REPUBLIC OF KENYA

MINISTRY OF ENERGY AND REGIONAL DEVELOPMENT

NATIONAL IRRIGATION BOARD

FEASIBILITY STUDY

ON

THE MWEA IRRIGATION DEVELOPMENT PROJECT

MAIN REPORT

MARCH 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of Kenya, the Government of Japan decided to conduct the Feasibility Study on the Mwea Irrigation Development Project and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA dispatched to Kenya a Study Team headed by Mr. Tadashi SAKAMOTO, Nippon Koei Co., Ltd., from January to March (Phase I) and July to September (Phase II), 1987.

The Team exchanged views with the officials concerned of the Government of the Republic of Kenya and conducted a field survey in close cooperation with the Kenyan Officials concerned. After the Team returned to Japan, further studies were made and the present report has been prepared.

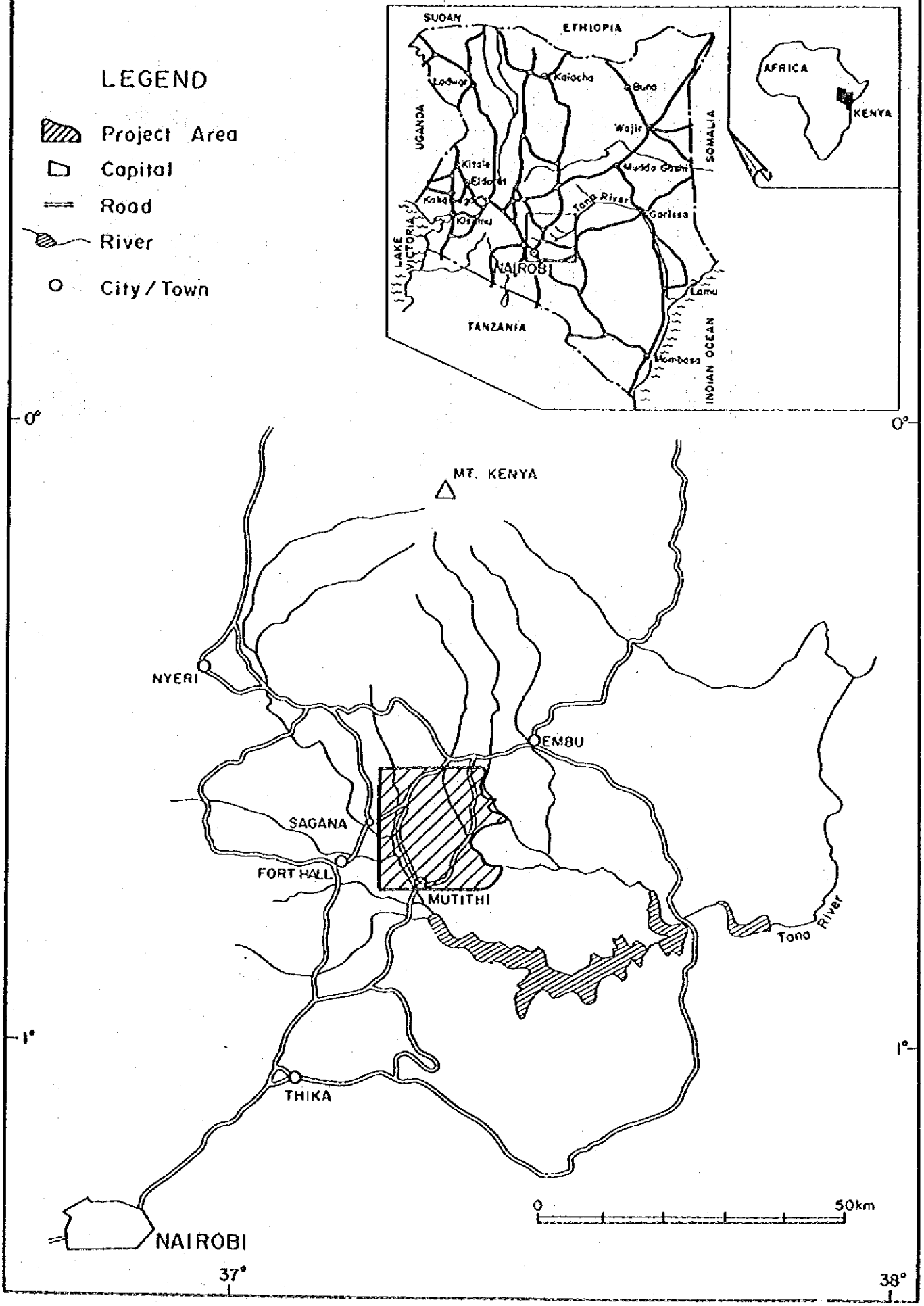
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between two countries.

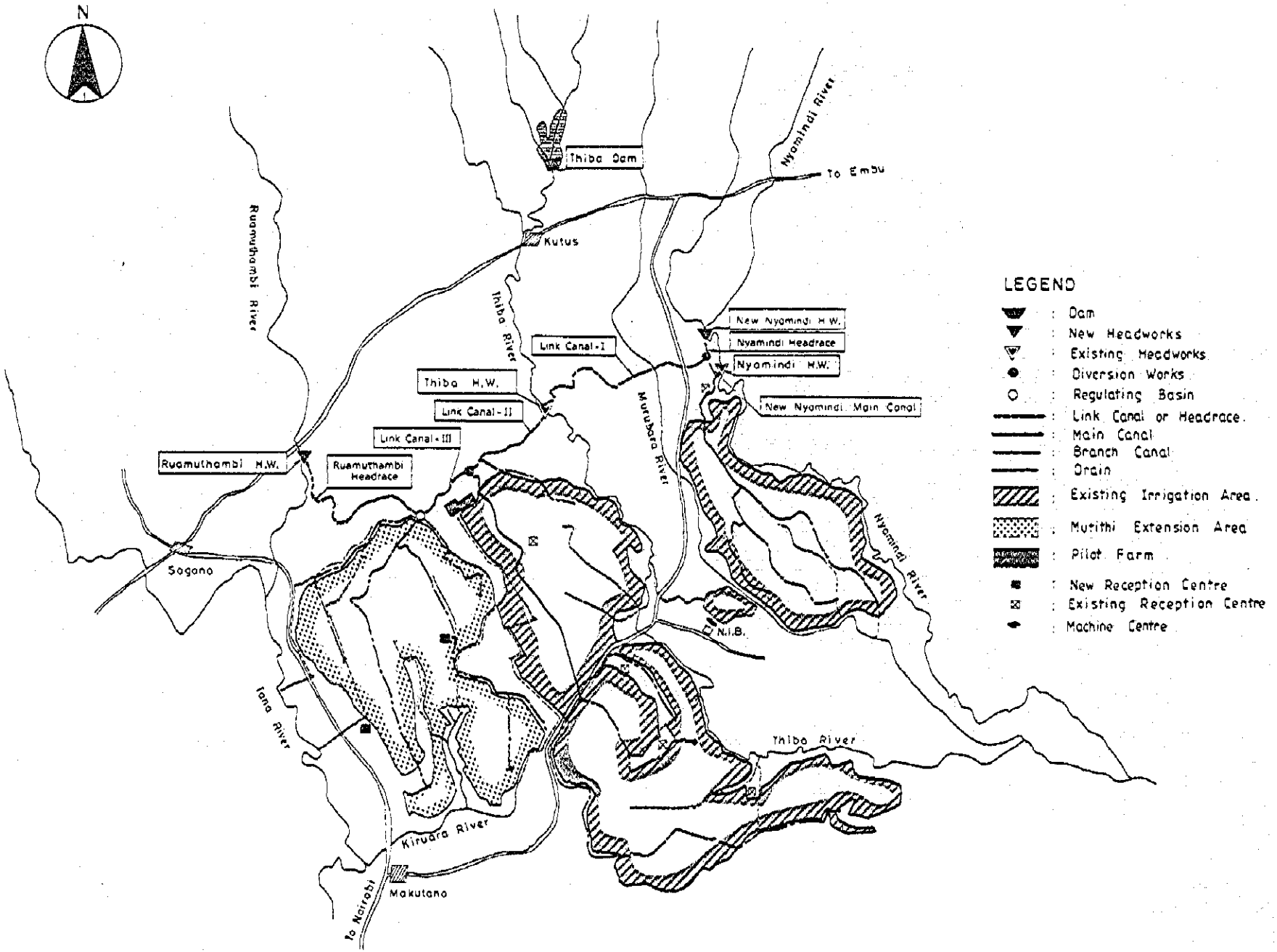
I wish to express my deep appreciation to the officials concerned of the Government of the Republic of Kenya for their close cooperation extended to the Team.

March 1988

Kensuke YANAGIYA
President
Japan International Cooperation Agency

LOCATION MAP





GENERAL PLAN OF THE PROJECT

BASIC DATA OF KENYA

Area (1,000 km²) /1	Land Area	Water Area	Total Area
Coast Province	83	1	84
North-Eastern Province	127	-	127
Eastern Province	156	4	160
Central Province	13	0	13
Site Valley Province	171	3	174
Nyanza Province	12	4	16
Western Province	8	0	9
Nairobi Area (municipality)	1	0	1
Total	571	12	583

Macroeconomic Indicators		1982	1983	1984	1985	1986
GDP at factor constant /1	(K£ million)	2,945	3,311	3,627	4,187	4,833
Real GDP growth /1	%	2.4	3.1	0.9	4.1	5.7
Consumer price inflation /1	%	20.5	14.5	9.1	10.7	5.7
Population /1	(million)	18.0	18.0	19.5	20.2	21.0
Exports fob /1 (Excluding Re-exports)	(K£ million)	546	633	755	785	958
Imports cif /1	(K£ million)	900	906	1,097	1,196	1,338
Current account /1	(K£ million)	-261	-89	-147	-169	-
Exchange rate /1	(KShs. per $)	10.92	13.31	14.41	16.4	16.2

Loans Raised (million K£) /1	1984/85	1985/86
Bilateral sources		
Canada	53.0	10.1
West Germany	9.8	1.2
United Kingdom	3.1	3.1
USA	2.1	1.9
Japan	0.6	1.3
Total (including others)	158.4	89.2
Multilateral source		
International Development Association	15.7	33.1
IBRD	17.0	8.9
African Development Bank	3.0	2.8
Total	35.7	44.8
Grand Total (including others)	247.2	185.3

Principal Exports (million K£) /1	1985	1986*
Coffee	231	388
Tea	192	173
Petroleum products	116	99
Total (including others)	785	958

Principal Imports (million K£) /1	1985	1986*
Fuel and lubricants	376	239
Industry supply (Non-food)	353	408
Machinery	180	254
Total (including others)	1,196	1,338

Origins of GDP /1 (% of total)	1985	1986
Agriculture, forestry & fishing	31.8	31.8
Mining & quarrying	0.3	0.3
Manufacturing	13.3	12.8
Electricity & water	1.5	1.4
Building & construction	4.1	4.1
Trade, restairamts & hotel	12.9	14.0
Transport, storage & communication	6.9	6.8
Government services	15.9	16.8
Others, net	13.3	12.0
GDP at factor cost	100.0	100.0

Main Destination of Exports (%) /1	1985	1986
United Kingdom	17	14
West Germany	12	14
Uganda	9	7
Netherland	7	9
U.S.A.	7	9
Japan	1	1

Main Origin of Imports (%) /1	1985	1986*
United Arab Emirates	19	8
United Kingdom	14	16
Japan	10	11
West Germany	8	11
U.S.A.	6	5

Remarks) /1: Economic survey 1987
/2: Statistical Abstract 1986
/3: Country Report 1982 published by EIU

SUMMARY

INTRODUCTION

01 This is the Feasibility Study Report on the Mwea Irrigation Development Project (hereinafter referred to as "the Project"). The report presents the comprehensive results of the feasibility study on the Project which was executed by the Japan International Cooperation Agency (JICA) in close cooperation with the National Irrigation Board (NIB) since January 1987.

02 The "Scope of Work" was concluded between JICA and NIB on November 13, 1985. It gives the framework of the "Feasibility Study on the Project" (hereinafter referred to as "Study") and defines the Study Area and the objectives of the Study as follows:

Study Area: The Project, situated near Embu, in the Central Province of Kenya, covers a gross Study Area of 16,000 ha which comprises (1) the existing Mwea Irrigation Settlement Scheme area of 12,000 ha (hereinafter referred to as "MIS") and (2) the Mutithi extension area of 4,000 ha.

Objectives of the Study: To formulate the irrigation development plan comprising the following major project components and assess the technical soundness and economic viability of the Project; (1) rehabilitation and improvement of the existing MIS irrigated paddy fields covering 6,000 ha, (2) irrigation development of the red soils in the MIS Scheme area, and (3) irrigation development of the Mutithi extension area of 4,000 ha.

03 The Feasibility Study was commenced in January 1987 and the following reports were submitted to NIB:

(1) Inception Report No. 1, January 1987
(2) Field Report, March 1987
(3) Inception Report No. 2, June 1987
(4) Interim Report, September 1987
(5) Draft Final Report, November 1987

This report (Final Report) has been prepared on the basis of the outcomes obtained through a series of discussions with NIB on these reports.

BACKGROUND

04 The Government's long-term strategies are set out in a Sessional Paper No.1 of 1986. It targets a 5.6% annual average growth rate for 1984-2000. The Sessional Paper put the most emphasis on development of rural sectors, as the only means of avoiding foreseeable social problems in the cities by the end of the century. The agricultural sector targets 5.0% annual average growth rate for 1984-2000. The Sessional Paper describes the target is to be attained through improved productivity and selective expansion of high value crops. It also states that the country will strive to reduce the import gap in three commodities that Kenya imports to meet her national demands; wheat, vegetable oils and rice.

05 The total population of Kenya as of 1985 is estimated to be 20.6 million. The population growth rate is 3.8% per annum. Future population is projected for the year 2000 to be 38.5 million.

Over past two decades, the country has been able to rely on the agricultural sector for the majority of her basic food requirements in most of the years. In recent years, serious food problems have emerged. The rapid expansion of population and unstable production of basic foodstuff are now beginning to expose a potentially dangerous imbalance between national supply and demand for foods. Under such situations the Government of Kenya has formulated the Fifth National Development Plan (1984-1988) which has given the highest priority to agricultural sector with emphasis on attaining self-sufficiency in food supply.

06 Kenyan agricultural production largely fluctuates year by year, mainly due to the present agricultural condition characterized by rainfed cultivation and an extreme yearly variations in rainfall pattern. In the country, only 36,000 ha or less than 2% of the total farmland are put under irrigation.

07 The Ministry of Water Development has identified that there exists an irrigation potential of 540,000 ha over the country. The existing irrigation area of 36,000 ha is equivalent to about 7% of the irrigation potential. Irrigated public land, totaling 13,000 ha, is comprised mostly of NIB Schemes (9,500 ha) and various small Schemes (3,100 ha). An additional 23,000 ha of private land are also under irrigation mainly for tea and

coffee. Compared to the existing high- and medium-potential land of an estimated 7.5 million ha, the irrigation potential of 0.54 million ha is rather limited and the existing irrigation area of 36,000 ha is quite insignificant. The Government of Kenya has, in the long run, striven to develop the irrigation potential of the country through innovative improvement of planning and implementation process as well as of operation and maintenance after implementation.

08 The present consumption level of rice is estimated around 6.0 kg in terms of paddy (equivalent to 4.0 kg of milled rice) per capita per annum. The latent national demand for rice is therefore approximately 120,000 tons in terms of paddy. The present paddy production is, on the other, approximately 40,000 tons out of which about 30,000 tons are produced in MIS Scheme. The country makes up for the deficit in rice demand from the donation and/or the commercial import.

09 The Mwea Irrigation Development Project is expected to improve the supply-demand imbalance of rice and also to be a good model for the irrigation development of the remaining potential areas.

PRESENT CONDITION OF STUDY AREA

10 The Study Area is situated approximately 100 km northeast of Nairobi. It extends over the flat land on the outskirts of Mt.Kenya, being situated between 1,100 m and 1,200 m above sea level. The Study Area administratively belongs to Kirinyaga district of the Central province.

11 Major rivers flowing down through the Study Area are Nyamindi, Thiba and Ruamuthambi which are considered as stable water sources for irrigation. Other small streams such as the Kiwe, Murubara and Nyaikungu are partly utilized for minor irrigation water sources and/or natural drains.

12 The climate of the Study Area is tropical with equatorial and medium high altitude characters and is also governed by seasonal monsoons. Rainfall pattern is characterized by bimodal rainy seasons; the long rains season from March to May and the short rains season from October to November. Annual mean rainfall is about 930 mm, out of which 510 mm concentrates in the long rains season and 290 mm in the short rains season.

13 The mean temperature is 22°C over the year with a wide range between mean maximum of 28°C and minimum of 17°C. Mean monthly maximum of 32°C is occurred in March and minimum of 15°C in January. Two periods each of high temperature and low temperature are observed: the high temperature periods are almost fixed from February to April and from September to November, and the low temperature periods are from June to August and December to January. There is a considerable change in temperature between day and night.

14 The Study Area receives high solar radiation, although there is a large seasonal variation ranging from 440 cal/cm^2/day in July to 670 cal/cm^2/day with an annual average of 570 cal/cm^2/day. The annual average evaporation is 6 mm/day. The average evaporation becomes highest (8 mm/day) in February and lowest (5 mm/day) in June. The relative humidity varies from 70% in the morning and 45% in the afternoon throughout the year.

15 The annual mean discharges of the relevant rivers at the existing gauging stations are as follows:

Rivers	Catchment Area	Annual Discharge
	(km^2)	(m^3/sec)
Thiba	353	11.1
Nyamindi	283	9.4
Ruamuthambi	86	2.1

16 The present land use in the Study Area is as follows:

(Unit: ha)

Land Use	MIS	Mutithi Extension Area	Total
Rice Field	6,900	-	6,900
Upland Field	2,200	1,600	3,800
Grass Land	2,200	2,400	4,600
Villages & Others	700	-	700
Total	12,000	4,000	16,000

17 The Study Area is covered with two kinds of soils; (1) black cotton soils and (2) red soils. The black cotton soils are suitable for irrigated rice cultivation. The present MIS irrigated rice fields are developed on these black cotton soils. The red soils are also rather intensively cultivated for maize and beans under rainfed condition. Some of these red soils are recognized as irrigable land for cultivation of horticultural crops.

18 The MIS Scheme started on a small scale in 1954. It was gradually expanded until about 2,000 ha of irrigated paddy was developed by 1960, and the Scheme was then managed by the Department of Agriculture up to 1966 when NIB was established and took over. The Scheme has been further expanded under NIB, and the total area under irrigated paddy cultivation is now 5,860 ha. Since MIS started rice production, a single cropping of paddy a year has been practiced. Rice production increased 2.3 times from 11,000 tons in 1960/61 to 26,000 tons in 1985/86 with expansion of the paddy field. Unit yield per ha, however, has been decreasing gradually from 6.0 ton level in early 1970's to 5.0 ton level in early 1980's.

19 The MIS Scheme area is divided into five (5) sections:

(Unit: ha)

Tebere	Mwea	Thiba	Wamumu	Karaba	Total
1,300	1,220	1,150	1,120	1,070	5,860

The MIS Scheme takes irrigation water from two sources; the Nyamindi and Thiba rivers. Water from these sources is supplied to the existing paddy field throughout by gravity flow after abstraction by means of two headworks both on the Nyamindi and Thiba rivers. Nyamindi irrigation system consists of a headworks, a main canal, three (3) branch canals and related structures, and supplies the water to Tebere section. Thiba irrigation system comprises a headworks, a main canal, four (4) branch canals and related structures, and distributes the water to Mwea, Thiba, Wamumu and Karaba sections.

20 The Scheme is of a settlement type and the farmers live in specific villages conveniently located within the Scheme area. NIB makes land preparation and provides inputs, extension

services and irrigation water at normal fee to the farmers. About 3,240 farmer families with an average family size of 9.5 persons are living in MIS Scheme area. The estimated population in MIS area is 31,000 as of 1987.

21 Although the Scheme is widely regarded as being the most successful irrigation rice project in Kenya, its performance has now begun to deteriorate with decreasing production level. Main contributory factor is lack of adequate rehabilitation with respect to all aspect of the Scheme operation and maintenance. The situation is likely to get worse with disastrous consequences unless corrective measures are urgently taken.

22 The Mutithi extension area is located next to the existing MIS Scheme area. The land in the Mutithi area is privately owned. There are about 1,580 land holders who own various sizes and shapes of land in the Area. The total population living in the Area is approximately 5,100 as of 1987, or 960 households with an average family size of 5.3 per household. The land holders are classified by size of land holding as follows:

Land Size (ha)	No. of Land Holders	Percentage (%)
Less than 1	98	6
1 - 3	865	55
3 - 5	404	26
5 - 7	108	7
7 - 9	54	3
More than 9	50	3
Total	1,579	100

23 The majority of the land holders living in the Mutithi area are full-time farmers. The farmers in the red soils areas use their land intensively for cultivation of maize and beans; on the other, those in the black cotton soils areas use their land mostly for cattle grazing. About 60% of the land holders on the black cotton soils are absent. They are staying outside elsewhere, while in the red soils areas almost fully occupied by the land owners or relatives.

It is estimated that the farmers with less than 3 ha earn an average of about KShs.500 per annum from the sales of their surplus produce, while the other farmers in 3-7 ha group earn

about double the amount. Their farm income is very low as compared to that of the MIS farmers who earn an average of KShs.10,000 per annum from the irrigated rice cultivation.

24 The questionnaire survey was carried out under the contract with UNICONSULT LTD. for confirmation of the land holders' intention to the irrigation development concept proposed by NIB. The questionnaire survey was made for 213 farmers living in the Mutithi area, 20 absent land holders and the opinion leaders who has prime ties with the communities in the Mutithi area. The results show that most of them are highly in favour of the proposed irrigation development. The results of the questionnaire survey are summarized as follows:

Concept Proposed by NIB	Agreed (%)	Comment (%)
1. Farmers to form a cooperative incorporating all farmers who are interested in irrigation development	98	2
2. Farmer to accept changes in boundary and sizes of land holdings due to irrigation infrastructures	78	22
3. Establishment of farmer's committee to deal with land transactions and valuations	92	8
4. To mortgage land as security for development costs	80	20
5. Farmers would build their own houses in the Area marked by NIB	77	23
6. Relation between farmers and NIB would be direct as is the case with MIS Scheme	85	15

The comments on the proposed irrigation development concept are mainly geared to the fear of the farmers in losing land. These farmers could be convinced through patient discussions under strong support of the cooperative who acts as a buffer between NIB and the farmers.

The absent land holders who live outside are generally recognized as those who have either inherited or purchased their pieces of land. They have similar views to resident farmers. In particular, all of them have no objection to the proposed

irrigation development and readily expressed their willingness to negotiate the transfer of the ownership of the land to NIB if fairly compensated. The local administrative officers and opinion leaders are wholly in support of the proposed irrigation development.

ASSESSMENT OF ENDOWED RESOURCES AND COMPARATIVE STUDY ON PROSPECTIVE DEVELOPMENT ALTERNATIVES

25 The potential maximum area for irrigation development in the Study Area is estimated to be 9,560 ha as shown below:

(Unit: ha)

Land Use	MIS	Mutithi	Total
Rice	5,860	2,470	8,330
Horticultural Crops	800	430	1,230
Total	6,660	2,900	9,560

26 The probability analysis on (1) area rainfall in the river basin, (2) discharges of the Thiba and Nyamindi rivers, and (3) rainfall in the irrigation area, for the period of recent 10 years from 1977 to 1986, indicates that, in all cases, the drought year with 5 year return period is 1980. The assessment of water resources is therefore made for the discharge data in the year of 1980. The 1/5 drought discharges of the relevant rivers (1980) are given below:

(Unit: m^3/sec)

Month	Thiba (4DA10)			Nyamindi (4DB5)			Ruamuthambi (RGS)		
	E	M	L	E	M	L	E	M	L
Jan.	4.96	4.44	4.75	2.81	2.45	2.60	1.73	1.30	1.50
Feb.	4.57	3.68	4.24	3.24	2.65	1.98	1.38	1.09	0.98
Mar.	5.72	5.56	5.35	3.15	2.62	2.22	0.96	0.87	0.85
Apr.	5.52	5.75	7.19	3.28	5.18	8.48	1.13	1.34	2.11
May.	7.17	12.84	11.53	15.79	13.88	7.12	2.91	2.69	1.92
Jun.	9.16	7.94	6.98	5.36	4.01	3.29	1.51	1.23	1.12
Jul.	6.83	6.18	5.85	3.01	2.97	2.83	1.33	1.20	1.12
Aug.	7.12	7.77	7.64	3.00	10.22	5.15	1.65	2.51	1.81
Sep.	7.03	6.37	5.59	3.59	3.52	4.41	1.53	1.18	1.25
Oct.	4.84	4.94	6.62	9.03	3.91	6.25	1.10	0.99	2.28
Nov.	9.07	12.15	12.61	7.58	10.22	9.30	3.17	4.90	2.98
Dec.	9.02	7.90	8.01	5.71	4.99	4.25	2.53	2.57	2.01

27 In the framework of the proposed cropping pattern, "rice" and "horticultural crops" such as tomatoes, onions and French beans are selected as major crops. Rice is grown in the black cotton soils areas and horticultural crops are in the red soils areas. All the irrigable land will be double-cropped with cropping intensity of 200%.

28 Irrigation water requirements are calculated based on the potential evapotranspiration estimated by the modified Penman method. The peak unit diversion water requirements for designs of canals and related structures are determined on the basis of studies on effective rainfall, percolation and irrigation efficiency:

For short rains rice : 1.74 l/sec/ha (mid September)
For long rains rice : 1.44 l/sec/ha (late March)
For short rains vegetables : 0.88 l/sec/ha (late June)
For long rains vegetables : 1.45 l/sec/ha (early February)

29 An overall irrigation efficiency is tentatively estimated at 55% based on the interim results of field measurement as shown below:

Item	Efficiency (%)
Application efficiency	76
Operation efficiency	80
Conveyance efficiency	90
Irrigation efficiency	55

30 The irrigable areas by drought discharges of the Nyamindi, Thiba and Ruamuthambi rivers are limited to 5,520 ha in total which correspond to only 58 % of the potential maximum area (9,560 ha) as shown below:

Month	Nyamindi	Thiba	Ruamuthambi	Total
Jan.	1,750	4,910	2,870	9,530
Feb.	1,750	4,910	1,100	7,760
Mar.	1,590	3,530	400	5,520
Apr.	1,750	4,910	860	7,520
May.	1,750	4,910	2,900	9,560
Jun.	1,750	4,910	2,040	8,700
Jul.	1,750	4,910	1,260	8,520
Aug.	1,750	4,910	1,250	7,910
Sep.	1,750	3,400	620	5,770
Oct.	1,750	3,380	620	5,750
Nov.	1,750	4,910	2,900	9,560
Dec.	1,750	4,910	2,840	9,500

31 The irrigation development plan in the Study Area will be formulated, with a view to utilizing the endowed land and water resources to the full extent for maximum production of rice and other horticultural cash crops. The plan should, however, be justified from both technical and economic viewpoints; it means that the best and final plan will have to be technically feasible and moreover be largest in development scale within economically reasonable range.

32 With this in view, comparative study on the possible development plans for expansion of irrigable area by use of available water resources is carried out. The following seven

(7) possible development alternatives are set out for this purpose:

ALTERNATIVE : T - 1

(1) Thiba dam
(2) New Nyamindi headworks
(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks
(4) Ruamuthambi headworks and headrace canal
(5) Rehabilitation of MIS
(6) Development of Mutithi and red soils areas

ALTERNATIVE : T - 2

(1) Thiba dam
(2) Ruamuthambi headworks and headrace canal
(3) Rehabilitation of MIS
(4) Development of Mutithi and red soils areas

ALTERNATIVE : T - 3

(1) Thiba dam
(2) New Nyamindi headworks
(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks
(4) Rehabilitation of MIS
(5) Development of Mutithi and red soils areas

ALTERNATIVE : T - 4

(1) Thiba dam
(2) Rehabilitation of MIS
(3) Development of Mutithi and red soils areas

ALTERNATIVE : N - 1

(1) Nyamindi dam
(2) New Nyamindi headworks
(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks
(4) Ruamuthambi headworks and headrace canal
(5) Rehabilitation of MIS
(6) Development of Mutithi and red soils areas

ALTERNATIVE : N - 2

(1) Nyamindi dam

(2) New Nyamindi headworks

(3) Link canal from new Nyamindi headworks to Mutithi area via existing Thiba headworks

(4) Rehabilitation of MIS

(5) Development of Mutithi and red soils areas

ALTERNATIVE : TA - 1

(1) New diversion from the Tana river by gravity

(2) Rehabilitation of MIS

(3) Development of Mutithi and red soils areas

33 The prospective headrace of the alternative TA-1 would have a total length of about 19 km which would cross the railway running within the densely populated area, and moreover, the Tana Power Station of Kenya Power and Lighting Co., Ltd. has been granted by the Ministry of Water Development the water right to use the full of the normal flow and 17 m^3/sec (610 cusec) of flood flow. The alternative TA-1 is, therefore, not a possible plan in a practical sense.

34 The irrigable area under each alternative case is obtained through water balance calculation as follows:

(Unit: ha)

Irrigable Area	T-1	T-2	T-3	T-4	N-1	N-2
1. MIS						
Paddy	5,860	5,860	5,860	5,860	5,860	5,860
Vegetables	800	570	450	570	0	0
Sub-total	6,660	6,430	6,310	6,430	5,860	5,860
2. Mutithi						
Paddy	2,470	1,660	2,410	1,060	2,70	1,460
Vegetables	430	0	0	0	0	0
Sub-total	2,900	1,660	2,410	1,060	2,070	1,460
3. Total	9,560	8,090	8,720	7,490	7,930	7,320

The above results indicate that only Alternative T-1 can cover the potential maximum area of 9,560 ha.

35 The preliminary development costs for each alternative are as follows:

Alternative Plan	Irrigation Area (ha)	Project Cost (KShs. million)	Economic Cost per ha (KShs. 1,000/ha)
T-1	9,560	1,603	168
T-2	8,090	1,368	169
T-3	8,720	1,538	176
T-4	7,490	1,264	169
N-1	7,930	1,595	201
N-2	7,320	1,480	202

Note: /1: Construction costs are tentatively estimated based on the "Current Construction Cost 1986" published by the Ministry of Works, Housing and Physical Planning. The estimate is of very preliminary nature.

36 Annual incremental benefits for each case of alternative plan are shown below:

Alternative	Irrigation Area (ha)	Irrigation Benefit (KShs. million)	Irrigation Benefit per ha (KShs. 1,000/ha)
T-1	9,560	282	29.5
T-2	8,090	222	27.5
T-3	8,720	240	27.6
T-4	7,490	203	27.1
N-1	7,930	207	26.1
N-2	7,320	188	25.6

37 The preliminary economic evaluation for each alternative plan is made in terms of economic internal rate of return (EIRR). EIRR in each alternative plan are calculated as follows:

Alternative Plan	EIRR (%)
T-1	17.7
T-2	16.9
T-3	15.9
T-4	17.0
N-1	12.8
N-2	12.6

38 It has been agreed between NIB and JICA Study Team that **Alternative T-1** be selected as the best development plan among the possible alternatives for the following reasons:

(1) The alternative T-1 shows the highest EIRR of 17.7% among all the possible alternatives.

(2) Only the alternative T-1 can irrigate the potential maximum area of 9,560 ha, including the Mutithi and red soils area.

(3) The alternative T-1 gives the largest paddy production of about 100,000 tons per annum when it becomes full operation.

(4) The alternative T-1 benefits the largest number of farmers among all the possible alternatives.

Based on the above result, it has been also agreed through discussions between NIB and JICA Study Team that further studies are made only for alternative T-1.

PROSPECTIVE DEVELOPMENT PLAN

39 The total irrigable area under the Project is 9,560 ha net as follows:

(1) Mwea Irrigation Settlement Scheme Area		
a. existing irrigated paddy area	:	5,860 ha
b. rain-fed red soils	:	800 ha
(2) Mutithi Extension Area		
a. uncultivated black cotton soils	:	2,470 ha
b. rain-fed red soils	:	430 ha
Total	:	9,560 ha

40 The present land use conditions in the above irrigable area will be changed by implementation of the Project as follows:

(Unit: ha)

Land Use	Without Project	With Project
MIS Area		
1. Rice		
Short Rains Rice	5,860	5,860
Long Rains Rice	0	5,860
2. Horticultural Crops		
French beans	0	800
Onions	0	400
Tomatoes	0	400
3. Upland Crops		
Maize	600	0
Beans	200	0
Mutithi Area		
1. Rice		
Short Rains Rice	0	2,470
Long Rains Rice	0	2,470
2. Horticultural Crops		
French beans	0	430
Onions	0	215
Tomatoes	0	215
3. Upland Crops		
Maize	430	0
Beans	0	0

41 With introduction of improved farming practices under assured irrigation system as well as proper water management, crop yields are substantially increased. The anticipated crop yields are set out as given below:

Rice
- Short rains rice : 6.0 tons/ha
- Long rains rice : 6.0 tons/ha

Horticultural Crops
- French beans : 10.0 tons/ha
- Onions : 10.0 tons/ha
- Tomatoes : 15.0 tons/ha

42 The crop production will increase gradually during the build-up period of 5 years after completion of the construction works. The incremental crop production at the full development stage is estimated:

(Unit: tons)

Crops	Without Project	With Project
MIS Area		
1. Rice		
Short Rains Rice	20,500	35,200
Long Rains Rice	0	35,200
2. Horticultural Crops		
French beans	0	8,000
Onions	0	4,000
Tomatoes	0	6,000
3. Upland Crops		
Maize	800	0
Beans	1,000	0
Mutithi Area		
1. Rice		
Short Rains Rice	0	14,300
Long Rains Rice	0	14,300
2. Horticultural Crops		
French beans	0	4,300
Onions	0	2,100
Tomatoes	0	3,200
3. Upland Crops		
Maize	600	0

43 The net incremental benefit of the Project which is defined as the difference between the respective net production values under future "with" and "without" project conditions, is estimated as follows:

(Unit: KShs. million)

Crops	Without Project	With Project	Increment
MIS			
Rice	50.9	202.8	151.9
Horticultural Crops	0.0	43.3	43.3
Upland Crops	3.6	0.0	-3.6
Mutithi			
Rice	0.0	85.4	85.4
Horticultural Crops	0.0	23.3	23.3
Upland Crops	0.7	0.0	-0.7
Total	55.2	354.8	299.6

44 The proposed Project will comprise the following:

(1) Thiba dam (storage capacity: 18 MCM)

(2) New Nyamindi headworks and 0.6 km headrace (existing Nyamindi headworks will be closed)

(3) Link canal from new Nyamindi headworks to Mutithi area (13.3 km) via the existing Thiba headworks which will be rehabilitated

(4) Ruamuthambi headworks and 6.4 km headrace

(5) Rehabilitation of MIS including reclamation of red soils area (6,660 ha)

(6) Development of Mutithi and red soils areas (2,900 ha)

(7) Provision of machinery and equipment for operation and maintenance of Project facilities

(8) Provision of farm machinery for 9,560 ha irrigated farmland

(9) machine center for operation and maintenance of the above machinery and equipment

(10) Improvement and expansion of reception centers

(11) Pilot farm (50 ha)

45 The proposed Thiba dams will have a storage capacity of 18 MCM with 35 m height. The dam is of zoned fill with inclined clay core type. The spillway is designed to release the floods of 625 year return period with due freeboard allowance. The spillway will be ungated chute type with design discharge of 560 m^3/sec. Intake structure will be drop inlet type. Tunnel driver through abutment will be adopted for river diversion.

Hydropower potential of the proposed Thiba dam is not large. Annual energy production is approximately 800 MWh with maximum output of 200 kw. The Project will not include the hydropower development.

46 Two headworks will be newly constructed on the Nyamindi and Ruamuthambi rivers. The existing Thiba headworks will be rehabilitated and incorporated into the future irrigation system under the Project. The existing Nyamindi headworks will be closed and the irrigation water to the Tebere section will be diverted from the new Nyamindi headworks which will be constructed at 2.1 km upstream from the existing headworks. The design intake discharges at the proposed headworks will be as follows:

Nyamindi (new)	7.0 m^3/sec
Thiba (existing)	11.1 m^3/sec
Ruamuthambi (new)	2.3 m^3/sec

The new headworks are designed to release the floods of 50 year return period. The weirs are fixed concrete type with design flood discharges of 390 m^3/sec for the Nyamindi headworks and 180 m^3/sec for the Ruamuthambi headworks. The rehabilitation works at the existing Thiba headworks will include raising-up of weir height by 0.5 m and protection works for downstream river bed and left side slopes.

47 Headraces will be constructed from the proposed Nyamindi and Ruamuthambi headworks. Canal section will be of a trapezoidal type. Inside slope of the canals will be 1:1.5. The proposed headraces will have the total length of 0.6 km for the Nyamindi and 6.4 km for the Ruamuthambi.

48 Link canal system is planned to convey the surplus water from the Nyamindi river to the Mutithi extension area via the

existing headworks where the irrigation water released from the Thiba dam will also be diverted to the Mutithi area as well as the Thiba part. Link canal-I (7.5 km) will connect the Nyamindi headrace with the existing Thiba headworks with design discharge of 4.9 m^3/sec. Link canal-II (3.4 km) will run between the existing Thiba headworks and the Thiba division works where the irrigation water will be diverted to the Mutithi area as well as the Thiba part, using a part of the existing Thiba main canal which will be enlarged to assure the design discharge of 11.1 m^3/sec. Link canal-III (2.4 km) will finally convey the irrigation water from the Thiba division works to the Mutithi area with the design discharge of 3.6 m^3/sec. The link canals are designed, applying same criteria as applied for the headraces.

49 The rehabilitation works for the existing MIS facilities will be carried out to the minimum required extent; however these include (a) desiltation of canal bottom and re-embankment of canal inside slopes, (b) concrete lining of irrigation canals having excessive seepage losses, (c) excavation of drains to lower the drainage level, (d) improvement of canal structures and (e) embankment and pavement of farm roads.

50 The irrigation and drainage facilities in the Mutithi area will be newly constructed. The preliminary layout of the irrigation and drainage facilities is made on the topographic maps on a scale of 1/5,000 prepared by JICA. The required facilities will comprise irrigation and drainage canals, farm roads and on-farm facilities. For preliminary designs of those require facilities, same criteria as those in MIS are applied.

51 After completion of the Project, water management system will become very important to attain the envisaged irrigation efficiency of 55% under the limited water supply conditions.

The reservoir capacity of the Thiba dam is determined under the conditions that rainfall in the irrigation area as well as the natural flows of relevant rivers would be fully utilized. It means that if rainfall and natural river flows will not be effectively utilized, reservoir water will have to be released due to the unexpected demand in the irrigation area and sufficient irrigation water supplies for total area of 9,560 ha will not be assured. A kind of water management system will therefore be required for full use of rainfall and natural river flows which always fluctuate.

52 The water management system to be applied to the Project will have to be simple and practicable under the present circumstances. The proposed water management system will have three aspects; i.e., (1) irrigation facilities for ensuring correct diversion at dam, headworks, division works and major turnouts from main canals to branch canals, (2) monitoring, data processing and communication systems for proper operations of irrigation facilities, and (3) institutional set-up for controlling the above irrigation facilities and monitoring systems.

53 As far as the irrigation facilities for water management are concerned, a supersonic flowmeter with automatic discharge recorder will be installed at the damsite, and cipolletti weir and automatic water level recorder at headworks, division works and major turnouts.

54 The proposed monitoring, data processing and communication systems will comprise the following:

(1) Rainfall monitoring system

Automatic rain gauges will be installed at damsite and seven (7) places nearby reception centers.

(2) Discharge monitoring system

Automatic flowmeter will be installed at the damsite, and automatic water level recorders at dam reservoir, headworks, division works and major turnouts.

(3) Communication system

Telephone system will be established between the head office and branch offices. Telemeter system will also be installed between the rain gauging and discharge measuring sites and the branch offices.

(4) Data processing system

The head office will be equipped with a personal computer for analysis of rain and discharge records and determination of weekly schedule for gate operation as well as occasional adjustment depending on rainfall.

(5) Central monitoring system

A graphic panel which shows daily situations of the released water from the dam, river and intake discharges at the headworks, diversion discharges at division works and major turnouts and rainfall at each gauging site, will be installed at the head office for effective and quick decision-making on overall water management.

(6) Control of irrigation facilities

Gate operations will be made manually. Telecontrol system will not be adopted.

55 For introduction of the above water management system, new organizational set-up will be required with increased staffing. It is recommended that a new section responsible for execution of the above-mentioned water management system be established in present MIS headquarters.

56 The Project will include establishment of a pilot farm which will have the following objectives:

(1) selection of rice varieties suitable for long rains crop and demonstration of double cropping to the farmers,

(2) field trials on farm machinery and equipment,

(3) field trials and demonstration of irrigated horticultural crops on the red soils,

(4) field trials on irrigation practices and water management both for rice and horticultural crops, and

(5) seed multiplication.

The proposed pilot farm site is located near Unit M-9 of the MIS. The required size is about 50 ha.

57 The Mutithi extension area is remoted from the public services and infrastructures such as electricity and domestic supplies, roads and agricultural institutions and facilities. Such present condition implies that irrigation development of the Area will require not only irrigation/drainage facilities but also other ancillary facilities such as electricity and

rural water supplies, health facilities for sanitary protection, and educational facilities which will help the farmers (land holders) to settle in the Area. The studies on these required facilities are, however, not included in the "Scope of Work for the Feasibility Study". These will have to be made, in close coordination with other agencies concerned, during the detailed design stage of the Project.

58 Dam construction coupled with irrigation development is generally considered influential in altering the environmental resources. Environmental study is, therefore, required before implementation will take place. Such study generally comprises manifold items of environmental impacts evaluation on physical resources, ecological resources, human use values, and quality of life values. In particular, the compensation problem for prospective reservoir area covering about 140 ha will have to be urgently solved. The studies on environmental impacts and compensation problem will have to be made during the stage of detailed design of the Project.

PROPOSED PROJECT WORKS

59 The principal features of the Project are summarized as follows:

a. Thiba Dam :

<u>Reservoir</u>	
Catchment area	172.6 km²
Total storage capacity	18.0 MCM
Effective storage capacity	15.0 MCM
Total water level	EL.1,380.0 m
Total storage area	1.2 km²
<u>Dam</u>	
Zoned fill type	
Dam Height:	35.0 m
Crest elevation	EL.1,385.0 m
Crest length	1,350.0 m
Crest width	8.0 m
<u>Intake Structure</u>	
Drop inlet	6.3 m x 6.3 m
Intake pipe	L=560m, D=2.0m

b. Headworks	:	<u>New Nyamindi Headworks</u>	
		Crest elevation	EL.1,209.5 m
		Crest length	45.0 m
		Crest width	1.0 m
		Weir height	4.5 m
		<u>Ruamuthambi Headworks</u>	
		Crest elevation	EL.1,213.0 m
		Crest length	36.0 m
		Crest width	1.0 m
		Weir height	3.5 m
c. Headrace	:	<u>Nyamindi</u>	
		Design discharge	7.0 m^3/sec
		Total length	0.6 km
		<u>Ruamuthambi</u>	
		Design discharge	2.3 m^3/sec
		Total length	6.3 km
d. Link Canals	:	<u>Total Length</u>	
		Link canal-I	7.5 km
		Link canal-II	3.4 km
		<u>Link canal-III</u>	<u>2.4 km</u>
		Total	13.3 km
		<u>Design Discharge</u>	
		Link canal-I	4.9 m^3/sec
		Link canal-II	11.1 m^3/sec
		Link canal-III	3.6 m^3/sec
e. Rehabilitation of MIS	:	Irrigation Area	5,860 ha
		Irrigation Canal	59 km
		Drainage Canal	33 km
		Canal Structures	370 nos.
		Farm Road	164 km
f. Development of Mutithi area	:	Irrigation Area	2,900 ha
		Irrigation Canal	33 km
		Drainage Canal	31 km
		Canal Structures	400 nos.
		Farm Road	81 km
g. Land Reclamation	:	MIS	800 ha
		Mutithi	2,900 ha

h. Ancillary Works : Reception centers
- expansion of existing 5 centers in MIS
- construction of 2 centers in Mutithi

Machine center
O/M equipment
Farm machinery

60 The financial cost is estimated to be about KShs.1,200 million on the basis of the current prices as of mid 1987. Construction cost for dam & reservoir and irrigation works would amount to KShs.637.2 million in total, corresponding to KShs.66,700 per ha.

(Unit: KShs. million)

	Components	Total	Foreign Currency	Local Currency
(1)	Dam & Reservoir	331.9	235.0	96.9
(2)	Irrigation Works	305.3	175.3	130.0
(3)	Farm Machinery	81.2	73.8	7.4
(4)	O&M Equipment	65.6	56.8	8.8
(5)	Farm Building	26.9	13.7	13.2
(6)	Land Acquisition	1.9	-	1.9
(7)	Administration	24.4	-	24.4
(8)	Engineering Services	81.1	48.6	32.5
(9)	Physical Contingencies	91.8	60.2	31.6
(10)	Price Contingencies	217.0	95.3	121.7
	Total	1,227.1	758.7	468.4

ORGANIZATION AND MANAGEMENT

61 NIB will be responsible for implementation of the Project. It is recommended that for smooth implementation of the Project, NIB organize a steering committee comprising the representatives from the relevant ministries. For supervision of the construction works, the Project Office will also be required under NIB.

62 After completion of the construction works, the Project office will be integrated to present MIS headquarters with a new section which will take charge of necessary services of water

management. The present MIS headquarters will be incorporated in the proposed O&M Office.

63 An integrated system of water intake control will be required for overall water management. For this, O&M branch office will be newly required at the Thiba dam which will be linked by telephone with the O&M head office where precise instructions for gate operation will be given. The O&M head office will also be linked with other branch offices at the reception centers where rainfall gauges will be equipped. The instruction for gate operations will be made at the head office through calculation by computer on the basis of the reports on the river discharges and rainfall from the branch offices.

64 The major irrigation facilities such as the Thiba dam, headworks, link canals and headrace, main and secondary canals, and farm roads will be put under the control of the O&M office. The water management of on-farm facilities in the Irrigation Units will however be put under the responsibility of the farmers co-operatives or water user's associations which incorporate all the farmers concerned.

PROJECT EVALUATION

65 The project evaluations are made in order to ascertain the feasibility of the Project in view of economic, financial and socio-economic aspects. The economic feasibility of the Project is evaluated in terms of the internal rate of return (IRR) and net present value (NPV) at the discount rate of 10%. The calculated results are as follows:

IRR : 18.4%
NPV : KShs.682 million

66 In order to evaluate the soundness of the Project against the possible changes in future economic conditions, sensitivity analysis is made for the following cases:

Case-1: 10% Project cost increase due to unforeseen geological and topographical conditions and unexpected increase of material cost

Case-2: 10% Project benefit decrease due to unexpected decrease in forecasted price of farm product and crop yield

Case-3: Two years overrun of the build-up period due to unexpected inefficiency in O&M management and agricultural extension services

Case-4: Two years overrun of construction period due to unexpected and unforeseen reasons

The effects of these changes in IRR and NPV (discount rate: 10%) are summarized as shown below:

Case	IRR (%)	NPV (KShs. million)
Case-1	17.0	598
Case-2	16.8	530
Case-3	17.6	626
Case-4	16.8	530

67 The results of economic evaluations indicate that the Project has a high economic viability and is rather insensitive to the possible changes in basic assumptions for economic evaluations.

68 Financial evaluation of the Project is made through the farm budget analysis on an average size of the Project-benefited farmers (1.8 ha for the MIS farmers and 3.2 ha for the Mutithi farmers) and also by preparing the repayment schedule for the anticipated loan.

The payment capacity is recognized as the ability of the Project-benefited farmers to bear the expenses required for operation and maintenance of the Project facilities as well as for repayment of capital cost, and is defined to be the difference of net disposable reserves under future "with" and "without" the Project conditions, which the farmers can actually earn from the Project after all the farm expenses and living costs are deducted from the gross farm income. The payment

capacity under the Project at the full operation stage is estimated as follows:

(Unit: KShs.)

Description	Farm Size (ha)	Disposable Reserve With Project	Disposable Reserve Without Project	Payment Capacity Per Farmer	Payment Capacity Per ha
(1) MIS	1.8	47,600	2,800	44,800	24,900
(2) Mutithi	3.2	76,200	500	75,700	23,700

The increased net disposable reserve would offer the better living conditions and welfare to the farmers, and the substantial payment capacity would let the farmers make some payment for the initial investment as well as operation and maintenance of the project facilities.

69 It is assumed that the initial investment for the Project will be arranged under the following conditions:

(1) For foreign currency portion, the capital is financed by bilateral or international organization with an interest of 3.0% per annum for a repayment period of 30 years including 10 year grace period.

(2) For local currency portion, the capital is arranged by the Government budget allocation with no repayment.

During 30 year repayment period, the Government budget for covering the loan repayment, loan interest, replacement costs and O&M expenses would amount to about KShs.98.10 million per annum. This corresponds to KShs.10,300 per ha per annum or about 40% of the above-mentioned payment capacity per ha per annum. The budget requirement would be mostly covered by the Project revenue in terms of water charges.

70 The Project will bring about a great improvement in farm budget, and give an incentive for further improvement of the irrigated land to the farmers. The farmers who will receive a large economic return, will spend their increased income for various purposes and the economic activities will thereby enhanced. Increased tax revenue will also be expected from such future economic circumstances. The Project could therefore be justified from financial point of view.

71 In addition to the direct benefits counted in the economic evaluation, various secondary and intangible benefits and/or favourable socio-economic impacts are expected from the implementation of the Project. Such socio-economic impacts are considered as follows:

(1) increase of employment opportunity
(2) foreign exchange saving
(3) Accumulation of technical knowledge and skill
(4) increase of land value
(5) improvement of local transportation
(6) mitigation of flood damages
(7) better quality of farm products
(8) improvement of rural water supplies
(9) potential uses of the reservoir for fish production and recreational benefits such as fishing and boating

RECOMMENDATIONS

72 The Mwea Irrigation Development Project is verified to be technically sound, and economically and financially feasible. It is highly recommended that NIB take next steps necessary for early implementation of the Project.

73 It is recommended that the Project be implemented in two stage of:

Phase-I : Establishment of a Pilot Farm (50 ha) and Rehabilitation of existing MIS Scheme (6,660 ha), and

Phase-II : Dam construction and development of Mutithi extension area (2,900 ha),

because Phase-I should be urgently implemented for improvement of the decreasing rice production level in MIS; on the other, Phase-II would require, before its implementation, a lot of preparatory works such as environmental study for dam construction, compensation for prospective reservoir area and land tenure problem in the Mutithi area.

74 The Project components to be implemented under Phase-I and Phase-II would be as follows:

Phase-I: Establishment of a Pilot Farm (50 ha) and Rehabilitation of MIS Scheme (6,660 ha)

(1) Establishment of a pilot farm (50 ha) and operation running-in,

(2) Construction of a link canal system from new Nyamindi headworks to the existing Thiba headworks,

(3) Rehabilitation of the existing irrigation and drainage system covering 5,860 ha as well as land reclamation and construction of a new irrigation and drainage system for uncultivated red soils area of 800 ha,

(4) Provision of farm machinery and O&M equipment, and

(5) Improvement of farm buildings and reception centres.

Phase-II: Dam construction and development of Mutithi extension area

(1) Construction of new dam (storage capacity: 18 MCM) at upstream of the Thiba river,

(2) Construction of link canal from the existing Thiba headworks to the Mutithi extension area,

(3) Construction of new headworks on the Ruamuthambi river and headrace therefrom,

(4) Land reclamation and construction of a new irrigation and drainage system covering 2,900 ha,

(5) Provision of farm machinery and O&M equipment for Mutithi area, and

(6) Construction of required farm buildings and reception centres.

75 It is strongly recommended, considering the pressing needs for rehabilitation of the existing MIS, that at least Phase-I of the Project be implemented as early as possible and also that necessary actions be taken for preparatory works required for continuous implementation of Phase-II.

76 It is also recommended that the Technical assistance from the rice-growing country during the period of initial stage of the Project be considered for (1) initial operation of the pilot farm and (2) introduction of the new water management system.

MWEA IRRIGATION DEVELOPMENT PROJECT

FINAL REPORT

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ABBREVIATION OF MEASUREMENT

Length

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

Area

cm^3	=	square centimeter
m^3	=	square meter
km^3	=	square kilometer
ha	=	hectare

Volume

cm^3	=	cubic centimeter
ℓ	=	lit = liter
m^3	=	cubic meter
MCM	=	million cubic meter

Weight

g	=	gram
kg	=	kilogram
ton	=	metric ton

Time

sec	=	second
min	=	minute
hr	=	hour
yr	=	year

Electrical Measures

KW	=	Kilowatt
MW	=	Megawatt
GW	=	Gigawatt
KV	=	Kilovolt

Other Measures

%	=	percent
°	=	degree
10^3	=	thousand
10^6	=	million

Derived Measures

mm/day	=	millimeter per day
ℓ/sec/ha	=	liter per second per hectare
m^3/sec	=	cubic meter per second
KWh	=	Kilowatt hour
MWh	=	Megawatt hour
GWh	=	Gigawatt hour
KVA	=	kilovolt ampere
cct	=	circuit
ton/hr	=	ton per hour
cal/cm^3/day	=	calorie per square centimeter per day

Money

KShs.	=	Kenya Shillings
K£	=	20 Kenya Shillings
US$	=	US dollars
¥	=	Japanese Yen

NOTATIONS

(1) Organization

CBS	:	Central Bureau of Statistics
FAO	:	Food and Agriculture Organization
HCDA	:	Horticultural Crops Development Authority
IBRD	:	The International Bank for Reconstruction and Development
IMF	:	International Monetary Fund
KSS	:	Kenya Soil Survey
MIS	:	Mwea Irrigation Settlement
MOA	:	Ministry of Agriculture
MOWD	:	Ministry of Water Development
MOWH&PP	:	Ministry of Works, Housing and Physical Planning
USBR	:	United States, Department of the Interior, Bureau of Reclamation
NAL	:	National Agricultural Laboratories
NCPB	:	National Cereal and Produce Board
NIB	:	National Irrigation Board
MOERD	:	Ministry of Energy and Regional Development
MOTC	:	Ministry of Transport and Communication
JICA	:	Japan International Cooperation Agency

(2) Others

API	:	Aerial Photo Interpretation
Alt.	:	Altitude above Mean Sea Level
C.I.F	:	Cost, Insurance & Freight
D/D	:	Detail Design
CEC	:	Cation Exchange Capacity
dia	:	Diameter
EC	:	Electrical Conductivity
EL	:	Elevation above Mean Sea Level
EIRR	:	Economic Internal Rate of Return
F.O.B	:	Free on Board
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
O&M	:	Operation and Maintenance

CONVERSION RATES

mm	Milimeter	
cm	Centimeter	10 mm
m	Meter	100 cm
km	Kilometer	1,000 m
in.	Inch	0.02340 m
ft.	Feet	0.30480 m
yd.	yard	0.9144 m
mile	Mile	1,609.3 m
m^2	Square meter	
acre		0.4047 ha
ha		Hectare 10,000 m^2
km^2	Square kilometer	100 ha
ft^2	Square feet	$9.1903 \times 10^{-2} m^2$
$mile^2$	Square mile	$2.5898 \times 10^{6} m^2$
m^3	Cubic meter	
ℓ	Liter	
kℓ	Kiloliter	1,000 ℓ
ft^3	Cubic feet	0.028317 m^3
acre-in.	Acre inch	102.79 m^3
acre-ft.	Acre feet	1,233.7 m^3
g	Gram	
kg	Kilogram	1,000 g
ton	Ton	1,000 kg
hr	Hour	60 min
US$	US dollar	KShs. 16.5 = Yen 150
m^3/sec	Cubic meter per second	
cusec	Cubic foot per second	0.02832 m^3/sec

CHAPTER I INTRODUCTION

1.1 Authority

This report is compiled in accordance with the "Scope of Work for Feasibility Study on the Mwea Irrigation Development Project", agreed upon between the Government of Kenya through the National Irrigation Board (NIB) and the Japan International Cooperation Agency (JICA). The agreed "Scope of Work" comprises two (2) major programmes:

(1) Preparation of topographic maps scaled 1/5,000

(2) Feasibility study on the Mwea Irrigation Development Project (the Study).

Preparation of the topographic maps was completed in February 1987 through the field survey which was made during three (3) months from July to September 1986. The Feasibility Study was commenced in January 1987 and the following reports were submitted to NIB:

(1) Inception Report No.1, January 1987
(2) Field Report, March 1987
(3) Inception Report No.2, June 1987
(4) Interim Report, September 1987
(5) Draft Final Report, November 1987

The Feasibility Study was commenced in January 1987 and the following reports were submitted to NIB:

(1) Inception Report No. 1, January 1987
(2) Field Report, March 1987
(3) Inception Report No. 2, June 1987
(4) Interim Report, September 1987
(5) Draft Final Report, November 1987

This report (Final Report) has been prepared on the basis of the outcomes obtained through a series of discussions with NIB on these reports.

1.2 Project History

Development of the Mwea Irrigation Settlement (MIS) started in 1953, primarily to utilize the abundant labour of the Mau Mau detainees made available after declaration of state of emergency in October 1952. Construction of irrigation facilities started in 1954 and the Nyamindi headworks was completed in 1956 and the Thiba headworks in 1957. Substantial irrigated rice cultivation was commenced in the short rains season of 1957. The Scheme was gradually expanded with the funds from Colonial Development and Welfare of United Kingdom and about 2,000 ha of irrigated paddy fields (mainly existing Tebere and Mwea Sections) were developed by June 1960. After the Mau Mau war (1952-1960), the Scheme had been managed by the Department of Agriculture up to 1966 when NIB was established and took over.

The Scheme was continuously expanded under the management of NIB since 1966 to date. The total area under irrigated rice cultivation is about 5,860 ha (14,500 acres) at present.

In May 1985, the Government of Kenya requested the technical cooperation for execution of feasibility study on rehabilitation of MIS and further expansion of the Scheme to the Government of Japan. In response to the request, the Government of Japan through JICA which is responsible for execution of the government technical cooperation programme, dispatched a preliminary survey team headed by Mr. Takeshi Nasu to Kenya. The team discussed with NIB details of the feasibility study requirement and concluded the said "Scope of Work", in November 1985 (See ATTACHMENT-1).

JICA dispatched, in accordance with the agreed "Scope of Work", a survey team to Kenya in June 1986 to carry out topographic survey for preparation of 1:5,000 scale maps. The survey was completed in September 1986 and the topographic maps were made available in February 1987.

The present Study Team was dispatched by JICA in January 1987 to carry out the feasibility study on the Mwea Irrigation Development Project. The JICA Study Team submitted to NIB the Inception Report No.1 which contains the plan of operation for the feasibility study in January 1987. The plan proposed by the Team was accepted by NIB and the feasibility study was started in accordance with the agreed plan (see Minutes of Meeting given in ATTACHMENT-2).

The first stage of the feasibility study was commenced in January 1987 and completed in April 1987. The JICA Study Team submitted the Field Report to NIB at the end of the first stage studies. The discussion on the Field Report took place between NIB and JICA Study Team on March 24, 1987. The proposed preliminary plan in the report was totally accepted by NIB (see Minutes of Meeting given in ATTACHMENT-3).

The second stage of the Study was started in June 1987 and the Team prepared the Inception Report No.2 which contained the results of preliminary studies on the irrigation development made in Japan during the month of June 1987. The JICA Study Team visited Kenya again in July 1987 and discussed with NIB the Inception Report No.2 (see Minutes of Meeting given in ATTACHMENT-4). JICA Study Team made the additional field investigation during the period from July to September 1987 and submitted the Interim Report that contained the basic development plan of the Project, to NIB at the end of September 1987 (see Minutes of Meeting on the Interim Report given in ATTACHMENT-5). JICA Study Team made further studies on the basic development plan of the Project in Japan during the period of October/November and submitted the Draft Final Report to NIB in the later part of November 1987. JICA Study team held the discussion meeting with NIB on December 1, 1987 (see Minutes of Meeting given in Attachment-6), and on the basis of the comments on the Draft Final Report, the Final Report was prepared and submitted to NIB in March 1988.

1.3 Outline of "Scope of Work for Feasibility Study"

The "Scope of Work" concluded between JICA and NIB on November 13, 1985 is outlined as follows:

(1) Study Area:

The Mwea Irrigation Development Project (hereinafter referred as "the Project"), situated near Embu in the Central Province, covers a gross Study Area of some 16,000 ha which comprises:

a.	Existing Mwea Irrigation Settlement (MIS) Scheme Area:	12,000 ha
b.	Mutithi Extension Area :	4,000 ha
	Total	16,000 ha

(2) Objectives:

The objectives of the Study are to formulate the irrigation development plan comprising the following major Project components and assess the technical soundness and economic viability of the Project:

a. rehabilitation and improvement of the existing MIS irrigated paddy field covering 6,000 ha

b. irrigation development of the red soils in the existing MIS Scheme area, and

c. irrigation development of the Mutithi extension area of 4,000 ha.

(3) Work schedule:

The Study is scheduled for a period of fifteen (15) months from January 1987 to March 1988. The Study is broadly divided into two (2) stages.

The Study in the first stage is to be carried out during the period from January 1987 to April 1987, with a view to clarifying the present condition of the Study Area and also identifying the constraints on irrigation development.

The Study in the second stage will follow immediately after completion of the first stage starting in June 1987 and be completed in March 1988. The second stage study will aim to formulate an overall irrigation development plan and verify the technical soundness and economic viability of the Project.

The general work schedule for the Study is shown in Fig. 1.3.1.

1.4 Activities of the JICA Study Team

During the first stage of the Study (Jan. - Apr., 1987), JICA Study Team made data collection and field investigation in accordance with the agreed Plan of Operation which was given in the Inception Report No.1. Major activities made during the First Stage of the Study are as follows:

(1) field reconnaissance,
(2) data collection in various technical and economic fields,
(3) review of available reports concerning the Project,
(4) review of MIS annual reports (1974/75 - 1985/86),
(5) field survey and investigation comprising:
    a. canal route survey,
    b. inventory survey of existing irrigation and drainage facilities,
    c. geological inspection at major structural site,
    d. soil and land use survey,
    e. installation of new gauging stations and measurement of river discharge,
    f. paddy yield survey at representative paddy plots,
    g. farm economic survey (51 farmers were interviewed),
    h. field measurements of cylinder and furrow intake rates on red soils area, and
    i. laboratory tests and analysis of earth materials, soils and water samples.
(6) preliminary study on current constraints for irrigation development, and
(7) preliminary assessment on land and water resources.

The findings and preliminary results obtained through such activities are described in the Field Report. The following four (4) issues were recognized as major constraints currently encountered in the irrigation development of the Study Area:

(1) deterioration of the existing irrigation and drainage facilities in MIS with decreasing production level of rice,

(2) technical and managerial difficulties involved in double cropping of rice,

(3) insufficient availability of irrigation water in the Study Area and necessity of new water resources development for further development of MIS and also of the Mutithi extension areas, and

(4) land tenure problem in the Mutithi extension area.

The second stage study started in June 1987 as scheduled. JICA Study Team made preliminary studies on irrigation development and prepared Inception Report No.2 in Japan. The Team was again despatched to Kenya. The Team arrived at Nairobi on July 7, 1987 and submitted the Inception Report No.2. The meeting on the Report was held on July 10, 1987. After confirmation of the "Plan of Operation for Second Stage Study", the Team carried out the following field investigations during the period of July - August, 1987:

(1) additional data collection in technical and economic fields,

(2) installation of temporary bridges on the Nyamindi and Thiba rivers and discharge measurement (the bridges on the Nyamindi installed in the first stage were washed out or totally damaged by the floods and re-installed),

(3) field measurement of application efficiency in Irrigation Unit of M-14 (for estimation of overall irrigation efficiency applied to the Project),

(4) supplemental inventory survey of the existing irrigation/drainage facilities, particularly of drainage canals and on-farm facilities,

(5) field inspection of prospective major structural sites and canal routes, including:

a. Nyamindi damsite
b. Thiba damsite
c. Nyamindi new headworks site and headrace canal route
d. Ruamuthambi new headworks site and headrace canal route, and

e. link canal routes,

(6) field investigation concerning water management,

(7) selection of pilot farm site and field investigation at the site,

(8) soil and land use survey in red soils and Mutithi extension areas,

(9) land use and socio-economic survey in the prospective reservoir areas, and

(10) unit price survey for construction cost estimates.

In September 1987, the Team made office work in Nairobi for analysis of data and information obtained through the above field investigations and comparative studies on prospective development alternatives, and submitted the Interim Report to NIB.

The Team was supported by the counterpart personnel assigned from NIB in every aspect of activities. As agreed in the Meeting on the Inception Report No.1, the regular meetings were held on every Monday morning from 9.00 a.m. at Board Room of NIB Head Office. During the field investigation periods from January to September, 17 regular meetings were held. The regular meetings offered good chances for both the Team and NIB counterpart personnel to avoid any misunderstanding on the Study and also to exchange views on future irrigation development in the Study Area. The minutes of the regular meetings are given in the Data Book attached to this Report.

CHAPTER II BACKGROUND

2.1 General Economic Situation

Kenya has a total land area of about 564,000 km^2. The total population as of 1986 is estimated to be about 21.3 million. The population density is about 38 persons per km^2. The population growth rate is about 3.8% per annum on an average during the last decade. The rate of population growth has been recently accelerated. Future population is projected for the year of 2000 to be 38.5 million (see Table 2.1.1).

The economic growth of Kenya since its independence in 1963 may be illustrated by the data in Table 2.1.3, where real growth rates of the Gross Domestic Products (GDP) are given. In the beginning years of independence, the Kenya's economy showed a steady growth rate of 5.8% for the period from 1964 to 1969. The economic growth accelerated in the early 1970's, but thereafter is slowed down except the period of coffee boom (1977 to 78). This slow down is primarily due to a series of sharp increases in price of crude oil for which Kenya depends totally on import. The annual growth rate in the 1970's was 5.1% on an average. The economy was generally stagnant in the early 1980's, partly reflecting international recession. In 1983 to 85, Kenya's economic performance showed a sign of recovery (see Table 2.1.4).

The agricultural sector plays a dominant role in the Kenya's economy, sharing about 30% of GDP (see Table 2.1.4) and contributing more than 50% towards its gross export earnings. The sector directly employs about 75% of labour force and sustains almost same ratio of the total population.

In particular, two main cash crops, i.e., coffee and tea, account for some 52% of the total export value (see Table 2.1.6). Another major export commodity is petroleum; its share in exports has been increasing to attain about 25% level. Such high dependence on a few products as foreign exchange earners makes the Kenya's economy vulnerable to natural conditions and changes in international markets. Composition of imports, on the other hand, is characterized by a large share of fuels, which approaches 25% of the total import value. These characteristics of economic structure together with the lack of fossil fuel resources are primarily attributed to large

imbalance in external trade (see Table 2.1.7), and accumulated deficits in national account.

2.2 Agriculture in Kenya

Kenya's economy is fundamentally based on agriculture. The population is still premonimantly rural (82%) and as of 1985, agriculture provides employment for nearly 78% of the nation's population (see Table 2.2.1). The sector produces almost all of the Kenya's food and serves as the main source of the raw materials for the growing agro-industrial sector. Moreover, agriculture accounts for about 30% of GDP and provides 50 to 60% of total export earnings.

The sector's production base consists of 2.3 million ha of cropped land, 3.8 million ha of meadows and pasture land and 3.7 million ha of forest and wood land. Those occupy only 15% of the total land area (see Table 2.2.2). Only a small part of Kenya's land area is suitable for agriculture or intensive animal husbandry. In terms of rainfall, only 19% of the land is classified as of high- and medium potential categories and can be considered as really suitable to agricultural uses (Table 2.2.3, to be referred).

Land tenure in Kenya has dual character. The bulk of the farming population are peasant farmers who produce mainly staple food crops for subsistence and very little surplus for marketing. On the other hand, there are commercial farmers who has large farms and produce both cash and food crops for local and export markets. The Area under large farms has been reduced under the Government policies to transfer the land from European to African ownership, in the source of which large farms have been divided into small holdings. The Area under large commercial farm,however, still remains large. Small farms are in transition from a subsistence type of agriculture to a commercial type of agriculture.

According to the "Integrated Rural Survey 1976-79" made by CBS in 1981, the number of small holdings is 2.6 million, while less than 4,000 large farms occupy about 20% of the cropped land. Small holdings include 250,000 to 300,000 of landless tenant farmers.

FAO estimate indicates that 2.6 million tons of maize was produced on 1.4 million ha of farm land in 1985 (see Table 2.2.4). Maize shares more than half of the total cropped land and about 60% of cereals production. Coffee, tea, sugar cane, sisal and pyrethrum are important as cash crops . These five (5) crops share about 60% of total marketed production value (Table 2.2.5, to be referred).

Kenya's agricultural production largely fluctuates year by year due to the present agricultural condition characterized by rainfed cultivation and extreme variations in climate (see Table 2.2.4). The extreme variation in climate has not warranted a total self-sufficiency in all years. There are some years in which substantial imports of basic foods are required to meet the domestic deficits (see Table 2.2.7). In Kenya, only 36,000 ha (1.9% of total cropped area) of farms are irrigated.

2.3 National Development Plan

The Fifth National Development Plan for the years of 1984-1988 was published in December 1983. Its theme is mobilization of domestic resources for equitable development. It aims to reduce reliance on external borrowing, to increase the private sector's share of GDP and make the "Districts" focus for development. The plan sets forth 4.8% annual growth target for the 1984-1988 period. It looked over-ambitious, in the light of the disappointing growth performance in the early years of the plan period and also of many problems that remain unresolved. However, the windfall gains from the increase in coffee prices and the drop in the oil price in 1986 could put the plan back on course for 1986-1988.

The Government's long-term strategy is set out in a Sessional Paper No.1 of 1986. It targets a 5.6% annual average growth rate for 1984-2000. The most rapid expansion is to be sought in manufacturing, with an annual growth rate target of 7.2%. The Sessional Paper, however, puts the most emphasis on development of rural sector including non-farming rural activities, as the only means of avoiding foreseeable social problems in the cities by the end of the century. The agricultural sector targets 5.0% annual average growth rate for 1984-2000. The Sessional Paper describes the target is to be achieved mainly through improved productivity and selective expansion of high value crops such as fruits and vegetables. It

also states that the country will strive to reduce the import gap in three major commodities that Kenya imports to meet her national demands; wheat, vegetable oils and rice.

(Unit: %)

Item	1984-1988	1988-2000	1984-2000
Non-monetary GDP	3.5	3.5	3.5
Agriculture	4.2	5.3	5.0
Manufacturing	6.5	7.5	7.2
Trade	5.0	5.5	5.4
Government services	3.7	5.4	5.0
Other sectors	5.2	6.7	6.3
GDP at factor cost	4.8	5.9	5.6
Population	3.8	3.7	3.7
Per capita GDP	1.0	2.1	1.8

2.4 Government Policy on Agricultural Development

2.4.1 National food policy

Over past two decades, Kenya's agricultural production as a whole has been doubled, growing at an average rate of 3.5% per annum, and the country has been able to rely on the agricultural sector for the majority of her basic food requirements in most of years.

In recent years, serious problems have emerged. The rapid expansion of population and unstable production of basic foodstuff are now beginning to expose a potentially dangerous imbalance between national supply of and demand for foods.

Kenyan agricultural production largely fluctuates year by year, due to the present agricultural condition characterized by rainfed cultivation and extreme variation in climate. In the country, only 36,000 ha or about 1.9% of the total farmland are irrigated.

Under such situations the Government has formulated the said Development Plan (1984 - 88) which has given the highest priority to agricultural sector with emphasis on attaining self-sufficiency in food supply. The strategies of increasing food production comprises:

(1) to execute intensification programme one for maize and wheat by introducing improved varieties and proper farming practices under rainfed condition,

(2) to rehabilitate and improve the existing irrigation systems,

(3) to reclaim potential agricultural land, and

(4) to expand irrigation area particularly for rice production.

The Government has emphasized, among other strategies, rehabilitation of the existing irrigation systems and encouragement of small scale irrigation development.

2.4.2 Irrigation development policy

In May 1981, the Ministry of Agriculture established a policy with regard to an accelerated programme on irrigation and drainage development in Kenya. It emphasizes that irrigation, land reclamation by drainage and flood protection are major and attractive alternatives for increased productivity and sizeable expansion of cultivable land to meet ever-growing demand for foods and re-structure the country's agricultural sector as well as to settle people in new land and create substantial employment opportunity.

The Ministry of Water Development has identified that according to the estimate shown in the "National Master Water Plan, 1979", there exists an irrigation potential area of 540,000 ha over the country, as shown below:

(Unit: ha)

Drainage Area	Irrigation Potential
Lake Basin	200,000
Rift Valley	70,000
Athi River Basin	40,000
Tana River Basin	200,000
Ewaso Ngiro Basin	30,000
Total	540,000

The Accelerated Irrigation and Drainage Programme for 1979-2000, envisages irrigation development of 200,000 ha and land reclamation of another 200,000 ha. The irrigation development area includes a total of 35,000 ha by private sectors.

	1984 -88	1989 -93	1994 -98	1999- 2003	1979- 2003	
Irrigation						
NIB	6,000	12,000	20,000	28,000	34,000	100,000
MOA	5,000	8,000	14,000	19,000	19,000	65,000
Private	6,000	8,000	8,000	7,000	6,000	35,000
Total	17,000	28,000	42,000	54,000	59,000	200,000
Land Reclamation						
MOA	5,000	15,000	30,000	60,000	90,000	200,000

It is reported that as of 1984, a total of 24 on-going irrigation Schemes are under operation in the country, having an approximate irrigation area of 36,000 ha in total, which is equivalent to about 7% of total irrigation potential area in Kenya. Irrigated public land, totaling 12,600 ha, is comprised mostly of NIB Schemes (9,500 ha) and various small Schemes (3,100 ha). An additional 23,000 ha of private land are also under irrigation.

Compared to the existing high- and medium-potential land of an estimated 7.5 million ha, the irrigation potential of 0.54 million ha is rather limited and the existing irrigation area of 36,000 ha is totally insignificant.

Although the Government of Kenya intends to realize a sizable irrigation development, the government's irrigation programme has been almost suspended. The major constraints to implementation of irrigation projects are (1) large fund requirement for project implementation and (2) relatively low economic performances in the existing irrigation Schemes (in most of the existing Schemes, large differences between the estimates of project return before implementation and the actual return from the project, are reported) In the Development Plan (1984-1988), the Government has therefore accorded its priority to rehabilitation of the existing irrigation Schemes and encouragement of small-scale irrigation Schemes by gravity flow.

The Government of Kenya, in the long run, strives to develop the irrigation potential of the country through innovative improvement of planning and implementation process as well as of operation and maintenance after implementation.

2.5 Demand and Supply of Rice

The "Scheduled" crops such as rice are marketed under sole responsibility of the National Cereals and Produce Board (NCPB). The total marketed output of milled rice that is sold to NCPB, is around 24,000 tons per annum. About 98% of the total output are produced in the existing NIB irrigation Schemes. The rest (2%) is produced in small rainfed paddy fields privately owned.

In recent years, the country has imported a remarkable quantity of milled rice to meet the ever growing demand for rice. The quantity of imported milled rice is rapidly increasing. It amounted to 44,800 tons in 1983 and 96,200 tons in 1984. Total availability of milled rice to the nation, including the imported, during the period of 1965-1984 is given below:

Year	Marketed Output (tons)	Imports (tons)	Total (tons)	Price Capita Consumption (kg)
1965-70	11,400	1,600	13,000	1.3
1971-75	21,100	2,700	23,800	1.9
1976-80	25,200	2,300	27,500	2.0
1981	27,300	4,600	31,900	2.0
1982	25,600	11,900	37,500	2.1
1983	24,200	44,800	69,000	3.7
1984	24,000	96,200	120,200	6.1

source: (1) Development Plan 1980-85
(2) Statistical Abstract 1986

It is clear that rice consumption has not kept pace with population growth. There is a tendency of the nation to move to rice as a basic food because of the considerable lower energy costs involved in preparing rice compared with traditional crops such as maize. The Ministry of Agriculture predicts that this trend is almost certain to continue and even accelerate as population increases and the energy costs continue to escalate.

During the 1970's, the population grew at an annual rate of 3.4%. The recent estimate given by the Central Bureau of Statistics suggests that the population in the year of 2000 will be 38.5 million compared with 20.5 million in 1986. The assumption that demand for rice is directly related to population increase, suggests that the demand for rice in the

year of 2000 will be in the order of 154,000 tons per annum under average per capita consumption level of 4.0 kg in 1982-84 (see Fig. 2.5.1).

The existing NIB Schemes will not be able to meet this increased demand, if their performance during the last decade is considered. The deficit in rice currently stands at some 58,000 tons (per capita consumption of 4.0 kg/annum is assumed). If the present level of rice production continues, the deficit is likely to reach some 130,000 tons by the year 2000.

The present economic situation of Kenya is unlikely to spend much foreign exchange to make up for the deficit in rice demand from the import of rice. Emphasis on imports of cereals has been placed upon other crops such as maize and wheat. This situation will continue and imports will never satisfy the increased demand for rice.

Under such situations, it is expected that NIB will be able to increase their rice production through every possible effort on expansion of irrigated paddy fields, improvement of present unit yield and introduction of double cropping system (two crops of rice a year).

The Mwea Irrigation Development Project is expected to improve the expected supply-demand imbalance of rice and also to contribute towards the achievement of the Government's goal of self-sufficiency in foods.

2.6 Present Condition of NIB Irrigation Schemes

NIB was established under the Irrigation Act (CAP 347) in 1966. NIB has been responsible for the development, control and improvement of all the national irrigation Schemes in Kenya. Since its establishment, NIB performed its functions under the Ministry responsible for agriculture and animal husbandry up to June 1987 when NIB was transferred to the Ministry of Energy and Regional Development in July 1987.

At present, NIB is responsible for the operation of the following six (6) irrigation Schemes:

Scheme	Area (ha)	Nos.of Farmers	Crops
Mwea	5,860	3,236	Rice
Ahero	1,070	519	Rice
West Kano	670	553	Rice & Sugar cane
Bunyala	210	131	Rice
Perkerra	100	342	Vegetables
Tana	830	603	Cotton
Total	8,710	5,384	Rice (7,560 ha) Others (1,150 ha)

NIB is operating four (4) rice Schemes with a total area of 7,560 ha. NIB supplies the tenant farmers with various services such as land preparation as well as supply of irrigation water, fertilizer, insecticides and transport. All these services have to be paid by the farmers at a fixed rate, sometimes somewhat lower than the actual costs. The farmers get these services as an advance on the payment of the harvested crops. The farmers have been selected and settled by NIB and are called as "tenants" in these Schemes. Each tenant farmer has been given 3-4 acres (1.2-1.6 ha) of the irrigated land on rent. At present, most farmers are making the higher revenues on their land than the neighboring small peasants.

The following shows the income and expenditure account for the NIB Schemes in the year of 1985/86:

INCOME AND EXPENDITURE FOR THE YEAR OF 1985/86

(Unit: KShs.1,000)

Scheme	Income	Expenditures	Balance
Mwea	29,542	28,069	1,473
Ahero	4,133	8,647	-4,514
West Kano	870	7,970	-7,100
Bunyala	788	2,421	-1,633
Perkerra	948	5,351	-4,403
Tana	2,839	10,019	-7,180
Total	39,120	62,477	-23,357

Only the Mwea Irrigation Settlement Scheme is self-supporting and the other five (5) Schemes depend their financial deficits on the Government subsidies. The current features of the NIB Schemes are summarized in Table 2.6.1. Details of the income and expenditure account in 1985/86 for the NIB Schemes are shown in Table 2.6.2. The income and expenditure account for the Mwea Irrigation Settlement Scheme over the past 10 years are also given in Table 2.6.3.

CHAPTER III PRESENT CONDITION OF THE STUDY AREA

3.1 Location

The Study Area is located near Embu in the eastern part of Central Province of Kenya, with a total area of 16,000 ha (see LOCATION MAP). It extends over the flat land on the outskirts of Mt. Kenya, being situated between 1,100 m and 1,200 m above the sea level. The Study Area stretches between latitudes 0°37'S and 0°45'S and longitudes 37°14'E and 37°26'E. The Study Area administratively belongs to Kirinyaga District. The administrative boundary of the Study Area is shown in Fig. 3.1.1.

3.2 Topography and River System

The Study Area has gently undulating relief. Broad ridges with slight slopes are interspersed and stretch down to almost flat bottom-lands in the Mwea plain. The Average slope in the direction of northwest to southeast is about 1:140.

The major rivers flowing down through the Study Area are the Nyamindi, the Thiba and the Ruamuthambi, which are to be considered as stable water sources for irrigation. In addition to the above major rivers, some small streams such as the Kiwe, the Murubara and the Nyaikungu also run across the Study Area. These small streams are partly utilized as minor irrigation water sources and/or natural drains.

The Tana river running nearby is also potential water source for irrigation development.

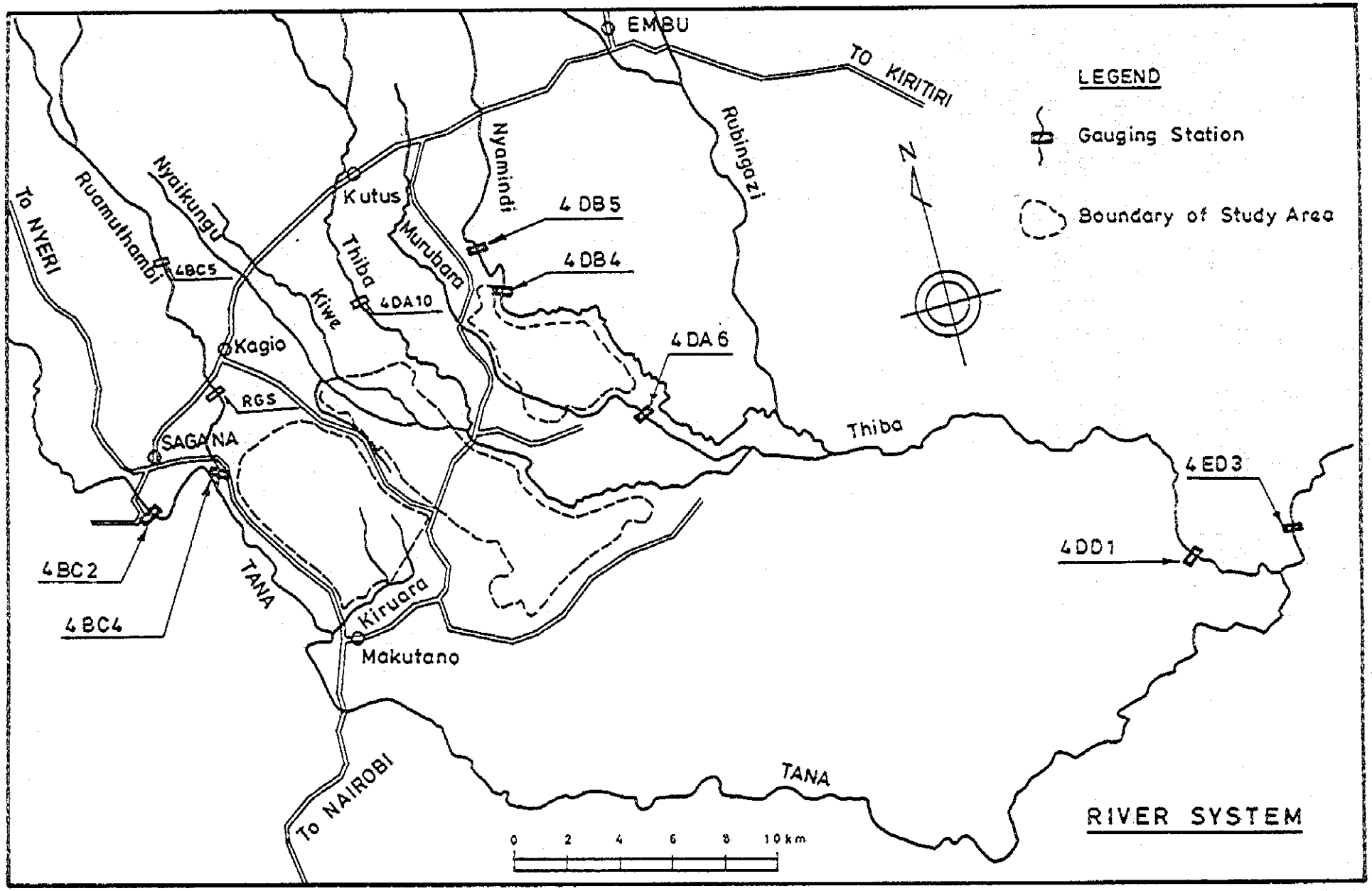
The river systems in the Study Area are summarized as follows (attached Figure, to be referred):

(1) Tana river

The Tana is the main river originating from the western slopes of Mt. Kenya. It has a drainage area of 2,365 km^2 at the gauging station 4BC2 and 9,324 km^2 at 4ED3.

(2) Thiba river

The Thiba is a tributary of the Tana and has a drainage area of 353 km^2 at the gauging station 4DA10 and 2,616 km^2 at 4DD1.


EMBU
TO KIRITIRI
LEGEND
Gauging Station
Boundary of Study Area
N
Rubingazi
Nyamindi
Nyaikungu
Ruamuthambi
To NYERI
Kutus
Murubara
Thiba
Kiwe
4DB5
4DB4
4BC5
4DA10
4DA6
Kagio
RGS
SAGANA
Thiba
4ED3
4DD1
4BC2
4BC4
TANA
Kiruara
Makutano
To NAIROBI
TANA
0 2 4 6 8 10km
RIVER SYSTEM

(3) Nyamindi river

The Nyamindi is the secondary tributary of the Tana. The drainage area of the Nyamindi is 283 km² at the gauging station of 4DB5.

(4) Ruamuthambi river

The Ruamuthambi is also a tributary of the Tana and has a drainage area of 86 km² at the gauging station of 4BC5.

(5) Small streams

a. Murubara river
The Murubara is a tributary of the Thiba and has a drainage area of 80 km² at the gauging station 4DA6.

b. Kiwe river
The Kiwe is also a tributary of the Thiba. The river crosses under the Thiba main canal and flows down to the Thiba river along the northern boundary of the existing MIS Scheme. The confluence is about 4 km upstream of the rubble weir from which irrigation water is taken to the Unit T-20.

c. Nyaikungu river
The Nyaikungu is also a tributary of the Thiba river. The original river course ran across the existing MIS Scheme area before the Scheme had been developed. The Nyaikungu river has been dammed up to create a small reservoir at its upstream part and the impounded water is supplied to the Thiba main canal through a gate. The excess water is drained through the waterway connecting to the Kiwe. The lower part of the Nyaikungu river up to the confluence with the Thiba functions as a natural drainage channel.

d. Kiruara river
Kiruara river is a tributary of the Tana. The river runs along the western boundary of the existing MIS Scheme and across the Mutithi extension area. It functions as a drainage canal.

3.3 Climate

The seasons of the East African climate are controlled by the northward and southward movement of the sun across the equator. The latitude of greatest heating occurs where the sun is directly overhead and results in a zone of low pressure. This zone is referred to variously as the Heat Trough, Equatorial Trough or Intertropical Convergence Zone. Climate, as the synthesis of weather on a time-integrated scale, can be explained in terms of movements of this zone, which is believed to lag behind the sun's position by four to six weeks. Thus, while the sun is directly overhead in Kenya during March and again in September, the two rainy seasons occur in late April through May and late October through November.

In these circumstances, the climate of the Study Area is defined as tropical with equatorial and medium high altitude characters, and which climatic conditions are dominated by the seasonal monsoons.

The monthly meteorological data of the Study Area are shown in Table 3.3.1 and Fig. 3.3.1.

(1) Rainfall

The rainfall pattern in the Study Area is characterized by bimodal rainy seasons: the long rain period from March to May and the short rain period from October to November. An annual mean rainfall is about 930 mm, out of which about 510 mm concentrates in the long rain period and 290 mm in the short rain period as shown below:

Average Rainfall, 1978-1986

(Unit: mm)

Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
21	12	94	281	137	12	6	7	17	142	147	50	926

(2) Temperature

The mean temperature is about 22°C over the year with mean monthly maximum in March (just over 31°C) and minimum in January (just under 15°C).

Average Temperature, 1978-1986

(Unit: °C)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
Max.	29.4	31.0	31.6	28.9	27.3	25.8	25.2	26.1	28.4	29.4	27.6	27.6	28.2
Min.	14.9	15.6	17.2	18.3	17.8	16.5	15.8	16.0	16.8	17.5	17.0	15.9	16.6
Mean	22.2	23.2	23.7	23.4	22.7	21.2	20.4	20.9	22.7	23.4	22.4	21.5	22.3

3.4 Hydrology

3.4.1 Rainfall

There exist seven (7) rain gauge stations in the river basin. The average annual rainfall at each rain gauge station above is as follows:

No.	Rain Gauge Station	Altitude (m)	Annual Rain Fall (mm)
1	Castle Forest	2,100	2,100
2	Lower Kamweti Forest	1,700	1,800
3	Kerugoya Water Development	1,500	1,500
4	Kianyaga	1,500	1,300
5	Njukiini Forest	1,400	1,200
6	Murinduko Forest	1,400	1,000
7	Sagana Fish Culture Farm	1,200	1,100

3.4.2 River discharge

The annual mean discharges at following discharge gauging station are as follows:

River	Station Name	Drainage Area (km^2)	Annual Mean Discharge (m^3/sec)
Thiba	4DA10	353	11.8
Nyamindi	4DB5	283	6.6
Ruamuthambi	4BC5	86	2.1

(1) Basic year for water resources assessment

The basic year for assessment of water resources is to be 1/5 drought year. For the selection of 1/5 drought year, analysis was made on the following three (3) hydrological data.

a. Areal rainfall in the river basin,
b. Discharges of the Thiba and Nyamindi rivers, and
c. Rainfall in the irrigation area.

The probability analysis on the above three hydrological data for the period of recent 10 years from 1977 to 1986, indicates that, in all cases, the drought year with 5 year return period is 1980. The assessment of water resources is therefore made for the discharge data in the year of 1980.

(2) 1/5 drought discharges

The 1/5 drought discharges of the relevant rivers (1980) are given below:

(Unit: m^3/sec)

Month	Thiba (4DA10)			Nyamindi (4DB5)			Ruamuthambi (RGS)		
	E	M	L	E	M	L	E	M	L
Jan.	4.96	4.44	4.75	2.81	2.45	2.60	1.73	1.30	1.50
Feb.	4.57	3.68	4.24	3.24	2.65	1.98	1.38	1.09	0.98
Mar.	5.72	5.56	5.35	3.15	2.62	2.22	0.96	0.87	0.85
Apr.	5.52	5.75	7.19	3.28	5.18	8.48	1.13	1.34	2.11
May.	7.17	12.84	11.53	15.79	13.88	7.12	2.91	2.69	1.92
Jun.	9.16	7.94	6.98	5.36	4.01	3.29	1.51	1.23	1.12
Jul.	6.83	6.18	5.85	3.01	2.97	2.83	1.33	1.20	1.12
Aug.	7.12	7.77	7.64	3.00	10.22	5.15	1.65	2.51	1.81
Sep.	7.03	6.37	5.59	3.59	3.52	4.41	1.53	1.18	1.25
Oct.	4.84	4.94	6.62	9.03	3.91	6.25	1.10	0.99	2.28
Nov.	9.07	12.15	12.61	7.58	10.22	9.30	3.17	4.90	2.98
Dec.	9.02	7.90	8.01	5.71	4.99	4.25	2.53	2.57	2.01

3.4.3 Water quality

The water quality analysis for the following rivers and canals were carried out both in the first and the second stages under the contract with Surtech Ltd.:

No.	Sampling Place	Stage
1	- Nyamindi existing headworks	1st & 2nd
2	- Murubara culvert	1st & 2nd
3	- Thiba existing headworks	1st & 2nd
4	- Kiwe river just upstream of cross drain with Thiba main canal	1st & 2nd
5	- Ruamuthambi river at bridge of trunk road B20/1	1st & 2nd
6	- B.P. of Kiruara main drain	1st & 2nd
7	- B.P. of Thiba main drain - I	1st & 2nd
8	- Thiba river just upstream of conference with Thiba main drain - I	1st
	- Tana river at Sagana bridge	2nd
9	- B.P. of Nyamindi main drain - II	1st & 2nd
10	- Murubara river just upstream of conference with Nyamindi main drain - II	1st & 2nd

As a result of the analysis, all the water are favourable for irrigation.

3.4.4 Load transports

The sampling of suspended load and bed load was carried out during the last rainy season from April to June at 4DB5 of the Nyamindi and RGS of the Ruamuthambi. The sampling at 4DA10 of the Thiba was made in September after completion of the temporary bridge for observation. The analysis results are as follows:

Place	Catchment Area (km^2)	Suspended Load (m^3/year)	Bed Load (m^3/year)
4DB5	283	6,300	100
RGS	117	12,700	10
4DA10	353	6,500	180

3.4.5 Flood

The flood with five (5)-year return period at 4DA10 of the Thiba and 4DB5 of the Nyamindi were estimated by the simulation of Storage Function Method as follows:

Description	4DA10	4DB5
Design rainfall (mm/day)	120	120
Base flow (m^3/sec)	40	15
Peak flow (m^3/sec)	145	185
Discharge at 70% of peak (m^3/sec)	100	130
Flood duration of 70% of peak (hrs.)	5	3

3.4.6 Water right

The water rights of rivers concerned are as follows:

a. Thiba river

(Unit: m^3/sec)

Section	Water Right
Upstream of proposed dam	1.33
Proposed dam to existing headworks	0.29
Downstream of existing headworks	0.35
Total	1.97

b. Nyamindi river

(Unit: m^3/sec)

Section	Water Right
Upstream of proposed new headworks	0.49
Downstream of proposed new headworks	0.02
Total	0.51

c. Ruamuthambi river

(Unit: m^3/sec)

Section	Water Right
Upstream of proposed headworks	0.32
Downstream of proposed headworks	0.15
Total	0.47

d. Tana river

The Tana Power Station of Kenya Power and Lighting Co., Ltd. has been granted by the Ministry of Water Development the water right to use the full of the normal flow and 17 m^3/sec (610 cusec) of flood flow.

3.5 Geology and Soil Mechanics

3.5.1 Geological condition

The Cenozoic volcanic materials cover the whole Study Area on the basement of gneisses. The following volcanic rocks are observed in the Study Area:

Rocks	Distribution
Gneisses (Archean)	Right bank area of the Tana river
Basalts (Pleistocene)	Almost whole Study Area
Agglomerates (Tertiary)	Southern outside of the Study Area
Tuffs (Tertiary)	Western and northern outside of the Study Area
Phonolites (Tertiary)	Left bank area of the Nyamindi river

The distribution of these rocks is illustrated on Fig. 3.5.1 (Geological Map).

(1) Geological conditions at damsites

(a) Nyamindi damsite

The Pleistocene basalts and Tertiary phonolites are observed around the Nyamindi damsite. The basalts extensively develop over the prospective reservoir area in southeast-northwest direction. The phonolites occur, on the other, on northern and northeastern part of the prospective reservoir area. In general, particularly around the prospective dam axis, the completely weathered pyroclastic materials (mainly soil-like weathered tuffs) cover these base rocks with an average thickness of 10-20 m.

(b) Thiba damsite

The Pleistocene basalts and Tertiary agglomerates are developed around the Thiba damsite. The completely weathered pyroclastic materials (mainly soil-like weathered tuffs) are observed over these basement rocks with an average thickness of 10-20 m. The completely weathered agglomerates with a thickness of 4 m are observed between Pleistocene basalts and Tertiary agglomerates which constitute the foundation rocks.

(2) Geological conditions at major structure sites

The geological conditions at other major structural sites are summarized as follows:

Structure	Geological Condition
New Nyamindi Headworks	The Pleistocene basalts are outcropped on the river bed.
Ruamuthambi Headworks	The Pleistocene basalts are outcropped on the river bed and a thin layer of terrace deposits is observed on flat both banks.
Murubara Syphon	Muddy soils are accumulated on the foundation rocks of Pleistocene basalts.
Nyamindi Division Works	The Pleistocene basalts are outcropped at the site.

In general, the proposed major structural sites have no special problem from the viewpoint of engineering geology.

3.5.2 Soil mechanics

(1) Black cotton soils

The black cotton soils have generally high moisture contents, and they shrink and make deep open cracks when they are dried, and on the contrary, they swell when they are wet. Canal side slopes composed of the black cotton soils are likely to slide down due to seasonal alteration of shrinking and swelling.

(2) Red soils

The moisture content of the red soils is generally low, compared to the black cotton soils. The bearing capacity of the red soils is around $Q_a = 20$ t/m^2. The red soils are generally permeable with a coefficient of permeability of $(n \times 10^{-4})$ and are cohesionless; therefore, canal side slopes of the red soils are likely to be eroded.

(3) Embankment materials

(a) Canal and road construction

The following sites are considered suitable as the borrow pits, and their endowed volumes are sufficient for the estimated requirement.

(i) Hill near Nyangati village located outside of northern boundary of the Study Area, and

(ii) Kiarukungu village situated at the center of the Study Area.

(b) Aggregates

The present survey results suggest that the favourable quarry sites for both fine and coarse aggregate are not to be found in and near around the Study Area.

Therefore, it is to be considered as one alternative to use crushed sand and stone produced from bed rock existing over the whole Study Area.

(c) Borrow sites for dam construction

The proposed borrow site for the Thiba dam is located at 1 km upstream, and for the Nyamindi dam at 1 km upstream. The estimated endowed volumes are as follows:

(i) Nyamindi dam

Earth materials	:	3.6 MCM
Rock materials	:	1.8 MCM

(ii) Thiba dam

Earth materials	:	2.0 MCM
Rock materials	:	1.5 MCM

3.6 Soil and Land Use

(1) Soil classification

Soils of the Study Area are broadly divided into the following six (6) soil groups:

(1) Pellic VERTISOLS - Black Cotton Soils
   a. Typical black cotton soils
   b. Shallow stony black cotton soils

(2) Verto-eutric NITOSOLS - Red Soils
   c. Typical red soils
   d. Brownish red soils

(3) LITHOSOLS - extremely shallow soils

(4) HISTOSOLS - Swampy peat soils

Major soils of the Study Area are typical types of black cotton soils and brownish red soils. These soils are mostly suitable for irrigation. Other soils are not suitable for irrigation development due to poor soil nature and undulating topography.

The soil map prepared according to the classification is given on Fig. 3.6.1. The extent of each soil is as follows:

(Unit: ha)

	MIS	Mutithi	Total
Typical black cotton soils	8,500	2,900	11,400
Shallow, stony black cotton soils	700	100	800
Typical red soils	750	400	1,150
Brownish red soils	2,000	550	2,550
Lithosols (extremely shallow soils)	-	20	20
Swampy peat soils	50	30	80
Total	12,000	4,000	16,000

Major characteristics of each soil group are summarized as follows:

The typical black cotton soils are black coloured clayey soils which are characterized by deep cracks at the surface when

they are dried. These soils are commonly planted with rice under irrigation. Non-irrigated typical black cotton soils are generally left fallow or utilized for cattle grazing.

The stony black cotton soils have shallow soil depth with gravels and stones. These soils are not irrigable and therefore left unutilized.

The typical red soils are well-drained, red to reddish brown coloured, deep, and clay to clay loam textured. These soils are not irrigable mainly due to excess permeability and steep slopes where the soils are developed. The residential areas are generally located on these soils.

The brownish red soils are of transitional type between the red soils and black cotton soils. The soils are well to moderately well drained, dark reddish brown to dark brown coloured, deep, loamy to clayey textured. The soils are highly cultivated with various crops. Some part of the soils in the existing MIS Scheme area is put under irrigation for cultivation of vegetables.

Lithosols (extremely shallow soils) are observed along the Kiruara river in the southernmost part of the Mutithi extension area. The surface of the soils is almost bare with very few plant cover. The soils are not suitable for agricultural purpose. The distribution of these soils is however negligibly small.

Swampy peat soils are also found in the southernmost part of the Mutithi extension area. The soils are poorly drained, having deep, gray coloured organic layer, and are not suitable for agricultural purpose. The Area of the soils is not extensive.

(2) Soil physical and chemical properties

Soil samples are analyzed in the laboratory of local contractor, Surtech Ltd. The results are shown in Table 3.6.1.

The pH value ranges from 6.30 to 8.40, and the black cotton soils show relatively high value. The Cation Exchange Capacity (CEC) of the soils is generally high, ranging from 25.2 to 132.0. The black cotton soils have a higher value of CEC, and the exchangeable Ca and Mg are also high.

Soil texture is classified into Clay (C), Silty Clay (SiC), Silty Clay Loam (SiCL), Sandy Clay Loam (SCL) and Silt Loam

(SiL). Most of the black cotton soils are classified into Clay (C), and other soils are very variable.

(3) Land use

Several types of land use such as rice field, other cropland, grassland, forest and villages are observed in the Study Area, as indicated on the land use map (see Fig. 3.6.2).

The extent of each land use type is as follows:

(Unit: ha)

	MIS	Mutithi Extension Area	Total
Rice Field	6,900	-	6,900
Upland Field	2,200	1,600	3,800
Grass Land	2,200	2,400	4,600
Villages & others	700	-	700
Total	12,000	4,000	16,000

3.7 Infrastructures

The Study Area is connected with Nairobi and other major towns by asphalt-paved National Trunk Roads B6-B20/1. In the Study Area, the national trunk road of B6 runs in north-south direction and road network of secondary class is well-developed, branching off from the major national roads, B6 and/or B20/1. The Mutithi extension area is less served by the present road network. In MIS area, about 60 km of settlement roads have been constructed and are connected with major national roads.

The Study Area except Mutithi extension has received major public services such as electricity supplies, post and telephone services, hospitals, schools, etc. The Area should not be recognized as one of the remote rural areas. The current problem in infrastructure might be lack of domestic water supply system. Most of the farmers usually use the water in irrigation canals without any treatment. Shallow wells are also one of domestic water supply sources. Water quality of shallow wells has not been guaranteed.

3.8 Existing Irrigation and Drainage System

3.8.1 Mwea Irrigation Settlement Scheme

(1) Scheme Area

The Mwea Irrigation Settlement (MIS) Scheme area is divided into two parts, i.e. Nyamindi part and Thiba part (Fig. 3.8.1, to be referred). Nyamindi part has only one section, Tebere Section. Thiba part is composed of four (4) sections; Mwea, Thiba, Wamumu and Karaba Sections. Furthermore, each section comprises some units.

The Scheme, having the gross area of about 11,600 ha, includes the existing irrigation area of 6,900 ha in gross or 5,860 ha in net which have been put under rice cultivation. The other area of the Scheme comprises upland crop area, unirrigable area, residential areas and roads. The irrigation area of each section is summarized below (for details, see Table 3.8.1):

(Unit: ha)

Section	Irrigation Area		Other Area	Total
	Net	Gross	Gross	Gross
Nyamindi part				
Tebere	1,300	1,600	1,700	3,300
Thiba part				
Mwea	1,220	1,400	900	2,300
Thiba	1,150	1,400	900	2,300
Wamumu	1,120	1,300	500	1,800
Karaba	1,070	1,200	700	1,900
Total	5,860	6,900	4,700	11,600

(2) Irrigation system

The existing MIS Scheme has two (2) different irrigation systems which are dependent on the water supply of two major rivers, Nyamindi river and Thiba river.

Nyamindi irrigation system consists of a unit of headworks, a main canal, three (3) branch canals and related structures, and supplies the water to Tebere section.

Thiba irrigation system comprises a unit of headworks, a main canal, four (4) branch canals and related structures, and