REPUBLIC OF KE[illegible]

MINISTRY OF AGRICULTURE
NATIONAL IRRIGATION BOARD

BURA IRRIGATION
SETTLEMENT PROJECT

PROJECT PLANNING REPORT

VOLUME 3 ANNEXES

August 1977

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Hunting Technical Services Ltd.
East African Engineering Consultants

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The Bura Irrigation Settlement Project, Project Planning Report, comprises the following volumes:

1	Main Report
	Annexes
2	Soils
	Hydrology
	Agricultural Planning
3	Livestock
	Fisheries
	Wildlife and Ecology
	Forestry
4	Sociology and Settlement
	Public Health
	Institutions and Services
5	Village Planning and Design
	Housing and Buildings
	Utility Services
	Processing
6	Principles and Criteria for Development
	Organisation, Management and Training
	Project Costs
	Economic and Financial Analyses
	Implementation

BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

LIVESTOCK ANNEXE

BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

LIVESTOCK ANNEXE

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

The project area at Bura is traditionally used by Orma pastoralists to herd their cattle and, more recently, by Somali people to herd their camels. Due to low and erratic rainfall the carrying capacity of the area is low, (estimated at 25 hectares per Livestock Unit (ha per LSU) and is exceeded by the present stocking rate of 20 ha per LSU. The productivity of the local herd is low and the commercial offtake is small. There are plans to improve the carrying capacity and commercial offtake of the area by setting up group ranches on the area to the west of the Tana River. One effect of these ranches may be to reduce the amount of land available to the Orma and their livestock.

Local livestock will be able to get to the river and floodplain to the east of the supply canal via the inverted siphons and fords which will be built into the canal. The Orma will also be able to water their stock at the eleven watering points along the supply canal. The supply of water to these ponds may have to be controlled to avoid overgrazing. The floodplain between the project and the river, which is a dry season reserve grazing area for the Orma, will not be readily available to them once the project is underway. Compensation will have to be provided for the Orma to make up for this loss of grazing which is of particular importance to their survival in drought periods. The people to be compensated, and the form the compensation ought to take, can only be determined after further study of the area. A number of Orma may wish to settle on the project; those whose grazing may be affected as a result of the development at Bura should be given priority in the allocation of tenant holdings.

The tenants at Bura will wish to keep their own livestock. If properly managed this would produce useful supplements to their diet in the form of meat and milk. Animals will have to be stall fed and very careful control of the tenants' stock will have to be maintained by the project management. The necessity for stall-feeding arises from the size of the project, the need to reduce damage to the irrigated area, its works, and the surrounding area, and the lack of provision for any alternative forms of stock keeping for the tenants. Theoretically there should be sufficient crop residues for each tenant to stall feed two cows or their equivalent in small stock. The storage and feeding of crop residues will require advice and help for the tenant. Six extension agents and one livestock officer should be provided to give this advice. These personnel should start to join the project in 1982. The tenants should be encouraged to keep cross-bred goats and small stock rather than cattle, because these would be better suited to the available crop residues. Trials should be set up in 1982 to investigate the management techniques to be used by tenants at Bura.

No special provision is to be made for the initial supply of milk to the tenants. Alternative forms of protein and other nutrients should be available from their irrigated vegetable plots and a certain amount of milk will be available from the tenants' own livestock. Alternative sources of milk will be available in the form of powdered milk, tinned milk and processed liquid (UHT) milk from private traders.

CHAPTER 1 THE PRESENT SITUATION

1.1 Livestock Types

The cattle kept by the Orma in Tana River District are typical of North Eastern Province, and are Boran stock. These animals are well adapted to the harsh environment of the area and are able to make good use of the poor grazing which is available for much of the year.

Small stock are of less importance to the Orma, though every settlement keeps both sheep and goats. The sheep are predominantly of the Blackhead Persian type, though there are also a number of Masai fat-tailed sheep in most flocks. Goats are of the Boran and Small East African type.

In recent years the numbers of camels on the west side of the river have increased due to the movement of the Abdullah and Waldei Gabbra from the east. The camels they bring with them are of the Benadir or southern Somalia type.

There is also a small number of donkeys in the area, typical of those found throughout Kenya. More detailed descriptions of the livestock types mentioned can be found in Mason and Maule (1).

1.2 Livestock Numbers

The most recent survey of livestock numbers in the area was undertaken in 1973 by Watson *et al* (2): a summary of the results is given in Table 1.1.

Table 1.1 - Summary of Livestock Numbers in Tana River District, 1973

Species	Number (1)	Conversion Factor	LSU Total	LSU Per Cent
Cattle	214 567	0.8	171 650	89.2
Sheep	39 394	0.1	3 940	2.0
Goats	15 210	0.1	1 520	0.8
Camels	12 834	1.1	14 120	7.3
Donkeys	2 205	0.6	1 320	0.7
TOTAL	284 210		192 550	100.0

(1) Source: Watson et al (1973); LSU - Livestock Unit

The importance of cattle to the Orma is emphasised by the fact that in 1973 they accounted for almost 90 per cent of the estimated livestock biomass. It is likely, however, that in the four years since Watson's survey was carried out, the proportion of camels in the area has considerably increased. Despite this cattle remain the dominant livestock species. There are many fewer sheep and goats in the Tana River District than there are in other similar pastoral areas of Kenya.

The estimated stocking rate, calculated from the total number of livestock units in the District is 20 hectares per livestock unit (ha per LSU).

The 1969 National Census (Republic of Kenya, 1970) calculated that there were approximately 16 000 Orma in Tana River District, which implies that there is an average of 13 cattle, 2 sheep and 1 goat per head of population.

1.3 Husbandry and Management

The Orma are highly respected for their standard of animal husbandry and are considered to be among the best stockmen of all the pastoral tribes of Kenya.

The herds are generally kept in two groups. One group is made up of lactating cows and their calves, and remains near the settlements which are based around a source of permanent water. The other group, the dry herd, contains dry cows, heifers, young stock and males. These dry herds are highly mobile and move considerable distances in search of the good grazing and temporary water holes which are to be found away from the river after rains.

Unlike many other pastoral tribes in East Africa the Orma do not always enclose their stock in predator-proof enclosures ('bomas') at night: calves, however, are always enclosed at night. Instead, the Orma often light a series of fires around their camp and the cattle congregate around the fires. If biting flies are troublesome at night the cattle move down-wind of the fires and the smoke helps to repel the flies.

Although there are lion throughout the area, the principle of not enclosing stock at night is effective. The Orma have found that if lion get into the boma many more cattle are killed in the general confusion that follows, than if the animals were not enclosed. This practice has has recently been adopted at Galana Ranch, to the south of Bura, and has been found to be very effective in reducing stock losses from predators.

The time that cattle are moved away from the camps to graze in the mornings depends on the quality of the grazing; the better the grazing the later the animals depart. On average cattle on this type of range spend just over six hours a day feeding. The daily feeding time increases as the quality and quantity of the grazing declines, but does not appear to be affected by the level of heat stress. This is a good indication of the degree of adaptation the Orma cattle have to the stress of their environment (3).

Whenever possible cattle with the mobile cattle camps are watered once a day, but it is more usual for the animals to be watered once every two or even three days. The milk herds are watered every day and are milked twice a day; before leaving the settlement in the morning and again in the evening when they return, about an hour before darkness.

The movement of Orma stock throughout the area has been described by Marsh (4). The main areas where there are permanent settlements are along the Tana River around Wayu, and at Assa on the Tiva River. After the rains the cattle camps range out from these centres. As the dry season progresses they fall back on the sources of permanent water, with a large number of cattle concentrated on the delta of the Tana River. Apparently there has been a recent trend towards a more settled existence.

1.4 Herd Composition

Table 1.2 summarises the data on herd and flock composition as presented in 1973 by the Food and Agricultural Organisation, FAO (5).

Table 1.2 - Summary of Herd and Flock Composition in Tana River District

Item	% Frequency in: Milk herd	Dry herd
A.CATTLE		
Cows (>3 years)	41.00	47.63
Heifers (1-3 years)	10.70	23.94
Female calves (<1 year)	18.62	7.50
Male calves (<1 year)	17.29	5.73
Young males (1-3 years)	9.20	7.78
Old males (>3 years)	3.19	7.42
B.SHEEP		
Male (>1 year)	—	12.0
Female (>1 year)	—	17.0
Male (<1 year)	—	9.5
Female (<1 year)	—	61.5
C.GOATS		
Male (>1 year)	—	14.0
Female (>1 year)	—	19.5
Male (<1 year)	—	9.5
Female (<1 year)	—	57.0

Source: FAO (5)

The overall male : female ratio for the district cattle herd was 1: 3.35.

1.5 Productivity

Data on the productivity of the stock in Tana River District have been presented by FAO (5) and Keymeulen (6).

Cattle production in the district is seriously affected by the high mortality; 33 per cent calf mortality and 8 per cent adult mortality. One of the main reasons for the high level of calf mortality is the fact that the calves have to compete with the stock-keepers for milk. The calving rate is 60 per cent.

The liveweight gains are similar to other arid areas in Kenya: males making 230 kilogrammes (kg) at 36 months and an adult weight of 338 kg; and females 221 kg at 36 months and 264 kg adult weight.

The length of lactation is at present about 220 days, producing an average of 1.4 litres per day, a little over 300 litres per lactation. It was calculated that in 1973 there were three million litres of milk produced in excess of local consumption, assuming home consumption of two litres per head per day.

1.6 Range Resources and Management

Considering the ecological and climatic environment of Tana River District the condition of the rangeland is not as bad as in many other areas of Kenya. The present estimated carrying capacity of the district is approximately 25 ha per LSU, slightly less than the estimated stocking rate of 20 ha per LSU.

Apart from the riverine floodplain and the main drainage channel (laga) beds there is a shortage of valuable perennial grasses. The recent increase in the number of camels in the District will improve the utilisation of large browse species of vegetation such as *Acacia* and *Grewia*. The system of highly mobile cattle camps traditionally used by the Orma is well suited to the conditions of the area. Over-grazing occurs around sources of permanent water and the recent trend towards a reduction in mobility needs to be discouraged, as it will lead to the degradation of the range resource and a decline in productivity.

At least 75 per cent of the district is *Acacia/Commiphora* bush, typical of much of the semi-arid and arid zones of East Africa. The grass cover in this vegetation type is low. Other vegetation types which were identified by the 1973 FAO study (5) included: floodplain grassland, bushed grassland, grassland, and bushland thicket.

Fire can be an important ecological factor in determining the vegetation type present in each locality. Fires are started by the pastoralists as a form of bush control. The use of fire is particularly important in the relationship between the extent of floodplain grassland and the riverine forest. Marsh (4) points out that fires in this area extend the grassland and reduce the forest, and he considers that fires started on the floodplain grassland 'are probably responsible for as much of the destruction of forests as clear felling for agriculture'.

In the areas away from the floodplain fires are of less importance, owing to the low standing crop of the herb layer. Fires in this area become signigicant only after years of high rainfall when, towards the end of the dry season, there is still sufficient grass to support a bush fire.

The main constraint to greater utilisation of the range resource is lack of permanent water. The provision of permanent water in such a delicate ecological system should be approached cautiously and water points should not be installed unless effective controls of stocking rates can be guaranteed.

There is a very real problem that the Ministry of Agriculture Ranches, the game parks and the irrigation schemes, will force the Orma into a situation of overstocking the remaining range to such an extent that the vegetation will be destroyed, leading to soil erosion and loss of stock in years of poor rainfall, and loss of productivity in other years.

1.7 Disease

The more important cattle diseases in the District are Contagious Borne Pleuropneumonia, Trypanosomiasis, Black quarter, Anthrax, Foot and Mouth, and various tick-borne diseases, such as East Coast Fever.

Apart from the immediate effect of reducing the productivity of the herds, diseases such as Foot and Mouth limit the movement of sale-cattle out of the area due to the imposition of quarantine restrictions.

Rinderpest, which used to be endemic in the area, appears to have been brought under control by the free compulsory vaccination campaign.

There are only a few dips in the area and the facilities for animal-health care are limited.

1.8 Livestock Marketing

It has been calculated by FAO (5) that present cattle requirements for home comsumption and commercial sales are 3.8 per cent and 4.4 per cent of the adult herd, respectively. This represents some 14 000 cattle, of which 7 500 would be available for commercial sale. Sales of adult goats are at 6 per cent of the flock, about 900 animals, and sheep sales are at 4 per cent of the flock, about 1 500 animals.

Unlike many other pastoralists the Orma are sometimes willing to sell cattle, and there are records of Orma trading cattle at Mombasa in 1920 (7). Quarantine restrictions however, often prohibit the movement of cattle out of the District.

There are stock routes along the east and west banks of the Tana River (Figure 1.1), designed to bring cattle out of the North Eastern Province. The east bank route comes from Garissa and passes through Bura before arriving at the coast at Mokowe: from there cattle are shipped to Mombasa. The west bank route passes through the proposed Bura Project, Stage I, area, (where the Ministry of Agriculture have plans for a holding ground at Bilbil) and, via holding ground at Wenje, to Karuwa and thence to Kipini.

The east bank route is the one most freguently used, and as many as 50 000 animals have been trekked along this route in one year (S. Meadows, L.M.D., pers, comm). Early in 1975, however, 15 000 cattle were moved down the west bank route due to disease restrictions on the east bank.

1.9 Development Proposals

According to the FAO report (5) the development of the livestock industry in Tana River District should be aimed at establishing a balance between the stocking rate and carrying capacity, increasing the productivity of each animal and increasing the saleable output of stock. To achieve these aims it will be necessary to: undertake range improvements through the use of fire; install more animal-health facilities; consolidate the west bank stock route and associated holding grounds; and encourage selective breeding within the pastoral herds. For these developments to be justified it would be necessary to obtain an undertaking from the pastoralists to increase their sales. The northern part of the District, which includes the Bura area, should concentrate on the production of immatures which could then be sold as store cattle for fattening in other areas. In the north there is a considerable potential for increased production from the two browsing species of livestock, camels and goats. The commercial potential of these two species very much depends on the future demand in the Middle East.

The Range Management Division of the Ministry of Agriculture is planning to set up a number of grazing schemes in Tana River District to be based on a co-operative system or private ownership. The location of each proposed ranch is shown in Figure 1.1. One ranch, Ida-sa-Godana, was started in 1968 with 100 members of the co-operative, and all the other ranches south of this are in an advanced stage of planning. The size of each ranch is shown in Table 1.3, and the total area to be used for grazing schemes amounts to almost half a million hectares. The water supplies for these ranches will generally come from water pumped from the Tana River.

Orma pastoralists who are not members of the co-operatives will not be allowed to graze on the ranches, but stock routes will be maintained to allow the Orma and their animals access to the Tana River.

Table 1.3 - Size of Proposed Ranches in the Tana River District

Ranch name	Area (ha)
Ida-sa-Godana	51 146 (already operating)
Giritu	42 340
Haganda	12 141
Dalu	15 000
Kitangale	23 541
Wachu	33 725
Kandertu	12 800
Umoja	59 000
Mpongwe	54 750
Wayu	60 729
Hera	16 000
Walenda	84 400
TOTAL	465 572

Source: Range Management Division, Ministry of Agriculture, pers, comm.

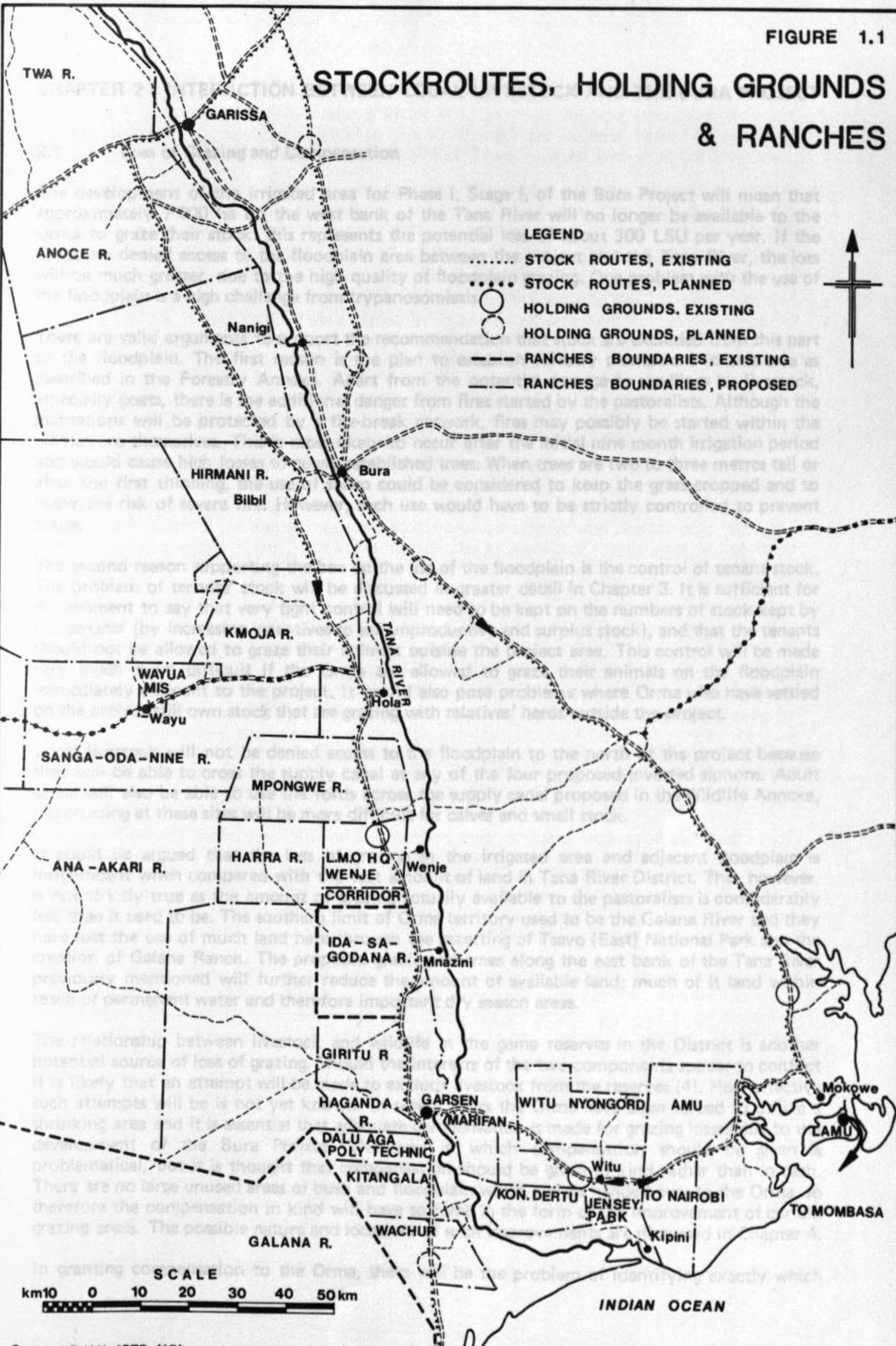

FIGURE 1.1

STOCKROUTES, HOLDING GROUNDS & RANCHES

CHAPTER 2 INTERACTION BETWEEN LOCAL LIVESTOCK AND THE BURA PROJECT

2.1 Loss of Grazing and Compensation

The development of the irrigated area for Phase I, Stage I, of the Bura Project will mean that approximately 7 000 ha on the west bank of the Tana River will no longer be available to the Orma to graze their stock: this represents the potential loss of about 300 LSU per year. If the Orma are denied access to the floodplain area between the project and the Tana River, the loss will be much greater, due to the high quality of floodplain grazing. One problem with the use of the floodplain is a high challenge from trypanosomiasis.

There are valid arguments to support the recommendation that stock are excluded from this part of the floodplain. The first reason is the plan to establish forestry plantations in this area as described in the Forestry Annexe. Apart from the potential damage to seedlings by livestock, especially goats, there is the additional danger from fires started by the pastoralists. Although the plantations will be protected by a fire-break network, fires may possibly be started within the plantations themselves. This is most likely to occur after the initial nine month irrigation period and would cause high losses to newly established trees. When trees are two to three metres tall or after the first thinning, the use of sheep could be considered to keep the grass cropped and to lower the risk of severe fire. However, such use would have to be strictly controlled to prevent abuse.

The second reason supporting the ban on the use of the floodplain is the control of tenant stock. The problem of tenants' stock will be discussed in greater detail in Chapter 3. It is sufficient for the moment to say that very tight control will need to be kept on the numbers of stock kept by the tenants (by increasing incentives to sell unproductive and surplus stock), and that the tenants should not be allowed to graze their animals outside the project area. This control will be made very much more difficult if the Orma are allowed to graze their animals on the floodplain immediately adjacent to the project. It would also pose problems where Orma who have settled on the project still own stock that are grazing with relatives' herds outside the project.

Local livestock will not be denied access to the floodplain to the north of the project because they will be able to cross the supply canal at any of the four proposed inverted siphons. Adult cattle will also be able to use the fords across the supply canal proposed in the Wildlife Annexe, but crossing at these sites will be more difficult for calves and small stock.

It could be argued that the loss of grazing in the irrigated area and adjacent floodplain is insignificant when compared with the vast amount of land in Tana River District. This, however, is not strictly true as the amount of grazing actually available to the pastoralists is condiderably less than it used to be. The southern limit of Orma territory used to be the Galana River and they have lost the use of much land here through the gazetting of Tsavo (East) National Park and the creation of Galana Ranch. The proposed grazing schemes along the east bank of the Tana River previously mentioned will further reduce the amount of available land; much of it land within reach of permanent water and therefore important dry season areas.

The relationship between livestock and wildlife in the game reserves in the District is another potential source of loss of grazing. Should the interests of the two components appear to conflict it is likely that an attempt will be made to exclude livestock from the reserves (4). How effective such attempts will be is not yet known. In recent years the Orma have been forced to utilize a shrinking area and it is essential that adequate compensation is made for grazing losses due to the development of the Bura Project. The way in which compensation should be given is problematical, but it is thought that compensation should be given in kind rather than in cash. There are no large unused areas of bush and floodplain which can be handed over to the Orma, so therefore the compensation in kind will have to come in the form of the improvement of certain grazing areas. The possible nature and locations of such improvements are discussed in Chapter 4.

In granting compensation to the Orma, there will be the problem of identifying exactly which groups have the right to be compensated. Such decisions can only be based on the results of a study of traditional land-use patterns. It is unlikely that the Somalis who at present run their camels on the west bank of the Tana River will be able to establish any claim to traditional usership of the Bura area, because they have moved into the area only recently.

2.2 Access to Water

North of the irrigation area access to water from the Tana River will be possible by the inverted siphons and crossings. Additional watering points will be supplied to the west of the main canal and the irrigation area as set out in the Wildlife Annexe. The drinking ponds are intended for use by both wildlife and livestock. As long as no settlements are allowed within two kilometres from each pool there should be no conflict between the two users; livestock will use the ponds during the day time and wildlife will tend to use them during the night.

The provision of water will require careful control, as there will almost certainly be a tendency for stock to over-utilise the vegetation in the vicinity of the ponds. It may be necessary to shut off ponds if this occurs so that the people and their stock are forced to move to another area. It is likely that this will not prevent them from grazing access to the ponds, however, and one possible undesirable result of the closure of ponds in over-grazed areas is that the people and their stock may then take water directly from the canal. This is a common practice at the Hola Irrigation Scheme and careful enforcement will be necessary to prevent it from happening on the much longer Bura supply and main canals. Education of the Orma in the reasons and benefits of grazing control may reap far greater response.

2.3 Crop Raiding

The destruction of crops by Orma cattle is unlikely to be a serious threat on the Bura Project. During the day cattle will be under the control of herdsmen and there will be no reason for them to enter the irrigated area. Although Orma stock are not always enclosed at night they should be kept sufficiently far away from the project area to discourage animals from leaving the camps and foraging the project tenants' crops during the night. Because of the increased likelihood of stock thefts by some of the large number of people on the project it is probable that Orma camps will start to 'boma' their animals at night if they did not previously do so.

There is a much greater potential danger from the tenants' own stock escaping and causing damage to crops. This should be preventable by advising tenants on the construction of proper pens and inflicting heavy penalties on those who allow their animals to stray.

CHAPTER 3 REQUIREMENTS FOR LIVESTOCK PRODUCTS BY TENANTS

3.1 National Irrigation Board Policy on Livestock

The Trust Land (Irrigation Areas) Rules state that there can be no grazing of stock within an irrigation scheme without the stockowner having a valid licence. Furthermore, stockowners within a scheme are required to comply with all instructions given by the scheme manager relating to animal husbandry; being required to keep their stock in stipulated areas, prevent their stock damaging crops; and to declare to the manager the annual natural increase of their stock. The scheme manager is empowered to confiscate and to sell all unlicensed stock, the proceeds of the sale, less expenses, being returned to the owner.

These rules, therefore, permit tenants to keep a controlled number of properly managed animals and give the scheme manager the powers to enforce disciplinary measures on those who do not obey the rules. As licences are given on an annual basis, the rules also give the manager the theoretical opportunity to control the total number of stock within the project. It is unfortunate that on the irrigation schemes at Mwea and Hola these rules have not been enforced and livestock wander, virtually without any control, over the irrigated area.

3.2 Tenants' Stock

It is unlikely that project tenants coming from the distant parts of Kenya to join the Bura Project will bring any livestock with them. A number of stock, however, may be brought onto the irrigated area by any Pokomo, Malakote or Orma people who obtain a holding on the project. As the majority of the tenants will not be local people, there will probably not be great numbers of stock present during the early years of project development. However, as the project progresses and the farmers pay off their loans they will have spare money to invest and it is likely that they will wish to invest at least some of this money in livestock. Those wishing to purchase stock would be able to do so from the Orma.

Apart from the floodplain, the rangeland surrounding the irrigation project is of very low carrying capacity (see the Wildlife Annexe). Allowing tenants' stock to graze outside the project would almost certainly lead to over-utilisation of the rangeland and degradation of the vegetation at the expense of the Orma pastoralists. Tenants' stock should therefore be confined within the project area.

It is obviously undesirable to have large numbers of animals wandering in an uncontrolled manner inside an irrigation project, because the damage to crops and the irrigation system would be considerable. Animals should therefore be permanently enclosed and stall fed. The practicality of doing this, from the point of view of food availability, is discussed below.

The type of stock to be kept by the tenants is a matter which, in theory at least, can be decided upon by the project manager when issuing licences. There will probably be a tendency among the richer tenants to wish to purchase cattle, but there are a number of reasons for discouraging tenant cattle. The milk yields of the local Orma cattle are low and have been measured by Keymeulen (6) to average 1.4 litres per day over a 220 day lactation period. Although these yields come from animals using the relatively poor quality grazing in Tana River District it is unlikely that the same cattle fed on the crop residues at the Bura Project would be able to attain very much greater yields. Although there will be some fresh grass available from cutting the canal banks, generally, there will be only a limited amount of green fodder available. The lack of green fodder becomes more serious if grade cattle are considered because the higher potential of these animals will not be realised if they are fed on a low quality ration lacking green fodder. A further problem with improved cattle is that they require a higher standard of husbandry which cannot be guaranteed for the tenants' stock at Bura.

It is thought that small stock, particularly goats, would be much better suited to the conditions under which tenants' stock will live. Goats will be able to make better use of the high fibre diet which will be offered to the animals. It should be possible to get as much as one litre a day during a lactation of about 170 days from an improved Boran or improved Small East African goat. The type of animal used to upgrade the local goat stock is important, and recent results in Kenya have indicated that Swiss Toggenburg cross-breds can do well (8).

One major problem associated with the tenants' stall-fed livestock will be the storage of fodder, because the crop residues to be used throughout the year are produced only at certain times. Storage by the tenant will increase his livestock costs.

The need for effective control oftenants stock cannot be overstressed. Experience at other irrigation schemes indicates that control and discipline will be difficult to enforce. It is unfortunate that tenants' stock should not be allowed to graze outside the Bura Project, but the consequences of letting them do so would be disastrous for the rangeland. To facilitate the control of tenants' stock these limitations should be made perfectly clear to prospective tenants before they join the project.

The tenants should be encouraged to keep poultry, as this will form a valuable source of additional protein to their diet. There are possible undesirable side effects to poultry from the residues of the pesticides used to protect the cotton crop, which include infertility and thin eggshells. The importance of these effects can only be determined after the project has been in operation for several years.

3.3 Meat and Milk Requirements

Table 3.1 gives estimates of the possible demand for milk and meat on Phase I, Stage I of the Bura Project for the first twenty years.

Meat

It is estimated that in Year 5 it will be necessary to slaughter 5 224 cattle; in Year 10, 6 235, and in Year 20, 8 991 cattle. The total supply of meat will not necessarily come from cattle alone and these figures can be adjusted accordingly: the conversion ratio is approximately six sheep or goat carcasses to one cattle carcass.

There is no doubt that the requirement for almost 9 000 cattle for slaughter in Year 20 could be met from local herds. The recent reduction in the commercial offtake from the North Eastern Province and the present low rate of 4.4 per cent for commercial sales from Tana River District (6) suggest that there is a large potential source of supply.

It is not proposed to establish any infrastructure to deal with the purchasing and marketing of meat. This can be left to the private sector, which will fill the gap between the demand and supply.

Facilities are provided for an abattoir. This may be required to slaughter 15 cattle or their equivalent per day in Year 5, 18 cattle per day in Year 10 and 25 cattle per day in Year 20.

Table 3.1 - Estimated Milk and Meat Requirements for Phase I, Stage I, of the Bura Project.

Year	Total population estimate	Estimated annual meat requirements Tonnes (1)	Cattle (2)	Estimated annual milk requirements (1 000 litres) High (3)	Low (4)
0	1 216	18	127	67	35
1	8 022	117	837	441	234
2	20 921	305	2 182	1 151	611
3	39 251	573	4 093	2 159	1 146
4	48 381	706	5 045	2 661	1 413
5	50 092	731	5 224	2 755	1 477
6	51 876	757	5 410	2 853	1 515
7	53 737	785	5 604	2 956	1 569
8	55 670	813	5 806	3 062	1 626
9	57 685	842	6 016	3 173	1 684
10	59 785	873	6 235	3 288	1 746
11	61 968	905	6 462	3 408	1 810
12	64 248	938	6 700	3 534	1 876
13	66 618	973	6 947	3 664	1 945
14	69 087	1 010	7 215	3 800	2 017
15	71 660	1 046	7 473	3 941	2 092
16	74 339	1 085	7 754	4 089	2 172
17	77 130	1 126	8 044	4 242	2 252
18	80 037	1 169	8 347	4 402	2 337
19	83 064	1 213	8 662	4 569	2 426
20	86 217	1 259	8 991	4 742	2 517

(1) Assumed 40 g/person/day = 14.6 kg/person/year.
(2) Assumed 50% slaughter out, 280 kg liveweight at slaughter.
(3) Assumed 55 litres/person/year. (Republic of Kenya, 1963 (9)).
(4) Assumed 20% of population under five years, and 400 g per person under five years of age per year.

Milk

Two different levels of requirements have been used in estimating the demand for milk for Phase I, Stage I of the Bura Project (Table 3.1). The high level of requirement has been calculated from a figure of 55 litres per person per year. This is the average annual milk consumption of the middle income bracket in Kenya (9). The lower level of requirement has been calculated on an assumed daily consumption of 400 g of milk by each child under five years of age. The high level of consumption would require approximately twice as much as the low level. At high consumption rates in Year 20 the Bura Phase I, Stage I, population would need 5 million litres of milk each year (13 800 litres a day) and 2.5 million litres a year (6 900 litres a day) at a low level of consumption.

3.4 Estimated Crop Residue Production

Before considering the possible strategies for milk production at Bura, it is worthwhile to review the possible sources of livestock food.

The main source of fodder will be from crop residues. It is expected that the main source of crop residues will be cotton seed, maize stover, and groundnut and cowpea hay. Additional residues will be available from cotton stalks, groundnut haulms and maize husks. The estimated production of cotton seed, maize stover, groundnut hay and cowpea hay is given in Table 3.2; the expected nutrient and protein production from these residues is given in Tables 3.3 and 3.4.

Table 3.2 - Estimated Annual Bulk Production of Crop Residues Phase I, Stage I, Bura Project (Tonnes)

Year	Cotton Seed[1] Total	Cotton Seed[1] Per tenant	Maize Stover[2] Total	Maize Stover[2] Per tenant	Groundnut Hay[3] Total	Groundnut Hay[3] Per tenant	Cowpea Hay[4] Total	Cowpea Hay[4] Per tenant
1	2 887	4.5	6 624	10.4	—	—	1 229	1.9
2	6 544	3.6	14 544	7.9	—	—	1 766	1.0
3	10 050	2.5	18 156	4.5	—	—	3 878	1.0
4	10 050	2.0	17 436	3.4	102	0.02	4 842	0.9
5	10 050	2.0	15 924	3.1	294	0.06	4 650	0.9
6	10 050	2.0	14 898	2.9	698	0.14	4 246	0.8
7	10 050	2.0	14 046	2.7	1 022	0.20	3 973	0.8
8	10 050	2.0	13 356	2.6	1 294	0.25	3 746	0.7
9	10 050	2.0	12 696	2.5	1 560	0.30	3 562	0.7
10	10 050	2.0	12 360	2.4	1 650	0.32	3 386	0.7
11	10 050	2.0	12 360	2.4	1 650	0.32	3 296	0.6

Assumptions:
1. Cotton seed production, 1.5 tonnes per ha
2. Maize stover production, 6 tonnes per ha
3. Groundnut hay production, 1.6 tonnes per ha
4. Cowpea hay production, 1.6 tonnes per ha

Table 3.3 - Estimated Annual Production of Total Digestible Nutrients (TDN) from Crop Residues, Phase I, Stage I, Bura Project (Tonnes)

Year	Cotton Seed[1] Total	Cotton Seed[1] Per tenant	Maize Stover[2] Total	Maize Stover[2] Per tenant	Groundnut[3] Total	Groundnut[3] Per tenant	Cowpea Hay[4] Total	Cowpea Hay[4] Per tenant	TOTAL Total	TOTAL Per tenant
1	2 627	4.1	3 776	5.9	—	—	476	0.7	6 870	10.7
2	5 955	3.3	8 290	4.5	—	—	671	0.4	14 916	8.1
3	9 145	2.3	10 349	2.6	—	—	1 474	0.4	20 968	5.2
4	9 145	1.8	9 938	1.9	41	0.01	1 840	0.4	20 964	4.1
5	9 145	1.8	9 077	1.8	118	0.02	1 767	0.3	20 107	3.9
6	9 145	1.8	8 492	1.7	279	0.06	1 613	0.3	19 529	3.8
7	9 145	1.8	8 006	1.6	409	0.08	1 510	0.3	19 070	3.7
8	9 145	1.8	7 613	1.5	518	0.10	1 423	0.3	18 699	3.6
9	9 145	1.8	7 237	1.4	624	0.12	1 353	0.3	18 359	3.6
10	9 145	1.8	7 045	1.4	660	0.13	1 287	0.3	18 137	3.5
11	9 145	1.8	7 045	1.4	660	0.13	1 252	0.2	18 102	3.5

Assumptions:
1. Whole Cotton Seed - 91% TDN
2. Mature Maize Stover - 57% TDN
3. Stemmy Groundnut Hay - 40% TDN
4. Cowpea Hay - 38% TDN

Source: Morrison, 1950 (10)

Table 3.4 - Estimated Annual Production of Digestible Protein (DP) from Crop Residues, Phase I, Stage I, Bura Project (Total in tonnes; per tenant in kg)

Year	Cotton Seed[1] Total	Cotton Seed[1] Per tenant	Maize Stover[2] Total	Maize Stover[2] Per tenant	Groundnut Hay[3] Total	Groundnut Hay[3] Per tenant	Cowpea Hay[4] Total	Cowpea Hay[4] Per tenant	TOTAL Total	TOTAL Per tenant
1	491	767	132	207	—	—	25	38	648	1 660
2	1 112	605	291	158	—	—	35	19	1 438	782
3	1 708	423	363	90	—	—	78	19	2 149	532
4	1 708	331	349	68	5	1	97	19	2 159	419
5	1 708	331	318	62	15	3	93	18	2 134	414
6	1 708	331	298	58	35	7	85	16	2 126	412
7	1 708	331	281	55	51	10	79	15	2 119	411
8	1 708	331	267	52	65	12	75	15	2 115	410
9	1 708	331	254	49	78	15	71	14	2 111	409
10	1 708	331	247	48	82	16	68	13	2 105	408
11	1 708	331	247	48	82	16	66	13	2 103	408

Assumptions: [1] Whole Cotton Seed - 17% DP
[2] Mature Maize Stover - 2 % DP
[3] Stemmy Groundnut Hay - 5% DP
[4] Cowpea Hay - 2% DP

Source: Morrison, 1950 (10)

The greatest overall production of residues, in terms of protein and digestible nutrients will be during Years 2 and 3, though the production per tenant will be greatest during the first two years. After this initial period, the level of production will gradually decline, stablising after Year 10.

By Year 11 the whole project will be producing over 18 000 tonnes of total digestible nutrients (TDN), which include over 2 000 tonnes of digestible protein (DP). On average, each tenant will produce 3.5 tonnes of TDN of which 0.4 tonnes will be DP. Digestible protein represents approximately 11 per cent of the total digestible nutrients. Over 75 per cent of the available digestible protein is expected to come from cotton seed.

Because of the presence of the pigment gossypol, a toxic glycoside, in cotton seed, care will have to be taken when feeding cotton seed to animals. Gossypol has an inhibiting effect on digestive enzymes and, due to its biological antioxidant effect, diminishes appetite and causes constipation. Mature ruminants can ingest gossypol but immature ruminants and monogastric animals are much more susceptible. Raw seeds contain between 0.4 and 1.4 per cent pure gossypol, but this is reduced to between 0.02 and 0.20 per cent by pressing. The biological effect of gossypol, when unpressed seed is used, can be prevented by the addition of ferrous sulphate. One tonne of seed can be expected to yield about 200 kg of oil, 500 kg of cotton seed meal and 300 kg of hulls. The proportion of cotton seed will have to be limited to 10 to 15 per cent of the concentrate in calf rations until three of four months of age, and should not be fed to sheep for long periods and then only at sufficient levels to balance rations.

From January to August 100 per cent of the irrigated area will be down to cotton; the crop is harvested at the end of this period. September is used for stalk removal and field preparation. From October to January the area will be used for maize and cowpeas (32 per cent), groundnuts (16 per cent) and fallow land (52 per cent), the crops will be harvested during January. The availability of crop residues will therefore be such that cotton seed and cotton stalks will be available during August, the other crop residues during January. Such a marked seasonality of crop residue production will mean that they will have to be stored for use throughout the year. The storage of crop residues at Bura will require well ventilated and waterproof stores. If each tenant is to store his own residues he will have to build facilities to store approximately 2 tonnes of raw cotton seed, 2.4 tonnes of maize stover and one tonne of cowpea and groundnut hay. Central storage of crop residues would require facilities for over 10 000 tonnes of cotton seed, 12 360 tonnes of maize stover and almost 5 000 tonnes of cowpea and groundnut hay.

3.5 Nutritional Requirements of Livestock

The estimated requirements for dry matter (DM), digestible protein (DP), and total digestible nutrients (TDN), for maintenance and growth of cattle and sheep of different liveweights are shown in Table 3.5.

Table 3.5 - Estimated Daily Nutritional Requirements for the Maintenance and Growth of Cattle and Sheep

	Liveweight	Kilogrammes DM	DP	TDN
A. CATTLE	23	0.45	0.09	0.50
	45	1.20	0.18	0.91
	68	1.64	0.23	1.36
	91	2.36	0.27	1.82
	136	3.20	0.33	2.77
	181	4.55	0.37	2.96
	227	5.45	0.39	3.82
End of growth	273	5.91	0.40	3.64
Start lactating	318	6.82	0.20	2.50
	341	8.14	0.22	2.73
	364	8.80	0.24	2.91
B. SHEEP	23	0.95	0.02	0.20
	27	1.05	0.02	0.22
	32	1.18	0.02	0.23
	36	1.25	0.02	0.25
	41	1.27	0.03	0.26
	45	1.32	0.03	0.27

Source: Morrison, 1950 (10).

The dry matter intake of cattle is at about 2.5 per cent of liveweight. Because of a higher rate of metabolism, dry matter intake for sheep is higher, between 3 and 4 per cent of liveweight. The figures for cattle have been divided into two parts: a growth period, during which food is required for maintenance and growth; and a lactation period, for which the figures shown cover the needs of maintenance only. Further intake is required to cover the demands of milk production, and this is shown in Table 3.6.

Table 3.6 - Estimated Additional Daily Nutritional Requirements for Milk Production

Litres produced	Kilogrammes DP	TDN
2	0.10	0.68
4	0.20	1.36
6	0.30	2.04
8	0.40	2.72

Source: Morrison, 1950 (10).

From Tables 3.4 and 3.5 it can be seen that a 318 kilogramme (kg) cow producing 6 litres of milk a day would require 5.22 kg of total digestible nutrients which should contain 0.5 kg of digestible protein. This is equivalent to the maintenance demands of approximately fifteen 45 kg sheep.

In comparison with cattle, goats generally produce more milk for the same quantity of nutrients, require less food for maintenance, but use more food for the processes of digestion and metabolism(11).

Trials in Kenya in recent years reported by FAO (12) have shown that stall-fed cattle can be as productive on a ration based on maize stover, with no green fodder, as they can on a ration based on fresh Napier grass. The milk yields in this trial averaged 7.5 litres per day per cow.

In view of the possibility of establishing stall-fed milk production systems at Bura, which is discussed below, it is worth mentioning the problem of heat load on productive dairy cattle. Apart from the heat stress on the animal due to the environmental heat load there is the additional heat load resulting from the animal's own metabolism. At Bura there will always be a high environmental heat load and animals fed high protein and carbohydrate rations will also generate a considerable amount of metabolic heat.

3.6 Sources of Livestock Milk and Beef and Possible Production Strategies

The calculations of estimated demands for milk and meat at Bura indicate that meat requirements could be met by the local pastoral herds.

It has been estimated that in 1973, 18 million litres of milk were produced in Tana River District and that only 15 million litres were required for human consumption (5). This means that there was a theoretical surplus of three million litres available for sale; this figure was expected to double by 1978. This surplus is considered to be purely theoretical because the assumed levels of human and calf consumption are much more likely to increase in response to increased availability than the milk to become available for sale. Even if this were not the case, the potential saleable surplus of milk remains theoretical due to the problems of seasonality of production and distribution.

If milk is therefore to be available at Bura it will either have to be produced in situ or be brought in from an area of high milk production.

Before discussing the possible sources of supply it is worthwhile considering the need, as opposed to the possible demand, for milk at Bura. The low level demand figures (Table 3.1) allow for 400 g of milk a day for each child under 5 years of age. This will give each child 400 calories and 12 g of protein each day. Alternative sources of energy and protein should be available to this, and other, sections of the Bura community, particularly from fresh vegetables and cowpeas. It is therefore questionable whether, from the nutritional point of view, a regular supply of milk is essential. Milk would certainly be a useful addition to the tenants' diet, but not an essential component. An exception to this rule would be a situation where the population at Bura came under severe nutritional stress. In such circumstances the use of powdered milk, distributed as part of a nutritional programme, would be important. These aspects are discussed in the Public Health Annexe.

The supply of milk at Bura cannot be considered as an initial priority. It should be looked upon as an aspect of project which may be developed at a later stage if there is a demand and when the needs and requirements of the tenants can be identified in greater detail.

The possible sources of milk for the Bura area have been discussed by Hampson (13). These sources include importing fresh liquid milk, treated liquid (UHT) milk or powdered milk, small-scale tenant milk production, Orma feedlots and local production form central dairy herds.

Importing fresh liquid milk

The nearest sources of commercially produced milk are at Malindi, Kilifi and Mombasa on the coast. The present supply of milk at the coast is not enough to meet local demands and it is therefore unlikely that the present system would be able to produce milk for Bura. The current government controlled retail price for fresh milk is K Sh 2.60 per litre. The cost of transporting fresh milk from Nairobi and the short shop life of the product makes it unsuitable for use at Bura.

Importing UHT milk

There is no government control on the retail price of treated liquid (UHT) milk. Current Nairobi wholesale price is K Sh 3.30 per litre this could be expected to rise to K Sh 4.00 at Bura. Due to high cost, UHT milk could be expected to have only a limited market at Bura. It is likely that private traders would import UHT milk to supply any demand for this product at Bura.

Importing milk powder

The current price of full cream milk powder is K Sh 240 per 25 kg bag. If made up to the correct concentration this is the equivalent of about K Sh 2.00 per litre. Apart from the possible reluctance of the tenants to use this form of milk there are health hazards associated with the use of powdered milk, especially as far as children are concerned. These hazards result from the tendency of mothers to give their babies powdered milk instead of breast feeding. All too often, the milk is too dilute and the bottles used to feed the babies are not properly sterilized, resulting in malnutrition and infection. One way to overcome the problem of the milk powder not being made up to the correct concentration would be to set up a central milk reconstitution plant which would undertake to reconstitute and package milk for distribution, but the high cost of such a plant could not be justified.

Without any centralised supply and distribution system of powdered milk, it is likely that private traders will stock and sell powdered milk. The potential danger to child health will therefore still be present and mothers must be educated in hygiene and child health care.

Milk from tenant stock

The two livestock species which could be used for milk production by tenants are cattle and goats. The productivity of the locally occurring cattle on rangeland is low, averaging about 1.4 litres per day for a lactation of 220 days. These Boran cattle however, are well adapted to the exigencies of the environment and would not require the high standard of husbandry needed for more productive exotic stock.

On average each tenant will produce 9.6 kg of TDN and 1.1 kg of DP each day. This is in theory almost enough to maintain two 318 kg cows producing 6 litres of milk a day each. It is however unlikely that such a high level of productivity will be achieved at Bura, and if cattle are to be kept by tenants, there will be a balance between hardiness and productivity. Nevertheless, even if each cow only gave 3 litres a day for a lacation of 220 days, the annual production would be much greater than the estimated high level milk demand.

As an alternative to cattle, the tenants could keep goats. Cross-bred Swiss Toggenburg and Boran or Small East African goats might prove suitable but trials should be carried out to assess the productivity of such crosses in the Bura area. These animals could be expected to make better use than cattle of the available fodder for milk production.

Not enough is at present known about the potential productivity of these animals under the Bura conditions. These theoretical calculations indicate that tenants could provide milk for themselves. The constraints of such a production system would be the level of management, both in terms of animal husbandry, crop residue storage and the productivity of the animals themselves.

The storage and feeding of crop residues will be difficult. The tenants will be required to remove all crop residues from their plots as soon as the crops have been harvested. The residues will then have to be carried back to the villages for feeding to stall-fed animals. Maize stover is difficult to transport and store and will have to be kept under a waterproof shelter. Cowpea hay will also have to be handled carefully, because it is very prone to leaf shatter.

The cutting and mixing of rations will require careful attention, especially if indigenous Boran cattle are used. Under range conditions these animals are relatively selective feeders and they continue to be selective feeders in the stall-fed situation. Unless the ration is finely chopped and well mixed, they tend to take the fibrous part of the diet and leave the high protein concentrate behind.

To manage their stock to their best potential, the tenants will require help and advice from livestock extension agents. Provision for six agents and one livestock officer has therefore been made in the livestock budget.

Trials should be set up to develop methods of crop residue storage, feeding techniques, and to investigate the breeds of stock, especially goats, which would be productive under the conditions at Bura. The results of these trials will be made available to the tenants through the livestock extension agents.

The proposed organisation of the communities on the project suggests that there is a possibility of organised village feedlots. In many ways this would be advantageous because it would help to centralise milk production and would make the work of livestock extension agents very much easier. Until it is known how each village community will develop, and the degree to which they will become cohesive units, it would be unwise to recommend the establishment of village feedlots. A further advantage of centralising tenants' livestock in village feedlots would be a reduction in the public health hazard from having livestock living adjacent to the tenants' houses.

Orma feedlots

The operation of Orma dairy feedlots on a low input - low output system has been suggested. The principle of the system is that the Orma should bring their cows to the periphery of the project when they start their lactation, feed them on crop residues during their lactation and then take their animals away again when they dry-off. Measurements on the potential yields of Orma stock under such a system are planned at the Hola Cattle Research Project. The major drawback to this sytem would be the willingness of the Orma to commit their animals to such a system. The Orma depend on their cattle for their families' food. Although during high rainfall years they may be willing to bring some animals into the feedlots, they would be unlikely to do so durig years of low rainfall when grass, and milk, was in short supply, unless the effect would be to prevent their stock from dying of starvation.

If it is shown that Orma cattle respond well to the crop residue rations at Bura, it may be possible to persuade a few Orma to bring their cattle close to the project, to buy residues from the tenants

Table 3.7 - Estimated Numbers of Cattle Required for Central Feedlot Phase I, Stage I, Bura Project

Yield (l/day)	Low Milk Demand *: Milking Cows	Dry [1] Cows	Total Cows	Heifers [2]	Heifers [3] Calves	TOTAL ANIMALS	High Milk Demand *: Milking Cows	Dry [1] Cows	Total Cows	Heifers [2]	Heifers [3] Calves	TOTAL ANIMALS
4	1 700	680	2 380	476	452	3 308	3 400	1 360	4 760	952	904	6 616
6	1 140	456	1 596	319	303	2 218	2 300	920	3 220	644	612	4 476
8	850	340	1 190	238	261	1 689	1 700	680	2 380	476	452	3 308

* See Table 3.1 and Section 3.3

Assumptions:
[1] 220 day lactation
[2] 20 per cent cull from dairy herd
[3] 5 per cent death rate in first year: all bull calves and excess heifer calves killed

Table 3.8 - Estimated Nutritional Requirements for Cattle on Central Feedlot Phase I, Stage I, Bura Project

Milk Yield (l/day)		Low Milk Demand * TDN (tonnes)	Low Milk Demand * DP (tonnes)	High Milk Demand * TDN (tonnes)	High Milk Demand * DP (tonnes)
4	Milk Cows	2 394	248	4 787	496
	Dry Cows	620	50	1 240	99
	Heifers [1]	1 307	156	2 637	314
	Heifer Calves [2]	226	41	452	81
	TOTAL	4 547	495	9 116	990
6	Milk Cows	1 889	207	3 811	419
	Dry Cows	416	33	839	67
	Heifers [1]	884	105	1 784	212
	Heifer Calves [2]	115	27	306	55
	TOTAL	3 304	372	6 740	753
8	Milk Cows	1 619	186	3 238	372
	Dry Cows	310	25	620	50
	Heifers [1]	659	78	1 307	156
	Heifer Calves [2]	130	24	226	41
	TOTAL	3 028	313	5 391	619

* See Table 3.1 and Section 3.3

[1] Assumed average weight - 136 kg

[2] Assumed average weight - 23 kg

and then to sell the milk they produce. This is a form of milk production which should be allowed to evolve by itself. If the trials at Hola indicate a potential the livestock extension officers should see if it could be developed. The extent to which it can be developed will depend on the reaction of the Orma. As Hampson (13) points out, if such a scheme could be developed, it would be one way displaced Orma could derive some benefit from the Bura project and would go a long way to solving many of the problems that would otherwise arise if they are excluded from the entire project.

Central feedlots

The last possibility for supplying milk at Bura would be through the development of centralised dairy feedlots. Tables 3.7 and 3.8 show estimates of the numbers of animals which might be required to meet the two levels of demand at different milk production levels given in Table 3.1, and the estimated amounts of DP and TDN they would require. Depending on demand and productivity a total herd of between 1 690 and 6 620 cattle would be required. These animals would require between 3 030 and 9 120 tonnes of TDN and between 313 and 990 tonnes of DP each year. The estimated nutrient production from crop residues (Tables 3.3 and 3.4) shows that this requirement could be met by Year 2 of the project.

Due to the lack of detailed information on the milk production potential from animals being fed crop residues at Bura it is not possible to put forward plans for a central dairy feedlot. In view of the fact the tenants will keep livestock and these animals should be able to provide sufficient milk for the families, the development of a centralised feedlot, which would require a high capital input, cannot be justified. It is however possible that as the project develops the tenants' stock will not realise their milk production potential and the demand for fresh milk will be large. If this situation should develop, the establishment of a central dairy feedlot would be possible. To establish the optimum method of managing the feedlots, and also to supply information on cattle husbandry to those tenants who wish to keep cattle, it will be necessary to undertake some trials specified below.

Should it appear necessary to establish central dairy feedlots, it is thought that commercial agricultural management agencies should be requested to tender for the operation. The problems of management, processing and distribution at Bura will be considerable and best overcome by a commercial operation.

From experience gained in feedlots in other parts of Kenya, it is estimated that the capital cost of establishing feedlots would be about K Sh 2.2 million per 1 000 animal unit (14). The cost of milking and cooling machinery would be about K Sh 80 000 for each 250 cow milking unit. The total estimated capital costs per 1 000 milking cows would therefore be some K Sh 8.5 million. The cost of rations cannot be worked out until more is known about the rations to be used. This is particularly dependent on how much of the ration will have to be made up of concentrates brought in from elsewhere. FAO (12) calculated that in 1973 the cost of producing milk on both Napier grass and Maize stover rations was between K Sh 0.37 and 0.41 per kg; the breakdown of these costs is given in Table 3.9.

Table 3.9 - Breakdown of Costs of Milk Production in Feedlots
(1973 prices)
(K Sh)

Average cost per cow per day	Napier Grass based Ration Low DM Yield	Napier Grass based Ration High DM Yield	Maize Stover based Ration Low DM Yield	Maize Stover based Ration High DM Yield
Roughage	0.44	0.17	0.04	0.04
Concentrates	2.08	2.08	2.66	2.66
Housing	0.20	0.20	0.20	0.20
Veterinary	0.17	0.17	0.17	0.17
Subtotal	2.89	2.62	3.07	3.07
Labour	0.80	0.80	0.80	0.80
Total cost	3.69	3.42	3.87	3.87
Average milk per day (litres)	7.1	7.1	7.5	7.5
Cost per kg milk:				
(i) ex labour	0.41	0.37	0.41	0.41
(ii) inc. labour	0.52	0.48	0.52	0.52

Source: FAO, (12)

3.7 Supply of Milk to Management Personnel

The supply of milk to management personnel poses a different problem to that of supplying milk to the tenants. The main strategy of tenant milk production will initially be based on the tenant stock. The management personnel will be unlikely to have many of their own stock and will consequently need to purchase milk.

It is envisaged that by Year 4 of the project there will be just over 10 000 administration personnel staff and traders. If these people consume an average of 55 litres per year each, the demand for milk from this section of the community will be over half a million litres per year.

A certain amount of surplus milk may be available from tenants who manage their stock well and achieve high levels of production. The bulk of this milk demand, however, will probably have to come from other sources, mainly powdered and UHT milk.

The total production of UHT milk in Kenya varies each year and the Kenya Co-operative Creameries (KCC) try to adjust the supply to fit the market, see (Table 3.10) below.

Table 3.10 - Annual UHT Milk Production from Kenya Co-operative Creameries

Year	UHT Milk produced (million litres)
1973-4	9.926
1974-5	7.394
1975-6	8.249

Source: R.B. Ryanga, Kenya Dairy Board; pers. comm.

The possible demand for UHT milk from the management and associated staff represents only about six per cent of the 1975-6 total production and there is no reason why this demand could not be met. The distribution of UHT milk would be through private traders.

3.8 Other Livestock

The possible effects of the pesticide residues on poultry production at Bura require further investigation, (see the Fisheries Annexe). However, should it appear that poultry production is possible the livestock extension agents should consider the introduction of improved poultry breeds.

Because of the pesticide spraying regime, it is unlikely that there will be any possibility of introducing bees for honey production.

CHAPTER 4 DEVELOPMENT PROPOSALS

4.1 Compensation for Loss of Grazing by The Orma

Without more information on the traditional usage patterns of the area to be affected by the Bura Project it will not be possible to identify the people who have valid claims for compensation. The form which compensation should take also needs further clarification, for unwanted or inappropriate compensation would be no better than no compensation at all. Compensation in kind, however, would be more suitable than compensation in cash.

Because the main effect of the project will be to reduce the amount of available grazing, compensation should, ideally, be in the form of offering alternative improved grazing in adjacent areas. Whether such compensation would be accepted by the Orma remains to be seen, for it might well necessitate the movement of permanent settlements to other areas.

In view of these uncertainties it is proposed that the District Officer, together with the Sociologist proposed for the Co-ordinators office, should study the problem and the possible solutions. They would be required to:

(a) identify those people who have a valid claim to compensation as a result of the development of the Bura Project,
(b) assess the numbers and present location of these people,
(c) determine the patterns of leadership within those people having a claim and thereby identify the leaders within the groups,
(d) determine the peoples' view of the effects that the development of the project will have on them, and
(e) determine the forms of compensation which would be acceptable to the people. This would include inquiry into whether the people would wish to settle on the project and whether they would be interested in establishing simple feedlots for their lactating cows, to provide milk for the project.

Proposals, for the sociological aspects of the study are given in the Sociology and Settlement Annexe.

The possibility of some of the Orma who have justified claims for compensation wishing to settle on the project is important. If a number do wish to become tenants they should be given an opportunity to do so; if they are not allowed to it could lead to a considerable source of ill-feeling and inhibit the integration of the project with its District. To avoid such a situation the study by the District Officer will need to have determined the number of Orma who wish to settle before the allocation of holdings has been completed. If the results of the study indicate that improvement of grazing will be an acceptable form of compensation to the Orma it will be necessary to decide how and where this should be done.

To improve grazing in the River District it will be necessary to provide water supplies. Water will be required for both the grass itself and for the livestock which are to use the grazing. Two possibilities have been considered, though it needs to be stressed that these are only tentative suggestions. The first possibility is that of water spreading from the large lagas which flow through the area towards the Tana River. This would involve diverting water from the main laga during floods so that it spread over the surrounding land. This method would require a considerable amount of engineering works and would have to rely on the low and erratic rainfall of the area. The second possibility is that of using surplus water in the supply canal. The amount of surplus water in the canal will vary during different months and will depend on the water requirements of the crops in the irrigated area and the supplies to the proposed fuelwood plantations.

A perennial grass such as Rhodes Grass *Chloris gayana* would be well suited to the conditions produced by such methods, though it would require careful management to produce good yields.

The development of the relatively small area required to compensate for the loss of land due to the project by this method has the advantage that it would be more easy for those to be compensated to control and that it would be less likely to interfere with other, non-compensatable, people. A potential danger of the intensive development of a relatively small area is that it may tend to make the people dependent on the small area and reduce their mobility. Ideally, the area of improved grazing should be managed in the same way that the floodplain is used at present, and form a dry season reserve area which is used only after the water and grazing of the hinterland has been used up.

Another possibility which needs to be considered is that of establishing group ranches for the Orma displaced by the irrigation project. The drinking ponds to the west of the supply canal would form the basis for a group ranch, though provision would have to be made for other sources of water further to the west. One problem which might arise if such ranches were created would be the fact that a ranch would also have to include Orma from the area to be used; if this were not done the compensation of one group of people would simply require yet another exercise to compensate yet another group.

4.2 Watering Points

The provision of eleven drinking ponds (see Wildlife Annexe) will compensate local stockowners for the limitation of access to water owing to the construction of the supply canal. Stock will be able to get to the Tana River via the inverted siphons, and adult stock will be able to use the for type canal crossing points provided for wildlife. The costs of these crossing points have been included in the Wildlife Annexe.

4.3 The Control and Management of Tenants' Stock

The need for strict control to be enforced on tenants' stock cannot be overstressed. If the tenants' stock are carefully controlled and well managed they will be a valuable asset to the project. If control and good management are missing the stock will be unproductive and a source of damage to the project and its surrounding area. It is not acceptable to assume that because control has not been possible at either the Mwea or Hola Schemes it will not be possible at Bura. The consequences for lack of stock control for a project the size of Bura will be very serious indeed. The responsibility for stock control rests with the project management, which will have to ensure that it is able to enforce the discipline required. The authority and infrastructure to enforce control will be available; it will be up to the personnel themselves to use it with backing from the NIB executive if necessary.

Tenants' stock should not be allowed to graze freely within the project or outside its boundary. All animals except poultry, which are unlikely to stray far from their owner's house, will need to be securely enclosed in pens and stall fed. This in itself will facilitate the control of stock, for any animal found wandering loose within the project will therefore be impounded. To claim his animal back from impoundment the offending owner should be required to pay a fine. It is suggested that for a first offence the fine should be ten per cent of the animal's value. Fines should increase for each subsequent offence. The values of different stock classes should be determined by the project livestock officer and reviewed regularly.

There will be occasions when tenants will have good reasons for wanting to move their stock about the project: for example, taking animals to slaughter or moving stock for mating. Before such occasions the tenants will be able to obtain a permit to move their animals from a named place of departure to their destination. The permits will be issued by the livestock extension agents.

The keeping of all stock under stall-fed conditions will cause many management and husbandry problems which would not be encountered if the animals were allowed to graze at liberty within and without the project. It is therefore unlikely that control regulations will be popular with the tenants, and it is essential that they are made quite clear to tenants before they are selected and join the project.

The tenants will require considerable help and advice on the management and husbandry of their stock under stall-fed conditions. The proposed livestock trials described below, should formulate management systems suitable to the conditions at Bura, and should establish methods of crop residue storage and feeding which could be used by the tenants. This information will be given to the tenants by six livestock extension agents, each of which will be responsible for four villages. The agents should have diplomas in Animal Husbandry and will receive six months general irrigation training on the project and spend a further six months working on the livestock trials before starting general extension duties. The rate of recruitment will be; one in Year 1, two in Year 2 and three in Year 3. The six agents will be under the authority of a project livestock officer who will be responsible for all aspects of livestock management on the project apart from the trials which will be the responsibility of the research section. The livestock officer should be a junior graduate in Animal Husbandry. The budget covering housing and equipment required for these staff are given later in this chapter.

The rate at which tenants' stock will build up on the project is not yet known, but it is unlikely that there will be any great number until Years 5 or 6. If by this time each tenant has acquired an average of half a cow, two goats and one sheep there will be a livestock population on the project of approximately 2 600 cattle, 10 300 goats and 5 200 sheep. Under stall-feeding conditions the veterinary problems are unlikely to be as great as under range conditions, and this livestock population could not justify a full time veterinary officer. The day-to-day problems of animal health should be dealt with by the stockowners, with assistance from the livestock officer and the livestock extension agents. Contact with the Veterinary Department should be maintained by the livestock officer and arrangements should be made for project animals to receive the compulsory vaccination against rinderpest as well as prophylactic cover against foot and mouth disease.

4.4 Milk Supply

In view of the alternative sources of nutrients available to the tenants from their irrigated vegetable plots it is not proposed to establish any formal milk supply system. If properly managed the tenants' stock will be able to supply a reasonable, though at present unknown, amount of milk. The private traders within the project are likely to offer a source of supplementary powdered and UHT milk to those who wish to purchase it. A further additional source of fresh milk may come from Orma herdsmen, who bring their lactating cows into the vicinity of the project and feed them on crop residues, but the development of this source must be left to the Orma themselves.

As it is possible that a demand for milk greater than the tenants' stock could supply may arise in later years, it is proposed to establish some simple dairy production trials. These trials will be of immediate value to those tenants who keep cattle, but will also provide valuable information on the future possibility of large scale milk production systems at Bura should the need for them arise.

4.5 Livestock Trials

At present there are some small-scale cattle trials underway at Hola and there are plans to increase their scope. It is thought that these trials should be supplemented by trials at Bura, which would be designed to provide information relevant to the management of tenants' stock and the possible future development of a large-scale milk producing system. The trials for tenants' stock are of greater importance than the large-scale milk production trials.

The livestock trials will be in two parts, one concerned with small stock and the other concerned with cattle.

Small Stock Trials

The sort of crop residues which will be available at Bura will probably be better suited to small stock than to cattle. If the tenants are to be encouraged to keep small stock it will first be necessary to have established the potential yields from small stock and to have developed relevant management techniques. It is envisaged that the tenants will wish to keep both sheep and goats for meat production, but it is hoped that they could be encouraged to keep cross-bred Swiss Toggenburg goats for milk production as well. The small stock trials should therefore concentrate on the management of Blackhead Persian and Dorpa sheep and on cross-bred Toggenburg goats.

Thirty animals of each breed would be required for the trials, each group of thirty being divided into three groups of ten animals each. Although, due to high individual variation in these sorts of animals, the numbers are rather low, it should be remembered that the trials are intended to provide information which can be related to management methods rather than detailed scientific data.

Each of the three groups from the three breeds will be fed a different ration:

RATION A - local crop residues with a small supplement of green waste from vegetable plots
RATION B - local crop residues with green fodder supplement
RATION C - local crop residues with a small amount of imported concentrates added

The growth rates and, in the case of the goats, milk yields will be measured for each group on the different rations and the results will be analysed to see whether there is any benefit in importing supplementary rations for small stock.

In addition to the thirty animals of each breed required for the trials a further six animals of each breed will be required to provide replacements for any losses during the trials.

The total period required for the trials will be three years. This will enable each trial to be replicated three times, the duration of each replication being nine months with a three month change-over period between each trial.

The trials with sheep will require new stock to be purchased for each replication; weaned animals without any permanent incisors should be used for each replication. It is probable that the same goats can be used for all three replications, though the selection of animals in each case must be fully randomised. To allow for losses during the three year period it will be necessary to purchase six new goats each year.

All small stock will be housed in individual pens, each of which will be supplied with ample shade, abundant water and a manger. There are often problems with stall feeding small stock and the way in which the rations are presented to the animals will have to be determined in the light of experience gained before the trials start. The goats should be hand milked twice a day.

Cattle Trials

The purpose of the cattle trials will be to investigate the potential milk yield from cows fed on a ration based on the crop residues at Bura. The main intention will be to provide information which can be of use to those tenants wishing to keep cattle and to compare the costs of milk production from cattle with those of milk production from cross-bred goats under the Bura conditions.

It is unlikely that high yielding European cattle will thrive under the conditions at Bura. It is therefore proposed that the trials shall include three types of cattle which would be well adapted to local conditions, Sahiwal, Sahiwal x Boran and Boran. The pure Sahiwal will have a greater milk production potential than the Boran, but will not be so well adapted to local conditions.

The cattle trials will be run in a similar manner as the small stock trials and the same rations will be provided. Because there will be only ten cattle from each breed it will not be possible to replicate each trial. One breed will be given a ration for the whole of a lactation and then changed onto a new ration for the next lactation. Cattle will be served by artificial insemination using Sahiwal cross-bred semen. Calves will be bucket-fed from 24 hours after birth and all bull calves will be destroyed. The cows will be required for the trials (ten of each breed) with two animals of each breed available as replacements. To allow for losses it will be necessary to purchase six new cows of each breed each year. To reduce variation due to differences in age all initial purchases should be of in-calf heifers.

The cattle will be run in three well shaded yards, with each yard containing ten animals of the same breed being fed the same ration. To facilitate the recording of milk yields each group of twelve animals will be milked at the same time in a central milking bay. The cattle will be milked by hand twice a day.

The livestock trial will require one research officer, one research assistant and a clerk/typist to collect, record and analyse the information. A manager, who should have a diploma in Animal Husbandry, one headman, eight milkers and stockmen and two general labourers, will also be required. During the first three years of the project the trainee livestock extension officers will each spend six months with the trials; their duties will be to assist the research officer and the manager.

Details of the buildings, housing, equipment and budget required for the livestock trials are given later in this chapter.

Forage Crop Trials

An ancillary activity to the livestock trials will be trials to see which fodder crops would be suitable for use at Bura under irrigation. These trials would only be justified if it appeared that there was a potential for a central milk producing feedlot.

If such a need was to arise it is proposed that at least ten fodder species should be included in the trial. These should include: Napier grass *Pennisetum purpureum*; Lucerne *Medicago sp.; Trifoliumm sp.*; Pigeon peas *Cayanus cajan; Dolichos lablab* and Sudan grass *Sorghum sudanese*. Four different treatments would be required and each trial would need to be duplicated three times. If 50 square metres is used for each species for each treatment the total land required would be 6 hectares. The cost of the fodder trials has not been included in the budget for the livestock trials for two reasons. Firstly they would be the responsibility of the crop research unit, and secondly, they would not take place unless the livestock trials indicated that there was a potential for centralised milk production systems and a market for the milk produced by such a system.

4.6 Phasing of Livestock Input

The District Officer, who will be required to make a study of the methods to be used in compensating the Orma for loss of grazing, should start work as soon as possible and it is hoped that the report would be available by the end of 1978.

The first three crossing points in the supply canal will be installed during 1979/80; the four remaining drifts will be installed by 1984. The eleven drinking ponds will be built in 1979/80, during the construction of the supply canal.

The livestock trials will start in 1982 and the first extension agent should spend the last six months of that year with the livestock trials. In order to have allowed six months general irrigation training the first agent will have to be recruited at the beginning of the same year. The Project Livestock Officer will be required in 1982.

A summary of the phasing of the livestock inputs for the project is given in Table 4.1.

Table 4.1 - Summary of Timing of Livestock Inputs

Year	Input
1977	Start of Orma study
1978	Report of Orma study
1979	Start construction of drifts and drinking ponds
1980	Complete construction of 3 drifts and drinking ponds
1981	
1982	Start of livestock trials, arrival of first extension agent and livestock officer
1983	Livestock extension agent onto project two more for trials
1984	Last three extension agents arrive, completion of livestock trials
1985	Full strength extension work starts

4.7 Costs

Table 4.2 summarises the capital and recurrent costs for the livestock input of the Bura Irrigation Project between 1979 and 1985.

Table 4.2 - Summary of Costs of Livestock Input for Phase I, Stage I, Bura Project (1 000 K Sh)

Year	Capital	Recurrent	Contingencies	Total
1979	—	—	—	—
1980	—	—	—	—
1981	—	—	—	—
1982	972	445	141	1 558
1983	126	463	59	648
1984	189	520	71	780
1985	—	167	17	184

A breakdown of the costs is given in Tables 4.3 to 4.6.

Table 4.3 - Capital Costs of Livestock Extension - Phase I, Stage I, Bura Project
(1 000 Kenya Shillings)

Item	Unit	Unit Cost	Year 1 (1982) No. units	Year 1 (1982) Cost	Year 2 (1983) No. units	Year 2 (1983) Cost	Year 3 (1984) No. units	Year 3 (1984) Cost	Total Capital Cost
Buildings:									
Office (1)	Office	48	1	48	–	–	–	–	48
Housing:									
House Type D (2)	House	110	1	110	–	–	–	–	110
House Type E (3)	House	58	1	58	2	116	3	174	348
Sub Total				216		116		174	
Vehicles:									
SWB 4WD Pick-Up	Vehicle	77	1	77	–	–	–	–	77
Motor-cycle (90 cc.)	Cycle	5	1	5	2	10	3	15	30
Sub Total				82		10		15	
Office Equipment (4)	Set	5	1	5	–	–	–	–	5
Total Base Costs				303		126		189	618
Physical Contingencies				30		13		19	62
TOTAL COST				333		139		208	680

Table 4.4 - Recurrent Costs of Livestock Extension, Phase I, Stage I, Bura Project (1 000 Kenya Shillings)

Item	Unit	Unit Cost	Year 1 (1982)		Year 2 (1983)		Year 3 (1984)	
			No. units	Cost	No. units	Cost	No. units	Cost
Salaries:								
Livestock Officer (5)	Man-year	23	1	23	1	23	1	23
Livestock Extension Agents (6)	Man-year	17	1	17	3	51	6	102
Sub Total				40		74		125
Vehicle Running:								
SWB 4WD Pick-Up	Vehicle/year	27	1	27	1	27	1	27
Motor-cycle	cycle/year	1.5	1	1.5	3	4.5	6	9
Sub Total				28.5		31.5		36
Building Maintenance				–		4		5
Administrative Running Costs				1		1		1
Total Recurrent Costs				70		110		167
Physical Contingencies				7		11		17
TOTAL COST				77		121		184

Table 4.5 - Capital Costs of Livestock Trials, Phase I, Stage I, Bura Project (1 000 Kenya Shillings)

Item	Unit	Unit Cost	No. Units	(1982) Total Capital Cost
Buildings:				
Office (8)	Office	55	1	55
Dairy (11)	Dairy	20	1	20
12 Cow shaded cattle yard (9)	Yard	10	3	30
12 Cow milking bay (10)	Bay	10	1	10
Fodder store (12)	Store	20	1	20
Individual calf pens (13)	Pen	0.1	30	3
Heifer yard (30 animals) (14)	Yard	70	1	70
Individual small stock pens (15)	Pen	0.1	108	11
Crush and dip	Crush & dip	27	1	27
Water tank (16)	Tank	40	1	40
Sub Total				286
Vehicles:				
2WD Pick-up	Vehicle	43	2	86
Tractor	Tractor	85	1	85
Flat bed trailer (3½ ton tipping)	Trailer	20	1	20
Fore end loader (utility blade)	F.e. loader	6	1	6
Sub Total				197
Equipment:				
Milk cooler (17)	Cooler	3.3	1	3.3
Milking buckets, churns and equipment (18)	Set	3	1	3
Milk balance	Balance	1.5	1	1.5
Veterinary equipment (18)	Set	7	1	7
Cattle weigh bridge	Bridge	23	1	23
Small stock weigh scale	Scale	8	1	8
Office equipment (19)	Set			
SubTotal				45.8
Housing:				
House type D		110	1	110
House type G		10	3	30
Sub Total				140
Total Base Cost				669
Physical Contingencies				67
TOTAL COST				736

Table 4.6 - Recurrent Costs of Livestock Trials, Phase I, Stage I, Bura Project
(1 000 Kenya Shillings)

Item	Unit	Unit Cost	Year 1 (1982) No. units	Year 1 (1982) Cost	Year 2 (1983) No. units	Year 2 (1983) Cost	Year 3 (1984) No. units	Year 3 (1984) Cost	Total Cost
Salaries:									
Research Officer (20)	Man-year	41.4	1	41	1	41	1	41	
Research Assistant (21)	Man-year	13.6	1	14	1	14	1	14	
Manager (22)	Man-year	21.2	1	21	1	21	1	21	
Head Man	Man-year	7.5	1	8	1	8	1	8	
Milker/Stockman	Man-year	6.0	8	48	8	48	8	48	
Clerk	Man-year	13.6	1	14	1	14	1	14	
General Labour	Man-year	6.0	2	12	2	12	2	12	
Sub Total				158		158		158	
Stock Purchases:									
In-calf heifers									
Sahiwal	I-c heifer	2	12	24	3	6	3	6	
Sahiwal & Boran	I-c heifer	1.5	12	18	3	4.5	3	4.5	
Boran	I-c heifer	0.7	12	8.4	3	2.1	3	2.1	
Yearling Small Stock:									
Blackfaced Persian Sheep	Sheep	0.070	36	2.5	36	2.5	36	2.5	
Dorpa Sheep	Sheep	0.070	36	2.5	36	2.5	36	2.5	
Toggenberg & Boran Goats	Goat	0.25	36	9	6	1.5	6	1.5	
Sub Total				64.4		19.1		19.1	
Building Maintenance						6		6	12
Vehicle Running:									
2WD Pick-Up	Vehicle/ year	20	1	20	1	20	1	20	60
Tractor		17.2	1	17.2	1	17.2	1	17.2	51
Sub Total				37		37		37	111

Table 4.6 (continued)

Item	Unit	Unit Cost	Year 1 (1982) No. units	Year 1 (1982) Cost	Year 2 (1983) No. units	Year 2 (1983) Cost	Year 3 (1984) No. units	Year 3 (1984) Cost	Total Cost
Veterinary Costs:									
Cattle (23)	Beast	0.06	65	3.9	88	5.3	88	5.3	14.5
Small stock (24)	Beast	0.03	108	3.2	108	3.2	108	3.2	9.6
Sub Total				7.1		8.5		8.5	24.1
Feeding:									
Cattle (25)	Beast	0.912	65	59.3	88	80.3	88	80.3	219.9
Small stock (26)	Beast	0.365	108	39.4	108	39.4	108	39.4	118.2
Sub Total				98.7		119.7		119.7	338.1
Transport of Stock to Bura:									
Sahiwal & Sahiwal Boran In-calf Heifers	Beast	0.2	24	5	6	1	6	1	
Small Stock	Beast	0.05	108	5.4	75	4	78	4	
Sub Total				10		5		5	
Total Base Cost				375		353		353	
Physical Contingencies				37		35		35	
TOTAL COST				412		388		388	

Notes on Livestock Costs (Tables 4.2 to 4.6)

Extension - Capital:

(1) Office for 7 people
(2) House for Graduate Research Officer
(3) Houses for Diplomate Extension Agents
(4) Equipment for Office for 7 people

Extension - Recurrent:

(5) Graduate Livestock Officer
(6) Diplomate Extension Officers
(7) Stationery for Office for 7 people

Livestock Trials - Capital Costs:

(8) Office for 8 people
(9) Should be 450 m^2, with at least 350 m^2 with permanent shade
(10) Made out of mangrove poles, well shaded, concrete floor 100 m^2
(11) Will require a concrete floor and walls, basins, 20 m^2
(12) Water proof, well ventilated, 80 m^2
(13) Each one 2 m^2, shaded, mangrove poles for sides
(14) 1440 m^2, at least 1000 m^2 of which is shaded, same basic design as (9)
(15) Same design as (13)
(16) Elevated 100 000 litres
(17) Ripple cooler (80 gall/hour)
(18) Includes insemination kit, liquid nitrogen containers
(19) To equip office for 8 people

Livestock Trials - Recurrent Costs:

(20) Research Officer, Graduate, with post-graduate experience
(21) A Diplomate or Technician
(22) A Diplomate with 10 years practical experience
(23) Assume 80% fertility and 20% calf and yearling mortality
(24) Lambs and kids included with adults
(25) Assume average of K Sh 2.50 per day per beast
(26) Assume average of K Sh 1.00 per day per beast

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BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

FISHERIES ANNEXE

BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

FISHERIES ANNEXE

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY AND RECOMMENDATIONS

Very little is known about the ecology of the fish of the Tana River and it is proposed that an ecological study be carried out to provide the necessary data. This information will be of value in assessing the possible effects of the ILACO design for the headworks weir and the irrigation project on the fish of the Tana River.

Although there is little commercial fishing in the vicinity of Bura, it is an important activity and most of the riverine people fish to supplement their diet. Commercial fishing is undertaken downstream of Bura, but recorded landed catches have reduced since a ban on the use of nets was introduced in 1975. The possible reduction of peak flood levels downstream of Bura following the construction of the ILACO design headworks may affect fishing, owing to a reduction in the flooding of the riverine lakes, which are the main source of fish.

It is unlikely that the proposed headworks weir will hinder the migration of fish going upstream to spawn, because this occurs during the floods, when the water will be passing over the crest of the weir.

There is a considerable potential for fish farming for the Bura Project and the development of this activity would provide a valuable supplement to the project tenants' diet. It would be necessary to locate any fish farming trials to the north of the project, near the headworks, to avoid contamination from a'rially sprayed pesticides. It is proposed that trials be established to investigate the potential prouuction from fish tanks and from fish cages suspended in the Supply Canal.

The levels of pesticide residues in the environment from aerial spraying of crops, particularly cotton, must be monitored to determine their effect on both aquatic and terrestrial ecological systems. Programmes for all the proposed fisheries activities, together with details of capital and recurrent costs, are given in the Annexe.

CHAPTER 1 THE PRESENT SITUATION

1.1 The Fish of the Tana River

Very little is known about the biology and ecology of the fish of the middle and lower Tana River. There are many problems in collecting information from such a large, fast flowing river where both hippopotamus *(Hippopotamus amphibius)* and crocodile *(Crocodilus niloticus)* are plentiful. The collection of such data would require several years work by well equipped and experienced biologists. Copley (1, 2) and Acres (3) give information on the fish of the Tana River but none of these accounts is specifically concerned with the Bura area.

A collection of fish in the river downstream of Garissa was made in 1959 by Whitehead (4). Twenty-two species from twelve different families were recorded (Table 1.1): Fourteen of these species are illustrated in Figure 1.1.

Table 1.1 - Fish of the Tana River, downstream of Garissa

Family	Species	Figure 1.1 Sketch No.
LEPIDOSYRENIDAE	*Protopterus amphibius*	1
MORMYRIDAE	*Mormyrus sp.*	2
	Gnathoneumus sp.	9
CHARACIDAE	*Alestes affinis*	10
CYPRINIDAE	*Labeo gregorii*	4
	Labeo sp.	
	Barbus zanzibaricus	12
	Barbus taintensis	
	Engraulicypris sp.	5
BAGRIDAE	*Clarotes laticeps*	8
SCHILBEIDAE	*Eutropius sp.*	6
	Physalia sp.	14
CLARIIDAE	*Clarias mossambicus*	7
MOCHOCIDAE	*Synodontis zambesensis*	
	Synodontis sp.	11
CYPRINODONTIDAE	*Lebistes sp.*	
CICHLIDAE	*Tilapia mossambica*	13
GOBIIDAE	*Glossogobius giurus*	
ANGUILLIDAE	*Anguilla mossambica*	
	Anguilla nebulosaa labiata	
	Anguilla bicolar bicolar	

This list represents only about half the total number of species which have been recorded from the entire river, and it will probably be expanded following the publication of the report of the 1976 Tana River Expedition.

The main breeding periods of the fish in the Tana River are during the floods, April to July and November to December. Anadromous species such as *Alestes, Anguilla, Barbus, Labeo, Mormyrus* and *Synodontus* move upstream to breed, but there is also a movement of fish up the small seasonal streams which connect the ox-bow and flood lakes to the river.

Because of the possible effects that the ILACO designed headworks near Nanigi and the upper catchment reservoirs may have on the flood patterns of the river, further detailed studies are required on the ecology of the fish of the Tana River and the fishing industry. The terms of reference and estimated budget for such a study are presented in Section 5.1 of this Annexe.

1.2 Fishermen

Interviews with the Malakote people living along the river between Garissa and Hola indicated that there were no full-time fishermen along that stretch of the river. Further downstream, however, there are a number of full-time fishermen, which include men who have moved into the area from Nyanza, as well as the local Pokomo. Although there are no full-time Malakote fishermen, fishing is an activity which everyone undertakes, and fish provide a valuable supplement to the Malakote basic diet of rice, bananas and maize. The frequency of fishing operations by the Malakote was difficult to assess but once or twice a week appeared to be the average.

1.3 Fishing Methods

In 1975 the use of nets for commercial fishing in the Tana River was banned because the fish resource was being over-exploited. More traditional methods of fishing have been employed since the introduction of the ban, although the Fisheries Officer responsible for the area has reported that owing to lack of staff to ensure proper enforcement a certain amount of netting has continued.

The traditional fishing methods used in Kenya have been described by Whitehead (5). The methods used on the Tana River include:

(a) Line fishing: either with a hand line or a line attached to a reelless rod; the latter is not often used on the Tana River. There is a simple hook which is baited with old meat, maize millings, insects, worms or frogs. Night lines are not often used on the middle and lower reaches of the Tana River as crocodiles often take the catch. Line fishing is the main method used to catch fish in the Bura area.

(b) Basket traps: these are often used downstream from Bura. They vary in size, but generally are not greater than 60 cm wide at the mouth. During the floods, when many fish are moving upstream to breed, the traps are often placed with the mouths facing downstream. The traps, which are intricately made from woven reeds and branches, are sometimes used in conjunction with fences which steer the fish into the traps.

(c) Poisons: the bark from *Mundelea sp.*, which has a high content of rotenone, is sometimes used to poison fish.

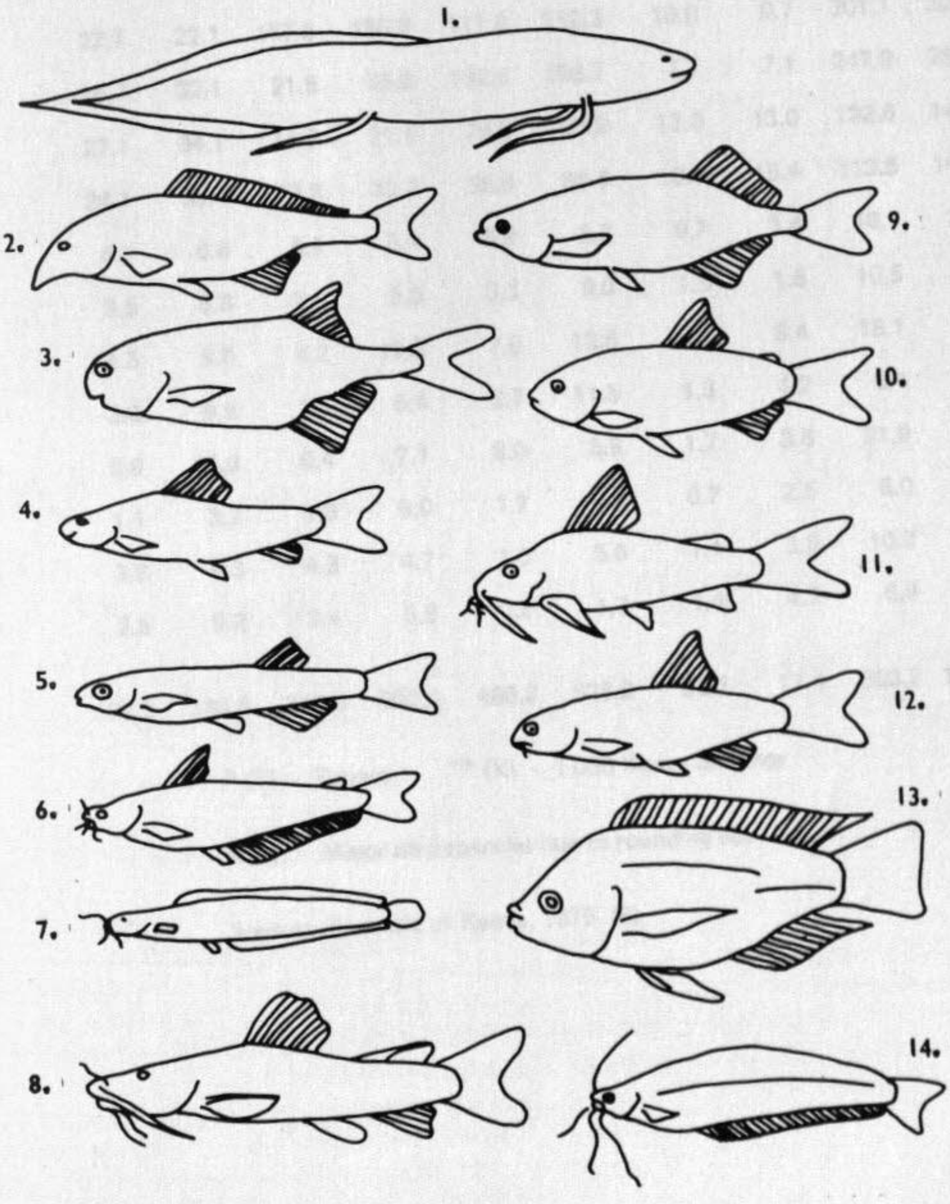
(d) Spear fishing: this method is sometimes used on the lower reaches of the Tana River, but it is not very effective and is very time-consuming.

1.4 River Transport

Dugout canoes are commonly used for fishing and river transport on the Tana River, and in 1976 Marsh (6) estimated a density of 2.4 canoes per kilometre on a stretch of river about 80 kilometres downstream of Bura. The canoes are hollowed out from tree trunks cut locally from the riverine forest. The tree species which make the longer lasting canoes have dense woods and take longest to cut and carve. According to Marsh (7), who made a study of canoes in the Tana River Game Reserve in 1975, the most popular tree species of those most easily worked are *Populus ilicifolia* and *Ficus syconorus* which take about three weeks to cut and carve, *Populus* lasting about two years and *Ficus* only about one. *Mimusops fruticosa* and *Garcinia* are the more common of the hard-woods, taking about seven weeks to cut and carve; their useful lives are however considerably longer about eight and seven years, respectively. To conserve the riverine forest, Marsh recommended that people should be encouraged to make their canoes from

FIGURE 1.1

FISH OF THE TANA RIVER DOWNSTREAM OF GARISSA



1. Protopterus amphibius (attains over 100 cm)
2. Mormyrus sp. (30 cm)
3. Petrocephalus catastoma (9 cm)
4. Labeo gregorii (30 cm)
5. Engraulicypris sp. (6 - 8cm)
6. Eutropius sp. (25 cm)
7. Clarias mossambicus (up to 100 cm)
8. Clarotes laticeps (up to 80 cm)
9. Gnathonemus sp. (20 cm)
10. Alestes affinis (14 cm)
11. Synodontis sp. (16 cm)
12. Barbus zanzibaricus (12 cm)
13. Tilapia mossambica (30 cm)
14. Physailia sp. (10cm)

Source, Whitehead (4) 1959

Table 1.2 - Total Freshwater Fish Landings, Tana River District (West Bank), 1975 (Tonnes and 1 000 Kenya Shillings)

Month	Tilapia		Clarias		Protoptetus		Other Species		Total	
	(T)*	(K)**	(T)	(K)	(T)	(K)	(T)	(K)	(T)	(K)
January	22.1	22.1	157.3	158.8	111.8	112.3	10.0	9.7	301.1	303.0
February	26.7	32.1	21.5	28.0	192.5	198.7	7.1	7.1	247.9	265.8
March	27.1	34.1	16.7	21.9	75.8	80.5	13.0	13.0	132.6	148.6
April	24.1	33.4	20.9	30.7	56.6	66.6	18.9	15.4	113.5	146.1
May	4.1	6.6	5.4	8.1	5.9	8.2	0.7	1.4	16.1	24.2
June	3.5	5.8	2.4	5.3	3.2	9.0	1.5	1.5	10.5	21.5
July	4.5	9.8	4.2	10.8	7.0	19.5	2.5	8.4	18.1	48.6
August	3.8	9.5	1.6	6.4	2.7	11.5	1.3	4.2	9.4	31.6
September	5.8	12.0	6.4	7.1	8.0	8.8	1.7	3.6	21.9	3.6
October	1.1	3.2	1.6	5.9	1.7	6.9	0.7	2.5	5.0	18.5
November	3.8	9.3	4.3	4.7	1.0	5.6	1.1	3.9	10.2	23.5
December	2.5	9.2	2.4	5.8	0.6	1.3	1.4	4.7	6.9	20.9
TOTAL	129.2	186.8	244.6	292.8	466.8	528.9	52.7	77.4	893.2	1085.6

* (T) - Tonnes ** (K) - 1 000 Kenya Shillings

Note: Minor discrepancies due to rounding up.

Source: Republic of Kenya, 1975 (8)

Table 1.3 - Total Freshwater Fish Landings, Witu Division (East Bank), 1975
(Tonnes and 1 000 Kenya Shillings)

Month	Tilapia		Clarias		Proteptetus		Total	
	(T)*	(K) **	(T)	(K)	(T)	(K)	(T)	(K)
January	1.0	1.0	5.0	17.6	6.6	23.0	12.6	41.7
February	1.0	1.0	5.0	17.6	6.9	24.0	12.9	42.6
March	0.8	0.8	4.5	15.7	4.7	16.3	10.0	32.8
April	0.9	0.9	4.5	15.9	4.7	16.6	10.2	33.3
May	0.9	0.9	4.6	16.2	4.7	16.5	10.2	33.5
June	–	–	–	–	–	–	–	–
July	–	–	–	–	–	–	–	–
August	trace	trace	0.1	0.4	trace	0.1	0.1	0.5
September	0.1	0.1	–	–	0.2	0.6	0.3	0.7
October	0.1	0.1	–	–	trace	0.1	0.1	0.2
November	trace	trace	trace	0.1	trace	0.1	0.1	0.2
December	–	–	–	–	–	–	–	–
TOTAL	4.7	4.7	23.9	83.5	27.8	97.3	56.4	185.5

* (T) - Tonnes ** (K) - 1 000 Kenya Shillings

Note: Minor discrepancies due to rounding up.

Source: Republic of Kenya, 1975 (8)

Garcinia, *Mimusops* and *Diospyros mespiliformis*. There are no commercially made boats owned in the area around Bura.

The canoes are punted in shallow water and paddled in deeper water. Outboard motors are uncommon and none is owned in the vicinity of Bura.

1.5 Fish Catches

The total recorded freshwater fish catches for the Tana River District (west bank) and Witu Division of the Lamu District (east bank) amounted in 1975 to about 950 tonnes, valued at about K Sh 1.27 million (8). This was less than the previous year, probably owing to the introduction of the ban on net fishing halfway through 1975. The actual numbers of fish caught is thought to be considerably higher than the reecorded quantity.

A breakdown of the catches on the east and west banks is given in Tables 1.2 and 1.3. The two most important genera were *Clarias* which made up 42 per cent of the catch on the east bank and 27 of the catch on the west bank; and *Protopterus* (49 per cent of east bank and 52 of west bank). *Tilapia* formed only 8 per cent of the east bank catch and 15 per cent of the west bank catch.

The effect of the ban on netting can be seen in the differences in catch size between the first and second six-month periods of 1975 (Table 1.4).

Table 1.4 - The Effect of the Ban on Netting on Recorded Catches on the Tana River 1975

	Total catch (tonnes)	January to June (tonnes)	(% of total)	July to December (tonnes)	(% of total)
East bank	56.4	55.8	99	0.6	1
West bank	893.2	821.7	92	71.5	8

1.6 Fish Prices

The prices obtained for fish caught are difficult to ascertain, and fish tend to be sold by numbers rather than by weight. Enquiries at Korakora during February 1977 indicated that a fish weighing about one kilogramme might be sold for up to K Sh 5 in Garissa. Analysis of the data on fish catches and values in Tana River District (Fisheries Department, 1975) indicates that the price of the three main species landed varied during different months. There was, however, a trend for the prices to increase as the year progressed (Table 1.5); this was perhaps the result of the ban on netting and the consequent decrease in supply.

Results recently published on a survey of the Upper Reservoir of the Tana River suggest that the retail prices of fish in Nairobi were considerably higher than those obtained on the Tana River: *Tilapia* retail at between K Sh 8 and 10 per kilogramme and prices from Lake Victoria area suggest that *Clarias* retail at about K Sh 4/50 per kilogramme.

Table 1.5 - Tana River District, Variation in Fish Prices, 1975
(K Sh per kilogramme)

Month	Tilapia	Clarias	Proteptetus	Total Catch
January	1.00	1.01	1.00	0.97
February	1.20	1.30	1.03	1.00
March	1.26	1.31	1.06	1.00
April	1.39	1.47	1.18	1.30
May	1.60	1.51	1.39	1.84
June	1.64	2.24	2.82	1.00
July	2.18	2.61	2.80	3.40
August	2.49	3.89	4.29	3.27
September	2.07	1.11	1.11	2.19
October	2.78	3.78	4.08	3.84
November	2.47	1.11	5.34	3.45
December	3.65	2.41	2.11	3.38

CHAPTER 2 POSSIBLE EFFECTS OF THE PROPOSED ILACO HEADWORKS WEIR ON LOCAL FISHING

2.1 General

A report from the Delft Hydraulics Laboratory (10) indicates that the construction of the headworks weir, as proposed by the ILACO design, after a few years, will raise the upstream and downstream river bed levels. In consequence flooding immediately upstream of the headworks is likely to increase and downstream flooding may decrease at moderate river flows. This downstream decrease in flooding may affect local fish catches.

Although many fish are caught in the river itself, a large number are obtained from the ox-bow and flood lakes which are inundated during flooding. Any reduction in downstream flooding in consequence of the headworks weir may reduce the extent to which many of these lakes are replenished and reduce a valuable fishing potential.

The fixed high crest of the proposed weir design may restrict the migration of anadromous fish which travel upstream to spawn. If the headworks are constructed according to the proposed ILACO design, the effect on migratory fish should be monitored by the Fish Ecology Research team (see Chapter 5).

CHAPTER 3 THE POTENTIAL FOR FISH FARMING AT THE BURA PROJECT

3.1 Introduction

Fish farming is rapidly becoming a highly productive activity in many parts of the world. Although fish culture has been practised in certain countries for many centuries, the recent increase in human populations and the shortage of productive agricultural land has stimulated interest in intensive food production systems. Fish farming is an intensive production system and many of the constraints which apply to more conventional agriculture, such as climatic and edaphic factors, do not limit the potential production. The four main requirements for successful fish production are a supply of water, a supply of suitable food, a modest amount of capital, and good management. If these requirements can be met and related to a market, there is a potential for the development of fish farming: the Bura Project is one such situation.

Fish culture has been practised in East Africa for several decades. Most of the work has been concentrated on production from ponds and dams (van Someren and Whitehead (11) to (14); Wurtz and Simpson (15); Stoneman (16); and Bailey (17), though more recently the use of tanks has been investigated (Haller) (18, 19).

3.2 The Demand for Fish

Fish are eaten in considerable numbers by some ethnic groups in Kenya and not at all by others. Although certain cultures may have a tradition of fish eating and others not, this is thought to be the result of availability. The settlers at Bura will be drawn from many ethnic groups, some of which will be used to eating fish and others which will not. It is assumed that those who do not traditionally eat fish will be willing to adopt the practice if a reasonably priced source is available, and that fish could therefore become an important protein supplement to the tenants' diet.

Table 3.1 presents the estimated total weight of fish required for the Bura Project Stage I, Phase I, during the first 20 years of development. Three levels of consumption have been assumed; Low (3 kilogrammes per person per year); Medium (10 kilogrammes per person per year) and High (20 kilogrammes per person per year). The national average fish consumption is about three kilogrammes per person per year (9), so the 'low' level of consumption assumed in this table is comparable with the national average.

By Year 5 of development the low estimated requirement will be 150 tonnes and the high, 1000 tonnes; by Year 20 the low estimated requirement will be 260 tonnes and the high, 1700 tonnes. If, as is expected, the tenants will be willing to eat fish a large-scale production system would be justified.

3.3 Methods

At present not enough is known about the possible technical problems of fish farming at Bura to justify any large-scale investment. Furthermore, the population during the first three years of the project would not require large quantities of fish. It is therefore proposed that trials are set up to determine the best methods of culture to be used at Bura and the development of a possible market. Details of the trials, which will cost a total of K Sh 1 486 thousand for three years, are given in Chapter 5.

Table 3.1 - Estimated Fish Requirements for Stage I Phase I of the Bura Project

		Requirements (Tonnes per year)		
Year	Population (1 000)	Low (3 kg/person/year)	Medium (10 kg/person/year)	High (20 kg/person/year)
0	1.2	3.6	12.2	24.3
1	8.0	24.1	80.2	160.4
2	20.9	62.8	209.2	418.4
3	39.3	117.8	392.5	785.0
4	48.4	145.1	483.8	967.6
5	50.1	150.3	500.9	1001.8
6	51.9	155.6	518.8	1037.5
7	53.7	161.2	537.4	1074.7
8	55.6	167.0	556.7	1113.4
9	57.7	173.1	576.9	1153.7
10	59.8	179.4	597.9	1195.7
11	62.0	185.9	619.7	1239.4
12	64.2	192.7	642.5	1285.0
13	66.6	199.9	666.2	1332.4
14	69.1	207.3	690.9	1381.7
15	71.7	215.0	716.6	1433.2
16	74.3	223.0	743.4	1486.8
17	77.1	231.4	771.3	1542.6
18	80.0	240.1	800.4	1600.7
19	83.1	249.2	830.6	1661.3
20	86.2	258.7	862.2	1724.3

Until the trials are completed, it will not be possible to give detailed information about the operation necessary to meet the estimated demands. Much will depend on the productivity that can be achieved and whether the estimated consumption figures will in fact be realised.

There are three methods of fish production which could be used at Bura:

(a) Fish tanks: These have been shown to have the potential for very high yields (Haller 18, 19). Circular self-cleaning tanks appear to be the most suitable. A constant flow of water can be maintained in the tanks and, if desired, this water can be supersaturated with oxygen by 'jetting' the water into the tank from above.

(b) Fish ponds: This more traditional method does not produce such high yields as the tanks and requires more space. There are also problems of the build-up of parasites and fish being eaten by predators such as otters, pelicans and cormorants.

(c) Fish cages: The culture of fish in cages suspended in the water has potential especially for the Supply Canal which will bring water from the headworks to the irrigated area. If this method proved suitable for Bura it would offer the opportunity of employment for a number of fishermen, while at the same time creating settlement along parts of the main canal, and thereby reducing the level of wildlife damage.

3.4 Fish Species

Species of the genus *Tilapia* have been found to be well suited to fish farming. There are many species in this genus, amongst which the following may have potential for use in East Africa:

T. zilii
T. mossambica
T. melanopleura
T. nigra
T. aurea
T. leucosticta
T. shirana
T. nilotica

One problem of rearing many of these species is the fact that in tropical evironments they breed profusely. This tends to lead to the production of large numbers of very small fish, which is obviously undesirable for commercial production. One way of overcoming this problem is to separate males from females before they reach maturity. Because many *Tilapia* species reach sexual maturity before any external sexual dimorphism is discernible, this is not always possible. Some species which show sexual dimorphism before maturity, such as *T. nigra*, also have differential growth rates between male and female fish; with males growing up to three times as fast as females. In this situation it is usual to remove the females from the production system and to convert them into fish meal which can then be fed back to the males.

A way to overcome the problem of *Tilapia* breeding before any sexual dimorphism is apparent, was described by Brown and van Someren in 1953 (20). This method entails the crossing of two species to produce a male mono-sex F_1 generation. This has been tried with a number of different species in various parts of the world with considerable success (Hickling, (21); Stoneman, (16); Hyder, (22); and Prugin *et al.,* (23)). Crosses which produce mono-sex F_1 generations include:

Male		*Female*
T. mossambica	*x*	*T. nilotica*
T. aurea	*x*	*T. nilotica*
T. nigra	*x*	*T. leniosticta*

Other species which should be considered for use at Bura include Grass Carp *(Xenopharyngon idella)*, Mirror Carp *(Cyprinus caprio)* Cat fish *(Clarias mossambica)* and Lung fish *(Protopterus amphibius)*. One problem which can be anticipated with carp is that of spawning and Haller (18) has found it necessary to induce spawning artificially by injecting ripe males and females with pituitaries. Wurtz and Simpson (15) have discussed the culture of carp in Uganda and recommended the introduction of the Nile Cabbage *(Pistia stratiotes)* into the breeding ponds to provide a substratum for carp spawning. However, to avoid the possible spread of this plant into the channels of the project, it is recommended that hessian or sisal rope should be used for these substrata.

Shell fish are another group which have shown potential for good production under intensive systems and both freshwater prawns *(Macrobrachium sp.)* and the Louisiana Red Swamp crayfish *(Procambarius clarkii)* have grown well at Bamburi (Haller, (18)). The production of shellfish at Bura cannot be recommended at present because it would cause too great a diversification of effort, and marketing may well prove a problem. *Procambarius clarkii* has been found to be very damaging to commercial netting operations and at Lake Naivasha is estimated to destroy about 30 per cent of the catch (Lowery and Mendes (24)). At present this crayfish does not occur within the Tana River catchment although it is found in both the Athi River and Ewaso Nyro catchments. It is strongly recommended that *P. clarkii* is not introduced into the Tana catchment, for it could cause a great deal of trouble should commercial netting operations start again.

3.5 Fish Food

Fish will consume food at a rate of between two and four per cent of their body weight each day.

The type of food offered to fish will obviously depend on the species concerned. In the sort of intensive production systems under discussion, it is necessary to ensure that an adequate supply of good quality food is available.

Commercially produced trout pellets, costing between K Sh 2.50 and 3.00 per kilogramme, could be used. The results of an analysis of commercial pellets is shown in Table 3.2.

Table 3.2 - Analysis of Commercial Trout Pellets

Ingredient	Percentage
Protein	44.0
Oil	6.8
Fibre	2.7
Calcium	6.6
Phosphorus	2.9
Methionine	0.7
Lysine	2.4
+ Vitamins and trace elements	Trace
Other	31.6

Source: Haller, 1974 (18).

It is very much cheaper to produce the fish food on site and a mixed fish food consisting of one-third vegetable offal and one-third maize bran can cost less than one shilling a kilo (Haller, 1974). The crop residues produced at Bura would form a good basis for fish feed. Care should be taken if cotton seed is used as the protein source and it may be necessary to boil the seed before feeding to destroy the toxic effects of glossypol.

3.6 Productivity

Under suitable conditions *Tilapia* can grow at the rate of 2.0 grams (g) per day; this represents a weight gain of 360 g in six months. Mirror carp can grow as fast as 12.0 g per day; over 2000 g in six months (Haller, (18)).

The Food Conversion Ratio (FCR) of fish is as important as absolute growth rates, for the economics of an operation will depend on how efficiently the fish utilise their food.

Young *Tilapia* have a good FCR which can be as low as 1:1.2. As the fish get older, however, the FCR rises and in one year-olds an FCR of 1:3.1 has been recorded. Carp and catfish generally have lower FCRs than *Tilapia*.

The productivity of fish is affected by their environment, salinity and oxygen content of the water and temperature, are important factors. Certain species are much more robust than others. For example *Tilapia* of the *T. mossambica* group are able to withstand high salinity (3 500 ppm) and temperatures (43°C) much better than *T. zillii.*, *Clarias* and *Protopterus* tolerate much lower oxygen concentrations than *Tilapia* though low oxygen concentrations are likely to reduce the productivity of these species.

At Bamburi *Tilapia* have produced as much as 100 kilogrammes of fish per cubic metre of water in six months (Haller, 18). If 12 000 litre tanks are used, this means that production will be at a level of 2.4 tonnes of fish per year per tank. If the tanks proudce only 70 kilogrammes of fish per cubic metre in six months, 1.68 tonnes of fish will be produced per tank each year. If fish are marketed at a weight of 200 grammes the higher level of production will yield 12 000 fish each year and the lower level 8 400.

3.7 Production Systems

As has already been mentioned, the details of the production can only be described after completion of the trials. However, by assuming certain production levels it is possible to estimate the scale of operation that might be required to meet the demand for fish at Bura. Table 3.3 shows the number of 12 000 litre tanks which will be needed to meet the different demands at Years 5, 10, 15 and 20, assuming production levels of 140 and 200 kilogrammes of fish per cubic metre of water every year.

Table 3.3 - Estimated Number of 12 000 litre Fish Tanks Required to Meet Demands for Fish on the Bura Project, Stage I, Phase I

	Year 5	Year 10	Year 15	Year 20
Low Demand				
Number of Tanks:				
High production (1)	63	75	90	108
Low production (2)	89	107	128	154
Medium Demand				
Number of Tanks:				
High production	209	249	299	359
Low production	298	356	426	513
High Demand				
Number of Tanks:				
High production	417	498	597	718
Low production	596	712	853	1026

(1) High production estimated at 200 kilogrammes per cubic metre of water per year.

(2) Low production estimated at 140 kilogrammes per cubic metre of water per year.

At Year 20 ten times more tanks will be required if there is a high demand and low production, than if there is low demand and high production.

Even with a low demand for fish by the project tenants, the amount of fish food that will be required to support the production system will be considerable. The total tonnage of fish food needed at Bura to meet the estimated requirements is shown in Table 3.4. In calculating these figures two FCRs have been used; a 'Good' FCR 1:1.5 and a 'Poor' FCR of 1:2.5.

Table 3.4 - Estimated Requirements of Food for Fish Farming on the Bura Project, Stage I, Phase I (Tonnes)

	Year 5	10	15	20
Low Demand				
Good FCR	225	269	322	388
Poor FCR	376	448	537	647
Medium Demand				
Good FCR	751	897	1075	1293
Poor FCR	1252	1495	1791	2155
High Demand				
Good FCR	1503	1794	2150	2586
Poor FCR	2505	2990	3583	4311

It should be stressed that these figures are only estimations. They will need to be modified in the light of experience gained at Bura. The potential production from fish cages has not been taken into account.

3.8 Water

The water to be used in the fish tanks will be pumped out of the Supply Canal, to which it will be returned after passing through the tanks. There are two possible problems associated with using water from the canal, the first is siltation and the second parasites.

Although the fish tanks will be downstream of the sediment trap at the head of the Supply Canal there will still be suspended sediment in the water. Apart from the effect this may have in reducing the life of the pumps used to circulate the water, it may also have an effect on the fish. The water in the Supply Canal comes from the Tana River and as such will contain the eggs spores and free-living stages of a number of fish parasites. It will therefore be necessary to keep a careful check on the parasite burden of the fish in the tanks.

3.9 Marketing

It is unlikely that it will be necessary to provide sophisticated refrigeration plants for the marketing of fish at Bura. The fish are being produced for local consumption and, unlike commercial netting operations, the number of fish 'caught' can be regulated to meet the daily demand. As well as producing fresh fish it will be necessary to consider drying fish, as this will enable the tenants to keep a supply readily available.

Without being certain of the level of the demand for fish it is not possible to make firm recommendations as to exactly how the fish should be marketed. Dried fish could be sold through the village shops in the same way as other commodities. Initially fresh fish could be sold through butchers, though if the demand justifies it, it may be necessary to establish specialised fish shops. Strict control of hygiene will have to be maintained because fish is likely to go bad quickly in the hot climate at Bura.

3.10 The Siting of the Fish Farm

Although for marketing and administration it would be desirable to have the fish farm near the population centres, this cannot be recommended for two reasons. Firstly, the sprays that will be used to control the pests of the cotton crop include carbaryl, dimethoate and endosulfan, which are extremely harmful to fish. The sprays will be aerially applied and there will inevitably be a certain amount of spray drift. Secondly, the introduction of untreated water near concentrations of population would increase health hazards. It is therefore recommended that the fish farm be located at the northern end of the Supply Canal, near Nanigi Village.

CHAPTER 4 PESTICIDE RESIDUES

4.1 Introduction

A number of pesticides will be used to protect the crops grown in the project area, particularly cotton. Table 4.1 lists pesticide sprays used on the Hola Scheme in 1976.

Table 4.1 - Pesticide Sprays used at the Hola Scheme, 1976

Spray No.	Insecticide	Application	Concentration
1	Sevimol 300	ULV	4.5 litres/ha
2	Thiodan 35 and Rogor 40	Conventional	3.5 + 0.5 litres/ha
3	Sevimol 300	ULV	4.5 litres/ha
4	Thiodan 35 and Rogor 40	Conventional	3.5 + 0.5 litres/ha
5	Sevimol 300	ULV	4.5 litres/ha
6	Thiodan 35 and Rogor 40	Conventional	4.0 + 0.5 litres/ha
7	Thiodan 35 and Rogor 40	Conventional	4.0 + 0.5 litres/ha
8	Sevin and DDT 75% WP; 85% WP		1.7 + 1.3 kg/ha
9	Sevin and DDT 75% WP;		1.7 + 1.3 kg/ha
10	Sevin and DDT		1.7 + 1.3 kg/ha

Source: NIB, 1976

Thiodan (which is the chlorinated hydrocarbon Endosulphur), Sevin and Sevimol (which are the carbonate carbaryl), Rogor (the organophosphate dimethoate) and DDT are all known to have harmful effects on non-target organisms. Thiodan, Sevin and Rogor all have particularly harmful effects on fish.

4.2 Pesticides in the Environment

The pesticides for the Bura Project will be applied from the air and will consequently have an effect on many other organisms apart from the crop which is to be protected.

Substances such as chlorinated hydrocarbons are very resistant to biodegradation and consequently are very persistent. Chemical residues in turf have been found to remain at 5 to 15 per cent of the application (Newsom, 25). Organophosphates are very much less persistent, especially in aquatic systems.

Pesticides proliferate within both terrestrial and aquatic ecological systems and, due to the promixmity of the Tana River to the Bura Project, it is likely that both will be affected. The movement of pesticides within an ecological system is highly complex, and often little understood. However, the process of biomagnification, whereby animals which are at the top end of the food chain tend to have higher concentrations of pesticides, has been often described.

Apart from the effects pesticides can have on both humans and wild life, they can also cause considerable damage to the micro-organisms in the soil and reduce productivity. Pesticides also affect domestic stock, and cattle at Hola have shown symptoms of poisoning after aerial spraying of the crops.

Cotton is a crop which requires much larger amounts and range of pesticides than most others, and the Food and Agricultural Organisation, FAO (26), has recommended that more extensive investigations into residues and their environmental impact is required.

4.3 Monitoring Pesticide Residues

A report of an FAO/UNEP consultation of experts on the impact monitoring of residues (27) has recently stressed the need for monitoring situations such as that likely to occur at Bura. The National Agricultural Laboratories of the Ministry of Agriculture have expressed a willingness to undertake some basic monitoring. Proposals for pesticide residue monitoring on the Bura Project are given in Chapter 5.

CHAPTER 5 DEVELOPMENT PROPOSALS

5.1 An Ecological Study of the Development and Management of the Fisheries of the Tana River

A study of the fish and fisheries of the Tana River will be a large undertaking which will require careful planning and a very high level of expertise in the collection and analysis of data.

If the study is going to be able to describe the probable ecological changes in the river as a result of the Nanigi headworks weir and the irrigation scheme itself, base line studies will have had to be completed before any large scale development has started.

The study should be designed to collect and analyse information on the biology and ecology of the reach of the Tana River likely to be affected by the development of the Bura Project, and should make recommendations on the management required to reduce any deleterious effects and to increase the commercial offtake from the river.

The study should include surveys of:

(a) Present fishing methods used
(b) Size, value and markets of the fish catch
(c) Physical and chemical parameters of the river
(d) Vertebrate, invertebrate and plant communities in the river
(e) Food and feeding habits
(f) Fecundity and patterns of reproduction
(g) Distribution and migration
(h) Age distribution within the population
(i) Size range of species population
(j) Age at maturation
(k) Length - weight relationship
(l) Stock assessment
(m) Physical condition
(n) External and internal parasites

The final report of the study should include: descriptions of the ecology of the river both before and after the development of the project; an assessment of the effects of the headworks weir and irrigated area; and, recommendations for the management of the fish resource.

Construction work on the Supply Canal and the headworks weir is scheduled to start in early 1979, but it is unlikely that the headworks weir will have any significant effect on river flows until at least one year later. To obtain data on the ecology of the river before the weir becomes effective, studies should be underway by the beginning of January 1979. The duration of the study should be three and a half years, three years of which will be field work and the remaining six months spent writing up the results. The period of field work will cover one year of 'pre-weir' ecology and two years of 'post-weir' ecology.

For a study of this scope and complexity a post-doctoral research worker will be required to head the team. He will be supported by two post-graduate students and one technical assistant. Further specialised technical work should be undertaken by supervisory consultants who would spend about 40 days a year with the study team. Other staffing requirements would be one boatman, two fishermen and two general labourers.

The equipment required for the study would include a boat, an out-board motor, a trailer, two LWB four-wheel drive vehicles and laboratory equipment. The following laboratory equipment would be required:

YS1 oxygen meter
Spectrophotometer
Portable pH meter
Conductivity meter
Thermistor probes
Photometer and filters
Ruttner water sampling bottles
Electric fish gear and generator
Micro and macro balances
Deep freeze
Portable gas refrigerator
Centrifuge
Vacuum pump and millipore filters
Fish traps
Binocular dissecting microscope
Binocular compound microscope
Glassware and chemicals
SLR Camera and lenses
Tools

Provision should be made for 25 return flights from Bura to Nairobi for each year of the study. This will enable the field workers to travel to Nairobi to consult libraries, to attend seminars and to obtain technical information and advice. It will also allow easy access to the study area for the supervisory consultants.

The study would require one laboratory with space for five people, three attached offices, a store, and small workshop. A total of six houses would be required, one senior, three junior and two others for supporting staff.

The study team should function as a separate unit and should be under the auspices of the National Environment Secretariat in the Office of the President. It should maintain close links with the University of Nairobi, and the team leader should hold the honorary post of Research Associate in the Department of Zoology. The Department of Zoology would supply the two M.Sc. students required each year and any expertise required by the study team. This close link with the University will be advantageous for two reasons. Firstly, it will enable the research team to maintain close contact with others involved in similar work and allow them access to the facilities which the University can offer research workers; and secondly, it will encourage interest in this increasingly important field of ecological research and offer an opportunity to train graduate students.

Because the studies will include the collection of data from the Nanigi weir site to downstream of Bura, it would be appropriate to site the study team's camp on the west bank of the Tana River in the vicinity of Bura. The capital and recurrent estimated costs of the study are given in Tables 5.1 and 5.2. The total cost would be just under K Sh 2 196 thousand, of which K Sh 890 thousand would be capital costs, and just under K Sh 1 306 thousand recurrent costs for the three and a half year period, at K Sh 373 thousand per year.

5.2 Fish Farming Trials

The intensive production of fish for the population of the Bura Project could provide a valuable protein supplement to their diet. However, before any extensive fish production system is established it will be necessary to set up some trials to determine the species of fish most suitable, the rations to be used, the best methods of production and the tenants' requirements for fish. After the completion of the fish farm works two years trials should be sufficient to establish production parameters and to have surveyed the potential market requirements.

It is proposed that two methods of fish culture are investigated during the trials; fish tanks, using

Table 5.1 - Capital Costs of Ecological Study of the Fish of the Tana River (1 000 Kenya Shillings)

Item	Unit	Unit Cost	No. units	Total Cost
Equipment:				
Boat and outboard	Unit	22	1	22
Trailer	Unit	3	1	3
Laboratory equipment (1)	Set	188	1	188
Fishing equipment	Set	10	1	10
Office equipment (2)	Set	4	1	4
Sub Total				227
Vehicles:				
4WD LWB Vehicle	Vehicle	77	2.	154
Buildings:				
Office (3)	Office	40	1	40
Laboratory (4)	Laboratory	40	1	40
Store (5)	Store	16	1	16
Workshop (6)	Workshop	10	1	10
Sub Total				106
Housing:				
Senior Staff House (7)	House	100	1	100
Junior Staff House (8)	House	58	3	174
Other Staff House (9)	House	14	2	28
Sub Total				322
Contingencies				81
TOTAL				890

Notes:
(1) List of equipment given in text
(2) Office equipment for four people
(3) Office for four people
(4) Laboratory for four people
(5) Small store, say 20 m^2
(6) Small workshop, say 10 m^2
(7) House for post-doctoral Researcher
(8) Houses for two graduate students and Research Assistant
(9) Two staff houses to accommodate boatman, two fishermen and two general labourers

Table 5.2 - Recurrent Costs of Ecological Study of the Fish of the Tana River (1 000 Kenya Shillings)

Item	Unit	Unit Cost	No. units/ year	Annual Cost	Total Cost for 3½ years
Salaries:					
Senior Research Officer (1)	Man-year	90	1	90	315
Graduate Students (2)	Man-year	7	2	14	49
Research Assistant (3)	Man-year	6	1	6	21
Boatman	Man-year	6	1	6	21
Fisherman	Man-year	6	2	12	42
General Labour	Man-year	4	2	8	28
Sub Total				136	476
Professional Services:					
Supervision and Technical Consultancies	Man-days	1.3	80	104	364
Maintenance of Buildings:				10.5	36.8
Maintenance of Equipment:				22.7	79.5
Vehicle Running:					
4WD Pick-Up	Vehicle/ year	20	2	40	140
Stationery:	Year	1	1	1	3.5
Travel:					
Return Bura/NBI	Trip	1	25	25	87.5
Sub Total				339.2	1187.2
Contingencies					118.7
TOTAL					1305.9

Notes:
(1) Post-doctoral research worker
(2) Graduates undertaking post-graduate for M.Sc. or Ph.D.
(3) Technician

water pumped from the Supply Canal, and fish cages suspended in the canal. Ten circular fish tanks would be required, each with an internal diameter of 5 metres and a depth of between 60 and 85 centimetres. The capacity of each tank will be about 12 cubic metres, or 12 000 litres. The tanks will be deepest at the middle so that faeces can be removed. Five of the tanks (A Tanks) should be provided with a strong flow of water, delivered from a pipe placed 20 centimetres above the water level. This will ensure super-saturation of the water with oxygen. The rate of flow of the water should be approximately one litre per minute per kilogramme of fish. At peak densities each tank might therefore require a flow of about 20 litres per second. One of the purposes of the trials would be to establish the most efficient, and economic, rates of flow for each species. The other five tanks (B Tanks) will be placed at a lower level and will receive the water drained from the A tanks. The water in the B tanks will have less oxygen than the A tanks, but will be rich in the detritus from the A tanks.

The trials should investigate the production from fish in cages suspended in the Supply Canal. Experiments by Haller (18) have shown that good growth rates can be achieved by this method, with the fish kept in cages measuring 150 x 90 x 60 centimetres made from 2.5 centimetre wire mesh.

One of the reasons for the success of this method is possibly that the nitrites and nitrates in the fish faeces fall through the bottom of the cage and therefore do not inhibit the growth of the fish, but more detailed information is required. Pagan-Font (28) found that cage culture was a good method of controlling the reproduction of *Tilapia aurea* because its eggs were lost through mesh greater than 0.3 centimetres.

The bulk of experience in fish farming in East Africa is with species of the genus *Tilapia*. These would form a good basis for the work of the Bura fish farming trials which should determine which species of *Tilapia* would be most suitable for the conditions at Bura. The trials should also undertake investigations into the possibilities of mono-sex culture. The possible use of *T. nilotica, T. nigra, T. zillii, T. mossambica, T. melanopleura* and *T. shirana* should be investigated.

The potential productivity and management of Grass carp *(Xenopharyngon idella)*, Mirror carp *(Cyprinus caprio)*, Cat fish *(Clarias mossambicus)* and Lung fish *(Protopterus amphibius)* should also be studied.

The use of both commercial pelleted fish feed and the production of a local fish feed based on available crop residues should be investigated. The supply of a high protein component for the locally produced feed may be problematic and until the proposed abattoir is working it may well be necessary to import the protein component.

The growth rates and food conversion ratios should be carefully monitored for all species used. Detailed records should be kept and production figures should be related to costs so that an economic assessment of the trials can be made.

The trials should start to produce saleable fish within six months of the completion of the construction of the tanks. These fish should be sold within the project and used as a basis for estimating the demand which can be expected in later years. The method of marketing and the form of presentation of fish, whether fresh or dried and what size of fish is best, should be investigated.

The fish farming trials will require detailed supervision and planning if meaningful results are to be produced. A decision as to the viability of a large scale production system will be based on the findings of the trials and the work will have to be of a high standard. The manager of the trials will need to be a person who is not only conversant with the current techniques of fish culture, but who also has experience in the scientific collection of production and marketing information. A scientific background alone will not be sufficient, for the manager will be responsible for the day to day running of the trials. He would be supported by two headmen, one technician, one clerk, one driver and ten labourers.

Apart from the ten tanks and two hundred fish cages, an office, store, workshop and small

Table 5.3 - Capital Costs for Fish Farming Trials *
(1 000 Kenya Shillings)

Item	Unit	Unit Cost	No. units	Total Cost
Buildings and Construction:				
Fish tanks (1)	Tank	11.5	10	115
Fish cages (2)	Cage	0.08	200	16
Store (3)	Store	3	1	3
Office (4)	Office	20	1	20
Workshop (5)	Workshop	5	1	5
Laboratory (6)	Laboratory	25	1	25
Sub Total				184
Housing:				
Senior Staff (7)	House	165	1	165
Junior Staff (8)	House	58	4	232
Other Staff (9)	House	14	4	56
Sub Total				453
Vehicles:				
2WD Pick-Up	Vehicle	43	2	86
Motor Cycle 90 cc.	Cycle	6	2	12
Sub Total				98
Equipment:				
Breeding tanks (10)	Tank	0.5	50	25
Silt removal plant (11)	Plant	60	1	60
Deep freeze and generator (12)	Deep freeze/ generator	7	1	7
Pumps (13)	Pump	7	1	7
Fish handling equipment	Set	5	1	5
Laboratory equipment (14)	Set	5	1	5
Office equipment (15)	Set	2	1	2
Sub Total				111
Contingencies				84
TOTAL				930

* Occurring in Year 1

Notes:

(1) Fish tank to hold 12 000 litres
(2) Cages to measure
(3) Covered store about 40 square metres
(4) Office for four people
(5) Small workshop
(6) Laboratory for two people
(7) House for Trial Manager (expatriate); graduate with experience in fish farming
(8) Houses for two Headmen, Technician and Clerk/Typist
(9) Other Staff: 10 labourers and 1 drive need to supply housing due to distan from Bura Project
(10) Concrete 1.0 x 0.5 x 0.5 m tanks
(11) Plant to deal with 120 litres/second
(12) 100 cu. ft deep freeze, generator also provide power for accommodation a laboratory
(13) Pumps to move 120 litres/second
(14) Laboratory equipment for 2 people
(15) Office equipment for 4 people

Table 5.4 - Recurrent Costs for Fish Farming Trials (Kenya Shillings)

Item	Unit	Unit Cost	Year 1 No. units	Year 1 Cost	Year 2 No. units	Year 2 Cost	Total
Salaries:							
Manager	Man-year	37 000	1	37 000	1	37 000	74 000
Headman	Man-year	14 300	2	28 600	2	28 600	57 200
Technician	Man-year	11 800	1	11 800	1	11 800	23 600
Clerk/Typist	Man-year	9 000	1	9 000	1	9 000	18 000
Driver	Man-year	6 800	1	6 800	1	6 800	13 600
Labourers	Man-year	4 000	10	40 000	10	40 000	80 000
Sub Total				133 200		133 200	266 400
Vehicle Running:							
2WD Pick-Up	Vehicle/ year	20 000	2	40 000	2	40 000	80 000
Motor Cycles	Cycle	1 500	2	3 000	2	3 000	6 000
Sub Total				43 000		43 000	86 000
Maintenance and Running:							
Pumps, Generator	Pump	1 400		1 400		1 400	2 800
Silt plant	Plant	6 000		6 000	1	6 000	12 000
Fish food	kg	2.5	20 000	50 000	30 000	75 000	125 000
Vetinerary cost	Year	4 000	1	4 000	1	4 000	8 000
Stationery	Year	500		500	1	500	1 000
Chemicals	Year	2 000		2 000		2 000	4 000
Sub Total				63 900		88 900	152 800
Contingencies							50 800
TOTAL							556 000

laboratory will be needed. One senior staff, four junior staff and accommodation for eleven supporting staff.

The following equipment will be needed:

- Pumps
- Silt removal plant
- Generator
- Small deep freeze
- Fish handling equipment
- Breeding tanks
- Scales
- Laboratory equipment and chemicals
- Two pick up trucks
- Two 90 cc motor cycles

The estimated capital and recurrent costs of the fish farm trials are detailed in Tables 5.3 and 5.4. The total cost is estimated to be K Sh 1 486 thousand of which K Sh 930 thousand would be capital costs, and K Sh 556 thousand would be recurrent costs for the two year period.

To be successful, the fish farming trials would have to be well managed and the collection of information must be of a high standard. It is therefore suggested that the management and operation of the trials be offered for commercial tender. These are commercial groups in Kenya with the necessary expertise to undertake such an operation, and this would enable the project management to concentrate on its main task of agricultural production.

5.3 Monitoring the Impact of Pesticide Residues

The type of pesticides that may be used on the Bura Project and the reasons why their effect on the environment should be monitored, have been discussed in Chapter 4.

It is expected that the Pesticide Residue Unit of the National Agricultural Laboratories will undertake the collection of samples and the chemical analyses necessary to determine the residue concentrations present. A field team of one research officer, two technicians and a driver is envisaged.

To assess the impact of the spraying regime for the Bura Project data on residue concentrations should be collected before any spraying begins. In this way base line levels of residues can be determined and compared with later results after spraying has started. These data should be collected as soon as funds are available and official approval for the impact monitoring programme has been obtained.

The field team should collect samples from both terrestrial and aquatic ecological systems. Terrestrial samples should be regularly collected along east-west transects extending from the river through the irrigated area and to a distance of at least 20 kilometres beyond the project.

Samples collected from the terrestrial ecological system should include:

- Soil
- Natural vegetation
- Crops
- Crop residues
- Livestock tissues
- Small and large wild mammal tissues
- Avian tissues (which should include a common resident bird of prey)

The monitoring of the aquatic environment should include the collection of samples at the headworks weir site at Nanigi, thereby ensuring that any apparent increases in residue levels recorded downstream could be related to changes in base flow levels of pesticides. Water, plant, invertebrate, and vertebrate samples should be collected from the river. River samples should be taken at the present Bura village and at 5 kilometre intervals for a distance of at least 20 kilometres downstream.

To collect these samples the field team will need the co-operation of the Project Management, the Wildlife Service (to collect wildlife tissue samples), a butcher (to obtain livestock tissue samples), and the fish ecology research group.

At least two, and preferably three, sampling trips should be made before any pesticide applications to obtain base line data. Once spraying has started samples should be collected at six monthly intervals.

The results of each analysis should be sent to the National Irrigation Board headquarters in Nairobi; the project manager; the Tana River Development Authority; the Research Division of the Wildlife Conservation and Management Department of the Ministry of Tourism and Wildlife; the Ministry of Agriculture; the National Environment Secretariat of the Office of the President; and the Water Development Board. Copies should also be sent to international organisations in Nairobi, such as UNEP, UNESCO and FAO.

The staff and equipment required for the residue monitoring programme are already available at the National Agricultural Laboratories. It will therefore only be necessary to provide finance for the recurrent expenditure of the programme. A breakdown of these costs is given in Table 5.5. The cost of the collection of base line data is estimated to be K Sh 31 thousand, and the costs each year after the start of spraying will be K Sh 20 thousand.

Table 5.5 - Recurrent Costs per Annum for Pesticide Residue Monitoring (1 000 Kenya Shillings)

Item	Unit	Unit cost (K Sh)	Number of units	Total
Base line data collection (three trips in one year only)				
Vehicle running	km	1.45	4 800	7.0
Sample analysis	Sample	70	300	21.0
Sub-total				28.0
Contingencies				3.0
Total				31.0
Annual data collection (two trips per year)				
Vehicle running	km	1.45	3 200	4.6
Sample analysis	Sample	70	200	14.0
Sub-total				18.6
Contingencies				1.4
Total				20.0

5.4 Phasing of Fisheries Activities

The study of the ecology of fish of the Tana River should begin in 1978 so that conditions prior to the construction of the headworks can be determined.

The fish farming trials should start in 1981, once the Supply Canal has been commissioned and the fish tanks have been completed. The monitoring of base line pesticide levels in the Bura environment should begin in 1980, regular monitoring should start in 1981 and be carried out twice a year.

Table 5.6 shows the timing of the various activities associated with the fisheries studies and their related activities.

Table 5.6 - Timing of Fisheries Input for the Bura Project

Year	Input
1978	Start of fish ecological study
1979	
1980	Collection of pesticide residues base line data
1981	Report from fish ecological study; start of fish farming trials; start of pesticide residue monitoring
1982	Report from fish farm trials

5.5 Summary of Costs

The total cost of the fish ecology study will be K Sh 2 196 thousand, K Sh 890 thousand of this will be capital costs and K Sh 1 306 thousand of this will be recurrent costs.

The fish farming trial is expected to cost K Sh 1 486 thousand, K Sh 930 thousand of which will be capital costs and K Sh 556 thousand of which will be recurrent costs.

The base line studies for pesticide monitoring will cost K Sh 31 000, all of which will be recurrent costs. The subsequent annual cost, which again will be recurrent expenditure, will be K Sh 20 000.

A summary of the phasing of the costs required for the fisheries input is given in Table 5.7, and a breakdown of these costs is given in Tables 5.1 to 5.5.

Table 5.7 - Summary of Costs for Fisheries Input for the Bura Project (1 000 Kenya Shillings)

Year	Capital	Recurrent	Contingencies	TOTAL
1978	809.0	339.0	115.0	1 263.0
1979	–	339.0	34.0	373.0
1980	–	367.0	37.0	404.0
1981	846.0	428.7	126.8	1 401.5
1982	–	283.7	28.2	311.9
1983	–	18.6	1.4	20.0
1984	–	18.6	1.4	20.0
1985	–	18.6	1.4	20.0

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BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

WILDLIFE AND ECOLOGY ANNEXE

BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

WILDLIFE AND ECOLOGY ANNEXE

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY AND RECOMMENDATIONS

Although animal densities tend to be low, the Tana River District is an important area for wildlife in Kenya. The Bura Irrigation Settlement Project can be expected to affect some 1 500 square kilometres of wildlife habitat. The loss of the actual area to be irrigated will not have such serious consequences for wildlife as the restriction of access to the riverine forest, the good grazing of the floodplain and the river itself. The proposed Supply Canal which will bring water from the headworks near Nanigi to the project area is of particular importance in this respect, and provision will have to be made to enable animals to cross the canal.

The ILACO designs provide for one inverted siphon and three aqueducts to carry the Supply Canal across four natural drainage lines, and it is now recommended that all four crossings should be inverted siphons and these may be used by animals to cross the canal alignment. However, additional crossings will be necessary. Preferably these should also be inverted siphons, but if these are too expensive fords or drifts might be built into the canal if these do not affect the canal design. It is proposed that initially three additional crossings be built, their locations being determined at the time of construction of the canal following discussions with Wildlife Service personnel and the Tana River Development Authority. Allowance has also been made in the estimates for a further four ford crossings which may be built after the canal has been constructed if there are additional sites of high challenge.

Eleven drinking pools will be provided along the west side of the canal, preferably some 250 metres from it: these will help reduce the number of animals wishing to cross the canal. The construction of extensive fences to reduce wildlife damage to the Supply Canal can be justified neither on the grounds of effectiveness nor expense. Experience at Hola has shown that after a time game animals become accustomed to the canal and cause little damage.

The proposed siting of the settlement villages around the perimeter of the project is well suited to reducing the challenge of wildlife to the irrigated area. The main canal to the west and the drainage channels to the north and south of the irrigated area will also do much to reduce damage by wildlife. Fencing to the irrigated area is considered to be of questionable value and trenching too expensive. It is proposed that trials should be started in 1978, at Hola, in conjunction with the tree species trials, using vegetative barriers of *Opuntia ficus-indica* and *Euphorbia breviarticulata*. These may well prove a cheap method of excluding wildlife from the irrigated area.

In 1980 twelve game scouts and one Junior Warden will be required to limit poaching, control wildlife within the irrigated area, and to deal with any game animals which may be trapped in the canal.

The ILACO high fixed crested headworks design may affect the flooding upstream and downstream of the headworks: and this in turn may have a detrimental effect on the downstream riverine forest habitat of two endangered species of primates and on Pokomo riverine cultivation. Careful monitoring of this situation would be required: a reduction of Pokomo riverine cultivation may provide an indication of any long-term effects on the changes in flood patterns.

The development of the east bank of the river as Stage II of the project would be detrimental to the endemic Hunter's antelope. The proposed irrigated area on this bank of the river is a centre of concentration for this animal and adequate safeguards must be provided if this area is to be developed.

CHAPTER 1 THE PRESENT SITUATION

1.1 Existing Proposals

Although the proposed Bura Project area cannot be compared with other parts of Kenya in terms of total wildlife densities, it is an important area for many game species, including Elephant *Loxodonta africana*. The rapid development of the irrigation project will inevitably bring the interests of wildlife and agriculture into conflict: careful planning is therefore necessary to minimise the extent of this conflict and to reduce the adverse effects that the project might have on wildlife, and that wildlife might have on the project.

Certain wildlife species could do considerable damage to the crops to be grown on the Bura Project and such damage could be financially disastrous to the tenant farmers. Wildlife could also damge the Supply Canal bringing the water from the headworks near Nanigi to the project area.

The development of the irrigated area itself will mean that a certain amount of land will no longer be available for use by wildlife. The total area for Stage I of the project, on the west bank of the Lower Tana River, which comprises 6 700 ha in Phase I, and a further possible 5 500 ha in Phase II, is relatively small when considered in relation to the total area of Tana River District, 309 million hectares. Furthermore, the poor quality of the vegetation in the area indicates that the total wildlife biomass that the land to be irrigated could support would not be large. A much more serious problem is the effect that the irrigation project and the Supply Canal might have in excluding wildlife from the floodplain and the riverine forest. It is proposed that part of the floodplain immediately to the east of the project should be used for supplementary irrigated forestry plantations. Irrigated forestry and wildlife are as incompatible as irrigated agriculture and wildlife, and it will therefore also be necessary to protect the plantations.

The Supply Canal will present a formidable obstacle to wildlife moving from the west to the east, towards the floodplain, the river and the riverine forest. Many of the smaller species of game animals will not attempt to cross this canal but the larger species, such as elephant, will almost certainly attempt to alter its banks and ford the canal.

A survey of the wildlife aspects of the Bura Project has been undertaken by Blankenship (1). The main recommendations presented in this report were that:

(a) the irrigation project should be developed as slowly as possible;

(b) drinking pools for wildlife and cattle should be provided on the west side of the Supply Canal;

(c) inverted siphons rather than overpasses should be used for the Supply Canal at natural drainage (laga) crossings;

(d) special canal crossings for elephants between the headworks and the first offtake should be provided;

(e) wildlife should not be permitted to travel along the course of the Hiraman laga;

(f) the main road should be used as a temporary barrier to livestock west of the proposed cultivated area;

(g) game scouts should be used as a deterrent to wildlife depredation of crops and to enforce other aspects of wildlife management.

These proposals were prepared when the initial size of the project was to be about 14 thousand hectares. In view of the reduction in the size of the first stage of the project to just under seven thousand hectares and the certain alterations in the overall design of the project, a number of these recommendations need reviewing.

1.2 Government Policy on Wildlife Conservation and Management

Current Government policy on wildlife management in Kenya is outlined in the sessional paper no. 3 of 1975 (Republic of Kenya, 1975) (2). This paper states that 'The Government's fundamental goal in respect to wildlife is to optimize the returns from this resource, taking account of returns from other forms of land use'. These returns are to include not only the economic gains from tourism and consumptive use, but also the aesthetic, cultural and scientific gains from the conservation of habitats and their associated fauna. In areas of high density arable agriculture, such as that which will be created at the Bura Project, it is the government's policy 'efficiently to minimise damage to crops by wild animals'.

To implement the Government's policy the Wildlife (Conservation and Management) Bill was passed in February, 1976 (Republic of Kenya, 1976) (3). This act incorporates the activities of the former National Parks with those of the Game Department. The intention being to permit the more flexible management of wildlife. The newly formed Wildlife Conservation and Management Department (Wildlife Service) comes under the Ministry of Tourism and Wildlife.

1.3 Wildlife Management and Utilisation in the Project Area

The Bura area falls under the responsibility of the Senior Game Warden (Coast), stationed at Mombasa. There are Wildlife Service posts at Nanigi, Bura, Hola, Wenje and Garsen, see Figure 1.1. There is also a Senior Game Warden at Garissa, though his responsibility is the North Eastern Province, which covers the east bank and does not include the Stage I project area. There are no gazetted game reserves in the immediate vicinity of the proposed irrigation project, but the Arawale Game Reserve, on the east bank, is very close to the area which is proposed for irrigation in Stage II. Approximately 150 kilometres to the north-west of Bura lie the Meru National Park and the Kora and Rahole Game Reserves, and 60 kilometres to the south the Tana River Primate Reserve.

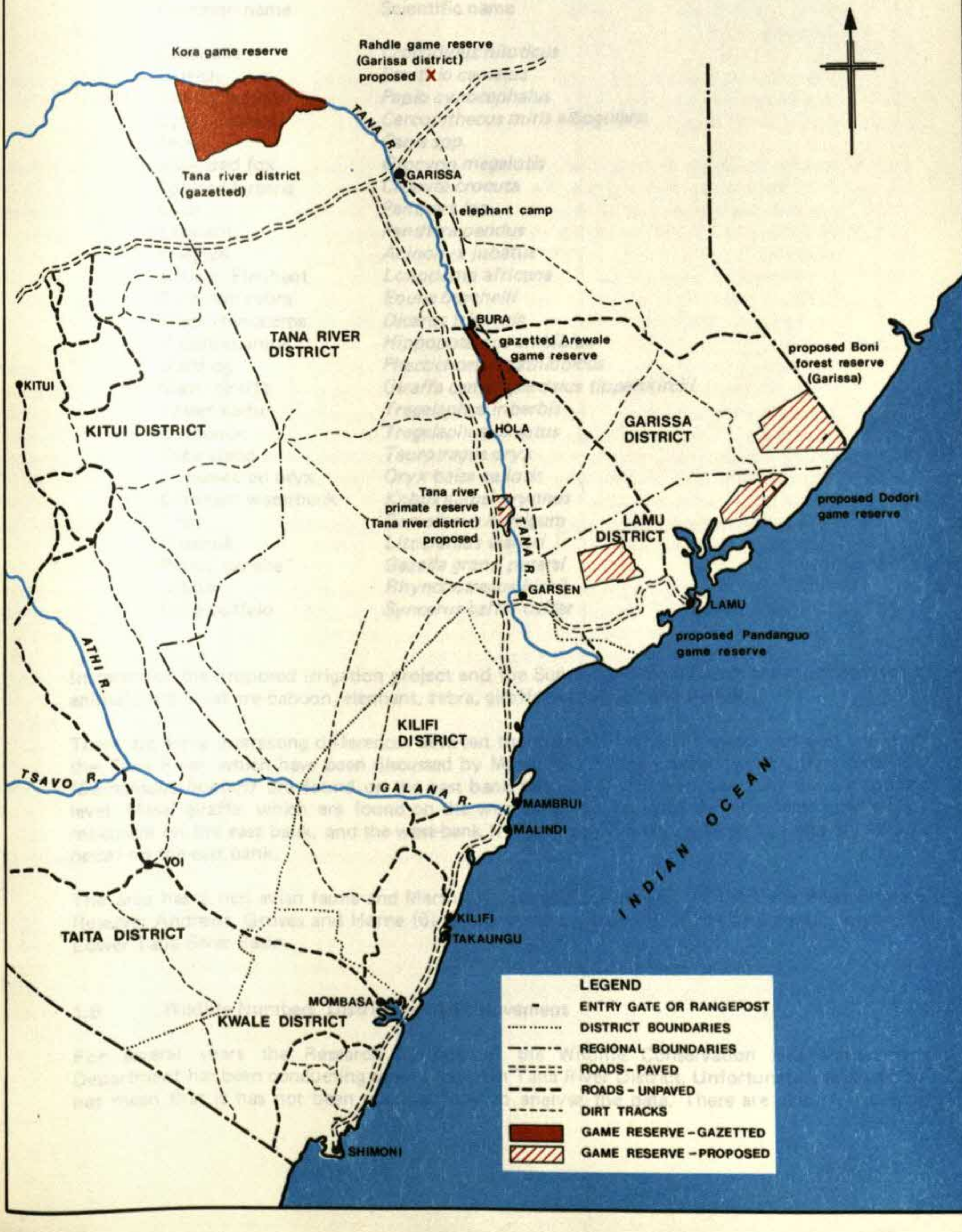
Meru National Park and the Game Reserves have their own staffing and transport infrastructure, and the activities of these Wildlife Service personnel are generally confined to the park and reserves. In the non-gazetted areas the responsibilities of Wildlife Service personnel are not confined by such well defined boundaries and the area to be covered is considerable. In the non-gazetted areas, as well as certain gazetted areas, there are considerable problems in the enforcement of the game laws, due to lack of staff and inadequate transport. The effective implementation of anti-poaching activities requires a highly developed system of communications and mobility. The Wildlife Conservation and Management Department have plans to reinforce the anti-poaching unit at Garissa and to supply the unit with a light aircraft, radios and a number of four-wheeled vehicles. Such a unit could make a significant contribution to the anti-poaching activities in the area.

Because the wildlife densities in the area are relatively low, there are no proposals for tourism development in the immediate vicinity of the irrigation project. However, both banks of the Tana and the hinterland are used for sport hunting and the area has been particularly well known for its large elephant trophies. Despite the recent ban on elephant hunting throughout Kenya, professional hunters still take their clients to the Tana to shoot other species of game.

The future development of the group ranches in the area (see the Livestock Annexe) has opened up the possibility of the hunting concessions being offered to safari firms. At present there is only one concession in operation in the area, at Ida-sa-Godana, but negotiations are underway for further concessions to be granted when the other ranches are in operation.

FIGURE 1.1

GAME RESERVES PROPOSED AND GAZETTED LOWER TANA RIVER JANUARY 1975



1.4 Wildlife Species

A list of the larger species of wildlife which occur in the Bura area is given in Table 1.1. The classification follows Dorst and Dandelot (4).

Table 1.1 - Larger Wildlife Species in the Proposed Bura Project Area

Common name	Scientific name
Crocodile	*Crocodylus niloticus*
Ostrich	*Struthio camelus*
Yellow baboon	*Papio cynocephalus*
Sykes monkey	*Cercopithecus mitis albogularis*
Jackal	*Canis spp.*
Bat-eared fox	*Otocyon megalotis*
Spotted hyaena	*Crocuta crocuta*
Lion	*Panthera leo*
Leopard	*Panthera pandus*
Cheetah	*Acinonyx jubatus*
African Elephant	*Loxodonta africana*
Common zebra	*Equus burchelli*
Black rhinoceros	*Diceros tricornis*
Hippopotamus	*Hippopotamus ambibius*
Warthog	*Phacochoerus aethiopicus*
Masai giraffe	*Giraffa camelopardalus tippelskircki*
Lesser kudu	*Tragelaphus inberbis*
Bushbuck	*Tragelaphus scriptus*
Cape eland	*Taurotragus oryx*
Fringe-eared oryx	*Oryx beisa callotis*
Common waterbuck	*Kobus ellipsi prynnus*
Topi	*Damaliscus korrigum*
Gerenuk	*Litocranius walleri*
Peters' gazelle	*Gazella granti petersi*
Dikdik	*Rhynchotragus kirkii*
Cape buffalo	*Syncerus caffer caffer*

In terms of the proposed irrigation project and the Supply and Main Canals the most important animals in this list are baboon, elephant, zebra, giraffe, waterbuck and buffalo.

There are some interesting differences between the mammal fauna of the east and west banks of the Tana River, which have been discussed by Marsh (5). At the species level, Hunters' antelope *(Damaliscus hunteri)* are found on the east bank but not on the west bank. At the sub-species level, Masai giraffe, which are found on the west bank, are replaced by reticulated giraffe *G.c. reticulata* on the east bank, and the west-bank fringe eared oryx are replaced by Beisa oryx *(O.b. beisa)* on the east bank.

The area has a rich avian fauna and Marsh (5) lists 252 species seen in the Tana River Primate Reserve; Andrews, Groves and Horne (6) also present a discussion of the bird population of the Lower Tana River Basin.

1.5 Wildlife Numbers, Distribution and Movement

For several years the Research Division of the Wildlife Conservation and Management Department has been conducting aerial surveys in Tana River District. Unfortunately lack of staff has mean that it has not been possible fully to analyse the data. There are plans for such an analysis to be undertaken in the near future. The results of the surveys, which will relate wildlife and livestock numbers and distribution to vegetation, water and human activity, will be very valuable in assessing the potential impact of the proposed Bura Project on wildlife, and vice versa. Part of the data from these surveys has been presented by Blankenship (1), who himself undertook an aerial count of the Bura area in August 1975. Marsh (5) gave the results of an aerial survey of an area to the south of Bura. A study of elephant ecology in the area has recently been undertaken by Mr. J. Alloway of Cornell University, USA: the results of this study are at present being written-up and should contribute much to the understanding of the ecology of the area.

Elephant

Elephant are probably the most important wildlife species in the area and have a considerable impact on the ecology of region, as well as being potentially the greatest threat to the crops to be grown in the irrigation project.

Results of counts presented by Blankenship (1) show that between September 1974 and March 1975 estimated elephant numbers in Tana River District varied between 11 007 and 5 683, representing densities of between 3.6 and 7.0 square kilometres per elephant. These figures are very much lower than the result obtained by Marsh (5) for the vicinity of the Primate Reserve, where he found a density of 0.75 square kilometres per elephant. A similar density of 0.7 square kilometres per elephant was found by Blankenship in the proposed Bura Project area east of the Garissa-Garsen road, although the over-all density found by the Blankenship count, which covered over 2600 square kilometres was 1.7 square kilometres per elephant.

The way in which elephant use the area on the east bank of the Tana River is dependent upon seasonal changes in water and forage availability. As soon as there has been sufficient rain to stimulate vegetation growth and to fill the temporary water pans in the hinterland, the animals move away from the river and travel throughout the area in search of food and water. During this period, usually April, May and November, elephant densities will be low and the animals widely dispersed. The location of elephants during and immediately after the rains will be determined by the location of the rain storms. As the vegetation and pools in the hinterland dry out elephant begin to move back towards the river. The highest concentrations of elephant along the river can be expected in September to October and February to March.

The relative importance of the vegetation of the floodplain and riverine forest and the water in the river is difficult to assess; Alloway's study should provide useful information on this aspect. This is relevant to the proposed Bura Project, because the Supply and Main Canals and irrigated area will considerably reduce the ease of access to the riverine area, while at the same time offering an alternative source of water at the drinking ponds. It is of value to compare the Tana River situation with that of the Galana River to the south. Like the Tana, the Galana River runs through an area of dry *Acacia Commiphora* bush and is the only source of water during the dry season in a very large area. However, unlike the Tana River, it supports no riverine forest. Despite the lack of forest the Galana River is heavily used by elephant during the dry season and the elephant have to forage in the surrounding dry-bush while using the river as a source of water. From this comparison it would appear likely that, although the riverine forest provides a valuable supplement to the diet of elephant, it is not an essential component. It is probable that the existence of the riverine forest on the Tana River increases the dry-season carrying capacity of the area.

The total area to be affected by the proposed Bura Project will be approximately 1 500 square kilometres. This includes the irrigated area itself and all the land between the Supply and Main Canals, the irrigation area and the river. Using the dry season high density figure of 0.7 square kilometres per elephant, it is calculated that the proposed project would directly affect about 2 200 elephant. This represents 20 per cent of the highest estimate available for elephant numbers in Tana River District, although the area is less than 1 per cent of the whole district.

Table 1.2 - Summary of Results of Aerial Wildlife Counts, Estimated Animal Densities, 1975 and 1976 (Square Kilometres per Animal)

Species	Tana River District Nov/Dec 1975	Tana River District March 1975	Bura Area - August 1975 Total	Bura Area - August 1975 East of Garsen Rd.	Bura Area - August 1975 West of Garsen Rd.	Tana River Primate Reserve October 1975
Common zebra	4.5	6.5	1.3	0.4	6.5	5.5
Fringe-eared oryx	5.5	9.4	6.3	2.6	14.3	2.2
Peters' gazelle	–	–	2.9	1.9	3.7	1.9
Giraffe	6.0	15.4	12.8	6.5	20.3	13.7
Gerenuk	–	–	14.1	6.9	23.8	20.6
Waterbuck	42.1	123.1	18.6	5.4	–	29.9
Lesser kudu	80.0	160.0	21.6	7.9	71.4	55.6
Topi	39.0	266.7	–	–	–	10.3
Buffalo	320.0	–	–	–	–	2.2
Rhinoceros	533.3	–	–	–	–	–
Ostrich	10.7	26.2	7.0	14.5	5.7	4.5
Warthog	–	–	11.0	3.7	71.4	8.0

Sources: Blankenship (1) and Marsh (5)

Other Wildlife

The results of aerial counts of other wildlife species in the Tana River District and in the vicinity of Bura are given by Blankenship (1) and results of counts in the vicinity of the Tana River Primate Reserve are given by Marsh (5). All these counts are summarised in Table 1.2.

The variation in the densities of species between different counts and different areas is large. The highest densities were recorded during the August 1975 count of the Bura area to the east of the Garissa-Garsen road and during the October 1975 count of the Tana River Primate Reserve. Both Blankenship and Marsh stress the potential sources of inaccuracy in the data caused by such factors as the preference for dense vegetation, unevenness of distribution and large herd size of certain species.

To obtain a rough estimate of the numbers of each species likely to be affected by the Bura Project the highest density recorded for each species in all the counts was applied to the 1 500 square kilometres area on the west bank of the river from Nanigi to the southern end of the irrigated area. These are given in Table 1.3.

Table 1.3 - Estimated Numbers of Animals Affected by the Proposed Project

Species	High Density figure km^2 animal	No. of animals
Common zebra	0.4	3500
Fringe-eared oryx	2.2	670
Peters' gazelle	1.9	800
Buffalo	2.2	700
Giraffe	6.5	230
Gerenuk	6.9	220
Waterbuck	5.4	280
Lesser kudu	7.9	190
Warthog	3.7	400
Ostrich	4.5	340
Total		7330

It should be stressed that the figures given in Table 1.3 are only approximations. Zebra, oryx, Peters' gazelle and buffalo are the most important species and comprise almost 80 per cent of the total estimated animal numbers.

The use of the area by each species depends on the animals' physiological and nutritional adaptations to the environment. Waterbuck, zebra and buffalo all appear to be dependent on water while oryx, gerenuk and Peters' gazelle are able to do without free water and can therefore use much more of the habitat. Certain species such as gerenuk, giraffe and kudu are browsing animals, and would therefore make little use of the floodplain. Buffalo and zebra, however, are predominantly grazing animals and the floodplain is an important area for these species.

CHAPTER 2 EFFECTS OF THE PROPOSED IRRIGATION PROJECT ON WILDLIFE

2.1 The Proposed Irrigated Area

It has already been mentioned that the development of the proposed irrigated area will mean a reduction in the amount of land available to wildlife. The land required for Stage I, Phase I, of the project represents only 0.2 per cent of the total land in the Tana River District.

The use of an area by large herbivores in an environment such as that at Bura very much depends on the distribution of rainfall during the the year. A more detailed account of elephant movements in the area is given in Acres (7). As a result of the low and erratic rainfall typical of the area most of the larger wildlife species move great distances in search of green forage and water. The wildlife carrying capacity of the area to be irrigated is low and both the quantity and quality of grazing and browsing available is not as high as in areas to the north and south. The loss of the land to be irrigated is therefore unlikely to have any serious effects on the wildlife although certain smaller sedentary species of wild herbivores such as dikdik, will inevitably suffer.

The increased human activity at Bura will inevitably lead to an increase in the level of poaching. The increase in poaching will start when the labour force for the civil engineering works arrives and will undoubtedly continue when the tenants arrive. Those animals most likely to suffer are the smaller game species (dikdik, duiker, Peters' gazelle and gerenuk), and the main method used will probably be wire snares, especially in the riverine forest and along game trails. The vigilance and efforts of the wildlife personnel at Bura could do much to reduce local poaching, and patrols to likely poaching areas, and spot searches of the houses of those suspected of poaching, will be an essential part of the anti-poaching activity. The education of tenants of the importance of wildlife could play a vital role in reducing the level of poaching in the area.

A further threat to wildlife resulting from the development of the proposed irrigated area is habitat destruction. The indiscriminate felling of trees, both in the immediate vicinity of the project and in the riverine forest, should not be allowed. There are provisions for the supply of firewood from irrigated fuelwood plantations and it is calculated that the production of these plantations supplemented by the use of dead wood, will be sufficient to meet the demands from the project population (see the Forestry Annexe). The result of indiscriminate felling can be seen around Hola, where potentially productive rangeland has been converted into unproductive scrub.

The uncontrolled grazing of tenants' livestock would also have an undesirable effect on the wildlife habitat. The carrying capacity of the surrounding range is low and is estimated at about one Livestock Unit (LSU) per 25 ha. It is already fully utilised by the livestock of the Orma nomadic pastoralists and by wildlife. Any increase in grazing pressure owing to the tenants' stock will inevitably lead to the depredation of the range, which will eventually become useless to both the Orma stock and wildlife. The management and control of tenants' stock is discussed in the Livestock Annexe.

2.2 The Supply Canal

The Supply Canal bringing water from the Nanigi headworks to the project area will be about 42 kilometres in length, and will run in a roughly southward direction at a distance of up to 14 kilometres to the west of the river (see Figure 2.1). One inverted siphon and three aqueducts have been proposed by ILACO where the canal crosses the Tula, Gelmathi, Bilbil and Walessa natural drainage channels (lagas): it is now proposed that all four crossings should be inverted siphons, and these will enable animals to cross the canal at distances of 6, 15, 32 and 36 kilometres from the headworks. In general, the natural drainage channels (lagas) are not extensively used as game trails, and it will probably take some time before the animals make full use of these crossings. For short periods during the rains, when the lagas are running, it will not be possible for animals to use these crossings.

The present uncertainty of the relative importance of water in the river and the forage of the riverine forest and floodplain (Section 1.5), makes it difficult to predict the role of the Supply Canal as a barrier stopping animals getting to water, as opposed to its role as a barrier stopping animals getting to good browse and grazing. It is probable that both factors are important, though the importance will vary with different species.

Apart from the proposed four inverted siphons, the canal will constitute a formidable boundary and will prevent most wildlife species from crossing from the hinterland to the floodplain and riverine forest on the east side of the canal. It is likely, however, that certain species, especially elephant, will attempt to reduce the slopes of the canal banks and ford the canal. Although in Kenya there is a great deal of experience in protecting forestry and areas of intensive agriculture from damage by elephant and other game animals, there is little experience in the protection of a canal as long as that proposed for the Bura Project. Although the canal which brings the water from the pumping station to the irrigated area at Hola is only 18 kilometres long, experience gained there is of relevance to the larger scale situation of the proposed Supply Canal. At Hola it was found that elephant tried, and succeeded, in crossing the canal during the first two or three years; after this initial period they found alternative routes and no longer challenged the canal. It should be remembered, however, that as well as being relatively short, the canal at Hola does not run parallel to the river. It is at an oblique angle so that animals wishing access to the floodplain and riverine forest only have to walk along the side of the canal to reach the river. It is important that wildlife are able to move between the hinterland and the riverine forest. Provision for crossings therefore has to be made, and these are discussed in Section 4.2.

The heavy machinery and large labour force that will be involved in the construction of the canal will cause much disturbance during the construction period. The immediate effect of this will be that the wildlife will move away from the area. The extent and duration of this move will very much depend on rainfall distribution during the construction period. It is therefore difficult to predict when, in relation to the completion of the canal, animals will start to attempt to cross. It is however likely that animals will wish to have access to the river when the vegetation and temporary water holes of the hinterland dry up.

As well as being a barrier to the passage of wildlife the canal represents a potential danger to animals which attempt to cross and drink from the canal. Animals drinking from the Tana River tend to use places where the banks are not steep. On the Supply Canal there will be a freeboard of 15 centimetres and a berm 1 metre high with a side slope of 1/2. It is possible that animals will fall in and drown. Animals may also become mired when trying to cross the canal or, once having got into the canal, be unable to get out again.

The provision of a limited number of crossing places along the Supply Canal will create an ideal situation for poaching. If with time the animals learn to use the inverted siphons and any other crossing provided there will be a considerable traffic of animals through these crossings; creating an ideal opportunity for poaching by snares or shooting. The approach of the anti-poaching personnel to this problem will need to be very discrete, because excessive activity in the vicinity of the canal crossings may deter animals from using them.

2.3 Possible Long-term Changes in River Flow Patterns

Tests carried out by the Delft Hydraulics Laboratory (8) on a model of the high fixed crest ILACO design of the headworks have indicated that local changes in bed level will occur. Initially, the proposed design would cause sedimentation upstream of the headworks and bed degradation immediately downstream of the headworks as the river water picked up additional sediment below the headworks. Thus, initially, more marked meandering will occur upstream owing to deposition, and more marked meandering will take place downstream owing to scour.

Once the river has re-established its previous slope upstream this deposition will cease and the river water will carry its full sediment load causing deposition immediately downstream of the

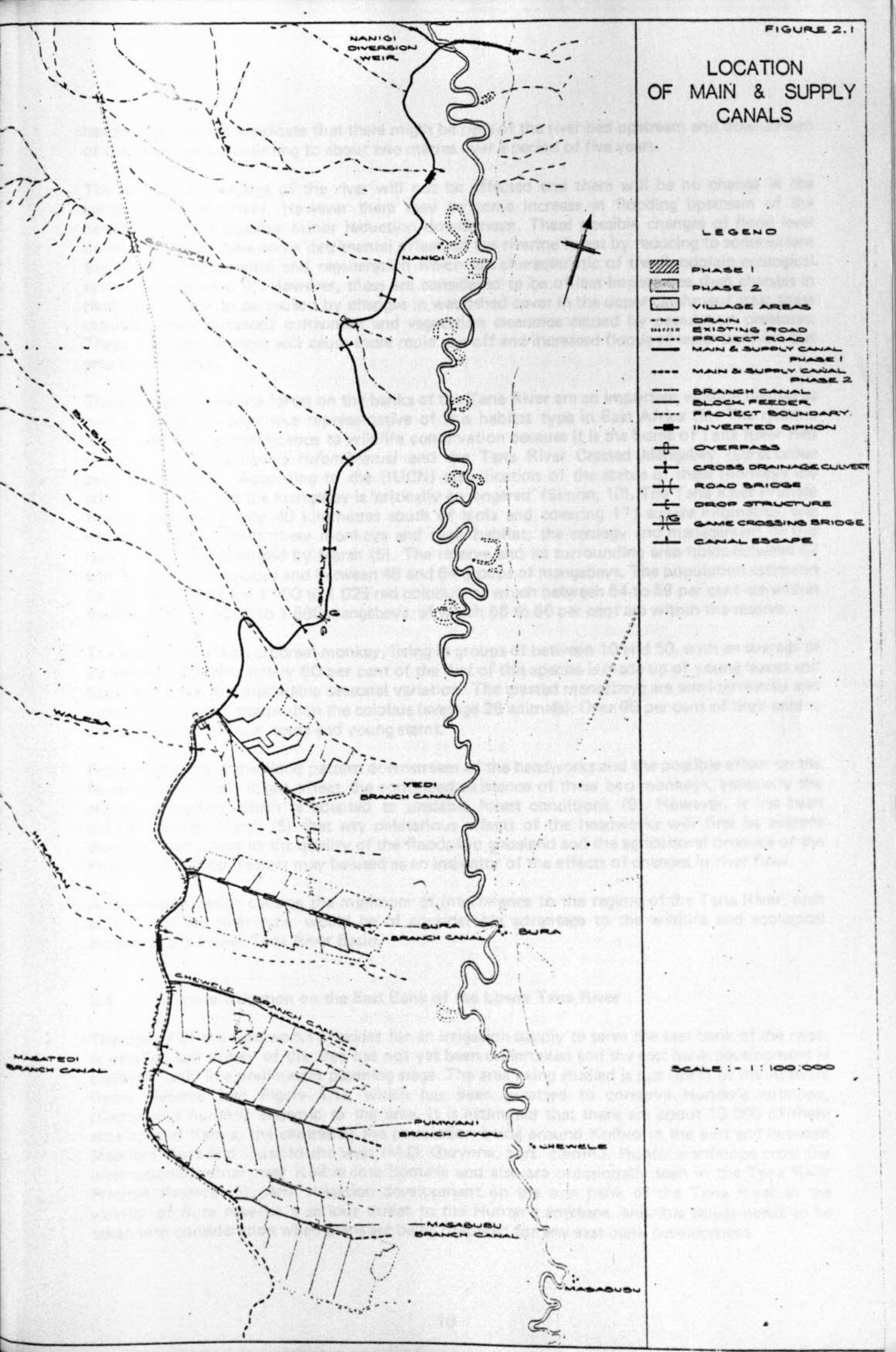


FIGURE 2.1

LOCATION OF MAIN & SUPPLY CANALS

headworks. The tests indicate that there might be rises of the river bed upstream and downstream of the headworks amounting to about two metres over a period of five years.

The dominant discharge of the river will not be affected and there will be no change in the behaviour of the river, However there may be some increase in flooding upstream of the headworks and a possible minor reduction downstream. These possible changes of flood level downstream may have some detrimental effect on the riverine forest by reducing to some extent the cycles of senescence and regeneration which are characteristic of the floodplain ecological system (Homewood 9). However, these are considered to be of less importance than changes in river flows likely to be caused by changes in watershed cover in the upper catchment area: these resulting from increased cultivation and vegetation clearance caused by population pressures. These upstream changes will cause more rapid run-off and increased floods of lesser duration but greater frequency.

The patches of riverine forest on the banks of the Tana River are an important wildlife habitat as well as being the only true representative of this habitat type in East Africa (5). The riverine forest is of special significance to wildlife conservation because it is the home of Tana River Red Colobus, *(Colobus badius rufomitratus)* and the Tana River Crested Mangabey *(Cercocebus galeritus galeritus)*. According to the (IUCN) classification of the status of these monkeys the colobus is 'rare' and the mangabey is 'critically endangered' (Simon, 10). The Tana River Primate Reserve, approximately 40 kilometres south of Hola and covering 171 square kilometres, was established to conserve these monkeys and their habitat; the ecology and management of this reserve has been discussed by Marsh (5). The reserve and its surrounding area holds between 62 and 90 groups of colobus and between 46 and 64 groups of mangabeys. The population estimates for the whole area are 1 400 to 1 025 red colobus, of which between 54 to 59 per cent are within the reserve, and 1 200 to 1 660 mangabeys, of which 56 to 60 per cent are within the reserve.

The red colobus is an arboreal monkey, living in groups of between 10 and 50, with an average of 23 animals. Approximately 60 per cent of the diet of this species is made up of young leaves and fruit, but there is considerable seasonal variation. The crested mangabeys are semi-terrestrial and have slightly larger groups than the colobus (average 26 animals). Over 90 per cent of their annual diet is made up of fruit, seeds and young stems.

Possible changes in the flood pattern downstream of the headworks and the possible effect on the forest regeneration, might affect the continued existence of these two monkeys, especially the crested mangabey which is adapted to unstable forest conditions, (9). However, it has been pointed out by Marsh (5) that any deleterious effects of the headworks will first be evident through a reduction in the quality of the floodplain grassland and the agricultural produce of the Pokomo, and these factors may be used as an indicator of the effects of changes in river flow.

A headworks design causing the minimum of interference to the regime of the Tana River, such as a run-of-the river type, would be of considerable advantage to the wildlife and ecological aspects of the Lower Tana River Basin.

2.4 Future Irrigation on the East Bank of the Lower Tana River

The design of the headworks provides for an irrigation supply to serve the east bank of the river. A detailed soil survey of the area has not yet been undertaken and the east bank development is therefore only in a preliminary planning stage. The area being studied is just north of the Arawale Game Reserve (see Figure 1.1), which has been gazetted to conserve Hunter's antelope, *(Damaliscus hunteri)* endemic to the area. It is estimated that there are about 13 000 of these antelopes in Kenya, the centres of the population being around Kolbio in the east and between Masalani, Bura and Ijara, to the west (M.D. Gwynne, pers. comm.). Hunter's antelope cross the international border near Kolbio into Somalia and also are occasionally seen in the Tana River Primate Reserve (5). Any irrigation development on the east bank of the Tana River in the vicinity of Bura may be a serious threat to the Hunter's antelope, and this threat needs to be taken into consideration when plans are being prepared for any east bank development.

CHAPTER 3 EFFECTS OF WILDLIFE ON THE IRRIGATION PROJECT

3.1 The Irrigated Area

The appearance of irrigated crops in an area which for much of the year is dry and unproductive is bound to cause problems of crop raiding by wildlife. The main crop to be grown at Bura is cotton and this is unlikely to prove to be very attractive to many species of wildlife, although, as Blankenship (1) has pointed out, the young buds may attract antelope and baboons, and baboons may also damage the bolls. The other crops to be grown, maize, cowpeas and groundnuts are much more likely to be raided. Apart from the loss caused by animals eating the crops themselves, there will be additional damage through trampling - this may also be a problem during the cotton crop if the grass, sedge and herb weeds, which would be very attractive to wildlife species, are not removed by the farmers.

There are a number of methods which may be used to exclude wildlife from areas of agricultural or forestry production, the two most frequently used being fences and ditches. Both these methods are expensive to construct and maintain. A fence can form an effective barrier against most of the smaller wildlife species which occur in the Bura area, and, provided with a suitable overhang, can even keep out such agile animals as baboons. Fences, however, are not able to withstand a challenge from elephants and if, as will be the case at Bura, this species is a problem, it may be necessary to use game ditches. To be effective a game ditch needs to have the 'inside wall' (the one on the side to be protected) at least two metres high. The width of the top of the ditch needs to be two metres but the 'outside' wall slopes down so that the bottom of the ditch is only 0.5 metres wide. All the earth which is excavated during the construction of the ditch should be piled up above the vertical 'inside' wall so that the effective height of this wall is considerably increased. Around the Aberdare National Park such ditches have been in use for more than 20 years and they are found to be very effective in preventing elephant, buffalo and rhinoceros, as well as smaller game species, from leaving the park and raiding the intensively cultivated areas immediately outside the park boundary. One fundamental difference between the Aberdares and Bura is the physical properties of the soils in the two areas. The soils in the Aberdares are sufficiently cohesive to enable an unsupported vertical wall of three metres or more to be built. At Bura a wall of such height may require considerable revetting, which would greatly increase the cost of the ditch.

The 6 700 ha to be irrigated in Stage I, Phase I of the project will have a total external boundary of approximately 52 kilometres; the development of Stage I, Phase II will increase this to 100 kilometres. It is estimated that effective game proof ditches will cost at least K Sh 200 thousand per kilometre to build, and about K Sh 20 thousand per kilometre to maintain. The cheapest form of fencing would cost approximately K Sh 70 thousand per kilometre to erect and about K Sh 7 thousand per kilometre to maintain. More effective fencing would cost over K Sh 150 thousand per kilometre. The total costs of providing complete protection to the irrigation area by game ditches would therefore be approximately K Sh 10.4 million for Phase I and K Sh 20 million for Phases I and II; annual maintenance costs would be approximately 10 per cent of the construction costs. Protection by fencing, which would not be effective against elephant, would cost K Sh 3.6 million for Phase I and K Sh 7 million for Phases I and II; annual maintenance costs would again be approximately 10 per cent of construction costs.

It can be seen from these figures that the cost of protecting the irrigation area from wildlife depredations by either ditches or fences, would be very high indeed. Experience at Hola has shown that the greatest challenge from game animals comes during the first three or four years of irrigation. There is no extensive crop protection system at Hola, and at the present, twenty years after the scheme started, the only challenge comes from baboons and waterbuck. It is thus difficult to justify the expense of constructing a large-scale crop protection system. Other less expensive methods will therefore have to be used; these are discussed in Section 4.1.

3.2 The Supply Canal

It has already been mentioned that certain species will attempt to reduce the side slopes of the banks of the canal and cross. Such activity is obviously undesirable and efforts should be made to reduce damage caused in this way to a minimum. The provision of suitable canal crossing points (Section 4.2) will do much to help, but a certain amount of damage to the canal banks will have to be accepted. Such damage can be expected to be greatest during the early stages of the project, before the animals have become accustomed to the crossing places provided.

Mired and dead animals may cause difficulties in the canal, and a winch will be needed to pull such animals out. Unless there are special provisions for the dart-immobilisation of mired animals, it may be necessary to shoot aggressive individuals before a cable can be attached to them to pull them out. Dart-immobilisation is a very specialised technique and should not be attempted by untrained personnel. If it is found that a large number of animals become mired in the canal and need to be dart-immobilised before they can be extracted, it would be worthwhile training a member of the Wildlife Service in this technique. Such a decision, however, could only be made after the project had been in operation for a year or so.

Large aquatic and amphibious animals such as crocodiles and hippopotamus may find their way into the upper end of the canal, where the canal is still close to the Tana. It is unlikely that it will be possible to dart-immobilise these animals and return them to the river, especially in the case of hippopotamus and it will therefore be necessary to shoot them. In view of the proposals to develop the fish production potential of the canal (see the Fisheries Annexe), it would be particularly undesirable to allow crocodiles in the canal.

3.3 Pests

The irrigation project will create an ideal environment for a number of inevitable pests which are likely to include American bollworm *(Heliothis armigea)*, spiney bollworm *(Earias spp.)*, pink bollworm *(Pectinophora gossypiellaa)*, stainers *(Dysdercus spp.)* and red spider mites *(Tetranychus spp.)*. It is proposed in the ILACO Feasibility Report that the control of these pests will be undertaken using a selection of pesticides sprayed from the air. The Bura Project will in effect be an 'island' of high primary production surrounded by relatively unproductive range land: an ideal environment for the buildup of resistance of pests to insecticides. There will be little dilution of genes within the pest population and the spray regime needs to be geared towards the control of the pests rather than their eradication.

The possible ecological consequences of the use of pesticides and the monitoring of pesticide levels in the environment are discussed in the Fisheries Annexe.

CHAPTER 4 PROPOSALS FOR WILDLIFE MANAGEMENT

4.1 Exclusion of Wildlife from the Irrigated Area

One of the most effective wildlife barriers is intensive human activity. Thus, considerable crop protection from wildlife could be readily provided if the tenants' villages are located on the perimeter of the project. In fact, for a variety of planning reasons villages will be mainly located on the perimeter of the project, and the activities in these villages and surrounding areas will do much to help reduce the crop damage by wildlife.

Because of the very high cost of either fencing or ditching the irrigation area (Section 3.1), and the experience at Hola, where the level of crop raiding is generally low, it is difficult to justify any large-scale crop protection scheme.

The drainage channels for the project will be wide, deep and steep sloped and will in themselves be a useful deterrent to wildlife entering the irrigated area. Main drains will cover both the northern and southern ends of the Phase I irrigation area.

One cheap form of game exclosure would be the development of a fence of impenetrable vegetation. The prickley pear *(Opuntia ficus-indica)* is used in many parts of Africa to form a predator-proof night enclosure for domestic stock. Its very fine prickles lodge in folds of the elephant's skin and become a major irritant; in consequence, elephant usually avoid any growth of prickly pear. It could be an effective barrier against elephant if it is grown as a hedge. Another plant which is similar and grows locally in the area is *Euphorbia grandicornis (E. breviarticulata)*. This has become well established in areas around the Hola Irrigation Scheme and there would appear to be no reason why this species could not be encouraged to grow around the Bura Project. It is recommended that trials be established as soon as possible to investigate the potential of these two plants as wildlife barriers. These trials could form part of the species trials recommended in the Forestry Annexe. Once established such a barrier would be very cheap to maintain, simply by running a grader along either side of the barrier once every six months. The capital costs of establishing such a barrier would be very low, and merely involve the labour costs of collecting and planting suitable cuttings. The use of *E. grandicornis* would be preferable, as collecting and transport charges would be lower than if *O. ficus-indica* was used. It is estimated that the cost of establishing such a barrier would be approximately K Sh one thousand per kilometre, with maintenance costs of about K Sh one hundred per kilometre. The siting of the barriers will depend on the location of villages, but initial sitings are indicated in Figure 4.1. Assuming that the drainage canals to the north of the Phase I area will provide a partial deterrent to wildlife entering the project, a provision for 40 kilometres of vegetative barriers should be sufficient.

It is unlikely that the drainage canals and vegetative barriers will be completely effective in stopping crop raiding by wildlife. It will therefore be necessary to make provisions for six game scouts and one Junior Warden to be responsible for game control activities within the project. These Wildlife Service personnel would have to work in close liaison with the irrigation project management and the game scouts involved in anti-poaching (Section 4.4), but would be accountable to the District Game Warden. The cost of the personnel and equipment involved in the game control operation would be about K Sh 106 thousand per year. A breakdown of the staffing requirements and costs involved in the protection of the project area is given in Table 4.3.

4.2 Access of Wildlife to Water

For species of wildlife which require access to the riverine area for water alone, an alternative source would be supplies provided by the construction of drinking ponds sited to the west of the Supply Canal. It is proposed that eleven drinking ponds be built, each being 250 metres from the Supply Canal. Each pond will be circular with a diameter of 50 metres and a maximum depth of

1.5 metres; an annual allowance of 0.01 cubic metres per second (cumecs) of water has been made for wildlife drinking ponds, which means an average of about 78 cubic metres per pond per day. The cost of each pond will be about K Sh 19 thousand. The ponds should be situated on or near strategic game trails, but the exact location of each must be decided during construction, after consultation with the Wildlife Service and the Tana River Development Authority's ecologist (1).

One problem at the drinking ponds will be the interaction between wildlife and nomadic livestock. The presence of permanent water will tend to induce the nomadic Orma tribesmen to establish their settlements near the drinking ponds. This must be actively discouraged because it not only would deter wildlife from using the ponds and ensure that the annual allowance of water for each pond will be fully utilised by stock, but it may encourage poaching. The ponds should be built with a lockable sluice at the canal end of the pipeline so that the projec management could close the ponds if considered necessary.

4.3 Minimising Damage to the Supply Canal

Although it would be desirable to afford the Supply Canal protection from wildlife b constructing either fences or ditches, the high cost of such an operation would be prohibitive The number of animals which will try to cross the canal is not known.

The provision of 11 drinking ponds along the west bank of the canal will probably help to reduc the challenge to the canal from animals requiring to cross in order to get the water to drink. Th one inverted siphon at a laga crossing will also give the animals a chance to cross the canal, but i will almost certainly take sometime before they learn to use this crossing.

To reduce still further the possible damage wildlife may cause to the canal, while at the sam time enabling animals to cross to the riverine forest and floodplain, it is proposed that furth crossings be provided. It is possible that the review of designs may suggest the use of inverte siphons instead of aqueducts proposed at three cross drainage sites. This would increase th number of possible wildlife crossings, but other types of crossings are recommended. Bridge typ crossings would probably not be used by elephant because they are reluctant to cross expos and elevated access. Inverted siphons are ideal, but expensive. A possible alternative is to for fords or drifts in the canal by flattening the slopes of the canal banks to 1/3 and pitching th slopes and canal bed with stone or rough concrete blocks. Ideally the fords should be 20 metr wide with a depth of water of about one metre, but this will depend upon the canal design. Th cost of each ford would be about K Sh 16 thousand.

The siting of these fords or drifts will be difficult. Blankenship (1) gave a list of ten areas wher prominent game trails were found during his survey. It was difficult to relocate these trails durin a field trip to the area in February 1977, despite two low level aerial surveys and ground survey It is probable that the use of trails varies with different years and it is therefore recommende that the exact location of the crossing periods be decided at the time of construction, aft consultation with Wildlife Service personnel and the TRDA ecologist. It is possible that th cutting of trace lines to the approaches of the crossings may encourage wildlife to use them.

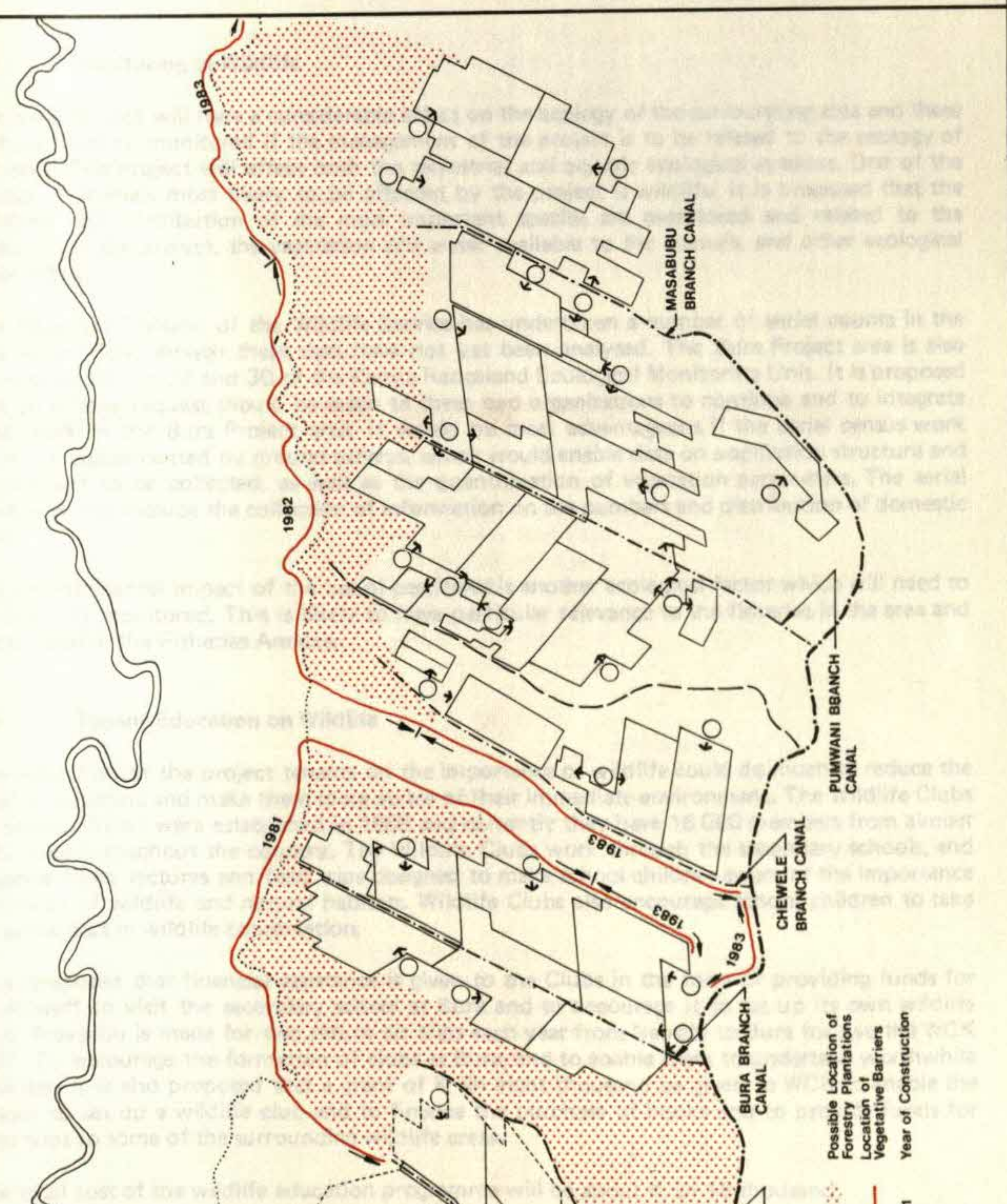
It is proposed that initially only three of these crossings be installed. This will enable the proje management to assess their value and to decide on any further crossings and their locations. breakdown of the costs of the crossings is given in Table 4.3. In the Fisheries Annexe th possibility of fish farming at Bura is discussed. Because of the deleterious effects of the pesticid used in the project these activities should be situated at the upper end of the Supply Canal. I consequence, there will be an increase in human activity along the canal and this should reduc wildlife damage. The fisheries settlements should not be located too close to the inverted sipho and canal crossings to avoid discouraging animals from crossing the canal at these places.

4.4 Control of Poaching

The large number of people in the project area will inevitably lead to an increase in poachin

FIGURE 4.1

SUGGESTED LOCATIONS OF VEGETATIVE BARRIERS TO THE PROJECT AREA



Although poaching can be expected to occur in the immediate vicinity of the project the inverted siphons and canal crossings will be foci for this activity. To control illegal hunting it will be necessary to reinforce the present Wildlife Service personnel stationed at Bura, and it is proposed that six extra game scouts are recruited for anti-poaching activities. These game scouts will require a vehicle and radios and will be under the Junior Warden in charge of the six scouts assisting in game control (Section 4.1). All these personnel will be under the Game Warden stationed at the rural centre of the project.

4.5 Monitoring of Wildlife

The Bura Project will have a considerable effect on the ecology of the surrounding area and these changes must be monitored if the management of the project is to be related to the ecology of the area. The project will affect both the terrestrial and aquatic ecological systems. One of the groups of animals most likely to be affected by the project is wildlife. It is proposed that the numbers and distribution of the most important species are monitored and related to the presence of the project, the vegetation and water available to the animals, and other ecological parameters.

The Research Division of the Wildlife Service has undertaken a number of aerial counts in the area since 1974, though these data have not yet been analysed. The Bura Project area is also covered by blocks 29 and 30 of the Kenya Rangeland Ecological Monitoring Unit. It is proposed that an official request should be made to these two organisations to continue and to integrate their work in the Bura Project area. It would be most advantageous if the aerial census work could be supplemented by ground surveys, which would enable data on population structure and recruitment to be collected, as well as the quantification of vegetation parameters. The aerial surveys would include the collection of information on the numbers and distribution of domestic stock.

The environmental impact of the use of pesticides is another ecological factor which will need to be carefully monitored. This is likely to have particular relevance to the fisheries in the area and is discussed in the Fisheries Annexe.

4.6 Tenant Education on Wildlife

The education of the project tenants on the importance of wildlife could do much to reduce the level of poaching and make them more aware of their immediate environment. The Wildlife Clubs of Kenya (WCK) were established in 1968 and currently they have 16 000 members from almost 400 clubs throughout the country. The Wildlife Clubs work through the secondary schools, and organise films, lectures and field trips designed to make school children aware of the importance and value of wildlife and natural habitats. Wildlife Clubs also encourage school children to take an active part in wildlife conservation.

It is proposed that financial assistance is given to the Clubs in the form of providing funds for WCK staff to visit the secondary school at Bura and to encourage it to set up its own wildlife club. Provision is made for two return air trips each year from Nairobi to Bura for two the WCK staff. To encourage the formation of clubs at Bura, and to enable them to undertake worthwhile activities it is also proposed that a grant of K Sh eight thousand be given to WCK to enable the school to set up a wildlife club and to finance the purchase of books and to provide funds for field trips to some of the surrounding wildlife areas.

The total cost of the wildlife education programme will be about K Sh 18 thousand.

4.7 Phasing of Wildlife Activities

The inverted siphons and the initial three crossings will be built when the Supply Canal is constructed and will therefore be installed during 1979/1980.

The trials on vegetative barriers will take place at the same time as the forestry trials and will start in 1978. This will allow for a two-year period before the start of large scale plantation for fuelwood. The planting of the vegetative barriers will coincide with the fuelwood planting: 15 kilometres will be required in each of the first two years, 1980 and 1981, and a final 10 kilometres will be needed in 1982.

The twelve game scouts and the Junior Game Warden should be installed at the rural (administrative) centre early in 1980. Although by then there will be only about 1000 settlers the early installation of wildlife service personnel will enable these staff to become fully aquainted with the area before the project becomes fully developed.

The bi-annual visit from WCK staff should start in 1983, when the first secondary school is operational. The grant of K Sh eight thousand should also be made at this time. The visits from WCK staff should continue every year.

A summary of the timing of the wildlife inputs is given in Table 4.1.

Table 4.1 - Summary of Timing of Wildlife Inputs

Year	Input
1978	Start vegetative barrier trials
1979	Preliminary results of vegetative barrier trials
	Start construction of crossings and ponds
1980	Install 12 game scouts and Game Warden
	Plant 15 kilometres of vegetative barriers
1981	Plant 15 kilometres vegetative barriers
1982	Plant 10 kilometres vegetative barriers
1983	Start WCK staff visits, grant to secondary school
	Barriers

4.8 Cost Estimates

The capital and recurrent costs of the wildlife aspects for the Bura Project between 1979 and 1985 at constant January 1977 prices are summarised in Table 4.2. The total costs up to 1985 are estimated to be K Sh 3 996 thousand including contingencies, of which K Sh 1 896 thousand would be capital costs and K Sh 1 675 thousand recurrent costs. Details of these costs are given in Tables 4.3 and 4.4.

The percentages allowed for contingencies vary from 10 to 15 per cent according to the degree of detail available for any particular item. Full details are given in the Project Costs Annexe. Because there is uncertainty of how wildlife will react to the canal crossings, drinking pools and vegetative barriers, it may be necessary to modify these in the light of experience, and 15 per cent contingencies have been allowed for the capital and recurrent costs of these items.

Table 4.2 - Summary of Expenditure on Wildlife Aspects of the Bura Project, Stage I, Phase I, up to 1985, constant 1977 prices (1 000 Kenya Shillings)

Year	Capital	Recurrent	Contingencies	Total
1979	438.3	–	66.0	504.3
1980	792.6	243.8	117.3	1153.7
1981	15.0	257.7	27.8	300.5
1982	330.0	287.3	78.2	695.5
1983	320.0	295.3	77.5	692.8
1984	–	295.3	29.5	324.8
1985	–	295.3	29.5	324.8
Totals	1895.9	1674.7	425.8	3996.4

Table 4.3 - Breakdown of Capital Costs of Wildlife Aspects of Bura Project up to 1985, at Constant 1977 Prices (1 000 Kenya Shillings)

Item	Unit	Unit Cost	1978/79	1979/80	1980/81	1981/82	1982/83	Sub-Total	Physical Contingencies	Total
I Structures:										
				15	*15*	*10*		*40*		
Vegetative Barriers (1)	km	1.0	–	15.0	15.0	10.0	–	40.0	6.0	46.0
			6	*5*				*11*		
Drinking Pools	Pond	19.7	118.3	98.6	–	–	–	216.9	32.5	249.4
			2	*1*		*2*	*2*	*7*		
Canal Crossings	Crossing	160	320.0	160.0	–	320.0	320.0	1120.0	168.0	1288.0
Sub Total			438.3	273.6	15.0	330.0	320.0	1376.9	206.5	1583.4
II Buildings:										
				1				*1*		
Office (2)	Office	40.0	–	40.0	–	–	–	40.0	4.0	44.0
				1				*1*		
Store (3)	Store	40.0	–	40.0	–	–	–	40.0	4.0	44.0
				1				*1*		
Staff House (4)	House	58.0	–	58.0	–	–	–	58.0	5.8	63.8
				12				*12*		
Staff House (5)	House	14.0	–	168.0	–	–	–	168.0	16.8	184.8
Sub Total				306.0				306.0	30.6	336.6
III Vehicles:										
				2						
4 WD Pick-Up	Vehicle	77.0	–	154.0	–	–	–	154.0	15.4	169.4
IV Equipment:										
				3						
VHF Mobile Pace Sets	Set	14.0	–	42.0	–	–	–	42.0	4.2	46.2
Winch	Winch	13.0	–	13.0	–	–	–	13.0	1.3	14.3
Office Equipment		lump sum	–	4.0	–	–	–	4.0	0.4	4.4
Sub Total				59.0				59.0	5.9	64.9
Total Base Cost			438.3	792.6	15.0	330.0	320.0	1895.9	258.4	2154.3
Physical Contingencies			66.0	92.9	2.0	49.5	48.0	258.4	–	–

Table 4.4 - Breakdown of Recurrent Costs of Wildlife Aspects of Bura Project, at Constant 1977 Prices (1 000 Kenya Shillings)

Item	Unit	Unit Cost	1978/79	1979/80	1980/81	1981/82	1982/83	Sub Total	Physical Contingencies	Total
I Salaries:	No.			*1*	*1*	*1*	*1*	*1*		
Junior Game Warden (7)	Man-year	17	–	17	17	17	17	68	6.8	74.8
	No.			*12*	*12*	*12*	*12*	*12*		
Game Scouts (8)	Man-year	11.7	–	140.4	140.4	140.4	140.4	561.6	56.2	617.8
Sub Total				157.4	157.4	157.4	157.4	629.6	63.0	692.6
II Maintenance of Works and Buildings:				*15*	*30*	*40*	*40*	*40*		
Vegetative Barrier (6)	km	0.6	–	2.4	4.8	6.4	6.4	20.0	2.0	22.0
				6	*11*	*11*	*11*	*11*		
Drinking Pools	Pool	1	–	6.0	11.0	11.0	11.0	39.0	3.9	42.9
				(3)	(3)	(5)	(7)	*7*		
Crossings	Crossing	8	–	24.0	24.0	40.0	56.0	144.0	14.4	158.4
Buildings	Year	6	–	–	6.0	6.0	6.0	18.0	1.8	19.8
Sub Total				32.4	45.8	63.4	79.4	221.0	22.1	243.1
				2	*2*	*2*	*2*	*2*		
III Vehicle Running Costs:	Vehicle/year	27.0	–	54.0	54.0	54.0	54.0	216.0	21.6	237.6
IV Administrative Running Costs :		lump sum	–	–	0.5	0.5	0.5	1.5	0.1	1.6
V Wildlife Education:						*4*	*4*			
Visits by WCK Staff (9)	Visit	1	–	–	–	4.0	4.0	8.0	0.8	8.8
Wildlife Clubs Grant (10)		lump sum	–	–	–	8.0	–	8.0	0.8	8.8
Sub Total						12.0	4.0	16.0	1.6	17.6
Total Base Cost			–	243.8	257.7	287.3	295.3	1084.1	108.4	
Physical Contingencies			–	24.4	25.8	28.7	29.5	108.4		
TOTAL COST			–	268.2	283.5	316.0	324.8	1192.5		

Notes on Tables 4.3 and 4.4 - Breakdown of Wildlife Costs

1. Until more is known about the management of the vegetative barriers, it is difficult to ascertain their cost. Allowance has been made for 65 man-days per kilometre at K Sh 11.00 per man day and K Sh 360 per kilometre for any fertilising and watering which may be necessary for establishment.

2. The office will be required for the Junior Game Warden and should have one large room for meetings with the 12 game scouts.

3. A small store to hold equipment.

4. House for Junior Warden (Gov't Grade F).

5. House for Game Scouts (Gov't Grade C).

6. To keep the barriers from spreading it is estimated that each side of the barrier will require one grader pass every six months: the grader is estimated to work at 2 kilometres per hour and to cost K Sh 160 per hour.

7. A Junior Warden (Grade F) is paid K Sh 13 800 per year plus a clothing allowance of K Sh 360 per year. He receives a field allowance of K Sh 30 per day for an estimated 100 days each year.

8. A game scout (Grade C) is paid K Sh 5520 per year plus a clothing allowance of K Sh 180 per year. He receives a field allowance of K Sh 30 per day for an estimated 200 days each year.

9. A visit by each WCK staff member will involve a return air fare, Nairobi - Bura - Nairobi. Two staff will make the trip twice each year.

10. A grant to be made to the wildlife club when it is formed at the secondary school.

Note:

Figures in italics are number of units introduced in a particular year.

No capital expenditure in 1984 and 1985.

Figures in brackets are the number of units introduced in a particular year.

CHAPTER 5 THE ECOLOGICAL IMPACT OF THE BURA PROJECT

5.1 Introduction

The development of almost 7 000 ha of irrigated land in the midst of a semi-arid ecological system is bound to disrupt the dynamics of the system. The effects of the irrigation project can be broadly classified into passive and active. The passive effects are those which result from the physical structures necessary for the project and the redistribution of water and human population within the ecological system. The active effects are those which result from the deliberate actions of the people associated with the project once the major physical changes have taken place.

5.2 Passive Effects

The headworks near Nanigi may hinder the migration of fish moving upstream to spawn. However, as the main migration of fish in the Tana River occurs during the floods, when the river will be flowing over the top of the weir, this is unlikely to be a serious factor. Because of changes in the bed levels above the headworks there will probably be an increase in flooding upstream. This may affect the amount of land which the riverine Pokomo and Malakote can cultivate, and may reduce the extent of flooding on the riverine floodplain, thereby affecting the grazing available to the Orma and may also reduce the recharging of the ox-bow lakes below Garsen. The ox-bow lakes are an important source of fish. The extent to which the floods downstream of the headworks will be affected is not known. It is likely that the agriculture of the Pokomo will be the first to suffer if there are serious changes in flood patterns. A further effect of the possible reduction of floods downstream of the headworks may be changes to the patterns of regeneration of the riverine forest. Apart from the possible decline in the forest itself, and this forest is the only example of its type in East Africa, changes in forest ecology may well affect two species of endangered monkeys. These monkeys, the Crested Mangabey and the Tana River Red Colobus, depend on the dynamic nature of the riverine forest and a change in forest ecology may well be detrimental to these animals.

A different headworks design allowing normal flows in the flood periods would alleviate many of these problems.

The Supply Canal bringing water from Nanigi to the irrigated area will act as a barrier to wildlife and domestic stock wishing to move between the river, the riverine forest the floodplain and the hinterland to the west of the canal. The impact of the canal will be reduced by the construction of inverted siphons and crossing points; for those animals which would wish to cross the canal simply for water, drinking ponds will be provided on the west side of the canal. The Supply Canal will also offer an alternative habitat to the river for various aquatic and amphibious animals which will include fish, crocodiles and hippopotomi.

The area proposed for possible irrigation for the Stage I of the Bura Project (i.e. Phases I and II) are small in relation to the total natural grazing area available for wildlife on the west bank of the River Tana. Their exclusion will therefore have little effect on wildlife densities. The exclusion of the possible irrigation area on the east bank of the Tana River, Stage II, may however be detrimental to the endemic Hunter's antelope *(Damaliscus hunterri)* because this area is currently a centre of concentration for this species. Any future studies for the development of this area must therefore give full consideration to the requirements of this animal.

The Supply Canal, and irrigation systems will increase the various invertebrates which are hosts to human parasites. The two most important of these will be: molluscs, acting as intermediate hosts for *Schistosoma spp.,* and mosquitos, acting as the insect vector for *Plasmodium spp.* The diseases caused by these organisms, schistosomiasis and malaria, will be a health hazard for the project tenants.

The increase in human population in the area will be associated with an increase in a number of invertebrate ecto-parasites, some of which may not be found in the area at present. The high density of human settlement will also lead to an increase of rodent pests unless their numbers are controlled.

The supply of water to the irrigated area will provide a very high level of primary productivity. This will be seen mainly in the production of the crops grown on the tenants' plots. Weeds may also occur along the banks of the canal and in badly tended plots. This area of high primary production will, for most of the year, be an 'island' in the midst of semi-arid bushland. The attraction of a large amount of green vegetation will be great to many herbivores and the project will consequently attract a number of animals wishing to utilise the green vegetation. The size of the animals will vary from elephant to insects. It is hoped that the siting of the villages around the project perimeter, and the canals, drains and the proposed vegetative barriers, will reduce crop raiding by larger herbivores. The smaller insect pests will have to be dealt with by pesticides applied from the air.

The development of the irrigated area will mean that there will be a reduction in the amount of grazing available to local domestic stock. Although in terms of the total area of Tana River District this is a relatively small amount of land, the area is already over-utilised (an estimated stocking rate of 20 ha per LSU and an estimated carrying capacity of 25 ha per LSU). For ecological, as well as social reasons it will therefore be desirable to provide some form of compensation for the loss of grazing. This should preferably be in the form of additional facilities for the nomadic Orma herdsmen.

5.3 Active Effects

The sudden increase in human population in the area will have an effect on the ecology of the area. The pastoralists and riverine farmers who at present use the Bura Project area have evolved food production strategies which, for the most part, are adapted to the exigencies of the area. The Bura Project itself will also help change the ecology of the area, allowing people to pursue activities which previously were not possible. The project will create a high density sedentary population where before human densities were low and, in the case of the Orma pastoralists, highly mobile.

The conservation of wildlife and its vegetative habitat is one factor which could be drastically affected if the proper control measures are not taken. The wildlife resource offers a potential source of meat and, through the sale of trophies and skins, money. Although, if properly utilised, the wildlife resource of an area can be effectively exploited, controlled exploitation will not occur at Bura. Illegal and uncontrolled poaching by the project tenants could lead to the rapid destruction of the wildlife resource of the area. Similarly, illegal and uncontrolled cutting of trees for firewood and for building could lead to the destruction of the riverine forest. The importance of both these natural resources to the long-term future of Kenya makes it essential that steps are taken to minimise the destruction of them by tenants.

Another active ecological effect of the Bura Project may arise from the need to use pesticides to protect the crops. Some of the pesticides which will be used at Bura have very persistent residues, which become transported throughout the aquatic and terrestrial ecological systems and can damage many parts of the biota. The extent of the damage will depend on many ecological factors.

5.4 Monitoring and Minimising the Ecological Impact

The steps necessary to monitor and minimise the undesirable ecological impact of the Bura Project have been proposed in the Annexes dealing with Health, Sociology, Forestry, Wildlife and Ecology, Livestock and Fisheries.

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BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

FORESTRY ANNEXE

BURA IRRIGATION SETTLEMENT PROJECT

PROJECT PLANNING REPORT

FORESTRY ANNEXE

LIST OF CONTENTS

Page No.

LIST OF TABLES

		Page No.

LIST OF FIGURES

INTRODUCTION AND SUMMARY OF PROPOSALS

The Bura Irrigation Settlement Project is essentially an agricultural scheme. Understandably, therefore, the majority of previous work has been concentrated upon agricultural and engineering aspects. The need for fuelwood and timber supplies has been recognised, however, and this annexe has been prepared in response to the terms of reference for the Project Planning Report, outlined in the Agreement between the National Irrigation Board and the Consultants. These terms of reference are also contained in Annexe 16, Appendix 2, of the IBRD (1976) White Cover Report.

Objectives of the Study and Approach Adopted

With the limited period allocated to this appraisal of the forestry sector, it has been necessary to work almost entirely within the bounds of the existing data base. In certain cases this has proved adequate, in others further information is required and hence a number of proposals are conditional upon the outcome of recommended research.

Four major topics have been investigated, namely:

(a) Conservation of the natural vegetation; particularly the riverine forests.
(b) The demand for and supply of timber and fuelwood.
(c) Forest extension and amenity requirements in the proposed settlement villages.
(d) Research.

In examining these topics, close liaison has been maintained with the Forest Department, which has been most co-operative. The forestry consultant made three visits to the project area, one extending over a period of a week, and also visited forestry officers and research trials in the following places:

Garissa	Mombasa
Lamu	Kwale
Gedde	Muguga

In addition to these field visits, discussions have been held with a range of organisations, including the International Bank for Reconstruction and Development (IBRD), the East African Agricultural and Forestry Research Organisation (EAAFRO), the United Nations Environmental Programme (UNEP), and the Tana River Development Authority (TRDA).

This report is divided into four parts, each dealing with one of the four topics mentioned above. Major conclusions and recommendations are summarised below.

Conclusions and Recommendations

Part 1 of the report deals with the conservation of the natural vegetation. Maps of this have been prepared at a scale of 1:50 000 from 1975-76 aerial photography with the aid of the Forest Department. These have been used as the basis for examining the IBRD proposal that the riverine forest area between Garissa and Garsen should be gazetted as a forest reserve (para 4.39 of the 1977 Yellow Cover Report (1)).

Examination of the area and discussions with senior forestry officials, have led to the conclusion that it is neither feasible nor necessary to gazette the entire stretch of the Tana River from Garissa to Garsen. Gazettement requires the removal of population from the area in question, and there is little point in doing this in heavily depleted or heavily populated regions. This was agreed with the IBRD forestry adviser who visited the project area in January 1977. Instead, it is proposed that specific blocks of natural vegetation should be selected for protection and that these should be gazetted as soon as possible.

Three areas appear to be critical in relation to the proposed irrigation project. The first is the riverine forest area to the east of Phase I, Stage I of the Bura Project. Here it is proposed that approximately 70 square kilometres, encompassing both banks of the river, are gazetted. The second area which it is considered necessary to protect is the area surrounding the irrigation headworks, to the north of Nanigi. This block, of approximately 85 square kilometres, includes the area which may be inundated by the headworks. Thirdly, there is an area of dense-medium *Commiphora* scrub to the north of the existing Hola Scheme which is of little value at present. In the future, however, if Phase II, Stage I of the project is implemented, this area would be commanded by the main canal, and could be used for a supplementarily irrigated afforestation scheme. It is recommended that 90 square kilometres are reserved before settlement in the area creates problems of gazettement.

For each of these blocks, management proposals and cost estimates have been prepared.

Part 2 of the report deals with the demand and the supply of timber and fuelwood. Demand has been projected over a 20 year period on the basis of population estimates, per caput consumption and an assumed rate of substitution of alternative fuels for wood. The projected demand has been compared with estimated supplies from the natural vegetation. It appears that unless the riverine forests are clear-felled, a policy which is not recommended, there will be a serious shortage of fuelwood. By the 1990's it is estimated that the annual deficit will be in the region of 45 thousand cubic metres (solid volume).

Alternative sources of supply have been examined. These include:

(a) Dry land plantations in the neighbourhood of Garsen.
(b) Irrigated plantations adjacent to the Bura Project.
(c) Natural forests such as Witu and Boni to the south-east of the project.
(d) Alternative fuels such as paraffin (kerosene).

Accepting that the riverine forests should be protected, the least cost method of meeting the project's demand appears to be from gravity-fed supplementarily irrigated plantations adjacent to the project. At a discount rate of 12 per cent, production costs are estimated at approximately 105 shillings per cubic metre.

To meet projected demand to the year 2000, a plantation programme has been prepared. This is based on the following critical assumptions:

(a) Demand projections as shown in Table 5.4.
(b) A rotation length of seven years.
(c) A mean annual increment of 15 cubic metres per hectare.

Of the three assumptions, that concerning yield may be the most controversial in view of the ILACO estimate of 35 cubic metres per hectare per annum, and that of 100 quoted in the NIB draft paper on forestry. Research records, however, indicate that yields of this magnitude are unlikely to be achieved in Bura. The proposed planting programme, which is subject to modification following the recommended species trials, is shown in Table 7.2. According to this, a net area of 3 900 hectares will be required for afforestation. Allowing for roads and irrigation works, a total area of 4 500 hectares is considered necessary.

Adjacent to, and immediately to the east of the proposed irrigated project area, there are approximately 6 000 hectares above the Tana River floodplain. Assuming that 25 per cent of this were to be rejected, on the grounds of topography and soil characteristics, sufficient land would still remain to implement the proposed afforestation programme.

Management proposals and cost estimates for the plantation are presented in Chapter 7.

The financial analysis of the proposed afforestation programme indicates that net returns to the project are likely to be relatively high. This is due to the fact that water, which is surplus to agricultural requirements, would be available at only marginal cost. Net returns to the project, with varying assumptions are summarised below.

Net Returns to Irrigated Afforestation at a Discount Rate of 15 per cent (Million Kenya Shillings)

	Costs Assumptions*		
	Low	Medium	High
Yield/price assumptions*			
High	**20.3**	**16.3**	**12.3**
Medium	**14.3**	**10.3**	**6.3**
Low	**8.3**	**4.3**	**0.3**

* High and low = ± 20% of medium (see Chapter 8)

The amenity aspects of forestry, which involve tree planting in the 23 village centres, are considered in Part 3. Experience in other settlements indicates that while part of the tree planting could be undertaken by the settlers themselves, an organised programme of tree planting in public places would be desirable. The Forest Department, which has its own extension service, could undertake part of this programme and it is recommended that the schools in each village are involved in the remainder. To this end it is proposed that the Wildlife Clubs of Kenya, the most active conservation-orientated organisation in the country, is provided with an annual grant to promote amenity tree planting and the conservation of the natural vegetation.

Proposed species, irrigation schedules and an annual planting programme are presented in Chapter 9. Management proposals and cost estimates of the extension programme are given in Chapter 10.

Finally, in Part 4, the question of research is considered. In 1965 a series of species trials were initiated at the Hola Scheme. Unfortunately, these were abandoned in 1974-75 and only one series of measurements, for four species, were obtained in 1972. These are quite inadequate to form the basis of a relatively large afforestation programme. It is recommended that new trials are started as urgently as possible. Twenty-four species are recommended for trial and it is proposed that these trials should be statistically replicated. Preliminary discussion with the research team (funded by the Government of the Netherlands) located at Bura, indicates that in principle the forestry trials could be supervised, provided the necessary funds were made available. Details of the species proposed, irrigation requirements, and costs of the trials are given in Chapters 12 and 13.

Summary of Cost Estimates

Both capital and recurrent costs are presented in constant 1977 financial price terms. For ease of reference, each section of the report contains estimates for the four topics considered. They are summarised overleaf for the forestry development proposals as a whole, over a period of 13 years (1977/78 - 1989/90).

In total a sum of just over 41 million Kenya Shillings (at constant 1977 prices) is required. Most of this is of course associated with the afforestation scheme. Revenue from the plantations would not commence until the first clear-felling in 1988; thereafter both capital and recurrent costs could be met from current revenue.

Summary of Costs Relating to Forestry Proposals : 1977 Constant Financial Prices
(Million Kenya Shillings)

	Fiscal Year												
Capital Costs	1977-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90
1. Natural Forests	0.50	0.50	0.30	–	–	–	–	–	–	–	–	–	–
2. Afforestation Programme	–	–	1.74	5.66	6.45	1.27	1.25	1.28	1.36	1.45	1.78	1.06	0.98
3. Amenity and Extension	–	– –	–	0.47	–	–	–	–	–	–	–	–	–
4. Research	0.07	–	–	–	–	–	–	–	–	–	–	–	–
Sub-Total	0.57	0.50	2.04	6.13	6.45	1.27	1.25	1.28	1.36	1.45	1.78	1.06	0.98
Recurrent Costs													
1. Natural Forests	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
2. Afforestation Programme	–	–	–	0.23	0.35	0.47	0.60	0.73	0.86	0.99	1.14	1.30	1.38
3. Amenity and Extension	–	–	–	0.15	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
4. Research	0.01	0.56	0.56	0.56	0.21	0.21	–	–	–	–	–	–	–
Sub-Total	0.25	0.80	0.80	1.18	0.97	1.09	1.01	1.14	1.27	1.40	1.55	1.71	1.79
TOTAL COST	0.82	1.30	2.84	7.31	7.42	2.36	2.26	2.42	2.63	2.85	3.33	2.77	2.77

CHAPTER 1 THE NATURAL VEGETATION OF THE STUDY AREA

1.1 Introduction

The vegetation associations to be found in the Bura Project have been studied in some depth on numerous occasions. Moomaw, Gillet, Marsh, the Acres-ILACO - consultant team, Andrews, Groves, Horne and Lamprey, are amongst those who have examined the vegetation of the Lower Tana in the past twenty years (2-7). Earlier studies by Shantz (8), Allen (9), Edwards (10) and Pichi-Sermolli (11), are also of relevance. These studies have been scientific, botanical investigations, providing much information on species occurrence and distribution. None, however, has examined the vegetation from a management/exploitation point of view and in only two cases (Marsh's and the Acres-ILACO Study (4, 5)) were the vegetation associations mapped. The purpose of this report is to examine the implications of settling a minimum of 60 000 people in the neighbourhood of Bura. Hence emphasis has been given to the interaction between the human population and the vegetation, rather than the nature of the vegetation itself. Thus, this chapter is essentially a summary of earlier work, updated as necessary in the light of our own visual assessment of the vegetation in the study area.

The general appearance of the vegetation is light to medium density deciduous bush which can be defined as dry savanna scrub. Apart from the riverine forest, there are few trees which exceed five metres in height and most have several stems, branching at or near ground level. The vegetation is in a drought-dormant condition for much of the year and evergreen species such as *Salvadora, Persica* and *Dobera spp.* are therefore particularly noticeable.

The most comprehensive description of vegetation types throughout the study area is provided by the Acres-ILACO report (Appendix D). Marsh (4), however, provides considerable additional information regarding the riverine forests and the vegetation types located to the south of Hola.

In their vegetation study carried out in 1964, the Acres-ILACO team recognised ten associations. These were surveyed on the basis of a square mile grid and the percentage vegetation cover recorded to the nearest ten per cent, by species, for each association.

The characteristics of the various vegetation types recognised are summarised below.

1.2 Semi-Desert Scrub

This association is characterised by *Acacia reficiens, Blepharis spp., Enteropogon macrostachyus, Salsola dendroides* and *Sporobolus marginatus*. In this association bare ground occupies more than ten per cent and the bush cover is usually less than five per cent. It is not found south of Hola-Thowa and is comprised of three sub-types which are related to varying soil formations. These are:

(a) Where there is less than about 50 centimetres of sandy top soil, a stunted ecotype of *Sporobolus marginatus* is characteristic. Other species include *Blepharis spp.* which are the most common, *Pavonia ellenbeckii* and *Sidera spp.*

(b) On Mazic Natrargids there are areas where virtually no vegetation occurs. A few species of *Portulaca* characterise this sub-type.

(c) Along the eastern edge of the old alluvial plain a very sparse cover of *Sporobolus marginatus* occurs with occasional stunted *Salsola* bushes.

1.3 Deciduous Scrubland

This type of scrubland is characterised by *Acacia reficiens, Aristida adscensionis, Blepharis linarifolia, Commiphora spp., Cordia spp.* and *Sporobolus marginatus*. Here bare ground occupies up to 20 per cent of the area and the bush cover is between 10 and 20 per cent. The bush cover is generally denser than in the semi-desert scrub and a range of annuals appear rapidly following rainfall.

The association is also characterised by a number of grasses, including *Aristida adscensionis* and *A. nutabilis, Chloris virgata, Dactyloctenium aegyptium, Eragrostis cilianensis, Sporobolus marginatus, Schmidtia bulbosa* and *Tetrapogon bidentatus*. Several of these species have a high nutrient value and it is not surprising that most of the herbivorous wild life in the area is to be observed in deciduous scrubland.

1.4 Shrub Thicket

The thicket is characterised by *Boscia coriacea, Commiphora spp., Dactyloctenium aegyptium* and *Indigofera spinosa*. In this association bush cover is assessed at between 50 and 100 per cent, although in some areas it may be as low as 20 per cent. *Delonix elata* occasionally grows through the thicket canopy and in the floodplain on sandy deposits *Acacia tortilis* is fairly common. Various species such as *Anthericopsis sepalosa* and *Clinus setiflorus* appear restricted to the neighbourhood of water holes and local occurrences of sansevieria are associated with old termite mounds.

Characteristic grasses include *Brachiaria leersoides, Digitaria aridicola* and *Urochloa scherochlaena* and associated herbs include *Indigofora spinosa*, which is almost invariably present, and *Aerva lanata*.

1.5 Open Bushland

The open bushland association is generally characterised by *Acacia reficiens, Cordia spp.* and *Neuracanthus spp.* The bush cover varies between 5 and 30 per cent and this association is the most common. The composition of the bush varies considerably and the number of species encountered is greater than in any other associations, with many distinct sub-types separated by mixed transitional comities. According to the Acres-ILACO report, a general observation is that the height of the bush species increases in a north-west - south-east direction.

Typical components of the herbaceous cover on open bushland include *Abutilon pannosum, Acalypha indica, Barlaria acanthoides* and *Indigofera schimperi*. Grasses which are common include *Aristada adscensionis, Chlorus spp.* and *Dactyloctenium scindicum*.

There are several sub-types of open bushland, the first of these is acacia bushland, characterised by *Acacia reficiens, A. paolii, A. nubica* and *A. mellifera*.

This sub-type covers only a minute fraction of the region, and while it is described by the Acres-ILACO report as having 'no apparent significance', this statement is from a botanical viewpoint. In terms of settlement planning and the related question of fuelwood supplies, this sub-type is of great importance because these almost pure stands of *Acacia spp.* will be highly sought after for firewood and charcoal production. Unfortunately, the area covered is small and will do little to meet the wood requirements of the projected population (see Chapter 5). In this sub-type three phytomers can be distinguished; namely:

(a) Almost pure stands of *Acacia reficiens* on eroded, somewhat sandy soils in the west-central part of the area.

(b) Pure stands of *Acacia paolii* scattered amongst the shrub-grassland (Section 1.7) in the south-central areas of the region.

(c) Very occasional mixed stands of *Acacia nubica* and *A. reficiens* near Hola; most of these having been felled since they were identified by the Acres-ILACO study.

The second sub-type is Middle Terrace Grass Land, characterised by *Dobera loranthifolia* and *Salvadora persica* in terms of bush species, and by the grasses *Lintonia nutans* and *Sporobolus helolus*. Bush cover is up to five per cent and this association is found at the junctions of the Hiraman, Bilbil and Walesa Lagas with the Tana River floodplain.

Closed bushland is the third sub-type characterised by *Acacia reficiens, Commiphora spp.* and *Euphorbia grandicornis*. Bush cover is fairly dense, between 40 and 80 per cent, and this sub-type is found to the immediate north of the Hola Scheme. Much of the *Acacia* has been removed by settlers over the past few years and the area is now dominated by *Commiphora* species which have virtually no value as fuelwood.

The fourth and last sub-type is a complex of semi-desert scrub and bushland with individual units too small to be recorded separately. It is usually dominated by *Commiphora* species and occurs in patches through much of the study area near the Tana River floodplain.

1.6 Thicket Dominated by *Terminalia orbicularis*

This association is characterised by *T. orbicularis* (at least 40 per cent), with *Commiphora* species and *Ptalycelyphium voense*. Bush cover is between 40 and 100 per cent and occurs in the north of the study area. Rather less dense but purer thickets of *Terminalia* were recorded by the Acres-ILACO team in the Hiraman basin, but recent examination of this location indicates that the area covered by this association is extremely limited.

1.7 Shrub Grassland

Characterised by *Acacia reficiens* and *Sporobolus helvolus* with bush cover of less than 20 per cent and grass cover of more than 50 per cent. The shrubs and herbs are similar to those encountered in open bushland (Section 1.5) but are limited to those species which survive better on soils with a higher clay content. *Blepharispermum fruticosum* is found more commonly here than in open bushland and both *Acacia borrida* and *A. mellifera* can be of local significance. This association covers quite an extensive area to the south of the Hiraman.

1.8 Valley Grassland

An association characterised by *Cyperus rotundus retzii* and *Sporobolus helvolus* this association has less than 10 per cent bush cover and over 70 per cent grass cover. There are considerable areas of 'valley grassland' in the Tana River floodplain and where there are confluences with other streams, dense patches of *Echinochloa haploclada* occur.

1.9 Floodplain Dominated by Non-Graminaceous Herbs

Characterised by *Cyperus rotundus, Eriochloa nubica, Ipomolea cordofana* and *Ocimum hadiense* the bush cover is negligible and grass cover is less than 50 per cent. Other herbs which are of importance in characterising this association include *Aspilia spp., Coccinia spp., Corchorus trilocularis* and *Dalechanpia scandeus*.

This association occurs mainly in the Hiraman floodplain although patches are to be found further to the north.

1.10 Floodplain Bushland

This bushland is characterised by *Dobera loranthifolia* and *Sporobolus helvolus* bush cover is usually more than 50 per cent and the bush species are commonly 6 to 7 metres tall. This type of bushland occupies a relatively narrow strip of up to three kilometres in width along the upper boundary of the Tana River floodplain.

Other species of significance in the association are *Abutilon pannosum, Acacia zanzibarica, Cordia gharaf* and *Lawsonia inermis*.

1.11 Tana Riverine Forest

This association, which is probably the most important from an ecological and botanical point of view, and certainly the most important in terms of forestry, is described by the Acres-ILACO study as 'a more or less complete cover of *Acacia elatior*'. This description conflicts with that provided by Marsh (4), who considers the riverine forests to be relatively diverse in terms of species composition. Our own appraisal of the area supports Marsh's work rather than the Acres-ILACO description and the following account is based, therefore, on Marsh's detailed survey.

The riverine forests may be subdivided into four types:

Type I: mixed evergreen forest, is characterised by *Sorindeia obtusifoliolata, Sterculia appendiculata, Albezia gummifera, Ficus sycamorus* and *Diospyrus mespiliformis*. Such forests follow the course of the river closely and rarely extend more than half a kilometre from either bank.

Type II: is dominated by *Pachystella brevipes* a large evergreen tree, with *Majidea zanguebarica* and *Alangium saliifolium* common in the under storey. This sub-type is found on sandy levees near the river which are rarely subjected to flooding.

Type III: *(Acacia/Diospyrus)* is more variable in terms of species dominance. It is characterised by species such as *Acacia clarigera (A. robusta), Diospyrus mespiliformis, Mimisops fruticosa* and *Cordia goetzii* to the south of the study area. Towards Garissa, however, *Acacia elatior* is much more common and is frequently dominant (as observed by the Acres-ILACO team). This sub-type is normally found between 0.5 and 1.0 kilometres from the river on soils which are intermediate between the sandy levees and the heavier clay soils.

Type IV: finally, in what Marsh describes as 'true backwater areas' which are subject to regular flooding a fourth sub-type can be distinguished. This is commonly found around old ox-bows and is characterised by *Garcinia livingstonei, Cynometra suahliensis* and *Cola elavata*.

One indigenous species which flourishes on the river banks is of specific interest: *Populus ilicifolia*. Pole requirements in the proposed irrigation project will be considerable, and the possibility of establishing this poplar in plantations is considered later in the report.

CHAPTER 2 GOVERNMENT POLICY

2.1 Introduction

The forests of Kenya cover approximately 2.5 million hectares, of which 1.7 million are classified as gazetted forest (2.9 per cent of the total land area). Of this total, about 1.1 million hectares is closed forest; 800 thousand hectares of which is productive.

In the portion of the Lower Tana River Basin with which this report is concerned (between Garissa and Garsen), there is no gazetted forest, although several blocks to the west of the river have been proposed for demarcation as forest areas. Eight blocks were proposed in 1974 by the Forest Department, covering approximately 3 300 square kilometres. Three of these are on Trust Land and the remainder on State Land. Although the corners of each block have been marked, they have yet to be surveyed. There are, however, two gazetted game reserves in the region which cover approximately 600 square kilometres. These are the Tana River Primate Reserve which straddles the river and the Arawale Game Reserve to the east of the Tana. In both of these reserves the natural vegetation is of course protected by statute. The proposed forest reserves and the two game reserves are shown in Figure 2.1.

2.2 Gazettement

Legal procedures for the reservation of land for either protection or production purposes are specified in the Laws of Kenya. The following Acts are of relevance:

		Chapter
(a)	The Forest Act	385
(b)	The Trust Lands Act	288
(c)	The Chiefs Authority Act	128
(d)	The National Parks Act	377
(e)	The Wildlife and Tourism Act	1 of 76
(f)	The Agricultural Act	318
(g)	The Grass Fires Act	327
(h)	The Water Act	372

With regard to the gazettement of new forest areas the first two of the above Acts are of importance. Where legal reservation of an area is impractical, as is often the case, control of exploitation can be effected, in theory at least, by such instruments as the Chiefs Authority Act. In practice, the experience of the Forest Department over the past ten years indicates that little or no control can be exercised in areas which have not been gazetted. New forest protection laws are being drafted at present, however, and these should give the Forest Department greater control of ungazetted forest areas.

The procedure followed and the legal instruments employed in reserving new forest blocks depends upon the ownership status of the area involved.

In the case of State Land the procedure is relatively straight forward. For Trust Land, (held by the County Council for the use of the local population), the question of individual compensation may give rise to great complexity. Unfortunately, in the portion of the Tana River Basin with which this report is concerned, much of the area is classified as Trust Land. The problems involved in the creation of forest reserves in these areas are illustrated by the fact that since 1969, when the new constitution was promulgated, the Forest Department has not established a single reserve on such land.

The two procedures are outlined below.

State Land

In the case of State Land the Chief Conservator of Forests approaches the Commissioner of Lands for authority to obtain a given area as a new forest or nature reserve. This application is supported by a map showing the proposed boundaries. If permission is given to proceed, the survey is registered with the Lands Department, the area is surveyed and a boundary plan is submitted for approval. A gazette notice is then prepared and published in the official Kenya Gazette. This is a notice of intention and usually allows a 28 day period for objections to be received by the Commissioner of Lands. If no opposition is encountered, a further notice is published in the Gazette Supplement whereby the demarcated area is officially recorded as a forest.

Trust Land

In Trust Land areas, the procedure to be followed is set out in the Trust Land Act (Chapter 288 of the Laws of Kenya) and the question of land acquisition / excision is dealt with in Part 4 of the Act. In this case the Chief Conservator of Forests approaches the Office of the President with details of the area required. If this is accepted to be in the national interest, the Office of the President notifies the relevant County Council that the land is required for Government purposes.

The County Council is then obliged to request the Commissioner of Lands to set the land apart under the Trust Land Act. On receipt of this request the Commissioner of Lands publishes details of the proposed area in the Kenya Gazette and a maximum period (usually one month) is specified for the receipt of compensation claims. Those wishing to claim apply to the District Commissioner who, in consultation with the Divisional Land Board, determines the level of compensation.

The District Commissioner informs the Commissioner of Lands of the total compensation required. In turn the agency or department wishing to acquire the land is informed and the necessary funds are transferred to the District Commissioner. When all claims have been settled, the District Commissioner informs the Commissioner of Lands and the area in question is designated as State Land. Notice to this effect is published by the County Council in the official Kenya Gazette. Once this has been done, the Forest Department can apply for the land to be gazetted as a reserve, following the procedure outlined above for the gazettement of forest blocks, on State Land.

Clearly the procedure is complicated and time-consuming. While the period required varies in relation to the number and complexity of the claims received, it is doubtful if an area of Trust Land could be gazetted as a forest in less than 12 months. As the complexity of the gazettement procedure is a function of the compensation claims received, which in turn is related to the population density, it is essential that a programme to gazette the riverine forests between Garissa and Garsen is initiated well in advance of the implementation of the Bura Project. Proposals for this programme are presented in Chapter 3.

2.3 Management and Exploitation of the Natural Forests

In that none of the natural vegetation in the area lies within designated forest areas, it is not surprising that no form of management is practised at present. None of the vegetation types has been surveyed by the Inventory Section of the Forest Department, although of course botanical surveys have been carried out as mentioned in Chapter 1. Within the study area the Forest Department has two extension forestry officers, one stationed at Garissa, and the other at Hola. Both are primarily concerned with amenity planting in the main centres of population. While little has been achieved in Hola, the progress of the tree-planting programme in Garissa is highly commendable.

With regard to protection of the natural vegetation, of which the riverine forest is particularly

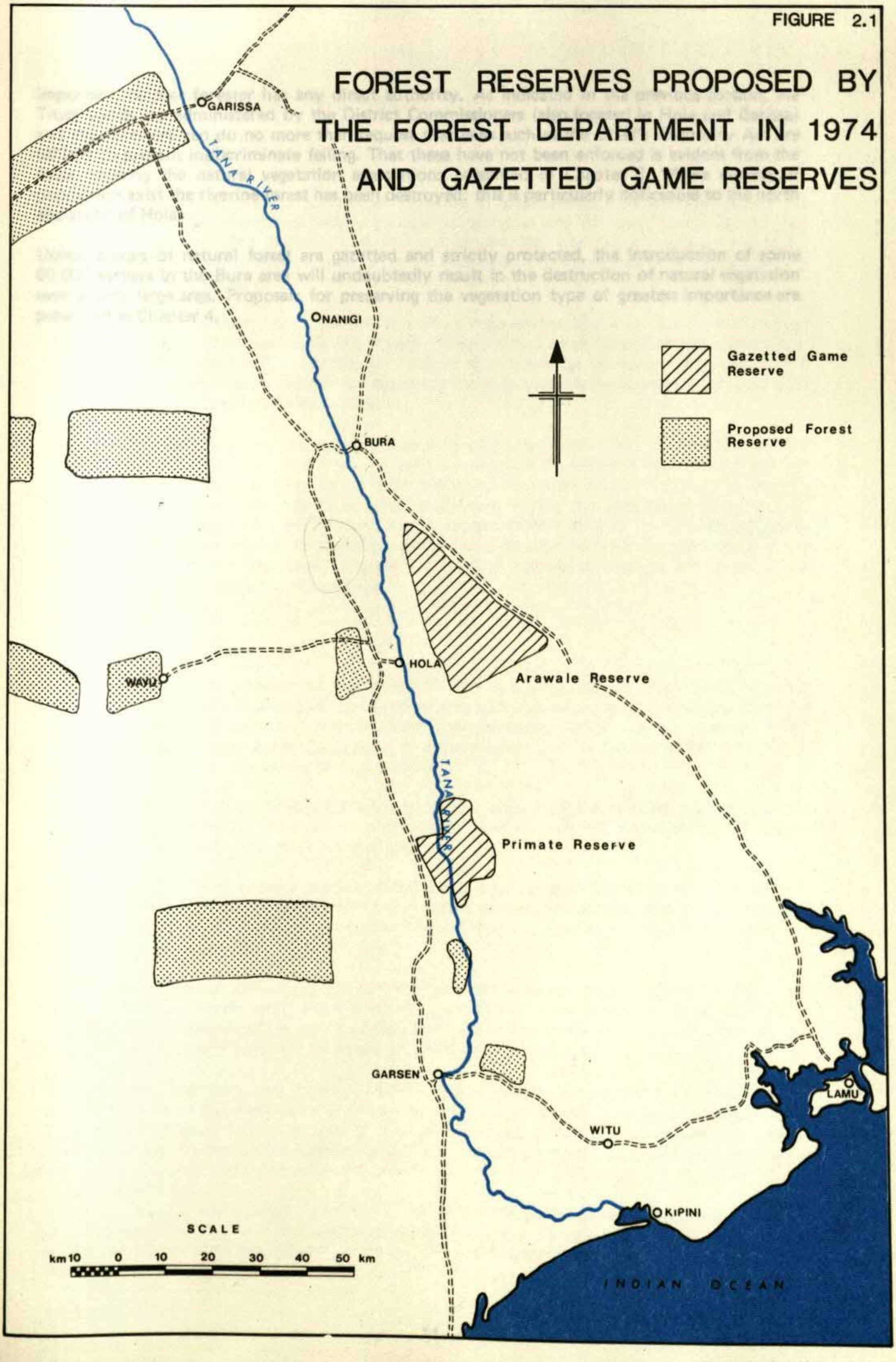


FIGURE 2.1

FOREST RESERVES PROPOSED BY THE FOREST DEPARTMENT IN 1974 AND GAZETTED GAME RESERVES important, neither forester has any direct authority. As indicated in the previous section, the Trust Lands are administered by the District Commissioners (also located in Hola and Garissa) and the foresters can do no more than request that laws such as the Chief's Authority Act are utilised to prevent indiscriminate felling. That these have not been enforced is evident from the maps showing the natural vegetation associations presented in Chapter 3. Where centres of population exist the riverine forest has been destroyed: this is particularly noticeable to the north and south of Hola.

Unless blocks of natural forest are gazetted and strictly protected, the introduction of some 60 000 settlers in the Bura area will undoubtedly result in the destruction of natural vegetation over a very large area. Proposals for preserving the vegetation type of greatest importance are presented in Chapter 4.

CHAPTER 3 DEVELOPMENT PROPOSALS

3.1 Introduction

The vegetation type which is of greatest interest is undoubtedly the riverine forest. The significance of these forests is widely recognised and the case for their protection is well presented by Brinck and Enckell, the ecology consultants, who participated in the IBRD Appraisal Mission for the Kenya Second Forestry Plantation Project, in late 1974. Their report is contained in Appendix A.

Furthermore, as a necessary condition of loan/credit negotiations, the World Bank has stipulated 'that the Government had gazetted as a Nature Reserve the riverine forest between Garissa and Garsen, including the riverine margins of the land that would be inundated upstream of the Nanigi weir; and had made adequate arrangements for its protection by forest guards' (para 8.05 (b) of draft appraisal report of January 1977).

Attention has therefore been concentrated on this vegetation type. Unfortunately the riverine forest between Garissa and Garsen had not been surveyed by the Forest Department Inventory Section, nor were up-to-date maps of the forest available when work began on this study. While it has not proved possible to organise an inventory survey during the consultant's short stay in Kenya, maps at a scale of 1:50 000 have been prepared from the 1975/76 aerial photography (DOS 1976 Crown copyright). This has been done in co-operation with the Survey Section of the Forest Department and the maps (Figures 3.1 to 3.5) have been used as the basis of the recommendations presented in this chapter.

3.2 Gazettement

The IBRD proposal to gazette the entire stretch of the riverine margins between Garissa and Garsen has been examined carefully. It has been discussed with senior forestry officers, members of the National Irrigation Board (NIB), District Commissioners, TRDA and also with the IBRD Forestry Adviser. From these discussions it is concluded that while the IBRD proposal is theoretically desirable, it is not feasible in practice.

Two major problems exist: firstly, there are numerous small settlements along the banks of the Tana, mainly inhabited by the Pokomo; and secondly, the nomadic tribes (mainly Orma) require access to the river banks with their herds of cattle.

Although the precise number of riverine inhabitants is not known, it is considerable. The number of claims received for compensation and the question of resettlement would inevitably result in major delays before gazettement could be achieved. Indeed, it is unlikely that the riverine forests would ever be gazetted at all.

On the second count, attempts to exclude the nomadic herdsmen from their traditional access routes to the river would meet with fierce resistance. Even if this could be achieved with a large force of forest guards, which is very doubtful, there appears to be no reason why the Orma's way of life should be totally disrupted in favour of a new irrigation project.

It is proposed, therefore, that instead of attempting to gazette the whole of the riverine forest between Garissa and Garsen, specific blocks along the river should be selected for reservation. These should be chosen on the basis of their present extent (in terms of the area covered by riverine forest), the population density within the proposed block, and the future pressure the area is likely to experience from new settlement.

In connection with the proposed Bura Project, three such blocks have been identified; in addition to the areas required for fuelwood plantations. These are discussed in turn in the following subsections. Other areas along the river should also be protected: including a block immediately to the south of Garissa and a further two areas between Hola and Garsen. It is essential, however, that attempts to gazette the riverine forest do not become too diversified. Furthermore, it is important that the programme for reservation is organised in such a manner that the areas facing greatest pressure are gazetted first. The three areas discussed below are presented in order of priority.

The Bura Block

Inevitably, with the influx of some 60 000 people between 1981 and 1985, the riverine forest to the east of the Bura Project will be subjected to intense pressure. As clearly shown by the vegetation maps (Figures 3.4 and 3.5), the riverine forests in the neighbourhood of the Hola Scheme have been virtually destroyed. Undoubtedly, the same destruction will take place at Bura, and with a much higher population, the rate of destruction will be correspondingly greater.

It is proposed, therefore, that a block of approximately 72 square kilometres is gazetted to the east of the proposed irrigation project, encompassing both banks of the Tana River. The location of this reserve is shown in Figure 3.6. It lies on Trust Land and hence its reservation will present considerable difficulties (as compared to State Land). The procedure to be followed is outlined in Chapter 2.

The total length of the proposed reserve boundary is approximately 72 kilometres. This will require survey and the boundaries will have to be cleared and demarcated. Estimated costs for this are presented in Chapter 4 and the management requirements are discussed in Section 3.3.

Clearly it is essential that the Bura Block is gazetted before settlement of the irrigation project commences in 1981. It is recommended, therefore, that funds are allocated to the Forest Department in the 1977/78 fiscal year for this purpose, if necessary by supplementary budget.

The Nanigi Block

As recognised in the recent IBRD report (January 1977, paragraph 4.39) it is essential that the headworks of the irrigation canal are fully protected. To this end the gazettement of a forest reserve of approximately 86 square kilometres is recommended. The location of this reserve is shown in Figure 3.7. On both banks of the Tana the proposed boundaries extend some distance from the river and include areas which are not covered by the riverine forest. This is in accordance with the IBRD proposal that the area which may be inundated by the Nanigi weir should also be protected.

This forest reserve is also located on Trust Land; considerable difficulty and hence delay can be anticipated therefore in its gazettement. As the headworks of the irrigation project should be protected from the start of operation, it is recommended that the process of gazettement is initiated as soon as possible. Funds for survey and boundary demarcation should be allocated to the Forest Department in the 1977/78 fiscal year, again if necessary by supplementary budget.

The total length of the reserve boundary is approximately 52 kilometres. Costs of survey and demarcation are given in Chapter 4 and the management requirements are discussed in Section 3.3.

Milalulu Block

As shown in Figure 3.4, there is a considerable area of dense-medium scrub between the Phase I project area (near Bura) and the Phase II project area (near the existing Hola Scheme). Until recently the vegetation in this area was characterised by an intimate mixture of *Acacia* and *Commiphora* species. Over the past 10 to 15 years, however, the settlers from the Hola Scheme have removed virtually all the *Acacia* for fuelwood and the remaining vegetation is almost entirely *Commiphora* (of no value as fuelwood).

As the population would increase with the possible implementation of Phase II, fuelwood

LOWER TANA RIVER BASIN, NATURAL VEGETATION

FIGURE 3.1 TO FIGURE 3.5

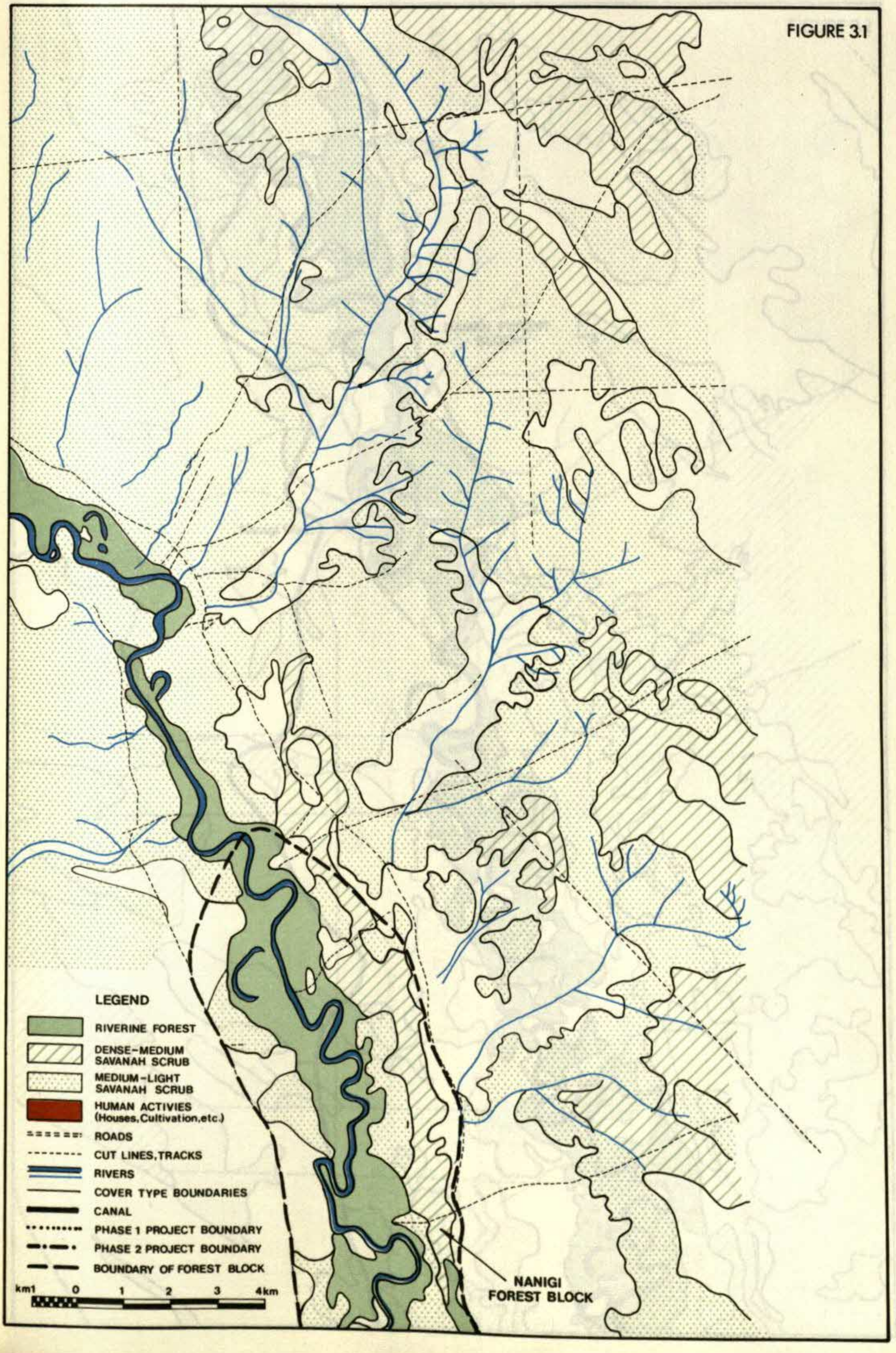


FIGURE 3.1
LEGEND
RIVERINE FOREST
DENSE-MEDIUM SAVANAH SCRUB
MEDIUM-LIGHT SAVANAH SCRUB
HUMAN ACTIVIES (Houses, Cultivation, etc.)
ROADS
CUT LINES, TRACKS
RIVERS
COVER TYPE BOUNDARIES
CANAL
PHASE 1 PROJECT BOUNDARY
PHASE 2 PROJECT BOUNDARY
BOUNDARY OF FOREST BLOCK
km1 0 1 2 3 4km
NANIGI FOREST BLOCK

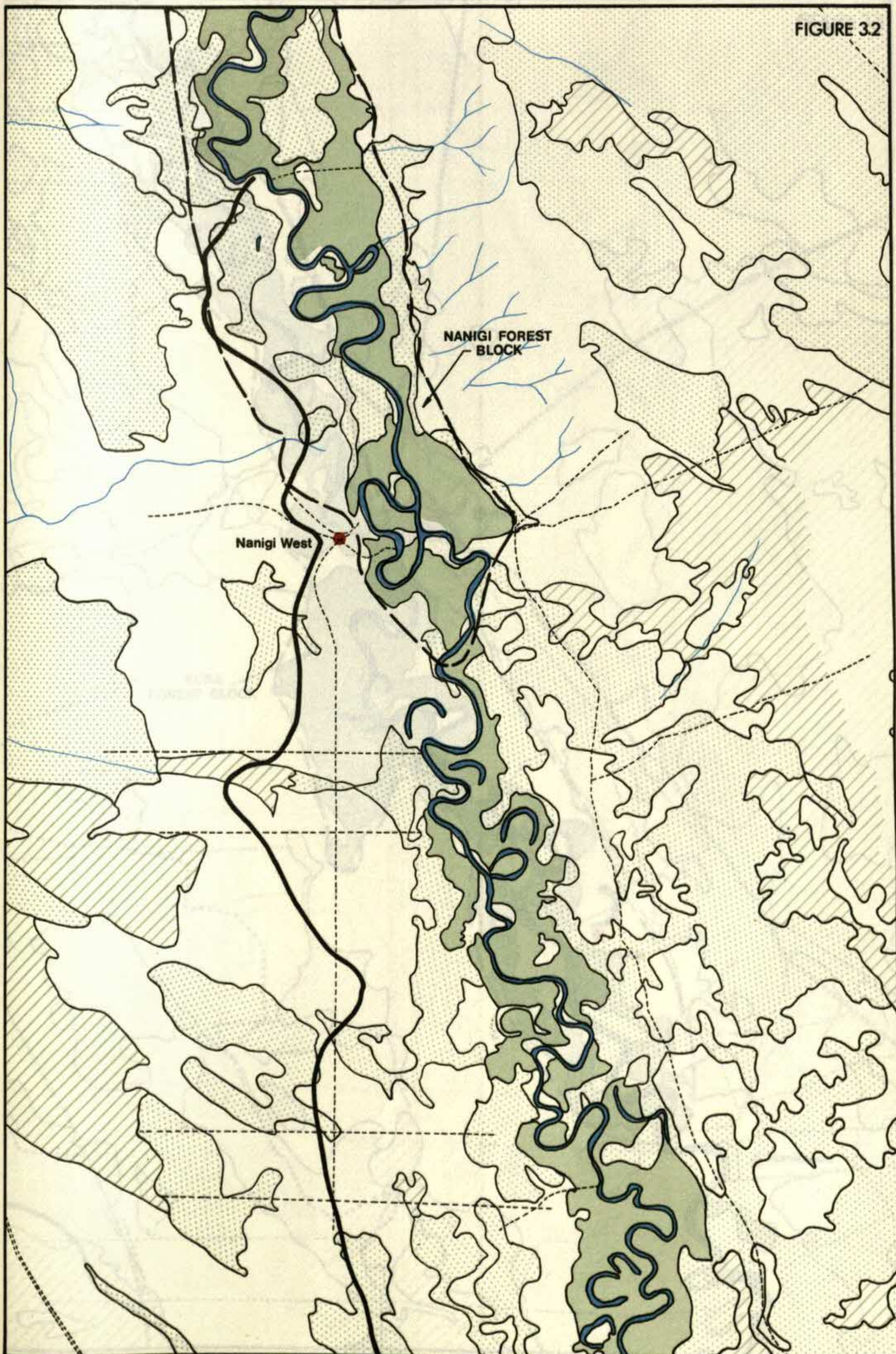


FIGURE 3.2
NANIGI FOREST BLOCK
Nanigi West

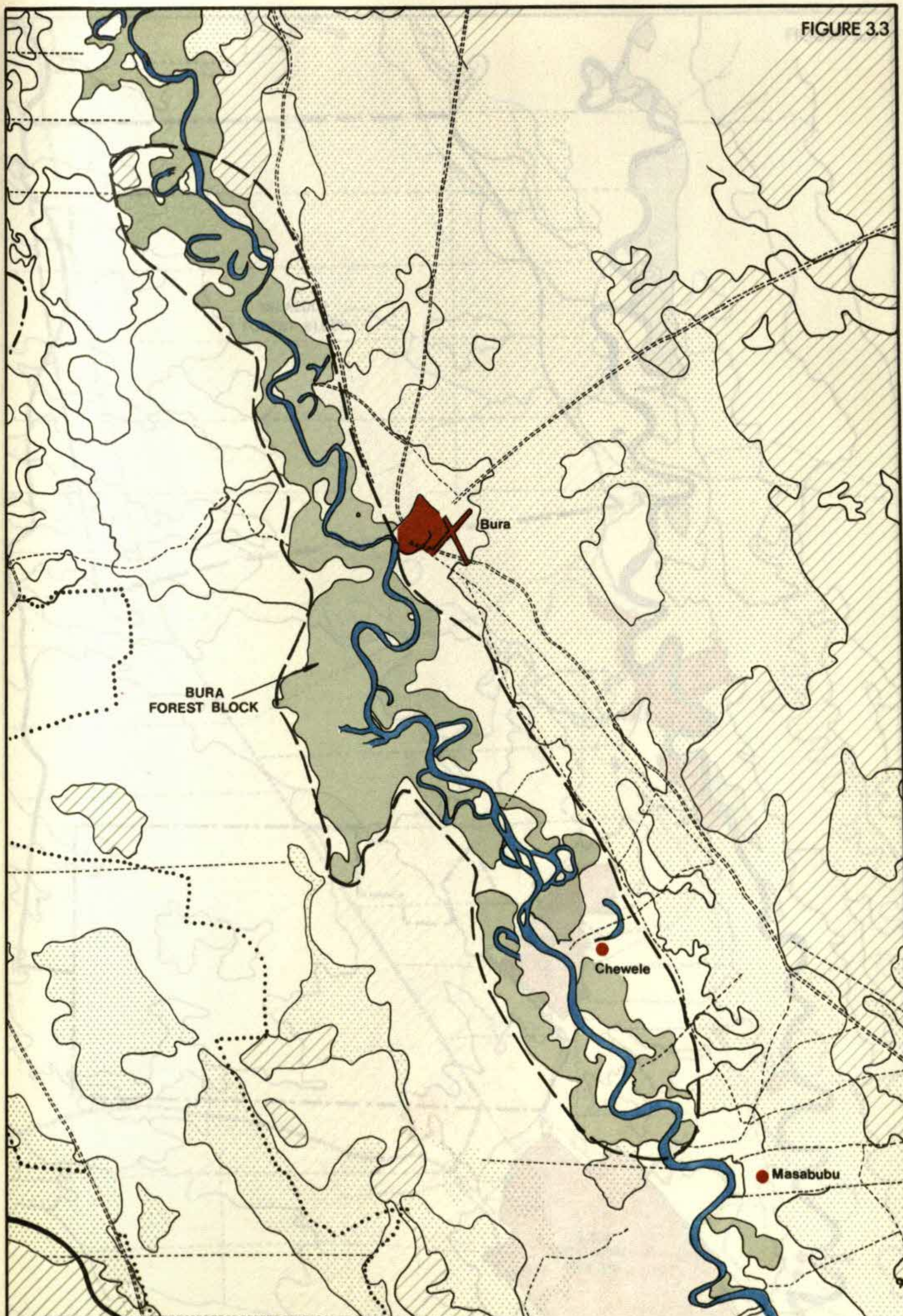


FIGURE 3.3
Bura
BURA
FOREST BLOCK
Chewele
Masabubu

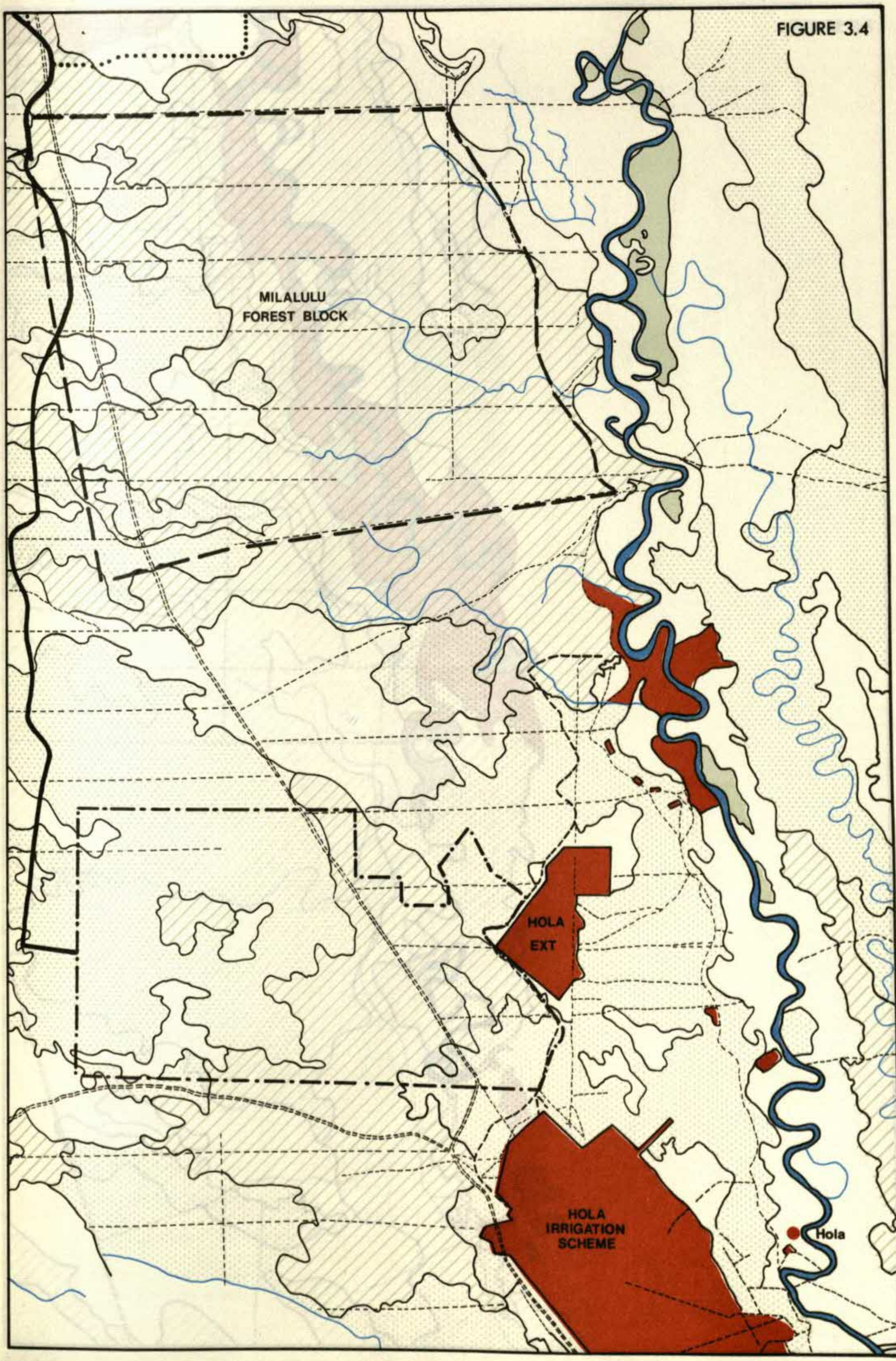


FIGURE 3.4
MILALULU
FOREST BLOCK
HOLA
EXT
HOLA
IRRIGATION
SCHEME
Hola

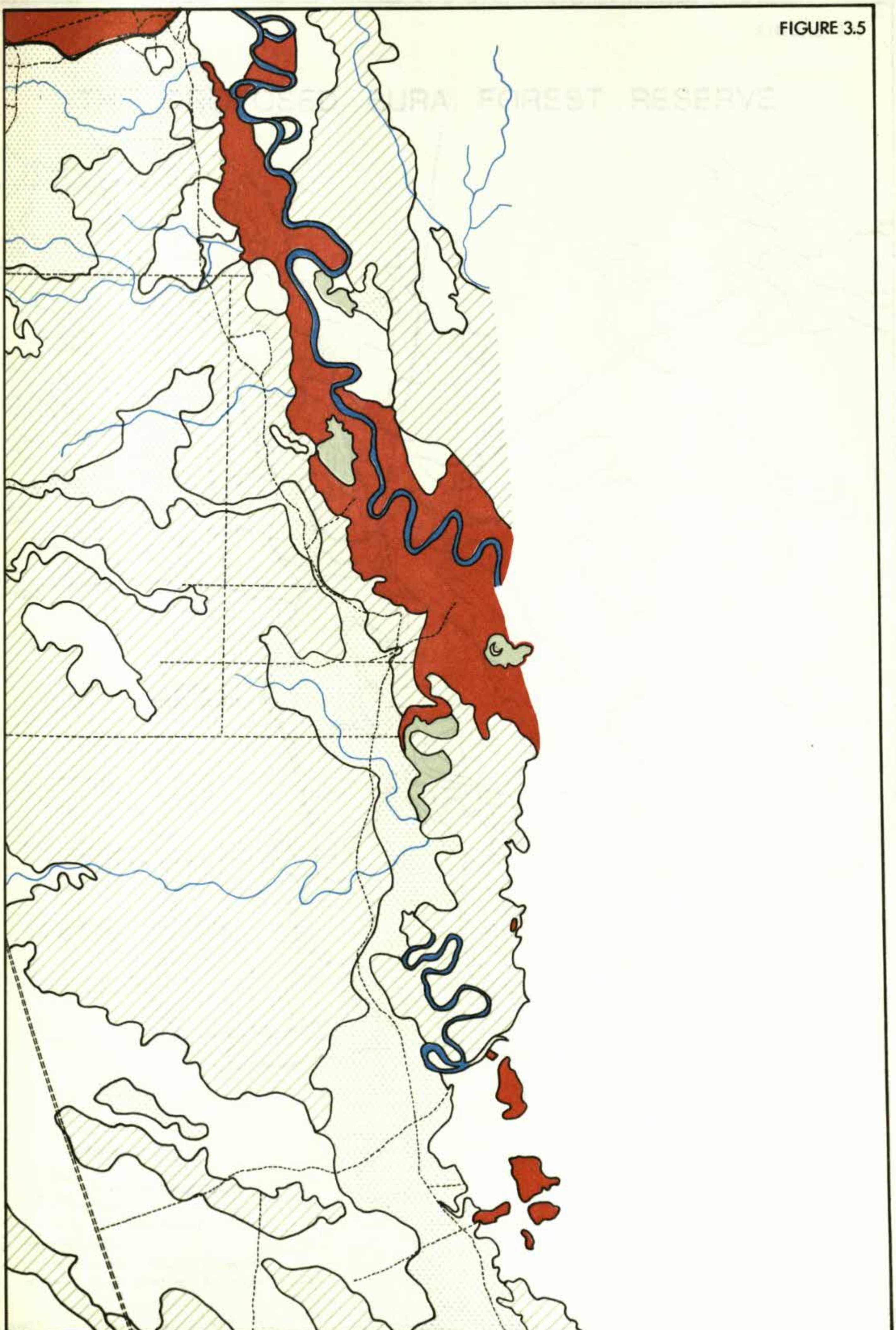


FIGURE 3.5

FIGURE 3.6

THE PROPOSED BURA FOREST RESERVE

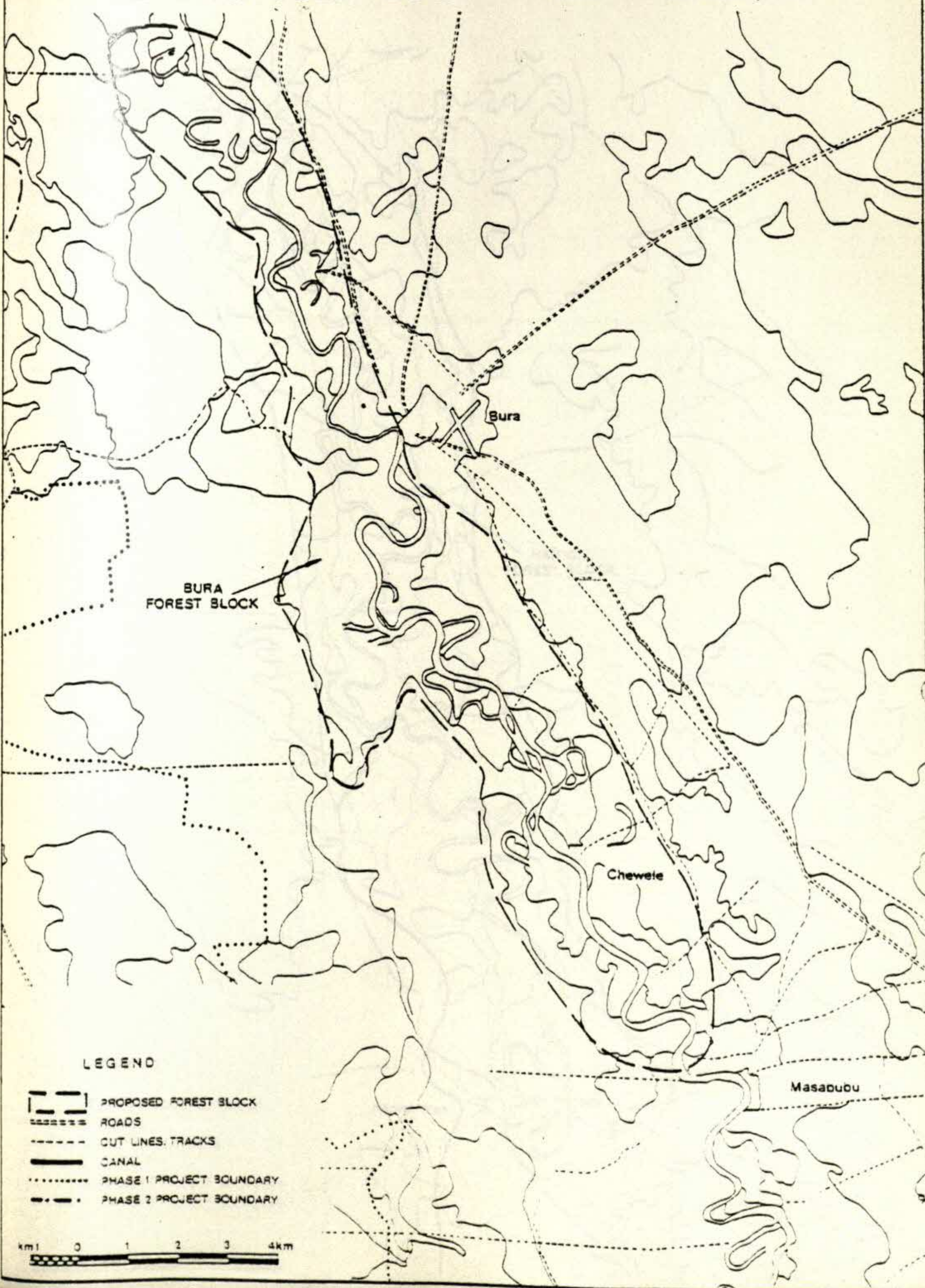


FIGURE 3.7

THE PROPOSED NANIGI FOREST RESERVE

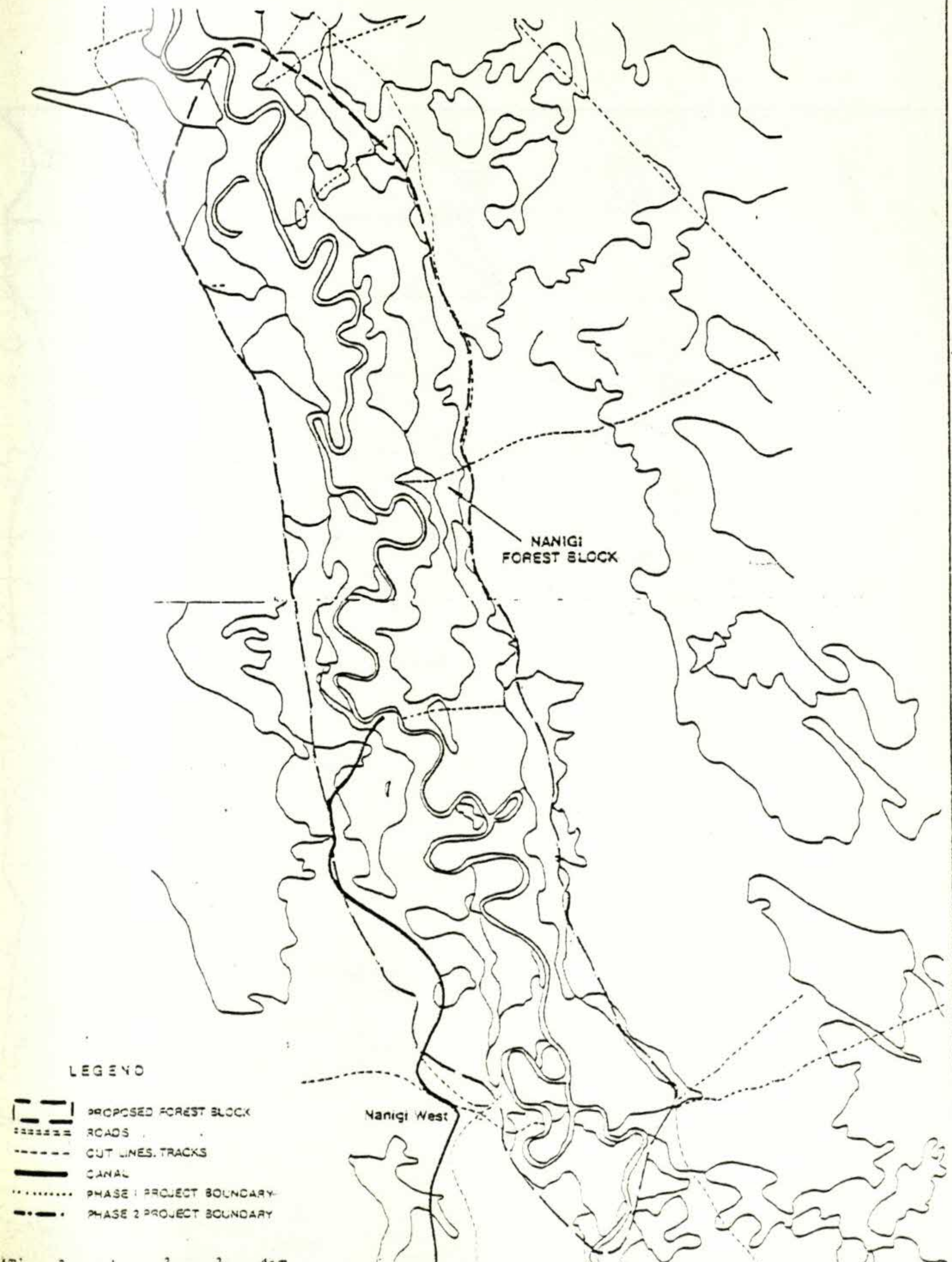
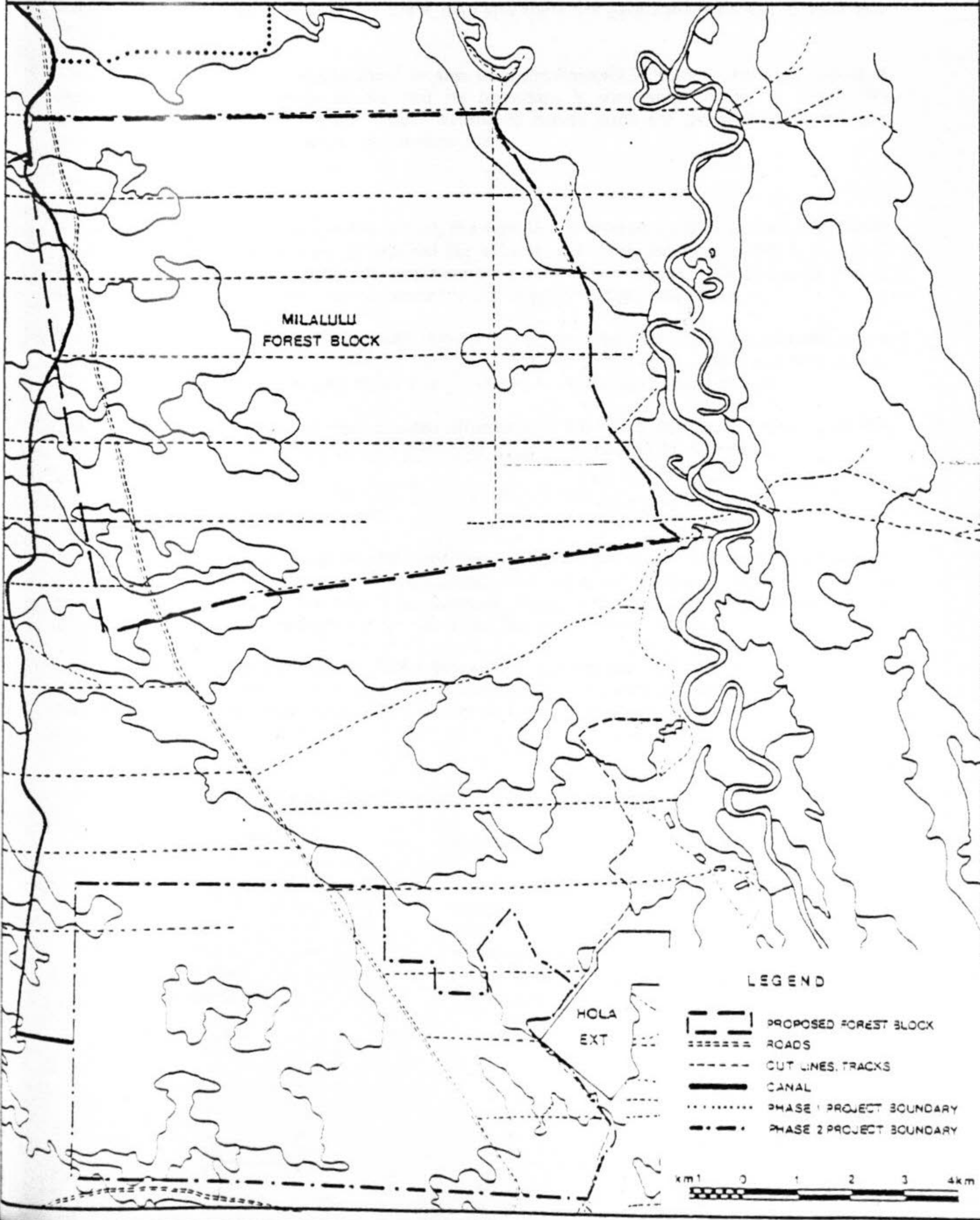


FIGURE 3:8

THE PROPOSED MILALULU FOREST RESERVE



requirements of the Bura Project, together with those of the existing Hola Scheme, may necessitate the establishment of additional fuelwood plantations. The Milalulu Block, shown in Figure 3.8, is ideally located for this purpose and, furthermore, it will be commanded by the main irrigation canal if and when Phase II of the project is implemented.

If this block is not reserved before the satellite population associated with the irrigation project builds up, considerable difficulty could be experienced in gazetting this area at a later date. It is proposed, therefore, that the Milalulu Block is gazetted following the reservation of the Bura and Nanigi areas. The area is located on State land and therefore gazettement should be relatively straight forward.

The proposed forest block would cover an area of approximately 90 square kilometres, which is larger than the two riverine blocks, but its boundary is somewhat shorter in length (45 kilometres) due to its rectangular shape. Estimated survey costs are given in Chapter 4 and management proposals are discussed in Section 3.3.

Forest Plantation Areas

Adjacent to, and immediately to the east of, the agricultural irrigation blocks an area of between four and five square kilometres is required for afforestation. The location of this is shown in Figure 7.1. Rather than gazette this area separately as a forest reserve, it is proposed that it should be included in the total area set aside for the irrigation project as a whole.

This approach would reduce the number of blocks to be gazetted officially and hence reduce the total time required. The forest will, of course, have to be demarcated clearly, but this can be done internally within the project rather than through the normal official procedure.

The management and cost of the proposed afforestation scheme is dealt with in Part 2 of this report. The following sections of this chapter refer only to the natural forest areas.

3.3 Protection and Management

Having gazetted the three forest blocks identified in Section 3.2, it will be necessary to protect them from destruction by the settler population. The degree of protection required at a given point is clearly related to the population pressure. Thus, in the case of the Bura Block, rather more forest guards are proposed than for the larger, but more distant Nanigi area.

Staffing proposals for the natural forest blocks are summarised in Table 3.1. These include provision for one forester, who would also be responsible for extension work within the project (see Part 3) and two forest rangers who would be directly involved in controlling exploitation (Section 3.4).

Table 3.1 - Staff Proposals - Natural Forest Reserves

Location of Staff	Position	Number of Staff
Bura Administrative Centre	Forester	1
	Rangers	2
	Clerk	1
Bura Block	Forest guards	10
Nanigi Block	Forest guards	6
Milalulu Block	Forest guards	4
Total Staff		24

In the Bura Block, five forest guard posts are considered necessary; three of these located on the west bank boundary and two on the east bank. Each guard post would be manned by two guards who would patrol the forest reserve boundaries in the normal way (as practised elsewhere in Kenya). In the future, should Stage II of the project be implemented on the east bank, one more guard post would probably be necessary.

For the Nanigi Block three guard posts are considered sufficient; two of these located on the west bank boundary and one on the east bank. Again, future development on the east bank may necessitate an additional post (and two extra guards).

The pressure on the Milalulu Block is unlikely to be severe, in that most of the desirable fuelwood species have been removed already. Initially, therefore, two forest guard posts are considered sufficient. When Phase II is implemented, however, this reserve may be afforested and then the staff requirements would clearly require revision.

Management of the three forest areas would be limited to improvement felling, whereby the dead and damaged trees would be removed. This could be done by settlers who would be allowed to remove such trees for fuelwood. These operations would be controlled by the forester in charge and the two forest rangers.

3.4 Exploitation

The primary function of the proposed forest blocks is protection and hence commercial exploitation of timber should not be undertaken at all. Nonetheless, visual inspection of the two riverine blocks (Bura and Nanigi) indicates that there are areas in which dead and elephant-damaged trees could be removed without reducing the protective efficiency of the forests. In fact, carefully controlled exploitation would be beneficial in that regeneration would be encouraged.

Unfortunately, the proposed reserves have not been inventoried and the volume of timber which could be removed for fuelwood can only be estimated. On the basis of the surveys of three forests located to the south east of the study area (Witu, Lungi and Boni), carried out by the Forest Department inventory section, the average standing volume of the riverine forests may lie between 50 and 100 cubic metres per hectare. Of this it may be assumed that roughly ten per cent is in the form of dead or severely damaged stems. Given a total area within the two proposed reserves of 158 square kilometres, and assuming that roughly half of this is high forest, it is possible that between 40 and 80 thousand cubic metres could be removed from the forest reserves without reducing their protective efficiency.

It is stressed that the above estimates are based on little more than a visual inspection of the two blocks during a brief visit to the area. Clearly it is essential that a more detailed survey of the potential of the riverine forests is undertaken before the plantation programme is finalised in 1981. The subject is considered further in Part 3.

It is proposed that each gazetted area is subdivided into blocks of approximately five square kilometres. By concentrating the removal of dead and damaged trees to specific blocks, it should be possible to control exploitation. As is the normal practice elsewhere in Kenya, permits to remove dead wood would be issued by the forester and the forest guards would inspect these while patrolling the reserves.

It may be argued that exploitation of the riverine forests should be prohibited completely. Certainly there are ecological arguments in favour of such a policy; the riverine habitat is considered unique and any human intervention may be regarded as undesirable. However attempts to prevent settlers from obtaining fuel from the obvious source of supply are likely to prove unsuccessful.

On balance it appears that strictly controlled removal of dead and dying trees is to be preferred to illegal felling, which would occur inevitably if exploitation was prohibited completely.

CHAPTER 4 COST ESTIMATES

The costs presented in this chapter are in financial terms at constant 1977 prices. Consequently they do not provide a precise estimate of budgetary requirements over the period considered in detail. These are presented in the Annexe on project capital and recurrent costs, where all project component costs have been inflated by a common factor.

4.1 Capital Costs

Based on unit cost estimates obtained from the Forest Department the capital costs associated with the natural forest reserves are shown in Table 4.1. These involve such items as personnel, accommodation, office buildings and transport, each of which is not wholly related to the protection and maintenance of the natural forest.

In such cases a comewhat arbitrary allocation has been made between the operations involved.

Table 4.1 - **Summary of Capital Costs for the Upkeep of Natural Forest Reserves (1977 constant prices)**

Item	Cost (1 000 Kenya Shillings)
Survey of natural forest reserves	486
Buildings	560
Vehicles	175
Equipment	20
Miscellaneous	60
Total	1 301

Survey of Natural Forest Reserves

The cost of survey, considered here as a capital cost, is detailed below for each block (Table 4.2).

Table 4.2 - Survey Costs, Natural Forest Reserves (1977 constant prices)

Item	Unit rate (K Sh)	Costs (1 000 K Sh) Reserve Bura	Nanigi	Milalulu	Total
Personnel:					
Labour at 10 man-days per kilometre	11/man-day	7.9	5.7	4.8	18.4
Accommodation allowance for half the labour force	15/man-day	5.4	3.9	3.3	12.6
Surveyors at 0.5 man-days/kilometre	60/man-day	2.2	1.6	1.3	5.1
Accommodation allowance	20/man-day	0.7	0.5	0.4	1.6
Supervision	10/kilometre	0.7	0.5	0.4	1.6
Transport:					
One 7 ton lorry	164 000	*	*	*	164.0
One LWB Landrover	77 000				77.0
Operating costs: 2 months at 3 000 km/month/reserve					
Lorry	2.00/kilometre	12.0	12.0	12.0	36.0
Landrover	1.35/kilometre	8.1	8.1	8.1	24.3
Aerial survey:	1250/sq. kilometre	90.0	107.5	113.8	311.3
Materials:					
Cement beacons at 1.1 per kilometre	30/beacon	2.4	1.7	1.5	5.6
Whitewash and labour	50/beacon	4.0	2.9	2.4	9.3
TOTAL COST		133.4	144.4	148.0	666.8
Less residual value of vehicles (75%)					180.8
NET COST					486.0

Buildings

It is assumed that the forester and the two rangers involved in supervising the natural forests and providing extension advice to the farmers would spend 70 per cent of their time on the former. Costs of the office and their accommodation have been allocated accordingly. The total costs are shown in Table 4.3:

Table 4.3 - Office and Accommodation Costs (1977 constant prices)

Item	Unit rate (1 000 K Sh)	Number	Total cost (1 000 K Sh)
Office	1.2/m²	1 (70 m²)	84
Garage	0.2/m²	1 (70 m²)	14
Store	0.75/m²	1 (30 m²)	23
Foresters house	165	1	165
Rangers house	58	2	116
Office clerk	14	1	14
Forest guards	14	20	280
TOTAL			696

Of this total, 560 thousand shillings are costed against the protection and management of the natural forests.

Vehicles

The forestry staff involved with supervision of the natural forest reserves and with the extension service will require the following vehicles:

	(1 000 K Sh)
One long wheel base Landrover at	77
One 7 ton lorry	164
Two motor cycles	10
TOTAL	251

Accepting that 70 per cent of the vehicle costs should be allocated to the protection of the natural forest reserves, transport capital costs are estimated at 175.1 thousand shillings.

Equipment

Apart from office furnishings and minor items for the 20 forest guards, the equipment requirements for this aspect of the forestry operations will be minimal. A lump sum of 20 000 shillings appears adequate for this item.

Miscellaneous Capital Costs

A nominal sum of five per cent of capital costs has been added to cover this item.

4.2 Recurrent Costs

Recurrent costs are summarised in Table 4.4. Salaries and wages of those involved in both natural forest management and extension work have been allocated according to the system used for capital costs in Section 4.1.

Table 4.4 - Summary of Annual Recurrent Costs, Natural Forest Reserves (1977 constant prices)

Item	Cost (1 000 K Sh)
Vehicle operating	35.0
Building maintenance	11.7
Replacement of equipment	4.0
Office stationery, etc.	1.0
Wages and salaries	185.5
TOTAL	237.2

Vehicles

Vehicle operating and depreciation costs are shown in Table 4.5. These are based on Forest Department estimates.

Table 4.5 - Vehicle Operating and Depreciation Costs (1977 constant prices)

Type of vehicle	(1 000 K Sh per annum) Operating cost	Depreciation	Total cost
LWB Landrover at 20 000 km/annum	27.0	15.4	42.4
Lorry (7 tons) at 10 000 km/annum	20.0	20.5	40.5
Motor cycles (2 No.) at 5 000 km/annum	3.0	2.4	5.4
TOTAL	50.0	38.3	88.3

As in the case of the capital costs, it is assumed that 70 per cent of the annual costs should be allocated to the management and protection programme for the natural forests. On this basis, operating and depreciation costs are estimated at 61.8 thousand shillings per annum.

Buildings

A figure of two per cent of the capital costs has been accepted as the annual maintenance cost for all buildings. From Table 4.3 this is estimated at 14.0 thousand shillings per annum, and of this 11.7 thousand should be allocated to the natural forest programme.

Replacement of Equipment

It is assumed that, on average, the life of equipment would be five years. On this basis, the annual replacement cost is estimated at 4.0 thousand shillings per annum.

Wages and Salaries

Staff requirements are shown in Table 3.1. Salaries will clearly increase over time, in accordance with statutory increments. For the purpose of these estimates, however, a mid-point in each salary scale has been assumed and this is considered to remain constant over the time period considered. On this basis, annual salary costs are shown in Table 4.6.

Table 4.6 - Forest Department Salaries and Wages (1977 constant prices)

Post	Number of staff	(1 000 K Sh) Unit cost/ annum	Total cost/ annum
Forester	1	27.9	27.9
Ranger	2	10.6	21.2
Clerk	1	6.8	6.8
Messenger	1	4.6	4.6
Driver Grade 1	1	9.0	9.0
Driver Grade 2	1	6.8	6.8
Forest guards 1	6	6.1	36.8
Forest guards 2	14	4.6	64.4
TOTAL			177.5

Of the various staff costs shown in Table 4.6, 70 per cent of the staff costs other than that of forest guards, are costed against the management of the natural forests. The guards, however, would operate entirely within the natural forest areas and hence the cost of salaries and wages is estimated at 154.6 thousand shillings per annum. To this has been added an on-cost of 20 per cent to cover travel, uniforms and allowances, giving a total annual cost for this item of 185.5 thousand shillings.

PART 2

SUPPLY OF TIMBER AND FUEL REQUIREMENTS

CHAPTER 5 DEMAND AND SUPPLY

5.1 Introduction

The planners of previous settlement schemes in Kenya appear to have given little thought to the settlers' timber and fuelwood requirements. The result, inevitably, has been the destruction of the natural vegetation in ever increasing areas surrounding the schemes. At Hola, for example, the riverine forest has virtually disappeared; the *Acacia* species in the large area of *Acacia/Commiphora* scrub thicket to the north of the scheme described by the ILACO/Acres team in 1964 have been exploited (see Chapter 1); and at present fuelwood is collected from considerable distances and transported to Hola by bicycle.

The Bura Project (Stage I) may eventually cover about 12 thousand hectares and even the first phase will virtually double the area under irrigation in Kenya. It is estimated that during Phase I, some 60 thousand people may locate in the Bura area, and Phase II, if implemented, would presumably result in a similar in-migration.

Clearly, the natural vegetation of the region is incapable of providing timber and fuel requirements for such a large population, even if its total destruction was acceptable. This being the case, it is essential to plan and make provision for alternative supplies to meet the wood requirements in the Bura area.

5.2 Demand

Estimates of demand for fuel, poles and sawn timber vary enormously from one data source to another. Ideally, a survey of present consumption in the Bura-Hola area should have been undertaken. This might have formed part of the Government's survey of wood requirements and sources of supply mentioned in the IBRD report (1). Unfortunately no such survey was carried out, nor has it been possible to undertake it in the time allocated for the consultants' appraisal of the forestry sector.

As a result, estimates of future requirements are based upon population projections and a range of per caput consumption estimates, formulated in various parts of Africa.

Per Caput Consumption

Seven consumption estimates have been obtained, these cover a number of countries and are discussed in turn.

The ILACO feasibility study (Annex E page 22) (12) estimated the wood requirements of a family at 2.0 cubic metres (m^3) per family per annum, equivalent to 0.33 cubic metres per caput per annum on the assumption of an average family size of six. The basis of this estimate is not stated.

The NIB in their draft paper entitled 'Forestry Aspect of the Bura Irrigation Scheme' accepted the ILACO estimate and claimed that it is supported by data obtained in Lamu. The data supplied in this NIB paper are as follows:-

Total recorded consumption of fuelwood	=	1 100 m^3
Charcoal (3000 bags)		
Round wood equivalent of charcoal	=	750 m^3
Total wood consumption	=	1 850 m^3
Population of Lamu	=	11 000 people
Per caput consumption	=	0.168 m^3

Assuming an average family size of 6, this is equivalent to 1.01 m^3 per family per annum.

The recent IBRD report (January 1977) contains an estimate based on a survey in Tunisia and is accompanied by the statement 'these figures are similar in Kenya' (Annex 9, Appendix 1, page 4). It states per caput consumption to be 2 kilogrammes (kg) per person per day (10-20 kg per family) of fuelwood plus 80-150 kg per family per annum for housing purposes. Assuming an average figure of 15 kg per family per day and a specific gravity of 0.75, this is equivalent to 7.3 cubic metres of fuelwood per family per annum, plus 0.1 cubic metre of timber for building purposes.

An unpublished survey of fuelwood requirements in Kenya, undertaken by Dyson of the East African Agricultural and Forestry Research Organisation, was quoted in a letter to the Director of the Tea Research Institute in 1972. This stated consumption to be between 10.0 and 11.5 cubic metres stacked volume per family per annum. Other work by Dyson has shown the round wood equivalent of this stacked volume to be between 6.25 and 7.20 cubic metres. Accepting a family size of 6, this is equal to about 1.12 cubic metres per caput per annum. It must be noted, however, that the survey was undertaken in an upland area where supplies of fuelwood were plentiful.

In 1962 Arnold, De backer and Pringle published their report on wood consumption in Kenya (13). This showed that in rural areas, at a medium income level, per caput consumption amounted to 1.03 cubic metres per annum.

The FAO (1974) report entitled 'Tree Planting Practices in African Savannahs', presents the following statistics based on surveys in a number of countries.

	m^3 per caput per annum
Fuelwood	0.90
Round wood (poles, etc.)	0.05
Sawn wood	0.03
Total	0.98

Finally, in 1976 Hunting Technical Services, in association with Sir M. MacDonald & Partners, undertook a survey of wood consumption in Tigrai Province, Ethiopia (14). In terms of the availability of fuelwood from natural vegetation resources, this area is not dissimilar to the Lower Tana River Basin and the following data were obtained:-

	m^3 per caput per annum
Fuelwood	0.553
Charcoal	0.014
Poles	0.052
Total	0.619

The various surveys discussed above are summarised in Table 5.1, in terms of per caput consumption.

Table 5.1 - Summary of Wood Consumption Surveys

Data source	Per caput consumption m^3 /annum (solid volume)
ILACO Feasibility study (2.0 m^3 per family)	0.333
NIB draft project planning paper (1.01 m^3 per family)	0.168
IBRD: 1976 report (7.43 m^3 per family)	1.238
EAAFRO: 1972 (6.73 m^3 per family)	1.122
Arnold *et al* (1962)	1.027
FAO (1974)	0.980
Hunting Technical Services (1976)	0.619
Average per caput consumption	0.784

Several of the surveys summarised in Table 5.1 were carried out in areas where wood supplies are not scarce. There is clearly a correlation between availability and consumption; and therefore for the purpose of planning the Bura Project an average figure of 0.7 cubic metre per annum per caput is accepted as reasonable in this report.

As in the case of other consumption items, the demand for wood is related to per caput income levels. This relationship was investigated in Kenya by Arnold *et al.* in 1962 (13). A good correlation was found between per caput consumption and income when consumption was expressed as a percentage of a theoretical saturation level and plotted on a cumulative probability scale, and income was expressed in logarithmic terms.

The relationship obtained was expressed by:

$$Y = 0.5941 + 1.23X$$

when Y = the t value corresponding to per caput consumption (expressed as a percentage of the saturation level)

and X = the log of per caput cash income (expressed in Kenyan pounds, i.e. K Sh 20/-)

It has not been possible to undertake a similar exercise for Bura, although before 1981 it is recommended that this should be done and the proposed planting programme modified accordingly. Instead it has been assumed that over the period 1980 - 1985, per caput consumption would remain constant at 0.70 cubic metre per caput per annum. Thereafter, between 1986 and 2000, it is assumed that consumption would increase by 0.02 cubic metre per caput per annum, reaching a level of 1.0 cubic metre per caput by the year 2000.

Population Projections

The rate of settlement during the implementation of Phase I, Stage I, of the Bura Project and the subsequent population growth is discussed in a separate Annexe. Over a 20 year period the population is expected to rise to 86 thousand people as a result of the Phase I, Stage I, Project alone.

Projected Demand

Based on the per caput consumption data and the population projections, total demand for wood products is presented, by year, in Table 5.2. This shows a very rapid increase in demand over the first five years of the project as new settlers and Government officials arrive. Thereafter the annual increase in demand is much less, rising from about 2000 cubic metres per annum between Years 5 and 6 to approximately 5000 cubic metres per annum between Years 19 and 20. The total demand is projected to reach 86 000 cubic metres per annum by the 20th year of the project.

Table 5.2 - Projected Gross Demand for Wood
Bura Project Phase I, Stage I, 1980 - 2000

Year	Projected population (thousands)	Estimated consumption (m^3/caput/annum)	Total demand (thousand m^3)
0 (1980)	1.2	0.70	0.8
1	8.0	0.70	5.6
2	20.9	0.70	14.6
3	39.3	0.70	27.5
4	48.4	0.70	33.9
5	50.1	0.70	35.1
6	51.9	0.72	37.4
7	53.7	0.74	39.7
8	55.7	o.76	42.3
9	57.7	0.78	45.0
10	59.8	0.80	47.8
11	62.0	0.82	50.8
12	64.2	0.84	53.9
13	66.6	0.86	57.3
14	69.1	0.88	60.8
15	71.7	0.90	64.5
16	74.3	0.92	68.4
17	77.1	0.94	72.5
18	80.0	0.96	76.8
19	83.1	0.98	81.4
20	86.2	1.00	86.2

The projections in Table 5.2 are based on the assumption that no substitution will occur between wood based fuel (either charcoal or firewood) and other fuels such as paraffin. In practice it is probable that substitution will occur, but at what rate or in relation to what level of per caput income is not known.

If the price differential between fuelwood and paraffin remains constant, substitution can be expected to occur as incomes rise. But, if the differential increases, the rate of substitution will fall.

This question is clearly of importance and should be considered further before the proposed planting programme (Chapter 7) is initiated.

To arrive at an estimate of future wood requirements, the assumptions shown in Table 5.3 have been made with regard to substitution.

Table 5.3 - Assumed Rates of Substitution of Alternative Fuels for Fuelwood Bura Project, Phase I, Stage I

Social group	Project (years)	Fuelwood	Alternative fuels (paraffin, gas)
		(per cent of total consumption)	
Government officials in the admn. centre	0 - 5	50	50
	6 - 10	30	70
	11 - 20	10	90
Junior Government staff in local centres	0 - 5	80	20
	6 - 10	70	30
	11 - 20	60	40
Farmers	0 - 5	95	5
	6 - 10	90	10
	11 - 20	80	20

It is stressed that these assumptions are not supported by a firm data base and, therefore, the projections of net demand, shown in Table 5.4, are only indicative. In the absence of other data, however, they are used in subsequent sections as the basis of planning future development.

Table 5.4 - Projected Net Demand for Wood Bura Project Phase I, Stage I, 1980-2000 (1 000 cubic metres)

Year	Consumption by social group			Total
	Senior Staff	Junior Staff	Farmers	Consumption
0 (1980)	0.3	0.2		0.5
1	0.8	0.6	3.0	4.4
2	1.9	1.4	8.7	12.0
3	2.5	1.8	19.3	23.6
4	2.5	1.8	25.3	29.6
5	2.5	1.9	26.4	30.8
6	1.5	1.8	26.8	30.1
7	1.6	1.9	28.7	32.2
8	1.6	2.0	30.7	34.3
9	1.7	2.1	32.8	36.6
10	1.7	2.3	35.0	39.0
11	0.6	2.1	33.0	36.0
12	0.6	2.2	35.5	38.3
13	0.6	2.3	37.9	40.8
14	0.6	2.5	40.4	43.5
15	0.6	2.6	43.1	46.3
16	0.6	2.7	45.9	49.2
17	0.7	2.9	48.8	52.4
18	0.7	3.1	52.0	55.8
19	0.7	3.2	55.3	59.2
20	0.7	3.4	58.8	62.9

5.3 Supply

As mentioned in Part 1, while the natural vegetation of the Lower Tana River Basin has been studied from a botanical viewpoint, there are no data concerning its productivity in terms of fuelwood or timber. The Inventory Section of the Forest Department has not undertaken any surveys in the area and therefore the estimates contained in this section are based on a visual assessment of the vegetation and the 1:50 000 scale maps prepared from the 1975-76 aerial photography.

The main sources of fuelwood are

- (a) The riverine forest
- (b) The dense-medium scrub
- (c) The light-medium scrub

Other vegetation classes, shown in Figures 3.1 to 3.5, are considered to be of no value in terms of fuelwood production.

The standing volume of the riverine forests is estimated to lie between 50 and 100 cubic metres per hectare, and of this approximately 10 per cent is in the form of dead or badly damaged trees.

In the dense to medium scrub areas the total standing volume may be approximately five cubic metres per hectare, of which perhaps two cubic metres are of any value as fuelwood. Lastly, the light to medium scrub areas may provide approximately one cubic metres of utilisable fuelwood per hectare. The total production from these three vegetation types is considered in turn.

It is recommended (Chapter 3) that the riverine forests within the neighbourhood of the Bura Project are gazetted and exploitation within these be limited to the removal of dead and severely damaged trees. The total area proposed for gazettement is 158 square kilometres of which roughly half is high forest. Assuming that 7.5 cubic metres per hectare could be removed without reducing the protective efficiency of these forests, a total volume of 59 thousand cubic metres of timber might be obtained from this source.

Within the irrigation project boundaries there is only an insignificant area of dense-medium scrub, estimated at less than 100 hectares. This would provide 200 cubic metres of utilisable fuelwood on the assumptions presented above. Medium to light scrub covers approximately 3600 hectares of the proposed Stage I area, and at one cubic metre per hectare the total volume available would be 3600 cubic metres.

Outside the project boundaries there may be an additional 10 to 15 thousand cubic metres of fuelwood within walking distance (5 kilometres) of the project.

Thus in total the supply of utilisable fuelwood within the neighbourhood is estimated at approximately 75 000 cubic metres. In view of the data base, this figure is clearly subject to a wide margin of error. It is recommended that before 1981 the Forest Department be requested to undertake an inventory of the fuelwood resources. The development plans for meeting timber demands, presented in the following chapters, can then be amended accordingly.

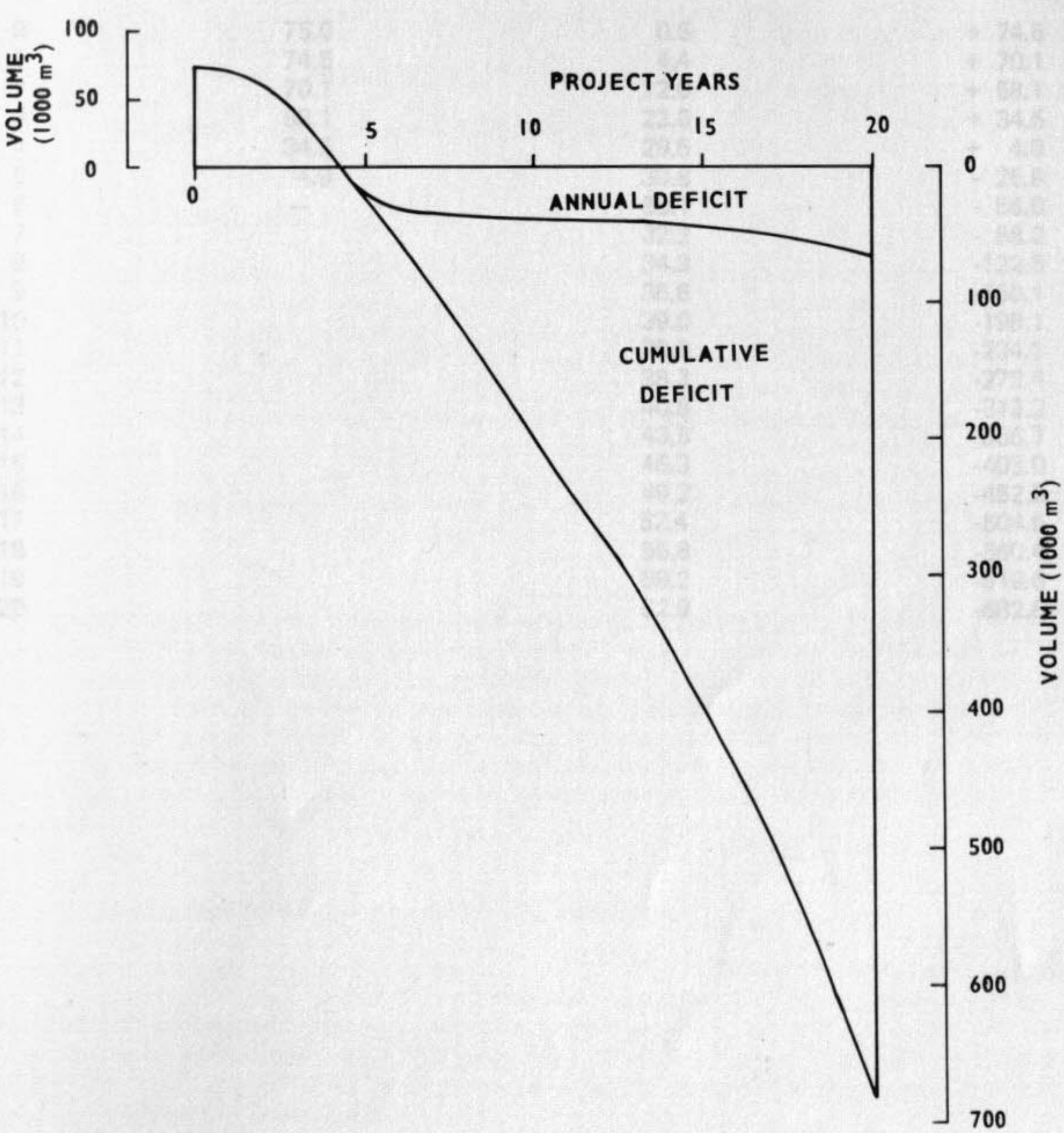
5.4 The Balance of Demand and Supply

On the basis of the estimates presented in Sections 5.2 and 5.3, the demand - supply balance over the 20 year period considered is shown diagramatically in Figure 5.1. Clearly, a severe deficit will occur within four to five years if the project population is left to obtain its timber and fuel requirements from natural vegetation resources.

Table 5.5 and Figure 5.1 also emphasise the enormous pressure to which the riverine forests will be subjected. Even with gazettement and protection by forest guards, it is apparent that their destruction is inevitable unless an alternative source of supply is provided.

FIGURE 5.1

THE BALANCE OF SUPPLY FROM NATURAL VEGETATION RESOURCES AND DEMAND FOR TIMBER - BURA PROJECT PHASE I STAGE I



The deficit between supply and demand is so great (reaching a cumulative total of 680 thousand cubic metres over the 20 year period considered), that despite the weakness of the data base, it is firmly concluded that specific provision will have to be made to meet future demand. Alternative methods of doing so are considered in the following chapter.

Table 5.5 - The Balance of Supply from Natural Vegetation Resources and Demand for Wood, Bura Project, Phase I, Stage I (1 000 cubic metres)

Year	Supply available from natural vegetation	Demand for Timber	Cumulative Balance
0	75.0	0.5	+ 74.5
1	74.5	4.4	+ 70.1
2	70.1	12.0	+ 58.1
3	58.1	23.6	+ 34.5
4	34.5	29.6	+ 4.9
5	4.9	30.8	- 25.9
6	—	30.1	- 56.0
7		32.2	- 88.2
8		34.3	-122.5
9		36.6	-159.1
10		39.0	-198.1
11		36.0	-234.1
12		38.3	-272.4
13		40.8	-313.2
14		43.5	-356.7
15		46.3	-403.0
16		49.2	-452.2
17		52.4	-504.6
18		55.8	-560.4
19		59.2	-619.6
20		62.9	-682.5

CHAPTER 6 DEVELOPMENT ALTERNATIVES

6.1 Introduction

Basically, five alternative methods of meeting the projected deficit in fuel requirements have been identified. These are from:-

(a) the riverine forests;
(b) unirrigated plantations located to the south of Garsen;
(c) irrigated plantations adjacent to the agricultural area in the Bura Project;
(d) natural forests to the south-east of the project area;
(e) charcoal;
(f) fossil fuels such as paraffin (kerosene).

Each of these is considered in turn in the following six sections.

6.2 The Riverine Forests

Where the natural forests adjacent to settlement schemes have not been protected, they have been exploited on an uncontrolled basis to the point of complete destruction. This has occurred in the vicinity of Hola and undoubtedly would occur at Bura. If this were to be allowed, the two forest areas proposed for gazettement (Bura and Nanigi - see Chapter 3) would provide somewhere in the region of 600 thousand cubic metres, if clear felled. This volume would meet the project's requirements for nearly the whole of the 20 year period considered. Assuming that no control was exercised by the Forest Department, neither capital nor recurrent management costs would be incurred and the cost of the fuelwood supplied to the project would be very low (approximately 50 shillings per cubic metre, see Section 6.5). In direct financial terms, there can be no doubt that clear felling the riverine forests would be the least costly method of meeting fuelwood and timber requirements.

It is strongly recommended, however, that this alternative should not be adopted. Reasons for preserving the riverine forests are presented in Part 1 and in Appendix A. Unfortunately the benefits associated with protecting the natural forests are extremely difficult to quantify, and hence it is not possible to justify the preservation of these forests upon conventional criteria such as cost/benefit ratios. There is, however, a rapidly growing public awareness of the need to protect the natural forests of Kenya and no less a person than His Excellency the President has recently expressed the national view that forests such as those along the Tana should be preserved.

6.3 Unirrigated Forests Located to the South of Garsen

To the south of Garsen the rainfall is markedly higher than at Bura (600 mm compared to 400 mm per annum) and this is reflected in the increased luxuriance of the natural vegetation. It is probable that unirrigated forest plantations could be established successfully in this area, from which fuelwood and timber could be transported to Bura. There are no such plantations at present and hence a number of assumptions have had to be made in determining the cost of fuelwood, delivered to Bura.

The most critical of these concerns the mean annual increment that could be achieved. Growth rates recorded in a number of research plots have been examined (see Section 7.4). On the basis of these it is thought unlikely that an increment in excess of 10 cubic metres per hectare per annum would be obtained from a species such as *Eucalyptus camaldulensis* or *E. tereticornis*. With this mean annual increment, a rotation length of 10 years would be required to give a volume of 100 cubic metres per hectare at clear felling.

Input and cost assumptions relating to dryland plantation establishment are summarized in Table 6.1. These are based upon Forest Department estimates used in the preparation of the Second World Bank Loan Forestry Project and data obtained in other countries by the consultants. Land costs are excluded on the assumption that State land would be utilised.

At a discount rate of 12 per cent the net present value of the costs involved over the 30 year period considered is 3483 shillings per hectare. To cover these costs, the price of timber (at road side) would have to be 70.7 shillings per cubic metre. To this cost must be added that of transporting the fuelwood to the Bura Project. The distance from Garsen to Bura is approximately 140 kilometres and transport costs are taken at 1.0 shilling per tonne-kilometre. Assuming the fuelwood to have a specific gravity of 0.5, the cost per cubic metre per kilometre is 0.5 shilling, giving a total transport cost of 70.0 shillings per cubic metre.

On the basis of the above calculations, it appears that the cost per cubic metre of fuelwood, delivered to Bura from dryland plantations in the vicinity of Garsen would be approximately 140 shillings per cubic metre.

Table 6.1 - Estimated Unirrigated Fuelwood Production per hectare near Garsen: Technical and Financial Assumptions at Constant 1977 Prices (Kenya Shillings)

Item	Year	Units	Quantity	Cost per hectare Unit	Total
Yield:					
1st clear felling	10	m^3/ha	100		
Coppice reduction	12	m^3/ha	10		
2nd clear felling	20	m^3/ha	100		
Coppice reduction	22	m^3/ha	10		
3rd clear felling	30	m^3/ha	100		
Inputs:					
Land demarcation	0	man-days/ha	3	11	33
Clearing	0	man-days/ha	20	11	220
Road construction	0	man-days/ha	20	11	220
Cutting stakes	1	man-days/ha	3	11	33
Staking out	1	man-days/ha	7	11	77
Pitting	1	man-days/ha	23	11	253
Seedlings	1	thousand/ha	1.6	290	464
Planting	1	man-days/ha	10	11	110
Beating up	2	man-days/ha	5	11	55
Weeding	2	man-days/ha	7	11	77
	3	man-days/ha	7	11	77
Clear felling	10	man-days/ha	64	11	704
Coppice reduction	12	man-days/ha	32	11	352
Clear felling	20	man-days/ha	64	11	704
Coppice reduction	22	man-days/ha	32	11	352
Clear felling	30	man-days/ha	64	11	704
Annual Costs:					
Road maintenance	1-30	sh/ha/annum		25	750
Fire breaks	1-30	sh/ha/annum		20	600
Overheads	1-30	sh/ha/annum		150	4 500
Total Cost over 30 years					10 285

6.4 Supplementarily Irrigated Plantations Adjacent to the Agricultural Area of the Bura Project

Adopting a similar approach to that followed in Section 6.2, the technical and financial assumptions used in appraising fuelwood production at Bura under supplementarily irrigated conditions are summarised in Table 6.2.

With supplementary irrigation, it is considered feasible to obtain an average mean annual increment of 15 cubic metres per hectare per annum. This figure may appear conservative in comparison to the ILACO assumption of 35 cubic metres per hectare per annum, and ludicrously low in relation to that of 100 cubic metres per hectare per annum contained in the NIB paper on forestry. Nonetheless, the consultants believe that yields in excess of 15 cubic metres per hectare per annum are unlikely to be achieved in the Bura area and, given the weakness of the data base, a conservative rather than optimistic assumption is thought appropriate. The question of growth rates under irrigated conditions is considered further in Chapter 7.

With a mean annual increment of 15 cubic metres per hectare per annum, a rotation length of seven years would provide a total volume at clear felling of 105 cubic metres per hectare. As in the case of the dryland plantation analysis, a main crop and two coppice rotations have been considered under supplementarily irrigated conditions. The levelling cost and that of installing the irrigation system are based on the estimated costs for the agricultural area.

The net present value of the costs incurred, discounted at 12 per cent, is 8763 shillings per hectare. To cover these costs the price of timber at road side would have to be 101.2 shillings per cubic metre. The distance to the market centres of the scheme is assumed to be 5 kilometres on average and, using the unit transport costs given in Section 6.3, the cost of transporting one cubic metre would be 2.50 shillings.

From the above analysis, it appears that the cost per cubic metre, delivered to Bura from supplementarily irrigated plantations adjacent to the agricultural project, would be 103.7 - say 105 shillings per cubic metre.

Table 6.2 - Supplementarily Irrigated Fuelwood Production per hectare, Bura: Technical and Financial Assumptions at Constant 1977 Prices (Kenya Shillings)

Item	Year	Units	Quantity	Cost per hectare Unit	Total
Yield:					
1st clear felling	7	m^3/ha	105		
Coppice reduction	9	m^3/ha	15		
2nd clear felling	14	m^3/ha	105		
Coppice reduction	16	m^3/ha	15		
3rd clear felling	21	m^3/ha	105		
Inputs:					
Land demarcation	0	man-days/ha	3	11	33
Clearing	0	man-days/ha	20	11	220
Levelling	0	sh/ha		1 000	1 000
Road construction	0	man-days	20	11	220
Installation of irrigation system	0	sh/ha			3 640*
Seedlings	1	thousand/ha	1.6	290	464
Planting	1	man-days/ha	10	11	110
Beating up	2	man-days/ha	5	11	55
Weeding	2	man-days/ha	7	11	77
	3	man-days/ha	7	11	77
Irrigation	1	man-days/ha	20	11	220
	2-21	man-days/ha/annum	10	11	2 090
Clear felling	7	man-days/ha	67	11	737
Coppice reduction	9	man-days/ha	34	11	374
Clear felling	14	man-days/ha	67	11	737
Coppice reduction	16	man-days/ha	34	11	374
Clear felling	21	man-days/ha	67	11	737
Annual Costs:					
(as for 6.1) plus Irrigation maintenance	1-21	sh/ha/annum		250	5 000
Total Cost over 21 years					16 165

* 70% for tertiary canalisation executed in first three years of afforestation development.

6.5 Natural Forests to the South-East of the Project Area

There are several blocks of natural forest to the east of the Tana River which could provide fuelwood for the Bura Project. Three of these have been examined and the characteristics of each are summarised below.

Boni Forest is located 130 kilometres north north-east of Lamu and approximately 130 kilometres south-east of Bura. The total area of this forest is 18 466 hectares of which 9952 are classified as productive. An inventory was carried out in 1973 by the Forest Department and the statistics are summarised in Table 6.3.

Table 6.3 - Boni Forest, Summary of 1973 Inventory

Cutting class	Area (ha)	Gross merchantable * volume (m³) Total	Per ha	Gross commercial ** volume (m³) Total	Per ha
3 Pole wood	353	8 434	23.9	176	0.5
4 Immature	6 177	270 994	43.9	44 175	7.2
5 Mature	3 422	103 640	30.3	64 846	19.0
TOTAL	9 952	383 068		109 197	

* The gross merchantable volume is the total volume in trees over 12 inch diameter.
** The commercial volume is the merchantable volume of commercially important species.

Accepting that commercially important species would not be utilised for fuelwood, the total volume available in Boni is estimated at 274 thousand cubic metres.

Lungi Forest, situated 65 kilometres north north-east of Lamu, and 140 kilometres from Bura, has also been surveyed by the Forest Department Inventory Section. Details of available volumes are summarised in Table 6.4.

Table 6.4 - Lungi Forest: Summary of 1973 Inventory

Cutting class	Area (ha)	Gross merchantable volume (m³) Total	Per ha	Gross commercial volume (m³) Total	Per ha
4 Immature	1 092	102 156	93.6	27 970	25.6
5 Mature	1 312	100 057	76.2	45 481	34.7
6 Over-mature	996	116 150	116.7	57 375	57.6
TOTAL	3 400	318 363		130 826	

It is apparent from Table 6.4 that 188 thousand cubic metres of non-commercial timber (of merchantable size) could be exploited to meet fuelwood requirements in the Bura Project, if this approach was considered desirable.

Thirdly, Witu Forest which is located on either side of the Malindi-Lamu road, 5 kilometres from the Witu trading centre and 16 kilometres from the Indian Ocean, could be exploited. This forest was also surveyed in 1973 by the Inventory Section and the results of the inventory are summarised in Table 6.5.

Table 6.5 - Witu Forest: Summary of 1973 Inventory

Cutting class	Area (ha)	Gross merchantable volume (m³) Total	Per ha	Gross commercial volume (m³) Total	Per ha
4 Immature	16	1 735	109.2	251	15.9
5 Mature	1 380	199 209	144.3	99 620	72.2
5-2 Mature-open canopy	137	11 218	82.0	987	7.2
TOTAL	1 533	212 152		100 858	

Subtracting the commercial volume from the gross merchantable volume shown in Table 6.5, it is apparent that 111 thousand cubic metres could be utilised to supply timber requirements in Bura.

In summary, the forests considered above could supply the following volume of timber:

Table 6.6 - Summary of Boni, Lungi and Witu Forests Practical Timber Supplies

Forest	Distance from Bura (km)	Available volume (thousand m³)
Boni	130	274
Lungi	140	188
Witu	180	111
TOTAL		573

In theory, this volume would be sufficient to meet projected Bura Project Stage I, Phase I, requirements over virtually the whole of the 20 year period considered (see Table 5.5). Assuming that the forests were exploited in a systematic manner and the timber was transported by road to Bura, the following calculations indicate the costs which may be involved. A basic premise upon which economic comparisons of alternatives are based is that 'like should be compared with like'. Clearly, plantation production is very different from natural forest exploitation and this presents problems in direct comparison of the two systems. The basic technical and financial assumptions adopted are summarised in Table 6.7.

Table 6.7 - Natural Forests: Technical and Financial Assumptions at Constant 1977 Prices (Kenya Shillings)

Item	Units	Quantity	Cost per hectare Unit cost	Total cost
Yield				
Selection felling*	m³ /ha	53		
Inputs				
Demarcation of coup	man-days	10	11	110
Road construction	man-days	20	11	220
Selection marking	man-days	4	11	44
Felling and cross cutting	man-days	175	11	1 925
Overheads	sh/ha/annum		50	50
TOTAL				2 349

*The average volume in the three forests considered.

From Table 6.7 it appears that production costs of wood from the natural forests may be as low as 44 shillings per cubic metre. To this must be added transport costs to Bura. Using the unit rate adopted in previous sections, the cost of timber, delivered to Bura, is shown in Table 6.8.

Table 6.8 - Comparative Costs of Wood Delivered to Bura
(Kenya Shillings per cubic metre)

Source	Cost
Boni Forest	109
Lungi Forest	114
Witu Forest	134

6.6 Charcoal

It is possible that charcoal could be produced in the natural forests referred to in the previous section. This could be transported to the Bura Project and used in place of fuelwood. In assessing the viability of this alternative the following assumptions have been made; these are based on kiln manufacturers' specifications.

(a) Kiln type: portable steel
(b) Kiln capacity: 8.5 cubic metres stacked, equivalent to 5.9 cubic metres solid volume
(c) Production: 0.5 tonne charcoal per firing; two firings per week
(d) Labour requirements:
loading kiln = 2 man-days per firing
tending kiln = 1 man-day per firing
unloading kiln = 1 man-day per firing

Based on Table 6.7 it is estimated that the cost of timber would be 44 shillings per cubic metre at roadside. To this must be added the cost of conversion to charcoal which has been estimated on the basis of the following cost assumptions:

(a)	Price of kiln f.o.b. U.K.	= £820 sterling
(b)	Shipping and handling	= £200 sterling
(c)	c.i.f. price Mombassa	= £1020 sterling
	(say)	= 14.5 thousand shillings
(d)	Transport to site	= 1.0
(e)	Total cost on site	= 15.5
(f)	Depreciation (8 year life) per annum	= 1.9
(g)	Depreciation per firing (104/annum)	= 0.02
(h)	Annual maintenance (3%)	= 0.5
(i)	Maintenance per firing	= 0.005
(j)	Miscellaneous equipment per annum	= 1.0
(k)	Miscellaneous equipment per firing	= 0.01

In summary the costs of charcoal production are estimated as follows:

	Kenya Shillings per firing
Kiln capital costs	35
Labour (4 man days)	44
Wood (5.9 m^3)	260
TOTAL	339

As each kiln load produces 0.5 tonne of charcoal, the cost per tonne is estimated at 678 shillings at the point of production. To this must be added transport costs and at the rates assumed in previous sections, the cost of charcoal delivered to Bura is shown below for each forest considered:

Source	Kenya Shillings per tonne
Boni	808
Lungi	818
Witu	858

The relative merits of fuelwood and charcoal have been compared in terms of the thermal energy each provides. This is assumed to be 7.1 calories per gramme for charcoal and 3.5 for wood. Thus, one tonne of charcoal produces 7.1 million calories while 1 tonne of wood provides 3.5 million calories. Assuming wood to have a specific gravity of 0.5, 4.1 cubic metres of wood provide the same thermal energy as one tonne of charcoal. This volume of timber, produced from irrigated plantations adjacent to the scheme is estimated to cost 430 shillings (Section 7.4). Conversely, to provide the same thermal energy as one cubic metre of wood, costing 105 shillings, 0.25 tonne of charcoal would be required. This would cost 202 shillings if obtained from Boni, 205 from Lungi and 215 from Witu.

6.7 Fossil Fuels

The use of fossil fuels has been advocated as an alternative to fuelwood. In comparing the relative costs of these two fuels the following assumptions have been made.

(a) The calorific value of paraffin (kerosene) is 10.4 calories per gramme while that of wood is 3.5 calories per gramme.

(b) The specific gravity of paraffin is 0.9; that of wood varies considerably from species to species and in the following calculation a value of 0.5 has been adopted.

On the basis of the above assumptions one cubic metre of fuelwood would provide 1750 thousand calories while 1 litre of paraffin provides 9.36 thousand calories. Thus in terms of thermal energy, one cubic metre of wood is equivalent to 187 litres of paraffin.

The price of paraffin delivered to Bura is not known; the 1977 wholesale price, however, is 1 353 shillings per 1 000 litres. If it is assumed that the retail price in Bura would be 25 per cent higher than this, the cost to the settler would be 1.7 shillings per litre. Thus, to provide the equivalent thermal energy to that provided by one cubic metre of fuelwood, 318 shillings worth of paraffin would be required.

6.8 Conclusions

The results of the various calculations shown in previous sections are summarised in Table 6.9. From this it is apparent that apart from exploiting the riverine forests, which is considered unacceptable for ecological reasons, the least costly method of meeting demand would be to establish supplementarily irrigated fuelwood plantations adjacent to the irrigation project.

Table 6.9 - Summary of Alternative Fuel Supply Costs (constant 1977 prices, Kenya Shillings per cubic metre wood equivalent)

Type of fuel	Source of fuel	Cost
Wood	1. Riverine forests adjacent to project	50
	2. Unirrigated plantations to the south of Garsen	140
	3. Supplementarily irrigated plantations adjacent to the project	105
	4. Natural forests to the south east of the project:	
	Boni	109
	Lungi	114
	Witu	134
Charcoal	Natural forests to the south east of the project:	
	Boni	202
	Lungi	205
	Witu	215
Paraffin	Retail outlets in Bura	318

There are various additional factors which require consideration in reaching a conclusion regarding the optimum source of fuelwood for the Bura project. Some of these cannot be quantified and hence precise comparison of the alternative options is extremely difficult.

The cost of supplying the project's requirements from both Boni and Lungi forests appears only marginally higher than the cost of irrigated fuelwood production. Two items which are not costed against the Boni or Lungi production option however are the upgrading of the road between Bura and Kulank, and the establishment of a ferry across the Tana River at Bura. Both items would be necessary if large volumes of timber were to be transported to the project. Furthermore, in estimating transport costs to Bura it has been assumed that the vehicles employed would obtain return loads from the project to the coast. This assumption is tenable over part of the year only (following the cotton harvest for example) but it is unlikely that every lorry would obtain a return load. These additional costs have not been calculated but clearly they would increase the differential cost between irrigated fuelwood supplies and those from natural forests such as Witu or Boni.

One additional factor which has not been examined is the other demands for wood exerted upon the three natural forests considered. It is not unreasonable to assume that the population located in the vicinity of these forests obtain their fuel supplies from them and it is known, for example in Witu, that other settlement schemes are being developed. It is considered unwise, therefore, to assume that Bura, located over 100 kilometres from the three forests considered here, could be supplied from them. The different types of fuel considered (wood, charcoal and paraffin) have been compared on the basis of their relative calorific values. There are of course other factors which have to be considered, including efficiency of use, consumer preferences, reliability of supply and additional or indirect costs.

In terms of efficiency, there can be little doubt that paraffin can be used more efficiently than charcoal, which in turn is somewhat more efficient than wood. The relative efficiences, however, depend very largely upon the traditional methods of cooking and upon the type of cookers or stoves used. Comparison of an open wood fire and a modern paraffin stove would give an efficiency factor in the order of 4.0 - 5.0 in favour of the latter. On the other hand, a modern wood burning stove would reduce the efficiency factor to approximately 2.0. Similar problems arise in comparing different charcoal burners with either wood stoves or paraffin cookers. If it is assumed that for a given sum of money the settler could purchase a modern efficient wood, charcoal or paraffin stove, the relative efficiency factors may be of the following order:

Wood	1.00
Charcoal	1.75
Paraffin	2.50

On the basis of these factors it appears from Table 6.9 that wood is to be preferred to either charcoal or paraffin in the case of Bura. In practice, of course, the settler is unlikely to purchase a stove of any sort and, in the absence of a controlled supply of fuelwood, he would utilise timber from the natural riverine forests in preference to purchasing paraffin and a stove. Evidence of this is clearly provided in the Hola scheme area.

Based upon data obtained in 1970 Earle (15) developed the following relative price indices for East Africa. Bura cannot be taken as an 'average' situation in East Africa and prices have changed in relation to each other since 1970. None the less, the following indices reinforce the conclusions of this report; namely fuelwood is to be preferred to either charcoal or paraffin.

Fuelwood	1.0
Charcoal	1.6
Paraffin	4.0
Electricity	8.9

On the basis of the calculations and discussion presented in this chapter, it is concluded that the most effective method of meeting the Bura Project's fuelwood and pole requirements would be to establish plantations adjacent to the project area and provide these with supplementary irrigation. Proposals for implementing this policy are presented in the following chapter.

CHAPTER 7 PROPOSED DEVELOPMENT

7.1 Introduction

Based on the conclusions of Chapters 5 and 6, this chapter contains development plans for meeting projected demand. These could not be implemented until 1980 (when irrigation supplies should first become available) and therefore they should be reviewed and modified if necessary before implementation, in the light of the research programme recommended in Part 4.

7.2 Plantation Area Required

The area that has to be afforested is determined by two factors, the projected demand for fuelwood and the mean annual growth rate of the plantations. The data base for the demand projections is considered to be reasonably accurate, but that of the assumed mean annual increment is less satisfactory (see Section 7.4). The median yield assumption made here is that the average mean annual increment (MAI) would be 15 cubic metres per hectare. This may be considered to be too conservative; however, should the proposed species growth trials indicate that higher growth rates can be achieved, the planting programme can be modified accordingly.

The optimum rotation length is not known. With an MAI of 15 cubic metres per hectare per annum, a seven year rotation would provide 105 cubic metres per hectare at clear felling. Once this standing volume has been achieved, it is considered probable that the current annual increment (CAI) would fall below the MAI. Information on this question would be obtained from the species trials at Hola, where it is proposed that the standing volume is measured annually and from this both the MAI and CAI could be calculated.

Thus, in calculating the area to be afforested the following premises have been adopted:-

(a) Demand projections as shown in Table 5.4
(b) A rotation length of seven years
(c) An MAI of 15 cubic metres per hectare per annum

On the basis of these three assumptions, the net area (i.e. excluding roads and fire breaks) to be felled each year is shown in Table 7.1: the corresponding planting programme is shown in Table 7.2.

Table 7.1 - Felling Programme Required to Meet Projected Net Wood Demand Bura Project, Phase I, Stage I

Year	Net demand (thousand m^3)	Net area (ha)	Year	Net demand (thousand m^3)	Net area (ha)
0	0.5	5	11	36.0	343
1	4.4	42	12	38.3	365
2	12.0	114	13	40.8	389
3	23.6	225	14	43.5	414
4	29.6	282	15	46.3	441
5	30.8	293	16	49.2	469
6	30.1	287	17	52.4	499
7	32.2	307	18	55.8	531
8	34.3	327	19	59.2	564
9	36.6	349	20	62.9	599
10	39.0	371			

The first year in which demand could be met from irrigated plantations is Year 8. By then the cumulative total of demand (Years 0-7) will have reached 163 thousand cubic metres. This will have to be met from natural vegetation resources. Locally these are estimated at 75 thousand cubic metres, sufficient for Years 0 - 4. Thereafter it is proposed that the natural forests to the south-east of the project are exploited until Year 8 (i.e. Years 5 - 7 inclusive) when the supplementarily irrigated plantations reach maturity.

In estimating the area required for afforestation (Table 7.2), it is assumed that the proposed forestry trials in Hola would indicate that the most suitable species for planting would be one that coppiced readily.

Table 7.2 - Planting Programme Required to Meet Projected Net Demand to the Year 2000 Bura Project, Phase I, Stage I (hectares)

Year	New planting	First coppice	Second coppice	Cumulative total
1	327	-	-	327
2	349	-	-	676
3	371	-	-	1047
4	343	-	-	1390
5	365	-	-	1755
6	389	-	-	2144
7	414	-	-	2558
8	441	-	-	2999
9	142	327	-	3141
10	150	349	-	3291
11	160	371	-	3451
12	221	343	-	3672
13	234	365	-	3906

The areas shown in Table 7.2 are of course net requirements and adding 15 per cent to allow for roads, irrigation works and fire breaks, the total area required for the proposed forestry scheme is estimated to be 4492 (say 4500) hectares.

As shown in Figure 7.1, it is proposed to locate the plantations adjacent to, and immediately to the east of, the Phase I agricultural area. In total an area of approximately 6000 hectares is available between the project and the edge of the Tana River floodplain. Assuming that no more than 25 per cent of this would be rejected on the grounds of topography or soil characteristics, there appears to be sufficient land available to implement the proposed afforestation programme.

7.3 Suggested Species for Afforestation

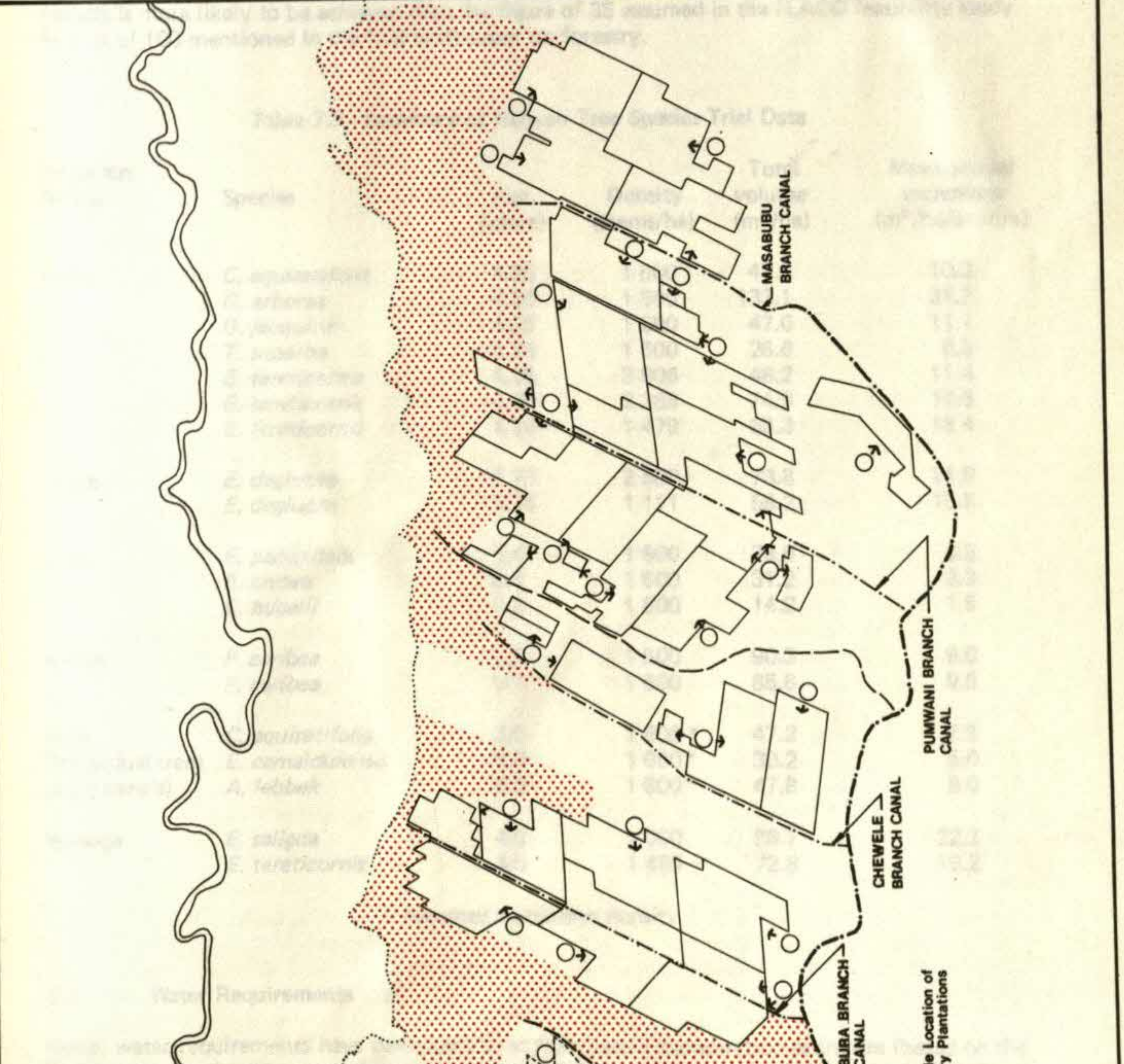
At this point in time it is not possible to recommend two or three particular species for the afforestation programme. In Chapter 12 proposals are presented regarding species trials at Hola. Although these will only have been in progress for a maximum of three years when the first plantations have to be established, they should provide sufficient data upon which to select several species for the first year's planting. Thereafter, as the data base improves, the number of species utilised could be reduced.

7.4 Yield Assumptions

Records of tree growth in the arid areas of Kenya are limited. Information has been obtained from research plots in Gedde, Jilore, the Shimba Hills (Kwale), and, less relevantly, from Muguga. In addition research records from experimental plots in low rainfall areas of Tanzania and the

FIGURE 7.1

PROPOSED LOCATION OF FUELWOOD PLANTATIONS



Sudan have been examined. Yields obtained for a given species vary widely from one trial to another and because there are obvious physical and climatic differences between Bura and the various trials for which records are available, it has not proved possible to estimate growth rates for the proposed afforestation scheme with any certainty. Table 7.3 contains records from the various trials examined.

The table illustrates the problem of arriving at an average yield figure for planning purposes. It also shows, it is believed, that an MAI of 15 cubic metres per hectare per annum (assumed in this report) is more likely to be achieved than the figure of 35 assumed in the ILACO feasibility study or that of 100 mentioned in the NIB draft paper on forestry.

Table 7.3 - Summary of Kenyan Tree Species Trial Data

Location of trial	Species	Age (years)	Density (stems/ha)	Total volume (m^3/ha)	Mean annual increment (m^3/ha/annum)
Gede	*C. equisetifolia*	4.25	1 600	43.6	10.3
	G. arborea	4.25	1 600	133.1	31.3
	G. jacquinii	4.25	1 600	47.0	11.1
	T. superba	4.25	1 600	26.6	6.3
	E. tereticornis	4.25	3 906	48.2	11.4
	E. tereticornis	4.25	2 268	74.9	17.6
	E. tereticornis	4.25	1 479	65.3	15.4
Jilore	*E. deglupta*	3.75	2 500	78.8	21.0
	E. deglupta	3.75	1 111	58.2	15.5
Uuni	*E. paniculata*	9.4	1 600	79.6	8.5
	E. crebra	9.4	1 600	31.2	3.3
	C. hugelii	9.4	1 600	14.2	1.5
Kwale	*P. caribea*	10.0	1 600	90.3	9.0
	P. caribea	9.0	1 600	85.6	9.5
Hola (individual trees along canals)	*C. equisetifolia*	6.0	1 600 *	47.2	7.9
	E. camaldulensis	6.0	1 600 *	30.2	5.0
	A. lebbek	6.0	1 600 *	47.8	8.0
Muguga	*E. saligna*	4.0	1 000	88.7	22.2
	E. tereticornis	4.0	1 450	72.8	18.2

* Assumed plantation density

7.5 Water Requirements

Initial water requirements have been calculated from evapo-transpiration estimates (based on the Penman method) and a crop factor of 0.75. Based on experience in the Sudan and locally at Garissa, it is clear that irrigation is critically important during the first year following establishment. Thereafter, supplementary irrigation, as and when there is surplus water available, should be adequate to ensure survival. There is an obvious correlation between growth rate and water supplied; within limits, the more water the higher the mean annual increment. Thus, following the first year during which the irrigation requirements shown in Tables 7.4 and 7.5 should be met, it is recommended that the plantation area should be supplied with whatever volume of water is surplus to agricultural requirements.

Table 7.4 - Estimated Water Requirements during First Year Following Establishment

Month	Gross requirement (mm)	Effective rainfall (mm)	Net requirements (mm)	Net requirements (m^3/ha)
August	148	2	146	1460
September	149	19	130	1300
October	162	26	136	1360
November	143	58	85	850
December	139	45	94	940
January	147	11	136	1360
February	140	5	135	1350
March	161	34	127	1270
April	151	81	70	700

Meeting the above water requirements would be equivalent to increasing the net effective rainfall of the area to 1340 mm per annum and this should guarantee a high rate of survival.

Table 7.5 - Required Discharge to Meet Water Requirements in First Year (cumecs per hectare)

Month	Net flow required	Total flow* required
August	0.00056	0.00224
September	0.00049	0.00196
Cctober	0.00052	0.00208
November	0.00032	0.00128
December	0.00036	0.00144
January	0.00052	0.00208
February	0.00052	0.00208
March	0.00048	0.00192
April	0.00027	0.00108

*Assuming an overall irrigation efficiency of 50 per cent and 12 hours a day irrigation.

From Tables 7.2 and 7.5 it is possible to calculate the water requirements for the proposed programme. These are shown for the first five years of the programme in Table 7.6. The upper half of the table shows the water required for the establishment phase each year while the lower half shows the supplementary requirements in subsequent years.

Table 7.6 - Discharge Requirements of the Proposed Afforestation Programme: Years 1 - 5 (cumecs)

Month	Year 1	2	3	4	5
Establishment:					
August	0.732	0.782	0.831	0.768	0.818
September	0.641	0.684	0.727	0.672	0.715
October	0.680	0.726	0.772	0.713	0.759
November	0.419	0.447	0.475	0.439	0.467
December	0.471	0.503	0.534	0.494	0.526
January	0.680	0.726	0.772	0.713	0.759
February	0.680	0.726	0.772	0.713	0.759
March	0.628	0.670	0.712	0.659	0.701
April	0.353	0.377	0.401	0.370	0.394
Supplementary*	—	0.132	0.273	0.424	0.562

*Equivalent to 600 mm effective rainfall and provided as surplus available.

The agricultural water requirements are presented in a separate Annexe: subtracting these from the available canal supply, the surplus flow available for the forest plantations has been calculated on a monthly basis. This is shown in Table 7.7 and to demonstrate the balance between supply and demand, the forestry water requirements in Year 5 are included in the table.

Table 7.7 - Water Balance in Year 5: Allowing for Agricultural Requirements (cumecs)

Month	Flow available after meeting agricultural requirements	Flow required in Year 5 by forest plantations: Establishment	Supplementary	Balance
January	7.00	0.759	0.562	+5.679
February	3.10	0.759	0.562	+1.779
March	0.90	0.701	0.562	-0.363
April	3.60	0.394	0.562	+2.644
May	0.70	—	0.562	+0.138
June	—	—	0.562	-0.562
July	2.10	—	0.562	+1.538
August	5.40	0.818	0.562	+4.020
September	4.40	0.715	0.562	+3.123
October	3.40	0.759	0.562	+2.079
November	4.70	0.467	0.562	+3.671
December	5.70	0.526	0.562	+4.612

From Table 7.7 it appears that (in Year 5) supplementary irrigation would not be possible in March and June. There are, however, several months such as January, February, July and August until December when there would be a net surplus and when supplementary irrigation of the plantations could be increased.

The calculations in this section are not based upon practical experience in the project area. It is important, therefore, that the irrigation applied to the proposed research trials in Hola (see Part 4) is monitored carefully and the experience gained used to modify these theoretical estimates.

7.6 Seedlings Requirements

It will be necessary to establish a nursery in the Bura area, a possible location being to the east of the Stage I irrigation area, on the existing minor road connecting Bura with the main Garissa-Garsen road. Seedling requirements are shown by year in Table 7.8.

Table 7.8 - Seedling Requirements for the Proposed Afforestation Programme: Years 1 - 5 (thousands)

Year	Seedlings required: Planting	Beating up	Total
1	523	131	654
2	558	140	698
3	594	148	742
4	549	137	686
5	584	146	730

Eventually seedling requirements will rise to approximately 1.2 million seedlings. To raise this number of plants approximately two hectares would have to be set aside for the nursery.

Nursery practices are well established in Kenya and it is therefore unnecessary to provide recommendations on this topic. The estimated staff requirements and costs are discussed in following sections.

One aspect of nursery management which is not well known in Kenya is the seedling water requirements in arid areas. The following data, taken from FAO (1955), may be adopted as guidelines until local experience is obtained.

Table 7.9 - Seedling Water Requirements (cubic metres per 1000 plants)

Condition	Seedling type	Water requirements
In tins:	conifers (12 months)	15.0
	broadleaved (7 months)	8.5
In pots:	conifers	30.0
	broadleaved	12.0
In beds:	conifers	20.0
	broadleaved	8.0

7.7 Management Proposals

It is recommended that once the afforestation programme has commenced the Divisional Forest Officer responsible for the area, who is located at Lamu at present should move to new offices in the Bura Administrative Centre (Rural Centre). This location would be central for the control of Garissa, Bura, Hola, and the stations to the north of Garissa and on the coast.

For the proposed plantation programme one forester, with some experience, should be posted to Bura. The success of the plantations will depend largely upon the calibre of the forester appointed to this post, and therefore it is essential that a competent and enthusiastic man should be selected. There are, no doubt, several such men in the Forest Department; one who would be particularly suitable for the post is the forester presently stationed at Garissa. In addition to the forester, two rangers would be necessary. Although this may seem too many for the relatively small planting programme envisaged, the techniques adopted will be new and it is considered important that the standards of management are kept as high as possible.

Supporting staff would include office clerks, drivers, and forest guards. The numbers of these are shown in Table 7.10, and again these are higher than the average in the country.

Table 7.10 - Staff Requirements for Plantation Management

Post	Number
Forester	1
Rangers	2
Office clerk	1
Typist	1
Messenger	1
Drivers	2
Forest guards	10
Nursery headman	1
Permanent labour	25

The need for protection in forest plantations is well recognised in Kenya, and the Forest Department General Orders, observed throughout the country, would be practised in Bura. It is unnecessary, therefore, to make specific recommendations on this topic. Fire will of course be a major hazard in the arid conditions of the project area.

7.8 Cost Estimates

As in previous sections costs are divided into capital and recurrent items and are expressed in constant 1977 price terms.

Capital costs

(a) Plantation establishment

The direct costs of plantation establishment are considered as a capital item. These are shown in detail in Table 6.2 on a per hectare basis (costs incurred in Year 0 and Year 1) and are summarised in Table 7.11. It is assumed that if irrigation supplies are provided towards the end of 1980/81, the nursery could produce seedlings for planting in 1981 (during the 1981-82 fiscal year).

Table 7.11 - Capital Costs of Plantation Establishment, 1977 Constant Prices (1 000 Kenya Shillings)

Year	Cost	Year	Cost
1980	1764	1987	1445
1981	5664	1988	1780
1982	6451	1989	1056
1983	1272	1990	983
1984	1246	1991	966
1985	1284	1992	1133
1986	1362	1993	1223

Source: Tables 6.2 and 7.2

(b) Nursery establishment

It is assumed that the nursery would be established in 1980-81 at a total cost of 88.5 thousand shillings. A breakdown of this amount is given in Table 7.12.

Table 7.12 - Construction of Two Hectare Nursery, 1977 Constant Prices
(1 000 Kenya Shillings)

Item	Units	Quantity	Unit rate	Total cost
Site clearing and levelling	Machine hours	70	0.07	4.9
Installing piped irrigation system (50 mm piping)	hectares	2.0	6	12.0
Road construction	hectares	2.0	1	2.0
Fencing	kilometres	0.6	40	24.0
Windbreaks/hedges	kilometres	0.6	1	0.6
Nursery store/office	Number	1	20	20.0
Pricking out shed	Number	1	10	10.0
Nursery equipment	Lump sum			15.0
Total cost				88.5

(c) Buildings

Office and housing requirements and costs for the afforestation programme are shown in table 7.13. It is assumed that these would be constructed during the 1980-81 and 1981-82 fiscal years and the total sum involved is estimated at 774 thousand shillings.

Table 7.13 - Building Requirements and Costs, 1977 Constant Prices
(1 000 Kenya Shillings)

Type of Building	Number	Unit cost	Total cost
Office	1 x 70 m²	1.2/m²	84
Garage	1 x 70 m²	0.2/m²	14
Store	2 x 31 m²	0.75/m²	46
Forester's house	1	165	165
Ranger's house	2	58	116
Clerk's/messenger's/ driver's house	5	14	70
Forest guard's and headman's house	11	14	154
Labour housing	25	5	125
Total Cost			774

(d) Vehicles

It is considered that the vehicles shown in Table 7.14 would be required for the afforestation programme, the table also shows the expected life of each type. It is assumed that all vehicles would be purchased in the 1980-81 fiscal year.

Table 7.14 - Vehicle Requirements, Plantation Programme, 1977 Constant Prices (1 000 Kenya Shillings)

Type of vehicle	Number	Expected life (years)	Unit cost	Total cost
Long wheel base landrover	1	5	77	77
7 ton lorry	1	8	164	164
65 h.p. tractor	1	7	85	85
Flat bed trailer	1	10	20	20
Motor cycles	2	5	5	10
Total Cost				356

(e) Equipment

Minor items of equipment such as hand tools are estimated to cost approximately 25 thousand shillings and in addition to this a sum of 50 thousand shillings should be allocated to fire-fighting equipment. The latter should include one portable motorised pump, in addition to the usual back-pack sprays.

Recurrent costs

(a) Plantation maintenance

Maintenance costs of the plantations are based on Tables 6.2 and 7.2. They are shown in Table 7.15 for the 13 year planting programme (designed to meet demand until the year 2000).

Table 7.15 - Recurrent Costs of Plantation Programme, 1977 Constant Prices (1 000 Kenya Shillings)

Year	Recurrent costs	Year	Recurrent costs
1 (81/82)	82	8	1031
2	205	9	1115
3	336	10	1168
4	462	11	1224
5	592	12	1298
6	729	13	1380
7	875		

Starting with a recurrent cost of less than 100 thousand shillings in Year 1, the proposed programme would require 1.4 million shillings per annum by 1993. Revenue from the plantations would begin in Year 8, however, and this would provide a surplus on the annual account from 1988 onwards.

(b) Vehicles

Based on Forest Department data, Table 7.16 contains estimates of operating costs and depreciation for the vehicles associated with the plantation programme. These do not include the salaries of drivers which are considered below.

Table 7.16 - Vehicle Operating and Depreciation Costs, 1977 Constant Prices (1 000 Kenya Shillings per annum)

Type of vehicle	Operating cost	Depreciation for financial analysis	Total cost
LWB Landrover	27.0	15.4	42.4
Lorry (7 ton)	20.0	20.5	40.5
Tractor (65 h.p.)	17.1	11.4	28.5
Trailer	1.2	2.5	3.7
Motor cycles (2 No.)	3.0	2.4	5.4
Total	68.3	52.2	120.5

(c) Building maintenance

A figure of two per cent of capital costs is assumed to cover annual maintenance on all buildings. Based on the estimates presented in Table 7.13, the annual cost of maintenance is estimated at 15.5 thousand shillings per annum.

(d) Replacement of equipment

Capital costs of equipment are estimated at 75 thousand shillings and, at an average life of 5 years, replacement costs are likely to be approximately 15 thousand shillings per annum.

(e) Salaries and wages

Staff salaries and labour wages are shown in Table 7.17. They are based on official rates, and mid-points in the various scales have been assumed.

Table 7.17 - Staff Salaries and Wages, Constant 1977 Prices (1 000 Kenya Shillings per annum)

Post	Grade	Number of staff	Unit cost	Total cost
Forester	J	1	27.9	27.9
Rangers II	E/F	2	10.6	21.2
Clerk	C	1	6.8	6.8
Messenger	A	1	4.6	4.6
Driver I	D	1	9.0	9.0
Driver II	C	1	6.75	13.5
Headman (nursery)	B	1	6.0	6.0
Forest guards I	B	2	6.15	12.3
Forest guards II	A	8	4.6	36.8
Permanent labour	A	25	4.0	100.0
Casual labour*	ungraded	100	2.8	280.0
Total:	Including labour			518.1
	Excluding labour			138.1

* Varies according to afforestation programme.

The total annual salary and wage cost is estimated at approximately 520 thousand shillings per annum. Of this 380 thousand shillings are labour costs which have been included in earlier sections dealing with plantation establishment and maintenance. To avoid double counting, this amount (380 thousand shillings) is excluded in the financial analysis presented in the following chapter. To the remaining cost of 138.1 thousand shillings has been added an on-cost of 20 per cent to cover the cost of travel, uniforms, etc., giving a total of 165.7 thousand shillings per annum.

Summary of costs

The total costs associated with the proposed afforestation programme are summarised in Table 7.18 for a period of 11 years. During this time some 32 million shillings would be required at 1977 constant prices. Of this total 24 million shillings (75 per cent) would be capital costs and the remaining 25 per cent recurrent.

Table 7.18 - Summary of Costs Associated with the First Eleven Years of the Afforestation Programme
1977 Constant Prices
(1 000 Kenya Shillings)

Item	Fiscal Year 1979/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90
Capital Costs:											
Plantation establishment	1764	4371.0	6451.0	1272.0	1246.0	1284.0	1362.0	1445.0	1780.0	1056.0	983.0
Nursery establishment		88.5	–	–	–	–	–	–	–	–	–
Buildings		774.0	–	–	–	–	–	–	–	–	–
Vehicles		356.0	–	–	–	–	–	–	–	–	–
Equipment		75.0	–	–	–	–	–	–	–	–	–
Total Capital Costs	1764	5664.5	6451.0	1272.0	1246.0	1284.0	1362.0	1445.0	1780.0	1056.0	983.0
Recurrent Costs:											
Plantation programme		–	82.0	205.0	336.0	462.0	592.0	729.0	875.0	1031.0	1115.0
Buildings		–	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Vehicles		68.3	68.3	68.3	68.3	68.3	68.3	68.3	68.3	68.3	68.3
Equipment		–	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Staff Salaries		165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7	165.7
Total Recurrent Costs		234.0	346.5	469.5	600.5	726.5	856.5	993.5	1139.5	1295.5	1379.5
TOTAL COSTS	1764	5898.5	6797.5	1741.5	1846.5	2010.5	2218.5	2438.5	2919.5	2351.5	2362.5

CHAPTER 8 FINANCIAL APPRAISAL

8.1 Introduction

The direct costs involved in supplementarily irrigated timber production have been presented in Chapter 6 on a unit area basis. Here costs and potential revenues over a longer period for the project as a whole, are considered in more detail.

The financial analysis detailed here is based on preliminary estimates which differ in detail from the up-to-date estimates presented in Chapters 6 and 7. The changes in the estimates do not have a significant effect on the result of the financial analysis.

8.2 Methodology

Having determined the least cost method of providing settlers with their fuelwood requirements in a previous section, this chapter contains an assessment of the total financial costs and returns involved in the proposed programme. No attempt is made to provide an economic analysis: costs and benefits are valued at 1977 market prices; no accounting or shadow values are used and no adjustment is made for foreign exchange costs. Furthermore, it follows that in practice an inflator must be applied to each year's budget forecast to obtain a realistic estimate of budgetary requirements.

The plantations would continue for an indefinite time period, each being replaced after 21 years, and hence a theoretical problem exists as to when to "stop" the analysis. It is assumed here that after the 13 year establishment programme (to meet demand in the year 2000), no new planting would take place and the analysis is based on a total net plantation area of 3906 hectares.

8.3 Revenue

In Hola at present, fuelwood is obtained from the natural vegetation at ever increasing distances from the project area. Current (1977) prices are approximately 10 shillings for one bicycle load of 25 kilogrammes at Hola. Assuming a conversion ratio of 1.4 cubic metres stacked is equivalent to 1.0 cubic metre solid volume (based on experimental records of the EAAFRO forestry research programme), the cost of fuelwood at Hola is estimated at 280 shillings per cubic metre solid volume.

The price of fuelwood in Hola is likely to rise beyond this value owing to shortage in supply. Nonetheless, this value has been used in calculating the value of clear-felled fuelwood, at road side, from the proposed plantations in Bura. In addition, reduction of coppice growth would provide an estimated 1 600 shillings per hectare (0.5 shillings per stem; 2 stems per stump). On the basis of the above assumptions, Table 8.1 contains an estimate of the total revenue which may be expected from the proposed afforestation programme (at 1977 constant prices). The revenue stream would not commence until Year 8 in which gross revenue is estimated at 9.6 million shillings. This would increase in proportion to the area felled, reaching a maximum of 18.5 million shillings in Year 20, and then decline as no new plantations are established.

8.4 Costs

Capital and recurrent costs are presented in detail in Chapter 7 for a ten year period. They are summarised in Table 8.2 for the entire time horizon covered by the analysis, that is until the last of the new plantations (established in Year 13) are clear-felled for the third time. Capital costs occur during the first 13 years, while recurrent costs continue through the entire period.

Table 8.1 - Supplementarily Irrigated Forest Plantations, Estimated Revenue Stream at Constant 1977 Prices (Million Kenya Shillings)

Year	Area clear felled (ha) 1st	Area clear felled (ha) 2nd	Area clear felled (ha) 3rd	Total area (ha)	Volume (1 000 m^3)	Revenue	Area in which coppice reduced: Rotation 1st (ha)	Area in which coppice reduced: Rotation 2nd (ha)	Area in which coppice reduced: Total (ha)	Revenue	Total Revenue
8	327			327	34.3	9.6					9.6
9	349			349	36.7	10.3					10.3
10	371			371	39.0	10.9	327		327	0.5	11.4
11	343			343	36.0	10.1	349		349	0.6	10.7
12	365			365	38.3	10.7	371		371	0.6	11.3
13	389			389	40.9	11.5	343		343	0.6	12.1
14	414			414	43.5	12.2	365		365	0.6	12.8
15	441			441	46.3	13.0	389		389	0.6	13.6
16	142	327		469	49.2	13.8	414		414	0.7	14.5
17	150	349		499	52.4	14.7	441		441	0.7	15.4
18	160	371		531	55.8	15.6	142	327	469	0.8	16.4
19	221	343		564	59.2	16.6	150	349	499	0.8	17.4
20	234	365		599	62.9	17.6	160	371	531	0.9	18.5
21		389		389	40.9	11.5	221	343	564	0.9	12.4
22		414		414	43.5	12.2	234	365	599	1.0	13.2
23		441		441	46.3	13.0		389	389	0.6	13.6
24		142	327	469	49.2	13.8		414	414	0.7	14.5
25		150	349	499	52.4	14.7		441	441	0.7	15.4
26		160	371	531	55.8	15.6		142	142	0.2	15.8
27		221	343	564	59.2	16.6		150	150	0.2	16.8
28		234	365	599	62.9	17.6		160	160	0.3	17.9
29			389	389	40.9	11.5		221	221	0.4	11.8
30			414	414	43.5	12.2		234	234	0.4	12.6
31			441	441	46.3	13.0					13.0
32			142	142	14.9	4.2					4.2
33			150	150	15.8	4.4					4.4
34			160	160	16.8	4.7					4.7
35			221	221	23.2	6.5					6.5
36			234	234	24.6	6.9					6.9

Table 8.2 - Supplementarily Irrigated Forest Plantations
Summary of Capital and Recurrent Costs at Constant 1977 Financial Prices
(Million Kenya Shillings) (Based on preliminary estimates)

Year	Capital	Recurrent	Total	Year	Capital	Recurrent	Total
1	3.3	0.4	3.7	19	–	3.0	3.0
2	2.1	0.6	2.7	20	–	3.2	3.2
3	2.2	0.7	2.9	21	–	2.1	2.1
4	2.0	0.9	2.9	22	–	2.2	2.2
5	2.2	1.0	3.2	23	–	2.4	2.4
6	2.3	1.1	3.4	24	–	2.5	2.5
7	2.4	1.5	3.9	25	–	2.7	2.7
8	2.6	1.7	4.3	26	–	2.9	2.9
9	0.8	1.9	2.7	27	–	3.0	3.0
10	0.9	1.9	2.8	28	–	3.2	3.2
11	0.9	1.9	2.8	29	–	2.1	2.1
12	1.3	2.0	3.3	30	–	2.2	2.2
13	1.4	2.1	3.5	31	–	2.4	2.4
14	–	2.2	2.2	32	–	0.8	0.8
15	–	2.4	2.4	33	–	0.8	0.8
16	–	2.5	2.5	34	–	0.9	0.9
17	–	2.7	2.7	35	–	1.2	1.2
18	–	2.9	2.9	36	–	1.3	1.3

Total costs are approximately three million shillings per annum over most of the period analysed, although they exceed four million in Year 8 when the plantation programme is at its height.

8.5 Net Cash Flow

The annual and cumulative net cash flow is shown in Table 8.3, based on Tables 8.1 and 8.2.

Table 8.3 - Supplementarily Irrigated Forest Plantations
Net Cash Flow at Constant 1977 Prices
(Million Kenya Shillings)

Year	Annual net cash flow	Cumulative net cash flow	Year	Annual net cash flow	Cumulative net cash flow
1	-3.7	-3.7	19	14.4	97.7
2	-2.7	-6.4	20	15.3	113.0
3	-2.9	-9.3	21	10.3	123.0
4	-2.9	-12.2	22	11.0	134.3
5	-3.2	-15.4	23	11.2	145.5
6	-3.4	-18.8	24	12.0	157.5
7	-3.9	-22.7	25	12.7	170.2
8	5.3	-17.4	26	12.9	183.1
9	7.6	-9.8	27	13.8	196.9
10	8.6	-1.2	28	14.7	211.6
11	7.9	6.7	29	9.8	221.4
12	8.0	14.7	30	10.4	231.8
13	8.6	23.3	31	10.6	242.4
14	10.6	33.9	32	3.4	245.8
15	11.2	45.1	33	3.6	249.4
16	12.0	57.1	34	3.8	253.2
17	12.7	69.8	35	5.3	258.5
18	13.5	83.3	36	5.6	264.1

On the cost and pricing assumptions adopted, it appears that the cumulative deficit would rise to nearly 23 million shillings (in Year 7) before the revenue stream began to reduce this deficit. On an annual basis, the plantation programme cash flow would become positive in Year 8, while the cumulative cash flow is positive from Year 11 onwards.

It must be noted that interest charges on the negative cash flows are not included in the calculations summarised in Table 8.3. They should be included, of course, but this cannot be done until funding arrangements for the programme have been finalised. It is clear from the table, however, that although the inclusion of interest charges would increase the deficit in the cumulative net cash flow (and hence extend the period before a positive situation was achieved), the effect on the proposal as a whole would be marginal only.

8.6 Return to the Project

Although the analyses presented in this chapter are in financial terms, the net present value of the proposed afforestation programme is still considered to be of interest. Net present values, at varying discount rates have been calculated, therefore, and these are shown in Table 8.4. From this table it can be inferred that the rate of return is approximately 21 per cent.

Table 8.4 - Net Present Value of Afforestation Project at Varying Rates of Interest

Discount rate	NPV in Year 0 (million shillings)
10	31.0
15	9.6
20	0.8
25	-3.5

This is relatively high, particularly in the case of an afforestation scheme. There are two reasons underlying the high rate of return, first the fact that the forestry programme bears only marginal capital costs for the irrigation works and second, the high price assumed for the timber produced.

The irrigation project works (main canal etc.) have been designed on the basis of agricultural requirements. The proposed afforestation programme has been designed to utilise only water which is surplus to these agricultural requirements and therefore it is considered correct to include only the costs of irrigation canals and structures which directly serve the plantations. This situation is of course rare; nonetheless it would exist for the Bura Project and hence returns to the forestry programme would be higher than would normally be the case.

The second reason for the high rate of return achieved is the price assumption of 280 shillings per cubic metre of timber (solid volume). This is based on the current situation in Hola where there is an increasingly severe shortage of fuelwood. In Bura, if the demand forecasts (Chapter 5) are correct and the proposed afforestation programme (Chapter 7) is implemented, the demand and supply for timber should be roughly in balance. It follows that a lower price than that obtaining in Hola (a deficit situation) would apply. This question is considered in the sensitivity analysis presented below.

8.7 Sensitivity Analysis

Two sensitivity analyses have been undertaken. The first, a limited analysis of the effect of varying costs and revenue (either prices or yield) upon the net return to the project, and the second an examination of the possibility of irrigating the plantations with pumped (rather than gravity) supplies during the first two years of the programme.

As revenue is equally affected by changes in either prices or yield, the limited sensitivity test shown in Table 8.5 illustrates the effect of altering revenue by plus or minus 20 per cent. Capital recurrent costs have also been varied by 20 per cent. As shown by Table 8.5, even if capital costs were to be increased by 20 per cent and revenue to fall by 20 per cent, the afforestation programme would still have an internal rate of return (financial) in excess of 15 per cent.

Table 8.5 - Sensitivity Analysis, Net Return to Project at a Discount Rate of 15 per cent (Million Kenya Shillings)

Yield or price	Costs Low	Costs Medium	Costs High
High*	20.3	16.3	12.3
Medium	14.3	9.6	6.3
Low†	8.3	4.3	0.3

* High = medium + 20%
† Low = medium - 20%

In the second sensitivity test, it has been assumed that the water requirements of the plantations during the first two years (shown in Table 7.6) would be met from pumped supplies. The cost of pumping is estimated at 6 500 shillings per cumec per month. On the basis of this figure, pumping costs are estimated at 383 thousand shillings in Year 1 and 464 thousand in Year 2.

The effects of these additional costs are shown in Table 8.6 and it appears that meeting water requirements in Years 1 and 2 from pumped supplies has little impact on the scheme as a whole. Of course, during these first two years only some 675 hectares would be established and hence water requirements are low. Only in the high (i.e. + 20 per cent) capital cost and low price or low yield situation does the internal rate of return fall below 15 per cent.

Table 8.6 - Effect upon Net Discounted Return* to Project of Meeting Water Requirements in Years 1 and 2 from Pumped Supplies (Million Kenya Shillings)

Yield or price	Costs Low	Costs Medium	Costs High
High	19.6	15.6	11.6
Medium	13.6	8.9	5.6
Low	7.6	3.6	-0.4

* At 15 per cent.

8.8 Conclusions

The two major conclusions drawn from the analysis presented above are:

(a) The scheme is financially viable.
(b) The afforestation programme could support the cost of pumped irrigation during the first two years.

Due to the unusual situation which will occur on the Bura Project, where agricultural irrigation requirements vary from month to month, and hence there is a considerable surplus of water (supplied by gravity) for forest plantations, supplementarily irrigated afforestation appears viable. As shown by the limited sensitivity analysis, even if costs have been underestimated by 20 per cent and revenue overestimated by the same amount, the net return to the project is still positive at a discount rate of 15 per cent.

The second conclusion, that pumping costs during Years 1 and 2 do not affect the net return significantly, indicates that the afforestation programme could be initiated before the gravity project has been constructed, possibly in 1978-79 rather than 1980-81. This approach would have the great advantage that project timber demands could be met from the plantations two years earlier than would be the case if afforestation did not begin until gravity supplies were available. However, the species trials considered essential to the project (see Part 4) could not be started before 1977-78 and hence, by 1978-79, only one year's records of survival and growth would be available. These would not provide sufficient information to select species for the afforestation programme. On balance, it may be better to await the completion of the gravity-supply system and start establishing plantations in 1980-81, by which time three years of research records may be available.

PART 3

EXTENSION AND AMENITY

CHAPTER 9 SCHEME REQUIREMENTS AND DEVELOPMENT PROPOSALS

9.1 Introduction

The desolate and unattractive appearance of the Hola Irrigation Scheme emphasises the need for amenity and shade trees on any new settlement project. This is particularly true in arid areas where the natural vegetation provides little protection or shade.

9.2 Requirements

Implementation of the Bura Project Stage I, Phase I, is likely to result in an influx of some 60 000 settlers and it is proposed that 23 villages of varying size should be constructed for them. These villages will cover an area of approximately 250 hectares and it is essential that provision is made in the development plans for planting shade and amenity trees.

It is difficult to quantify the value of amenity, of shade, or of attractive tree-lined roads and market centres. Nonetheless, these aspects of community development are of considerable social importance. As benefits cannot be measured precisely, it is hard to justify the cost of an amenity tree-planting programme and this difficulty may explain why no provision was made in earlier development schemes such as Hola and Mwea.

In the Stage I Phase I development of the Bura Project the following communities are proposed.

Table 9.1 - Proposed Types of Community, Bura Project

Community	Number	Area per community (hectares)	Projected population per community
Rural centre	1	160	8 000
Market centre	4	36	2 500
Local centre	8	33	2 500
Sub-local centre	11	32	2 500

As a long-term objective, it is suggested that approximately five per cent of the total community area should be devoted to trees. Translating this objective into practical terms, the target numbers of trees to be planted in each community type would be as follows:

Table 9.2 - Amenity Trees for each Type of Community

Community	Number of trees
Rural centre	9 000
Market centre	2 000
Local centre	1 800
Sub-local centre	1 800

In total, it is estimated that 51 200 seedlings should be planted. This is an ambitious target and methods of achieving it are discussed in the following section.

9.3 Development Proposals

Accepting that amenity tree-planting in new communities is desirable, the question arises as to who should be responsible for raising the seedlings, planting them and for their subsequent protection.

It is conventionally argued that unless the villagers undertake the work themselves, the young trees would not be cared for and would be used for fuelwood at the earliest opportunity. However, based on the history of the Hola Scheme, it appears that even if a forest nursery is established to raise amenity trees and sell these to the settlers, the village inhabitants are unlikely to purchase trees in sufficient numbers to make any impact upon the appearance of their communities.

If the target mentioned in Section 9.2 is to be achieved, it is considered necessary to supplement the individual efforts of the villagers. This could be done in several ways; these include:-

(a) An active extension programme whereby occasions such as the 'National Tree Planting Day' are brought to the attention of the settlers.

(b) An environmental education programme directed at the various schools within the project - such a programme could be related to school wildlife conservation clubs.

(c) An amenity tree-planting programme undertaken by the Forest Department.

In 1972 the Forest Department established an extension service and, in areas such as Garissa and Hola where there are no gazetted forests, extension foresters are attempting to encourage tree planting. The success of this scheme is heavily dependent upon the enthusiasm and ability of the foresters involved. In Garissa, for example, the extension programme has already had a significant impact upon the appearance of the town. In Hola, on the other hand, little has been achieved. It is clearly important, therefore, that the extension forester assigned to the Bura Project is carefully selected. Liaison with agricultural extension workers and direct contact with farmers themselves is obviously necessary. This, together with the provision of seedlings at a low cost, should lead to an increasing awareness of the value of trees and, hopefully, to participation of the farmers in tree planting within their own household areas.

Secondly, it is believed important to involve the large numbers of school children in the project area in some form of tree planting exercise. The school age population is estimated at about 16 000 in 1985; provided with encouragement and direction these children could plant and care for a significant proportion of the total number of trees (51 000) required. The Wildlife Clubs of Kenya, an organisation which has grown rapidly since its creation less than ten years ago, is actively involved in school tree-planting programmes elsewhere in Kenya. It is strongly recommended that this organisation is requested to assist in the Bura area.

Thirdly, it is proposed that the Forest Department should undertake a planting programme in each of the 24 settlements. The object of this exercise would be to supplement rather than replace the tree planting efforts of farmers and school children. It is recommended, therefore, that the Forest Department should concentrate its efforts on establishing amenity and shade trees in public areas, such as market places, and along roadsides. The Forest Department could also be given the responsibility of planting and caring for trees around the various Government offices and institutions.

Proposed planting programme

It is impossible to assess the likely impact of the first two approaches suggested in the preceding section. It is advisable, therefore, to allocate a considerable portion of the planting programme to the Forest Department, at least during the first few years. It is recommended that 50 per cent of the total number of seedlings required are planted and cared for by the Department; the remainder of the work being undertaken by the settlers themselves and by school children.

Initially both settlers and Government officials will have a great deal to do in reorganising their lives in a completely new environment. Thus, it is probable that little time could be given to tree planting and the programme shown in Table 9.3 is therefore a modest one.

Table 9.3 - Proposed Amenity Tree Planting Programme
(Number of seedlings)

Year	Forest Department	Schools	Settlers	Total
1	1 280	640	640	2 560
2	1 280	640	640	2 560
3	1 280	640	640	2 560
4	2 560	1 280	1 280	5 120
5	2 560	1 280	1 280	5 120
6	2 560	1 280	1 280	5 120
7	2 560	1 280	1 280	5 120
8	3 840	1 920	1 920	7 680
9	3 840	1 920	1 920	7 680
10	3 840	1 920	1 920	7 680
Total	25 600	12 800	12 800	51 200

The relatively small number of seedlings required annually would be produced in the main forest nursery (see Chapter 7). Proposed species, planting and post-planting protection are discussed below.

Recommended species

Based mainly on the Forest Department's experience in Garissa and Hola, the following species are recommended for ornamental and shade purposes. One additional species, *Leucaena glauca*, is included for its value as forage. This could be of particular value to the settlers for planting around their homesteads.

1 *Azadirachta indica*
2 *Delonix regia*
3 *Cassia spectabilis*
4 *Acacia elatior*
5 *Acacia xanthiphloea*
6 *Casuarina glauca*
7 *Cassia simea*
8 *Parkinsonia spp.*
9 Mango
10 *Melea azadirachta*
11 *Artocarpus spp.* (jack fruit)
12 *Ficus spp.*
13 Tamarind
14 *Euginea jambolina*
15 *Leucaena glauca*

Each year the forestry extension officer should assess the survival and performance of the various species planted. This should enable him to advise the public on which species to plant and hence reduce the risk of failure.

Planting techniques

The extension forester and his assistants should demonstrate correct planting techniques at the village schools and also teach the settlers, possibly with the help of the agricultural extension workers.

Seedlings, approximately 20 centimetres tall, planted in polythene tubes, would be provided by the forest nursery. These should be planted in pits. Within limits, the larger the pit and the more carefully the soil is prepared, the greater the chance of the seedlings' survival. Pit dimensions should not be less than 0.5 x 0.5 x 0.5 metre. If possible a little fertiliser (that used on the agricultural holdings) or manure should be mixed with the soil before the seedlings are planted. Termite damage may prove to be a problem, and if this occurs, the soil should be treated before planting.

Finally, it is essential that each pit is watered thoroughly before the trees are planted. After planting, mulching of the soil surface around the seedling would be desirable.

Post-planting care and protection

Unless the seedlings are well protected they will be destroyed by small livestock within the villages. Protection can be achieved with wire netting or, less expensively, by interwoven sticks.

During the first year after establishment it will be necessary to water the trees and the schedule proposed is shown in Table 9.4. Each application of water consisting of 10 litres per tree.

Table 9.4 - Proposed Watering Schedule for Planted Seedlings

Month	Number of applications	Total water supplied (litres/seedlings)
1	4	40
2	2	20
3	2	20
4	2	20
5	1	10
6	1	10
7	1	10
8	1	10
9	-	-
10	1	10
11	-	-
12	1	10
Total	16	160

Total of 160 litres per seedling is approximately equivalent to a rainfall of 640 mm and this should be adequate to ensure survival.

Trees would be watered by those responsible for planting them. Trees planted by the Forest Department would be supplied by a water bowser, as is the practice in Garissa at present. Each watering (in the first year of the programme) would require two bowser loads of water (assuming a water bowser capacity of 1 500 gallons or 6 800 litres).

CHAPTER 10 MANAGEMENT PROPOSALS AND COST ESTIMATES

10.1 Introduction

The implementation of a village amenity tree-planting programme clearly requires careful supervision if it is to be successful. As mentioned in Chapter 9, much depends upon the calibre of the staff assigned this responsibility. Unfortunately, the Lower Tana District is regarded unfavourably by staff who prefer less remote postings, and it is important, therefore, that the men allocated to Bura are given sufficient incentives.

10.2 Management and Staff

As discussed in Part 1, Chapter 3, it is proposed that one forester should be appointed to manage the natural forest work, including the proposed amenity planting programme. He would be based in the rural centre and it is estimated that approximately 30 per cent of his time would be spent upon extension. In addition, two forest rangers would also have dual responsibilities involving natural forest protection and extension.

This staff is not considered adequate, however, if the amenity planting programme in the 23 village centres is to be implemented successfully. If the target of planting some 50 000 seedlings over a 10 year period is to be achieved, a concentrated and prolonged extension effort will be required. It is recommended therefore that four additional staff should be appointed, solely for extension activities, that one man is stationed at three of the four market centres, and the fourth at the rural centre.

The rank or grade of these four men is of less importance than their individual enthusiasm for extension work. One possibility would be to utilise four senior forest guards for this task; a second would be to give plantation headmen additional pay to undertake extension duties. One approach which is not recommended is the use of junior rangers who would command little respect in the communities. The respect given to an extension worker is clearly of great importance and, as age and experience command respect, the use of veteran forest guards may well provide the best solution. The fact that protection of the seedlings after planting is critical, adds weight to the proposal that forest guards should be involved in the programme.

Thus in total seven Forest Department employees would be involved in extension work. Three of these, the forester and the two rangers responsible for overall supervision, would be directly involved in the programme at the time of planting. The remainder, located in the market and rural centres, would carry out day-to-day extension and also provide a measure of protection to trees planted in public areas.

10.3 Cost Estimates

As in preceding sections of this report, costs are presented in constant 1977 prices and are subdivided into capital and recurrent items.

Capital costs

The main capital items are buildings, vehicles and equipment. Building costs shown in Table 4.3 include those to be charged against the extension programme. Accepting that 30 per cent of these costs should be borne by village tree-planting activities, it is estimated that the total cost would be approximately 136 thousand shillings.

Vehicle costs have also been subdivided between natural forest protection and extension; those for the latter are estimated at 75.9 thousand shillings. In addition to this amount, a sum of 235 thousand shillings should be allocated for the purchase of a 1 500 gallon (6 800 litre) water bowser. Total vehicle costs are therefore approximately 311 thousand shillings.

Equipment required would be limited to tools for pitting and planting, and wire mesh for protecting the seedlings from village livestock. A total sum of 25 thousand shillings should be sufficient for purchasing all necessary equipment.

In total, capital costs are estimated at 472 thousand shillings, as shown in Table 10.1.

Table 10.1 - Summary of Amenity Tree-Planting Capital Costs, 1977 Constant Prices (1 000 Kenya Shillings)

Item	Cost
Buildings	136.0
Vehicles	311.0
Equipment	25.0
Total Cost	472.0

Recurrent costs

Recurrent costs, at 1977 constant prices are summarised in Table 10.2. The amenity planting programme extends over a ten year period and hence, in total, a sum of 1.5 million shillings would be required to cover recurrent costs.

A large element in the costs is that of vehicles (35.0 thousand shillings per annum) which appears high. Experience indicates, however, that a common cause of failure in extension efforts is the lack of transport.

Table 10.2 - Summary of Amenity Tree-Planting Recurrent Costs, 1977 Constant Prices (1 000 Kenya Shillings per annum)

Item	Cost
Vehicle operation	35.0
Building maintenance	2.7
Replacement of equipment	5.0
Wages and salaries*	27.5
Casual labour	56.0
Grant to schools' planting programme	20.0
Total Annual Cost	146.2

* Includes 20 per cent on-costs

The casual labour cost estimate is based on the assumption that 40 men would be employed for an average of 6 months a year.

One item which may appear questionable is the proposed grant of 20 thousand shillings per annum towards amenity planting by school children. It is recommended that this sum is given to the Wildlife Clubs of Kenya, the most active conservation organisation in the country. Individual schools (approximately 20 in total) would then be assisted by the Society in their annual tree planting efforts. This grant could also be used by the Wildlife Clubs in fostering an awareness of the value of the natural riverine forests.

PART 4

RESEARCH

CHAPTER 11 PREVIOUS RESEARCH EFFORTS

11.1 Introduction

The Kenya Forest Department, established during the first decade of this century, has been undertaking research into a wide range of topics for many years. Most of the research, however, has been undertaken in upland areas and the data base concerning species selection, planting techniques and silvicultural programmes for arid areas is weak. Apart from a small plot of less than ten hectares in Garissa, irrigated afforestation has yet to be attempted in Kenya and hence recommendations for establishment, irrigation and plantation maintenance have not been formulated.

There are, of course, records from other countries, such as the Sudan (for example the Gezira Scheme), where irrigated plantations have been established successfully. While these provide useful indicators for the afforestation project in Bura, obviously locally obtained information would be highly desirable before a large-scale planting programme is initiated.

The history of research efforts in the Hola Scheme, which is particularly relevant to the Bura Project, is discussed in Section 11.2, while research in the riverine forest areas is considered in Section 12.3.

11.2 Past History of Trials in the Hola Scheme

The need for species trials in arid areas has been recognised for some time, and indeed it is more than ten years since the Forest Department was first invited to recommend suitable species for establishment in the Hola-Bura area.

A species trial was proposed and details of this were sent to the Manager of the Tana River Basin Study in May 1965. Later the same year 13 species (mainly *Eucalyptus*) were planted at Hola. Unfortunately, responsibility for maintaining the trials and monitoring them was not clearly defined and, as a result, the plots were neglected. Survival, height and diameter growth were not recorded and the plots have now disappeared completely.

In 1968 a second attempt was made to establish trials at the Hola Scheme. This time 15 species were planted; the names of 13 of these species were recorded and are given below.

Table 11.1 - Some of the Tree Species Used in 1968 Hola Scheme Trials

Species	Provenance
Eucalyptus maidenii	Nairobi
Eucalyptus paniculata	Nairobi
Eucalyptus saligna	Nairobi
Eucalyptus tereticornis	Mombo Arb. 66/107
Eucalyptus camaldulensis	Zanzibar 66/114
Acacia seyal	Uuni 1965
Acacia acuminata	Australia serial no. 1697
Acacia graffiana	Australia serial no. 2041
Acacia aneura	Australia serial no. 1728
Acacia nilotica	Uuni 1965
Cassia artemizoides	Israel 1963
Cassia australis	Israel 1963

Each species was established in both irrigated and unirrigated conditions on two planting sites, known respectively as 'Eight Acres' and 'Red Soils'. When these were visited by the Forest Department Silviculturalist in 1969, he reported that both plots were being 'maintained as prescribed'. Three species were noted as promising, *(Eucalyptus camaldulensis, Acacia aribica* and *Albizzia lebbek)* although there are no records of height or diameter measurements.

A further three species, *Casuarina glauca, Caesalpina pulcheri* and *Brachyciton populneum* were raised in the Hola nursery and planted at the 'Eight Acres' site in mid-1969. This brought the total number of species to 18 and each species was planted in both irrigated and unirrigated conditions. Clearly by mid-1969 a well laid out species trial had been established.

Unfortunately, in September 1969, the Project Manager of the Tana Pilot Scheme informed the Forest Department that due to 'financial strain' the board was unable to continue maintaining the species trials. The Forest Department agreed to increase specialist staff visits but the correspondence between the Tana Scheme Manager and the Forest Department indicates that the question of local labour costs for maintaining the plots was not clearly settled. Despite this, a further 13 species were established in late 1969 or early 1970; some being planted along the Maendeleo and the Matanja drainage canals.

Later in 1970 the Forest Department Silviculturalist inspected the trials; again no measurements of growth or survival were recorded. Four species were reported to have 'good survival and good growth'. These were:

Acacia nilotica
Acacia seyal
Casuarina equisetifolia
Eucalyptus camaldulensis

The *Acacia nilotica* was estimated to be between 7 and 8 metres tall at the age of 5 years, and the standing volume to be about 30 cubic metres per hectare, giving a mean annual increment of 6 cubic metres per hectare per annum.

A. seyal was estimated to have achieved a height of 5 metres at the age of 21 months; a very rapid growth indeed. Unfortunately no estimate was made of the standing volume.

Casuarina equisetifolia was observed to have a mean height of 4 metres at the age of 21 months; again a very good rate of growth but there is no record of the estimated volume for this species.

Eucalyptus camaldulensis had reached a height of between 7 and 8 metres at the age of 5 years and *Albizzia lebbek* 6 metres at the same age; the form of the latter was observed to be poor.

In 1972 the trials were again visited and the height, diameter and percentage survival of four species planted in 1968 were measured. Details of these measurements are shown in Table 11.2.

Table 11.2 - Recorded Performance of Four Species at the Hola Scheme

Species	Mean ht. (m)	Mean dia. (cm)	Percentage survival (%)	Volume Total (m^3/ha)	Volume Annual increment (m^3/ha/annum)
Casuarina equisetifolia	9.8	7.4	68	20.6	5.3
Eucalyptus camaldulensis	7.2	6.9	87	16.9	4.3
Acacia nilotica	8.1	1.4	31	0.28	0.1
		(10.4)		(15.4)	(3.9)
Albizzia lebbek	6.7	9.0	68	20.9	5.4

Note: (a) Age at measurement = 3.9 years
(b) Assumed spacing = 2.5 x 2.5 m
(c) Assumed form factor = 0.45
(d) Figures in brackets assume recorded diameter of 1.4 cm to be a typing error in official records.

Source: Forest Department records.

Unfortunately it is not known whether the plots to which the data in Table 11.2 refer were irrigated or not. From the estimated mean annual increments, however, it is assumed that the plots cannot have been irrigated.

In 1973 the number of species under trial was increased by a further eight species and, in addition, the silviculturalist recommended spacement trials for *E. camaldulensis* and *Casuarina equisetifolia*. There are no records of any growth or survival measurements in 1973.

The files indicate a complete absence of correspondence regarding the species trials between 1973 and 1975, when the forester responsible for extension in the Tana area wrote to the silviculturalist. He reported that he had visited the trials and found 'the whole experiment interferred and damaged completely by grazing and cutting down everything'.

Thus after 10 years of work, during which nearly 40 different species were planted, nothing remains apart from one record of measurements of four species in 1972 and the visual estimates made in 1970. Indeed, when the Hola Scheme was visited in January 1977 by the consultants, together with senior Forest Department officials and a representative of the World Bank, the site of the trials could not be located.

11.3 Research Regarding the Riverine Forest

As mentioned in Chapter 1, the vegetation of the Lower Tana River Basin, including that of the riverine forests, has received considerable attention over the past 75 years. The first recorded visit to the area by a forester took place in 1902 when Ross surveyed the potential of the riverine forests during a tour of the Tana from Nyeri to the coast. He is reported to have found 'thick bush and jungle' in the floodplain but as it has not been possible to trace his original report to the Ministry of Works, further details of his findings are not known.

Since then a number of botanical studies have been undertaken, the majority concentrating upon plant collection and identification. Apart from the work of Marsh (4), who spent three years studying the ecology of a riverine area to the south of Hola, these studies have not dealt with the dynamics of the ecological systems involved. Marsh's interest lay predominantly in the fauna of the area and while the vegetation of the area was examined, understandably its study was not given prominence. In his proposals for further research Marsh recommended that an aerial survey should be made each year and as part of this survey, the destruction or regrowth of the riverine forests should be monitored. This proposal has yet to be implemented.

As far as the consultants are aware, no other ecological studies of the riverine forests in the Lower Tana River Basin have been undertaken. It is widely recognised that these are necessary (for example by Lamprey (7), Gillet (pers. com.), and IBRD (1)), and proposals for further research are presented in Chapter 12.

CHAPTER 12 RESEARCH PROPOSALS

12.1 Introduction

Research requirements fall into two distinct categories; those relating to the proposed afforestation programme (Part 2) and those connected with the natural vegetation (Part 1). These are discussed in Sections 12.2 and 12.3 while management aspects and costs are considered in Chapter 13.

12.2 Research Proposals Relating to Afforestation

In view of the past history of the trials at the Hola Scheme (Section 11.2) and the pressing need for a firm data base upon which to plan the afforestation programme for Bura, it is essential that new trials are commenced urgently. Furthermore, it is clearly important that the trials are adequately supervised and evaluated systematically.

Ideally, the species trials should be located at Bura, upon the soil types and within the areas which would be afforested eventually. This is not feasible, unfortunately, as the first irrigation supplies would not be available until 1980, and it is essential that trials are initiated as soon as possible. If they are not, the planting programme proposed in Part 3 would either have to be delayed, or undertaken at considerable risk due to the lack of local experience concerning species performance. A site for the trials should be selected at Hola to ensure that its soils are comparable to those in the areas which will be afforested at Bura in future.

Recommended species for trial

Although the Hola Scheme trials failed to provide a data base upon which to formulate an afforestation programme, they did provide several useful indications regarding species selection. Taking these into account the species given in Table 12.1 are recommended for experimental planting.

Table 12.1 - Species Recommended for Experimental Planting

1	*Eucalyptus tereticornis*	*13*	*Azadirachta indica*
2	*Eucalyptus camaldulensis*	*14*	*Albizzia lebbek*
3	*Eucalyptus deglupta*	*15*	*Cassia simea*
4	*Eucalyptus microtheca*	*16*	*Gmelina arborea*
5	*Acacia xanthiphloea*	*17*	*Tamaryx aphylla*
6	*Acacia nilotica*	*18*	*Terminalia spinosa*
7	*Acacia tortilis*	*19*	*Cordia africana*
8	*Acacia elatior*	*20*	*Populus ilicifolia*
9	*Acacia seyal*	*21*	*Garsinia livingstonii*
10	*Casuarina equisetifolia*	*22*	*Prosopis juliflora*
11	*Casuarina glauca*	*23*	*Simmondsia californica*
12	*Conocarpus lancifolius*	*24*	*Cordeauxia edjulis*

Of the four *Eucalyptus* species proposed, *E. tereticornis* could prove to be the most desirable in terms of growth rate and volume increment, provided a vigorous strain or provenance is planted. The Zanzibar C. strain is probably the most suitable, and care should be taken to ensure that this provenance is obtained from a reliable source. The limited research evidence available from Gedde is conflicting in that certain plots of *E. camaldulensis* are now thought to be *E. tereticornis*. However, *E. camaldulensis* is known to do well in conditions similar to those prevailing in Bura, and it is therefore included in the proposed species list. *E. microtheca* has been used extensively on the Gezira scheme in the Sudan and although growth rates are lower than either *E. tereticornis* or *E. camaldulensis*, its drought resistance and hence survival, is greater. *E. deglupta* is included in the list of proposed species due to its excellent performance at Gedde, where a mean annual increment in excess of 20 cubic metres per hectare per annum has been recorded. It is not highly drought resistant but given adequate irrigation it may prove suitable.

Five *Acacia* species are recommended for trial. Three of these, *A. tortilis, A. elatior* and *A. seyal*, occur naturally within the area. With irrigation all three should not prove difficult to establish and given adequate supplies of water, their rate of growth should be excellent. *Acacia xanthiphloea* (the well known Naivasha Thorn) may appear an unlikely choice for Bura. However, it has been planted in Garissa, and with irrigation has achieved a height of between three and four metres at the age of two years. *A. nilotica* was included in the original Hola Scheme species trials, and is one of the few species for which height and diameter growth measurements were obtained (see Table 11.2). The records show an average height growth of more than two metres per annum, which is excellent. Diameter at the age of 3.9 years, however, is recorded as 1.4 centimetres; presumably this is a typing error in the silviculturalist's report.

Casuarina equisetifolia has grown well under irrigated conditions at the Hola Scheme. There is a possibility, however, that this species is liable to die-back of the leader between its fifth and sixth years when planted at some distance from the coast. *C. glauca* is included, therefore, as an alternative, because it is less likely to suffer from this defect.

Conocarpus lancifolius has performed very well on the coast in extremely adverse soil conditions, achieving a height of approximately 10 metres and a diameter of 25 centimetres at the age of 6 years. It is known to do somewhat better if planted in a mixture (possibly with *Casuarina equisetifolia*) than as a pure stand.

Albizzia lebbek has also done well at the coast and it is one of the four species for which records exist from the original Hola Scheme trials. Although these records cannot be taken as more than indicative, they show that at the time of measurement *A. lebbek* had achieved a greater average annual increment than *E. camaldulensis.*

Cassia simea has been planted in Garissa under irrigated conditions and at the age of four years has reached a height of about six metres. It is thought unlikely to prove suitable for a large scale afforestation programme but could be used in the extension scheme discussed in Part 3.

Gmelina arborea has been planted at Gedde and, if the silvicultural research records are to be accepted, has achieved a mean annual increment of about 30 cubic metres per hectare per annum. If similar growth could be achieved under irrigation in the Hola-Bura area, this species could well prove important in the afforestation programme.

As far as the consultants are aware, *Tamarix aphylla (articulata)* has not been utilised in Kenya. However, it is known to be doing well in the Gulf States (for example around Basra), and is therefore included in the proposed list of species for trial at Hola.

Terminalia spinosa, Cordia africana, Populus ilicifolia and *Garsinia livingstonii* are all indigenous in the Lower Tana River Basin. Adaptation to local conditions should not pose any major problem, therefore, provided the trees are grown under irrigated conditions. *P. ilicifolia* and *G. livingstonii* are known to grow vigorously within the riverine forests and could prove to be a valuable source of poles.

The last three species in the proposed list are not of interest from the point of view of fuelwood production. They could prove to be of considerable value however for other reasons. *Prosopis juliflora* (from Arizona) provides good forage and an edible nut. It is extremely drought-resistant and could be of interest to the settlers for planting in their house-lots and vegetable garden areas. *Simondsia californica* is a shrub or small tree which also produces edible nuts. These are the source of jojoba oil which is attracting considerable interest in North America at present. In the long term this species could achieve considerable commercial importance and its inclusion in the species trials at Hola appears worthwhile.

The last of the species recommended is *Cordeauxia edjulis,* which is indigenous over large areas of Somalia. It is a slow growing but extremely drought-resistant shrub, producing the Ye-eb nut. These have a high nutrient value and can be stored for considerable periods without becoming rancid. The Ye-eb nuts are much prized in Somalia and, despite limited production, they are traded widely. If grown in plantations this species could become commercially important and is worth including the Hola trials for this reason.

Plot size and layout

Each species should be established on five plots, each of 0.1 hectare. Thus a total of 120 plots would be required, the dimensions of each being 31.6 x 31.6 metres. The layout of the plots should follow a randomised block design, with each species occurring once in each block of 24 plots. The total area required would be 12 hectares and an additional 3 hectares should be allowed for access roads and rides.

Seedling requirements

At a planting espacement of 2.5 x 2.5 metres, each plot would contain 160 trees and hence a total of 800 seedlings of each species would be planted. To allow for establishment failures, it is recommended that the Forest Department be requested to provide 1 000 seedlings (20 boxes) of each species. These could be raised at the existing nursery in Hola, at the forest nursery in Garissa, or possibly at the research nursery in Gedde.

Establishment techniques

The seedlings (raised in polythene tubes) should be planted in the sides of the irrigation furrows, which should be prepared in the normal way at a spacing of 2.5 metres.

The seedlings should be planted 2.5 metres apart along the furrow and at the time of establishment the soil surrounding each seedling should be treated with termite-repellant chemicals. The Forest Department uses 'Aldrin' at present, but a non-toxic pesticide would be preferable.

Irrigation requirements

In the absence of locally obtained data concerning irrigation requirements, the following proposals can only be taken as guidelines and adjusted in the light of field experience.

Based on our estimation of evapo-transpiration, a crop factor of 0.75, and assuming the trials could be initiated by August 1978, the gross water requirements (unadjusted for effective rainfall) shown in Table 12.2 appear reasonable.

In practice, the newly established seedlings will require rather more water during the first few months (while root development is beginning) and correspondingly less later on. For the 12 hectare trial area the schedule shown in Table 12.3 might be adopted until field experience is obtained.

Table 12.2 - Estimated Gross Water Requirements

Month	Water required (mm)	Net equivalent (m³/ha)	Irrigation flow required (cumecs/hectare) Net	Allowing for 50% overall losses and 12 hours irrigation/day
August	148	1 480	0.00056	0.00225
September	149	1 490	0.00057	0.00227
October	162	1 620	0.00062	0.00247
November	143	1 430	0.00054	0.00218
December	139	1 390	0.00053	0.00212
January	147	1 470	0.00056	0.00224
February	140	1 400	0.00053	0.00213
March	161	1 610	0.00061	0.00245
April	151	1 510	0.00057	0.00230

Table 12.3 - Adjusted Water Requirements for Twelve Hectare Tree Species Trial Area

Month	Percentage of total supplied	Flow required (cumecs/ha)	Flow required for 12 ha (cumecs)
August	25	0.00510	0.06123
September	20	0.00408	0.04898
October	15	0.00306	0.03674
November	10	0.00204	0.02449
December	10	0.00204	0.02449
January	5	0.00102	0.01225
February	5	0.00102	0.01225
March	5	0.00102	0.01225
April	5	0.00102	0.01225

As shown by Table 12.3 irrigation distribution canal to the trial area should be designed to a capacity of 0.1 cumecs. After the initial establishment phase of nine months, irrigation should be further reduced; the extent to which this is possible depending upon soil type and rooting depth.

Plot maintenance

Each plot will require weeding twice a year and, accepting the Forest Department's estimate of labour requirements (7 man-days per hectare), 168 man-days per annum will be required for this task. No other silvicultural operation is envisaged.

Plot monitoring

As demonstrated by the original trials at Hola, experimental plots which are not monitored are of little value.

The following schedule of appraisal is recommended for the proposed species trials:-

(a) Every two weeks: visual inspection of health and survival.
(b) Every three months*: record of survival.
(c) Every twelve months: record of height and stem diameter.

* For the first 12 months only.

In addition to obtaining the above data, it would be most useful if careful records were kept concerning the irrigation of the plots (total volume supplied and time required) and the labour inputs necessary for plot maintenance and irrigation.

Analysis of data

Assuming the proposed trials are established in 1978, records should be available for three years before a decision must be taken concerning species selection for the first year of the afforestation programme (discussed in Part 3). This is admittedly an extremely short period; nonetheless, the records of survival and initial height growth should provide guidelines for selecting four or five species to be raised in early 1981 for afforestation later the same year.

Monitoring of the trials should continue, of course, and the accumulated data base used to modify species selection for the planting programme in subsequent years.

Additional research topics relating to afforestation

In addition to the species trials proposed in preceding sections, it would be desirable to undertake research into optimum spacing, planting techniques, post-establishment protection and maintenance (including irrigation schedules) and rotation length.

It is doubtful, however, that sufficient management expertise is available to undertake a range of experimental work at the same time. (This question is considered further in Section 13.2). Because it is critically important that the proposed species trials are initiated and properly maintained, it is recommended that the other research topics are not investigated until the plantation programme has commenced.

One topic, which could be included in the species trials, is research into the value of various species as hedges or natural vegetative barriers for use around the irrigation project. This work would be of interest to both the forestry and livestock sectors and could be undertaken at Hola.

Initially it is proposed that two species are evaluated, *Opuntia ficus indica* and *Euphorbia grandicornis*. These should be planted as hedgerows in both irrigated and unirrigated conditions and, as for the species trials, five replicates of each situation are recommended. Thus in total 20 'hedges', each of approximately 10 metres length, should be established.

These hedges should not be maintained, but their survival and growth should be monitored. This could be done at the same time as the species trials are evaluated.

12.3 Research Relating to the Riverine Forests

Three topics for research in the riverine forest areas are recommended; two having been suggested in earlier reports.

Investigation of the riverine ecological system

As stated by Brinck and Enckell (IBRD (1977) Annex 9, Appendix 1): 'The development of indigenous forests often results in widespread changes in the flora and fauna, the effects of which are little known and poorly understood'.

The impact of the Bura Project upon the riverine forests will be significant. Hopefully the gazettement proposals in Chapter 3, will prevent the complete destruction of the high forest areas, along part of the river at least. Even within these protected areas, however, changes can be expected following the construction of the diversion weir and the main irrigation system. Access to the river by wildlife and cattle will be restricted, there will be surface run-off of surplus irrigation supplies and the level and frequency of flooding in the floodplain may alter. Each of these factors is liable to alter the existing ecological balance and it would be of scientific interest, if not of direct relevance to the Bura Project, if these changes could be monitored.

It is proposed that an ecological study is undertaken, over a period of several years. The scientists involved would no doubt wish to formulate their own research plans but the following approach might be adopted.

Fixed or permanent transects could be established at right angles to the course of the Tana, extending from the edge of the floodplain to the river banks. Plots established along these transects could be appraised at three, six or twelve month intervals to determine either seasonal or longer term changes in the flora. Ideally these transects should be located in both gazetted and unprotected areas. This would enable those involved to assess the effectiveness of the forest protection measures in addition to monitoring changes in both ecological systems.

Monitoring the extent of the riverine forest

Marsh (4) proposed that an aerial survey of the riverine forests and the Lower Tana River floodplain should be undertaken annually, and that as part of this survey, changes in the boundary of the riverine forest should be recorded. There is clear evidence of changes in the location and extent of the natural forest; nonetheless the rate of change is not known, nor are the various factors involved clearly understood. It is recommended, therefore, that Marsh's proposal is given serious consideration. Management proposals and cost estimates for this are presented in the following chapter.

Management and exploitation of the natural vegetation

While considerable attention has been given to the vegetation of the Lower Tana River Basin, from a botanical point of view, little thought has been given to its management and its potential for exploitation.

While it is clearly important to reserve areas of vegetation in their natural state, it may well be that under careful management, areas within the floodplain could produce much needed fuelwood and charcoal. It is possible that this could be achieved without increased erosion, without disruption of the wildlife and without disturbing the traditional life style of the nomadic pastoralists.

Apart from the FAO range management programme, little has been done in this field and it is strongly recommended that a programme involving such elements as selective felling, reseeding, grazing control and possibly even soil cultivation is initiated.

This proposal may be strongly opposed by environmentalists, but the fact that within the next 20 years the population along the margins of the Lower Tana may have increased, by perhaps as many as a quarter of a million people, must be faced. Unless specific and relatively restricted areas of natural vegetation can be made productive, large areas will be completely devastated. Management proposals and cost estimates relating to this proposal are presented in the following chapter.

CHAPTER 13 RESEARCH MANAGEMENT PROPOSALS AND COST ESTIMATES

13.1 Introduction

The first section of this chapter contains recommendations regarding the implementation of the various proposals presented in Chapter 12. The estimated costs associated with each are discussed in Section 13.3; these are clearly related to the management proposals and hence, if alternative management systems are adopted, the costs will require revision.

13.2 Management Proposals

Species trials

In view of the past history of the trials at the Hola Scheme, and the pressing need to obtain a firm data base upon which to plan the proposed afforestation programme for Bura, it is essential that new trials are commenced urgently and that these are supervised and monitored correctly. It is doubtful that the Forest Department is in a position to undertake the trials immediately, due to budgetary and staff constraints. Two alternative approaches appear feasible.

The ideal solution would be to enlarge the terms of reference of the research team, funded by the Government of the Netherlands, which has recently (February 1977) arrived in Kenya and will be engaged in agricultural research in the Hola-Bura area. The addition of one species trial and one natural vegetation barrier trial to their work programme should not be a major problem. This approach was suggested to the NIB in a preliminary discussion paper.

The alternative, which would take longer to organise and is therefore less attractive, would be to employ a forestry consultant who would be given responsibility for implementing the trials. He could either be assigned to work within the framework of the Dutch research team, or he could be attached to the Forest Department. In either case, the appointment of one man, concerned specifically with forestry in the Hola-Bura area, should ensure that the necessary data base for the afforestation programme is obtained in time. In fact, if this approach was adopted, the forestry consultant could also initiate and supervise the spacing and establishment trials mentioned in Section 12.2.

Research in the riverine forest

Of the three research topics proposed in this field (Section 12.3), the IBRD report (January 1977) contains proposals for implementation of the ecological studies recommended. The Bank proposed that the National Museum undertook this research. It is assumed that in referring to the Museum, the Bank intended that the work should be done by the Herbarium, which is of course a separate entity, funded by the East African Community. This proposal has been discussed with both the present director and her predecessor. In view of the current uncertainty over the future of the Community, both feel it unwise to commit the Herbarium to the proposed research project.

As an alternative, the Director of the Herbarium has suggested that the proposed ecological studies would form a suitable topic for post-graduate research. This could be organised in a similar manner to the study of the Tana River Game Reserve undertaken by Marsh, which was funded by the New York Zoological Society. The post-graduate research worker would be assisted by the Herbarium staff, but would be responsible to his/her university and the funding agency.

This approach appears satisfactory and the Tana River Development Authority (TRDA) would be a suitable agency through which universities and funding agencies could be contacted.

The second research topic, proposed by Marsh, involves the monitoring of changes in the extent of the riverine forest area. The most suitable agency for this project is likely to be the United Nations Environmental Programme, which has its headquarters in Nairobi. Preliminary discussions with UNEP indicate that although the agency is not operating within Kenya at present, similar monitoring studies are in progress in other African countries, such as Nigeria. It is recommended, therefore, that UNEP is approached officially with a request to undertake monitoring studies of the Lower Tana River Basin, with particular reference to the riverine forest.

Finally, it is considered necessary to study the potential productivity of the natural vegetation, particularly within the floodplain. As in the case of the ecological studies proposed, this topic appears suitable for post-graduate research. The Forestry Department of the University of North Wales is orientated towards the utilisation of forest products and is therefore a potential source of a suitably qualified research worker. Again it is recommended that TRDA is approached for assistance in organising this study.

13.3 Cost Estimates

Clearly, until the method of undertaking the various research proposals has been determined, costings can only be indicative. It is emphasised, therefore, that the following costs will require revision.

Species trials

Assuming the Dutch agricultural research team stationed at Hola undertake these trials, without recruiting additional staff, management costs for supervision and monitoring would be covered by the team's existing budget.

Local costs would include:

(a) Land clearing and levelling
(b) Installation of irrigation works
(c) Layout of plots
(d) Seedlings
(e) Planting
(f) Weeding
(g) Irrigation
(h) Plot assessment and tree measurement

Based on unit rates used in other sections of this report and Forest Department estimates, an approximation of the costs involved is shown in Table 13.1.

Table 13.1 - Species Trials Estimated Costs at 1977 Constant Prices (1 000 Kenya Shillings)

Item	Unit Cost (shillings)	Total Cost
Capital Costs:		
Land clearing and levelling*	1 000/ha	12.0
Installation of irrigation works*	3 640/ha	43.7
Layout of plots (10 man-days/ha)	11/man-day	1.3
Seedlings (24 000)	290/1 000 seedlings	7.0
Establishment (15 man-days/ha)	11/man-day	2.0
Sub-total		66.0
Recurrent Costs:**		
Weeding (14 man-days/ha/an)	11/man-day	5.5
Irrigation (20 man-days/ha/an)	11/man-day	7.9
Plot assessment: Year 1 (7 man-days/ha)	11/man-day	0.9
Years 2 and 3 (3 man-days/ha)	11/man-day	0.8
Sub-total**		15.1
TOTAL		81.1

Notes: * As for normal agricultural development.
** Total shown is for a period of three years according to schedule proposed in Section 12.2.

In addition to the above 81.1 thousand shillings, it is necessary to allocate a small sum to cover the cost of the natural vegetation barrier trials. In total, a figure of 100 thousand shillings should be adequate for the local costs involved in both trials.

It is emphasised that the above cost does not include management. Should the alternative procedure of employing a consultant be adopted the total budget over the three year period would have to be increased substantially.

Research regarding the riverine forests

If the proposal to utilise post-graduate research workers for two of the three recommended studies is adopted, the budget shown in Table 13.2 may be required for each, covering a three year period.

Table 13.2 - Budget for a Three-year Riverine Forest Research Study (1 000 Kenya Shillings)

Item	Cost
Research workers subsistence grant: at 36 000 shillings/annum	108
Housing in Bura/Hola (construction cost)	58
One long wheel base Landrover	77
Vehicle operating and maintenance costs	126
Visits to Nairobi: 1 per month at 1 000 shillings/return trip and 3 nights accommodation/trip at 200 shillings/night	58
Supervision: 1 day per month at 1 000 shillings/night	36
Air fares: 2 return tickets to Europe at 10 000 shillings each	20
Sub-total	488
Plus 10 per cent for miscellaneous items	49
TOTAL COST	537

In total, it appears that approximately 1.1 million shillings would be required for the two post-graduate research projects.

The last item to be costed is the monitoring of the riverine forests, as proposed by Marsh (4). It is recommended (Section 13.2) that this project is undertaken by UNEP and it has not been possible to obtain even a preliminary budget for this work. A sum of 200 thousand shillings per annum may be taken as a preliminary figure, but it is emphasised that until official meetings are held with the agency, this is little more than a guess.

APPENDIX A

APPENDIX A

IRBD YELLOW COVER REPORT

ANNEX 9 APPENDIX 1

BURA IRRIGATION SETTLEMENT PROJECT

Preservation of Indigenous Forests (1)

1. Until recently vast land areas within the tropics have been covered by forests. In the past few years much of this area has gradually been taken over by agriculture, as the fertile soils and the favorable climate make the land ideal for cultivation. The tropical forests have also been devastated by uncontrolled logging which has opened previously impenetrable areas to unrestricted use by charcoal producers, pastoralists and small farmers. These activities have disturbed the natural soil regime, and the result has often been leaching and pan formation, destruction of organic matter, loss of plant nutrients and general soil erosion. The establishment of forest plantations to replace the indigenous forest cover has received little support, with the result that today only marginal areas are still available for planting, and even in these areas there is constant pressure from agriculturalists and livestock owners.

2. Only recently has attention been drawn to the necessity of preserving at least representative samples of the various forest types. These forests demonstrate an unparalleled richness and diversity of life, and their preservation is essential not only as a learning tool for science, but also because they represent an important tool in the conservation of valuable land resources and a source of both present and future economic wealth. The destruction of these indigenous tropical forests is an irreversible act whose ultimate environmental consequences are not always fully appreciated. If the case for preservation is to be made in a cohesive and rational manner, however, some means must be found for evaluating the various conflicting interests and for establishing a scale of priorities. Once this has been done, an overall land use plan can be drawn up; this will not only help to minimize the adverse ecological effects of uncontrolled forest development, but should also help to reduce the present undesirable conflict of interest between foresters and agriculturalists.

3. It has become evident that the only way to retain biological diversity and to preserve the full richness and complexity of these indigenous forests is to preserve an entire forest ecosystem. Early conservationists made considerable efforts to preserve rare (endemic) species, irrespective of any concern for the status of the environment in which the species existed. This approach should be avoided, as it often leads to isolation or extinction of the species in a small part of an incomplete ecosystem. The survival of a rare species can be ensured only by preserving complete and viable parts of the ecosystem. Given present experience, it is evident that some form of legal protection is necessary if an ecosystem is to be allowed to remain undisturbed. The main instrument to be employed is the creation of a Nature Reserve under the administration of the Forest Department. However, some method must be available to the administrators so that they can make intelligent choices between different forms of competing land uses. Each proposal for the protection of a particular forest area must be evaluated with extreme care, so that ultimately the most effective sample of various forest types is preserved for future generations. The criteria outlined below are set forth as an indication of the variety of factors which should be considered in making the necessary choices.

Conservation of Land Resources (2)

(a) Soil status: organic contents, nutrients, texture.

(b) Erosion preventive features.

(c) Water catchment and influence on water movement.

(d) Climatic influence: humidity, air filtering capacity.

Present Economic Value (3)

(e) Exploitation of single tree species.

(f) Extraction of wood for fuel, housing, fencing and carving.

(g) Habitats for game birds and mammals.

(h) Tourist attraction, because of scenic and recreational value and a rich and diverse plant and animal life.

Future Economic Potential

(i) Development of uses for currently economically non-merchantable species of trees and plants.

(j) Development of uses of active natural chemical compounds present in large numbers in forest plants and animals.

(k) Gene pools, retaining the range of variation within the species, and forming the basis for future search for attractive characters in useful species.

(l) Development of uses of ecological mechanisms which stabilise inter-relations between species and (i) form the basis for future biological control in the tropics and sub-tropics, and (ii) make control possible of the great variations in numbers of individuals occurring in exploited or otherwise perturbed ecosystems(4).

Present and Future Scientific Value

(m) Differentiation in structure and function of species and their adaptation to the complex environment. This is the basis of biological evolution.

(n) Optimum utilisation of energy and soil resources. This is a characteristic of humid tropical forests in contrast to man-made ecosystems. The possibility of studying natural ways of increasing productivity.

(o) Biologically generated substances which pass information and release reactions among individuals and species.

(p) Life forms analysis (autecology) of species.

(q) Degree of endemicity (species/genera restricted to the area in question).

(r) Degree of diversity (complexity of plant and animal communities).

Local Utilisation of Indigenous Forests

4. All over Africa local population groups meet their need of wood for fuel, housing and fencing from indigenous forests and plantations. This consumption is considerable. For Tunisia, it has been shown that the daily ration of fuelwood is about 2 kg per person (10-20 kg per family); and 80-150 kg are used per family for housing purposes each year. The figures are similar in Kenya. This means an out-take of 26 000 tons each day for fuelwood alone in Kenya (9.6 million tons each year). Housing material contributes about 6-7% of this figure. It has been calculated

(FAOSWE/TF 28, 1970) that by the year 2000 total consumption will have doubled, while the plantation program is expected to yield only 1.25 million tons per year at that time. These figures thus indicate that the pressure on indigenous forests will increase considerably.

5. There are several different ways of neutralizing the impact of this trend. In Kenya one successful method used by the Forest Department has been to surround forests in exposed locations with a protective zone of plantations; this scheme should be extended. The Forest Extension Service serves the same purpose by stimulating local tree planting through rural afforestation and County Council forestry schemes.

The Need for Documentary Studies of Indigenous Forests

6. The development of indigenous forests often results in widespread changes in the flora and fauna, the effects of which are often little known and poorly understood. In similar circumstances, certain countries have found it advisable to provide funds for documentary studies of the various ecosystems. In Kenya the possibilities for such a study are particularly favorable owing to the capability of the National Museum and its staff. It is recommended that studies of this kind be undertaken under the auspices of the Museum.

Notes: (1) This Appendix was prepared by Messrs. P. Brinck and P.H. Enckell, ecology consultants, who participated in the IBRD Appraisal Mission for the Kenya Second Forestry Plantation Project (Loan 1132-KE and Credit 656-KE) in September/October 1974.

(2) It has been argued that carefully managed forest plantations and farm crops can achieve these aims as well as natural vegetation. Given defined cultivation methods, short term experiments seem to support this opinion. Long term observations of prevailing conditions in most tropical countries seem to show that traditional forms of land use (i.e. the shamba system) are not sufficient to conserve soil and water resources. More research is needed on the importance of tropical forests for water catchment, soil conservation and local climate.

(3) Only (f) and (h) are of considerable importance. In practice, tourism increases at a fast rate in countries where attractive forests can be opened for tourists by the provision of adequate facilities.

(4) It has been argued that chemists will produce needed substances in the laboratory and that geneticists will use gene pools available in plantations and arboreta. This idea does not take into account the recent great development and success of natural products chemistry, nor the fact that plantations/arboreta contain only part of the genetic variation of a small number of species.

APPENDIX B

APPENDIX B

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APPENDIX C

APPENDIX C

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