30	3.41
Total	5,649,750	7,917,054	11,182,751	3.43	3.51	3.47

Source : Statistical Abstract 1991

On the other hand, the actual working population (wage population) for the modern sector is shown below for the last 9 years since 1982:

Province	Actual working population (persons)			Annual average growth ratio(%)
	1982	1989	1990	
Nairobi	291,327	361,767	370,378	3.05
Central	156,409	195,554	203,210	3.33
Coast	142,621	170,147	177,648	2.78
Eastern	84,514	111,513	118,274	4.29
North-Eastern	9,325	12,158	12,494	3.72
Nyanza	84,517	131,944	138,344	6.35
Rift Valley	226,372	290,978	300,798	3.62
Western	54,305	81,626	92,402	6.87
Total	1,049,390	1,355,507	1,413,548	3.79

Source : Statistical Abstract 1991

Concerning the actual working population mentioned above, there are the data by town (so called "urban center") for the same period. Comparing with the above data, the urbanization situation can be clarified from these figures. Its summary is shown below with urbanization ratios:

Province	Actual working population by town			Urbanization ratios (%)		
	1982	1989	1990	1982	1989	1990
Nairobi	291,327	361,767	379,378	100.00	100.00	100.00
Central	40,404	46,677	49,420	25.83	23.87	
Coast	106,548	134,382	138,566	74.71	78.98	78.00
Eastern	20,020	33,959	34,950	23.69	30.45	29.55
North-Eastern	0	0	0	0.00	0.00	0.00
Nyanza	23,567		43,686	27.88	31.39	31.58
Rift Valley	63,078	80,192	83,595	27.86	27.56	27.79
Western	8,218	13,104	13,581	15.13	16.05	14.70
Total	553,162	711,498	734,176	52.71	52.49	51.94

Source : Statistical Abstract 1991

As indicated in the table above, all workers in the Nairobi province are categorized into those in urban area, while the North-Eastern province has no urban area. In the Coast province, about 80% of wage workers resided in urban area in 1989. The second largest commercial city, Mombasa, gives the higher ratio.

The self-waged workers such as retailers are included in the actual working population (wage employment) mentioned above, however the non-waged workers including family workers for agriculture are excluded.

According to the Economic Survey 1994 issued by Central Bureau of Statistics, 50% of household heads are occupied in farming, 20% are in regular wage works, 10% are in casual wage works and 10% are in commercial business and/or trading works. Following table shows such working occupation situation:

As of 1992 (Unit: %)

Working type	Whole nation	Rural clusters	Urban clusters
Farmer	50	63	4
Pastoralist	2	2	1
Regular wage earner	22	14	55
Casual wage earner	11	9	15
Business/trade	11	8	20
Domestic worker	2	2	2
Student	0	0	0
Non-stated	2	2	3
Total	100	100	100

Source : Economic Survey 1994

2.1.5 Economic Profile and Gross Regional Domestic Products

According to the statistical information, the gross regional domestic products (GRDP) in Kenya was K.£.21,866 million as of 1996 in current price level at an annual increase rate of increased as 28% from 1992 to 1996.

Among industries of origin, agriculture is the highest contribution factor to the GRDP as 28% in current price level and 25% in 1982-constant price level, while the second contribution factor is the services of trade/restaurant/hotel as 19% in current price, but manufacturing is the second one as 13% in 1982-constant price level. That is to say, the former and the latter have reversed their share rates in current price level and in 1982-constant price level. It means that the manufacturing was developed more than trading in Kenya since 1982. According to the statistical data, in the fact, the average annual growth rate in the manufacturing was 3% and that in trade/restaurant/hotel was 7% for the last 4 years from 1993 to 1996.

GRDP by district is not available from existing statistic data. However, the Study on the National Water Master Plan made by JICA in 1992 estimates that the GRDP per capita by district as of 1989 as shown in Figure 2.1.3. According to this figure, the Tana river basin is one of the lowest areas in terms of the GRDP value.

As mentioned in the aforementioned clauses, 50% or more of people are engaged in farming in Kenya. The above mentioned situation in GRDP reflects this situation.

According to statistical data, land utilization is shown in the following table:

As of 1987 (Unit: ha)

Province	Cereal crops	Temporary industrial crops	Temporary fodder crops	Other temporary crops	Temporary meadows/ fallows	Permanent industrial crops	Fruit	Uncultivated meadows/ pastures	Total
Nairobi	101	1	1	0	314	755	0	1,348	2,520
Central	2,141	73	1,503	1,901	7,527	41,174	55	106,066	160,445
Coast	44	0	22	43	14	50,632	187	8,798	59,740
Eastern	8,907	0	298	0	4,087	14,847	20	66,912	95,071
N. Eastern	0	0	0	0	0	0	0	0	0
Nyanza	250	6,299	0	190	566	2,909	0	12,952	23,166
Rift Valley	164,042	13,646	14,255	1,142	7,045	26,966	524	372,219	599,839
Western	0	6,789	0	0	0	0	0	0	6,789
Total	175,485	26,813	16,079	3,276	19,553	137,283	786	568,295	947,570
Share rate (%)	18.5	2.83	1.70	0.35	2.06	14.49	0.08	59.97	100.00

Source : Statistical Abstract 1991

The total area of 947,570 ha mentioned in the above table is nominated to farm area but around 60% of that area was not cultivated and used for meadow and/or pasture in 1987. Most of uncultivated meadow and/or pasture area are located in the Rift Valley province (65.5%), Central province (18.7%) and Eastern province (11.8%). Of those provinces, the latter 2 areas belong to the Tana river basin.

Cereal crops area and perennial industrial crops area have the second and third high share rates to those in total area as 18.5% and 14.5% respectively. But the production of cereal crops representing as wheat, maize and paddy were decreased during these 3 years since 1990 as from 78 thousand tons in 1990 to 73 thousand tons in 1993, from 528 thousand tons in 1990 to 242 thousand tons in 1993 and from 19 thousand tons in 1990 to 11 thousand tons in 1993.

At the present time, Kenya has several systematic irrigation development projects as Mwea (5,820 ha), Ahero (827 ha), Tana River (867 ha), Perkerra (237 ha), Bunyala (213 ha), West Kano (475 ha) and Bura (2,454 ha). Among these irrigation projects, the largest 2 projects as Mwea and Bura irrigation schemes belong to the Tana river basin. The main crops harvested are paddy in Mwea and cotton in Bura.

The following table shows number of registered total firms and permanent employees by industrial group in Kenya.

As of 1990

Industry group	Establishments	Employees
Agricultural & forestry	2,658	239,600
Mining & quarrying	46	8,625
Manufacturing	2,002	187,203
Electricity & water	106	10,440
Construction	1,388	46,718
Whole sales & trading/merchandise	7,033	113,966
Transportation & communication	1,193	72,719
Finance & banking services	2,933	64,674
Community/social & personal services	5,793	329,125
Total	23,152	1,073,070

Source : Statistical Abstract 1991

Numbers of establishments of wholesales and trading/merchandise are the biggest according to the above table, but 23% of them have no employees and 36% of them have employees with only 1 to 4 persons according to the statistical data as of 1990. It means that nearly 60% of them are small scale firms representing as retail shops.

While, the statistical data indicates that 25% of those of agriculture and forestry have employees with 50 persons or more, and 12% of them have employees with 20 to 49 persons. In agriculture and forestry, 37% of the establishments are medium and large scale firms, while the firms with employees of 1 to 4 persons were 42%. It may say that small scale farm industry was slightly higher than those of medium and large scale farm industry but working situation of medium and large scale establishments are the same situation with small ones considering availability of employment of temporary workers in working season due to their scale merit.

Numbers of manufacturing are ranked at 5th among the industry group according to the above table, but the numbers of employees are ranked at 3rd of them. Thirty (30)% of them have the employees with 50 persons or more, and 16% of them have employees with 20 to 49 persons. Namely, about half of establishments are medium and large scale industries.

Among the total establishments, numbers of establishments, employees, productivity and quantum indexes of products in manufacturing sector are summarized as below:

Item	As of 1990	Annual growth rate (%) (1986 - 1990)
Numbers of establishments	612	0.12
Number of employees	166,777	2.40
Input (K.£000)	6,054,381	20.79
Output (K.£000)	6,887,248	19.79
Value added (K.£000)	832,867	13.57
Quantum index (%) (1989 - 1993)	3.03	-

Source : Statistical Abstract 1991

Numbers of establishment shows not so high increase but number of employees shows constantly increase during last 5 years from 1986 to 1990 as indicated in the above table, and the table shows a high increase of value added. Production of their output is also constantly increased during last 5 years from 1989 to 1993. It means that value added would be increased constantly up to 1993.

According to the statistical data, manufacturing products are classified into 25 kinds, meat and dairy products, canned vegetable/fish/oils/fats, grain mill products, bakery products, sugar and confectionery, miscellaneous foods, beverages and tobacco, textiles, clothing, leather products and footwear, wood and cork products, furniture and fixtures, paper and paper products, printing and publishing, industrial chemicals, petroleum and other chemicals, rubber products, plastic products, pottery and glass products, non-metallic mineral products, metal products, non-electrical machinery, electrical machinery, transport equipment, and miscellaneous manufactures.

Several productions among them decreased, meat and dairy products, industrial chemicals, rubber products, plastic products, non-metallic mineral products, non-electrical machinery, electrical machinery, and transport equipment with a rate of -28%, -11%, -39%, -34%, -23%, -22%, -16%, and -21% respectively since 1986 until 1990. However, numbers of employees did not correspond to the numbers of establishment. On the contrary, input, output and value added increased highly. From this, it seems that the scales of establishments have gradually became large during these years.

Here, principal manufacturing commodities in production and consumption are summarized as follows:

Commodities	Unit	1984		1990		1993		Annual growth rate (%)	
		Prod.	Cons.	Prod.	Cons.	Prod.	Cons.	Prod.	Cons.
Excisable commodities									
Cigarette/cigars	mill.stick	5,391	5,052	6,648	6,187	7,266	-	3.37	3.44
Beer	mill.ltrs.	230	230	331	325	349	-	4.74	5.93
Paints	1,000 ltrs.	5,597	4,724	9,319	5,506 [a]		-	8.87	3.90
Spirits	1,000 ltrs.	530	653	1,193	1,711	2,259	-	17.48	17.41
Soap	tons	28,339	15,266	37,202	41,067	-	-	4.64	17.93
Distempers	1,000 ltrs.	293	302	368	366	-	-	3.87	3.26
Principal foodstuffs									
Ghee and fats	1,000 tons	49	-	112	-	-	-	14.77	-
Jams/marmalades	tons	819	-	1,125	-	-	-	5.43	-
Refined salt	tons	58,352	-	78,158	-	-	-	4.99	-
Certain industrial commodities									
Cotton yarns	1,000 kg	1,686	-	2,873	-	-	-	9.29	-
Blankets	1,000 units	2,253	-	31,421	-	-	-	55.15	-
Cement	1,000 tons	1,135	532	1,512	1,182	1,416	894	2.49	5.95

Note [a]: shows the figure in 1988

Prod.:Production. Cons.:Consumption. -:Lack of data.

Source: Statistical Abstract 1991, Economic Survey 1994, Monthly Statistical Bulletine Jan.-Mar. 1994

It appears that the increase in production and consumption of those commodities in the above table shows a change of people's life style and quality, as well as the increase of their trading activities. Furthermore the increase in production and consumption of cement shows the increase of construction activities reflecting their life style and urbanization.

2.1.6 Infrastructure

In Kenya as of 1990, there are 74,556 km long roads in total distance including special purpose road in 1990 except for those in the Nairobi province. The data on road in Nairobi province is not available at the present study stage. Among them, general roads except special purpose road in Kenya are classified into 6 classes totalling at 59,183 km. The following table shows its summary:

As of 1990 (Unit: km)

Province	General road							Special purpose road	Grand total
	Class A	Class B	Class C	Class D	Class E	Not classi-fied	Total		
Nairobi	(No data available)								
Central	290	182	1,043	1,834	3,114	416	6,879	1,866	8,745
Coast	446	752	562	1,147	3,638	29	6,574	1,721	8,295
Eastern	636	733	1,061	1,588	5,870	2,035	11,923	3,422	15,345
N. Eastern	201	586	534	767	4,412	0	6,500	1,005	7,505
Nyanza	217	151	831	1,880	2,474	316	5,869	1,352	7,221
Rift Valley	1,185	833	3,316	4,066	7,819	563	17,782	5,170	22,952
Western	211	193	738	847	1,624	43	3,656	837	4,493
Total	3,186	3,430	8,085	12,129	28,951	3,402	59,183	15,373	74,556

Source : National Water Master Plan 1992, JICA

According to the statistical data, Kenya has 2,758 km long railway lines in total length consisting of 1,919 km for public and 839 km for private and sidings. The representative sea port in Kenya is Mombasa, and there are several small ports along sea coast faced to the Indian ocean. In these ports, there are registered steamships with 1,725 units and sailing ships with 101 units, and their registered tonnage is 6,184 thousand tons in total. Also Kenya has 2 international airports, namely Jomo Kenyatta International Airport in Nairobi and Moi International Airport in Mombasa. Among them, Wilson domestic airport is usually used for sightseeing in addition to local flight between Nairobi and Kisumu, Garissa and Malindi. So these 3 towns have also facilities for aircraft and passengers.

Of existing 1,783 public services centers in Kenya, 999 centers or 56% were covered by piped water distribution system in 1990. Those service centers comprised 102 urban centers, 139 rural centers, 279 market centers, and 479 local centers. There were 89 communal water points or 5% of the total. Those systems are maintained by local community, self-supporting, non-governmental authorities, local authorities, MOWD, NWCPC, donors, etc.

There are 377 services centers or 21% of the total public service centers which are installed by sewerage systems, while the refuse collection is conducted in 704 service centers, or 40% of the total public services centers.

A rural Electrification Program was established in 1973. It was a Government policy to promote the extension of electricity services in the rural area. To promote the program, several agencies were involved as responsible bodies, which include MOE for administration and policy promotion, KPLC for implementation and operation, Rural Electrification Technical Committee for management, and DDCs for identification and bringing up for electrification. In early 1980's, all district headquarters were supplied with electricity through this program.

KPLC, which is a 60% government-owned entity, coordinates the national power network, purchases electricity in bulk from KPC, TRDC and TARDA, and distributes it to consumers. Recently, the Government of Kenya decided that KPC implemented the power plant and generated the electricity and KPLC distributed the electricity to consumers.

In 1990, 246 thousand customers were covered by the KPLC's service system in Kenya. Of the total customers, 240 thousand or 98% were domestic or small non-domestic customers. The domestic users were enumerated at about 200 thousand. The total number of households was estimated at 4.7 million for a total population of 24,396 thousand in the same year. An electrification rate, therefore, was figured out to be 4.3% in Kenya.

As mentioned in previous clause, tourism is one of the important industries for Kenya's economy. The main accommodation for tourists are hotels including lodges and/or camping facilities. According to the statistical data, rooms and beds constantly increased from 4,500 in 1983 to 5,600 in 1990 at an average annual increase rate of 2.6% and 8,500 in 1983 to 10,600 in 1990 at an average annual increase rate of 2.4%, respectively. Their average occupancy rates were around 53% and 44%, respectively.

The Government of Kenya records 19 kinds of wildlife species as elephant, buffalo, giraffe and so on. The wildlife can be seen in several national parks, game reserves, and museums. Those facilities totals 37 places in the whole Kenya.

2.1.7 Family Income and Expenditure

Following table shows a summary of results of the rural and urban household budget survey made by Central Bureau of Statistics of Kenya from 1982 to 1984. After that time, this kind of survey has been no longer carried out until 1994.

As of 1983 (Unit: K.Shs/month)

Class of family by income	Income	Expenditure	Balance
Low class	912	1,034	-122
Middle class	3,604	3,677	-73
High class	13,822	8,964	4,858
Average	1,931	2,068	-137

Source : National Water Master Plan 1992, JICA

In the table above, all families are classified into three different income levels, namely the low income class, the middle income class and the high income class, whose annual income ranges are based on income level of K.Shs. 2,000 or less, from K.Shs. 2,000 to K.Shs. 7,999, and more than K.Shs. 8,000, respectively.

As long as the table above shows, it is guessed that only high income class families could have lived comfortably at that time, though it is not applicable to the present situation because that the figures are expressed at the 1983-price level. Then, present situation is discussed hereunder based on the present minimum wage level gazetted.

As mentioned in the aforesaid Subsections 2.1.3 and 2.1.4, a total number of households and economically active population in 1989 were 4,353,000 families and 11,183,000 persons respectively. It means that around 2.7 persons per family were able to get the wage employment formally or casually.
Besides, a total of the actual working population in urban area in 1990 was estimated at 734,000 persons. Hence, it is estimated that the remaining actual working population of 10,449,000 persons resided in the rural areas assuming that the total economically active population in 1990 is almost same as that in 1989.

On the other hand, the Economic Survey 1994 reported the basic minimum monthly wages for rural agricultural industry and monthly minimum wages in urban areas (excluding housing allowance). Those minimum wages are summarized in the following table:

(Unit: K.Shs.)

Wage basis	1991	1992	1993
Rural agricultural industry	647	716	941
Urban occupation	1,199	1,343	1,760

Source : Economic Survey 1994

With the figures above, the weighted average wages in 1991, 1992 and 1993 are calculated at K.Shs.684, K.Shs.757 and K.Shs.995 per person, respectively, in a total of rural and urban area. Therefore, the average household incomes come to K.Shs.1,847 in 1991, K.Shs.2,044 in 1992 and K.Shs.2,687 in 1993. Thus, the average household income of K.Shs.1,931 in 1983 became K.Shs.2,687 in 1993.

The aforesaid Economic Survey 1994 also says that the total wage payment were estimated at K.£.3,496.6 million and that the actual wage population was 1,475,000 in 1993. This means that the average monthly wage was K.Shs.3,951 per employee. It seems that this amount exceeds the gazetted minimum wage mentioned above. But this amount of wage includes house allowance and/or other allowance.

For reference, construction cost for a typical house newly built is estimated as shown below according to the National Water Master Plan prepared by JICA in 1992.

As 9.4 1991

Item	Average in whole Kenya		
	Permanent house	Semi-permanent house	Thatched house
Average floor area (m^2)	81	53	28
Unit price (K.Shs./m^2)	5,533	2,542	903
Total construction cost (K.Shs.)	448,173	134,726	25,284

Source : National Water Master Plan 1992, JICA

Annual inflation rates have highly increased during these years since 1991 as mentioned in the next clause. Applying the inflation rates, the construction costs of permanent house, semi-permanent house and thatched house at the 1993 price level come to K.Shs.834,274, K.Shs.250,792 and K.Shs.47,066, respectively . It seems that these costs are too high considering the employees' income. Therefore, the house allowance should be helpful for the employees.

2.1.8 External Trade

Concerning the international balance of payment, the current account is usually divided into 2 items, merchandise representing as external trading, and services rendered. In Kenya, the balance of external trading was constantly minus side for the period from 1985 to 1993. It means that the amount of import was larger than that of export. However, in 1993, the balance of total current account became plus side. This is a reason why that the income from the tourism industry in 1993 was much more than those before 1992 according to the statistical data.

The exports and imports in Kenya for 5 years from 1989 to 1993 are summarized below:

(Unit: K.£million)

Exports/ imports	1989	1990	1991	1992	1993	1994	1995	1996	Annual growth rate (%)	
Exports	1,000	1,232	1,534	1,708	3,625	4,171	4,656	5,696	37.99	28 21
Imports	2,239	2,546	2,646	2,829	4,845	5,556	7,495	8,144	22.59	20.26
Balance	-1,239	-1,314	-1,112	-1,247	-1,431	-1,385	-2,839	-2,418	-	

Source : Economic Survey 1994

According to the statistical information, among the exports, food and beverages was the highest amount exported as over 50% in every year since 1989, and the second ones were industrial supplies (non-foods) as around 20% in the same period. And the third ones were fuel and lubricants as around 10% or more during the same period also. The main export commodities were coffee, tea, soda ash, fluorsper and horticulture.

At the viewpoint of the international trading as discussed hereunder, food and beverages representing as coffee, tea, etc. are the highest exported amount as 50% or more. On the other hand, sightseeing activity is also not small amount of income at the viewpoint of international balance of payment not only in 1993 but during these several years. From this viewpoint, it may say that Kenya is the state established on the basis of farming and sightseeing, and the manufacturing seems to be now overtaking.

On the other hand, industrial supplies (non-foods) were the highest imported amount as 34% in 1989 becoming around 40% in 1993. The second ones were fuel and lubricants with sharing as around 15% in 1989 that became as around 25% in 1993. Furthermore, the third ones were the machinery and other capital equipment, but this sector decreased from 21% in 1989 to 15% in 1993. The food and beverages shared on around 6% during the same period.

2.1.9 Consumer Price

(1) Consumer Price Indexes and Inflation Rate

The consumer price indexes in whole Kenya by income class are shown in Table 2.1.1 together with annual inflation rate. The inflation rates are summarized in the following table:

(Unit: %)

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Inflation rate	12.12	21.54	12.30	9.88	12.61	4.73	8.71	12.34	13.46	15.68	19.62	27.50	46.00	53.91	1.6	9.0

Source : Ref. to Table 2.1.1

The average annual inflation rate was 18.40% per annum since 1981 as shown in the table above. Especially, it seriously increased since 1991 as compared with those in the previous years. It seems that the economic inflation must press the living condition of the people in Kenya.

(2) Exchange Rate

The exchange rate of the Kenya's currency (K.Shs.) varied largely since 1990 against both the US Dollar currency and Japanese Yen currency as compared with that of 1977's and 1980's. As shown in Table 2.1.2, against US Dollar, the value of the Kenya's currency has fallen from K.Shs.24.084 per US$1.00 in December 1990 to K.Shs.57.400 per US$1.00 in July 1997.

For Japanese Yen, its value has fallen more largely than that in US$. The exchange rate varied from K.Shs.17.860 per Yen100.00 to K.Shs. 49.800 per Yen 100.00 during the same period.

However, it seems that the Kenya's currency had recovered the value against those US$ and Japanese Yen to some extent from January 1994 to September 1994 and from April 1994 to September 1994, respectively.

2.1.10 Public Finance for Development

(1) Government Budget Out-Turn

Following table shows the Government budget out-turn during last 20 years since 1972 in Kenya.

					(K £million)
Revenue/expenditure	1972/73	1982/83	1988/89	1992/93	Average annual growth (%)
Current revenue	153.61	832.12	1,918.55	3,263.46	16.51
% of GDP (current price)	19.53	23.00	25.38	24.32	-
Current expenditure	109.29	875.87	1,967.24	3,504.68	18.93
% of GDP (current price)	16.77	24.21	26.02	26.11	-
Current balance	44.32	-43.75	-48.69	-241.22	-
External grants	2.50	56.30	186.65	513.40	30.50
Total development expenditure	48.45	172.78	480.66	908.40	15.78
% of GDP (current price)	6.21	4.78		6.77	-
Overall deficit	-25.33	-160.23	-342.70	-636.23	17.49
Financing of deficit					
Net external borrowing	9.27	91.27	200.00	177.25	15.90
Net domestic borrowing	19.42	245.60	88.00	795.00	20.39
Cash balance	3.36	176.64	-54.70	336.02	25.89
GDP at current price	733.21	3,420.28	7,559.61	13,420.79	15.65

Source : National Development Plan 1994-1996

The role of fiscal policy in sustainable economic development to the year 2000 was articulated in *Sessional paper No.1 of 1986* on Economic Management for Renewed Growth. First of all, concerns had been raised on the sustainability of fiscal policies considered expansionary budget financing tending to fuel inflation. Secondly, there was the tendency to crowed-out private sector expansion even as import-substitution gave way to export oriented growth. The paper also laid down the framework for Structural Adjustment Programs (SAPs). The new economic approach would control fiscal deficits to manageable levels and limit the development of other imbalances in the economy notably the growth in money supply. However, major fiscal indicators show only limited success in controlling recurrent over-run of Government spending.

As shown in the table above, the nominal revenue increased from K.£.154 million in 1972/73 to K.£.3,263 million in 1992/93 at an average annual growth rate of 16.5%, while recurrent expenditure had increased from K.£.109 million in 1972/73 to K.£.3,505 million in 1992/93 at an average annual growth rate of 18.9%. The Government has analyzed this situation that the increases of expenditures were generally due to the expansion of expenditure for vital services such as education, health and the need to maintain the real value of other services because of rising inflationary pressures in current National Development Plan.

The ratios of development expenditure to the aforesaid total expenditure in 1972/73, 1982/83, 1988/89 and 1992/93 were 30.7%, 16.5% , 19.6% and 20.6%, respectively.

The water development expenditures consist of 6 sectors; (1) water supply, (2) sewerage, (3) irrigation, (4) livestock, (5) hydropower, and (6) flood control. During these 5 years from 1986/87 to 1990/91, the amount spent for those sectors accounted for 38.8%, 3.6%,10.0%, 0.0%, 47.4% and 0.2% of the total development expenditure deflated, respectively according to the aforementioned National Water Master Plan in

1992. As indicated by these figures, the expenditure spent for hydropower development was the highest in Kenya.

2.2 Population Trend

2.2.1 Population

(1) Provincial Distribution

According to the population census in 1969, 1979 and 1989, the provincial distributions of population in whole Kenya have changed as shown below:

Province	Area (km^2)	Population distribution					
		1969-census		1979-census		1989-census	
		Population	(%)	Population	(%)	Population	(%)
Nairobi	693	509,286	4.65	827,775	5.40	1,324,570	6.18
Central	13,236	1,675,647	15.31	2,345,833	15.31	3,116,703	14.53
Coast	84,113	944,082	8.63	1,342,794	8.76	1,829,191	8.53
Eastern	154,354	1,907,301	17.43	2,719,851	17.75	3,768,677	17.57
North-Eastern	126,186	245,757	2.25	373,787	2.44	371,391	1.73
Nyanza	12,507	2,122,045	19.39	2,643,956	17.25	3,507,162	16.36
Rift Valley	182,413	2,210,289	20.20	3,240,412	21.14	4,981,613	23.23
Western	8,285	1,328,298	12.14	1,832,663	11.95	2,544,329	11.87
Total	581,787	10,942,705	100.00	15,327,071	100.00	21,443,636	100.00

Source : Population Census 1969, 1979, 1989

(2) Growth

According to the results of population census made in 1969, 1979 and 1989, the total population of Kenya increased from 11 million in 1969 to 21 million in 1989 through 15 million in 1979 as shown in the table above. The average annual growth rate of population was 3.43% between 1969 and 1979, 3.42% between 1979 and 1989, and 3.42% between 1969 and 1989.

The population growth rates by province in and around the Tana river basin during the same period are summarized as follows:

(Unit: %)

Province	Annual growth rate between:		
	1969 - 1979	1979 - 1989	1969 - 1989
Central	3.42	2.88	3.15
Coast	3.59	3.14	3.36
Eastern	3.61	3.32	3.46
North-Eastern	4.28	-0.06	2.09

Source : Population Census 1969, 1979, 1989

As indicated above, the growth rates of population in the Tana river basin for the period from 1979 to 1989 were smaller than that for the period from 1969 to 1979.

(3) Population Projection

A population projection for the year 2010 was made in the course of the study on the National Water Master Plan, which was carried out by Japan International Cooperation Agency (JICA) in 1992. On the basis of the study results, the population growth rate for the period from 2010 to 2020 was estimated by using the extrapolation method as shown in Table 2.2.1.

In succession, the population projection was made for urban and rural areas of each province as shown in Table 2.2.2. and summarized below. The figures up to 2010 is quoted from the said study.

Figures:Total (urban + rural) (thousand persons)

Province	1995	2000	2005	2010	2015	2020
Nairobi	1,780	2,260	2,785	3,465	4,333	5,416
Central	3,696	4,178	4,678	5,249	5,892	6,616
Coast	2,274	2,631	2,993	3,390	3,885	4,446
Eastern	4,629	5,328	6,037	6,813	7,782	8,876
North-Eastern	424	514	597	697	813	950
Nyanza	4,064	4,517	5,008	5,577	6,170	6,836
Rift Valley	6,345	7,628	9,007	10,532	12,513	14,843
Western	3,177	3,656	4,105	4,582	5,208	5,906
Total	26,389	30,712	35,210	40,305	46,469	53,541

Source : National Water Master Plan 1992, JICA, in 2020 by Study Team

2.2.2 Labor Force

The National Development Plan 1994 - 1996 sets a labor force projection as sown in the following table:

(1,000 persons)

Item	1990	1993	1996
Population	22,777	24,968	27,176
Economic active population	11,347	12,825	14,496
Other	11,430	12,143	12,680
Employment projection			
Labor participation rate (%)	82.72	81.09	79.12
Labor force	9,386	10,400	11,469
Employment expected (low)	7,722	8,523	9,471
Employment expected (high)	7,825	8,657	9,660

Source : National Development Plan 1994-1996

According to the table above, unemployment rates in 1990, 1993, 1996 in Kenya range between 16.6% and 17.7%, between 16.8% and 18.1% and, between 15.8% and 17.4%, respectively. Differences between low scenario and high scenario of expected employment are based on the situation of urban informal employment. Using these figures, an extrapolation is made for estimation of labor force in the target year of 2020 of the Project. As a result, the economic active population and labor force are obtained to be 38,611 thousand persons and 28,955 thousand persons, respectively, and the expected employment in low scenario and high scenario in 2020 are estimated at 22,081 thousand persons and 23,261 thousand persons, respectively. Consequently, the unemployment rate is derived to range between 19.7% and 23.7%. It is not expectable that employment in urban area will increase at a higher rate to harmonize with the rate of labor force.

2.3 Economic Development Plan

2.3.1 National Development Plan

The 7th National Development Plan started from July 1994, aiming to attain the projected growth of the nation's economy over the 3 calendar years from 1994 to 1996, and more especially, the investment program of the Government in the 3 three fiscal years from 1994/95 to 1996/97. It will end in June 1997.

The overall theme for the 7th National Development Plan is "Resource Mobilization for Sustainable Development" which expresses the commitment by the Government of Kenya to ensure the sustainable development of the nation's financial. human and natural resources for the benefit of present and future generation following the Rio Declaration on Environment and Development, namely "Agenda 21", adopted in Earth Summit held in June 1992 in Brazil.

(1) Overview of National Development Plan

For tackling key environment and development problems and to launch Kenya's transition to sustainable development, the Government of Kenya identified the following imperatives:

(1) to ensure an equitable and sustainable pattern of development,
(2) to sustain growth to meet the needs and aspirations of the majority,
(3) to reduce widespread rural and urban poverty,
(4) to modify the rate and spatial distribution of population growth,
(5) to improve human and environmental health,
(6) to provide adequate shelter and services, especially for the poor,
(7) to conserve and enhance the environment and natural resource base,
(8) to make efficient use of energy and expand the use of new and renewable sources,
(9) to ensure sustainable industrial production and use of environmentally sound technologies,
(10) to improve national and local capacities for sustainable development planning and management, and
(11) to strengthen international cooperation and programs in support of sustainable development.

(2) Target of Development Plan

Under the imperatives mentioned above, the Government of Kenya has issued in the National Development Plan. It is represented by the following 3 overall goals for 1994 - 96:

(1) to secure renewed economic growth with greater self-reliance,
(2) to improve the health, income and living conditions of the majority of Kenyan people, and,
(3) to ensure key economic and sectoral policies support development that is sustainable.

On the basis of the above, the National Development Plan has stated the following targets:

Economic Growth

While the 6th National Development Plan had laid out a target of economic growth during the 1989 - 1993 period at an average annual rate of 5.4%. The average growth rate during the 4 years from 1988 to 1992 has been 3.1%. The collapse of the international prices of coffee in mid 1989 and the suspension of quick disbursing donor aid in November 1991 were the main cause of the low economic growth rate. The Plan says that the influence of these adverse factors has been wearing off shortly over the recent years, allowing the country to look cautiously forward to a period of gradual economic recovery.

Employment Generation

Population in Kenya is expected to grow from projected figure of 25 million in 1993 to 31 million in 2000. With this population growth rate, total labor force is expected to grow from an estimated figure of 10.4 million in 1993 to about 11.5 million in 1996. On the other hand, total (rural and urban) employment is expected to grow from the range between 8.5 million and 8.7 million in 1993 to in the range between of 9.5 million and 9.7 million in 1996. This implies that unemployment rate will drop slightly in the range between 16.8% and 18.1% (1.7 million or 1.9 million persons) in 1993 to the range between 15.8% and 17.4% (1.8 million or 2.0 million persons) in 1996. The Plan says that it is clear, therefore, that no significant problem of unemployment can be expected in the course of the period through 1996.

Gross Regional Domestic Products (GRDP)

The Government of Kenya had issued a *"Sessional Paper No.1 of 1986"* on economic management for renewed growth in 1986. The Plan says that this paper set the target growth rate in real GRDP at 5.9% per year between 1988 and 2000. This was considered absolutely necessary if per capita incomes were to grow at 1.8% during the period, coupled with an overall employment growth rate of 3.4% during the same period. However, the country has experienced a rapid deceleration in growth rate, which started in 1989 and has continued to date.

On the basis of the above paper, and considering the several factors led to the deceleration of growth, the Government has set the growth of GRDP as shown in the following table:

(Unit: K.£million)

Industrial sector	1993	1994	1995	1996
Traditional economy	450.8	462.6	474.2	485.1
Agriculture	2,308.2	2,346.0	2,497.0	2,625.5
Industry	1,684.1	1,715.9	1,803.8	1,932.6
Services	3,009.0	3,122.7	3,255.1	3,436.6
Government	1,394.7	1,445.1	1,498.1	1,534.3
Total GRDP	8,846.8	9,092.2	9,228.1	10,014.1
Annual growth rate(%)	0.8	2.8	4.8	5.1

Source : National Development Plan 1994-1996

2.3.2 District Development Plan

The Government of Kenya establishes District Development Committee in each District under the Rural Planning Department of the Office of the Vice-President and Ministry of Planning and National Development for providing district development plan corresponding to the said 7th National Development Plan.

All of 41 districts under province have made their own development plan, namely "District Development Plan 1994 - 1996". Among them, 14 districts are belong to the Tana river basin, they are the districts of Kiambu, Kirinyaga, Muranga, Nyandarua, and Nyeri under Central province, Kilifi, Lamu, and Tana River in the Coast province, Embu, Isiolo, Kitui, Machakos, and Meru in the Eastern province, and Garissa in the North-Eastern province. The District Development Plans for 13 districts among them were available in the present study stage. Nyandarua district's one was not available this time.

According to these District Development Plans, local authorities of these districts have recognition that they faced to such problems as (1) inadequate water supply, (2) low land productivity, (3) environmental degradation, (4) poor communication network, (5) prevalence of pests and disease for agricultural products, (6) poor marketing facilities, (7) inaccessibility to credit facilities for farmers, (8) inadequate supply of electricity and (9) inadequate education facilities and so on.

The District Development Plans of these districts express the policy and strategy to have solution of the problems mentioned above by adjusting situations of each district following the national development policy.

2.3.3 Tourism

Theoretically, the Project area has potential for tourism but practically the area is inaccessible due to poor and inadequate infrastructure. The area is geographically located in proximity to several national parks and game reserves, enjoyable with beautiful landscape, archaeological, historical and cultural sites, series of reservoirs and dams, coupled with a climate that is conductive to human habitation. With the development of the fisheries, crocodile farming and sporting facilities, there is no doubt that the area can form an important transit and circuit for tourists provided the infrastructure including security is improved.

CHAPTER 3 SITE CONDITIONS

3.1 Location and Topography

The Tana river, the largest river in Kenya, originates from Mount Kenya and Nyandarua Ranges. Its catchment covers some 100,000 km^2 and stretches for about 1,000 km between the Kenya Highlands with the peak of Mt. Ol-dolinyo at EL. 3,999 m and the Indian Ocean.

The river basin is sub-divided into the following physiographic regions:

- An upper catchment (9,520 km^2) upstream of Kamburu with elevations above 1,000 m
- A middle catchment (15,700 km^2) between Kamburu and Koreh Rapids with elevations between 200 and 1,000 m, wherein the Project site is located
- A lower catchment (70,000 km^2) downstream of Koreh Rapids with elevations below 200 m

The proposed Mutonga/Grand Falls Hydropower Project (the Project) is located 25 and 50 km downstream of the existing Kiambere power station and about 150 km north-east of Nairobi. The Mutonga dam site is located immediately downstream of the confluence of the Tana river and the Mutonga river, one of main tributaries of the Tana river. Both river banks have steep slopes of 30 to 40 degrees and the ground level is about 20 m above the river bed. Relatively flat plains develop at the edges of the steep slopes.

The Grand Falls dam site is located about 4 km downstream of the Grand Falls rapids. The river banks have the steep slopes, followed by gentle slopes. A flat area with a high elevation land extends on the right bank.

The Tana river reaches the Koreh Rapids after flowing down about 100 km from the Grand Falls. River bed elevations are about 450 m at the Grand Falls dam site and about 200 m at the Koreh Rapids, creating a water head of about 200 m between the two locations. Thereafter the river runs through a vast alluvial flood plain and finally reaches the Indian Ocean after flowing down about 700 km. The main river channel which has a width of about 100 m only meanders through a flood plain with a width of 3 to 4 km.

The reservoir area and the downstream corridor are covered by navigation maps on scales of 1: 1,000,000 and 1: 500,000, and by topographic maps on scales of 1: 250,000 and 1: 50,000. Aerial photos were taken for the Tana delta area of about 1,300 km^2 on a scale of 1: 25,000 and for the reservoir area of about 300 km^2 on a scale of 1: 20,000. Topographic maps on scales of 1 : 1,000 and 1 : 5,000 were newly produced to obtain detailed topographic information on the proposed structures and the reservoir area. The dam profile and cross sections and river cross sections also were prepared.

3.2 Meteorology and Hydrology

3.2.1 Meteorology

The Tana river basin with a total drainage area of some 100,000 km² originates from Mount Kenya and Nyandarua Ranges and flows down for about 1,000 km to finally pour into the Indian Ocean. The annual rainfall in the Tana basin varies from more than 2,000 mm in the mountainous areas located around Mount Kenya to less than 300 mm in the low-lying areas near Garissa in the lower reaches of the Tana mainstream.

The aerial distribution of annual rainfalls in the project catchment was clarified based on long-term mean rainfalls at some 160 rainfall stations in and around the project catchment. The isohyetal map for the project catchment is illustrated in Figure 3.2.1. This figure shows that high annual rainfall of more than 2,000 mm takes place in the northern and western areas of the project catchment. It decreases as the altitude goes down toward the Tana mainstream, coming to less than 800 mm in the right bank side area downstream of the existing Masinga dam.

The tributaries in the project catchment are divided into two types, namely the perennial river and seasonal river, being dominated by the rainfall amount as well as the geographical position. The seasonal rivers appear in the area on the right bank side downstream of the Masinga dam, where the annual rainfall is less than 1,000 mm as shown in Figure 3.2.1. In these seasonal rivers, no surface flow is seen during the dry periods.

3.2.2 Hydrology

(1) Estimate of Long-term Naturalized Daily Runoff

Basin Rainfall

The runoff analysis principally aims at estimating the naturalized long-term runoff at the planned Mutonga and Grand Falls dam sites as well as the existing five dams located upstream of those planned dams, taking into account the basic hydrological data required for the examination of the artificial floods planned for improving the environmental condition in the downstream areas. To accurately examine the effective storage capacities of the planned dams, the runoff analysis was carried out on a daily basis.

Taking into consideration the availability of the existing meteo-hydrological data related to the project catchment, the runoff analysis for estimating the naturalized long-term mean daily discharges at the planned dam sites was carried out applying the rainfall-discharge simulation model to the respective sub-basins so as to generate daily runoff data from daily rainfall data over the period when the rainfall data became completely available. In the method, the long-term runoff at the planned dam sites was estimated to be a sum of those of the respective sub-basins for the period, which were to be derived through the simulation.

To make the low flow analysis consistently, the project catchment area of 17,234 km^2 was divided into 14 sub-basins in consideration of the locations of the existing dam sites and those of the selected key stream gauging stations.

The sub-basins are depicted in Figure 3.2.2. Of the 14 sub-basins, six sub-basins; 4CA2, 4CB4, 4BE2, 4DD1, 4EA7, and 4F19 are covered by the stream gauging station. These sub-basins were categorized as "gauged sub-basin", while the other eight sub-basins as "ungauged sub-basin".

Taking into consideration the available periods of daily rainfall data at the 154 stations, the simulation was made by using the Tank Model to generate the runoff data for 34 years between 1957 and 1990.

To estimate the basin average rainfall for the project catchment for 34 years from 1957 to 1990, the Thiessen's polygons were worked out for the entire project catchment. As a result of estimate of the annual basin average daily rainfalls between 1957 an 1990 by applying the Thiessen's polygons, the basin average rainfall for the project catchment with an area of 17,234 km^2 was estimated to be about 1,249 mm/year as shown below:

No.	Name of Sub-basin	Catchment Area (km2)	Nos. of Rainfall Stations Applied	Basin Average Rainfall (mm)
1	4BE2	3,672	58	1,477.3
2	4CB4	316	12	1,835.8
3	4CA2	518	16	1,619.8
4	MASI-RL	2,829	22	967.9
5	4DD1	1,961	24	1,494.4
6	KAMB-RL	224	4	704.0
7	GITA-RL	147	5	773.4
8	KIND-RL	140	5	707.2
9	KIAM-RL	2,168	10	767.1
10	MUTO-L	1,045	18	1,063.2
11	MUTO-R	465	6	802.5
12	4EA7	1,880	24	1,605.3
13	GRAF-RL	196	4	855.8
14	4F19	1,673	25	1,380.2
Total	Grand Falls Catchment	17,234	154	1,249

Long-term Daily Runoff of Gauged Sub-basins

The seven stream gauging stations SGS 4CA2, 4CB4, 4BE2, 4DD1, 4EA7, 4F19 and 4ED3 were selected as the key stream gauging stations to be used for the runoff analysis from the viewpoint of their geographical positions as well as the consistency of the processed runoff data in comparison with the basin average rainfall.

The runoff analysis was conducted by constructing the Tank Model for each of the 14 sub-basins. Six sub-basins (4CA2, 4CB4, 4BE2, 4DD1, 4EA7 and 4F19) were categorized as gauged sub-basins where runoff data to the Tank Model were available. Taking into account the availability of the runoff data, the parameters of the Tank Model for each sub-basin were determined in the following steps:

Step-1 : Establishment of tank parameters for each of the six gauged sub-basins through trial calculations to get the best coincidence of the mean daily discharges observed and simulated with Tank Model for their concurrent periods, and estimate of the daily runoff for these six gauged sub-basins

Step-2 : Establishment of tank parameters for the two ungauged sub-basins located upstream of SGS 4ED3, MASI-RL, and KAMB-RL, and estimate of the daily runoff for these two ungauged sub-basins

Step-3 : Establishment of tank parameters for the six ungauged areas in the downstream sub-basins of SGS 4ED3, estimate of the daily runoff for these six ungauged areas, and estimate of the daily runoff at the Mutonga and the Grand Falls dam sites by summing up those of the 14 sub-basins.

Through a number of trial calculations in Step-1, a combination of tank parameters which gave the best coincidence of the observed and simulated mean daily discharges at the seven stream gauging stations including SGS 4ED3 were derived to generate the daily runoff data for the interrupted periods between 1957 and 1990. The flow duration curves thus derived for each of the seven stream gauging stations are illustrated in Figure 3.2.3. The long-term mean discharges of the gauged sub-basins thus estimated between 1957 and 1990 are summarized in the following table:

Name of Sub-basin	Catchment Area (km2)	Basin Average Rainfall (mm/year)	Mean Discharge between 1957 and 1990 (m3/sec)	Runoff Coefficient (%)
4CA2	518	1,620	8.79	33.1
4CB4	316	1,836	7.11	38.8
4BE2	3,672	1,477	64.37	37.5
4DD1	1,961	1,494	26.60	28.7
4EA7	1,880	1,605	28.85	29.0
4F19	1,673	1,380	15.67	21.0
(Total)	10,020			
SGS 4ED3	9,520	1,351	118.11	29.0

Long-term Daily Runoff of Ungauged Sub-basins

As explained in the above, the long-term daily runoff of SGS 4ED3 consisting of 6 sub-basins, 4CA2, 4CB4, 4BE2, 4DD1, MASL-RL and KAMB-RL is simulated by the Tank Model. Out of those six sub-basins, two sub-basins MASL-RL and KAMB-RL are ungauged area, while daily runoff of other gauged 4 sub-basins were made available the same procedure as that for SGS 4ED3. It was considered that runoff of the ungauged 2 sub-basins correspond to a difference between runoff of SGS 4ED3 and a sum of runoff of the ungauged 4 sub-basins on a daily basis, unless the difference comes to zero or less. For the ungauged sub-basins MASI-RL and KAMB-RL, trial calculations by the Tank Model method were made by varying the Tank parameters in order to find the most suitable ones which result in the satisfactory coincidence of the daily runoff data at SGS 4ED3 and the sum of those of the six sub-basins constituting the catchment of SGS 4ED3. As a result of trial calculations, the tank parameters for two ungauged sub-basins were derived so that the long-term mean daily discharges derived by summing up the runoff values of the four sub-basins coincide consistently with those estimated based on the observed ones at SGS 4ED3 in terms of their hydrographs and flow duration curves as shown in Figures 3.2.4 and 3.2.5.

Long-term Daily Runoff of Existing Dams and Mutonga and Low Grand Falls Dam Sites

There are six ungauged sub-basins in the catchment enclosed by the two stream gauging stations 4ED3 and 4F13 on the mainstream.

As a result of trial calculations, the tank parameters for the ungauged sub-basins were determined so that the synthesized daily runoff data coincide precisely with the low flow observed at SGS 4F13 for the period between 1963 and 1968 when the natural flows were observed at SGS 4F13. The precised coincidence of these two series daily runoff is seen in Figures 3.2.6 and 3.2.7. The estimated long-term mean discharges therein between 1957 and 1990 are summarized below together with the mean annual runoff coefficients for the same period:

No.	Name of Sub-basin	Catchment Area (km2)	Basin Average Rainfall between 1957 and 1990 (mm/year)	Mean Discharge between 1957 and 1990 (m3/sec)	Runoff Coefficient (%)
1	GITA-RL	147	773	0.23	6.4
2	KIND-RL	140	707	0.20	6.3
3	KIAM-RL	2,168	767	3.21	6.1
4	MUTO-L	1,045	1,063	5.33	15.2
5	MUTO-R	465	803	1.17	10.0
6	GRAF-RL	196	856	0.55	10.3
Total		4,161	848	10.69	9.6

The long-term naturalized mean daily runoff data at the existing dam sites and planned Mutonga and Grand Falls dam sites on the Tana mainstream were derived by summing up those at the upstream sub-basins. The mean monthly discharges thereat thus estimated are shown in Tables 3.2.1 and 3.2.2 and summarized below:

No.	Name of Dam	Existing or Planned	Catchment Area (km2)	Estimated Mean Discharge between 1957 and 1990 (m3/sec)
1)	Masinga	Existing	7,335	91.28
2)	Kamburu	Existing	9,667	118.03
3)	Gitaru	Existing	9,520	118.26
4)	Kindaruma	Existing	9,807	118.46
5)	Kiambere	Existing	11,975	121.67
6)	Mutonga	Planned	15,365	157.02
7)	Grand Falls	Planned	17,234	173.24

As seen in the table above, the mean discharges at the planned Mutonga and Grand Falls dam sites between 1957 and 1990 were estimated to be 157.02 and 173.24 m^3/sec.

(2) Flood Analysis

Frequency Analysis for Recorded Maximum Discharge at SGS 4ED3

The probability of floods at the dam sites was examined based on the results of the frequency analysis on other stream gauging stations located within the project catchment. In consideration of the catchment area of 17,234 km^2 at the Grand Falls dam site as well as the runoff characteristics that it had not been affected by the upstream dam during the runoff observation period, the stream gauging station 4ED3 was considered to be the most suitable one whose annual maximum discharges were applied to size the probable floods at the Grand Falls dam site. The frequency analysis was carried out applying the following methods based on the annual maximum discharges at SGS 4ED3:

i) Gumbel
ii) Log Pearson's Type III
iii) Iwai

As a result of the frequency analysis, the 50-year and 10,000-year probable floods at SGS 4ED3 with a catchment area of 9,520 km^2 were estimated to be 2,150 and 6,650 m^3/sec.

The estimated probable floods at SGS 4ED3 were transferred to the proposed Mutonga and Grand Falls dam sites by the Creager's equation.

The probable floods of various return periods were calculated with the Creager's C values derived for the catchment of SGS 4ED3 as summarized below:

Return Period (year)	SGS 4ED3 (C.A.=9,520 km2)		SGS 4F13 (C.A.=17,234 km^2)
	Probable Flood (m^3/sec)	Creager's C Value	Probable Flood (m^3/sec)
1.01	150	0.82	190
2	607	3.30	750
5	1,038	5.65	1,280
20	1,629	8.87	2,010
50	2,144	11.67	2,640
100	2,578	14.03	3,180
200	3,052	16.61	3,760
500	3,748	20.40	4,620
1,000	4,331	23.58	5,340
10,000	6,654	36.22	8,200

<u>Flood Analysis by Storage Function Model</u>

The flood hydrographs at the proposed Mutonga and Grand Falls dam sites were simulated applying the storage function models. As a result of trial calculations for finding out the parameters of the storage function model of the project, the 1967 flood was elected since flood records were available at SGS 4ED3, 4ED7 and 4F19. The parameters derived from the 1967 flood were applied to the rainfall records of the 1961 flood between 2 October and 30 November 1961 which caused the historical maximum flood in the project catchment. The duration of the design rainfall was set at 60 days, taking into account the rainfall records which resulted in the major large-scale floods in the project area. The simulation model for the project catchment is shown in Figure 3.2.8, for which the parameters were attempted to be worked out through the trial calculations in order that the simulated flood hydrograph come to similar to the observed one with respect to its shape and peak discharge. The simulation was carried out in the following two cases:

Case-1 : Simulation on the condition with the Masinga and Kiambere reservoirs
Case-2 : Simulation on the condition without the Masinga and Kiambere reservoirs

The flood hydrographs at SGS 4ED3 and the proposed Mutonga and Grand Falls dam sites, which were constructed by the storage function model applying the aforesaid procedures, are shown in Figures 3.2.9 and 3.2.10. The estimated hydrographs of the Mutonga and Grand

Falls dam sites with the upstream reservoirs are shown in Figure 3.2.9, and those without the upstream reservoirs in Figure 3.2.10. The peak flood discharges at the proposed Mutonga and Grand Falls dam sites were estimated for various return periods in each of the two cases above as summarized below:

(Unit: m^3/sec)

Return Period (in years)	Case-1: Without Masinga and Kiambere Reservoirs		Case-2: With Masinga and Kiambere Reservoirs	
	Mutonga Dam	Grand Falls Dam	Mutonga Dam	Grand Falls Dam
50	2,400	2,800	1,600	2,000
200	4,000	4,500	2,600	3,100
10,000	10,900	12,800	8,900	10,800

The 50-year and 200-year probable floods estimated by the Storage Function Model on the condition without the upstream reservoirs are comparable to those transposed from SGS 4ED3 with the Creager's C values. Besides, the 10,000-year probable flood estimated by the storage function model has a sufficient allowance in comparison with that transported from SGS 4ED3.

3.2.3 Sediment Load

(1) General

Most of the sloped lands in the Tana river basin are subject to erosion of surface soils. It is foreseen that high sediment transport occurs in the high mountainous areas around Mt. Kenya where high annual rainfall of more than 1,500 mm/year takes place. In the moderately sloped areas, the lands are utilized for cultivation of paddy and other place. Besides, new irrigation projects are planned to be developed in the upper Tana basins. The irrigated paddy fields would reduce the intrusion of eroded materials into the river. On the other hand, the sediment transport rate will increase with development of lands in the catchment. Therefore, a sedimentation study needs to be carried out taking into consideration the increase of erosion rate attributed to the expansion of land use in the future.

Since the Mutonga/Grand Falls hydropower project is planned to be developed as a reservoir type project, the sedimentation study aims ultimately at determining the sediment volume transported into the planned reservoirs and its deposiion rate therein. The sedimentation study was made primary based on the results of the suspended load measurements. The water sampling for the suspended load analysis was carried out at 6 locations, the downstream point of Kindaruma, the downstream point of Kiambere, SGS (stream gauging station) 4EA7 on the Mutonga river, SGS 4F19 on the Kathita river, SGS 4F13 at the Grand Falls dam site, and SGS 4G1 in Garissa city. The data of sediment load were also provided by MOWD. Those suspended load data were incorporated in analyzing the sediment yield at the proposed dam sites.

(2) Suspended Load Yield

The sediment load is broadly divided into suspended and bed loads. Usually, the suspended load contained in stream flow can be quantified by load measurement, while it is not possible to accurately measure the bed load in natural river. In the usual estimate, the rate of bed load transport is assumed to be equivalent to 10 to 20% to the suspended load. Aiming at making its estimate conservative, the radio of 20% was adopted for the Mutonga/Grand Falls project. The unit weight of sediment load was assumed at 1.4 ton/m^3.

On the basis of the results of suspended load measurement, the average and adopted rating curves of suspended load at the Kiambere dam downstream point, SGS 4EA7, SGS 4F19 and SGS 4F13 were plotted on a log-log axis as shown in Figures 3.2.11 to 3.2.14. The average rating curves are constructed by using all measured suspended load data. The adopted rating curves are established by discarding uncertain data deviated largely from the average curve as well as to make the conservative estimate of the sediment volume for the safety design of the dam.

The daily river flow series of the Mutonga and Kathita rivers and the simulated daily outflow series from the Kiambere dam were applied to the above equations to estimate the suspended load quantity. The result of the sedimentation study are summarized as follows:

(Unit: Million m^3/year)

Classification	Kiambere	Mutonga	Kathita	Total	4F13 (GF)
Suspended load	0.09	1.32	0.79	2.20	2.00
Bed load	0.00	0.26	0.16	0.42	0.40
Total	0.09	1.58	0.95	2.62	2.40

As seen in the above table, the total sediment load from the Kiambere dam, Mutonga and Kathita rivers was estimated at 2.62 million m^3/year, while the transported sediment load at SGS 4F13 was estimated at 2.40 million m^3/year. These sediment rates are similar to a considerable extent. Consequently, the higher sediment rate of 2.62 million m^3/year was adopted as the design value for the planned dams in order to secure the reservoir life more conservatively.

(3) Sediment Deposition in the Proposed Reservoirs

In the stage of detailed design for the Kiambere hydroelectric development project, a 50-year sediment deposition of 55 million m^3 was adopted in planning the reservoir. On the other hand, the design code in Japan specifies that the reservoir life is taken at 100 years, unless the facilities for flushing sediments deposited in the reservoir are provided in the dam body or its appurtenant structures. In this study, the sediment deposition volume in the planned reservoirs was estimated adopting the reservoir life of 50 years in the case that the sand flushing facilities be provided. The sediment trapping efficiency of the proposed reservoirs was determined based on the emperical Bruneis curve as shown below:

Reservoir	Sediment Trapping Efficiency
Mutonga reservoir	66 %
Low Grand Falls reservoir	92 %
High Grand Falls reservoir	98 %

Figure 3.2.15 presents the sediment volume of each reservoir which is estimated by using the adopted rating curves of suspended load, daily river flow series of the Tana river and sediment trapping efficiency of each reservoir.

The estimated sediment volumes of the Mutonga, Low Grand Falls and High Grand Falls reservoirs are summarized as follows:

Name of Dam	Sediment Inflow (Mill. m^3/yr	Trap Efficiency (%)	Sediment Deposition			Sediment Outflow (Mill. m^3/yr)
			Annual Sediment (Mill. m^3/yr)	For 50-year Life (Mill. m^3)	Sediment Level (El m)	
Mutonga dam	1.67	66	1.10	55	540.35	0.57
Low Grand Falls dam	1.52	92	1.40	70	477.79	0.12
High Grand Falls dam	2.62	98	2.57	128	482.53	0.05

3.3 Geology

3.3.1 Geology in the Region

The Tana river basin can be divided into three distinct physiographic units from west to east, the eastern slopes of Aberdare Range and the southern - eastern slopes of Mt. Kenya, the Kenya Basement System terrain (peneplain) and Tertiary - Quaternary sediments area.

The eastern slopes of Aberdare Range and the southern - eastern slopes of Mt. Kenya are formed by the volcanic formations which overlie the basement complex formations (Kenya Basement System). The volcanic formations are composed of basalt, phonolite, agglomerate, tuff, etc., originates from Mt. Kenya and the Aberdare Range.

The volcanic activity (eruption) of Mt. Kenya is estimated to be in the late Tertiary (Miocene-Pliocene) to early Quaternary (Pleistocene) age, and no evidence of volcanic activity is found in the Recent (Holocene).

The middle reach of the Tana river runs on the Kenya Basement System terrain which is composed mainly of high-grade gneisses of the Kenya Basement System of Archaean age. Several types of intrusive rock (mainly granite) are found in the gneisses.

The lower reach of the Tana river flows on the rather flat plain formed by the sedimentary rocks or sediment layers of Tertiary to Quaternary age. The river forms the flood plains along the course which comprises river levee land and river basin land. The river levee land lies just above the normal flood level and is generally flat. The river basin land is seen in the outside of the levees, is periodically flooded. The Tana river forms the delta (recent deposits) at the outlet to the Indian ocean. In the delta, the Tana river has periodically changed its course. Figure 3.3.1 presents the geology in Kenya.

3.3.2 Geology in the Reserviors

The reservoir areas of the Mutonga and Grand falls dams are located in the middle reach of the Tana river. The geology of both reservoir areas is composed of high-grade gneisses of the Kenya Basement System of Archaean age. The gneisses (metamorphic rocks) show a wide variety of rock facises in the area, reflecting the varied nature of the original sediments from which the gneisses were derived. They range from granitic gneiss through semi-pelitic banded gneiss to biotite-rich pelitic-mafic, semi-felsitic and hornblende plagioclase gneisses.

There are two prominent ridges (monadnock); (a) Kijege forest - Kierera forest (N-S direction) and (b) Gikingo forest - Mutejwa forest - Kamuwongu - Kiuga - Mumoni forest (NNE-SSW direction), formed by mainly granitic gneiss which have rather higher resistance to weathering than the other gneisses. The Tana river runs in the area between those two ridges from south to north until Grand Falls. In the downstream from the Grand Falls, the river course changes toward the east and cuts the later ridge (b). The area between two ridges is formed mainly by semi-pelitic banded gneiss, biotite rich pelitic - mafic gneiss, etc. poorly resistant to weathering as shown in Figure 3.3.2.

The river courses of the Tana river and other tributaries are generally adapted by the slopes of Mt. Kenya and structures of the Kenya Basement System, mainly strike of the gneisses formation which shows between north - south and northeast - southwest direction over the reservoir areas.

Basalt lava flow, originating from Mt. Kenya, of Tertiary or even younger age, develops on a long narrow ridge about 1.5 km north of the Mutonga damsite. The lava flow is found more than about 130 m above river level and no other outcrops can be seen at lower elevation.

Overburden in the reservoir areas consists of a thin covering of residual soil which is mainly sandy gravels, silty sand, silty clay and clayey silt. Sandy deposits are seen in some seasonal rivers, such as Kalange, Kamura, Konyu, etc.

No noticeable fault structures are found in the reservoir areas.

3.3.3 Geology in the Project Areas

(1) Mutonga Dam Site

Dam Site

The Mutonga dam site is located approximately 37 km downstream from the Kiambere dam site. The geology consists of gneisses of the Kenya Basement System and some granitic intrusions.

The dam type will be zoned type rock fill dam or concrete gravity dam.

Overburden consists of a thin covering of residual soil and alluvial deposits. Alluvial deposits exist along the banks of the Tana river and in the river beds of some of the seasonal rivers surrounding the dam site area.

Bedrock belong to the Archaean Kenya Basement System consists of mafic - semi-felsitic and granitic gneisses which have been intruded by small contemporary bodies of granite and pegmatite. The mafic gneiss is the dominant rock type in the area. Generally the mafic gneiss is more highly weathered and weaker than the semi-felsitic gneiss and granitic gneiss. Results from the drilling investigation, the bedrock is typically weathered to a depth of several meters to 15 m in maximum approximately.

The gneisses have a foliation of N20-40°E/60-80°NW in general. Major joint structures also are of a generally similar direction and dip of the foliation. No major fault structures were identified in the dam site area.

The right and left river bank slopes for about a 10m height from the river level are very steep, 40 - 60 degrees in general. The upper half of the left bank slope is rather gentle, 20 - 30 degrees, where gneisses (highly to moderately weathered) are rarely outcropped. The right bank is formed by gently sloped hills with fewer outcrops of rocks than that in the left bank. Moderately - slightly weathered to fresh, and hard gneisses are seen along both banks in the Tana river channel. River bed deposit is distributed in the right bank narrowly, seems to be rather thin, several meters in maximum thickness.

The seismic survey was performed for the newly selected dam axes in 1995. The surface depth of the zones which have seismic velocity of more than 2.8-3.0 km/sec (CM-CH-B class rocks) on the dam axis is 10 to 12 m at the left abutment and 10 to 13 m at the right abutment. While the zones below the above depth show very low permeability, the foundation treatment is required for the dam foundation.

The geological map is shown in Figure 3.3.3 and the geological profile along the dam axis is shown in Figure 3.3.4. As a result of the geological investigations, both rockfill type dam and concrete gravity dam can be constructed at the proposed dam site.

Spillway

The spillway will be located at the left bank behind the left abutment hill of the dam site in the case of the rockfill dam. The foundation rock will be mafic gneiss and some granite intrusions which are in appropriate condition as the spillway foundation. The area has no thick overburden layer. According to three investigation bore hores and seismic survey, weathering shows very deep, 14.35 to 19.00m in this area. For the construction of the spillway weir of the rockfill dam, such deep excavation will be required. The foundation treatments of curtain grouting and consolidation grouting will be required for the construction of the spillway weir.

Diversion tunnel

The diversion tunnel can be located to be in the both banks. The tunnel length will be about 600m. Rocks along the expected tunnel route will be mainly mafic gneiss with good quality in general in both banks. No major fault structure was observed in those areas. Highly to moderately weathered zones exist at the inlet and outlet portions in which rather dense tunnel support works will be required. The seismic survey results show that the diversion tunnel route will be mostly in the area where the rocks show the seismic velocity of more than 3 km/sec and the rock classification of CM-CH-B.

Power house and intake structure

Both banks of the Tana river will be geologically appropriate for the construction of the power house in the case of the rockfill dam type. As the power house location will be close to the river, it is anticipated that the thickness of highly weathered rocks will be thin and the excavation will be in good quality rocks in general.

An intake tunnel with the length of 300-500m will be required from the dam reservoir to the power house in the case of the rockfill dam. More tunnel support works will be required comparing to the diversion tunnel, because the tunnel will penetrate through shallow rock zones which have more weathering than that in the deeper zones.

(2) Grand Falls Dam Site

Dam Site

The Grand Falls dam site is located about 25 km downstream from the Mutonga dam site. The proposed dam will be a zoned type rock fill dam, and a combine type dam of a rock fill dam (right bank section) and a concrete gravity dam (river channel section). Three alternative dam axes A-D-B (upstream), C-D-B (midstream) and E-F-G (downstream), were selected as shown in Figure 3.3.5 together with the geological condition. Geological profile along dam axis E-F-G is show in Figure 3.3.6.

The overburden in the dam site area consists of mainly residual soil which is a generally thin layer of 1-2m thick. Alluvial deposits are found in relatively small quantities narrowly along the Tana river and the river beds of small seasonal rivers in the surrounding area of the damsite.

Bedrock is Archaean metamorphic gneisses of the Kenyan Basement System. Some intrusions of granitic rock are seen in the gneisses. The main rock types are mafic gneiss which has generally good foliation. Granitic gneiss and semi-felsitic gneiss are also seen in some places. Granitic gneiss is less foliated than the mafic gneiss.

The bedrock is generally deeply weathered. The mafic gneisses tends to be the most highly weathered compared with the granitic gneiss and semi-felsitic gneiss. The results of the drilling investigation, the bedrock is typically weathered to a depth of several meters to 18m in maximum approximately. Ridge topography and hills are generally formed by granitic gneiss or semi-felsic gneiss, and rather flat/wide and gentle slope are formed by mafic gneiss.

Foliation of the gneisses shows strike of consistently north-northeast/south-southwest and dip generally steeply to the west-northwest. Major joint structures also are generally in a similar strike and dip of the foliation. Other joint structures are the strike of west-east and almost vertical dip, show direction similar to the Tana river flow, can be observed on the outcrops distributed along both banks of the Tana river. No major fault structures were identified in the damsite area.

The upper half of the left bank slope is rather steep, 20-30 degrees, where gneisses (highly to moderately weathered) are well outcropped. Moderately to slightly weathered gneisses are seen along both banks in the river channel. River bed deposit seems to be rather thin, several meters in maximum thickness. The right bank is formed by gently sloped hills with less outcrops of rock than that in the left bank.

The depth of slightly weathered rock surface in both abutments observed in the investigation bore holes for each alternative dam axis is estimated as shown in Table 3.3.1. Below the highly to moderately weathered rock, moderately to slightly weathered rocks exist. Moderately to slightly weathered rocks will be appropriate for the foundation of a core zone of rock fill type dam and for the foundation of a concrete gravity dam. According to the investigation results, 3 to 9 meters excavation for the left abutment, and 5 to 15 meters or more excavation in the right abutment will be required. The excavation depth in the river channel is estimated to be 2 - 5m in general.

Seismic survey was performed for the alternative dam axes in 1995. The depth of the zones which have seismic velocity of more than 2.8-3.0 km/sec (CM-CH-B class rocks) for each alternative dam axis is shown in Table 3.3.2. Some low velocity zones are found in the seismic survey results in the geological profiles. These may suggest the existence of fault structures which have some fractured zones. However, the fractured zones of these fault structures observed in the field and in the drilling core samples show mostly re-consolidated and hard/in good condition, without any thick clayey zones, in general, while they have more joints and are sometimes more friable than the normal rock.

According to the results of laboratory tests on rock core samples carried out in the Mutonga dam site (1979), the compressive strength of gneisses is 650 - 1,000 kgf/cm^2. The rocks in the Mutonga dam site are also mainly the same type of gneisses in the same formations of the Kenyan Basement System as the rock in the Grand Falls damsite. It can be said that the foundation rock of the dam site are medium to hard rock, and the rock properties of those in moderately - slightly weathered to fresh condition (CM-CH-B) will be appropriate as the foundation of high dam, both of fill type and concrete gravity type.

As the result of the permeability tests, high pervious rock, more than 10 Lugeon or coefficient of permeability of more than 1.0×10^{-4} cm/sec, is seen in the zones of depth shown in Table 3.3.3 in both abutments for each alternative dam axis. The zones below the above depth, show very low permeability, almost impermeable. The foundation treatment (curtain grouting) will be required at least for the above depth.

Diversion tunnel

The diversion tunnel will be in the left bank near the bore hole No. G95-3 and G95-7, or in the right bank near the bore hole No. 94-2 and G95-10. The zone from the ground surface to the depth of about 3 to 7m is formed by residual soil and moderately to highly weathered rocks.

In the left bank, the tunnel depth (ceiling) will be about 20 to 30m, which means that more than 10 m of moderately to slightly weathered rock covers the tunnel in the section near the bore hole No. G95-7. A seismic survey results show that the zone which have seismic velocity of more than 2.8 km/sec (CM-CH-B class rocks) exist in very deep, more than 15 - 30m deep in the right bank, while it is 10 - 20m deep in the left bank. From the geological point of view, the left bank condition will be more preferable than the right bank for the diversion tunnel construction.

Spillway

The spillway for the rock fill type dam will be in the left bank, the north side of the dam. The depth of moderately to slightly weathered rock surface in the bore holes located in the left abutment is estimated to be 1.5 m to 9.0 m. Below the above depth, the rock is moderately to slightly weathered or fresh, which will be appropriate as the spillway foundation.

Power house and intake structures

Both banks of the Tana river will be geologically acceptable for the construction of the power house for the fill type dam, while some deep open excavation will be required. As the power house location will be close to the river, it is anticipated that the thickness of highly weathered rock will be thin and the excavation will be in good quality rock in general.

For the fill type dam, an waterway tunnel with a length of 300-500m will be required from the dam reservoir to the power house. If the tunnel is designed at the elevation above diversion tunnel, more tunnel support work will be required, comparing to the diversion tunnel, because the tunnel will penetrate through shallow rock zones which have more weathering than that in the deeper zones. Deeper tunnel may be recommendable.

3.3.4 Seismicity and Seismic Risk

(1) Seismic Coefficient for Dam Design

The design seismicity for the dams of the Mutonga/Grand falls Project is reviewed through estimation of the probable maximum accelerations in the return periods of 100 years and 200 years (Cornell's method), and estimation of maximum credible earthquake, based on the earthquake record of the years from 1906 to 1994 for the area within a distance of 500 km from the Grand Falls damsite. The earthquake record has been obtained from the British Geological Survey, Edinburgh, U.K.

The results of Cornell's method indicate that a design seismic coefficient of 0.01g for the return period of 100years and/or 0.03g for the return period of 200 years can be applied to this project. The maximum credible earthquake indicates that 0.023g to 0.070g can be applied to this project.

According to Loupekin (1971), the project area is located in the seismic zone of V which is the lowest seismic zone in Kenya. The Kiambere dam is located in the upstream of the Mutonga damsite, in the border area of seismic zones VI and V. A value of k = 0.12g is adopted for the Kiambere project as a seismic coefficient to occur once in 100 years. Lower seismic coefficient for this project than that of Kiambere dam can be applied considering these locations in the seismic zone map.

Taking these conditions into consideration, the design seismic coefficient of 0.10g for the design in the Mutonga/Grand Falls project is deemed reasonably conservative.

(2) Reservoir Induced Seismicity (RIS)

Some examples show that earthquakes occurred during initial impounding of reservoirs deeper than 100 metres, such as Koyna dam in India, Hoover dam in USA, etc., with Magnitude ranging from 5.0 to 6.5.

The 130 m high High Grand Falls dam produces a reservoir of more than 100 m in depth, and may induce earthquakes in initial impounding of the reservoir.

The dam site is located in a lowest seismicity zone of Kenya with no previous earthquake epicenter nearby. Reservoir-induced earthquakes, however, can occur even in regions of relatively low historical seismicity.

In the seismically active rift valley zone to the west, a major part (67%) of influential earthquakes falls under Magnitude 4. Magnitude 6 virtually represents the strongest earthquakes with proportion of 5 percent, with exceptions of one Magnitude 9 and three Magnitude 7's. Magnitude 5 with a proportion of 22%, the second group to the strongest, is deemed appropriate to assume for the reservoir-induced earthquake in the low seismicity zone.

Assuming that an earthquake of Magnitude 5 is generated at the distance of 3 km from the dam site and at the depth of 10 km, peak acceleration felt at the dam site is estimated at 215 gal, by formula of Cornell. The peak acceleration will work only for a fraction of a second and will not effect any practical damage on the dam body. Effective is the acceleration of lower level, e.g. one third of the peak, that endures longer time. Earthquake with the peak acceleration of 215 gal, therefore, will not damage the dam with design acceleration of 0.10g.

Reservoir of the Mutonga/Low Grand Falls dam will be 70 to 80 metres at the maximum depth. Strength and frequency of reservoir-induced earthquakes there, if any, will be not more than those at the High Grand Falls dam site.

No problem is envisaged on the reservoir-induced earthquake, that can be well covered with the design acceleration of 0.10g.

3.4 Construction Materials

3.4.1 Introduction

Construction materials for rockfill dam and concrete dam will be obtained from the borrow areas and quarry sites in the project area.

In 1979/1980, a material investigation at pre-feasibility study level was carried out by the British consulting firm, Engineering and Power Development Consultants (EPDC), as part of their work on the Kiambere Feasibility Study, and some additional investigation was done in 1986/1987 by UNDP/World Bank. In 1994/1995, a construction material investigation was carried out to grasp the availability and suitability of rockfill materials for rockfill dam and concrete aggregates for the concrete dam and relevant concrete structures.

There are a lot of the river bed deposits in the seasonal rivers which flow mostly from the right bank of the Tana river. Residual soil originated gneiss and granitic mother rock which show appropriate quality as impervious core materials in the previous study, exist widely on both banks of the Tana river. Rock quarries are located near both the Mutonga and the Low Grand Falls dam sites. Gneiss and granitic rock which have sufficient quality are available as rock materials for the rockfill dam and concrete aggregates.

The locations of borrow areas and quarry sites for the Mutonga dam and the Grand Falls dam are shown in Figures 3.4.1 and 3.4.2.

3.4.2 Mutonga Project

(1) Rockfill Materials

Rockfill dam and concrete dam are conceived as alternative dam types of the Mutonga project. In the case of rockfill dam, the required quantities for construction are estimated to be 171,000 m^3 for impervious core material, 81,500 m^3 for filter and drain materials, 49,200 m^3 for inner shell (weathered rock material), and 508,000 m^3 for outer shell (fresh rock material).

Three borrow areas for impervious core material (MC-1 to MC-3), five borrow areas of river bed deposit (MS-1 to MS-10) in the tributaries of the Tana river, and one quarry site for filter, rock materials and concrete aggregates were located within 5 km from the proposed dam site as shown in Figure 3.4.1.

Core Materials

The available quantities of core materials are estimated at 18,500 m^3 at MC-1, 96,000 m^3 at MC-2 and 152,000 m^3 at MC-3, totaling 266,500 m^3. The residual soils at the three borrow areas have an appropriate quality as impervious core materials. However, the thickness is thin in general. This was also pointed out in the investigation reports of EPDC (1980) and UN/World Bank (1987). According to the result of permeability tests of the compacted samples under the optimum moisture content and at 98 % maximum dry density, core materials obtained from MC-1 to MC-3 have very low permeability of less than 10^{-5} cm/sec which assures sufficient water tightness of the core zone. The triaxial test also revealed that those materials have an internal friction angle of 28.5 to 33.5 degree (average 30.7 degrees) and cohesion of 1.0 t/m^2 on average.

Filter and Drain Materials

River bed deposits of sand with some gravel and boulders are available in the borrow areas MS-1 to MS-10 in the four seasonable rivers on the right bank of the Tana river as shown in Figure 3.4.1. From the result of 10 samplings at the borrow areas for filter materials, it is considered that sand and gravel materials are available with a sufficient quantity of about 150,000 m^3 satisfying the standard requirement of filter materials. It is noted that a coarser filter as transition zone composed of quarry rock should be provided between the filter zone and the rock zone.

Rocks Materials

Excavated materials of the weathered and fresh granite intrusion, granite gneiss, mafic and semi-felsic gneisses in the spillway, diversion tunnel, and dam foundation around the dam site can be used as the rock materials for the rockfill dam. Weathered rocks from these excavations could be used for the inner shell of zoned rockfill. Fresh rocks obtained from the tunnel and spillway excavations which are estimated to be more than 1,000,000 m^3, could be used for the outer shell as well as for concrete aggregates.

Drilling investigation was carried out on the small hill located about 1 km south of the dam site for the purpose of finalizing a reserve quarry and for quality check. According to the results of drilling investigation and laboratory test including specific gravity, absorption test and durability test, fresh rocks have enough soundness for use in any rockfill zones.

(2) Concrete Aggregates

Fine aggregate

The required volume of fine aggregates is estimated at some 130,000 m^3 in the case of the concrete gravity dam. River deposits (MS-1 to MS-10) distributed in the seasonal rivers will be usable as concrete fine aggregates. Coarse aggregates in natural river sand have a diameter of more than 10 mm as shown in Figure 3.4.3. After screening of coarse particles, the gradation curve is within the allowable gradation limit. The laboratory tests revealed that river deposits satisfy the quality of requirements including gradation, specific gravity, absorption, soundness and strength for concrete aggregates. An alkali chemical test indicated that the sand material is innocuous as shown in Figure 3.4.4.

Coarse aggregate

The required volume of coarse aggregate will be about 290,000 m^3 for the concrete dam and related structures. There is no noticeable distribution of gravel deposits near the project area. Gravel is found only in the seasonal rivers. The quantity available in these deposits does not seem sufficient. Coarse aggregates can be produced by a crushing plant from the material obtained from quarry sites. This material has physical and chemical soundness suitable for use as concrete aggregates.

3.4.3 Grand Falls Project

(1) Rockfill Materials

Rockfill dam, concrete facing dam, combined dam with rockfill and concrete dam, and concrete gravity dam are considered as alternative dam types for the Grand Falls dam. In the case of rockfill dam, the required quantities of construction materials for the low and high dam schemes are estimated as follows:

Material	Required quantity (m^3)	
	Low Dam	High Dam
Impervious core material	860,000	2,900,000
Filter and drain material	373,000	1,180,000
Inner shell (weathered rock material)	292,000	650,000
Outer shell (fresh rock material)	3,850,000	17,400,000

In the case of combined dam, core material of 430,000 m^3, filter and drain of 190,000 m^3, and rock material of 2,130,000 m^3 at maximum will be required for the rockfill dam. In addition, the concrete facing dam will need filter of 96,000 m^3, and rock material of 4,800,000 m^3. Based on the results of field reconnaissance and review of the previous study, four borrow areas for impervious material (GC-1 to GC-4), two borrow areas of river bed deposit (GS-1 and GS-2), and one quarry site for the filter, rock materials and concrete aggregates were found within 10 km from the proposed dam site as shown in Figure 3.4.2.

Impervious core material

Residual soils also develop widely in the upstream area near the proposed dam site. Four borrow areas which are conceived as possible borrow areas for core materials are located upstream of the proposed dam site. The available quantities of materials are estimated at 1,350,000 m^3 at GC-1, 1,000,000 m^3 at GC-2, 480,000 m^3 at GC-3 and 800,000 m^3 at GC-4, totaling 3,630,000 m^3. The only drawback of the above borrows is the exploitable thin layer up to the impervious core, which is only 1.0 m or more mostly. Accordingly, the borrow areas shall be selected inside the area to be submerged by reservoir to avoid environment and scenery problem.

A material survey was carried out through a total of 62 test pits and 30 auger borings in the selected 4 borrow areas in this stage in 1994/1995. The results of laboratory test revealed that the residual soil materials in Borrow GC-1 to GC-4, are suitable for the impervious core, which have sufficient shear strength and trafficability, good deformation properties and low permeability after compaction. The core materials have a very low permeability of less than 10^{-5} cm/sec, and an internal friction angle of 26.5 to 35.0 degree (average 30.8 degrees) and a cohesion of 0.5 t/m^2 on average.

Filter and drain materials

River bed deposits of sand with some gravel and boulders, are available in GS-1 and GS-2 along the two seasonable rivers of Ngoru and the Karange within an economical distance from the dam site as shown in Figure 3.4.2. The available quantities in GS-1 and GS-2 are estimated to be 330,000 m^3 or more each.

The gradation curves of river deposits in GS-1 and GS-2 are shown in Figure 3.4.5. Comparing with the gradations of core material from GC-1 to GC-4, the sand and gravel materials from GS-1 and GS-2 satisfy the standard criteria for filter material. In addition, judging from the test results of specific gravity, absorption test and sodium sulphate soundness test, it is considered that all sand and gravel from borrow areas GS-1 and GS-2 can be used as filter material with sufficient safety against the core material.

Rock materials

Weathered and fresh rocks can be obtained from the various open and tunnel excavations required for the dam and related structures. In addition to those, rock quarry for the outer shell or coarse aggregate for concrete will be required. The Tiamber and Kamuwongu hills located on the right bank of the Tana river are formed by mainly granitic gneisses which have suitable quality as the rock materials. The borehole GQ95-1 was drilled at the top of the small hill near the right abutment of the dam. In the borehole GQ95-1, rocks are granitic gneiss and semi-felsic gneiss. The rock condition shows that it is suitable for use as rock material. The available quantity in this hill is estimated to be 6,000,000 m^3 or more.

The laboratory tests of rock from GQ95-1 and G95-8 and G95-10 at the dam site revealed that fresh rock obtained on the right abutment of the dam has a sufficient strength, and specific gravity, soundness and durability as rockfill material. The weathered rock materials produced from the dam and spillway excavation can be used for the iner shell zone or transition zone.

(2) Concrete Aggregates

Fine aggregates

In the case of the combined dam, fine aggregates of 320,000 m^3 will be required for the concrete gravity dam and related structures. River deposits for dam filter material distributed in the Ngoru and Karange rivers (GS-1 and GS-2) will be also utilized as fine aggregates. Figure 3.4.5 shows that natural river sand contains coarse aggregates with a diameter of more than 10 mm. Screening of coarser particles will improve the gradation of which fine aggregates range in the allowable gradation band. Laboratory tests of river deposits revealed that physical and chemical properties of specific gravity, absorption and durability are all within the allowable range. Alkali chemical test also indicated that the sand material is innocuous as shown in Figure 3.4.6.

Coarse aggregates

Some 750,000 m^3 of coarse aggregates will be required for the concrete dam. There is no distribution of gravel deposits near the project area. Gravel is found only in the seasonal rivers. The available quantity in these deposits does not meet the required quantity. Accordingly, coarse aggregates will be produced by a crushing plant from the material obtained from quarry sites. This material has physical and chemical soundness suitable for use as concrete aggregates.