distributes the water to Mwea, Thiba, Wamumu and Karaba sections. A rubble weir is established about 10 km downstream from Thiba headworks for supply of water to unit T20 in Tebere section.

The irrigation water taken from offtakes in main and branch canals runs through a main feeder canal in Unit to respective feeder canals which in their turn distribute the water to the individual fields.

(3) Drainage system

The Scheme has four (4) rivers which act as drains, i.e. Nyamindi, Murubara, Thiba and Kiruara rivers. Some units which are located along the river, have field drains flowing directly into the river.

There are three (3) main drains in Nyamindi system which collect the water from two or more units and evacuate the water to one of above rivers. Thiba system has five (5) main drains and two (2) branch drains. The downstream parts of the Mukou and Nyaikungu river are used as main drain-III and -IV.

Field drain runs almost along the opposite side of field to feeder canal. Drainage water from field drain is collected in a collector drain and is evacuated out of Unit.

The irrigation and drainage diagrams of the existing MIS area are presented in Fig. 3.8.2 and Fig. 3.8.3.

3.8.2 Irrigation and drainage facilities

The major existing irrigation and drainage facilities are classified as follows:

(1) Nyamindi headworks
(2) Thiba headworks
(3) Irrigation and drainage canals
(4) Irrigation and drainage related structures
(5) Farm roads
(6) On-farm facilities

The present conditions of the above facilities are described hereinafter:

(1) Nyamindi headworks

Nyamindi headworks was completed in 1956 and commands the irrigation area of Tebere section. The headworks is constructed on stable rock foundation and properly maintained. It is not subject to much deterioration from structural viewpoint.

However, the protection works for side slopes are much deteriorated or disappeared upstream and downstream of headworks. The existing scouring sluiceway is prevented from its proper function for flashing out the siltation since there is retaining wall just in front of the scouring sluiceway.

(2) Thiba headworks

Thiba headworks was completed in 1957 and distributes the irrigation water to Mwea, Thiba, Wamumu and Karaba sections.

The headworks is provided at suitable location with stable rock foundation and well functioned. The protection works of side slopes are destroyed and sedimentation is found on left side upstream of the weir.

(3) Irrigation and drainage canals

Nyamindi system has a main, three (3) branch irrigation canals and three (3) main drains. In Thiba system, there are a main, four (4) branch irrigation canals, five (5) main and two (2) branch drains as shown in Fig. 3.8.1.

The total length of irrigation and drainage canals is summarized as follows:

(Unit: km)

Canal Name	Nyamindi System	Thiba System
a. Main irrigation canal	4.5	12.4
b. Branch irrigation canals	16.6	30.2
c. Main drains	5.9	23.5
d. Branch drains	-	3.4

The type of both irrigation and drainage canals are unlined open channel with trapezoidal section.

Both side slopes of irrigation and drainage canals are eroded to some extent in most routes of canals. As result of the

side slope erosion, the irrigation canals are silted in large part of canal routes.In addition, the irrigation canals especially in Nyamindi system are covered by thick weeds to some extent.

In connection with drainage canals, canals are also silted by eroded soils of side slopes and canal bottom is shallowed. The downstream of cross sections of some drains become smaller than those of the upstream.

(4) Related structures

Many kinds of related irrigation structures are provided for distribution of irrigation water, regulation of discharge and water level and crossing with road and rivers.

The major related structures provided in irrigation canals are listed below:

- Turnout or offtake
- Check structure and horse shoe weir
- Drop and chute
- Culvert and bridge
- Concrete flume and washing step
- Spillway and cross drain
- Parshall flume and cipolletti weir

According to inventory survey, the total numbers of the existing irrigation related structures are about 350, out of which about 35% are seriously deteriorated as shown in Table 3.8.2 and necessitate the rehabilitation.

Some kinds of re-use structures exist in the MIS area and most of them are deteriorated or are not equipped with control structures for the effective re-use of return flow from paddy fields.

Four (4) kinds of related drainage structures such as culverts, drops, drainage inlets and checks are provided at crossing with road, regulating the water level and protecting canals. The total numbers of drainage related structures are about 50, among which about 55% are considerably deteriorated as shown in Table 3.8.3 and need the rehabilitation.

(5) Farm roads

Farm roads in the Scheme are sufficiently developed with enough width. However the ground level of roads are mostly

lower than that of the paddy field. The roads are sometimes flooded by overflow from the canals and interrupt the smooth traffic conditions.

(6) On-farm facilities

On-farm facilities consist of the following components:

a Main feeder canal and feeder canal

b. Collector drain and field drain

c. Related structures such as offtake with check, culvert, check with drop, field inlet and outlet.

d. On-farm roads

According to the inventory survey, main feeder and feeder canals are properly maintained. Field drain and collector drain are more or less silted. About 40% of check structures in a unit, on an average, are collapsed and need the rehabilitation. Other facilities are well functioned and properly maintained.

On-farm roads are well developed in each Unit. However, the roads in black cotton soils are prevented from smooth traffic due to the characteristics of the soils which become muddy in the rainy season and cracked in the dry season.

3.8.3 Present water management

(1) Organization set-up for water management

The organizational set-up of MIS Scheme is described in Section 3.9.1. The MIS tenant farmers are granted the licences from NIB to stay within the MIS Scheme area and cultivate the irrigated paddy of 4 acres (1.6 ha), provided that they have to follow the instructions from the NIB management. Individual farmer is not allowed to cultivate, by his own idea, the allocated paddy fields. Water management is therefore made by the MIS staff, not the farmers.

MIS has 320 staff in total, comprising 20 senior staff, 150 intermediate and 150 subordinates, out of which the staff for water management is limited to only 42 as of 1987.

In the MIS headquarters, the Department of Works is responsible for the allocation and distribution of water and maintenance of irrigation facilities.

The MIS is divided into five (5) sections, each of which is self-contained with its staff responsible for water management. Each section has an Irrigation Officer in charge assisted by a Head Field Assistant, 5-7 Field Assistants, a Head water guard, 7-8 Water guards and other intermediate and subordinates. The liaison with the tenant farmers is maintained via the head cultivator who represents the farmers.

The irrigation officer is a senior staff under the Production Department and is responsible for preparation of cropping schedule in his section. He asks the Scheme Manager to allocate the irrigation water based on his cropping schedule. The Scheme Manager informs his decision to the weir inspector through the Department of Works.

The weir inspector prepares, in accordance with the directive from the Scheme Manager, the irrigation schedule on the basis of his experiences and makes gate operations at the headworks by himself accordingly and gives the necessary instructions to the head water guard for operations of all the gates in each section.

The head water guard is responsible for the gate operations in his section. No one else can open the gates along the main and branch canals. The water guard is allocated his respective irrigation units in charge and responsible for application of irrigation water to the fields.

(2) Canal discharge measurement

There are installed many measuring devices in whole area of the MIS Scheme. Generally speaking however those devices are not effectively utilized at present. For example, in Thiba part existing measurement devices are only 13 nos. which are now being used out of 25 existing devices.

(3) Facilities maintenance

MIS management is concentrated on the operation works and rice production, and the maintenance works for irrigation and drainage facilities are not at present taken care. The maintenance works for irrigation and drainage facilities are composed of repairing, desilting and removal of weeds. The removal of weed on feeder canals and levee of paddy field is carried out periodically by farmers. The desilting and removal of weeds on main and branch irrigation canals are conducted intermittently. However, the other maintenance works for

irrigation canals are not a little performed. The drainage canals are not maintained at all.

3.9 Present MIS Operational Activities

3.9.1 Organization set-up

The Mwea Irrigation Settlement (MIS) Scheme office has following eight (8) departments as shown in Fig. 3.9.1.

(a) Production
(b) Research
(c) Workshop
(d) Construction Maintenance Operation
(e) Building Maintenance Construction
(f) Works
(g) Mainstores
(h) Health and Nutrition

A total of 320 staff are working in various fields under the office. The MIS staff comprises 16 senior staff, 152 junior staff and 152 subordinates.

Each section has an irrigation officer who controls the management of rice production in respective section. Each section is staffed with Head Field Assistant, Field Assistant, Head Water Guard and Water Guard.

All of the farmers in MIS are so-called "Tenants" who have settled under the Irrigation Regulation, 1977. The number of the tenant farmers is gradually increased with expansion of irrigated paddy field, and as of 1986, the tenant farmers total 3,236 as shown in Table 3.9.1.

The tenant farmers communicate with MIS Office and NIB Management through:

(a) Mwea Irrigation Scheme Committee
(b) Mwea Irrigation Scheme Sub-Committee
(c) Tenants Advisory Committee
(d) Tenants Liaison Council
(e) Tenants Meeting

In the meetings of the above, major operational issues are discussed (see ANNEX VII, 1.1.1).

3.9.2 Operational regulation

Activities of MIS and tenant farmers are regulated under the Irrigation Act (Cap.347). Major regulations concerned with farming practices are as follows:

(1) Regulations for MIS Office

a. MIS office supplies following services to the tenant farmers

- to rotavate the rice field for tenant farmers by tractors,
- to provide the tenant farmers with farm inputs such as fertilizer and insecticide.

b. MIS office purchases necessary farm inputs through NIB head office and distribute them to each tenant farmer.

c. MIS office is responsible for collection of the harvested paddy, drying, re-bagging and sales to the National Cereals and Produce Board (NCPB). MIS office collects the payments for the sales of paddy on behalf of the farmers and makes payments to each farmer, deducting the service charge and costs of farm inputs that the farmer had used for production of his paddy.

(2) Regulations for tenant farmers

a. Tenant farmers follow Irrigation Regulation, 1977 and all instructions given by MIS office.

b. Tenant farmers deliver all paddy harvested to MIS reception centre. The farmers are, however, allowed to keep some bags of paddy for their own consumption with permission from the office.

c. Tenant farmers maintain at all times for his holding and all field feeders and drainage channels to satisfactory.

d. Tenant farmers are not allowed to hire or employ stock/machinery for cultural operations. The farmers are requested to accept all the services offered by MIS office.

3.9.3 Farming practices

(1) Farming practices

Farming practices are conducted according to the cropping programme prepared by MIS office (see Fig. 3.9.2).

a. Land Preparation

During 1957-1960, the field was dry - ploughed using oxen-drawn mouldboard plough, followed by flooding and levelled in wet by dragging a fineless levelling board several times over the field.

In 1960, 6 tractors were first introduced to MIS, and thereafter, mechanical rotavation has been carried out with about 30 tractors (See ANNEX-VII). The fields are given a pre-rotavation flooding of about 10 cm of water and rotavated within three days of the flooding. Pre-rotavation flooding for longer periods is likely to result in bogging down of tractors.

Generally, the rotavation begins in March and it continues through to August. In each Section the farmers are organized into four rotavation groups. Group I rotavates first in beginning of March and group IV rotavates last (July/August). The farmers rotate through the groups with time. Sowing in the nurseries is done according to the rotavation groups and this begins in mid-July with almost weekly intervals between the groups. Transplanting is usually done four weeks later (25 to 28 days). The farmers in Group I plant first and farmers in Group IV plant last. The pre-planting flooding periods for the various groups vary as follows:

Group I	:	160-95 days
Group II	:	100-55 days
Group III	:	65-40 days
Group IV	:	4-30 days

b. Nursery Preparation

Each tenant farmer seeds their own nursery to cater for his holding paddy field. The nursery measures about one-sixteenth of the holding. The nursery is usually prepared manually. The seeds are broadcasted at the rate of 18 kg/per each quarter of the nursery, a total

of 72 kg of seeds per four (4) acre holding. Nitrogen is also broadcasted at the sowing time at the rate of 25 kg N in each holding's nursery.

After sowing the water level in the nursery is increased gradually following the growth of the seedlings up to a depth of about 5 cm.

c. Transplanting

It has been recommended that transplanting be made at a spacing of 10 cm x 10 cm with one seedling per hill. Transplanting is usually done during the school holidays in August, and with hired labour transplanting a holding (4 acres) takes 4-5 days. For a man and his wife only, it takes them up to 5 days to complete transplanting one acre.

d. Fertilizer Application

Nitrogen is applied before transplanting by broadcasting, in the form of sulphate of ammonia at the rate of one bag of 50 kg per acre (26 kg N/ha). Triple superphosphate is also applied before transplanting at the rate of one bag of 50 kg per acre (57.5 kg P_2O_5/ha).

Top dressing with nitrogen is recommended at 42 days after transplanting. Thus the total amount of nitrogen applied per crop is 52 kg N/ha.

No potassium response has been realized at MIS and, therefore, its application is not recommended.

e. Field Maintenance

After transplanting, the water level in fields is increased as required, and it normally does not exceed 10 cm in depth. The water stands in the fields throughout the growing period.

Besides the water control in the fields, other operations such as bird scaring, top dressing and weeding are conducted from time to time when required. Minor cases of damage by insect such as leaf minor, stem borer, leaf eating caterpillars are occasionally noticed and effectively controlled by spraying Sumithion or Furadan.

f. Pre-harvesting Drainage

After transplanting, the water level is maintained up to the ripening stage of the rice plant. Before harvesting the fields are drained and dried out for three to four weeks.

g. Harvesting

After cutting, threshing by beating, wind-winnowing and bagging are carried out in the harvested fields before the bags of paddy are collected and transported to the reception centre. Casual labour is usually employed for harvesting.

After harvesting it has been recommended that the paddy straw be evenly spread over the fields and then be burned. Not all the farmers follow this instruction.

3.9.4 Rice production

Since MIS started rice production in 1957, rice production increased about 2.3 times from 10,887 tons (1960/61) to 26,408 tons (1985/86) with expansion of the paddy fields (Refer ANNEX-VII, Section 1.1.4). Unit yield per ha, however, has been decreasing gradually from 6.0 tons level in early 1970's to 5.0 tons level in early 1980's.

Large variation in unit yield between units is observed according to using rice production records in each unit for the period from 1974/75 to 1983/84 (Refer Section 1.1.4, ANNEX-VII).

Large variation in unit yield is also observed between tenant farmers. In 1984/85, about 14% of farmers harvested only less than 15 bags per acre (2.8 tons/ha); on the other, about 16% of the farmers got more than 35 bags/acre (6.5 tons/ha) (See Table VII-5, ANNEX-VII).

Reasons for the large variations in unit yield have not been clearly identified yet.

3.9.5 Farm economy of tenant farmers

Table 3.9.2 shows crop budget for two major varieties, Sindano and Basmati at an average level of production in the years 1982/83-1985/86. Sindano is more profitable than Basmati at the present level of government price, KShs.3.00/kg for Sindano and KShs.4.00/kg for Basmati. High rate of increase in

farm input costs has worsened the profitability of rice cultivation. Present actual income in 1985/86 corresponds to only 30% of that in 1976/77 (See Fig. VII-5, ANNEX-VII). Table 3.9.3 shows yearly distribution of farmers in different income classes. Large variation in income level between the farmers is recognized. Number of low income class farmers who receive less than KShs.3,000 per annum is gradually increasing.

According to farm economic survey, the net farm income of average farmer is KShs.8,400 as shown in Table 3.9.4.

3.9.6 Processing and marketing of rice

After bagging at field, paddy is transported by lorries to each Reception Centre. The paddy is dried on the concrete floor of the reception centres in each respective section, to a constant moisture content 14%, re-bagged to a standard weight of 75kg bags and stored until milling. The paddy is milled at the Mwea Rice Mill Ltd, which is located within MIS area. The milled rice is marketed under sole responsibility of the National Cereal and Produce Board (NCPB).

The paddy bags sent to Mwea Rice Mill Ltd. are stored at the warehouses within the rice mill compound which are managed by NCPB. The stored paddy is gradually milled by full use of 2 rice mill machines with 5 ton/hr capacity and another two with 2 ton/hr capacity.

The total capacity of Mwea Rice Mill Ltd. is around 28,000 to 32,000 tons per annum under 2-shift operation. The broken rice is marketed at KShs.1.5/kg, and the bran is sold at KShs.0.8/kg. Milled rice is shipped to the depot of NCPB at Sagana and later sold to the consumers, through another depot of NCPB. The present controlled price as of February 1987 is KShs.7.30/kg for Sindano and KShs.9.05/kg for Basmati.

3.9.7 Field research and trials for future development

(1) Double cropping trials

A trial on double cropping (two crops of rice a year) was started at the Mwea Irrigation Research Station in 1975 under the Operational Research and Training Project of NIB. Besides, in MIS, double cropping trials of commercial scale were conducted in 1976/77, 79/80, 80/81 and 85/86, but those trials ended in total failure. The results were far below the expected level of production and later all of the persons involved in the

trials gave up the further attempt of double cropping (see Table VII-13, ANNEX-VII).

The cropping patterns of double cropping trials in the years of 1979/80, 1980/89 and 1985/86 are summarized in Table 3.9.5.

Possible explanations for poor performance of double cropping, given by the authorities concerned, are:

a. bogging-down problems of tractors resulting from disappearance of hard layer in the subsoils which is caused by continuous flooding for double cropping.

b. shorter wet fallow period after rotavation which may reduce the good effects of long wet fallow on paddy yield.

c. cool and cloudy climate during the period from June to August which affects normal ripening of rice.

d. harvesting and drying difficulties under wet weather which are likely to be involved in long rains crop or rice.

e. increase in crop damages caused by propagation of insects and diseases resulting from continuous cropping, and

f. shortage of irrigation water, especially in Thiba part of the Scheme, during low water period.

Small scale trials of double cropping which have been continued at the Mwea Irrigation Research Station, shows better results of long rains rice as seen from Table 3.9.6. The experiment results indicate that long rains rice will depend on availability of cold tolerant, early matured and disease resistant varieties. Such varieties have not been made available for release.

(2) Crop rotation trials in paddy fields

In January 1984, His Excellency The President Moi directed, during his visit to the Scheme, that after hearing the difficulties of double cropping of rice, other early maturing crops should be tried in the paddy field soon after the harvesting of short rains rice was completed.

A trial was started immediately after the presidential directive and several crops such as sunflower, cowpeas and green grams were put under the trial. About 10 acres of irrigated paddy fields were used. For this trial, a committee comprising Ministry of Agriculture, NIB, Research Station and Provincial Administration was organized and all of the members worked jointly to implement the Presidential directive without delay.

The trial ended with some technical problems and was discontinued.

(3) Development of red soils

In 1978/79, about 32 ha (80 acres) of Red Soils at Tebere Section were allocated to 40 tenant farmers for cultivation of various crops such as beans, maize and cotton under rainfed condition. A dairy cattle feedlot and piggery were also constructed in 1978/79 for the purpose of establishing a semi-zero grazing system to be supported by rice by-products.

The rainfed cropping of various crops was repeatedly tried. Based on the past experimental results, rainfed crops of maize and local beans are selected as promising ones and are kept under further examination. Irrigated crops of French beans, dudhi and chillies have recently been tried with 2 ha of sprinkler irrigation at Tebere Section.

Some farmers of Tebere Section grow horticultural crops such as tomatoes, French beans and onions in red soils area nearby the existing canals, under irrigated condition. Such irrigated farming on the red soils is quite successful; however the area under cultivation is limited at present. Rice is not cultivated in the red soils area because of excessive seepage losses.

3.10 Present Condition of Mutithi Extension Area

3.10.1 Demography

The Mutithi extension area falls under Mutithi Location, Mwea Division of Kirinyaga District. The Area represents about 20% of the Mutithi Location whose area is 187 km^2, falling within the following sub-locations:

(1) Mutithi/Chumbiri
(2) Mwerua/Rukanga
(3) Mwerua/Kabirini

(4) Mutithi/Kabirini
(5) Mwerua/Kagio
(6) Kiirie/Sagana

According to recent estimate, total population living in the Area is around 5,100 as of 1987, or 960 households with an average family size of 5.3 persons per household.

The land in the Mutithi area in many other part of the Central Province is privately owned. It is freehold obtained from the Trust Land in accordance with the Land Adjudication Act 284 and Land Consolidation Act Cap.283. In particular, the Mutithi area contrasts sharply with the adjacent MIS Scheme area where the former Trust Land is least to the tenant farmers by the Government through NIB.

The present JICA study identified there are about 1,580 land holders who own various sizes and shapes of the land in the area. In the black cotton soils, about 1,060 of land holdings are identified and 520 land holdings in the red soils area. However, about 60% of the land holders on the black cotton soils area are absent, while in the red soils areas almost fully occupied by the land owners or their relatives. There seems to be a steady population growth in the red soils areas. The rate of population growth however is very low on the black cotton soils area.

3.10.2 Land tenure and holding

In early 1950's when land demarcation in the Central Province was taking place, the demarcation of the Mutithi extension area was intentionally left out with the hope that the Area would be irrigated for rice cultivation like the adjacent MIS Scheme which was constructed in early 1950's. However, the Mutithi area was not included in the Scheme due to lack of water.

The County Council decided therefore demarcate all the reserved land and issued them out accordingly on clan basis. The demarcation in the Mutithi area took place between 1968 and 1972.

The recent socio-economic survey revealed that as of 1987, about 67% of the land owners in the Mutithi area obtained their land from clan, and about 24% by purchase and the rests have the inherited land from their fathers. This means land transaction in the Area is not significant since the demarcation took place.

The land holders in the Mutithi area 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

3.10.3 Present land use

The majority of the land owners living in the Mutithi area are full-time farmers. The farmers in red soils area use their land intensively for cultivation of maize and beans; on the other, those in the black cotton soils area use their land mostly for cattle grazing. Normal cropping on the black cotton soils areas is very limited due to difficulties of crop cultivation under rainfed condition which are resulted from the nature of the soils. The black cotton soils are usually flooded during the rainy season and become very hard with deep cracks on the ground surface during the dry season. These natures of the soils give the farmers a lot of difficulties for normal cropping.

Crop yield is generally very low, as indicated that an average unit yield of maize is about 1.1 tons/ha.

3.10.4 Present farm economy

Considering the results of socio-economic survey, the average farm size is 3.2 ha and his net farm income is KShs.500 per annum (See Table 3.9.4). Their farm income level 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. With a very few exceptions, most of the Mutithi farmers are engaged in subsistence farming which limits them to a poor standard of living.

3.10.5 Land holder's intention to irrigation development

The land in the Mutithi area is privately owned. The land tenure condition is quite different from that of the existing MIS area, and the Government regulation (Irrigation Regulation 1977 - Legal Notice No.68) which has been applied to MIS, may not be applicable to the Mutithi area.

The development strategy to be applied to the Mutithi area should be best suited to nature of the Area and acceptable to both NIB and the land holders. JICA Study Team considered that such strategy would be possibly determined only through the study on the land holder's intentions to the irrigation proposal to be prepared by NIB. After full discussion on this idea with NIB, JICA Study Team decided to employ a local consultant to carry out the questionnaire survey for this purpose, and made a contract with UNICONSULT LTD. (hereinafter referred to as "the consultant"). The consultant prepared the questionnaire on the basis of the NIB's idea for irrigation development in the Mutithi extension area which is given as follows:

NIB' DEVELOPMENT CONCEPT

1) Farmers to form Company or Co-operative Organization incorporating all farmers who are interested in irrigation development within the Mutithi area. This body corporate to secure the necessary commitments from the members and to be responsible for dealing with NIB in all land issues in the Area. Legal machinery for this arrangement will need to be fully explored and applied.

2) Farmers to accept adjustment of their boundaries to facilitate suitable irrigation layout and must further accept some reductions in parcel sizes necessitated by construction of irrigation network i.e. canals, drains, roads, reception centres etc.

3) Farmers to accept to surrender their titles to the Farmer's Organization which will in turn surrender same to the National Irrigation Board. The Board will in turn charge these titles for a period of 30 years after which the titles will be surrendered back to the Farmer's Organization. The titles may be discharged earlier if the Farmer's Organization is able to repay proportionate development costs to NIB.

4) The Farmer's Organization to handle all land cases within the developed area through a committee. This committee would also be responsible for valuation of houses and land, with advice of NIB and Government experts, whenever a land transaction takes place. The committee would also be involved in disciplinary cases such as when a farmer fails to comply with Irrigation Area Rules accepted between NIB and Farmer's Organization.

5) NIB will only develop the irrigation and road works and other communal facilities such as reception centres, offices, etc. The individual farmers will be expected to put up their own houses in the Areas surveyed and marked out for the purpose without any assistance from NIB. Modest compensation may be possible where permanent houses may have to be moved to allow for construction of irrigation/road network.

6) Once the land is developed, relation between the NIB and each farmer would be direct as the Mwea Irrigation Settlement Scheme and Advisory Committee would continue to form the necessary forum for interactions and communication between the farmers and NIB.

The consultant executed the questionnaire survey in the field for a period of one month in August 1987. The consultant interviewed 213 land holders living in the Mutithi area and 20 absent holders who are living outsides the Area. The consultant also interviewed local administrative officers and opinion leaders with primary ties with the community in the Mutithi area. The results of the questionnaire survey show that most of the Mutithi farmers, the local administration and leaders are highly in favour of the proposed irrigation development. The farmers especially in the black cotton soils area are very much keen to join an irrigation Scheme since their land is highly underutilized as a result of factors beyond the control of any individual farmers.

The results of the questionnaire survey are summarized as follows:

NIB Concept No.	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

Those who made comments on the proposed irrigation development concept according to the consultant' view, seem to mistrust the real intention of NIB mainly because of recent delay in payment to the MIS farmers which has resulted from the financial problems of NCPB. This negative image of NIB might explain their comments which 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 outsides 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; about half of them readily expressed their willingness to negotiate the transfer of the ownership of the land to NIB if fairly compensated and another half of them to join the irrigation farming in accordance with the NIB proposal.

The local administrative officers and opinion leaders are wholly in support of the proposed irrigation development.

CHAPTER IV COMPARATIVE STUDY ON PROSPECTIVE DEVELOPMENT ALTERNATIVES

4.1 Current Situation of the Study Area

The Mwea Irrigation Settlement (MIS) Scheme, situated approximately 100 km north-east of Nairobi on the foothills of Mt. Kenya, 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 about 5,900 ha.

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 provide inputs, extension services and irrigation water at a normal fee to the farmers. 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 (see Fig.4.1.1). The main contributory factor is lack of adequate maintenance and rehabilitation with respect to all aspects of Scheme operation and maintenance. The situation is likely to get worse with disastrous consequences unless corrective measures are urgently taken.

At present, the MIS Scheme produces some 27,000 tons of paddy (about 18,000 tons of milled rice) per annum over about 5,900 ha of irrigated paddy fields. It means that 75-80% of Kenya's rice production comes from the MIS Scheme. The present national latent demand for rice is estimated to be approximately 126,000 tons of paddy (or about 82,000 tons of milled rice) under the present per capita consumption level of 6.0 kg (or about 4.0 kg of milled rice). Deficits in supply of rice are partially supplemented through food donation and commercial imports. The country has been facing to serious shortage of rice. The MIS Scheme, however, has lowered its production level from 36,000 tons in 1976/77 to 27,000 tons in 1985/86.

The MIS Scheme settles about 3,230 farmer families who each grow 1.6 ha of paddy field. Total population of the Scheme area is approximately 29,000. The MIS farmers have also lowered their farm income from KShs.8,500 per farmer in 1976/77 to

KShs.2,300 in 1985/86 at 1976 constant price level due to decreased production, stagnant producer prices in some years, and price hike in farm inputs (see Fig.4.1.2). During the past 30 years since the MIS Scheme was started, the population remarkably increased; however, number of settlers has been almost constant because the settler farmers are not allowed to divide the irrigated paddy among their sons and therefore surplus labour forces are likely to go outside for new jobs or to stay idle.

Under such situations, it has been long desired among the government officials as well as the MIS farmers that NIB will be able to increase the rice production through every effort to realize the expansion of irrigated paddy, improvement of present unit yield per ha and introduction of double cropping of rice a year.

Considering all these, the basic concept for the "Mwea Irrigation Development Project" is set out in view of maximizing rice production in the said area as follows:

(1) rehabilitation and improvement of the existing irrigation/drainage system,

(2) Exploitation of the endowed land and water resources for expansion of irrigated rice fields,

(3) Introduction of double cropping of rice for improvement of present unit yield per ha per annum as well as the farmer's income, and

(4) Development of irrigable red soils for up-lifting of the farmer's income through production of horticultural cash crops.

4.2 Assessment of Land Resources

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

The potential maximum area of 9,560 ha is determined through the present study on soils and topography on the basis of the detailed topographic maps scaled 1/5,000.

4.3 Assessment of Water Resources

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 the year 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

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 in the red soils areas. All the irrigable land will be double-cropped with cropping intensity of 200%.

Irrigation water requirements are calculated for the proposed cropping pattern based on the potential evapo-transpiration 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)

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

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

The water balance study indicates that 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 (for details, see Table 4.3.1):

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

Possible development plans for expansion of irrigable area by use of available water resources are as follows:

(1) Nyamindi river
   a. Construction of new dam
   b. Construction of new headworks
   c. Rehabilitation of existing headworks

(2) Thiba river
   a. Construction of new dam
   b. Rehabilitation of existing headworks

(3) Ruamuthambi river
   a. Construction of new headworks

4.4 Prospective Development Plan

The irrigation development plan in the Study Area is 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. With this in view, the following seven (7) possible development alternatives are set out (Fig. 4.4.1 to be referred):

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

The alternative TA-1 has been recognized as the least priority plan because the prospective canal of about 19 km would cross the railway running within the densely populated area and also 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.

4.5 Water Balance Calculation

The water balance calculation for each alternative case is made on the following conditions:

(1) Potential maximum area is 9,560 ha.

(2) Potential maximum scales of the dams are as follows:

Dam	Dam Height	Total Storage Capacity
Thiba	35 m	18 MCM
Nyamindi	35 m	10 MCM

(3) Irrigation water is to be supplied in the following priority order:

1. : 5,860 ha of paddy field in MIS Scheme
2. : 2,470 ha of paddy field in Mutithi area
3. : 800 ha of horticultural crops field in MIS Scheme
4. : 430 ha of horticultural crops field in Mutithi area

(4) The priority is given to the natural flow of the relevant river in water resources utilization.

(5) The paddy field to be irrigated by re-use water in MIS Scheme (500 ha) are not considered in water balance calculation.

(6) Losses counted in the water balance calculation are as follows:

a. overall irrigation efficiency : 55%
b. losses from dam to headworks : 5%
c. losses in the reservoir : 5%
(Effective storage capacity = 1.1 x net storage capacity)

(7) Service discharge from the headworks to downstream comprises the total discharge with water right between headworks and the junction to the Tana plus river maintenance flow. Service discharge from the dam to headworks consists of the total discharge with water right between the dam and headworks plus river maintenance flow.

(8) The water balance calculation is made on a 10 day basis, using data for the year of 1980.

The result of water balance study is as follows (for details, see Table 4.5.1):

(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.

4.6 Preliminary Facility Plans of Prospective Development Alternative

The facility plan for each development alternative is outlined as follows:

(1) It is confirmed that through water balance study, all the alternative cases require almost maximum scale of the dam:

a. T-1 : Thiba dam with 34.5 m height
b. T-2 through T-4 : Thiba dam with 35.0 m height
c. N-1 and N-2 : Nyamindi dam with 35.0 m height

The total required storage capacity of each alternative is as follows (In the case T-1, the Thiba dam will have a surplus storage capacity of 1 MCM):

Alternative	Thiba Dam		Nyamindi Dam
	T-1	T-2,3,4	N-1,2
Total Storage Capacity	17 MCM	18 MCM	10 MCM

(2) The proposed dams are of earthfill with inclined clay core type. The spillway is designed to release the floods of 625 year return period with due freeboard allowance. The spillway of Thiba dam is ungated chute type with design discharge of 560 m^3/sec. Nyamindi dam will have ungated side channel type spillway with design discharge of 730 m^3/sec. Intake structure will be drop inlet type for both dams. Tunnel driver through abutment will be adopted for river diversion.

(3) The following headworks and link canals are considered for each alternative:

Works	T-1	T-2	T-3	T-4	N-1	N-2
1. New Nyamindi headworks and Nyamindi headrace	*		*		*	*
2. Link canal-I	*		*		*	*
3. Link canal-II	*	*	*	*	*	*
4. Link canal-III	*	*	*	*	*	*
5. Ruamuthambi headworks and Ruamuthambi headrace	*	*			*	
6. Improvement of existing Thiba headworks	*	*	*	*	*	*
7. Improvement of Nyamindi headworks		*		*		

(4) The following rehabilitation works are considered in MIS Scheme area:

a. Irrigation canal : desiltation of canal bottom and re-embankment of canal inside slopes

b. Drainage canal : excavation of drains to lower the drainage water level

c. Canal structures :

re-construction/replacement	:	30%
new construction	:	10%
provision of transition	:	20%

d. Farm road : embankment and laterite pavement

e. On-farm facilities : new field drain outlet, rehabilitation of related structures to on-farm irrigation canals, farm road and construction of new farm approaches

f. Reclamation of : field reclamation with red soils area improvement of original land slopes and construction of irrigation system

(5) The proposed works for development of the Mutithi area are as follows (in case of T-1):

a. Irrigation canal : total length 33.0 km

b. Drainage canal : total length 30.8 km

c. Canal structures, farm roads and on-farm facilities : same criteria as applied in MIS

d. Reclamation of red soils area : same criteria as applied in MIS

(6) The following building facilities, farm machinery and O/M equipment are considered for each alternative:

a. Farm buildings

MIS Scheme area

Reception centers : expansion of concrete floor, construction of fertilizer store, and receiving depot for vegetables

Machine center : headquarters, workshop, garage, fuel station, etc.

Mutithi area

Reception centres : construction of new reception centers equipped with concrete floor, weighing facilities, warehouses, farm inputs stores, garages, etc.

Machine center : a centralized center established in MIS Scheme area will cover the Mutithi area as well.

b. Farm machinery and O/M equipment

A number of farm machinery such as 60 PS class tractor and rotavators as well as various O/M equipment are considered for each alternative, depending on requirement estimated based on the development scale.

4.7 Selection of Best Development Alternative

The preliminary development costs for each alternative are tentatively estimated based on the "Current Construction Cost 1986" published by the Ministry of Works and Housing as shown below:

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

Annual incremental benefits for each case of the alternative plans were also tentatively estimated as shown bellow (See Table 4.7.1):

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

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

It is recommended that Alternative T-1 be selected as the best development plan among the possible alternatives on 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 soil 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.

It was agreed between NIB and JICA Study Team after discussions on the Interim Report on September 28, 1987 (see ATTACHMENT-5) that the proposed Alternative T-1 should be selected as the best alternative and the JICA Study Team would make further studies only for the Alternative T-1.

CHAPTER V PROSPECTIVE DEVELOPMENT PLAN

5.1 Agricultural Development Plan

5.1.1 Assessment of land resources

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

The irrigable area of 9,560 ha is determined through the present study on soils and topography on the basis of the detailed topographic maps scaled 1/5,000.

5.1.2 Change in land use

The present land use in the above irrigable area will be changed by the 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. Upland Crops		
Maize	600	0
Beans	200	0
French beans	0	800
Onions	0	400
Tomatoes	0	400
Mutithi Area		
1. Rice		
Short Rains Rice	0	2,470
Long Rains Rice	0	2,470
2. Upland Crops		
Maize	430	0
Beans	0	0
French beans	0	430
Onions	0	215
Tomatoes	0	215

Rice cultivation is suited to the black cotton soils and horticultural crops to the brownish red soils. In the black cotton soils area, single cropping of rice has been practiced under irrigated condition in MIS area and those in the Mutithi area are mostly used for cattle grazing. The brownish red soils are more intensively cropped at present for cultivation of maize and various beans.

After implementation of the Project, the land will be double-cropped under full irrigation with a cropping intensity of 200%. In the black cotton soils area, double cropping of rice will be practiced. The brownish red soils will be cropped with highly marketable vegetables such as French beans, tomatoes and onions.

The upland where the farmers now grow maize and beans for their home consumption (1,230 ha) will be converted to the horticultural crops field and the present production of maize and beans on these land (1,250 tons of maize and 1,000 tons of

beans) will be lost annually; however, the irrigated farmers will surely be compensated with the increased farm income from the cultivation of horticultural crops on these land.

5.1.3 Proposed cropping pattern

The following basic principles, which govern the selection of crops and cropping patterns under the Project, are conceived:

(1) The crops and cropping pattern must create maximum benefits for the farmers as well as the nation as a whole,

(2) The crops and cropping pattern must make optimum use of water to be supplied by the Project,

(3) The crops and cropping pattern should be practicable with the limited number of available family labour, and

(4) The crops and cropping pattern must conform with the present social traditions and be acceptable to the farmers.

Considering the principles mentioned above, "rice" and "horticultural crops" such as tomatoes, onions and French beans are selected as major crops in the framework of the future cropping pattern.

Rice is the most profitable crop, among other possible crops, under present economic situations. There is no marketing problems. Increase in rice production largely contributes to achievement of self-sufficiency in food which the Government of Kenya has strongly emphasized in the long-term development plan. The farmers in the Area have long experience for the rice cultivation under irrigated condition and are likely to realize the maximum benefits from irrigated rice cultivation.

Tomatoes, onions and French beans have relatively large market outlets and significantly profitable among other horticultural crops (see Table 5.1.1). These crops are selected from various crops presently marketed in large quantity to Nairobi. These crops will show large irrigation benefits resulting from increase in unit yield as well as improvement in quality of the products.

The proposed cropping pattern is shown in Fig.5.1.1.

(1) Proposed cropping pattern for rice

In the proposed cropping pattern, long rains crop of rice is transplanted in March/April and harvested in June/July, and short rains crop transplanted in August/September and harvested in December/January.

The early maturing varieties with a total growth period of 110-120 days will be used for long rains crop and the present varieties and/or improved varieties such as BW196, IR54, IR1561, IR2793 with the growth period of 150-160 days will be for short rains crop. For long rains crop, early-maturing varieties are inevitably needed. Such varieties could easily be obtained through variety trials, because a number of such high-yielding varieties with short duration of maturity are widely available in the world. For example, high-yielding improved varieties such as IR36, IR50, IR58 and IR60 would be recommendable. In addition, early maturing varieties of Basmati strain will also be preferable for long rains crop due to its high marketability.

In preparing the proposed cropping pattern for rice, the following has been considered:

a. low temperature in July/August and December/January

The booting stage, particularly meiosis stage, of rice growth is very sensitive to low temperature so that cropping calendar be adjusted to avoid such critical stage from the low temperature periods.

b. high precipitation and wet condition in April/May and October/November

In case of harvesting in these rainy seasons, various difficulties in harvesting and drying as well as large post-harvest losses are expected, and therefore, harvesting seasons should be set out in other periods.

c. necessity of vacant period that no rice is observed

Vacant period of at least one (1) month will be required for maintenance and repair of irrigation

facilities and also to prevent rice plant from damages caused by building-up of insects and diseases.

The proposed cropping pattern for rice meets all the conditions mentioned above.

In particular, the proposed pattern for rice is formulated, with a view to minimizing the damages caused by low temperature in July-August, on the basis of the study on the probable yield reduction of paddy against the low temperature with five year return period.

For this study, the yield reduction against low temperature in five (5) consecutive days is considered, because reduction in paddy yield is likely to occur when low temperature continues for more than six (6) days, and in the Project area, the low temperature less than 20°C seldom continues for more than five (5) days.

First of all, using the daily mean temperature records at the Embu-Mwea meteorological station for the period of nine (9) years from 1978 to 1986, the low temperature year with five (5) year return period is determined to be 1986 through probability analysis on annual accumulated daily mean temperature. Secondly, using the actual daily mean temperature records for the year of 1986, moving average values of the daily mean temperature for five (5) consecutive days are calculated, and the lowest moving average values in each 10 day period are selected, as being the five (5) consecutive day low temperature with 1/5 probability on a 10 day basis. Thirdly, the yield reduction rates at different periods of plant growth against the five (5) consecutive day low temperature with 1/5 probability are estimated, as shown in Fig. 5.1.2, on the basis of the "guideline for estimation of yield reduction against low temperature" published by the Ministry of Agriculture, Forestry and Fisheries of Japan (Fig. 5.1.3, to be referred).

The relationship between reduction in unit yield and low temperature in the proposed cropping pattern is summarized in Fig. 5.1.4 (for short rains crop) and Fig. 5.1.5 (for long rains crop). The study results indicate that there is no clear difference in crop yield reduction against low temperature between short rains crop and long rains crop.

The following facts are identified through this study:

a. The paddy planted earlier shows better yield, as generally experienced in MIS area (Fig. 5.1.2, to be referred).

b. Early start in planting gives better results; however, it will increase the peak water requirement for irrigation. On the contrary, late start in planting results in enormous loss of harvest due to high sterility caused by low temperature in July-August.

c. Shorter period of transplanting gives better production. On the contrary, it will increase peak water requirement and number of machinery for rotavation. The proposed transplanting period of 60 days might be optimum in an economical sense.

The proposed cropping pattern for rice is optimum among other possible patterns, considering all the factors mentioned above.

(2) Proposed cropping pattern for horticultural crops

The proposed cropping pattern for horticultural crops is prepared on the basis of the following considerations:

a. To minimize the crop water requirement

The periods of peak water requirement for horticultural crops should not be overlapped with that for rice, and

b. To market the products during the period of high marketing prices in Nairobi

Tomatoes and beans are high priced in dry season of February/March, on the other, the price of onions is almost constant throughout the year.

The proposed cropping pattern for horticultural crops meets all these requirements and conditions mentioned above.

5.1.4 Proposed farming practices

After the Project is realized, the present farming practices will be gradually changed under introduction of double cropping system:

(1) Paddy cultivation

a. Land preparation

In order to complete the rotavation within 60 days before transplanting, the tractors will have to be increased in number. The required number of tractor will be 126 in total which will comprise 112 units of 60 PS class four wheel driven type tractor with wide floating type tyre and cage wheel, and 14 units of 60 PS class crawler type tractor. The wheel type tractors will be used mostly for ordinary rotavation and sometimes for chisel ploughing in the cases that no irrigation water is available in time and the soils will have to be ploughed under the dried conditions in order to keep the planting time schedule. The crawler tractors will be used for rotavation of the land with soft foundation where the ordinary tractors are bogged down.

The paddy field will be pre-flooded with about 12 cm of water before rotavation. Prolonged period of pre-rotavation flooding is likely to result in bogging-down of the tractors. About three (3) days after flooding will be the best timing for rotavation. The present system of grouping the farmers for rotavation is reasonable and realistic because early planting group will certainly get better yield. Therefore, the

present rotational grouping system will not be changed even after the Project is realized.

b. Nursery preparation

The farmers will prepare their own nurseries within their paddy plots. The nursery measures about 1/20 of each holding. The nursery beds will be prepared manually. The seeds will be broadcasted on the beds at the rate of 45 kg/ha (namely, 45 kg per nursery required for one ha of main field to be transplanted). The required amount of fertilizer for nursery will be 6 kg N per nursery for one ha of main field to be transplanted. Prior to the seeding, seeds should be selected by a solution of 1.13 specific gravity and further be treated with seed disinfectants like Benrate-T or Homai.

c. Transplanting

For transplanting, the recommendable number of seedings will be 3-4 per hill, and planting density of 20-30 hills per m^2 will be recommendable under the conditions that the improved varieties be introduced. The presently recommended density of 100 hills per m^2 (10 cm x 10 cm) is derived from low tillering ability of Basmati and Sindano.

d. Fertilizer application

Ammonium Sulphate of about 150 kg/ha and Triple Superphosphate of 125 kg/ha will be applied as the basal fertilizers at the time of about five (5) days before transplanting. Top dressing will be carried out 2-3 times; about 15 days after transplanting, at the young panicle formation stage and at the full heading stage. The amount of fertilizer for top dressing will be 20-30 kg N/ha in a form of Ammonium Sulphate. It is recommended that compound fertilizer containing Nitrogen and Phosphorus be tested in future in order to save the costs of transportation and storing as well as labour cost for application.

e. Field maintenance

Insect and disease control should be carried out at the proper time without delay. Recommendable chemicals will be Sumithion, Diazinon, Furadan,etc. for insect control, and Kasumin, Kitazin, etc. for disease control. Weeding will be made manually several times according to the condition of weed growth. Use of herbicides for weed control will not be recommended.

The water level in the paddy field will be maintained at 7.5 cm in depth after transplanting. There are critical periods in the life of the rice plant against the shortage of irrigation water,i.e.,just after transplanting, panicle initiation stage, reduction division stage and flowering stage. Irrigation water will have to be maintained in the field at these stages of plant growth. Proper water management, considering the plant growth stage, will be desired.

f. Post-harvest drainage

Before harvesting, the paddy field will be drained and dried out for about 3 weeks as the MIS Scheme does at present.

g. Harvesting

Harvesting will be made manually by sickle. Threshing, winnowing and bagging will also be carried out manually in the harvested field. In future, however, the mechanical harvesting and threshing by means of engine-driven harvester and treadle thresher will have to be considered.

(2) Cultivation of horticultural crops

Modern cultivation techniques such as introduction of high yield varieties, reasonable fertilizer application and control of insects and diseases as well as proper supply of irrigation water should be introduced into the Area.

As far as irrigation method is concerned, furrow irrigation method will be applied for all the crops.

In case of tomatoes, irrigation water will be applied through furrows at an interval of every 7-14 days. Enough water must be applied at each irrigation time to thoroughly moisten the soil in the root zone. It is desirable to have the soils well watered before ripening begins so that subsequent irrigation can be kept to the minimum.

For onions, irrigation water should not be applied too frequently in the early stages, as seedings are likely to rot off in the seed-beds. Excess water to young transplants causes rank growth, thick necks and poor bulbing.

French beans have the critical growth period towards water stress from flowering to ripening, while the crop is sensitive to over irrigation.

5.1.5 Anticipated crop yield and production

After completion of the Project, the crop yields will be stabilized and increased through assured supply of irrigation water, improvement of farming practices and water management and further expansion of agricultural supporting services.

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

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

5.1.6 Farm inputs and labour requirement

Farm inputs and labour requirement for the proposed farming practices are summarized as follows (for details, refer Section 2.6, ANNEX-VII):

(Unit: ton)

Farm Inputs	Unit	MIS	Mutithi
With project			
Seed	ton	560	240
Fertilizer	ton	6,970	3,030
Agro-chemicals	ton	40	20
	lit	25,000	10,700
Without project			
Seed	ton	320	10
Fertilizer	ton	2,330	50
Agro-chemicals	ton	20	0
	lit	12,300	430
Incremental amount			
Seed	ton	240	230
Fertilizer	ton	4,640	2,980
Agro-chemicals	ton	20	20
	lit	12,700	10,270

The proposed farming operations will possibly be practiced by family labour as indicated in Table Fig. VII-21, ANNEX-VII, in which the labour balance between family labour availability and farm labour requirement under future "with Project" condition is studied. The crop production costs are estimated on the basis of requirement of the farm inputs and labour, and those are shown in ANNEX-VII.

5.1.7 Marketing and price prospect

(1) Marketing prospects

The "Scheduled" crops such as rice are marketed under sole responsibility of the National Cereals and Produce Board (NCPB). There will be no marketing problem for rice, because it is "Scheduled" crop and furthermore the Kenya's latent demand for rice is large enough compared to the anticipated production of 100,000 tons in the Project area as mentioned in Chapter II (See Fig. VII-22, ANNEX-VII).

The horticultural crops are marketed through the free channels. The selected crops such as tomatoes, onions and French beans have relatively large marketing outlets particularly in Nairobi. The domestic demand for these crops will surely increase with the population growth in cities and increase in income level.

The assumption that demand for these crops is directly related to population growth, suggests that even under the present level of per capita consumption, the additional demand for these crops in Nairobi will amount to 70,000 tons of tomatoes, 13,000 tons of onions and 20,000 tons of French beans per annum by the year of 2000. The anticipated marketable production of these crops from the Project area will be, on the other, 9,200 tons of tomatoes, 6,200 tons of onions and 12,300 tons of French beans. This indicates that considering the limited possibility of additional production in other areas due to very limited availability of irrigated land, the Project will have enough market outlets for these horticultural crops (See Fig. VII-23, VII-24 and VII-25, ANNEX-VII).

(2) Price prospects

Economic prices of rice/paddy at the farm gate are estimated, on the basis of the projected international market prices forecasted by IBRD for the year of 1995 in 1985 constant US dollars and further taking into account the costs for transportation, processing and others, to be KShs.3,670 per ton, as shown in Table 5.1.2.

Financial prices of rice/paddy at the mill gate is fixed by the Government as of mid-1987 to be:

Paddy

Basmati	:	KShs. 4,000/ton
Others	:	KShs. 3,000/ton

Milled rice

Basmati	:	KShs.9,050/ton
Others	:	KShs.7,300/ton

The financial farm gate prices of horticultural crops are estimated on the basis of the projected prices for the year of 1995 using available data on wholesale prices at Nairobi from 1981 to 1986 and further costs for transportation and others as well as sales margins. The economic prices are obtained by multiplying the estimated financial prices by the standard conversion factor of 0.86. The estimated prices are summarized as follows (See Table VII-23, ANNEX-VII):

Financial Prices

Tomatoes	:	KShs.3,400/ton
Onions	:	KShs.4,500/ton
French beans	:	KShs.3,700/ton

Economic prices

Tomatoes	:	KShs.2,900/ton
Onions	:	KShs.3,900/ton
French beans	:	KShs.3,200/ton

5.1.8 Farm budget

The farm budget analysis is made for both cases of "with" and "without" Project conditions, on the basis of the estimated crop yield, crop production costs and financial crop prices. Farm budget will reflect the future conditions in target year of 1995. The analysis is made for average size of farmers; 1.8 ha for the MIS farmers and 3.2 ha for the Mutithi farmers.

The results of the analysis are summarized as follows (for details, see Table 5.1.3).

I. MIS

(Unit:KShs.1,000)

	Without Project	With Project
Planted Area		
Rice	1.6	1.6
Horticultural crops	0.2	0.2
Total	1.8	1.8
Gross Income		
Farm income	21.8	84.2
Others	1.5	-
Total (A)	23.3	84.2
Out-go		
Farm expenses	4.9	14.6
Living expenses	15.5	22.5
Total (B)	20.4	37.1
Net Reserve (A - B)	2.9	47.1

II. Mutithi extension area

(Unit: KShs.1,000)

	Without Project/1	With Project
Planted Area		
Rice	-	2.7
Horticultural crops/Upland Crops	1.0	0.5
Total	1.0	3.2
Gross Income		
Farm income	2.6	160.7
Others	6.2	-
Total (A)	8.8	160.7
Out-go		
Farm expenses	1.1	27.9
Living expenses	7.2	22.5
Total (B)	8.3	50.4
Net Reserve (A - B)	0.5	110.3

Note: /1: Out of total farm land (3.2 ha), planted area is 1.0 ha and the rest of 2.2.ha is the potential arable land in black cotton soils area.

The implementation of the Project will significantly increase the farm income.

5.1.9 Gross and net crop production values under the Project

Net incremental benefit of the Project is defined as the difference between the net production value "with" the Project and the net production value "without" the Project. The net production value is defined as the difference between the gross production value and the production cost.

The following table shows the net incremental benefits of the Project at the full development stage (for details, see Table 5.1.4):

(Unit: KShs. million)

	Without Project/1	With Project	Incremental Benefit
I. MIS			
Long rains rice	-	101.4	101.4
Short rains rice	50.9	101.4	50.5
Maize	1.0	-	-1.0
Beans	2.6	-	-2.6
Tomatoes	-	13.3	13.3
Onions	-	10.6	10.6
French beans	-	19.4	19.4
Sub-total (I)	54.5	246.1	191.6
II. Mutithi			
Long rains rice	-	42.7	42.7
Short rains rice	-	42.7	42.7
Maize	0.7	-	-0.7
Beans	-	-	-
Tomatoes	-	7.2	7.2
Onions	-	5.7	5.7
French beans	-	10.4	10.4
Sub-total (II)	0.7	108.7	108.0
III. Total (I + II)			
Long rains rice	-	144.1	144.1
Short rains rice	50.9	144.1	93.2
Maize	1.7	-	-1.7
Beans	2.6	-	-2.6
Tomatoes	-	20.5	20.5
Onions	-	16.3	16.3
French beans	-	29.8	29.8
Total	55.2	354.8	299.6

5.2 Irrigation and Drainage Development Plan

5.2.1 Irrigation water requirement

Rice will be the principal crop in the Project area and upland crops such as French beans, onions and tomatoes are also recommended as consumable and profitable crops for the Project. Therefore, the study of irrigation water requirement was made for these crops.

The irrigation water requirements were calculated for the proposed cropping pattern on a 10-day basis for the drought year with a five (5)-year return period, which was determined to be 1980 in regard to annual rainfall in the irrigation area.

The crop water requirements for paddy and horticultural crops were calculated as follows:

- Paddy

$$CWR = NWR + PWR + FCU + P$$

Where, CWR: Crop water requirement (mm/day)
NWR: Nursery water requirement (mm/day)
PWR: Puddling water requirement (mm/day)
FCR: Field crop consumptive use of water (mm/day)
P: Percolation rate (0.1 mm/day)

- Horticultural crops

$$CWR = LP + FC$$

Where, CWR: Crop water requirement (mm/day)
LP: Land preparation requirement (mm/day)
FC: Field crop requirement (mm/day)

In the above calculation, the potential evapotranspiration, which is used to assess the crop water requirement, was calculated by Modified Penman Method using meteorological data at Embu-Mwea Meteorological Station. The crop coefficient was estimated on the basis of the actual investigation in the "Mwea Water Use Study, 1982, NIB" and the results of the "Design Manual for Water Supply in Kenya, 1986, MOWD". The percolation was estimated at 0.1 mm/day based on the results of "Mwea Water Use Study, 1982, NIB" and actual field measurement results.

The farm water requirement was assessed on 10-day basis, deducting the effective rainfall from crop water requirement. The effective rainfall for paddy was estimated by the daily water depth balance method and that for horticultural crops was estimated by the daily moisture level balance method. The estimated 10-day effective rainfalls for paddy and horticultural crops and the 10-day farm water requirement are shown in Table 5.2.1.

The diversion water requirement is defined as the amount of farm water requirement plus allowances for farm waste, conveyance and operation losses. The overall irrigation efficiency for paddy was roughly estimated at 55% consisting of application efficiency of 80%, operation efficiency of 76% and conveyance efficiency of 90%, based on the results of "Mwea

Water Use Study, 1982, NIB" and the actual field measurement. The overall irrigation efficiency for horticultural crops was also assumed to be about 55% also. The peak 10-day unit diversion requirement for each crop is shown below.

(Unit: ℓ/sec/ha)

Crop	10-day	Peak Unit Diversion Requirement
Paddy (Long rains)	Mar. 3rd.	1.44
Paddy (Short rains)	Sep. 2nd.	1.74
French beans (Long rain)	Apr. 3rd	0.86
French beans (Short rain)	Feb. 1st.	1.32
Onions (Long rains)	Jun. 3rd.	0.88
Tomatoes (Short rain)	Feb. 1st.	1.45

The unit diversion requirement for the above each crop is presented in Table 5.2.2.

The diversion water requirements on 10-day basis for respective proposed irrigation systems are shown in Table 5.2.3. The irrigation diagram is presented in Fig. 5.2.1.

In the existing MIS area, the drainage water from upper part of the unit is re-used as irrigation water in lower part of the same unit or in lower adjacent unit, or restored to lower reaches of main and branch canals through the existing re-use structures or directly from drainage canals. The re-use of the return flow from paddy fields was taken into account in calculating the diversion water requirement for MIS area.

The rate of return flow was estimated at 25% of the water supplied, assuming 70% out of the overall irrigation losses will be effectively re-used in lower rice fields commanded by re-use structures. The total irrigable area by each re-use structure was estimated at about 500 ha (for detail, see Table 5.2.4).

5.2.2 Drainage water requirement

The drainage water requirement for design of the proposed drainage system is determined, separately one for the excess rainfall from rice fields and the other for the run-off from the land surrounding the irrigated paddy field, on the basis of the design daily rainfall with a 5-year return period, which is estimated at 100 mm/day by Thomas Method by use of annual

maximum daily rainfall records from 1979 to 1986 at the Embu-Mwea Meteorological Station.

The design daily rainfall in the paddy field should be removed within one day. The drainage water requirement is calculated using the following equation:

$$QP = (R_{24} \times 10^{-3} \times A \times 10^{4})/(T \times 60 \times 60)$$

Where, QP: Drainage water requirement for paddy field (m^3/sec)

R_{24}: Design daily rainfall (100 mm/day)

T: Drainage period (24 hours)

A: Drainage area (ha in gross)

The unit drainage water requirement for paddy field is thus estimated at 11.6 l/sec/ha.

The drainage water requirement for the run-off in the surrounding areas is estimated by McMath formula suggested in "Drainage Manual", USBR:

$$QH = 9.15 \times 10^{-3} \times C \times i \times S^{1/5} \times A^{4/5}$$

Where, QH: Drainage water requirement for surrounding areas (m^3/sec)

C: Coefficient representing the surrounding areas' characteristics (0.36)

i: Rainfall intensity for the time of flood concentration (mm/hr)

$$i = R_{24} \times (1/24)^{1/3}$$

S: Average slope (1/150)

A: Drainage area (ha)

The unit drainage water requirement for the surrounding areas is estimated at 12.4 l/sec/ha.

The design drainage water requirement at each section of drainage area was calculated by use of the following formula:

$$Q = (Qp \times Ap + Qh \times Ah)$$

Where, Q: Design drainage water requirement (m^3/sec)
Qp: Unit drainage water requirement for paddy field (0.0116 m^3/sec/ha)
Qh: Unit drainage water requirement for surrounding areas (0.0124 m^3/sec/ha)
Ap: Area of paddy field (ha)
Ah: Area of surrounding land (ha)

The drainage diagram is illustrated in Fig. 5.2.2.

5.2.3 Proposed irrigation and drainage system

(1) Proposed irrigation system

There are existing irrigation facilities in the MIS area and no facilities in Mutithi extension area. Based on the result of study on the optimum scale of the development plan, the following irrigation works were proposed:

a) Construction of a storage dam, new Nyamindi headworks and Ruamuthambi headworks

b) Construction of new facilities such as link canals, headraces and related structures for diverting irrigation water from Nyamindi system to Thiba system and from Ruamuthambi headworks and Thiba system to Mutithi system.

c) Establishment of irrigation facilities such as canals and related structures for Mutithi extension area and brownish red soils area which are proposed to be newly irrigated in the Project.

d) Rehabilitation of the existing irrigation facilities.

The diversion method of irrigation water to the respective irrigation system is mentioned below and shown in Fig. 5.2.3.

Nyamindi irrigation system will take the water from new Nyamindi headworks through Nyamindi headrace and new Nyamindi main canal. Thiba system will take the water, which is released from Thiba dam and diverted from Nyamindi river, at the existing Thiba headworks and diverted to the existing Thiba main canal through link canal-II to be improved. The water for Mutithi system will be taken from Thiba diversion works constructed at the end of link canal-II and diverted to main canal through link canal-III and regulating basin. In addition, Ruamuthambi

headworks will divert the water to Mutithi system through headrace and regulating basin.

The proposed irrigation system is divided into three (3) irrigation systems, i.e. Nyamindi, Thiba and Mutithi system. Nyamindi and Thiba systems are respectively composed of one (1) and four (4) sections as the same as the existing ones. Mutithi system consists of two (2) sections; Kibiriri and Rukanga sections.

The total irrigation area is 9,560 ha in net, which comprises of paddy area of 8,330 ha and horticultural crops area of 1,230 ha as shown below.

(Unit: ha)

Irrigation system	Paddy		Horticultural Crops		Total	
	Net	Gross	Net	Gross	Net	Gross
Nyamindi system	1,300	1,600	600	705	1,900	2,305
Thiba system	4,560	5,300	200	235	4,760	5,535
Mutithi system	2,470	2,900	430	510	2,900	3,410
Total	8,330	9,800	1,230	1,450	9,560	11,250

The net irrigation area of each unit is summarized in Table 5.2.5 and the average area is about 90 ha.

The irrigation canal layout of the existing irrigation systems; i.e. Nyamindi and Thiba systems, will not be changed. Mutithi irrigation system consists of a main canal and five (5) branch canals to be newly developed. The general layout of the proposed irrigation system is shown in Fig. 5.2.4.

(2) Proposed drainage system

The proposed drainage system is divided into three (3) systems, namely Nyamindi, Thiba and Mutithi systems. The drainage plan in the Project was made by mean of rehabilitating the existing facilities in Nyamindi and Thiba systems and construction of new drainage facilities such as main drains, branch drains and related structures for Mutithi system.

The drainage canal layout of the existing systems, i.e. Nyamindi and Thiba systems, will not be changed basically. Mutithi drainage system comprises five (5) main drains and two

(2) branch drains. The general layout of the proposed drainage system is shown in Fig. 5.2.4.

The total drainage area covered by the above main and branch drains is about 11,910 ha, which is composed of paddy area of about 5,750 ha and surrounding land area of 6,160 ha and the total drainage blocks are 103 as summarized below:

(Unit: ha)

Drainage System	No. of Drainage Blocks	Paddy	Surrounding Land	Total
Nyamindi system	8	649	258	907
Thiba system	49	3,364	3,261	6,625
Mutithi system	46	1,734	2,638	4,372
Total	103	5,747	6,157	11,904

The drainage water from other area in the Project area is evacuated directly to the rivers, i.e. Nyamindi, Murubara, Thiba, Kiruara and Tana rivers.

The drainage area of each drainage block is presented in Table 5.2.6.

(3) Proposed farm road system

For adequate operation and maintenance of the Project facilities and effective agricultural activities after implementation of the Project, the establishment of the farm road system is indispensable.

The proposed farm road system for Mutithi extension area will be provided to cover every four units in average and to link the Project area and national roads. The existing roads in Nyamindi and Thiba systems will be also improved in conformity to the above.

Nyamindi system consists of twelve (12) farm roads, Thiba system of 19 and Mutithi system of 20. The general layout of the farm road system is shown in Fig. 5.2.5.

(4) Proposed on-farm system

Based on the water balance study, the net irrigation area in the Project comprises the paddy area of 8,330 ha, which includes the existing paddy area of 5,860 ha, and horticultural

crop area of 1,230 ha. For the introduction of the modernized farming practice in the Project, the following on-farm works are proposed:

(a) Reclamation of paddy field in Mutithi extension area.

(b) Reclamation of horticultural crop field in Mutithi extension area and the MIS area.

(c) Construction of on-farm facilities such as main feeder canal, feeder canal, collector drain, field drain and their related structures for Mutithi extension area and horticultural crop area.

(d) Rehabilitation of the existing on-farm facilities in the MIS area.

The land levelling will be the major works for the reclamation of paddy field in Mutithi extension area. The cutting of and/or banking on the original ground with surface soil handling will be required to some extent for the reclamation of horticultural crops fields.

In the development plan of main irrigation system, one hundred ten (110) units in total will be formulated, of which net average area is about 90 ha.

The standard sizes of farmland block to be reclaimed to paddy field in Mutithi extension area will be the same as those in the MIS as below:

Paddy Farmland Block	Size
Field lot	0.4 ha (100 m x 40 m)
Field block	10.0 ha (100 m x 1,000 m)
Farm block	20.0 ha (200 m x 1,000 m)

The standard size of farmland block for horticultural crop field was determined as follows, taking into consideration the farming practice, topography and soil conditions.

Horticultural Crop Farmland Block	Size
Field lot	0.4 ha (100 m x 40 m)
Field block	6.0 ha (100 m x 600 m)
Farm block	12.0 ha (200 m x 600 m)

One unit will comprise some farm blocks. On-farm irrigation system in a unit consists of a main feeder canal, some feeder canals and related structures such as offtakes with check, culverts, checks, field inlets and outlets. On-farm drainage system is composed of a collector drain, some field drains and related structures such as culverts, drops, farm approaches, drainage inlets and drainage junctions.

For operation and maintenance of the on-farm facilities and effective agricultural activities, the proper on-farm roads will be established.

5.2.4 Proposed water management system

(1) Objectives

The irrigation project is generally planned on the basis of the field water requirement which is derived deducting the effective rainfall in the field from the crop water requirement assessed based on the cropping pattern.

After implementation of the project, however, actual water supply is made through irrigation facilities so as to meet the actual water requirement in the field and the effective rainfall is likely to be neglected. It means that irrigation water becomes short by the amount of irrigation water corresponding to the design effective rainfall, resulting in water shortage in downstream areas.

Rainfall in the field should therefore be monitored for its effective use and moreover timely information on rainfall be utilized for gate operations of intake and turnout structures. Water management system will have to be introduced for this purpose. In addition to the above, the proposed water management system will have the following objectives:

(a) To distribute the required irrigation water to each field properly and timely,

(b) To utilize the rainfall effectively and save the irrigation water (in drought years),

(c) To maintain the irrigation facilities properly and prevent the disaster on these,

(d) To save the operation and maintenance costs, and

(e) To collect data on rainfall, river discharge, etc. for further improvement of water management.

(2) Basic concept of proposed water management system

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.

(3) Irrigation facilities for water management

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.

The facilities to be managed by NIB are as follows:

(a)	Dam	:	Thiba	
(b)	Headworks	:	Nyamindi	(New)
			Thiba	(Existing)
			Ruamuthambi	(New)
(c)	Division Works in Link Canal System	:	Nyamindi Thiba	
(d)	Turnouts in Main Canals	:	8 places	

(4) Monitoring data processing and communication systems

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

(a) Rainfall monitoring system

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

(b) 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.

(c) 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.

(d) 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.

(e) 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.

(f) Control of irrigation facilities

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

The required numbers of the systems facilities are as follows:

Central station

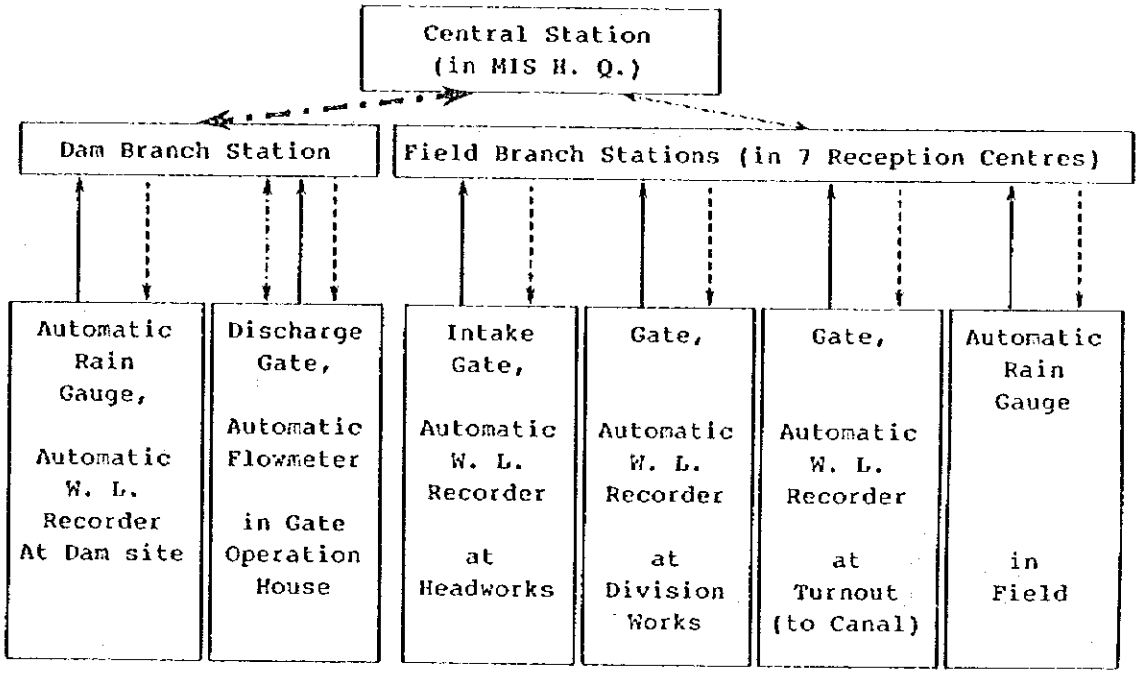
Graphic panel	1 unit
Personal computer	1 unit
Central processing unit (CPU)	16 bits
Read only memory (ROM)	256 K bites
Random access memory (RAM)	128 K bites

Dam branch station

Automatic rain gauge (damsite)	1 no.
Automatic water level recorder (reservoir)	1 no.
Automatic flowmeter (discharge conduit)	1 no.

Field branch station (7 places)

Automatic rain gauge	7 nos.
Automatic water level recorder	27 nos.



(5) Water management rules

The general water management rules were tentatively made as follows:

- Gate operation at the dam, headworks, division works and turnouts would be made simultaneously on the same day, because the time lag of flow from the dam to fields is within one day.

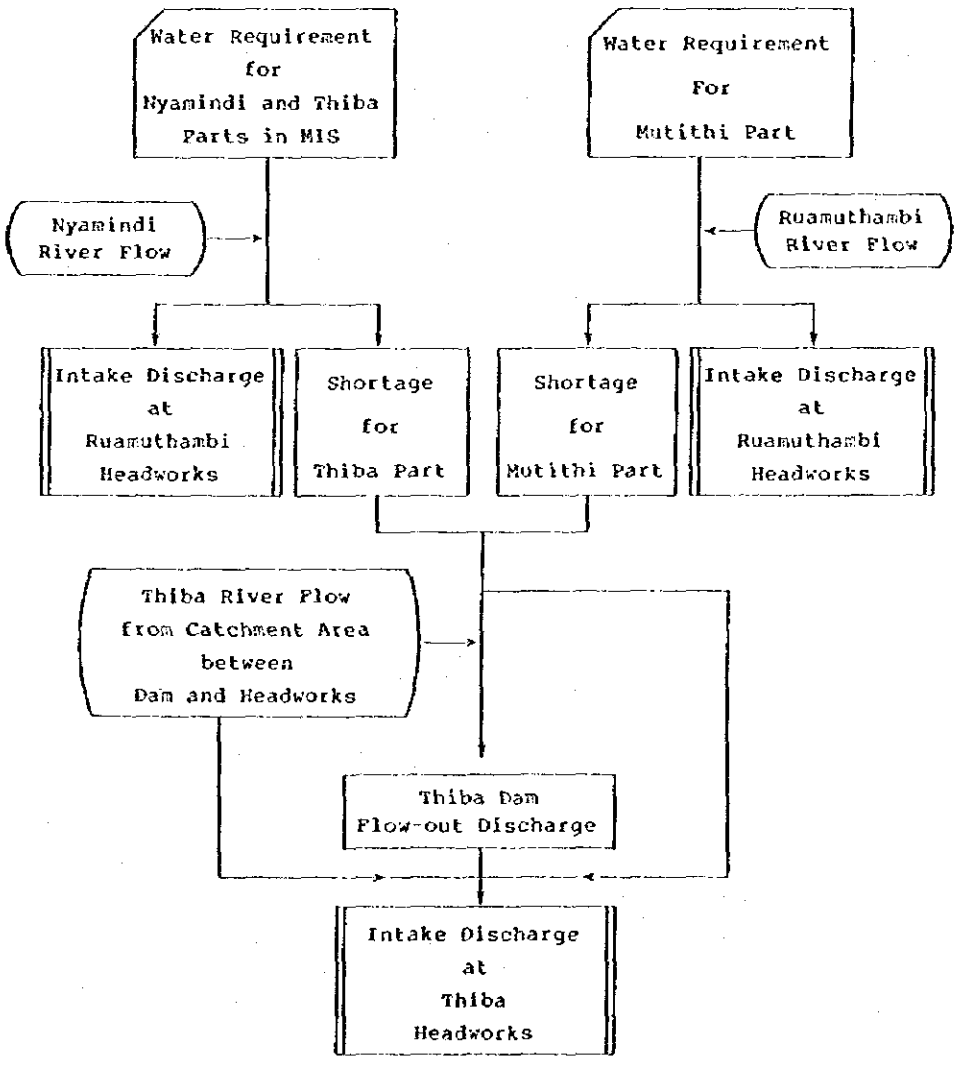
- The regular gate operation for all the facilities concerned would be made once a week on Monday.

- Released water from the dam would be stopped till weekend, when accumulated rainfall in the field for the week concerned would have reached to a certain depth and the field water requirement for remaining period from the day to its weekend could almost be satisfied only by use of natural river flows.

- Intake discharge amount at headworks would be determined firstly for the Nyamindi, secondly for the Ruamuthambi and finally for the Thiba.

- At headworks, irregular gate operations would sometimes be required depending on river flow fluctuations to keep the required intake discharges constant.

Flow Chart
For
Intake Discharge Decision at Headworks

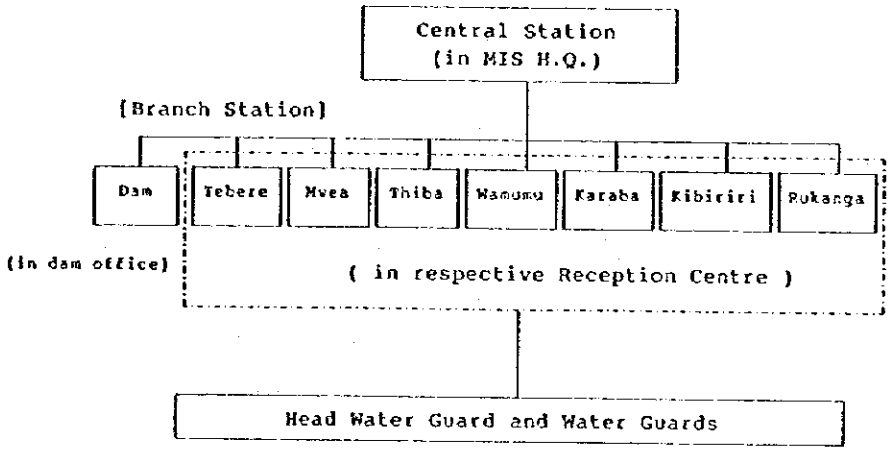


In order to establish the suitable rules to the Project, a trial and error over certain period will be required. Accordingly, the water management rules would be modified and improved in the course of actual irrigation practices in the Project operation stage.

(6) Organization for water management

The proposed organization for water management is as follows:

(a) Organization structure



(b) Staff requirement for water management

Central station

	(persons)
Head of water management section	1
Deputy of water management section	1
Secretary	1
Monitoring staff	1
Data processing staff	2
Communication staff	1
Total	7

Dam branch station

	(persons)
Head of dam sub-section	1
Reservoir control staff	1
Gate operator	1
Total	3

Field branch station

Staff	Tebere	Mwea	Thiba	Wamumu	Karaba	Kibiriri	Rukanga	Total
Head of field sub-section	1	1	1	1	1	1	1	7
Headworks staff	1	1	-	-	-	-	1	3
Diversion points staff	1	1	1	-	-	1	-	4
Rain gauge staff	1	1	1	1	1	1	1	7
Total	4	4	3	2	2	3	3	21

(c) Farmers organization for water management

In each Irrigation Unit, water user's groups will have to be organized for effective water utilization under the guidance by the water guard. With this system, the water management in each unit would be executed under farmers' responsibility.

5.3 Other Considerations for Development

5.3.1 Pilot farm

(1) Objectives of pilot farm

In the existing MIS, the double cropping of paddy has not been practiced on a commercial basis since cultivation started in 1954. Although MIS has made a series of double cropping trials, all of the trials have ended in failure. The reasons for the failure in double cropping trials are manifold; however, the decisive factors are considered as follows:

(a) Lack of suitable variety for double cropping

The varieties of the paddy cultivated in Kenya at present are those of which growth period is 150-160 days. The double cropping with those varieties of paddy makes the harvest in April-May during the long rains season which causes much post-harvest losses, or it makes the panicle formation stage in June-July which causes serious unit yield reduction by low temperature.

The key factor for successful introduction of double cropping of paddy is therefore to select the rice varieties with the growth period of 110-120 days which are also tolerant to low temperature and insects/diseases and furthermore have good cooking quality.

(b) Deterioration of irrigation facilities, insufficient supply of irrigation water, and lack of proper water management system

The existing irrigation facilities in MIS have been deteriorated due to lack of proper maintenance. The intake water at the headworks is usually less than requirement in the field. The shortage of irrigation water is almost normal condition in MIS. Furthermore, lack of the water management system based on sufficient technical background, also results in various difficulties for proper water supplies to every part of the paddy field. It is therefore considered that in parallel with the rehabilitation works, the most applicable water management system should be established through technical studies on water management method and system.

(c) Insufficient mobility in farming operation

MIS has only 26 workable tractors of 60 PS class at present, and for ploughing 5,860 ha of paddy (rotavation), it takes about 150 days to complete. Rotavation will necessarily have to be completed within about 50 days for successful introduction of double cropping. Furthermore, the present processing capacity of the existing reception centres is rather small in comparison with the expected daily harvest. The period for receiving and drying the harvested paddy will become shorter when double cropping of paddy is introduced. This also makes double cropping of paddy difficult under present condition.

Large scale trials on the double cropping of rice were made four times in the past by the order of the Government of Kenya. None of the trials however succeeded mainly due to the above

reasons. The success in the double cropping of rice has long been desired by the Government as well as the MIS farmers.

For successful introduction of double cropping of rice, the above constraints will have to be solved. The Project will certainly give the way to solve some of the technical constraints such as deteriorated irrigation facilities, shortage of irrigation water and unsatisfactory mobility in farming operation However, some other constraints will still remain particularly in the fields of agronomy and water management. With this in view, it is recommended that a pilot farm be established in the Project area. The pilot farm will have the following objectives:

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

(b) field trials on farm machinery and equipment,

(c) field trials and demonstration on irrigated horticultural crops cultivation in the red soils,

(d) field trials on irrigation practices and water management at on-farm level both for rice and horticultural crops, and

(e) seed multiplication.

(2) Outline of pilot farm plan

(a) Location

The proposed pilot farm site is located near Unit M-9 of the existing Mwea Section in MIS with a total area of about 100 ha. The proposed site is mostly grassland at present. The site location is indicated in Fig.5.3.1.

The proposed site is selected, taking the following into account:

- Favourable road condition for access to the site,
- Easy availability of irrigation water,
- Availability of large virgin land of about 50 ha,

- Availability of both red soils and black cotton soils in one place, and
- Area near the Mutithi extension area.

The selected site meets all the above conditions. However, the proposed site for the pilot farm is privately owned. Preliminary enquiries among the land owners at the proposed site have been made by NIB.

(b) Present condition of the proposed pilot farm site

The proposed site consists of flat lowland (65 ha) where black cotton soils are developed and hilly land (35 ha) covered with red soils. The present conditions of both areas are as follows:

Area	Topography	Soil	Land Use
Flat lowland	Slope : 1/200 Elevation : 1,188-1,190 m	Black cotton soils	Grassland
Hilly land	Slope : 1/80 Elevation : 1,189-1,195 m	Red and brownish red soils	Upland field

(c) Scale of the pilot farm

The following will be minimum requirement for pilot farm operation:

(Unit: ha)

Farm	
1. Irrigated paddy field	30
2. Irrigated horticultural crops field	10
3. Experimental farm	5
Buildings and related facilities	5

(d) Pilot farm facilities

(i) Irrigation facilities

The irrigation water will be taken through a turnout to be newly constructed in the existing Thiba main canal at water level of 1,196 m. The main feeder

canal will directly taken water from the turnout and convey to the fields. The highest irrigable area will be 1,194 m. It is recommended that these irrigation facilities be constructed in parallel with the new Nyamindi headworks as well as the Link canal-I and -II, because irrigation practices by use of water from the existing Thiba main canal will surely affect the irrigation condition particularly at the peak requirement period (September/October) in the existing Thiba part. The general layout is shown in Fig.5.3.2.

(ii) Drainage facilities

The existing natural drain flowing into the upstream end of the existing Kiruara main drain at the northwest end of unit M-9 in MIS will be improved as the main collector drain of the pilot farm.

(iii) Buildings and related facilities

The following buildings and related facilities will be provided:

1) Pilot farm main office
2) Warehouse for equipment and tools
3) Drying facilities and rice mill
4) Agricultural machinery, garage and workshop
5) Experimental facilities including laboratory equipment
6) Meteorological observation facilities
7) Warehouse for spare parts, fertilizer and pesticide and others.

5.3.2 Resettlement and rural community development in the Mutithi extension area

The land in the Mutithi extension area is privately owned. There are about 1,580 land holders who own various sizes and shapes of land in the Area. The farmers in the red soils area use their land mostly for cultivation of maize and beans; on the other hand, those in the black cotton soils area use their land mostly for cattle grazing. About 60% of the land holders in the black cotton soils area are staying outside elsewhere.

Most of the farmers living in the Mutithi area, the absent land holders who stay outside and the opinion leaders who have prime ties with the communities in the Area, are highly in favour of the proposed irrigation development. However, some comments are also observed among the resident farmers who have relatively small land holdings and the fear in losing their land. In order to convince these farmers, NIB will have to continue the patient explanation and discussions under strong supports of the cooperative who acts as a buffer between NIB and the farmers.

The Mutithi extension area is remoted from the public services and infrastructures such as electricity and domestic water supplies, roads and agricultural institutions and facilities. Villages are not well developed, particularly in the black cotton soils area, no single village is observed. Such present condition implies that irrigation development of the Area will require not only irrigation/drainage facilities but also other ancillary facilities which will help the farmers (land holders) to settle in the Area. These may include electricity and rural water supplies, health facilities for sanitary protection, and educational facilities. In order to realize the Project smoothly, such rural community development will be required. These studies 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.

5.3.3 Environmental study on dam construction and irrigation development

Dam construction and irrigation development are 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. They are further classified as follows:

(1) Physical resources

a. Surface water hydrology
b. Surface water quality
c. Groundwater hydrology
d. Groundwater quality
e. Soils

f. Geology/Seismology
g. Erosion/Sedimentation
h. Climate

(2) Ecological resources

a. Fishery (inland fishery)
b. Aquatic biology
c. Wildlife
d. Forest

(3) Human use values

a. Agriculture/Irrigation
b. Aquaculture
c. Water supplies
d. Navigation
e. Recreation
f. Power
g. Flood control
h. Dedicated area uses
i. Industry
j. Agro-industry
k. Mineral development
l. Highway/Railway
m. Land use

(4) Quality of life values

a. Socio-economic condition
b. Resettlement
c. Cultural/Historical values
d. Aesthetic values
e. Archaeological values
f. Public health
g. Nutrition

The anticipated environmental impacts affected by the Project are divided into (1) those by construction of dam and reservoir and (2) those by development of irrigation system.

Environmental Impacts by Dam Construction

The following items are conceivable as the environmental impacts due to construction of the Thiba dam:

Physical resources

(1) Changes in the river flow pattern, sediment transportation mechanism and water quality in the river system

(2) Increase of groundwater potential in the river basin

Ecological resources

(3) Impact on aquatic fauna and flora

(4) Increase of productivity of aquatic life, especially fish population

(5) Impacts on terrestrial wildlife

(6) Loss of forest resources in the reservoir area

Human use values

(7) Mitigation of flood damages

(8) Development potential of hydropower

Quality of life values

(9) Inundation of farm land and houses in the reservoir area

(10) Development potential of recreation area in the vicinity of the reservoir

Environmental Impacts by Irrigation Development

The following items are conceivable as the environmental impacts due to development of irrigation system:

Physical resources

(1) Changes of soil fertility condition under irrigation

(2) Change of surface and groundwater quality

Ecological resources

(3) Increase of productivity of fish production and possibility of aquaculture in the irrigation area

Human use values

(4) Increase of crop production

(5) Acceleration of development for agro-industry and marketing activities in the irrigation area

(6) Provision of easy access to domestic water for the farmers

Quality of life values

(7) Improvement of local transportation

(8) Increase of employment opportunity

These impacts on environmental resources will have to be carefully studied by NIB during the stage of detailed design of the Project.

5.3.4 Compensation problem for prospective reservoir area

The present land use conditions in the reservoir area are illustrated in Fig.5.3.3. The present land use is summarized as follows:

Land Use	Area (ha)	%
Coffee	14	10
Maize	66	47
Forest	10	7
Bush	19	13
Swampy grassland	31	22
Residential	2	1
Total	142	100

The land in the reservoir area is privately owned and will have to be compensated for construction of the Thiba dam. The rough estimate based on aerial photo interpretation indicates that there also exist about 28 houses in the reservoir area. These houses will also be translocated or compensated.

CHAPTER VI PROPOSED PROJECT WORKS

6.1 Dam and Reservoir

6.1.1 Damsite

(1) Location and accessibility

The Thiba damsite is located on the Thiba river, about 4 km to the north of the Route B20/1, and in the Kiritini Sublocation, Gichugu Division, Kirinyaga District.

The damsite is easily accessible from the Route C198 or C199 that would not be widened, straightened and surfaced for use as an access road.

(2) Topography

A topographic map of 1:5,000 scale with 5-meter contour intervals covering Thiba damsite and reservoir area was completed in August 1987 under the contract with Surtech Ltd. This map is used in the design of the dam and the area-storage capacity curve for the proposed reservoir. An aerial topographic map of 1:50,000 with 50-feet contour intervals is used for general purposes.

The Thiba damsite is located at the junction of the Thiba river and the Kaboyo river. Valley shape is narrow at the damsite and is wide upstream, so the topography is suitable for the damsite.

(3) Geology and embankment materials

Geological investigations of the Thiba damsite and the reservoir area were carried out to determine the soundness of the site and the water-tight qualities of the reservoir. Two holes, including permeability tests and standard penetration tests, were drilled to a total depth of 55 m.

One test pit of 1 m x 1 m was excavated for a depth of 2.5 m in order to investigate the embankment materials and to obtain the samples for soil mechanical tests. Two auger borings were conducted around the prospective borrow area for a total depth of 5 m. All these geological investigations and soil mechanical laboratory tests were executed under the contract with Surtech Ltd.

The Pleistocene basalts and Tertiary agglomerates are developed around the damsite. The completely weathered pyroclastic materials 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 in the foundation. Dissolvable limestone groups or gypsum are not expected in the reservoir geology.

Available embankment materials near the Thiba damsite are red soils, highly weathered agglomerates, moderately weathered basalts and faint weathered basalts. The abundant materials are red soils and faintly weathered basalts.

(4) Hydrology

The catchment area of the proposed Thiba damsite is 172.6 km^2. The annual inflow to the reservoir is about 92 MCM in the year 1980, 1/5 drought year. The total storage capacity of 18 MCM is required to irrigate 9,560 ha with a surplus storage capacity of 1 MCM. The reservoir capacity and the dam height are determined on the basis of the comparative study. The area-capacity curve of the reservoir is shown in Fig. 6.1.1. The summary of reservoir hydrological data is as follows:

Total storage capacity	18 MCM
Effective storage capacity	15 MCM
Dead storage capacity (100 year)	2.6 MCM
Water level at total storage (N.W.L)	El. 1,380.0 m
Water level at dead storage (D.W.L)	El. 1,363.0 m
Flood water level (H.W.L)	El. 1,382.5 m
Area at total storage	1.2 km^2

6.1.2 Selection of dam type

It is quite evident that a concrete dam would not be economical on the geological conditions.

Completely weathered agglomerates with a thickness of about 4 m are observed in the damsite foundation, so impervious blanket is recommendable as the foundation treatment. In such case, the inclined impervious core type is advantageous on the smooth joint between blanket and core zone.

The zoned fill dam is selected for the following reasons.

(1) In case of the homogeneous type dam, the shear strength of the embankment materials is low, so the gentle slopes are required. In addition to the large embankment volume, compaction control by moisture content is difficult in the weather conditions like Kenya.

(2) In general, facing type dam is adopted for lack of the impervious materials, and is not economical.

(3) There should be the possibility of the hydraulic fracturing caused by the arch action in the core zone, if rock materials are embanked in the transition zone between inclined core zone and downstream rock zone.

(4) In case of the zoned fill dam, the shear strength of the embankment materials is high. And execution management of the embankment is not difficult in the weather conditions like Kenya.

It is therefore concluded that zoned fill dam is suitable in all aspects such as materials availability, suitability for dam height and economic construction.

6.1.3 Selection of dam axis

The study on available topographic map of 1:50,000 scale leads to the comparison study on the alternative dam axes. Three alternative dam axes are selected for comparison as shown in Fig. 6.1.2.

The selection of dam axis is carried out from the viewpoint of the potential storage capacity. The results are summarized below and dam center line No. 3 is selected.

Potential Storage Capacity

Dam Center Line	Storage Capacity
No. 1	8 MCM
No. 2	13 MCM
No. 3	18 MCM

6.1.4 Dam design

(1) Features governing design

- Sediment deposition, 100 years	2.6 MCM
- Spillway design flood	560 m^3/sec
- Maximum intake capacity	25 m^3/sec
- River diversion, 10-year probability	280 m^3/sec

(2) General description

The Thiba dam is classified as a zoned fill dam with an inclined impervious core. Major dimensions of dam and reservoir are summarized in Table 6.1.1. General plan and cross section of dam are shown in Fig. 6.1.3 and Fig. 6.1.4.

The dam has a crest length of about 1,350 m, width of 8 m and the maximum height of 35 m above the base of impervious core. Total volume of earth and rock materials in the embankment is about 1,200,000 m^3 and is divided into five zones to permit optimum use of materials available in the vicinity of damsite.

Rock zones are divided into two zones, upstream and downstream rock zone. Source of rock materials is faintly weathered basalts. Quarry site is located at about 2 km upstream.

The width of the impervious core zone is designed at about 40% of the water depth. The source of materials is red soils. The borrow area is located at about 1 km upstream.

One of the purposes of the transition zone is to mitigate the arch action in the core zone by embanking the medium materials between core zone and downstream rock zone in the sense of the modulus of deformation. Source of this zone is red soils or highly weathered agglomerates.

Impervious blanket zone is designed to control the seepage from the foundation. The source of materials is red soils.

6.1.5 Foundation treatment

The completely weathered agglomerates with a thickness of about 4 m are observed at the borehole No. BT-1. It is recommended that the impervious blanket method be adopted to prevent the leakage from the foundation, because the improvement of its permeability by grouting is difficult.

As for the seepage control of cracky zone in both abutments, the improvement of its permeability by curtain grouting will be possible.

A relief well is designed to reduce the uplift in the foundation, occurring at the draw-down.

6.1.6 Spillway

The spillway design flood is determined to be the peak flood derived from one-day rainfall of 275 mm with 625-year return period, occurring uniformly over the entire basin. The design flood is determined at 560 m^3/sec.

The main spillway is located at right side abutment. Main spillway consists of un-gated side-flow intake crest of 75 m in length and 2.5 m of overflow design depth, guide channel of 16 m in width, chute channel of 10 m in height and 175 m in length, stilling basin of 15.5 m in height and 75 m in length.

There is no suitable site for the emergency spillway around the reservoir. Therefore, the main spillway is designed to withstand the flood of 1000-year return period with sufficient freeboard allowance in order to make up for the emergency spillway.

6.1.7 River diversion

Flood scale of 10-year return period is adopted as the diversion requirement, considering the required period of about 5 years for the dam construction works.

A diversion tunnel alignment is selected at right abutment from the topographic conditions. Diversion of the river will be accomplished through a concrete lined tunnel, 6.3 m in diameter and 550 m in length, which will pass the design flood of 280 m^3/sec with a water surface elevation of 1,360 m at upstream.

To avoid the possibility of over-topping during the early stage of construction, the crest of the upstream coffer dam is set at an elevation of 1,361 m.

6.1.8 Intake and outlet works

Design intake capacity for irrigation is about 7 m^3/sec. On the other hand, design discharge in case of the draw-down is about 25 m^3/sec. Maximum capacity of the intake structure is

designed to release the discharge of 25 m^3/sec. The period of the draw-down for the emergency is considered about 7 days.

The intake structure is designed to be located at the inlet portion of diversion tunnel with a drop inlet type. The intake pipe of 2.0 m in diameter will be located through diversion tunnel. The flow water through the pipe will be controlled by the jet flow gate of 2.0 m in diameter.

6.2 Irrigation and Drainage Facilities

Based on the irrigation and drainage development plan, the following irrigation and drainage facilities will be established and rehabilitated for the Project in accordance with the basic condition and design criteria mentioned in ANNEX-VI in detail.

(1) Construction of new Nyamindi headworks and Ruamuthambi headworks.

(2) Rehabilitation of the existing Thiba headworks.

(3) Construction of headraces, link canals and related structures.

(4) Construction of irrigation and drainage facilities for Mutithi extension area and horticultural crop field in the MIS area.

(5) Rehabilitation of the existing irrigation and drainage facilities in the MIS area.

6.2.1 Headworks

(1) New Nyamindi and Ruamuthambi headworks

New Nyamindi and Ruamuthambi headworks will be newly constructed and the major features of both headworks are as follows:

Headworks	New Nyamindi	Ruamuthambi
- Location	2.1 km upstream from existing headworks	0.5 km downstream from national road B20/1
- Design intake discharge	7.01 m^3/sec	2.30 m^3/sec
- Design flood discharge	390 m^3/sec	180 m^3/sec
- Weir		
Type	Fixed concrete type	Fixed concrete type
Crest elevation (m)	EL. 1,209.50	EL. 1,213.00
Crest length (m)	45.0	36.0
Crest width (m)	1.0	1.0
Weir height (m)	4.5	3.5
Side slope (Upstream)	vertical	vertical
Side slope (Downstream)	1:0.75	1:0.75
- Intake structure		
Intake gate	Slide gate	Slide gate
Width (m)	1.5	1.3
Height (m)	2.1	1.1
Number	3	2
- Scouring sluiceway		
Scouring gate	Slide gate	Slide gate
Width (m)	2.0	2.0
Height (m)	3.1	2.1
Number	2	1
- Length of protection (m)	22.0	13.5
- Length of apron (m)	8.0	6.5

(2) Thiba headworks

In order to take the design discharge of 11.12 m^3/sec, weir height will be raised with height of 0.5 m, taking account of the necessary heads at intake gate, because water surface elevation in link canal-II after improvement will become the same as crest elevation of the existing weir.

In addition, the protection works for left side slope and downstream river bed will be rehabilitated.

6.2.2 Headrace and link canal

Major features of designed headraces, link canals and related structures are summarized as below and the location of these facilities is shown in Fig. 6.2.1.

(1) Headraces and link canals

(a) Headraces

Headraces	Nyamindi	Ruamuthambi
Design discharge (m^3/sec)	7.01	2.30
Gradient	1/5,000	1/4,000
Base width (m)	2.90	1.80
Water depth (m)	2.13	1.35
Velocity (m/sec)	0.54	0.44
Embankment height (m)	2.70	1.70
Length (km)	0.64	6.3

(b) Link canals

Link Canals	I	II	III
Design discharge (m^3/sec)	4.91	11.12	3.62
Gradient	1/5,000	1/3,200-3,400	1/5,000
Base width (m)	2.50	5.00-7.00	2.30
Water depth (m)	1.87	1.71-2.02	1.65
Velocity (m/sec)	0.49	0.68-0.69	0.46
Embankment height (m)	2.30	2.30-2.60	2.10
Length (km)	7.5	3.4	2.4

(c) New Nyamindi main canal

Design discharge (m^3/sec)	2.28
Gradient	1/4,000
Base width (m)	1.80
Water depth (m)	1.35
Velocity (m/sec)	0.44
Embankment height (m)	1.70
Length (km)	0.6

(2) Related structures

In connection with headraces and link canals, the following related structures will be provided in headraces and link canals.

i) Nyamindi diversion works
ii) Thiba diversion works
iii) Regulating basin
iv) Other related structures such as culverts, drops and cipolletti weirs

6.2.3 Rehabilitation of existing MIS irrigation and drainage facilities

Major facilities to be rehabilitated and improved are as follows:

- Reclamation of horticultural crops field
- Rehabilitation of irrigation canals and related structures
- Rehabilitation of drainage canals and related structures
- Rehabilitation of farm roads
- Rehabilitation of on-farm facilities

(1) Reclamation of horticultural crops field

The horticultural crops field will be newly reclaimed in brownish red soils area and the Area in net is as follows:

Irrigation System	Horticultural Crops Field
- Nyamindi system	570 ha
- Thiba system	230 ha
Total	800 ha

(2) Rehabilitation of irrigation canals and related structures

In order to meet the design discharge, canal base which is shallowed owing to erosion of inside slopes and sedimentation

will be excavated and the destroyed inside slopes will be re-embanked. General features of the existing irrigation canals are given in Table 6.2.1.

The existing related structures in main and branch irrigation canals will be rehabilitated and improved according to the results of inventory survey and check of canal profile sections. The numbers of related structures to be rehabilitated and improved are listed in Table 6.2.2.

(3) Rehabilitation of drainage canals and related structures

Most of canals will be required to be expanded for obtaining the design water level and sufficient flow capacities, and eroded inside slopes will be re-embanked. General features of the existing canals are shown in Table 6.2.3.

The existing related structures in main and branch drains will be rehabilitated and improved on the basis of the results of inventory survey and check of canal profile sections.

The numbers of related structures to be rehabilitated and improved are presented in Table 6.2.4.

(4) Rehabilitation of farm roads

The existing farm roads will be rehabilitated and some farm roads will be expanded to link the Project area to the national roads.

The total length of farm roads is about 164 km as mentioned below and the length of each farm road is given in Table 6.2.5.

Road System	Length (m)	Density (m/ha)
Nyamindi	41,000	22
Thiba	122,720	26
Total	163,720	25

(5) Rehabilitation of on-farm facilities

The following on-farm facilities will be rehabilitated for each unit.

- On-farm irrigation facilities such as a main feeder canal, feeder canals, offtakes, culverts, checks and field inlets
- On-farm drainage facilities such as a collector drain, field drains, culverts, drops, drainage inlets, drainage junctions and field outlets
- On-farm roads and farm approaches

6.2.4 Irrigation and drainage facilities of the Mutithi extension area

The following works will be established for Mutithi extension area:

i) Reclamation of paddy field and horticultural crop field
ii) Construction of irrigation canals and related structures
iii) Construction of drainage canals and related structures
iv) Construction of farm roads
v) Construction of on-farm facilities

(1) Reclamation of paddy field and horticultural crop field

The land reclamation area in net of both fields are as follows:

- Paddy field	2,470 ha
- Horticultural crop field	430 ha

(2) Irrigation canals and related structures

The irrigation system comprises one main canal and five (5) branch canals. The general features of irrigation canals are given in Table 6.2.1. The following related structures are proposed.

- Turnouts and offtakes for distribution of irrigation water
- Checks for regulation of water level
- Drops and chutes for conveyance of water from a higher to a lower elevation
- Culverts for conveyance of water under roads

- Cross drains provided under canals for conveyance of water over rivers
- Spillways for protection of canals
- Cipolletti weir for measuring the flow of water
- Washing step for washing

The numbers of above related structures are listed in Table 6.2.2.

(3) Drainage canals and related structures

The drainage system consists of five (5) main drains and two (2) branch drains. The general features of drainage canals are shown in Table 6.2.3. The following related structures will be provided.

- Drainage inlet for drainage to parent canal crossing under its inspection road
- Drainage junction for protection of canals
- Syphon for conveyance water under the existing water supply pipeline
- Drop for conveyance of water from a higher to a lower elevation

The numbers of above structures are presented in Table 6.2.4.

(4) Farm road

The total length of farm roads is about 81 km and the length of each farm road is given in Table 6.2.5.

(5) On-farm facilities

The following on-farm facilities is proposed to be established for each unit.

- On-farm irrigation facilities such as a main feeder canal, feeder canals, offtakes, culverts, checks and field inlets
- On-farm drainage facilities such as a collector drain, field drains, culverts, drops, drainage inlets, drainage junctions and field outlets
- On-farm roads and farm approaches

6.3 Pilot Farm

6.3.1 Preliminary design of the pilot farm

(1) Irrigation canals and related structures

The irrigation system in the pilot farm comprises one (1) main feeder canal, three (3) branch feeder canals and eleven (11) feeder canals. The required structures related to the above canals would be a turnout in Thiba main canal, offtakes in the main feeder canal for diversion of water to branch feeder canals, offtakes in branch feeder canals for distribution of water to feeder canals, checks and culverts.

The general features of the proposed irrigation facilities are shown below:

Turnout	Type	:	double orifice, pipe conduit
	Intake W.L	:	1,196 m
	Intake discharge	:	0.07 m^3/sec
	Gate	:	W 0.3 m x H 0.3 m

Canal	Length	Bed Width	Canal Height	Remarks
	(m)	(m)	(m)	
Main feeder canal	1,650	0.30	0.50	Concrete lining
Branch feeder canal No. 1	1,250	0.30	0.40	Concrete lining
Branch feeder canal No. 2	600	0.30	0.30	Concrete lining
Branch feeder canal No. 3	1,550	0.30	0.35	concrete lining
Feeder canal (11 nos.)	4,000	0.30	0.30	Earth canal

Related structures			
in Main feeder canal	Offtake	:	2 nos.
	Check	:	2 nos.
	Culvert	:	9 nos.
in Branch feeder canal	Offtake	:	12 nos.
	Check	:	12 nos.
	Culvert	:	18 nos.
in Feeder canal	Check (plank)	:	101 nos.

(2) Drainage canals and related structures

The drainage system in the pilot farm comprises two (2) main collector drains, four (4) collector drains, 15 field drains and four (4) catch drains. The required structures

related to the above canals would be drain inlets, drainage junctions, culverts, drops and cross drains.

The general features of the proposed drainage facilities are shown below:

(Unit: m)

Canal	Length	Bed Width	Canal Height
Main collector drain No. 1	1,050	0.50	1.20
Main collector drain No. 2	1,550	0.40	1.00
Collector drain No. 1	850	0.40	1.10
Collector drain No. 2	800	0.50	1.10
Collector drain No. 3	400	0.40	0.90
Collector drain No. 4	350	0.30	0.70
Field drain (15 nos.)	5,750	0.30	0.70
Catch drain No. 1 (Existing)	1,350	1.20	1.50
Catch drain No. 2 (Existing)	450	0.60	0.90
Catch drain No. 3	750	0.50	0.80
Catch drain No. 4	450	0.40	0.70

Related structures			
in Drains in farm field	Drain inlet	:	4 nos.
	Drainage junction	:	19 nos.
	Culvert	:	17 nos.
	Drop	:	10 nos.
in Catch drain	Culvert	:	13 nos.
	Cross drain	:	2 nos.

(3) Roads and related structures

The proposed road network would consist of trunk road, farm road and on-farm road. The existing road C289, linking the national road B6 and the pilot farm, would be improved with the asphalt pavement so that this road would be the trunk road for the pilot farm. The other farm roads would be newly provided for effective agricultural activities.

The general features of the proposed roads are summarized as follows:

(Unit: m)

Road	Length	Total Width	Effective Width	Pavement
Trunk road	400	6.0	5.0	Asphalt
Trunk road (Existing part)	7,850	6.0	5.0	Asphalt
Farm road No. 1	3,150	6.0	5.0	Gravel
Farm road No. 2 (Existing)	1,050	6.0	5.0	Gravel
On-farm road (9 nos.)	4,500	5.0	4.4	Laterite

Related structures			
to Trunk road	Cross drain	:	4 nos.
to Farm road	Farm approach	:	5 nos.
to On-farm road	Farm approach	:	34 nos.

The farm layout of the above facilities is shown in DRAWINGS.

(4) Buildings

The buildings required for the pilot farm would consist of two categories, i.e. the buildings for farm operation and the buildings for experiment and demonstration.

The breakdown of buildings is preliminarily summarized as follows:

(i) Buildings for farm operation
(Total floor space: 3,000 m²)

- Pilot farm main office
- Garage for vehicles
- Rice mill house
- Warehouse for fertilizer and pesticide
- Workshop
- Garage for agricultural machinery and O/M equipment
- Warehouse for equipment and tools

(ii) Buildings for experiment and demonstration
(Total floor space: 700 m²)

- Laboratory and lecture hall
- Meteorological station office

The layout of area for the above buildings is shown in DRAWINGS..

(5) Utility facilities

(a) Electric power supply system

The electric power supply system for the pilot farm would be installed by connecting with the public electricity service line.

(b) Water supply system

The surface water to be conveyed through the branch feeder canal No. 3 would be used after treatment. Then, the water supply system would comprise the following:

- Water tank
- Water treatment facilities
- Distribution pipes

(6) Machinery and equipment

For effective activities and smooth operation of the pilot farm, the following machineries and equipments would be required:

- Agricultural machinery
- Operation and maintenance equipment
- Vehicles
- Rice mill
- Workshop equipment
- Experimental and training equipment
- Meteorological and farm observation equipment

6.3.2 Preliminary cost estimate

The cost of the pilot farm comprises the construction cost of farm facilities, buildings and utility facilities, the equipment cost, the engineering cost, the miscellaneous cost, and physical contingency. The total cost was roughly estimated to be KShs.65 million as shown below:

(Unit: KShs.x10^3)

Item	Cost
1. Construction Cost	25,000
2. Machinery & Equipment Cost	33,000
3. Engineering Cost	2,500
4. Miscellaneous Cost	2,000
5. Physical Contingency	2,500
Total	65,000

For the above cost estimate, the following were taken into account:

(1) The cost was estimated on the basis of "Current construction cost" issued by the Ministry of Works and Housing in 1987 and the present market prices in Kenya.

(2) The construction works would be executed on the contract basis.

(3) The engineering cost was tentatively set at 10% of the construction cost.

(4) The physical contingency related to the work quantities was set at 10% of the construction cost.

6.4 Ancillary Works

6.4.1 Farm buildings and reception centre

(1) MIS Scheme area

The existing five (5) reception centres of MIS would be improved and expanded to the scale that would be able to accommodate the increased production of double cropping of rice and horticultural crops. A centralized machine centre would be also required for effective operation and maintenance of increased number of the farm machinery and equipment. The proposed site for the machine centre should be located near the existing MIS Headquarters.

The following farm buildings are included in the proposed works (for details see Table 6.4.1):

Reception Centres

a. Expansion of concrete floor
b. Construction of warehouse for fertilizer and agro-chemicals
c. Construction of short-term storage for collecting/shipping of horticultural crops

Machine Centre

a. offices for controlling all the machinery including O/M equipment
b. workshop
c. fuel tanks
d. garages

(2) Mutithi extension area

The Mutithi extension area of 2,900 ha would have almost same irrigation layout as the existing MIS and be divided into two (2) sections, or Kibiriri and Rukanga (tentative name).

Reception Centre

a. Office
b. Weighing facilities
c. Concrete floor for drying grains
d. Short term storage house for dried paddy
e. Warehouse for fertilizer and agro-chemicals
f. Temporary garage for farm machinery and equipment

Machine centre

Machine centre would be centralized and located near the existing MIS headquarters. Accordingly, machinery centre will not be established in Mutithi extension area. The centralized machine centre in MIS would be shared with the Mutithi extension area.

6.4.2 Rice processing facilities

In future, under with project condition, irrigable rice field of 8,330 ha will be developed (MIS: 5,860 ha, Mutithi: 2,470 ha) and the paddy production will attain about 100,000 tons per annum under double cropping system with cropping intensity of 200%.

The paddy sold to NCPB is processed on the commercial basis by the existing two (2) large millers who hold the license from NCPB.

One is the Mwea Rice Mill (MRM) and the other is the United Millers Ltd.located at Kisumu in the Western Province. All of paddy harvested in MIS has been processed at MRM.

Presently, MRM operates its milling machines for six (6) days a week, or 50 weeks a year excluding two (2) weeks in June and December. The operation hours are eight (8) hours a day for normal season and 16 hours in 2-shift operation for peak season. The present milling capacity during the normal season is 112 tons/day, and for the peak season, 224 tons/day. It corresponds to annual milling capacity of 33,600 tons under normal operation and 67,200 tons in 2-shift operation throughout the year.

The present processing capacity of MRM will not meet the future rice production of about 100,000 tons. However, if considered 3-shift operation throughout the year, the milling capacity of MRM would be 336 tons/day or 100,800 tons/year and MRM would be able to process the future paddy production of 100,000 tons.

The 3-shift operation throughout the year is not realistic under the present socio-economic circumstances in the Area. It is therefore, recommended that an additional rice mill be established in future when the existing MRM will have the difficulties to process the paddy harvest from the Project area.

6.4.3 Farm machinery

The proposed system of farm machinery operation will be mostly conformed to the present one; namely, MIS headquarters will own all of farm machinery and carry out the mechanical cultivation for the farmers. In the Mutithi extension area, same service system will be applied. The proposed farm machinery is considered for rice cultivation, not for upland cultivation. For effective utilization of tractors, the trailers for transportation of farm inputs and harvests and large sprayers for effective operation of plant protection work. The proposed number of farm machinery is shown in Table 6.4.2. The proposed general specifications of farm machinery are as follows:

Wheel Tractor : 60 ps class (4-wheel drive)
(for operation under swampy condition)

Crawler Tractor	: 60 ps class		
Rotavator	: Width;	200	cm
Trailer	: Load capacity;	2.0	ton
Sprayer	: Tank volume;	500-1,000	lit
Chisel Plow	: Width;	150	cm

6.4.4 O&M equipment

Adequate number and kind of heavy equipment, light vehicles and workshop equipment will be one of the pre-requisites for proper operations and maintenance of the Project.

The proposed O/M equipment is listed in Table 6.4.3.

6.5 Construction Plan

6.5.1 General description

The construction works of the Project comprise the following five (5) items:

a) Construction of dam
b) Construction/rehabilitation of headworks
d) Construction of link canals
c) Rehabilitation and improvement of the existing MIS Scheme
e) Development of the Mutithi extension area

As these construction works are mainly concerned with earth works, due attention should be paid to the characteristics of earth materials which directly affect earth moving plan, selection of construction equipment, etc.

Major construction works having a large amount of earth volume would be executed by heavy construction equipment but the remaining minor works would be implemented by manpower to increase the employment opportunity for the local people in and around the Project area. Earth works consists of excavation, loading, hauling, spreading and compacting. The following equipment would be basically introduced on these earth works:

Earth Works	Earth Materials	Proposed Equipments
Excavation	Sand, Common Soil, Gravel	Bulldozer, Back-hoe Shovel
	Weathered Rock	Ripper Dozer, Back-hoe Shovel
	Rock	Blasting & Bulldozer
Loading	Any Kind of Excavated Materials	Crawler loader, Wheeled Loader, Back-hoe Shovel
Hauling	Any kind of Excavated Materials	Tipper Lorry
Spreading	Any Kind of Excavated Materials	Bulldozer
Compacting	Impervious Materials	Tamping Roller
	Coarse Materials	Vibration-Roller
	Common Soil	Compactor, Tamper

Earth works are mostly governed by rainfall. Since embankment of impervious materials are controlled by moisture density, special attention must be paid to execute the construction works for rainy days. The annual workable days were estimated to be 311 days.

6.5.2 Dam construction

(1) Construction procedure

After preparatory works, the dam construction works will be commenced by the river diversion works. After the river would be diverted by the coffer dam, the foundation excavation and foundation treatment works will be carried out.

The dam embankment will be commenced after the foundation treatment works at the river bed will be finished.

The construction of spillway will be carried out in parallel with the dam embankment, because the useful excavated materials are planned to haul directly to the dam.

Waiting for the dam embankment been completed, the river diversion tunnel will be plugged and the construction of outlet works will be carried out in parallel with the plug works.

(2) Major temporary works

Taking account the proposed quantity and placement plan of concrete for the relevant structures, a concrete batching plant having 150 m^3/day of productive capacity and a aggregate production plant of 500 tons/day will be installed as a temporary construction equipment.

Furthermore, 500 kVA of power transform station will be required for above equipment.

Besides, construction of reservoir which can store the muddy water caused by the excavation works during the construction will be required.

6.5.3 Construction of irrigation and drainage facilities

(1) Headworks

The construction works of headworks will be mainly executed during dry season in due consideration of magnitude of flood in the rivers.

After river diversion works, foundation excavation will be commenced. The concrete will be produced by several number of portable concrete mixers and placed by man power.

(2) Link canals

Earth work of the link canals will be mainly made by heavy duty equipment such as back-hoe shovels and bulldozers.

Earth lining for preventing leakage will be made by combination of back-hoe shovel and man power using vibratory plate compactor.

Concrete for proposed structures will be produced by portable mixers and placed by man power.

(3) Irrigation facilities

Irrigation facilities will comprise irrigation canals, drainage canals, farm roads and related structures.

Excavation for canal works will be executed by back-hoe shovels and embankment will be made by man power using compactors. Road works will be made by bulldozers, motor

graders and road rollers. Related structures will be constructed by man power using light equipments.

(4) On-farm

Land reclamation works will be executed by bulldozers and on-farm road works will be made by road construction equipments same as farm road, but other works such as canal works and related structures will be made mainly by man power using light equipments.

(5) Implementation schedule

The implementation period is assumed to be six (6) years from 1988 to 1993 as shown Fig.6.5.1. 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.

The detailed design and preparatory works for Phase-I (Rehabilitation of existing MIS Scheme) would be carried out in 1988 and actual construction works of Phase-I would last for two years from 1989. The detailed design for Phase-II would be made continuously from 1990. During the period from 1988 to 1990, the preparatory works for Phase-II would be made accordingly. The construction works for Phase-II would be completed within three (3) years from 1992.

6.6 Cost Estimate

6.6.1 Basic assumptions

The construction cost is estimated based on the following conditions:

(1) The unit prices are estimated based on the market prices in Kenya according to the Japanese standard on unit price estimation, and are checked using "Current Construction Cost" issued by the Ministry of Works, Housing and Physical Planning as of January, 1987.

(2) The exchange rate used in the estimate is shown as follows:

US$1 = KShs.16.5 = ¥150

(3) The depreciation costs of machinery and equipment are considered in the estimate of the construction unit cost, based on the hiring rate given in the "Current Construction Cost".

(4) Taxes on the construction materials, machinery and equipment to be imported from abroad are excluded in the cost estimate.

(5) The construction cost is divided into local and foreign currency portions. Local currency portion is estimated on the basis of current price in and around the Project area. Foreign currency portion is estimated based on the CIF prices at Mombasa.

6.6.2 Financial project cost

Financial project cost comprises construction cost for infrastructural facilities, cost for initial farm investment, administration cost, engineering cost, land acquisition cost, physical contingency and price contingency. The total project cost is estimated at KShs.1,227.1 million., comprising KShs.468.4 million (40% of the total cost) of local currency portion and KShs.758.7 million (60% of the total cost) of foreign currency portion. The construction cost for infrastructural facilities would amount to KShs.637.2 million in total, corresponding to KShs.66,700 per ha.

The Project costs are summarized in Table 6.6.1.

6.6.3 Annual disbursement schedule

The annual disbursement schedule is worked out based on the construction implementation schedule. The details are given in Table 6.6.2.

6.6.4 Annual operation and maintenance costs

The annual operation and maintenance costs including the salaries of project administration staff and technical staff for water management, the materials and labour costs for repair and maintenance of O&M equipment, and running cost of project facilities. The annual operation and maintenance costs are estimated at KShs.53 million (see Tables 6.6.3 and 6,6,4).

6.6.5 Replacement cost

Some of the facilities, especially mechanical works have shorter useful life than the civil works and require replacement at a certain time within the project useful life. The Table 6.4.5 shows the useful life and replacement cost of the mechanical works.

CHAPTER VII ORGANIZATION AND MANAGEMENT

7.1 Organization for Project Execution

The National Irrigation Board (NIB) will be responsible for implementation of the Mwea Irrigation Development Project under close coordination with relevant ministries such as the Ministry of Energy and Regional Development, Ministry of Water Development, Ministry of Works and Housing, Ministry of Agriculture and Ministry of Land and Settlement. It is recommended that, for smooth implementation of the Project, NIB organize a steering committee comprising the representatives from the relevant ministries. The organization chart of the Government of Kenya appears at Fig.7.1.1.

7.1.1 National Irrigation Board (NIB)

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. Policy matters relating to NIB operations have been decided by the Board of NIB which comprises representatives from the Ministry of Agriculture, Ministry of Finance, Ministry of Health, Ministry of Water Development, National Cereals and Produce Board (NCPB) and Provincial Agricultural Board (PAB) from all the provinces of the country. Under the Board, NIB is headed by the General Manager who is responsible for the execution of the policy of the Board and for the control and management of its day-to-day business.

NIB operates presently six (6) national irrigation Schemes as mentioned in Section 2.6 of Chapter II and employs a total staff of 923 comprising 83 senior staff, 418 junior staff and 422 subordinates. The organization chart of NIB is shown in Fig.7.1.2. In general, all the NIB Schemes are well managed even under current financial limitations. NIB has mainly been involved in operation of the existing Schemes and therefore very scarce number of engineers are working in the present organization due to the limited job opportunity. The Project would require new recruitment of the engineering staff for detailed design and supervision of construction works.

7.1.2 Ministry of Energy and Regional Development

MOERD was newly established in 1979, and NIB has been put under the control of this Ministry in June 1987. The Ministry is in charge of executing Government' policies in the fields of energy and regional development including the national irrigation Schemes. MOERD has accorded its highest priority for early implementation to the Mwea Irrigation Development Project. Strong administrative support is expected from the Ministry for implementation of the Project.

7.1.3 Proposed Construction Office

For the execution of the Project, NIB will have to organize a Steering Committee as mentioned above. The General Manager of NIB will be responsible for execution of the Project in consultation with the Steering Committee. NIB will also have to establish a Project Construction Office which will transact the day-to-day business of the Project execution. The Project Manager who will be appointed by the General Manager of NIB will be responsible for operation of the Project Office. NIB will delegate to the Project Manager the power, subject to any instructions that may be given by the General Manager of NIB:

(1) to control and supervise the acts of all staff of the Project Office in the matters of executive administration in the whole field of project execution and in all matters concerning the account and record of the Project Office, and

(2) to dispose of all issues and questions relating to the Project staff and agents of the Project Office and/or NIB.

Any contracts for the Project works will be concluded by tendering which will be monitored by the tender evaluation committee comprising the members to be appointed by the General Manager of NIB. The Project Office will be responsible for execution of the policy decisions of NIB as well as the Steering Committee.

Because of the high priority given to the Project, NIB is expected to implement the Project in the shortest possible time. Such being the situation, NIB' activities will increase drastically, and it may become questionable whether the existing

organizational framework is optimal, taking into consideration the enormous tasks ahead. It is therefore recommended that NIB conduct a thorough review of its organization, management methods, staffing and accounting policies, and if necessary, revise the Government regulations which presently govern the NIB's activities; the Irrigation Act 1966 and the Irrigation Regulation 1977.

The proposed organization chart of the Project Office is given in Fig.7.1.3. The Project Office will comprise a head office and four (4) branch offices. The head office will be established within the existing NIB headquarters at Nairobi, having three (3) sections such as administrative, engineering and construction. The branch offices will take responsibility for quality control of the construction works, measurement of the work quantities, records of the work progress,etc. at each work site. The branch offices will be established at the Thiba damsite and appropriate places within three (3) irrigation parts; Nyamindi, Thiba, and Mutithi.

7.2 Organization of Operation and Maintenance

7.2.1 Proposed O&M Office

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, therefore, will be incorporated in the proposed O&M office which be in charge of:

(1) planning of irrigation schedule,
(2) rainfall and hydrological measurement,
(3) control of irrigation water supplies from dam to each irrigation unit,
(4) day-to-day administration relating to the water management according to the operation rule,
(5) periodical data recording,
(6) maintenance and repair of the Project facilities,
(7) operation and maintenance of the equipment and machinery,
(8) farming guidance and farm inputs supplies to the farmers, and