REPUBLIC OF KENYA

HARAMBEE

DRAFT

MAJI NI UHAI

National Water Conservation & Pipeline Corporation

SECOND MOMBASA & COASTAL WATER SUPPLY

ENGINEERING AND REHABILITATION PROJECT

REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS

ENVIRONMENTAL IMPACT ASSESSMENT

REPORT

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1. EXECUTIVE SUMMARY

In accordance with the Terms of Reference, environmental impacts have been assessed and proposals for mitigation and monitoring prepared in respect of the present project for the rehabilitation and augmentation of the Sabaki river water intake and waterworks near Baricho and its associated transmission pipelines.

The descriptive parts of this report include the water supply system, the policy, legal and administrative framework for the project, as well as geographical, hydrological, socio-economic and biological conditions that are found in the areas affected. The project itself is described in terms of its principal objective, which is the mechanical, civil and hydraulic engineering design and implementation. The project also includes a better distribution of water along the transmission pipelines and it touches upon some requirements for better staffing and management.

Baseline environmental data are assembled in more detail for the impact area and surounding study area and over a wider range of topics than are directly related to significant impacts associated with the implementation of the present project. This was required by the Terms of Reference.

The Consultant's study team, comprising an institutional specialist, an hydrologist, an ecologist and a resource economist, concluded that:

1. The most significant positive impact, affecting a total population of just under a million people in the study area, is the utility benefit to many consumers of receiving more adequate water supplies. (see Figure 1: PROJECT, STUDY AND IMPACT AREAS)

2. By selling more water and by reducing water treatment costs there is a financial benefit to the National Water Conservation and Pipeline Corporation.

3. There is the generation of more income by some consumers with more time for productive activities.

4. There are cost savings in the tourist industry by not having to arrange for alternative water supplies.

5. Water supply along the pipeline and improvements to the pipeline road are expected to draw settlement into the impact area in the long term. This will be positive if supported by the services, such as land adjudication, that are provided at the District level by other agencies.

6. The most significant negative impact, resulting from increased diversion of water at the intake, and which affects drawers of water, fishermen and some plants and animals, is the reduction in low flows in the Sabaki for 65 km. of river channel downstream of Baricho to the river mouth. Should there be a return of drier conditions such as were experienced in the late 1950s this section of the river is expected to dry up during a month or so of the dry season about one year in two, on average.

Mitigation of the latter negative impact can be achieved by using water stored at or near the intake site for supply during unusually dry periods. Two possibilities for storage are identified:

a. In the natural off-channel reservoir site near Chakama. Further survey of this site is recommended.

b. In the palaeochannel, there is an aquifer 40 to 60 metres beneath the Sabaki river at Baricho. Possibilities for storage in this aquifer will be better defined during the current hydrogeolological investigations being conducted by the Consultant.

7. A fall in the outflow at Mzima Springs is the condition under which mitigation, in respect of Sabaki river low flows, may be required. An investigation of the Chyulu Hills, which is the recharge area for the Mzima Springs aquifer, was conducted during 1984-87. A follow-up to this study is recommended to evaluate the risk of such drier conditions returning. Year by year changes in the mean outflow from Mzima Springs are small. Even if a sequence of drier than average years of rainfall was to commence now, from present levels of Mzima Spring outflow, it would take at least five years for outflows to return to their mid 1950 lows. It is therefore recommended that any decision on implementing any mitigation scheme should await the results of this follow-up study, and decisions on the new bulk water source for the Coast.

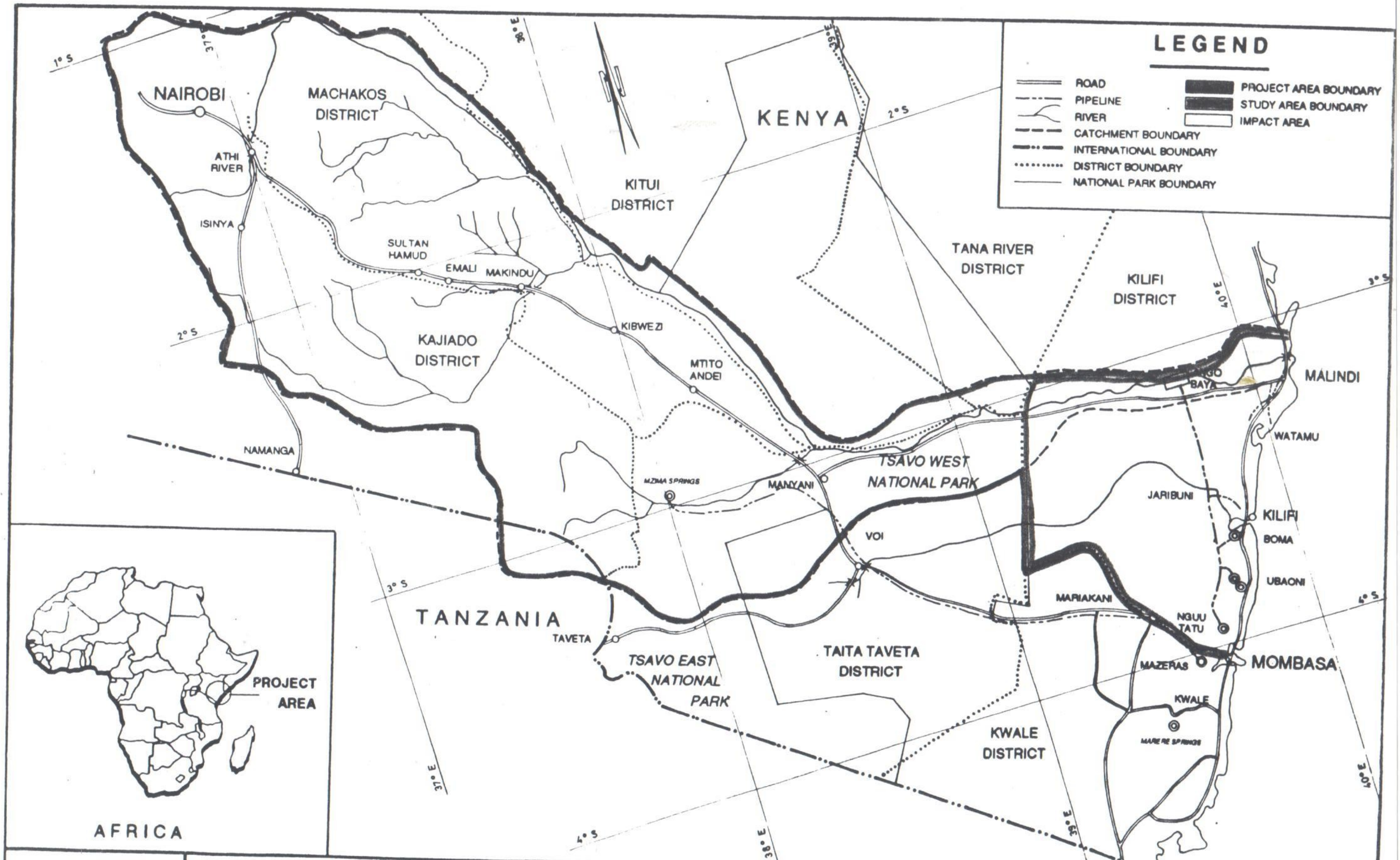
8. Sabaki river water has been analyzed by the Consultant, particularly to detect the presence of poisonous heavy metals and pernicious organic compounds such as pesticides. The results reveal that the water is of potable quality but there are undesirable traces of two types of pesticide.

9. A plan for monitoring water quality, and over a whole range of items of environmental interest is proposed. The monitoring plan allocates a supervisory role to the National Water Conservation and Pipeline Corporation, with most of the measurements and observations to be entrusted to agencies in the private sector who can demonstrate a good track record.

10. There are difficulties in quantifying all impacts expected from the implementation of the present project. These difficulties arise partly from available data being incomplete, partly from the fact that much of this rehabilitation project does not have any distinct new impact, but is really just more of the same. A useful summary of the expected impacts has been prepared in the form of an impact analysis matrix and is shown in the Table below:

IMPACT IDENTIFICATION MATRIX

	ACTIVITY	IMPACT	MITIGATION	ESTIMATED COST TO PROJECT (US $)
A.	PRECONSTRUCTION			
	Survey	Vegetation/Clearing Trampling	Natural Regeneration	-
		Limited crop destruction & loss of income	Compensation	$ 1,000
B.	CONSTRUCTION			
	Drilling	Site clearance	Reinstatement & natural regeneration	$ 2,500
	Pipelaying	Clearing/Trampling Excavation	Reinstatement & natural regeneration	$ 5,000
	Powerline construction	Clearing/Limited excavation	Reinstatement & natural regeneration	$ 1,000
	Water storage and kiosks	Clearing/Excavation Building construction	Land/ Crop compensation Drainage Natural regeneration	$ 6,500
	Pipeline refurbishment	Clearing/Excavation Construction	Improved Security/Drainage Natural regeneration	$ 15,000
	Pipeline road improvements	Construction	Natural regeneration	($ 100,000)
	Sewage works rehabilitation	Pollution	Refurbish & realign outfall to swamp	$ 27,000
C.	OPERATION & MAINTENANCE (DIRECT)			
	Disposal of alum sludge	Pollution of river downstream	Reduce alum/ introduce polyelectrolytes	$ 500,00 per year
	Disposal of TCL sludge	Pollution	Landfill disposal	-
	Pumping from aquifer	Groundwater Depletion	Monitoring/ Avoid overpumping	-
D.	OPERATION & MAINTENANCE (INDIRECT)			
	Limited increase in traditional agriculture	Loss of biodiversity	Improve agricultural practices	none (MoA)
	Concentration of settlements and encroachment on critical habitats	Increased soil erosion	Soil conservation	none (MoA)
		Loss of biodiversity	Environmental protection	$ 12,500 (to DEO)
	Pipeline road	Loss of biodiversity Erosion	Routine maintenance	none (MoW)
E.	ADDITIONAL STUDIES			
	Mzima Springs outflow analysis	Level of downstream low flows	Decision on mitigation measures	$ 125,000
	Pesticide study & monitoring programme	Potability of Sabaki River & Aquifer	Decision on long term use of source	$ 42,500
F.	FUTURE ALTERNATIVES			
	Downstream low flow maintenance using groundwater	Avoid loss of aquatic life Avoid loss of water source for riverside dwellers	Introduce compensation water into river channel	$ 6,000,000
	OR			
	Construction of off river storage near Chakama	Avoid loss of aquatic life Avoid loss of water source for riverside dwellers Loss of terrestrial species Colonization by aquatic plants	Reservoir management	$ 12,000,000
		Loss of pasture	Compensation	$ 25,000



Gauff Ingenieure JBG	SECOND MOMBASA & COASTAL WATER SUPPLY ENGINEERING AND REHABILITATION PROJECT	SCALE: 1:1,250,000 APPROX	REHABILITATION AND AUGMENTATION OF BABAKI WATER WORKS ENVIRONMENTAL IMPACT ASSESSMENT **PROJECT, STUDY AND IMPACT AREAS**	**FIGURE 1** July 1993

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2. POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

2.1. Environmental Legislative and Regulatory Framework

Kenya does not enjoy one Environmental Law. Discussion on a National Environment Policy and Law has been going on for about twenty years (GOK, 1989). The policy paper has been in draft for more than ten years. The National Environment Secretariat, a relatively small department of the Ministry of Environment and Natural Resources, is thus not in a position to demand compliance on any environmental actions for it has no formal basis in law. There are of course laws regulating many sectors which have environmental components.

For purposes of this assessment, the relevant laws are deemed as the ones dealing with water, agriculture, forestry, wildlife and marine protection. The World Bank guidelines for Environmental Impact assessments have been used in the preparation of this report.

2.1.1. Water

The Water Act is the major legislation for policy on water. It provides for a Water Resources Authority, charged with policy generation, and environmental management of the water and wetlands resources of the country. The Act specifies the functions of the Authority as inter alia:

> ".... to investigate the water resources of Kenya; to advise and make recommendations to the Minister in regard to improvement, preservation, conservation, utilisation and apportionment of water resources, and as to the provision of additional supplies.... to make regulations for preventing pollution of water."

All waters are owned by the State as provided by section 3 of the Act. Sections 4 and 7 empower the Minister to control and plan water use. All subsidiary water related bodies, including the National Water Conservation and Pipeline Corporation, get their operational power from this Act.

Study of the Water Act, from an environmental point of view, shows serious shortcomings in terms of the failure to demand environmental assessment of all water development projects. Other shortcomings include the fact that delineation of wetlands is caught between the Agriculture Act and the Water Act, the lack of national effluent standards and of permanent measures for abating flood effects.

Several other acts are relevant. The Chiefs Authority Act provides that a chief may mobilise communal labour in connection with conservation of natural resources including water. The others are the Agriculture Act, the Forests Act, the Irrigation Act, the Malaria Prevention Act, the Public Health Act, the Trust Land Act, the Land Adjudication Act; and for specific areas of the country, the Lake Basin Development Authority Act, the Tana and Athi Rivers Development Authority Act, the Coast Development Authority Act, the Ewaso Ngiro North Development Authority Act, the Ewaso Ngiro South Development Authority Act, and the Kerio Valley Development Authority Act.

On the side of regulation, and not unlike other sectors, one finds overlapping regulatory regime practices. The NWCPC was created to construct large schemes leaving the small ones to the Ministry in charge of water. It has assumed distribution responsibilities in practice, as is the case in Mombasa, Kilifi and Machakos among others. It also has assumed sewerage responsibilities for example in Nakuru. It is not yet clear whether its all embracing role will be given to other bodies in the near future given the divestiture macro-economic framework. For example, the Standard newspaper reported on 12/5/93, that water distribution in Mombasa, supplied by the Baricho Pipeline among others, will be undertaken by the Mombasa Municipality. This seems to reflect a municipal desire and not a formal national policy directive. The role confusion is apparent in rural districts such as Kilifi, where Ministry of Water staff are now working with NWCPC staff in the field. Other donor funded projects are also found in Kilifi. At times they assist the NWCPC as in the reconstruction of the Bamba pipeline, leaving one unclear of the role of the Ministry of Water field officials and Corporation field staff.

It should also be further noted that the Sabaki Waterworks scheme is in the area covered by the Coastal Development Authority which is new and does not have supervisory capacity. It seems to the study team that the regulatory regime needs some role clarification as well as systematising in the posting of scarce staff for in Districts like Kilifi, there are many senior officers in the water sector and it is not exactly clear who has water resources development responsibilities over and above pipeline construction and operation.

For this assessment, the environmental issues considered include the contamination of water by urban, agricultural and manufacturing activities upstream from the intake over and above the environmental impacts of the project itself. This is treated below under land and water conservation for which the Agriculture Act is a more powerful tool although the Water Act has provisions for ensuring that there is no permanent encroachment on water courses as well as for catchment protection.

2.1.2. Soil Conservation and Water Sources Protection

The main legislation covering soil conservation and water sources protection is the Agricultural Act which empowers the Minister to make rules on land preservation under section 48 related to agricultural use as well as relating to deforestation and afforestation. This act is supplemented by a plethora of acts among which are: the Crop Production Act, the Livestock Act; Agricultural Finance Corporation Act; Plant Protection Act; Seed and Plant Varieties Act; Pest Control Products Act; Irrigation Act; Chiefs Authority Act, Land Adjudication and Land Registration Acts and the Coast Development Authorities Act amongst others.

Relevant environmental issues are erosion in the impact area and pesticide, nutrient and chemical contamination of the Sabaki water and river bank protection. On erosion along the pipelines and river banks, the powers of the Agricultural Act can be used to enforce better land use in the environs so that trampling by cattle and clear cutting of environmentally important areas like the Rare River Gorge and the Ndzovuni River Gorge is prevented. This act is enforced through the District Agricultural Officers or through the Provincial Administration utilising the Chiefs Authority Act under the coordination of the District Environment Offices, whose legal basis is the Chiefs Act as they are extensions of Provincial Administration.

There is no historical data on the chemical, nutrient, or pesticide content of the Sabaki waters at the intake. Samples were taken under this study to establish a bench mark. For future monitoring and enforcement, the Agriculture Act and the related acts, reinforced by the Factories Act, will be important in enforcing regulations regarding the pollution detected.

2.1.3. Protection of Forests, Monuments and Cultural Sites

From this assessment, it will be shown that the pipelines do not touch the sacred Kaya sites. The study also presents data on the future plans of setting up different forest areas, protecting major watersheds and protecting the kayas which are usually located in forested areas. The Forest Act, the National Museums Act and the Wildlife Conservation and Management Act are the operating law for achieving these objectives. The Agriculture Act provides for controlling deforestation and afforestation of denuded land. The Forest Act also provides for protection of wildlife in the forested area.

2.1.4. Wildlife and Marine Resources

Kenya Wildlife Resources are managed under the Wildlife Conservation and Management (Amendment) Act of 1989 which replaced the 1978 Act. The body created to manage wildlife by the 1989 act is a parastatal, the Kenya Wildlife Service. Marine resources are managed under the Maritime Zones Act and the Fisheries Act managed by the Fisheries Department of Ministry of Environment and Natural Resources and the Kenya Wildlife Service.

There is but limited terrestrial wildlife in the impact area. However, there is wildlife in the study area and particularly in the Arabuko Sokoke Forest which is near the pipeline, including some rare species. There are birds and fish in the Sabaki River. Most important is the marine flora and fauna in the Malindi and Watamu area which are directly influenced by the Sabaki River, details of which are found in Annexe 2.

Kenya Wildlife Services and the Forest Department have made plans to utilise the Sokoke Forest for tourism where there is limited wildlife. Upstream from the intake is Tsavo East National Park, one of the major national parks. There also are Galana and Kulalu ranches who have planned game ranching schemes.

The waterworks clearly have no negative impacts on the existing or planned terrestrial wildlife activities upstream. Downstream alternative proposals are made that will leave enough water for wildlife. Other than limited numbers of crocodile, hippopotamus and fish in the Sabaki, on its banks there is hardly any wildlife. Occasionally the Sokoke elephants and other game stray from the forest to drink from the river.

Within the Malindi and Watamu Marine Parks and Reserves, sediment from the Sabaki River influences the marine flora and fauna (IUCN/UNEP.1985). Kenya Wildlife Services and the Kenya Marine and Fisheries Institute already have a memorandum of understanding on research on utilisation of the marine resources. Sediment pollution of the Sabaki is a major ecological problem for the marine parks and reserves. It also threatens the tourism industry for the beaches, the main attraction in coastal tourism, are polluted by river sediments for significant parts of the year (Visser, 1992.). The waterworks and the pipeline have no impact on the sediment load going into the sea from the Sabaki. This is a national environmental problem which can only be tackled by conservation utilising the various acts on the whole Sabaki River catchment (see Section 4). This problem has been focus at senior levels of government for a considerable number of years and in spite of many typologies for watershed management no solutions seem to be forthcoming (Okoth-Ogendo. 1989.). Details on the sediment load of the Sabaki are found in Annexe 2.

2.1.5. Mineral Resources

The premier law in this sector is the Mining Act which was enacted in 1940 before environmental issues came to the fore. It is under revision. The key institution is the Department of Mines and Geology in the Ministry of Environment and Natural Resources.

In the study area there are some low output mines for marble, iron, limestone and quarry aggregate. None were identified as threatening the integrity of the pipeline. However, some miners just abandoned sites and there was no reclamation. The law should be applied for reclamation. More significant for the pipeline is the potential of attracting more extensive mining since there is water available in areas which did not have any. Kilifi district has potential for extensive mining. Consequently, it is not unrealistic to hypothesize that the pipeline will attract large scale operations in the long term. In the section on planned activities, it is pointed out that a mining combine is planning to establish a cement factory. T he environmental impacts of such operations will need careful study and monitoring. This can most efficaciously be done by the District Environmental Officer as the executive officer of the District Development Committee.

2.2. NWCPC Institutional and Planning Capacity

Among the proposals for the rehabilitation and augmentation of the Project are systematic staffing, simplified design for operations and maintenance, including provision of transport for examination of the pipeline (Gauff. November, 1992.). The Regional Office of the NWCPC is the planning and management backup to the personnel operating the waterworks.

Currently, there seems to be split responsibility between the staff in Baricho, Kilifi, and Mombasa on supervising breakdowns of the pipeline. This was not clear in the original management practices and seems to have evolved as the NWCPC has located area managers in the field. A decision needs to be made by the NWCPC on whether this is the most efficacious way or whether the original practice of having a mobile workshop based in Baricho, which was currently unserviceable is more useful.

Alternatively, a useful way maybe to get the Area Manager Baricho to be responsible for the pipeline up to the second pumping stage on the Nguu Tatu pipeline. The Area Manager Kilifi can be responsible for the Second Pumping Stage up to the gravity feed tanks in Lower Ribe. Finally Mombasa Office can be responsible for the gravity portion of the pipeline.

2.3. Compensation

According to the original Sabaki Waterworks engineering reports and the rehabilitation and augmentation engineering proposals, it is implied that 500 acres of land for the intake and treatment works was acquired. This does not seem to have been the case. This land did not embrace a national park or reserve. It is not anticipated that there will ever be claims from the National Parks or the Kenya Wildlife Services, however, there could be claims by local people. The study team has pursued this matter with local chiefs, the County Council, engineering staff employed by the Consultant, and the Department of Lands.

This land belongs to the Weru ranch according to Kilifi District Lands Office records. The Weru Group Ranch was, by 1978, registered under the Group Ranches Act. It was issued with a title deed under the Registered Land Act (Chapter 300) on 14/3/1978 by the Kilifi District Land Registry, Title Number Kilifi/Weru/ 18. The title has four portions of 3,100, 3,600, 3,900 and 2,300 hectares for a total of 12,900 ha. The sketch accompanying the title deed shows that the group ranch owns land up to the statutory boundary of the Sabaki River. It is probable then that the land was not trust land when the construction started. If this is so, then the Weru Group Ranch should be compensated or get rent from the state for the 500 acres which it will forfeit, for the state should not just regard it as trust land and not pay for it.

No compensation seems to have been paid for crops and materials on the Nguu Tatu pipeline. However, when the Malindi pipeline was being constructed, K.shs 141,528.05 was paid for crop compensation, whilst Ksh. 11,248 is yet to be paid for various administrative reasons . The sum of K.shs 100,000 was paid to Weru ranch, K.shs 70,000 for wayleave and K.shs 30,000 for murrum soil for building the Malindi access road to the waterworks. Since the Malindi pipeline had to acquire sites for water kiosks, money was set aside to compensate the land owners. An amount of Ksh. 84,385 was set aside for this, but is yet to be paid.

On the Nguu Tatu pipeline road, there is no evidence at the district or national level to show that it was acquired. Neither is there evidence to show that the eleven metre pipeline wayleave was published.

The Consultant formally wrote to the Corporation to request information on the acquisition of land. The issues which need to be resolved are:

a. Acquisition of waterworks site.
b. Acquisition of roads and road reserves.
c. Publication of pipelines wayleave details.
d. Payment of compensation, if any, for land, aggregate and soil used for road construction and crops.
e. Publication of the acquisitions.

In the wellfield area and along the new interconnecting pipelines, there will be need to compensate farmers for trampling and destruction of their crops and pasture. A figure of $9,500 has been allowed for all stages of the Work from survey through construction.

3. PROJECT DESCRIPTION

3.1. Water Sector Environment

This project is in the general water sector environment which has been dominated by issues of the history of the water sector in Kenya, water engineering professional standards and management problems, policy making constraints, and since the late 1970's, the primacy of donor projects in the sector.

3.2. Project Genesis

The regional water supply system for the Coast Province is, since mid-1988, the responsibility of the National Water Conservation and Pipeline Corporation. The service area for this system is divided into eight sub-areas. The coastal strip comprises Malindi, Kilifi, North Mainland, Mombasa Island and South Mainland. The Voi and Mazeras sub-areas are between Voi and Mombasa near the Mzima pipeline and along the rail and road alignments. The Kwale sub-area includes Kwale town.

Five sources, listed below, can supply water to the existing system:

Source	Average production m3/day
1. Marere Springs, South Coast	9,100
2. Tiwi Boreholes, South Coast	3,900
3. Mzima Springs, Tsavo river	35,000
4. Kwa Alenya Intake, Sabaki river (Malindi only, to be phased out at end of 1993)	1,000 - 2,000
5. Baricho Intake, Sabaki river (the subject ofthis rehabilitation and augmentation project)	35,000 - 40,000

A pipeline was laid in 1916 from Marere Springs to Changamwe reservoir and provided the water source for Mombasa until the Mzima Springs pipeline was brought into operation in 1957. In 1982 the Baricho intake and Sabaki Waterworks on the Sabaki river was put into operation as a component of the First Mombasa and Coastal Water Supply Project. This project now serves Mombasa and the north mainland as far as Malindi.

Since 1957 therefore, water resources for additional water supplies to Mombasa, and the coast north of Mombasa as far as Malindi, have been derived from the Athi/Sabaki river watershed. This is shown in Figure 2: SABAKI CATCHMENT AND ENVIRONS, whilst the Mombasa and north mainland supply is shown in Figure 3: SCHEMATIC OF NORTH MAINLAND SYSTEM.

Normal flow in the Athi river is largely from the upper Athi river catchment. The dry season low flows in the Sabaki river are mainly, and for some of the time entirely, outflow from the Mzima springs. The Mzima springs are recharged by rainfall over the Chyulu hills, which are near the middle of the catchment. Sediment discharge in the river comes largely during flood events from the Athi-Kapiti plains, the Machakos area and the Tsavo river catchment.

The Sabaki river source was put forward in the early 1970's as one of a number of alternatives. The terms of reference for the then consultants required that a water source be found to provide an additional 55,000 m3/day of water to meet expanding demand in Mombasa until 1990 (Scott Wilson Kirkpatrick & Partners, March 1972). On the basis of economic merit, the consultants recommended the Pemba river as source with a yield of 32,000 m3/day. As alternatives to provide the full amount there were schemes based on the Sabaki river, the Mwachi river or a second pipeline from Mzima Springs.

The then client, the Mombasa Pipeline Board, decided that the scope of the original study should be widened to include water supplies not only to Mombasa but also to the northern coastal region from Mombasa to Malindi. In 1972, three alternative schemes were proposed, two of which were based upon a development of the Sabaki river while the third was based on a further development of Mzima Springs (Scott Wilson Kirkpatrick & Partners, July 1972). It was concluded that for the 1990 supply to the entire area, estimated at 72,000 m3/day, a two stage scheme, based upon the Sabaki river, was most suitable. The first stage capacity was to be 54,000 m3/day. After study of possible intake sites it was found that the most promising river reach was on a 10 km. section of the Sabaki river between Chakama and Baricho, whilst the Baricho area also offered the possibility of a dam site on the Sabaki river with a reservoir storage potential of over 1,100 million cubic metres.

In May 1973, design started for the first Mombasa and Coastal Water Supply Project with the Baricho intake on the Sabaki river as source. Construction started in 1977 and Phase I of the Project was put into operation in 1982. Difficulties in operation were encountered almost immediately. The Project has never been able to sustain production of its full design capacity for the first phase, and the second phase of stage 1, to be implemented by 1984, was never constructed.

3.3 Impact Area of the Existing Baricho System

Water for Mombasa and the coast north of Mombasa is provided by a system shown schematically in Figure 4: SCHEMATIC OF BARICHO INTAKE AND WATER WORKS. Its principal components are:

1. A 75m long weir across the Sabaki river near Baricho to assist in diverting water into an intake structure.

2. An intake that includes an intake bypass channel from which two pump intakes lead to two screened sumps each with pumpsets to lift raw water to two small balancing tanks at the treatment plant.

3. Six pre-settlement tanks from which water gravitates to three clarifiers before passing through six anthracite filters.

4. Disinfection by chlorination.

5. A treated water pumping station with six pumps for the Mombasa supply and space for three additional pumps for supply to Malindi.

6. A main transmission pipeline to Nguu Tatu bulk storage, which is the distribution point for Mombasa.

7. A booster pumping station on the main transmission pipeline at Jaribuni and three branch pipelines that supply the North Mainland coast including Kilifi.

The system was modified in 1988 by the addition of a pipeline from Baricho to Malindi and installation of the Malindi pumps. This system is currently (June, 1993) being provided with an alternative raw water source from two wells sunk to a depth of over 40m. into the palaeochannel that has been found close to the Sabaki river at Baricho. These current improvements to the Malindi and Watamu water supplies are funded through German financial assistance.

This description of the existing situation can be more completely understood by reference to Fig. 3.1: Schematic of North Mainland System, showing the whole of the primary supply system for the North Mainland and Mombasa Island, together with the proposals for augmentation that are the subject of the current report.

3.4. System Defects

System defects at the existing Sabaki Water Works Intake (Gauff, September 1989) and for the system, including the Baricho-Nguu Tatu transmission pipeline, were identified during investigations by the Consultant (Gauff, August 1992).

These investigations confirmed that parts of the system, in particular the intake and water treatment works, are not performing adequately and cannot achieve the design output because of design faults, inappropriate technology, the lack of completion of several of the original contracts and levels of maintenance and operation below that necessary for proper and efficient functioning. The details of the system defects are:

1. At the intake, the original design concept, intended to reduce the passage of silt and sand into the intake, has not been realized because of aggradation of the river bed. The weir has been completely buried in river sediment, which was quite unexpected and is a hydraulic phenomenon so far largely unexplained (Mertens W. & Negressus F., April 1993).

2. For the higher flows, the construction of gabion spurs either side of the intake entrance has disrupted the river flows anticipated in the design.

3. Excessive amounts of sand and silt in the raw water has caused many pumping failures.

4. The vertical trunk slung pump type adopted has proved inappropriate. This type of pump was not included in the original design but recommended subsequent to tender as a 'cheaper' alternative.

5. At the treatment works, the original concept included mechanical and electrical equipment and control gear when most objectives could be achieved more reliably by use of gravity, non-mechanical alternatives, hydraulic phenomena and manual controls.

6. Installation of some control systems was never completed during the construction works.

7. Problems are also noticeable along the transmission pipeline at most air valves and washouts, although not with the pipes themselves. Vandalism at air valves by local inhabitants to gain access to water has contributed significantly to the problem.

8. There has been a lack of air valve maintenance and of washout operation and maintenance. This has resulted in water loss and the build up within the pipeline at low spots of large quantities of septic sludge. After extended periods of disuse a number of washout valves no longer function properly and must be repaired or replaced.

9. Lack of washing out may also require the pipeline to be swabbed to return it to its design flow capacity.

To rehabilitate the system and to augment the supply, the Consultant submitted a report (Gauff, February 1993) that lists 111 separate proposed measures. From these measures, 16 would appear to have some possible environmental impacts. These are identified in the next two sections.

3.5 Proposed Rehabilitation

The following rehabilitation measures have been identified, from the total of 111 separate proposed measures (Gauff, February 1993), as being of interest in connection with possible project environmental impacts:

1. To streamline river flow in the vicinity of the intake to reduce the amount of coarse sediment entering the intake/bypass channel. This will be achieved by removing the stub groyne upstream of the intake entrance and by modifications at the intake entry (Mertens

W. & Negrassus F., April 1993). The groyne disrupts medium to high flow patterns in its vicinity, currently turning the intake into a sand trap.

2. The aesthetic improvement of the treatment works by descaling and repainting all metal surfaces and applying cement-based white paint to concrete surfaces.

3. An improvement of staff welfare by the provision of social facilities (clinic, and associated vehicle, social halls, canteen etc.), fully equipped for all staff and their families.

4. Enhancement of the supply reliability of chlorine, used as principle disinfectant, by installing an on-site sodium hypochlorite production unit.

5. Augmentation of Baricho housing by building (i) two guest (rest) houses for visitors, and (ii) an appropriate house for the engineer in charge.

6. Improvement of Baricho effluent treatment by reinstating effluent ponds and realigning the outfall.

7. An accurate assessment of the quantity of water consumed at each individual connection and communal water point off-take along the transmission pipeline by (i) replacing faulty meters on individual connections to homes and roadside communal water points, (ii) routine inspection of connections, repair of leakages and reporting of faulty meters, and (iii) provision of bulk meters at offtakes currently unmetered.

8. A reduction in damage along the transmission pipeline to washout chambers located within the area of natural drains downstream of access road culverts by relocation of washout valve chambers and their respective discharge chamber/outfalls away from the natural water courses, and by erosion protection measures around the chambers and outfalls.

9. The reduction to a minimum of water shortages in areas of high population concentration (Matano Mane, Mayembe Matano) in the event of pump shut down at Baricho or pipeline swabbing, by building 90 m3 ground storage tanks at appropriate high level sites in the vicinity of these market centres and by providing suitable storage for distribution to kiosks where considered appropriate.

10. The reduction to a minimum of vandalism of covers at washouts and air valves by (i) providing perforated covers to air valve and washout chambers where covers are missing, (ii) regular inspection of pipeline, (iii) drilling holes in existing metal covers to discourage alternative use and (iv) installing 'key type' locking mechanism in place of padlocks.

11. The reduction to a minimum of pollution at open outfall type washouts by dredging outfall drains to ensure free flow of washout water to suitable discharge points and by stonepitching the drains to minimise vegetation growth within these drains and reduce the resultant swampy areas.

3.6 Proposed Augmentation

The following augmentation measures (Gauff, February 1993) have been identified as being of interest in connection with possible project environmental impacts:

1. An increase in the availability of raw water free of sand or silt using groundwater abstraction from the palaeochannel below the Sabaki river by sinking a number of wells, equipping them with lift pumps, and providing pipeline connections to the treatment works.

2. The supply of power to the wellfield development by procurement and installation of 2 x 750 KVA power transformers together with overhead powerlines, cables and distribution boards.

3. An improvement in the transmission through the pipeline by providing a new booster pumping station, probably at Km. 53, equipped with 6 pumps (3 duty, 3 standby) with pumping head of 190m and capacity of 70,000m3/day.

4. A provisional proposal to by-pass the lower Ribe Reservoir and convert the reservoir to local distribution purposes.

5. Improvements to access roads where augmentation works are expected.

4. BASELINE DATA

4.1. Project, Study and Impact Areas

The project area includes the Athi Sabaki Watershed that has an influence on the project, the study area which is approximately coincident with Kilifi District and which contains the impact areas.

The study area is located in Coast Province, which has the third largest population concentration area in Kenya after the Central and Eastern Provinces. The Sabaki-Nguu Tatu water pipeline falls within Kilifi and Mombasa Districts. Kilifi is one of the six districts in the Province. Kilifi district covers an area of 12,523 km2. Mombasa District, which is also a municipality, comprises Mombasa Island, north mainland as far as Mtwapa Creek which borders with Kilifi District, the South Mainland, to about 5 km. south of the Likoni ferry and the West Mainland as far as Miritini. The district has an area of 275 km2 of which 65 km2 is water surface. Mombasa is one of the major ports on the east coast of Africa.

The impact area of the Project is much smaller (see Figure 1. page iv and Figure 5: PIPELINE AND ACTUAL SUB- LOCATIONS SERVED). It comprises:

- the rural and urban areas where the population is served by the project's water supply;
- the Sabaki river and its immediate surroundings in the vicinity of and downstream of the Baricho intake in so far as they may be affected by the operation of the water works.

Satellite SPOT imagery 146-356, 146-357 and 146-358 has been used to map land use along the pipeline. This imagery is of high quality and cloud-free. Imagery of similar quality is not available for the late 1970's when the pipeline construction started. The present imagery dates from February 1989. It allows interpretation and mapping of land use (see Figure 6: LAND USE ALONG PIPELINE.) to assess possible changes and provides the basis for future assessment of land use changes.

There are four distinct geographical zones in the project area which determine the resources and land use patterns of the project area. These are:

-The Coastal Plain; a narrow belt 3 to 20 km wide, rising to approximately 30m above sea level, except for north of Malindi where it reaches approximately 60 m above sea level; the area is dissected by creeks and drainage lines and the Sabaki river channel.

- West of the coastal plain; undulating terrain rising from an elevation of 30 m up to 135 m; this plateau country is seaward-sloping with the terrain dissected by dry watercourses with underlying jurassic sediments consisting of marine deposits, sandstones and impervious clay; vegetation is grasslands and stunted, dry bush; developments along the coast for tourism have resulted in a population movement into the area; this is a risk area in respect of soil erosion, the results of which are evident in places.

- The Coastal Range; a distinct set of sandstone hills varying from 135 m to 420 m above sea level, running parallel to the coast line; a region with some of the best farming areas in the province with good rainfall and fertile soils; this zone and the Nyika Plateau are west of the immediate project area, but form part of the Sabaki river catchment.

- The Nyika Plateau; a low-lying region which occupies approximately 60 % of the total Kilifi district area; terrain is gently undulating; vegetation is sparse; there are shallow depressions overlain by poor soils; climate is semi-arid with very low potential for rainfed agriculture; used for ranching and traditional herding of cattle, sheep and goats with some farming of sorghum and millet.

4.2 The Athi/Sabaki Watershed

There are two major rivers, the Tana river and the Athi river, draining in a south-easterly direction from the central highlands of Kenya into the Indian Ocean. Of these two, the Tana which lies to the north of the Athi, is the larger river in catchment area and runoff. The Athi river, however, includes Nairobi and its surroundings in its upper catchment.

The Athi river rises over 500 km. from the ocean on the southern slopes of the Nyandarua range, where average annual rainfalls are about 1200 mm. These headwaters represent only a few percent of the catchment, most of which lies in the semi-arid plateau foreland of Kenya that separates the highlands from the coastal belt. In this dry part of the country, annual rainfalls are from 400 to 800 mm.

The total catchment area of the river, from headwaters to the Indian Ocean, near Malindi, is 38,000 sq. km. There are 35,000 sq. km. above Baricho which is about 40 km. from the coast. Baricho is the village near the intake site for the water supply system that serves Mombasa, Malindi and the coast between.

The river above the confluence with the Tsavo river is known as the Athi. Just below the confluence, from Lugard's Falls to the ocean, the river is known as the Sabaki river, the upper parts of which are also called the Galana river.

The Tsavo river is partly fed from Mzima Springs, which derives flow from a very substantial aquifer under and to the south east of the recent volcanic Chyulu Hills. The Mzima Springs outflow is rather constant from season to season but varies slowly when there are periods of high or low rainfalls sustained over several years (British Geol. Survey et al., February 1988).

The surface flow of the Athi river, above the Tsavo confluence, sometimes ceases for short periods during spells of dry weather sustained over one or more seasons. During such periods the Sabaki river flows are derived from Mzima Springs outflows. There are substantial channel losses along the Tsavo and Sabaki rivers (Mansell-Moullin M., November 1973; Gauff, September 1989). However, the Sabaki outflow to the ocean has not been observed to dry up in living memory (Mansell-Moullin M., November 1973).

From the headwaters to the ocean the river brings down large quantities of silt and sand during periods of heavy rainfall and high flow. Erosive action is principally in areas where the density of surface drainage is greatest.

The annual sediment transport for the Sabaki river has been estimated (Tippetts Abbett McCarthy Stratton, 1980) at just under 10 million tonnes, equivalent to 400 tonnes per sq. km. or about 0.3 mm. depth of soil when averaged over 25,000 sq. km, which is the proportion of the total area in which erosion processes may be significant. This can be compared with erosion processes in the Tana catchment where the river at Garissa is estimated to carry over 35 million tons annually.

These estimates, when compared with the estimates for the Athi river, indicate that the difficulties with erosion in the catchments, and sediment transport in the Athi/Sabaki river, are in line with difficulties experienced in other parts of the country. Accelerated erosion is a country-wide concern. The very considerable nuisance caused by waterborne erosion products in the ocean at Malindi and at the Baricho water works is not considered a sufficient reason for treating the Athi catchment as a special case.

Results from river records up to 1972, in other parts of the country than the Athi river catchment, have suggested that there is a trend to higher annual runoff as the years go by. There was evidence that the dry weather flows had also increased. These changes are attributed to lower evapotranspiration and increased ground water recharge where shallow rooted vegetation on settled land has replaced original deeper rooted vegetation.
In default of any recent nationwide review of trends in streamflow, for the purposes of this report, it can be assumed tentatively that a similar positive trend would be found in Athi river flows, if sufficient data were available.

Another positive trend in Athi river catchment runoff results from increasing volumes of effluent from Nairobi, all of which must find its way into the Athi river. This trend can be expected to continue to increase so long as Nairobi water supplies are obtained from the neighbouring Tana River catchment.

The climate is tropical over the watershed but varies from the coast to the headwaters. At the coast conditions are humid with a very weakly bimodal rainfall distribution. The rest of the catchment varies from sub-arid/arid in the plateau foreland to sub-humid in the upper part of the catchment with a strongly bimodal rainfall distribution in all parts. The rainy seasons are associated with the north and south movements of the intertropical convergence zone.

River flows in the Athi/Sabaki river have been estimated from records obtained at regular gauging stations. The earliest records are from 1949. Since then new stations have been opened, and some closed and abandoned.

There is a recent report that is intended primarily as an assessment of the low flow regime at the Baricho intake site on the Sabaki river (Gauff, 1990). After careful inspection of available data it proved possible, by noting the characteristics of the flow during periods of concurrent records at two or more gauges, to piece together a near continuous estimate of monthly river flows at Baricho for the period 1956 to 1989. This very useful result is used later in this report.

Flood flows have not been well recorded. The largest floods within the period of record were in 1951 and 1961 (Mansell-Moullin M., November 1973). The peak discharge for a 100-year return period is estimated at 7,500 cu. m/sec. Flood waters at Baricho in 1968 were reported to be over 9 m. deep (Scott Wilson Kirkpatrick & Partners, July 1972).

For the whole of the catchment above Baricho, the rainfall can be reckoned at 600 mm. in an average year, and the mean annual runoff at 40 mm. (Tippetts Abbett McCarthy Stratton, 1980). The difference of 560 mm. is accounted for largely by actual evapotranspiration.

4.3 The Sabaki River

4.3.1 Geology and Hydrogeology

A thick wedge of Mesozoic sediments covers bedrock at and near the coast. The bedrock is dislocated along several north-south trending faults. This coastal section of Kenya has been alternately elevated and depressed above and below sea level over a period of perhaps the last 250 million years. The great depth of sedimentary rocks, which dip gently east seawards, are therefore of both marine and continental origin.

Sea level fluctuations in Pleistocene times and their possible hydrogeological implications for Kenya have been the subject of considerable speculation and some investigation since the turn of the century. The present investigations of the Sabaki river in connection with abstracting groundwater from the sediment filled palaeochannel near Baricho were commenced in 1988.

Because the ocean level was some 40 to 60 m. lower at an earlier time, the river channel was incised below its present level from downstream of the Galana Causeway to the ocean. When sea levels rose to the present levels then the deeper palaeochannel was infilled with erosional products brought down by the river. Where these depositional materials are sufficiently coarse, high potential aquifers are to be found.

The site for the surface water intake, near Baricho, was selected principally for the favourable topography just downstream of the Lango Baya fault. The river section here is relatively stable where it is confined by the sides of the valley that the juvenile river cut through the sandstone/siltstone/mudstone barrier. It is precisely this relatively steep section of the palaeochannel, where flow velocities would have been high, that is the location where the deposited alluvial material is coarse with the finer sediments washed out. There may be a number of other favourable upstream sites for wellfields along the Sabaki, where the transmissivity of the aquifers is high. However, it may turn out that Baricho, selected for other reasons as a water supply intake site, is also the location of the best aquifer in Kenya.

Generally the character of the Sabaki river channel changes little as it approaches the ocean. The river is typically about 80 m. wide, and shallow. The river where it enters the sea has a tidal wedge, or volume of sea water entering the river at high tide, that is either absent or very small; therefore the Sabaki cannot be said to have an estuary. There is a small deltaic deposit of sand usually to be found at the bar. Salt water is occasionally detected at low flow during high tide at the Sabaki bridge. This can be assumed to occur when the river flows are of the order of 3 cu. m/sec or less. This would be expected for about two months in the year, on average. A condition of zero discharge in the Sabaki river would allow sea water to enter about 1 km. upstream of the bridge at high tide.

Currently, (June 1993) a research project is being undertaken by J. Abuodha of Moi University on the development of beach and dunes from Malindi to Mambrui. In his unpublished work the aggradation of the beaches at the Sabaki river mouth is illustrated by a comparison of several aerial photographs of different dates. A simplified mapping on the same lines has been prepared for this report and is shown in Figure 7: BEACH AGGRADATION, 1969 TO 1989.

The southern beach was eroding somewhat at some time between 1954 and the early 1960's (Abuodha, J., personal communication; evidence supported by an inspection of erosion features, just below the terraces of the Eden Roc Hotel), but has been aggrading rapidly since then. (Delft Hydraulics Laboratory, 1970). The northern beach was slowly aggrading prior to 1969, and has aggraded rapidly since then. Any satisfactory explanation of the processes forming beach and dunes and the apparent changes over the last four decades is likely to be quite complex.

4.3.2 Water Balance at Baricho

Baricho and its surrounding area receive water inputs from:

- the Sabaki river flows (inflows from upstream, surface and sub-surface);
- from rainfall.

Water outputs from the same area are from:

- onwards Sabaki river flows (outflows, surface and sub-surface);
- water pumped to Mombasa and the north coast down the pipelines;
- water lost by evaporative processes from vegetation and any open water surfaces;
- local runoff into the river, including treated effluent;
- water percolating downwards to provide local groundwater recharge.

The mean annual flow of the Sabaki river at Baricho is 39 cu. m/sec, equivalent to 1,230 million cubic metres per year, of which 12.5 million cubic metres are currently pumped from the Baricho water works into pipelines. By contrast, the local rainfall amounts to 800 mm. annually, equivalent to 80 million cubic metres per year over, say, a local area surrounding Baricho extending over 100 sq. km.

For the palaeochannel aquifer, the water balance for the Sabaki river flows indicates that the annual average recharge is of the order of a hundred times greater than the likely amounts of groundwater abstraction from a pumped wellfield. The current state of knowledge indicates that horizontal subsurface flows in the palaeochannels are very small compared with surface flows, so long as there is flow in the surface channel. If surface flow ceases, then the subsurface groundwater movements become of significance.

4.3.3 Groundwater abstraction at Chakama-Baricho

The present state of knowledge regarding groundwater development at Baricho has been summarized in recent communications from the hydrogeologists who are responsible for the current investigations (Van Dongen P., May 1993, and Gauff, March 1993) as follows:

1. The two production boreholes on the south bank upstream of the Baricho intake have been successfully test pumped at 1000 cu. m/hr.

2. The quality of the pumped water is good. Initially the water smelt of H_2S, but not after several days pumping.

3. The transmissivity of the aquifer is in the range of 8,000 m2/day, which is an exceptionally high value for Kenya.

4. There appears to be a direct hydraulic connection between the surface flow in the river and the aquifer.

5. A very large quantity of water can be pumped without significantly lowering the water table. The pumped water was free of fine suspended particles.

Currently, (June 1993), investigations continue in order to better define:

1. aquifer dimensions;
2. permeability and storage capacity;
3. recharge mechanism;
4. groundwater flow pattern;
5. water quality distribution pattern.

A successful outcome of these investigations would render it possible to set up a groundwater management computer model to evaluate the various possibilities and constraints for groundwater development of the palaeochannel.

It can be assumed that the present wellfield will pump from an aquifer with a storage of tens of millions of cubic metres of groundwater, say, 20 million cubic metres. It can be further assumed that this aquifer is in good hydraulic connection with the surface water flows in the Sabaki river. It is expected that more locations along the river will be identified where similar wellfields can be established. What cannot be assumed is that the process that yields clean water from the muddy Sabaki flows can be exploited without constraint in perpetuity.

The present investigations, together with experience gained from the operation, expected later in 1993, of the two existing production wells to supply water to Malindi, will provide the information needed to develop a management plan. Careful monitoring of various aspects of the development of groundwater are needed to assist in decision making. In particular, surface water flows in the Sabaki should be measured in a regular and reliable manner.

Two ground water development options are considered for the purposes of the present study. These are:

1. A pumped storage scheme, where water is pumped from groundwater to an off-river natural reservoir site near Chakama. Pumping constraints assumed are that there is no pumping when Sabaki river flows are very muddy, above 100 cu. m/sec, or very low, that is below 2 cu. m/sec. Water from the reservoir is delivered by pumping to transmission pipelines.

2. A scheme where the aquifer is pumped continuously, and therefore depleted during those periods when the Sabaki flows are less than the rate of abstraction. During such periods the river flows would be expected to dry up in the vicinity of the wellfield. Flow would be restored downstream to an agreed compensation level by introducing pumped groundwater into the downstream river channel.

These alternative options are referred to in a later section of this report. Both of them mitigate one of the significant negative environmental impacts of the rehabilitation and augmentation of the Baricho water works, namely, the reduction in downstream Sabaki dry season flows when more water is diverted from the river at Baricho. They would also maintain the supply during unusually low flows.

Where groundwater is used for village supplies from shallow wells in the area surrounding Baricho or downstream near the river, the current state of knowledge indicates that groundwater development of the palaeochannel will have no effect outside of the immediate vicinity of the palaeochannel. This is because the transmissivity of locally occurring aquifers is so much lower than that of the palaeochannel that any changes in water levels in one will not affect the other. Expected changes in water levels away from the river channel are not expected to occur as a result of changes in the Sabaki river flows. Recharge to locally exploited groundwater resources is from rainfall, as described in 4.3.2 above.

4.4. Biological Conditions

4.4.1 Baseline Information

Baseline information on soils, terrestrial, riverine and marine vegetation and fauna are assembled as annex 3 to this report.

4.4.2 Water Quality

The results of normal water analysis from Sabaki River and Borehole water are presented in Table 1: WATER QUALITY OF SABAKI RIVER SYSTEM AT BARICHO. For comparison purposes the study team has presented results of raw water and treated water as analyzed on 25/6/1990. Although the results of several analyses are available for Sabaki River water, this was the only occasion when water from the same batch was analyzed before and after treatment.

Based on the results of the above analyses, both the Sabaki River and wellfield water are of good chemical quality as potable water. Levels of fluorides and nitrates, substances detrimental to humans in high concentrations, are lower them maximum limits recommended by the WHO and Kenya Government as shown in Table 2: GUIDELINES FOR DRINKING WATER QUALITY FOR KENYA AND THE WORLD HEALTH ORGANISATION.

Although the raw river water is turbid (155 NTU) and contains levels of iron (1.9 mg/l) above the maximum desired limits (0.3 mg/l), the Sabaki water does not contain levels of other substances that may require any other special treatment over and above the conventional treatment of flocculation, coagulation, filtration and disinfection.

Other Sabaki River samples, probably taken from higher river flows, have shown lower iron content. Analysis of raw river water (near old Treatment Works) done on 8/11/85 (Sample 865) and again on 24/9/86 (Sample 1703) showed values of 0.1 mg/l or less. Analysis of treated water

(Baricho) done on 6/6/84 (Sample 205), 31/5/85 (Sample 861) and on 24/8/85 (Sample 294) gave similar results. The manganese levels were similar, in the range 0 to 0.1 mg/l.

Nutrients such as phosphorus and nitrogen are essential for all living organisms. They are the major limiting nutrients in both the terrestrial and aquatic ecosystems.

The concentrations of phosphorus and nitrogen in water arise from natural breakdown of organic and inorganic matter in soil and water. Occurrence of these nutrients may also arise from application of fertilizers such as urea, NPK complex, ammonium sulphate and diammonium sulphate (DAD).

Occurrence of nitrogen and phosphorus in large concentrations leads to eutrophication with subsequent over-production of macrophytes and algal blooms. The results of the water analysis show normal concentrations of phosphorus and nitrogen, characteristic of a natural unpolluted river. During field observations along the river, eutrophic conditions were absent.

Generally, trace amounts of metals are always present in waters from the weathering of rocks. Some of the metals like manganese, zinc, and copper, in trace amounts, are important for physiological functions of living tissues and regulate many biochemical processes. However, heavy metals when present in water at high concentrations are poisonous for humans and aquatic life. Increase of heavy metals in natural waters is mainly attributed to discharge of industrial and sewage effluents such as those discharged at Nairobi; mining activities may also contribute.

The present analysis, as shown in Table 3: LEVELS OF PESTICIDES, HEAVY METALS AND NUTRIENTS IN SABAKI RIVER WATER, showed concentrations of heavy metals in Sabaki water below the maximum allowable values recommended by WHO, EC countries, USA, Canada and USSR for drinking water, fisheries and other aquatic use. Guidelines for maximum allowable values are given in Table 4. MAXIMUM ALLOWABLE CONCENTRATIONS OF HEAVY METALS, NUTRIENTS & PESTICIDES FOR DIFFERENT USES.

Pesticides are chemical compounds toxic to a wide range of organisms from bacteria to higher plants and animals. These compounds do not occur naturally in the environment. Consequently, any detectable pesticide concentrations indicate pollution.

Results of pesticide analysis as illustrated in Table 3, show that out of 21 pesticides analyzed 5 were found to be present in Sabaki water. The pesticides found to be present in the water were aldrin (0.45 ug/l), captan (3.8 ug/l) dieldrin (1.3 ug/l) and the metabolites of DDT namely, pp'DDD (4.2 ug/l) and op'DDE (0.13 ug/l).

These pesticides belong to three groups, the sulfenimide fungicides (captan), diene-organochlorides (aldrin and dieldrin) and the degradation products of DDT (pp`DDD and op`DDE). These are products that are chemically stable and hence their persistence in the environment.

Levels of aldrin (0.45 ug/l) and dieldrin (1.3 ug/l) in Sabaki water are above the maximum allowable limits recommended by WHO. These are highly toxic chemicals and their use has been banned or restricted in countries such as USA.

Although DDT was not detected in Sabaki water, one of its metabolites (pp`DDD) was present (4.2 ug/l) at higher than the maximum limit (1.0 ug/l) recommended for DDT by WHO. The captan concentration (3.8 ug/l) in Sabaki water is also higher than the maximum limits (0.1 ug/l) allowed for individual pesticide in EC countries.

There were no organophosphorus pesticides (malathion, parathion, paraoxon, diazinon etc) found in Sabaki water. This may be attributed to the low chemical and biochemical stability of this group of pesticides. Many of the organophosphorous pesticides decompose within a month of their introduction into the environment.

It would be unwise to draw firm conclusions from the above data. The pesticide results in particular are based on a single sampling during the fieldwork exercise, analysed by a single laboratory. What is clearly indicated is that detailed sampling and split sample analyses are imperative to ascertain the principle sources of this probable pollution and its spatial and temporal variation.

4.5 Social Conditions

4.5.1 Baseline Information

Baseline information on land use, population, structural problems, and observations made by the Study team during fieldwork are annexed to this report. Some conclusions on the impact of the transmission pipelines are summarised in the following section.

4.5.2 Impacts of Pipelines

The population distribution has been reviewed and the land use seen on the ground described (see Annex 4). It is clear to the study team that it is not the pipeline which is driving land use now. Land use is driven by historical processes, especially of the Giriama. Specifically, land use is driven by the household coping strategies developed in historical times of slash and burn agriculture, building households, and splitting them to exploit production in different zones. There is a veneer of non-Giriama influences as the other Kilifi Mijikenda, who face tremendous land hunger, move into some of the Giriama areas and buy land. The pipeline has made life easier in Lango Baya and Makobeni sublocations of Jilore location for people who claimed the land historically and who moved back for economic reasons.

The comments above should not be used to deny the potential for the pipeline making a difference in terms of the kind of people who will move next to the pipeline in the long term. On the Nguu Tatu pipeline, there are three farmers who are large scale operators and they have bought land next to the pipeline since it assures them comfortable operations. One has a fruit plantation of close to 50 ha. He is very busy buying land and is reputed to have bought close to 1,000 ha. at the Mwengea Hill base. On the land abutting the pipeline he is careful not to make an individual connection but rather uses local labour to draw water for his orchard from the public supply. The second large scale operator has bought more than 100 ha. and planted it with sisal, orchard and casuarinas for poles. The third has a completely modern mixed farm with improved livestock.

The point is that non-Mijikenda are beginning to speculate on the land next to the pipeline. It is expected that this will grow. Its environmental impacts are likely to be positive for the new operators use modern farming techniques and conserve the land and forest resources. Whether the social impacts are positive is doubtful, for in the long term these settlers will be throwing poor people out of this land; they in tur n will go to exploit drier lands with negative environmental impacts. It is not clear that the Kilifi Mijikenda, and the Giriama in particular, have an answer to this social threat for their squatting strategies. These strategies assured access to different ecological areas which had been zoned for transient settlers - the Arabs and the British - whilst the local large scale operators are here to stay.

4.5.3 Water Supply and Impacts on Health

There are three hospitals in the district, forty dispensaries and six health centres. These services are very unevenly distributed and large sections of the population have little access to them.

The most important endemic diseases in Kilifi District are malaria, bilharzia and diarrhoea (Katui-Katua et al, 1985). Studies in Kilifi District (Wellcome Trust) show that disease patterns vary considerably from one location to another. The ongoing KEMRI/JICA work is highlighting the need to better understand and identify causal agents. The principal causes of morbidity in the Kilifi and Mombasa districts are shown in Table. 5: PRINCIPAL DISEASES IN KILIFI AND MOMBASA DISTRICTS 1986, 1987.

Annual totals do not provide a clear indication of trends in water-related diseases. For example, the total number of out-patients diagnosed with diarrheal diseases at Coast General Hospital in 1981 was 53,594. This fell to 27,461 in 1987, and 1991 rose to 29,174. However, 1981 was a very dry year and it is thought that consumers were obtaining water from depleted, contaminated sources. In Malindi there is a very seasonal and intense diarrheal disease problem in the wet season when the poor town drainage is unable to cope with rainfall. This is coupled with heavy population density, especially in the unplanned settlements without sanitation infrastructure.

There is little evidence to show that there will be any significant change in disease incidence which is related to water. Although water-borne diseases are of great importance many factors contribute to their transmission and impact. Enhancing supply is a prerequisite for reduction in disease problems, but practices such as storage and handling within the household units are more important. Water is rarely boiled, and during acute shortage periods, traditional wells and dams are being used for consumption. These are usually contaminated. In Mombasa seepage from pit latrines, that exist in close proximity to wells, is known to occur (Ministry of Health, pers comm.) Dams in the hinterland have also been tested and are heavily contaminated (Katui-Katua et al,1985).

It is clear that the link between water supply per se and the incidence and intensity of disease and parasite problems is insufficiently known to provide a basis for estimating the impact of improved water supply. Other, more important factors are: the use of water, storage, sanitation, personal habits and attitudes. However, isolated events such as cholera outbreaks in Kayafungo and Bamba areas, in the early 1980's, during the driest periods, suggest that surface water sources used at these times were probably contaminated. The close proximity of shallow wells to pit latrines in Mombasa apparently provides a link in the faecal-oral routing of some diseases. An estimated 70% of all Mombasa residents use pit latrines. 20% have septic tanks. Only 10% are connected to the piped sewerage system. Finally, other diseases such as respiratory diseases will continue to cause high morbidity in rural areas.

Health benefits usually rely on high rates of water usage that are typically provided only by household connections. There is a sharp decline in the quantity consumed when the source is outside the house or compound, and there is a direct relationship between distance to water and consumption per capita (above minimum requirements). Water supply alone is not sufficient to mitigate disease, but it is recognized that it is essential to "..provide adequate quantities (of water) near to the home to encourage and facilitate regular washing by all." (Katui-katua et al, 1985). Hygiene education, improved sanitation, disposal of waste water and enforcement of regulations are other essential inputs.

Kilifi district water resources are only now being studied in toto by the Dutch funded Water Resources Assessment Programme. The situation described by the Appraisal Mission on Kilifi Water and Sanitation Programme, that there was no data to evaluate the impact of water on water borne diseases still obtains (Katui-Katua.1985, KIWASAP 1991, various). It is not possible to establish the impacts on the health of the population as a result of supplying fresh water for the basic data on the health of the district is missing. Table. 6: KILIFI DISTRICT: NOTIFIABLE DISEASES 1981 TO 1992, shows the diseases which by law have to be reported. There is no pattern to the data.

From discussions with health, water and administration field personnel and previous WHO work, (WHO/UNEP. 1982.), the study team concludes that the majority of the people of the district have mixed water strategies whereby they use pond, pan, well and river water if it is nearer their homes than piped water. Consequently, it is unrealistic to expect the impacts of piped water to be clear. There is a second research problem. It is estimated that only 20-40% of the district population have at one time or other attended a health facility. Most of the district population get their health needs taken care in the traditional medicine system. Consequently it would be impossible to develop realistic parameters for the impacts of improving water supply system. The developed pipeline supply, as argued under population, reaches about 363,631 people or 61% of the districts population in 1989 occasionally. Since this coverage is episodic, it is not possible to conclusively show its impacts. As the WRAP data becomes available and sets up a baseline, it will be possible to specify these impacts in the future.

Water is however a very definite "felt need", due to the district's semi-arid nature, and improved supplies undoubtedly produce benefits in terms of time savings and reduced physical effort. For example, at present women have to carry water up to 12 km. in the dry season in the Bamba area and all non-piped sources have been determined to be heavily contaminated.

One of the key activities in the district is the water hygiene programme of the Kilifi Water and Sanitation programme which has been operating in the district since 1988. It seeks to improve handling of water in the home and at limited sources. In the long term, this activity, more than perhaps pipelines, will have positive health impacts for the major environmental health issue are contaminated sources and handling contamination and not contamination of piped supply.

4.6. Economic Conditions

4.6.1. Agriculture

The immediate impact area along the pipeline to Mombasa lies almost entirely within the Cashewnut-Cassava zone, L4. The areas closer to the coast, served by the water subsidiary pipelines fall under the Coconut-Cassava Zone, L3. In general, agricultural land use can be summarised as traditional, with a low degree of modernization. The cultivation of food crops for home consumption predominates (Hoorweg, 1991; Foeken, 1989). Mixed cropping is the normal strategy. Yields are low. However, the farming system is complex, although land use practices and farming tools appear simple. Slash and burn farming is still employed in some areas, notably closer to the Kilifi Creek area. This form of land use requires long fallow periods which are no longer possible under present population densities, and will have to be abandoned in favour of resource-conserving practices. The farming system employed by an extended family unit typically straddles all three ecological zones described, as a risk aversion strategy.

Average farm size is approximately 3.2 ha., but this statistic conceals the strategy families adopt in owning and farming more than one plot. Households usually have two and sometimes three and four plots in different agro-ecological zones. On average house-holds have 2.7 plots (Foeken, 1989). Plots vary in size down to 1.5 ha. Main crops are cereals, cassava, legumes and bananas. There is only one reliable cropping season, although cassava acts as a food storage crop and is harvested in the dry season. Maize and cassava are the main food crops. Food crops cover 70% of the land in Kilifi district.

In general food production is low and covers only half the family's energy requirements. Only 15% of households succeed in covering their total food requirements. Coconuts, cashews and mangos or citrus are grown by more than half of all farmers, and cover approximately half their farm areas although inter-cropping is normal. Pests and diseases are principal constraints. Mosaic virus is particularly bad for cassava.

There is an average of 4.3 adult labour units per household, of which 1.2 units (25%) is engaged in off-farm employment. Off-farm employment plays a vital role in the agricultural economy of the project area, accounting for two-thirds of household income on average Ksh. 6,560 in 1985. Over 60% of all families obtain income from employment. Less than 10% restrict themselves to farming only. A diversified household economy is the norm, involving off-farm income, through wage employment or the informal sector.

Tree crop and livestock sales provided only Ksh. 1,258 per household in 1985 on the Kenya Coast, and Ksh. 820 in Kilifi in Zone 4. The value of food crops was estimated at Ksh. 2,207 in the wider Kenya Coast and Ksh. 3,815 in Kilifi in Zone 4. The total value of household agricultural production represented a return of Ksh. 2,200-2,900 per hectare in the Kilifi Zone 4 sample (Foeken, 1989). This was equivalent to US $ 137-180.

Even so, some 40% of rural households in Kilifi district live below the food poverty line, although variation in income and income composition is considerable. Location and access to labour markets is of vital importance in determining non-farming income opportunities. There is no significant difference in household income among the agro-ecological zones represented. This may be construed to suggest that most households are living at or near to basic subsistence level. There is very limited ability to create surpluses and invest in human capital (education) and the farming system. Agricultural credit is not available, in practice, and technical support negligible, so agricultural households in the study area have limited scope to make the economic transition to greater prosperity and food security.

4.6.2 Tourism

Tourism is the dominant commercial sector in Kilifi District and has stimulated activities in all spheres of the economy especially agriculture, manufacturing, road and air transportation, and construction.

There are more than 7,200 hotel beds on Mombasa Island and the north coast to Malindi. A further 800 beds are planned or under construction. This estimate does not include cottages and flats and boarding houses used for tourism.

In 1993, occupancy rates on the coast have fallen 12% by comparison to the same period last year, but is still in excess of 58% overall. The peak occupancy period was 1991, with a an average of 78% room occupancy. In 1992, it fell to 71%, probably due to Kenya's adverse international publicity. The industry has entered an uncertain stage. There is world-wide recession and Kenya's image was tarnished by insecurity and political changes, and strong competition is being presented from alternative destinations for travellers. South Africa has offered a new market, but Kenya's success in capturing this market has been limited by economic and political constraints at home in South Africa. There was a decline in the industry in 1992, and the trend is a further fall in 1993, although sales to agencies housing staff involved in the Somalia and Sudan relief activities will bolster a flagging industry.

The Malindi and Watamu Marine National Parks and the Malindi Marine National Reserve are vital tourist attractions for the industry. The Arabuko-Sokoke Forest is in its early stages of development as an attraction, but is a focus of conservation concern for its unique avifauna. It is an important lowland dry forest.

4.6.3 Fisheries

In 1992, total fish catch was 1,005 tons as recorded at seven landing stations in Kilifi District. The informal fishing industry is not a large employer. It covers approximately 475 fisherman using 160 boats. However, it is economically important for the total value of catch was Ksh. 22 million in 1992. The extent of the catch that goes unrecorded is not known, but undoubtedly would add significantly to the income, subsistence value and employment from the industry.

There is extensive commercial trawling off Malindi and north to Lamu, in Ungwana Bay. The catch is landed in Mombasa, or processed at sea and transferred to motherships, and it is not possible to identify the catch component relevant to the project area offshore from Malindi. Data on production is sketchy and under-reporting is believed to be rampant.

There is no noticeable trend in total fish catch, at least in the artisanal sub-sector. Production has varied from a low of 629 tons in 1990 to 1,390 tons in 1991. The data may reflect the extent of reporting, rather than accurate production trends, in any case. Netting with fine gauge nets and traps within the river mouth area of the Sabaki River may be important in affecting catch potential. Such fishing is however only undertaken during medium to high flows, for during low flows there are hardly any fish to catch.

Sportfishing for tourists and residents is an important sub-sector and there has been a strong growth in the number of registered charter boats operating out of Malindi, Watamu, Kilifi Creek and Mtwapa Creek. There are 23 charter and 10 private game fishing boats in Kilifi district. The main season is August through to March. In 1992, just over 150 tons of game fish were landed. The majority of fish were released after tagging, a trend that is being strongly promoted by game fishing organizations.

4.6.4 Commerce, Industry and Mining

There is limited industrial and commercial development in the study area. The main towns of Mombasa, Malindi and Kilifi form the central economic places, in a hierarchy of urban centres, rural, market and local centres. The economic linkages are weak beyond these, except in terms of repatriation of wages and supply of essential foodstuffs. The main agricultural cash crop production is along the coastal strip, and the hinterland, where the pipeline is situated, is a substantial net food importer. In addition, agro-processing; oil extraction, cashewnut processing, cotton ginning and copra making; is confined to the main towns. There is virtually no saw-milling potential from natural woods in the impact area.

Commerce is typically trading in food crops and consumer trade goods, and follows closely the administrative structure of centres.

Mining is limited to Bamburi Portland Cement (limestone), Vitengeni Mines in Ganze, gypsum at Roka, south of Malindi, extraction of rock for building and decorative use on the pipeline road by Athi River Mining, and the Associated Battery Manufacturers lead mine near Mombasa. Sand and stone, hard and limestone, is locally important but not recorded in district statistics. Other minerals in the study area include limestone in the Jaribuni area and manganese and galena in the Kivara area near Jaribuni, but these are limited in potential. Once water becomes more available it is thought that more mining in the area will occur. The construction industry is also locally important but restricted in its impact to the coastal area; value added accrues in the principal urban areas, especially Mombasa.

Salt production and shrimp farming are conducted north of Malindi, outside the impact area.

Although hotels and the service industries are an important employer in the study area, over 90% of the population remains dependent on agriculture as the main economic pursuit. The tourist industry is vital to rural families as an important source of off-farm income.

A large area of land lying just west of the pipeline route, and south of Baricho, was an important charcoal exporting area in the 1970's (National Environment and Human Settlements Secretariat, 1984). The area is no longer an important source of charcoal. The study team found no

(Baricho) done on 6/6/84 (Sample 205), 31/5/85 (Sample 861) and on 24/8/85 (Sample 294) gave similar results. The manganese levels were similar, in the range 0 to 0.1 mg/l.

Nutrients such as phosphorus and nitrogen are essential for all living organisms. They are the major limiting nutrients in both the terrestrial and aquatic ecosystems.

The concentrations of phosphorus and nitrogen in water arise from natural breakdown of organic and inorganic matter in soil and water. Occurrence of these nutrients may also arise from application of fertilizers such as urea, NPK complex, ammonium sulphate and diammonium sulphate (DAD).

Occurrence of nitrogen and phosphorus in large concentrations leads to eutrophication with subsequent over-production of macrophytes and algal blooms. The results of the water analysis show normal concentrations of phosphorus and nitrogen, characteristic of a natural unpolluted river. During field observations along the river, eutrophic conditions were absent.

Generally, trace amounts of metals are always present in waters from the weathering of rocks. Some of the metals like manganese, zinc, and copper, in trace amounts, are important for physiological functions of living tissues and regulate many biochemical processes. However, heavy metals when present in water at high concentrations are poisonous for humans and aquatic life. Increase of heavy metals in natural waters is mainly attributed to discharge of industrial and sewage effluents such as those discharged at Nairobi; mining activities may also contribute.

The present analysis, as shown in Table 3: LEVELS OF PESTICIDES, HEAVY METALS AND NUTRIENTS IN SABAKI RIVER WATER, showed concentrations of heavy metals in Sabaki water below the maximum allowable values recommended by WHO, EC countries, USA, Canada and USSR for drinking water, fisheries and other aquatic use. Guidelines for maximum allowable values are given in Table 4. MAXIMUM ALLOWABLE CONCENTRATIONS OF HEAVY METALS, NUTRIENTS & PESTICIDES FOR DIFFERENT USES.

Pesticides are chemical compounds toxic to a wide range of organisms from bacteria to higher plants and animals. These compounds do not occur naturally in the environment. Consequently, any detectable pesticide concentrations indicate pollution.

Results of pesticide analysis as illustrated in Table 3, show that out of 21 pesticides analyzed 5 were found to be present in Sabaki water. The pesticides found to be present in the water were aldrin (0.45 ug/l), captan (3.8 ug/l) dieldrin (1.3 ug/l) and the metabolites of DDT namely, pp'DDD (4.2 ug/l) and op'DDE (0.13 ug/l).

These pesticides belong to three groups, the sulfenimide fungicides (captan), diene-organochlorides (aldrin and dieldrin) and the degradation products of DDT (pp`DDD and op`DDE). These are products that are chemically stable and hence their persistence in the environment.

Levels of aldrin (0.45 ug/l) and dieldrin (1.3 ug/l) in Sabaki water are above the maximum allowable limits recommended by WHO. These are highly toxic chemicals and their use has been banned or restricted in countries such as USA.

Although DDT was not detected in Sabaki water, one of its metabolites (pp`DDD) was present (4.2 ug/l) at higher than the maximum limit (1.0 ug/l) recommended for DDT by WHO. The captan concentration (3.8 ug/l) in Sabaki water is also higher than the maximum limits (0.1 ug/l) allowed for individual pesticide in EC countries.

There were no organophosphorus pesticides (malathion, parathion, paraoxon, diazinon etc) found in Sabaki water. This may be attributed to the low chemical and biochemical stability of this group of pesticides. Many of the organophosphorous pesticides decompose within a month of their introduction into the environment.

It would be unwise to draw firm conclusions from the above data. The pesticide results in particular are based on a single sampling during the fieldwork exercise, analysed by a single laboratory. What is clearly indicated is that detailed sampling and split sample analyses are imperative to ascertain the principle sources of this probable pollution and its spatial and temporal variation.

4.5 Social Conditions

4.5.1 Baseline Information

Baseline information on land use, population, structural problems, and observations made by the Study team during fieldwork are annexed to this report. Some conclusions on the impact of the transmission pipelines are summarised in the following section.

4.5.2 Impacts of Pipelines

The population distribution has been reviewed and the land use seen on the ground described (see Annex 4). It is clear to the study team that it is not the pipeline which is driving land use now. Land use is driven by historical processes, especially of the Giriama. Specifically, land use is driven by the household coping strategies developed in historical times of slash and burn agriculture, building households, and splitting them to exploit production in different zones. There is a veneer of non-Giriama influences as the other Kilifi Mijikenda, who face tremendous land hunger, move into some of the Giriama areas and buy land. The pipeline has made life easier in Lango Baya and Makobeni sublocations of Jilore location for people who claimed the land historically and who moved back for economic reasons.

The comments above should not be used to deny the potential for the pipeline making a difference in terms of the kind of people who will move next to the pipeline in the long term. On the Nguu Tatu pipeline, there are three farmers who are large scale operators and they have bought land next to the pipeline since it assures them comfortable operations. One has a fruit plantation of close to 50 ha. He is very busy buying land and is reputed to have bought close to 1,000 ha. at the Mwengea Hill base. On the land abutting the pipeline he is careful not to make an individual connection but rather uses local labour to draw water for his orchard from the public supply. The second large scale operator has bought more than 100 ha. and planted it with sisal, orchard and casuarinas for poles. The third has a completely modern mixed farm with improved livestock.

The point is that non-Mijikenda are beginning to speculate on the land next to the pipeline. It is expected that this will grow. Its environmental impacts are likely to be positive for the new operators use modern farming techniques and conserve the land and forest resources. Whether the social impacts are positive is doubtful, for in the long term these settlers will be throwing poor people out of this land; they in tur n will go to exploit drier lands with negative environmental impacts. It is not clear that the Kilifi Mijikenda, and the Giriama in particular, have an answer to this social threat for their squatting strategies. These strategies assured access to different ecological areas which had been zoned for transient settlers - the Arabs and the British - whilst the local large scale operators are here to stay.

4.5.3 Water Supply and Impacts on Health

There are three hospitals in the district, forty dispensaries and six health centres. These services are very unevenly distributed and large sections of the population have little access to them.

The most important endemic diseases in Kilifi District are malaria, bilharzia and diarrhoea (Katui-Katua et al, 1985). Studies in Kilifi District (Wellcome Trust) show that disease patterns vary considerably from one location to another. The ongoing KEMRI/JICA work is highlighting the need to better understand and identify causal agents. The principal causes of morbidity in the Kilifi and Mombasa districts are shown in Table. 5: PRINCIPAL DISEASES IN KILIFI AND MOMBASA DISTRICTS 1986, 1987.

Annual totals do not provide a clear indication of trends in water-related diseases. For example, the total number of out-patients diagnosed with diarrheal diseases at Coast General Hospital in 1981 was 53,594. This fell to 27,461 in 1987, and 1991 rose to 29,174. However, 1981 was a very dry year and it is thought that consumers were obtaining water from depleted, contaminated sources. In Malindi there is a very seasonal and intense diarrheal disease problem in the wet season when the poor town drainage is unable to cope with rainfall. This is coupled with heavy population density, especially in the unplanned settlements without sanitation infrastructure.

There is little evidence to show that there will be any significant change in disease incidence which is related to water. Although water-borne diseases are of great importance many factors contribute to their transmission and impact. Enhancing supply is a prerequisite for reduction in disease problems, but practices such as storage and handling within the household units are more important. Water is rarely boiled, and during acute shortage periods, traditional wells and dams are being used for consumption. These are usually contaminated. In Mombasa seepage from pit latrines, that exist in close proximity to wells, is known to occur (Ministry of Health, pers comm.) Dams in the hinterland have also been tested and are heavily contaminated (Katui-Katua et al,1985).

It is clear that the link between water supply per se and the incidence and intensity of disease and parasite problems is insufficiently known to provide a basis for estimating the impact of improved water supply. Other, more important factors are: the use of water, storage, sanitation, personal habits and attitudes. However, isolated events such as cholera outbreaks in Kayafungo and Bamba areas, in the early 1980's, during the driest periods, suggest that surface water sources used at these times were probably contaminated. The close proximity of shallow wells to pit latrines in Mombasa apparently provides a link in the faecal-oral routing of some diseases. An estimated 70% of all Mombasa residents use pit latrines. 20% have septic tanks. Only 10% are connected to the piped sewerage system. Finally, other diseases such as respiratory diseases will continue to cause high morbidity in rural areas.

Health benefits usually rely on high rates of water usage that are typically provided only by household connections. There is a sharp decline in the quantity consumed when the source is outside the house or compound, and there is a direct relationship between distance to water and consumption per capita (above minimum requirements). Water supply alone is not sufficient to mitigate disease, but it is recognized that it is essential to "..provide adequate quantities (of water) near to the home to encourage and facilitate regular washing by all." (Katui-katua et al, 1985). Hygiene education, improved sanitation, disposal of waste water and enforcement of regulations are other essential inputs.

Kilifi district water resources are only now being studied in toto by the Dutch funded Water Resources Assessment Programme. The situation described by the Appraisal Mission on Kilifi Water and Sanitation Programme, that there was no data to evaluate the impact of water on water borne diseases still obtains (Katui-Katua.1985, KIWASAP 1991, various). It is not possible to establish the impacts on the health of the population as a result of supplying fresh water for the basic data on the health of the district is missing. Table. 6: KILIFI DISTRICT: NOTIFIABLE DISEASES 1981 TO 1992, shows the diseases which by law have to be reported. There is no pattern to the data.

From discussions with health, water and administration field personnel and previous WHO work, (WHO/UNEP. 1982.), the study team concludes that the majority of the people of the district have mixed water strategies whereby they use pond, pan, well and river water if it is nearer their homes than piped water. Consequently, it is unrealistic to expect the impacts of piped water to be clear. There is a second research problem. It is estimated that only 20-40% of the district population have at one time or other attended a health facility. Most of the district population get their health needs taken care in the traditional medicine system. Consequently it would be impossible to develop realistic parameters for the impacts of improving water supply system. The developed pipeline supply, as argued under population, reaches about 363,631 people or 61% of the districts population in 1989 occasionally. Since this coverage is episodic, it is not possible to conclusively show its impacts. As the WRAP data becomes available and sets up a baseline, it will be possible to specify these impacts in the future.

Water is however a very definite "felt need", due to the district's semi-arid nature, and improved supplies undoubtedly produce benefits in terms of time savings and reduced physical effort. For example, at present women have to carry water up to 12 km. in the dry season in the Bamba area and all non-piped sources have been determined to be heavily contaminated.

One of the key activities in the district is the water hygiene programme of the Kilifi Water and Sanitation programme which has been operating in the district since 1988. It seeks to improve handling of water in the home and at limited sources. In the long term, this activity, more than perhaps pipelines, will have positive health impacts for the major environmental health issue are contaminated sources and handling contamination and not contamination of piped supply.

4.6. Economic Conditions

4.6.1. Agriculture

The immediate impact area along the pipeline to Mombasa lies almost entirely within the Cashewnut-Cassava zone, L4. The areas closer to the coast, served by the water subsidiary pipelines fall under the Coconut-Cassava Zone, L3. In general, agricultural land use can be summarised as traditional, with a low degree of modernization. The cultivation of food crops for home consumption predominates (Hoorweg, 1991; Foeken, 1989). Mixed cropping is the normal strategy. Yields are low. However, the farming system is complex, although land use practices and farming tools appear simple. Slash and burn farming is still employed in some areas, notably closer to the Kilifi Creek area. This form of land use requires long fallow periods which are no longer possible under present population densities, and will have to be abandoned in favour of resource-conserving practices. The farming system employed by an extended family unit typically straddles all three ecological zones described, as a risk aversion strategy.

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Although hotels and the service industries are an important employer in the study area, over 90% of the population remains dependent on agriculture as the main economic pursuit. The tourist industry is vital to rural families as an important source of off-farm income.

A large area of land lying just west of the pipeline route, and south of Baricho, was an important charcoal exporting area in the 1970's (National Environment and Human Settlements Secretariat, 1984). The area is no longer an important source of charcoal. The study team found no production going on during field work. No evidence of transport vehicles carrying charcoal or firewood from the area was collected. However reports to members of the study team in the field indicate that forest reserves such as Arabuko-Sokoke are now sources of subsistence charcoal and fuelwood.

It is possible that 15-20% of the potential labour force of Kilifi District is engaged in wage employment, with a rate of job creation of 8-10% per annum (National Environment and Human Settlements Secretariat, 1984). In the early 1980's over 60% of all employees at Kilifi hotels were from the district, and a total of 74% were from Coast Province (Migot-Adholla et al, 1982). Agriculture provides wage employment for only about 4% of the potential labour force. Locally the Kilifi Plantations and Vipingo Estates are important employers with a labour force of approximately 3,500.

Off-farm employment is primarily a male activity, involving 60% of adult men (Foeken, 1989). There are few opportunities for wage employment in the farming areas, so those seeking labour must move to sites of work opportunity. Off-farm employment provided an average wage of Ksh. 10,000-12,000 in 1985 (US $ 625-750) in a sample of 324 rural households. An estimated 60% was available for repatriation to families, after housing and subsistence costs at the place of work. Where agricultural production is more than adequate there is less off-farm labour.

About 70% of the income of the district is thought to originate in the coastal belt (Kilifi District Development Plan 1989-1993).

5. ENVIRONMENTAL IMPACTS

5.1 Impacts to Ecosystems

The Baricho Pipeline was installed in 1982. No study on environmental impacts was carried out before the construction of the pipeline. The present environmental impact study pertains to rehabilitation and augmentation of existing works.

Construction activities for the rehabilitation and augmentation project will involve vegetation cutting, trampling, excavations, and other earth moving activities. The result will be some loss of biodiversity and a reduction in the complexity of plant communities at the sites. These impacts are minor and natural regeneration processes will heal the land.

Ecological impacts of this project mainly falls into four broad categories. These are:

1. Impacts of modifications to the intake.
2. Impacts of development of wellfields.
3. Impacts associated with the operation of water treatment works.
4. Impacts of water transmission pipelines.

Intake modification will be carried out to streamline the flow pattern. This development will not interfere with the river ecology, the river flow volumes, water characteristics and flora and fauna composition. It will not affect the marine ecosystem downstream.

Abstraction of water from the Sabaki during exceptionally low flow periods may have adverse effects on aquatic flora and fauna. The Sabaki River maintains a specialized community of aquatic, flora and fauna. The riverine aquatic life will be threatened if flow becomes very small or ceases. This can be mitigated against as described in section 6.

That the decision may be made to abstract groundwater rather than surface water from the Sabaki river has no significant ecological impact. There are no water springs, swamps, or other forms of wetlands which are fed from the aquifer.

The present impact of the treatment works is associated with the disposal of used alum, the sludge from tropical chloride of lime and domestic sewage from the staff facilities.

Aluminium sulphate (alum) is the sole coagulant used at the Baricho Treatment Works. Between 1989 and 1991 an average of 4935 kg. of alum was used daily in the treatment of raw river water. The used alum is disposed into the Sabaki River just below the intake. The concentration of aluminium downstream of intake may be high although no analytical measurements have been carried out. The discharge of large quantities of alum into the Sabaki River is a source of pollution to the river. A problem associated with the introduction of alum is an increased solubility of the aluminium ion when the pH of the water is low. The resultant increase in concentration can be toxic to fish and plants and also render the water unsuitable for other uses. Should it be confirmed that toxic levels occur, then it would be necessary to reduce the amounts of alum used by the introduction of polyelectrolytes into the treatment process.

Tropical chloride of lime (TCL) is the most commonly used source of hypochlorous acid which is used to disinfect water. In the process of hypochlorous acid preparation sludge is produced. The sludge is currently dumped on an open site near the transformer station. Although the sludge is mainly calcium carbonate, it contains traces of hypochlorous acid injurious to plant life. This effect was observed during the field visit.

The dumping of the sludge derived from tropical chloride of lime (TCL) in the open is unacceptable. This impact will be mitigated against in the future by disposal as landfill into the nearby abandoned quarry.

The sewage from the staff houses is treated in a series of ten oxidation lagoons situated three kilometres from the water treatment works. During the field visit it was found that four of the lagoons (maturation ponds) were empty and dry. Hence the presence of lagoons has no eutrophication or pollution impact on the surrounding areas. The lagoons are to be refurbished and the outfall realigned to discharge into a downslope swampy area as mitigation.

There will be no ecological impact on the marine habitat associated with the rehabilitation of water works at Baricho which is 65 km upstream of the river mouth. The sea receives a lot of silt from the Sabaki river. This increases the turbidity of water thereby reducing primary production. Siltation gradually smothers and kills the coral reefs. Siltation turns the productive sea grass beds to mud flats. The sediment loads carried by the river to the sea, however, are not affected in any way by the operation of a water works at Baricho.

The transmission pipelines traverse mainly through Kilifi woodlands and have no direct impacts on critical habitats such as the Arabuko-Sokoke Forest Reserves, the Kayas, sacred groves or monuments. Mostly the direct impacts occurred during the installation of the pipeline in the 1980s. There was destruction of plant communities through vegetation clearing, excavation, trampling and other construction activities. Since then, the ecosystem seems to have recovered from the impact. Mitigation has been through natural regeneration. It can be assumed that the same natural process will occur when the minor project construction works for off pipeline storage and for water kiosks are complete.

At many places along the pipelines air valves have been broken in order to gain access to water in air valve chambers. This exposes the water in the pipeline to faecal pollution. This water can transmit waterborne diseases such as cholera, dysentery and typhoid. This threat exists specially at times when efficiency at the Baricho water works is low. This will be mitigated by the provision of water kiosks and the rehabilitation of the air valves in better secured chambers.

At the location of some of the pipeline washouts, which were sited to take advantage of natural drainage lines, small marshy areas with impeded drainage are found; at other places the drainage lines are eroding. Mitigation of these two problems is a component of the rehabilitation and augmentation project using erosion control techniques.

The existence of the pipeline and pipeline road has some indirect impacts: effects on human settlement, river gorge habitats and movements of the Arabuko-Sokoke Forest elephant population.

The availability of water along the pipeline has attracted limited permanent settlement around the pipeline, which is mainly woodlands. Slash and burn cultivation practice kills indigenous tree species during land preparation. Consequently, it reduces both the complexity and biodiversity of the ecological communities, and leads to environmental degradation. Mitigation of these impacts must be by the introduction of resource conserving agriculture by the extension services of the Ministry of Agriculture.

The pipeline passes across the Rare River and Ndzovuni River gorges. This does not significantly damage these unique sites but it has exposed the area to human encroachment. These gorges have little agricultural potential, but gorge vegetation is cut and set on fire. This is done to destroy the habitat of primates which are considered a menace on the surrounding farms. Measures to limit human encroachment should be implemented under the direction of the District Environmental Officer.

Previously, until the late 1960's, the coastal elephant population moved across woodland and bushland towards Tsavo National Park and back. The elephant population in this area is no longer migratory and is confined to the Arabuko-Sokoke Forest Reserve. Their previous migration route has been completely cut off by human settlement, some of which occurs along the pipeline.

With the loss of their migration route, elephants have now become permanent residents of the Arabuko-Sokoke Forest Reserve. This area lacks a permanent source of water. In order for elephants to stay in the forest through the dry season they need a permanent source of water. This issue should be addressed by the Kenya Wildlife Service.

5.2. Socio-Economic Activities

5.2.1 Impact of Improving Access to Water along Pipelines

The impact associated with improving water supplies along the pipeline extends 3 km to each side of the alignment. The Corporation's plan is to provide water kiosks along the alignment for the use of those living near the pipeline. A principal concern of the Corporation is to prevent vandalism of air valves, station chambers and the pipeline itself by providing formal access to a water supply.

It is expected that the provision of water along the pipeline will influence land values in the project area.

Although there are usually net economic benefits from rural road upgrading projects, the pipeline road should not be improved unless this is done as a specific road development project, following from a feasibility study of the kind normally undertaken for rural road projects. This would have the effect of limiting development of the road as a major transport corridor, unless it is found to be desirable by the District Development Committee, and the road is drawn fully into the Ministry of Works road system.

The study team is of the opinion that the road could play an important role in rural development of the project area as it is an essential transport link route. But if the Corporation is concerned that the impact of the project should be minimised rather than undertake any development that may have an uncertain outcome, it is advisable to opt for the "do nothing" scenario. Furthermore, project funds for road upgrading are rather limited.

The most significant impact that consumers will experience is the utility benefit of receiving adequate water for their needs.

There will also be lower costs for those families which spend on water collection, and more productive time available to those who collect water for their families.

There is a potential health impact, but a quantitative assessment of this has been excluded from the analysis: health benefits should not be assumed to arise from the improved water supply because the provision of essential complementary inputs (education, primary health services) and investments (sanitation, drainage) to achieve first order health benefits cannot be assumed, and it is beyond the scope of the project to provide these. It is clear that health benefits can and do occur but there are so many inter-dependencies with other cultural, social, educational, environmental and economic factors that the water related benefits to health have not been successfully isolated.

5.2.2 Cost savings in urban and rural areas

There is little recent data on average per capita water demand related to consumption. In the period 1948-62 average daily consumption in Mombasa fell from 110 to 100 litres per capita. The reduction is thought to have resulted from the growth of unplanned areas where consumption is lower because water is carried from a source or bought from hand cart operators. From 1962-1969 Mombasa grew by 5.7% per annum. The original waterworks consultants, Scott Wilson Kirkpatrick, concluded that demand increased from 1952-1972 at 5% per annum, closely in line with population growth. Thus, it is believed that demand has exceeded supply for the last three decades, but has been most acute from the mid-1970's to mid-1980's.

Much of the domestic water for the majority of low income families is sold through water kiosks. For example, in 1983 150,000 m3 was sold by 35 kiosks on Mombasa Island and 240,000 m3 by 113 kiosks on the North Mainland part of Mombasa district. Distribution by hand-cart operators is an established business. Water should be sold to consumers at Ksh. 2 per 20 litres by distributors or kiosks. The purchase price is Ksh 1 per 20 litres. However, in areas or at times when there is no water shortage the price is Ksh. 5-10 per 20 litres. When demand is high the price rises to Ksh. 15-20 per 20 litres. Water cart operators make 5 trips per day with an average of 10 debes (20 litres) of water.

Displacement of kiosk operators and hand-cart businesses is unlikely to occur once supply is increased because the constraint for low income domestic users, the main market for hand-cart operators, is distribution, rather than supply. In fact it is possible that a greater and more reliable supply will provide more employment. Employment will also be generated by new industries once guaranteed water is available.

5.2.3 Agriculture and Trade

Possible indirect benefits from water supply to urban and rural communities are higher cash incomes and increased and more reliable subsistence agricultural production. These accrue only if time saved is devoted to productive activities, and if gains can be made in yields, crop sales or wage incomes. Labour is a production constraint in the Kilifi farming systems, so greater labour availability at planting and weeding times should generate second order benefits.

Second order benefits that may be generated include more crops, more high value crops, new crops, higher yields, improved technology for husbandry of crops and livestock. Once again, complementary inputs, such as farm credit and extension services are required. A common observation is that more successful families in urban areas and farmers in rural areas served with new water supplies take advantage of water supply improvements and obtain first and second order benefits. In other words, effective and efficient water use is a consequence of development, rather than its progenitor. The water supply itself can be considered as a development-oriented input.

Along the transmission pipeline alignment, the most important infrastructure to consider in assessing the socio-economic impact, is the function of the pipeline access road, rather than the provision of water to communities along the pipeline. This is trafficable by four-wheel-drive vehicle over its whole distance, although in places it is severely eroded and difficult to negotiate in many places. At present, the road carries limited transport, including 3 matatus and 2 buses daily from Lango Baya through Matano Mane to Kilifi. The pipeline road is classified as the E 1922 from Matano Mane to Nguu Tatu. Between Matano Mane and Baricho intake, it is part of an old road, D553 which is supposed to cross the river and connect Baricho town. The road has the potential to bring about both benefits; better marketing network, improved and cheaper transport; and costs; greater net exploitation of fuelwoods and erosion.

In combination, the water supply along the pipeline and presence of the pipeline road, are expected to have the long term effect of drawing settlement into the immediate impact area. Settlement and more intensive land use is likely to lead to greater agricultural production, but at the expense of greater resource use and lower production in the areas from which settlers are drawn unless they were in surplus.

The land use and the agricultural households in the study area indicates how fragile the typical or average household economy is. The low degree of food self-sufficiency makes households dependent on cash crops, which also face severe ecological constraints, livestock and off-farm employment. Land availability and socio-economic conditions appear to be directly linked, and it appears that at least 1 ha per household of food crops is required (Foeken, 1989). Thus, it is unlikely that the provision of water along the pipeline and to other new beneficiaries will have a measurable impact on agricultural production. These families, in general, do not have the assets nor financial and technical ability to acquire or implement the complementary inputs.

Land use would benefit from more secure land tenure. The result of non-ownership is a tendency to over-exploit the land, mine the soil and ultimately negate agricultural production (National Environment Secretariat, 1985). A similar cause-effect is believed to be associated with squatting on land owned by absentee landlords or trust land for example in the area on the North Mainland of Mombasa district. The conversion of coastal forests or bushland to agriculture or exploitation for fuelwood results in dramatic increases in erosion, ranging from 4-15 tons/ha. in central Kilifi. Rates of 8-16 tons/ha have been recorded at Magarini, in Kilifi District, resulting from clearing and settlement (National Environment Secretariat, 1985).

If the immediate impact area is treated as a "settlement scheme", adjudicated, and supplied with soil and water conservation and extension services in the near term, it can be concluded that agricultural production will increase and living conditions improve markedly. This has been the experience on settlement schemes at the coast (Hoorweg et al, 1991). However, it is emphasized that changes of this nature would not be the result of the improvement of water supply from the Sabaki and provision at points along the pipeline. It will be the result of gradual processes in keeping with population growth, gradual agricultural management improvements and, fundamentally, job creation that provides the essential off-farm income for these communities to generate a surplus which is to be invested in agriculture.

5.2.4 Cost savings in the tourism sector

The tourism industry is one of the main sectors that has been severely affected by the water shortages in Coast Province. With current supply running at approximately 45-50% of establishment demand, many hotels are bringing their water in from distant sources by bowser. Provision of adequate water is expected to have a positive impact on the sector through:

- reduced costs to the economy of carting water;
- improved image of Kenyan beach hotels in the international trade.

Interviews with representatives of the tourism industry and hotel operators, has provided the basis for estimates for the hotel industry in the impact area. Costs are not uniform due to the location of hotels, sizes and their occasional requirements in relation to occupancy. Some hotel companies have invested in water tankers and additional storage facilities. The average price of water per litre (bulk) was Ksh. 0.36 per litre delivered in 1992, or US $ 0.01 (one cent). This excludes capital investments and depreciation. This is equivalent to Ksh. 5,000 (US $ 140) per room per annum in 1992. For all hotels on Mombasa Island and North Coast, water shortages may have cost as much as Ksh. 18 million (US $ 0.5 million) in 1992. This cost is, however, a transfer payment to other companies and individuals who made the water deliveries, and not a direct loss to Kenya. Nevertheless there are net costs to the economy in terms of vehicle operating costs and the opportunity cost of workers and vehicles utilised for water transport.

The net economic value added is believed to be approximately 12% for Kenya's transport industry, based on input-output ratios. Therefore intermediate inputs account for 88% of total cost and can be regarded as the economic cost, diversion of resources, of supplying water. Therefore, a rough estimate of net economic savings, the opportunity cost, from providing an adequate supply would be something less than 88%, and in the order of US $ 0.3-0.4 million per annum (1992). The extent of investment, and its economic cost, for water storage imposed by water shortages from the system are not known.

5.2.5 Level of Tourist Activity

It is not possible to establish the extent of cancellations of bookings to Kenya Coast have been caused by water shortages and attendant problems, such as restricted use of showers and swimming pools. However, our enquiries in the industry suggested that there has been a significant negative impact on visitor numbers and on Kenya's image as a beach destination. This is unwelcome at a time when there is unprecedented competition in beach tourism, from countries such as Seychelles, Mauritius, Maldives, Reunion and destinations in the Red Sea and Far East.

5.2.6 Negative Impacts of Tourism

Demand for resources, including foreign exchange to import capital goods and consumables, required by the industry is a negative impact on the economy. Previous studies have shown that tourism has a 40% foreign cost content (Economist Intelligence Unit, 1979; Mitchell, 1968,1971), but is a net contributor to Kenya in terms of economic transactions. Improvements could be made in distribution of benefits and repatriation to Kenya from overseas tourism sales by agents.

The demand for beach sites has contributed to displacement of people from traditional land. This is less driven by the requirements of tourist hotels than by the twin factors of land speculation and poverty among traditional households. Physical planning is disastrously neglected and outdated, and the process of land adjudication and registration is extremely slow.

Concern that tourism has negative impacts on the environment, through unplanned settlement, rapid urban growth and modification of natural sites, and on social behaviour and customs, is a subject beyond the scope of this study. Prostitution is often quoted as an example, and is clearly prevalent in Malindi and Mombasa. It should be noted, however, that the guidelines and legislation and necessary regulatory bodies exist to manage and control tourism development, its impact on the environment and society. For example, the Government recently established the Coast Development Authority, and the Kenya Tourist Development Corporation has been in place for two decades to plan and oversee development of the industry. Any detrimental effects from tourism are likely to be shortcomings in practice at the management level, rather than inevitable consequences of tourism.

5.2.7 Siltation of Beaches and Reefs

Sediment loads in the Sabaki river cause considerable concern to hotel operators in Malindi. The silt load carried by the river into the sea deposits on the Malindi beach and affects reefs in the Malindi-Watamu Marine National Park. There is a total of 16 km. of beach in the Malindi area. Of this, 6 km. is estimated to be seriously affected by the Sabaki silt load. This 6 km. is where the majority of hotels are situated. This jeopardizes the tourism in the Malindi area.

The project has no impact on the behaviour of the Sabaki river in respect of sediment transport.

5.2.8 Fisheries

The extraction of additional water from the Sabaki river will not significantly affect artisanal fishing in the vicinity of the river mouth as this is only of significance during medium and high river flows. There will be no effect on offshore commercial trawling.

5.2.9 Mining, Industry and Commerce

The project will have no impact in the long-term on the structure and size of mining, industrial and commercial sectors. However, it will significantly reduce costs and management problems through the utility function of improving piped supply to premises in these sectors. Approximately half the supply is consumed by commercial and industrial users as shown in Table. 7: TOP WATER CONSUMERS. Among them are Kenya Ports Authority, Kenya Breweries, Kilimanjaro Mineral Water, Ministry of Public Works, Bamburi Portland Cement, Kenya Petroleum Refineries. As in the case of the hotel industry, these institutions have been committed to incremental costs of water supply and storage, but no cost estimates for these sectors is available.

No direct (quantifiable) impact on job creation and income levels is foreseen. Contribution to a long-term indirect effect of incremental job opportunities is expected.

5.4. Financial and Economic Impact on NWCPC

An improved supply of water from Baricho will provide opportunities for improved financial and economic performance from the Corporation, which will lead to direct benefits to Kenya. These possible benefits are: reduced cost of maintenance, reduced use of chemicals, and increased income from the greater water supplied and reduced delinquency rates. The lowered costs of operation imply foreign exchange savings.

The estimated incremental project revenues generated by the sale of the additional water produced under the project provide a partial valuation of net project benefits, and can be added to the net benefits of obviating the present system of carting water to hotels, commercial, industrial and domestic premises. Other unquantifiable benefits discussed previously are health, impact on urban development, tourism and recreation. The Project Appraisal, using incremental project revenues as a measure of benefits, determined an economic rate of return of 23% over 35 years. The very positive nature of net benefits reflects the large gains to be made by the interim (short-term) measures of improving supply from Baricho.

To achieve these benefits the Corporation should be financially viable and autonomous. This implies that the Government's stated policy on cost recovery will be fully implemented. The Corporation must also be institutionally sound and adequately manned by competent staff, a subject being tackled under a separate ongoing consultancy. Maintenance is a significant factor which needs to be addressed urgently.

5.5. Environmental Impact Benefit-Cost Matrix

Since many of the implications of the project to increase water production at Baricho have indefinite or unquantifiable impacts, it is useful to consider the possible effects in the form of an Environmental Impact Benefit-Cost Matrix that combines subjective and quantifiable representation of the range of possible consequences. The Matrix is a table showing the nature of impact, the criteria that can be assessed, the expected changes or effects and their classification as first or second order impacts, and an opinion describing the impact (positive, negative, indefinite). Where money values or quantities can be provided these are included in the Matrix, to support the overall conclusions of the study team. The matrix is presented as Table. 8: ENVIRONMENTAL IMPACT ANALYSIS: SOCIO-ECONOMIC CRITERIA.

6. ANALYSIS OF ALTERNATIVES

6.1. Alternatives for Sustaining Sabaki Low Flows

Present circumstances are that about 80,000 cubic metres per day, equivalent to 930 l/s, are diverted from the natural flows of the Athi/Sabaki river system. Of this amount 430 l/s are abstracted from the Mzima Springs on the Tsavo river, and 500 l/s from the Sabaki river at Baricho. The abstraction below Baricho, at Kwa Alenya, is both very small and to be phased out by the end of 1993. The present level of abstraction for the Mombasa and coastal water system, under the present conditions of flow, has been maintained during the past decade without any perception of a serious negative environmental impact.

For the future there is the possibility that the drier conditions of the late 1950s could return. This return to drier conditions, in the most unfavourable circumstances, would take five years to establish itself. With the current level of abstractions, and a return to the Mzima Springs outflows characteristic of the 1950s, there would exist a perceived negative environmental impact. During that period:

1. Sabaki river flows would be very low during each dry season.

2. The river downstream of Baricho would be expected to dry up during any periods when the Athi river flows at the Tsavo river confluence dried up.

3. Such events could be expected to occur over a period of several years, on average about 1 year in 2.

Obviously, rehabilitation of the Baricho water works will increase any perceived negative environmental impact. Augmentation of the supply will increase it even more.

Unfortunately there is no hydrological technique available for assessing the level of risk associated with the sustainability of Mzima Springs outflows, based simply on an analysis of the available record. This is because the annual series of minimum outflows at the Springs are not independent of each other. What is needed is an application of the model proposed in an earlier study (British Geol. Survey et al., February 1988) that relates spring outflows to antecedent rainfalls over the Chyulu Hills. This model, with a synthetically extended rainfall record could be expected to yield an objective assessment of risk (see annex 2).

Together with the need for coming to a decision on the risk level and its acceptability in respect of environmental impact, the risk to the sustainability of the water supply source is to be taken into account.

The storage schemes that constitute the present proposals for mitigation, summarised below in the following sections, are not only effective in respect of environmental impact but also would be effective in safeguarding the sustainability of the water supply.

6.2.. Storage Schemes

The suggestion that off-channel storage should be considered for the augmentation of the coastal water supplies from the Sabaki river during periods of dry weather flow was made during the earliest investigations (Mansell-Moullin M., November 1973).

6.2.1. The Off-Channel Reservoir Site near Chakama

The Consultant (Gauff, September 1989) identified a very promising off-channel storage site near Chakama as shown in Fig. 8.: CHAKAMA DAM SITE. Two alternatives were originally proposed for using the Chakama reservoir site for water abstraction schemes so that there would be no water diverted from the river at low flow:

1. By gravity flow from a new surface water intake on the Sabaki river upstream of Chakama, with onward gravity flow to the Baricho intake.

2. A pumped storage scheme with water pumped up from Baricho during periods of moderate river flow to augment the dry weather supply when river flow was insufficient.

In the light of the recent success of the ground water pumping tests at Baricho, with yields from each borehole of about 1000 cu m/hr, a pumped storage scheme from groundwater is a third alternative. This third alternative, which is chosen for consideration for the purposes of this report, has the advantage that the requirement for treatment of the water would be minimal, and no dead storage is required in the reservoir for sediment deposition.

Any of the three alternatives would give a yield that can be estimated by a simulation of reservoir operation. A computer simulation of reservoir operation has been set up to demonstrate the possibilities of operating the Sabaki river source with minimal negative environmental impact with a storage scheme using water pumped from the palaeochannel aquifer. The simulation uses an upper and lower limit for the river flows of 100 and of 2 cu. m/sec., beyond which limits the pumping stops. The lower limit has the effect of leaving the downstream flows unaffected by the operation of the Baricho water works during periods of low flow. The upper limit is set to allow the top layers of the aquifer to be reworked and cleaned of fines during flood events; further investigations will indicate whether this upper limit is realistic or whether it is over cautious.

The results are presented graphically as flow duration curves for six drafts from 50,000 to 300,000 cu. m/d. and also a graph showing how the required pumping capacity increases with draft Figs. 6.2: Simulation of Reservoir Operations and 6.3: Simulation of Reservoir Operations.

6.2.2. Palaeochannel Storage Scheme

The aquifer for the current two production wells at Baricho has been tentatively estimated to have a storage capacity of 20 million cubic metres (20 Mcm). If investigations indicate that there is no constraint on pumping at high river discharge, that is no risk of drawing muddy water into the wells, then the storage available in the palaeochannel is available for a pumping scheme that would provide water for the transmission pipelines and, during low Sabaki river flows, provide additional water for compensation downstream of the wellfield.

In this scheme it is envisaged that the river channel at the wellfield would dry up whilst Sabaki river flows were insufficient to fully recharge the palaeochannel aquifer. The pumping rate during these low flows would be increased as required to provide extra water to reintroduce sufficient into the Sabaki river channel, say 2 km. downstream of the production wells, to maintain flow in the Sabaki river channel into the ocean.

A simulation, using an adapted version of the computer program as above, has been performed. The results, based on the 31 years of flow records at Baricho suggest that for the assumed groundwater storage capacity of 20 Mcm, and a compensation flow of 2000 l/s, the maximum steady yield without failure during the period of record was of the order of 160,000 cubic metres per day. As indicated in the preceding section, this can be taken as an estimate of the 95 percent reliable yield.

7. ENVIRONMENTAL MITIGATION PLAN

7.1 Scope

The scope of mitigation proposals is not wide since no widespread negative impact from the project to rehabilitate the Baricho water works and associated transmission pipelines has been identified. The most widespread environmental impact is seen as positive, namely the benefit to consumers of an improved water supply.

There are three items related to the project, of concern in respect of possible negative impact, which involve wider issues of policy:

i) The future possibility of drying up the Sabaki River downstream of Baricho when the drier conditions as experienced in the late 1950s return; not only does this have negative impact on the ecosystem of the river, but also these conditions would threaten the sustainability of the water supply. At the present time the level of risk of the drier conditions returning is indefinite. Mitigation proposals include a proposal for a study to define the level of risk, and two alternative schemes for drawing water supplies from storage during low flow conditions in the river. The two alternatives have been described in section 6 above.

ii) The need to provide services and implement some regulatory measures to settlements along the pipelines in order to avoid perceived potential and actual negative impacts. The provision of water supplies along the pipelines and some upgrading of the pipeline roads both have direct positive impacts but will tend to promote further settlement. These matters are addressed in section 7.2 below.

iii) The residues of very undesirable pesticides have been identified in the Sabaki River water. This is a matter that will need to be addressed at a national level. Monitoring the levels of this sort of pollution is an essential element of the Monitoring Plan presented in section 9 of this report.

There are a number of isolated identified negative impacts associated with the existence or operation of the water supply system that may be important but are of limited concern. They are dealt with piecemeal in the following paragraphs of this section of the report. On the other hand the perceived degradation of the marine environment, in the vicinity of the Sabaki River's outlet to the sea, arouses widespread concern but no action is proposed herein because this problem is not influenced in any way by the operation of the water supply system.

7.2 Impacts Associated with Project Construction

After the site preparation and the construction activities are completed, the impact area should be landscaped and planted with indigenous trees and grass to at least restore some of the lost biodiversity and increase the aesthetic value of the site.

7.3 Impacts Associated with Water Treatment

Raw river water treatment:-
For as long the raw river water treatment is continued, then survey is required to determine the aluminium levels in the Sabaki below the intake. If aluminium concentrations are above the WHO maximum allowable levels (0.2 mg/l.) the use of alum as a coagulant should be reduced or stopped. The use of polyelectrolytes in place of alum should be introduced.

Disposal of Tropical Chloride of Lime (TCL) sludge:-
The sludge plus other waste (paper, plastic ware, textiles, polythene, rubber etc.) should be disposed of using a landfill method. A disused quarry situated 200 meters from the treatment works can be used for disposal purposes.

Disposal of domestic sewage:-
After rehabilitation, the outfall should be realigned to a nearby swamp. Wetlands have considerable water purification properties. The swamp will remove nutrients and pollutants and render harmless pathogens such as viruses and coliform bacteria left after sewage treatment in the oxidation ponds.

7.4 Impacts Associated with the Water Transmission Pipelines

Water transmission pipeline air valves:-

Bacteriological examination of pipeline water for faecal coliforms such as *Escherichia coli* should be carried out with urgency. Levels of chlorine should be determined and the appropriate action taken when chlorine concentrations are below 0.4 ppm. Monitoring of the above parameters should be conducted as routine, with extra monitoring following any major repair or after exceptional rainfalls.

Water transmission pipeline washouts:-

Mitigation of impeded drainage and erosion are components of the rehabilitation and augmentation project.

Destruction of gorge habitats:-

With increased settlement close to the pipeline, the Rare and Ndzovuni gorges should be protected from human encroachment. Mitigation of this impact is by application of the Agricultural, Forest and Chiefs Acts by the District based officials on those who are misusing the land. The institution to coordinate this is the District Environmental Committee as discussed in Section 8.2.3. Using the Chief's Act, it is possible to protect a riparian zone of 30 metres on either side of the gorge.

Elephant migration:-

Technically, there is no mitigation of this for the level of human settlement in Kilifi is such that elephants cannot be allowed to meander anywhere. The best solution is to keep them in Arabuko-Sokoke Forest and to attempt to introduce new material into the gene pool now and then. This is beyond the scope of the Corporation. The issue of permanent supply of water to the elephants should be addressed by the Kenya Wildlife Service.

Land values:-

As it is expected that the provision of water along the pipeline under the proposed project will influence land values in the project area. It would be wise for the land to be adjudicated and titles issued prior to commencement of work. This would help to ensure that traditional land holders become the rightful owners. Whether they sell the land later is another matter.

7.5 Monitoring Plan for Pesticides

It will be important to implement detailed monitoring of pesticides to establish their source. It is therefore proposed that water samples be collected from the following gauging stations four times a year to catch the two high flows and the two low flows.

Malindi Bridge,	RGS 3HA5
Baricho Intake,	RGS 3HA13
Lugard's Falls,	RGS 3HA12
Tsavo,	RGS 3G2
Thwake,	RGS 3F2
Munyu,	RGS 3DA2
Nairobi River,	RGS 3BA32
Ndarugu,	RGS 3CB5
Mbagathi,	RGS 3AA4
Athi,	RGS 3AA6

This distribution of sample sites is chosen to reflect the various land use patterns obtaining in the Athi Sabaki Catchment.

Collection of water, fish and sediment samples should be supervised by a senior technician, supervised by the Consultant, to ensure that the proper procedures are followed, including river flow at the time of sampling. This strategy is recommended since study of the sources of pesticide pollution is part of establishing baseline data so that the NWCPC can continue routine monitoring. In the long term it will become part of the responsibility of the Environment Officer in the NWCPC.

After samples are collected they will be given to the National Agricultural Laboratories of Kenya Agricultural Research Institute, for analysis. This laboratory has already established a track record for pesticide analysis. For purposes of Quality control, the CSIR Laboratories in South Africa will be used. The first batch sample will be split analyzed. After this each alternative season, a batch will be split analyzed for two years. This is a sufficient period to establish the data on sources of pollution firmly.

After two years, normal pesticide monitoring will become part of the routine work of the MWCPC Environment Officer.

Of particular importance in all analysis, will be the analysis of:

1. the organo-chlorides including aldrin, dieldrin and DDT and its metabolites;

2. sulfenimide fungicides, especially captan, and

3. organo-phosphorous pesticides, including malathion, parathion and diazinon.

These pesticides are known to be used in the farming systems which include coffee growing, livestock keeping and horticulture as well as in the eradication of mosquitoes especially in the urban areas.

The budget for this activity, to include the costs of a Technician, Vehicle Running, Driver, Field Equipment and Local Laboratory analysis, is estimated as Ksh. 1,250,000 yearly for a total of Ksh. 2.5m. or US$ 31,250 over the two year period. The cost of analysis for the quality control in CSIR is estimated at US$ 10,000 .

8. ENVIRONMENTAL MANAGEMENT AND TRAINING

8.1. Institutional Issues

8.1.1. Monitoring Raw, Treated and Pipeline Water

The rehabilitation and augmentation proposals simplify plant operation and management and propose improvements in the laboratory. It will be possible to manage the waterworks with the established staff. The current problem is that the original establishment was not kept up as people left the Baricho site. Table. 4.16: Baricho Staff shows the originally planned staffing and current staffing.

With simplified plant management and the original staffing, there will be the capability to monitor raw water at the intake, water under treatment, treated water, and to test water along the pipelines to check for contamination.

Staff working in the laboratory need refresher courses and courses to learn new techniques.

8.1.2. Monitoring Heavy Metals, Pesticides and Fertilisers

There is no training component for this activity, since it is foreseen that these activities will be contracted out by the NWCPC to competent agencies.

8.1.3. Monitoring Erosion, Water Hygiene and Wildlife Use

This is a function of the District Environmental Officers (see Section 8.2.3 below).

8.2. Environmental Assessment Implementation Capacities

8.2.1. Legal Basis for NWCPC Activities

The National Water Conservation and Pipeline Corporation was created by Legal Notice No. 270 of 1988 which was published in the Kenya Gazette Supplement No. 35 on 24/6/1988. It was established under the powers of the Presidency under the State Corporations Act (Cap 466) Section 3 which empowers the President to create state corporations from time to time for specific operations. The law allows the corporation to develop water projects and to assist the government in formulating a water policy.

The legal basis of the Corporation enables it to undertake any environmental activities related to water provision. Under its Scientific Services Unit, which is under the Corporate Services Department (as shown in the Corporation's organisation chart, Figure 9: NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION: ORGANISATIONAL STRUCTURE) it has had an environmentalist, qualified to MSc level, who was employed to work on environmental issues related to its work. The environmentalist recently resigned his post and so the study team did not benefit from discussing with him his past work.

The Consultant proposes that the Environmental Office - which is not shown on the organisational chart - be staffed with an equivalent person who will be responsible at headquarters for supervising the recommendations of the environmental assessment. These include:

1. Supervising monitoring activities at the Sabaki River, the water works and along the pipelines.

2. Administering contracts for the analyses of water for heavy metals, pesticide and fertiliser.

3. Liaising with local institutions on matters such as erosion, water borne disease prevention, wildlife.

The National Parks and Kenya Wildlife Services, who have residual powers over all wildlife nationally, are not likely to be ready to be much involved with the environmental impacts associated with this project, because the water works and pipelines do not touch any park areas.

8.2.2. An Environmental Unit for the NWCPC

The NWCPC organisational structure proposes a Scientific Services Unit to supervise a Laboratories Unit, Water Quality Control Unit, Water Treatment Process Unit, Pollution Monitoring Unit, Water Use Monitoring Unit, and Hygiene and Health Standards. The corporation currently has several consultancies touching on management structure and since their reports will be available after this consultancy, the study team offers these comments on the existing structure:

- Water Use Monitoring seems to fit more into the Planning side of things.
- Laboratories are a service function to the other units under the Scientific Unit.
- The remaining units are environmentally related.
- Apparently in the present structure, the main elements for environmental monitoring exist within the corporation.

There are some problems:

- There is no appropriate laboratory at NWCPC Nairobi Headquarters.
- People with qualifications to man the subsidiary units exist within the corporation and within the ministry, but the staffing of the Scientific Unit seems to be unsystematic.

The Consultant therefore recommends:

1. That the functions of the Scientific Unit as provided for in the current organisation chart be retained in the new management proposals.

2. That the Unit be retitled the Environmental Monitoring Unit.

3. That it is headed by an Environmentalist with at least Msc. level training in environmental studies.

4. That methods and procedures for contracting out the bulk of the work of the Unit be worked out in detail between NWCPC and the World Bank so as to keep the unit in a supervisory role.

The rationale for these recommendations is that the study team's impression is that the corporation will spend the next few years building up operations staff and methods and that environmental issues will not be central.

For purposes of supervising the collection of data, monitoring, evaluation and implementation of mitigating measures related to the Baricho project, it is estimated that an operational budget for the Environmental Monitoring Unit of Ksh. 1,000,000 (US$ 12,500) yearly will suffice.

8.2.3. District Environmental Committees

In every district in Kenya, there is a District Environment Officer, who is a member of the District Executive Committee and the District Development Committee. He chairs a District Environment Committee which is a subcommittee of the District Development Committee. The committees in Mombasa and Kilifi District, have representatives from the relevant government ministries, the active environmental NGOs, the trade and manufacturing sector, Kenya Wildlife Service district based staff, and the tourism sector. They have shown determination to pursue the environmental issues in their districts.

The environmental issues of the assessment have to do with conservation along the pipelines, pollution of marine resources, water for maintaining flora and fauna, and the quality of the water. These can be effectively handled at the local level where the representatives of the environmental NGOs, trade and manufacturing sectors, government departments and tourism industry as well as local populations can get representation.

Consequently, it is recommended that the project grant the District Environment Officers of Kilifi and Mombasa Ksh. 200,000 each annually to enable them to travel, hold meetings and reproduce data on the environmental issues which touch on the waterworks and the pipeline.

It is recommended that the Kilifi and Mombasa District Environment Committees be recipients of the monitoring reports on heavy metals, pesticides and water quality for which the NWCPC is responsible. Contracts for monitoring should provide for the circulation of their reports directly to these two committees without the NWCPC mediating.

9. MONITORING PLAN

9.1 Monitoring of the Sabaki at Baricho

River levels at Baricho are currently (June 1993) recorded three times a day, morning, noon and evening, at upstream, downstream and centrally placed staff gauges. This provides a completely adequate record of water levels for deriving the flow rate of the river for flows of up to, say, 20 cu. m/sec, that is for at least six months of most years. This practice of reading the staff gauges, and maintaining them in readable condition, should continue.

An autographic water level recorder should be installed to provide a continuous record for higher discharges, when the flow may vary significantly from hour to hour. An air bubble type autographic recorder is recommended for this site, with provision for maintaining air pressure in the storage bottle by foot pump. This type of recorder can be mounted a considerable distance from the river, an important consideration if there are exceptionally high floods. If the outlet for the air bubbles is disturbed during a high flood then it is readily restored to working order.
The tasks of gauge reading, water sampling, assisting in hydrometric measurements, constitutes a full time job for a resident junior technician. River flow measurements are made by a visiting professional or senior technician experienced in hydrometry.

River flow should be measured at regular intervals. This is a difficult site for flow measurements by conventional use of a current meter. The river at low flow up to about 20 cu. m/sec. can be waded without much difficulty. Wading measurements much above this level become hazardous because there is usually a deeper channel, about a metre deep scoured out for a few metres width, with water velocity approaching 1 m/sec. These are near the limits for wading measurements.

For the higher discharges, which are very significant for estimating the total water resource of the Athi/Sabaki river, the conventional method is to install a cableway to carry a travelling pulley from which the current meter and weight can be suspended. Poor results are often obtained with this sort of installation. There are important systematic errors that arise with these measurements, which anyway are often frustrated by equipment failures. The Consultant will research alternative technologies to the cableway and report the results. At the same time quotations for a cableway installation will be sought. The decision on what method to adopt for the high discharge measurements should follow an appraisal of the results of these enquiries.

It is recommended that the current meter measurements should only be entrusted to an agency that has, or can quickly establish, a good track record in accomplishing this specialised type of fieldwork.

The annual cost of this work, excluding the junior technician who would be water works staff member, is estimated at 1 man-month at KSh 200,000 with travel expenses at KSh 100,000 (at total of US$ 3,750). The procurement and installation costs for the level recorder and flow measuring installation is assigned a budget figure of KSh 1 million. (US$ 12,500)

9.2 Monitoring of the Pipeline System

The principal issues for monitoring the system have to do with upgrading the operations of the waterworks to ensure that properly treated water enters the pipeline, that there is no contamination in transmission, and that erosion does not threaten the pipeline installations. The tasks envisaged are routine inspections and collection of samples by water works staff, analysis of samples by contractors, and presentation of results and supervision by the Environmentalist of the NWCPC.

9.3 Sabaki River Water Quality Monitoring

In this context, monitoring refers to maintaining long-term records of measurements, observations, evaluation and reporting of aquatic environment in order to define status and trends of the Sabaki River. In order to ensure success and sustainability of the monitoring programme, certain standard elements must be institutionalised by the NWCPC. Monitoring will be done for water physical, chemical and biological parameters as outlined in Table 4.23: Analytical Methods for Determination of Major Variables.

The study team established that there was no clear understanding on what water quality standards to use at the various NWCPC laboratories. There was no adequate reference material. Consequently, the following references are suggested to give a detailed analytical procedures for all environmental variables pertaining to river systems:

1. APHA. Standard Methods for Examination of Water and Wastewater. 17th Edition. Washington D. C.: American Public Health Association. 1268 pp. 1989.

2. Strickland, J.D.P., and Parsons, T.R. A Practical Handbook of Seawater Analysis. 2nd Edition, Bulletin 167. Ottawa: Fisheries Research Board of Canada, 310 pp. 1972.

3. Golterman, H.L., Clymo, R.S. and Ohnstad, M. A.M. Methods for Physical and Chemical Analysis of Fresh Waters. 2nd Edition, IBP Handbook No. 8. Oxford: Blackwell Scientific Publications. 1978.

9.4 Monitoring Heavy Metals, Pesticides and Fertilizers

Currently the laboratories at Baricho and Mombasa are not equipped to monitor the parameters on heavy metals, pesticides and fertilisers. A case can be made for the analysis of these parameters to be outside the corporation for the data to be believed by the public and also so that the data can be used by the corporation management to ensure that the plant operators are doing their work effectively. Since some of these parameters will be required at quarterly intervals, it is suggested that the work be contracted out to the private sector, universities or other government parastatals. This involves sampling of raw water, treated water and pipeline water at distribution destinations. It is estimated that contracting this service will cost about Ksh. 500,000 (US$ 6,250) per year. The results should be published for public information.

9.5 Monitoring Erosion, Water Hygiene and Wildlife Use

This is really a function of the District Environmental Officers. See discussion under District Environmental Committees Section. 8.2.3.

9.6 The Plan

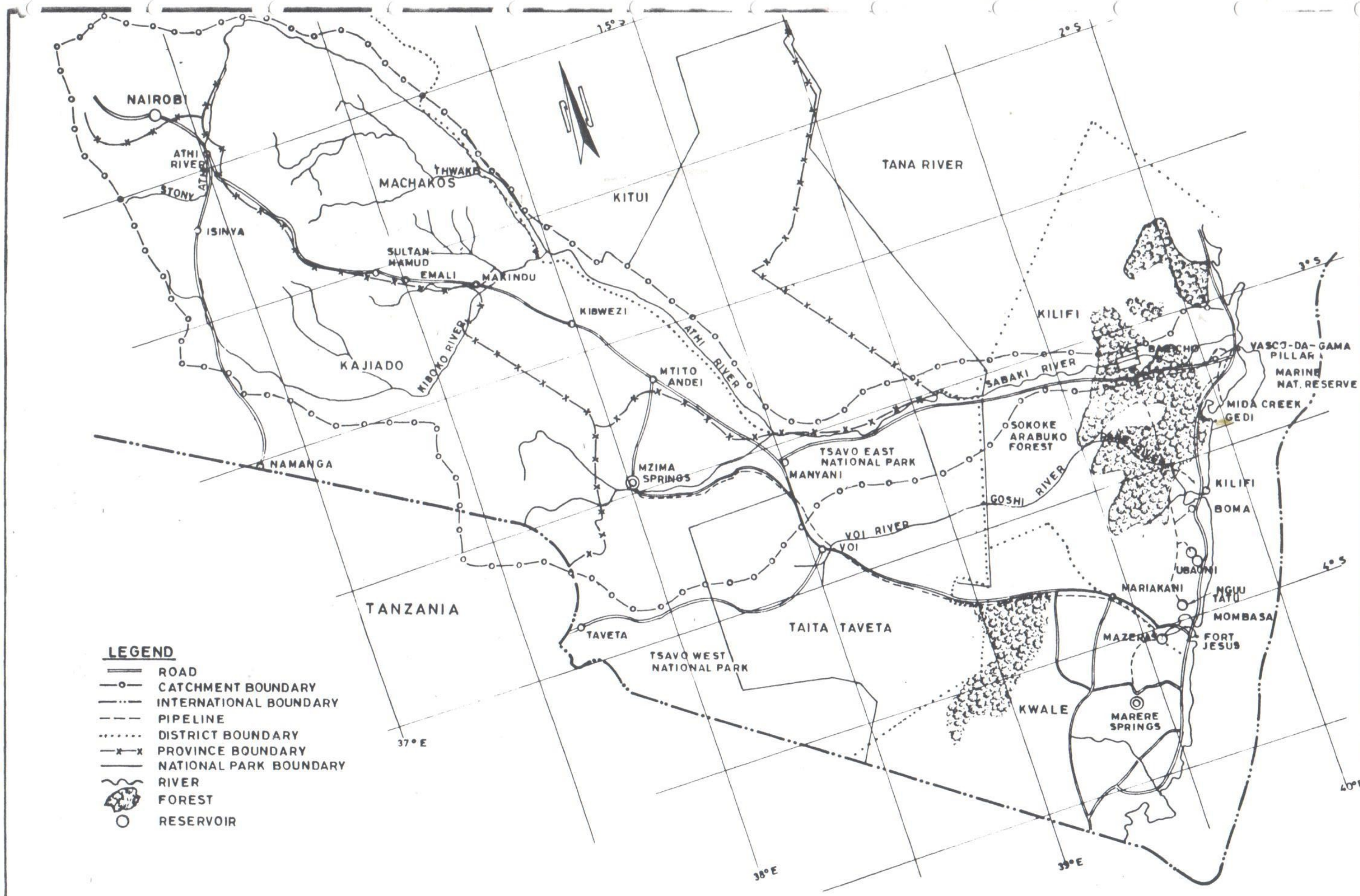
The key participants in the monitoring plan are the NWCPC management, the NWCPC Environment Officer, the upgraded NWCPC Baricho Laboratory, Contractor(s) for Heavy Metal Analysis, Contractor(s) for Pesticide Analysis, Contractor(s) for Nutrient Analysis, Kilifi and Mombasa District Environment Committees, the NWCPC Water Technician and a Contractor for Hydrometry.

The rationale for setting up the environmental monitoring plan in this manner are as follows. First, the Environmental Monitoring supervisory function of the NWCPC should be highlighted in the operations of the corporation by creating a unit headed by a senior environmentalist. Second, there is need to improve the river monitoring system by appointing specific personnel to do the function. Such personnel will also be trained to collect samples systematically for scientific analysis by the corporation's Baricho laboratory and by contracted agencies. The information gathered must be made available to the public. This is assured by sending the formal analysis results to the two district Environmental Committees. These have technical personnel who are able to digest it and forward it for consideration to the main District Development Committees who in the final analysis are responsible for all development matters in the districts. Public availability of this data is essential for protecting the Corporation from irrational charges as well as highlighting its work. The detailed proposals are explained shown below and shown in Figure 10: MONITORING PLAN BAR CHART. The following is specification of the plan.

A. NWCPC

ACTIVITY	TIME/INTERVAL
1. Hires a Senior Environmental Officer	Month one
2. Upgrades Baricho Laboratory	Month one
3. Hires River Monitors	Month one
B. NWCPC Environment Officer	
1. Upgrades Baricho water quality monitoring procedures	Month one
2. Contracts for Heavy Metal Analysis	Month 1-3
3. Contracts for Pesticides Analysis	Month 1-3
4. Contracts for Nutrient Analysis	Month 1-3
C. NWCPC Baricho Laboratories	
1. Daily Treatment Water Quality Mon.	Daily
2. Treated Water Quality Control	Daily
3. River Water Quality Monitoring Seasonally/Various sites	4 Times Yearly
4. Monitors Water Treatment Effluent	4 Times Yearly

5. Monitoring Plant Sewage Effluent	4 Times Yearly
6. Issues Reports to among others DECs	4 Times Yearly
D. Contractor(s) Heavy Metal Analysis	
1. Receives Samples from Baricho	4 times/year
2. Conducts Heavy Metals analysis	4 Times Yearly
3. Circulates Batch Reports to DECs	4 Times Yearly
E. Contractor(s) Pesticide Analysis	
1. Receives Samples from Baricho	
2. Conducts Heavy Metals analysis	4 Times Yearly
3. Circulates Batch Reports to DECs	4 Times Yearly
F. Contractor (s) Nutrient Analysis	
1. Receives Samples from Baricho	4 times/year
2. Conducts Heavy Metals analysis	4 Times Yearly
3. Circulates Batch Reports to DECs	4 Times Yearly
G. District Environment Committees	
1. Receives NWCPC Laboratory/Contractors and discusses with them	4 Times Yearly.
H. NWCPC Water Technician at Baricho	
1. Reads river gauges	3 Daily + Autographic
2. Collects River Water samples for NWCPC Laboratories and Contractors.	Daily/Seasonally/Quarterly
1. Collects Pipeline Water Samples for NWCPC Laboratories	Weekly
I. Contractor for Hydrometry	
1. Measures River Flow	12 times/year



SECOND MOMBASA & COASTAL WATER SUPPLY
ENGINEERING AND REHABILITATION PROJECT

H.P. GAUFF K.G.
CONSULTING ENGINEERS
P.O. BOX 49817
NAIROBI

SCALES 1:1,250,000 APPROX.

REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS

SABAKI CATCHMENT & ENVIRONS

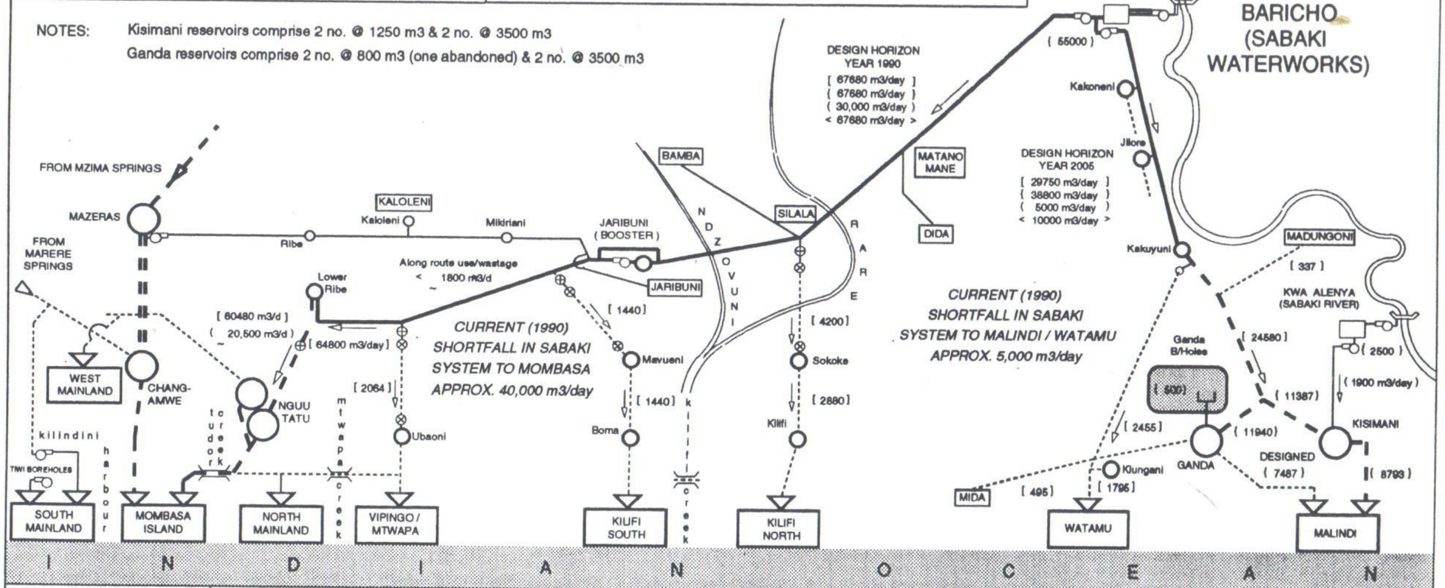
RESERVOIR DATA

NAME	VOLUME	T.W.L.	B.W.L.	INLET	OUTLET
SOKOKE	2 x 100 m3	105.00 masl	100 masl	250 mm	250 mm
KILIFI	3550 m3	50.55 masl	42.00 masl	250 mm	
JARIBUNI	2 x 480 m3	163.00 masl		700 mm	800 mm
MAVUENI	2 x 200 m3	60.00 masl	57.20 masl	150 mm	250 mm
BOMA	1450 m3	45.48 masl	42.00 masl	250 mm	
UBAONI	2650 m3	80.44 masl	74.00 masl	200 mm	
LOWER RIBE	2 x 475 m3	180.55 masl	176.55 masl	700 mm	600 mm
NGUU TATU (OLD)	9100 m3				
NGUU TATU (NEW)	18000 m3	74.50 masl	60.00 masl	600 mm	800 mm
KAKONENI	90 m3	94.25 masl	91.1 masl	200/100 mm	150 mm
JILORE	90 m3	62.50 masl	59.35 masl	200/100 mm	150 mm
KAKUYUNI	1250 m3	126.20 masl	123.00 masl	600/400 mm	450 mm
KAKUYUNI BPT	225 m3	97.50 masl	93.93 masl	200/150 mm	150 mm
KISIMANI	9750 m3	61.25 masl	56.25 masl	300/250 mm	350 mm
GANDA	8600 m3	50.25 masl	45.25 masl	300/250 mm	350 mm
KIUNGANI	1250 m3	43.00 masl	39.80 masl	200/100 mm	200 mm

KEY

- RIVER INTAKE
- TREATMENT WORKS
- PUMPING STATION
- MAIN STORAGE
- Other Storage
- BREAK PRESSURE TANK
- BOREHOLE (existing)
- BOREHOLE (proposed)
- BRIDGE CROSSING
- PRESSURE REDUCING VALVE
- SERVICE AREA
- PUMPING MAIN (MAJOR)
- GRAVITY PIPELINE (MAJOR)
- PUMPING MAIN (MINOR)
- GRAVITY PIPELINE (MINOR)
- [ ] PIPELINE DESIGN CAPACITY m3/day
- { } THEORETICAL CAPACITY m3/day
- ( ) ESTIMATED 1990 ACTUAL AVERAGE FLOW m3/day
- < > ESTIMATED 1990 DEMAND m3/day
- PRESSURE SUSTAINING VALVE
- DISUSED WATER SOURCE

NOTES: Kisimani reservoirs comprise 2 no. @ 1250 m3 & 2 no. @ 3500 m3
Ganda reservoirs comprise 2 no. @ 800 m3 (one abandoned) & 2 no. @ 3500 m3



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SABAKI WATER WORKS

MOMBASA AND COASTAL WATER SUPPLY

SCHEMATIC LAYOUT OF NORTH MAINLAND SYSTEM - CURRENT SITUATION

NOT TO SCALE

FIGURE 3

July 1993

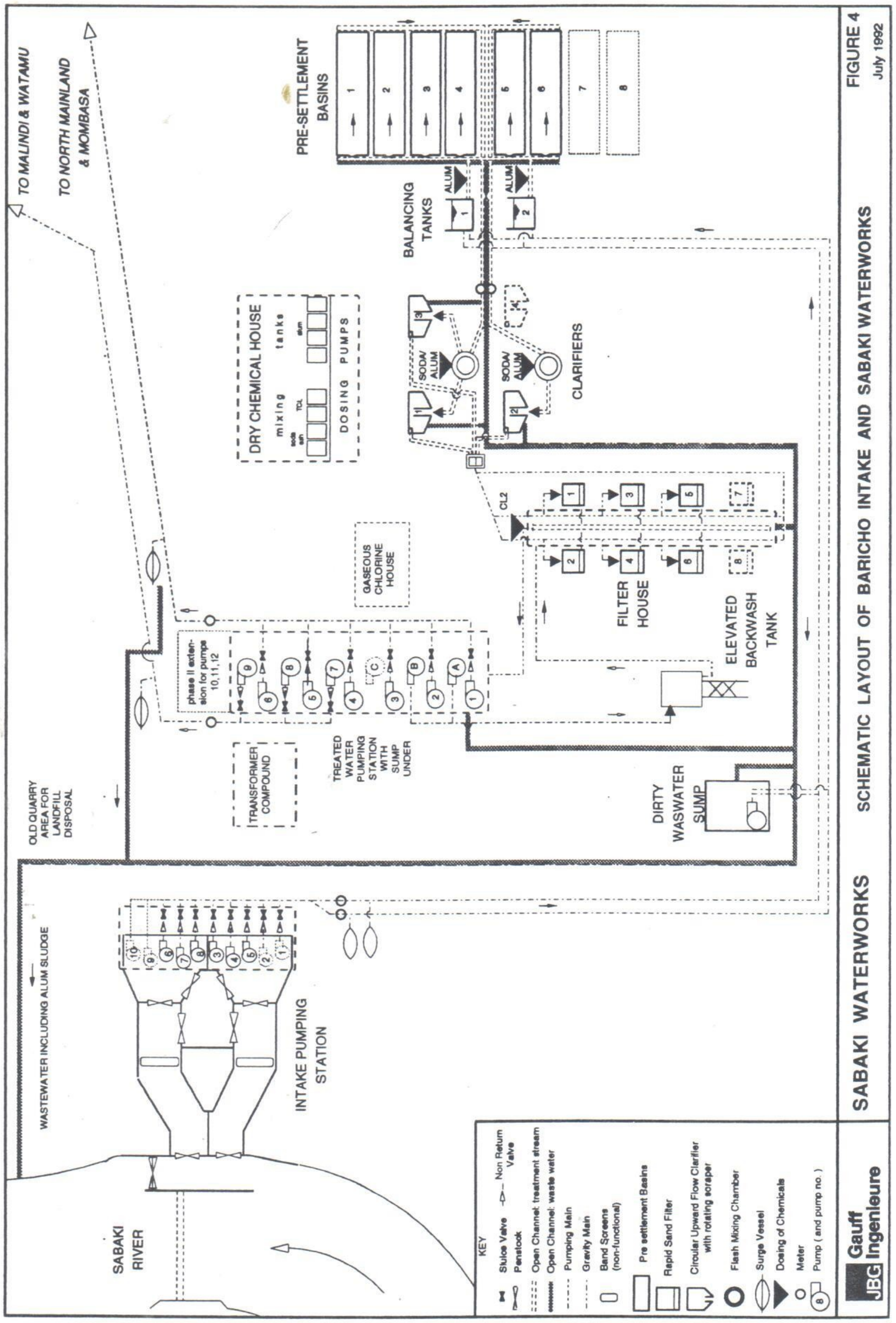


FIGURE 4 SCHEMATIC LAYOUT OF BARICHO INTAKE AND SABAKI WATERWORKS

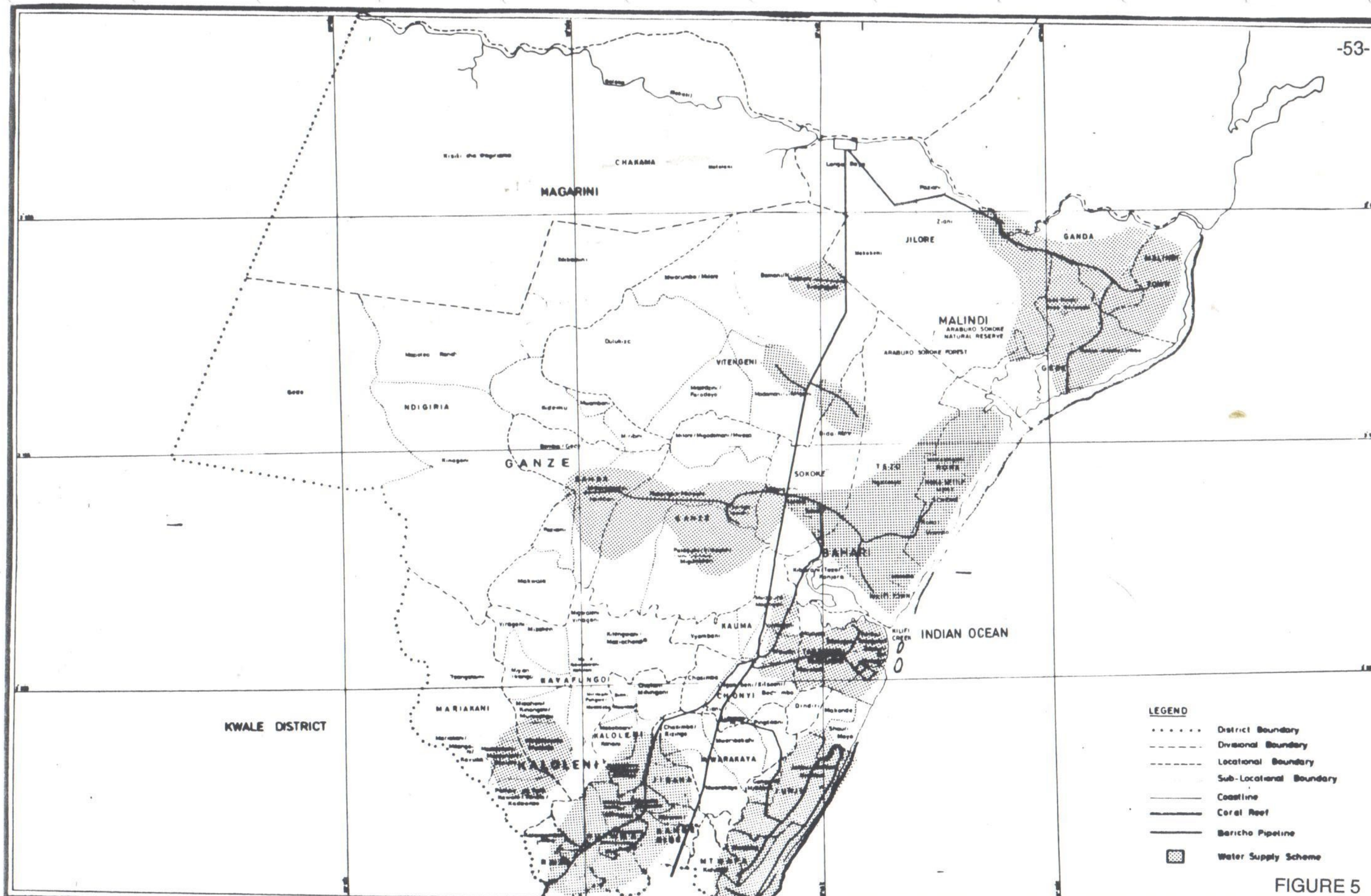
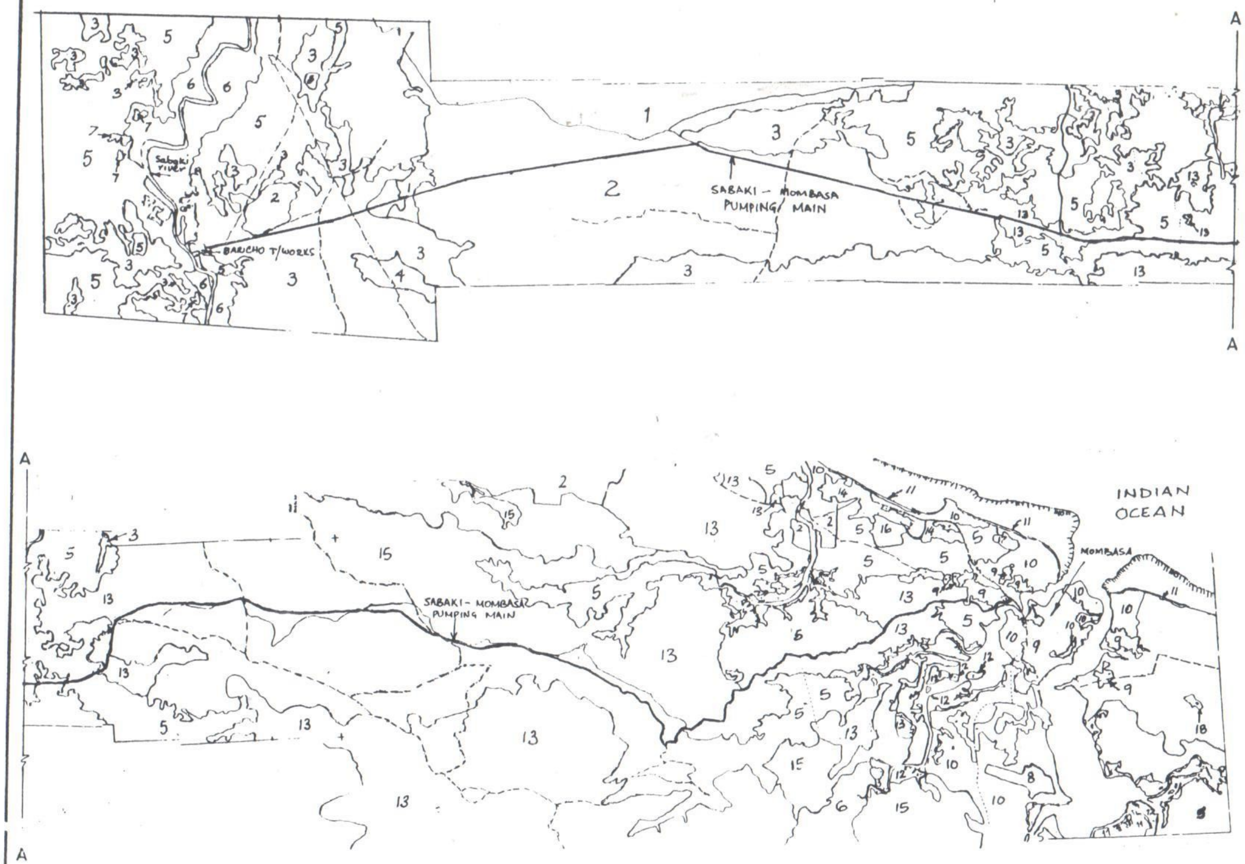


FIGURE 5

SECOND MOMBASA & COASTAL WATER SUPPLY ENGINEERING AND REHABILITATION PROJECT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION P. O. BOX 30173	REVISIONS	VARIATIONS	H.P. GAUFF K.G. CONSULTING ENGINEERS P.O. BOX 49817 NAIROBI	SCALES 1 : 300,000	REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS PIPELINE AND SUBLOCATIONS SERVED



LEGEND

1. FOREST
2. LARGE SCALE FARM/BUSHES
3. GRAZING
4. DENSE SHRUBLAND
5. CLOSED BUSH
6. RIVERINE/SWANP VEGETATION
7. LAKES AND PONDS
8. AIRPORT/AIRSTRIP
9. BUILT UP AREAS
10. BUILT UP AREAS WITH TREES
11. SAND/SILT
12. MANGROVE
13. SMALL SCALE FARMING/SETTLEMENT
14. MINING/QUARRY
15. BUSH/SMALL SCALE AGRICULTURE
16. OPEN WOODLAND
17. GOLF COURSE

——— WATER PIPELINE
- - - - - ROADS

Gauff JBG Ingenieure	SECOND MOMBASA & COASTAL WATER SUPPLY ENGINEERING AND REHABILITATION PROJECT	A3 SIZE SCALE: 1: 200,000 APPROX	REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS ENVIRONMENTAL IMPACT ASSESSMENT LAND USE/LAND COVER TYPES	FIGURE 6 July 1993

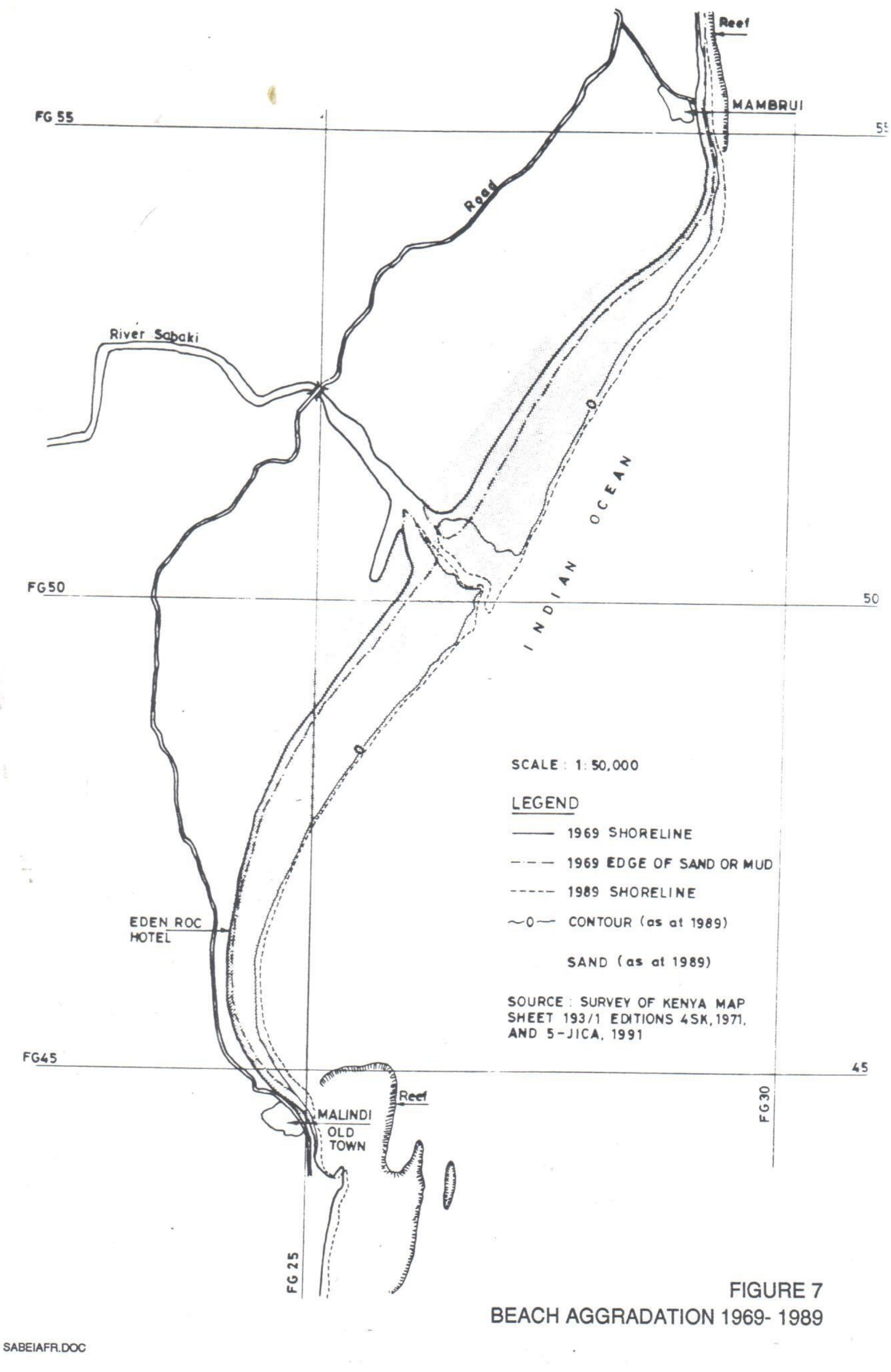
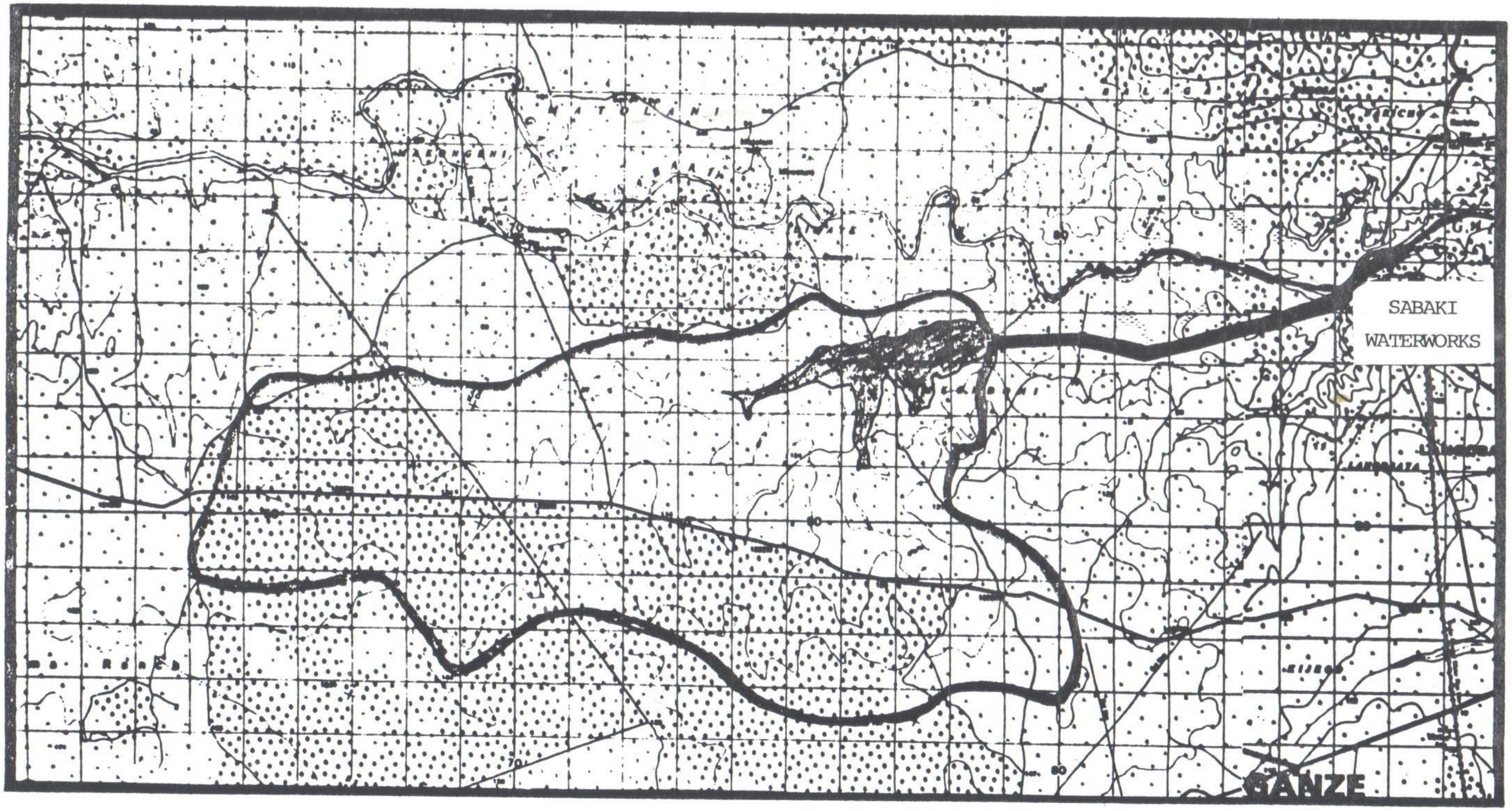


FIGURE 7
BEACH AGGRADATION 1969- 1989



KEY:

- RESERVOIR
- CATCHMENT
- PIPELINE

NOTES:

Based on Survey of Kenya map- sheets 1:50,000 series Y731, edition 4-JICA sheets 192/1 MATOLANI & 192/2 JILORE

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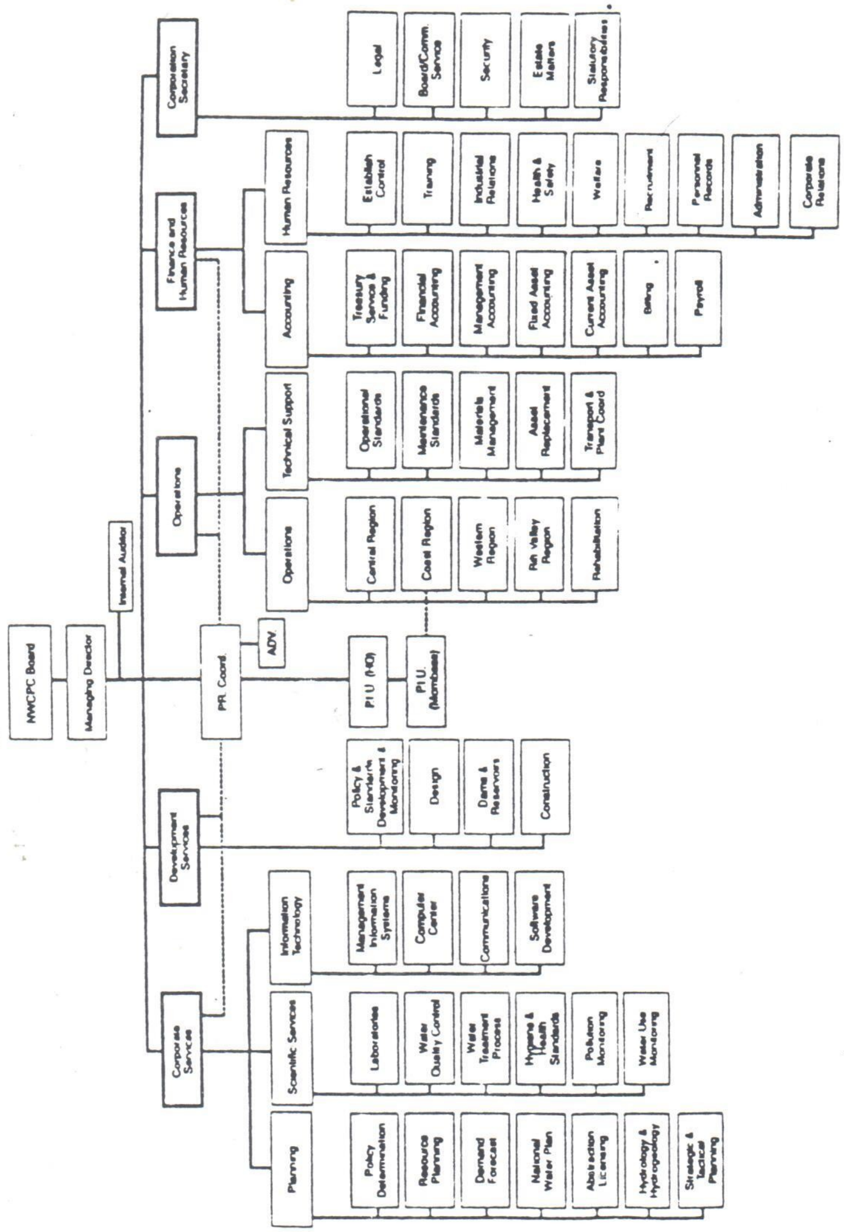
LAYOUT PLAN OF BARICHO INTAKE WITH PUMPED CHAKAMA OFF- RIVER STORAGE

SCALE: 1;100,000

September 1992

FIGURE 8

NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION
Organization Structure



ORGANISATION STRUCTURE N.W.C.& PC
FIGURE 9

IMPLEMENTING PARTY	ACTIVITY	ASPECT / MONTH	Initial Activities 1	2	3	Routine Procedures 1	2	3	4	5	6	7	8	9	10	11	12
NWCPC Management	Hire EO		■														
	Hire Contracted Laboratories and River Monitor			■	■												
	Upgrade Baricho Laboratory		■	■	■												
	Discuss Reports						●			●			●			●	
EO [Environmental Officer]	Establish Monitoring and Reporting Procedures			■	■												
	Monitor Testing Procedures					C O N T I N U O U S											
	Report to NWCPC Management and to DEC						O			O			O			O	
	Discuss Reports						●			●			●			●	
Baricho Works Staff	Treated Water Quality Monitoring and Control					D A I L Y											
	Pipeline Water Quality Testing					OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO	OOOO
	River Water Quality Testing					O			O			O			O		
	Treatment Works Effluent Testing					O			O			O			O		
	Sewage Works Effluent Testing					O			O			O			O		
	River Gauging					T H R I C E D A I L Y											
	Report to EO					O			O			O			O		
Contracted Laboratories	Analysis of River Water Samples					O			O			O			O		
	Report to EO					O			O			O			O		
Hydometry Contractor	Measure River Flow					O	O	O	O	O	O	O	O	O	O	O	O
District Environment Committee	Discuss Reports						●			●			●			●	

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2nd Mombasa & Coastal Water Supply
Engineering and Rehabilitation Project
Rehabilitation and Augmentation of Sabaki Water Works

Environmental Impact Assessment Study

ENVIRONMENTAL MONITORING PLAN

WATER QUALITY OF SABAKI RIVER SYSTEM AT BARICHO

WATER CONSTITUENT	UNITS	RAW WATER SAMPLE 516 FOR BALANCING TANKS 25 May 90 *	TREATED WATER SAMPLE 515 25 May 90 *	BOREHOLE (1A) UNTREATED WATER 14 May 92 **
pH	pH Scale	7.9	8.1	7.6
Colour	mg Pt/1	250	< 5	< 5
Turbidity	NTU	155	0.8	< 0.5
Conductivity	uS/cm	346	410	380
Iron	mg/1	19	0.1	0.4
Manganese	mg/1	0.6	0.4	0
Calcium	mg/1	29	29	
Magnesium	mg/1	0.5	3.9	
Sodium	mg/1	31	34	
Potassium	mg/1	7.3	6.7	
Copper	mg/1			
Lead	mg/1			
Boron	mg/1			
Chromium	mg/1			0
Chlorides	mg/1	28	29	92
Florides	mg/1	< 0.1	0.7	0.8
Silica	mg/1			18
Nitrates	mg/1	0.01	0.01	0.12
Sulphates	mg/1	10	47	12
Phosphates	mg/1			0.14
Orthophosphates	mg/1	< 0.1	0.01	
Calcium Hardness	mg/1			28
Total Hardness	mg/1	74	88	58
Carbonate Alkalinity	mg/1			0
Total Alkalinity	mg/1	88	76	52
Dissolved Oxygen	mg/1			6
Biochemical Oxygen Demand	mg/1			4
Chemical Oxygen Demand	mg/1			6
PV (20min)	mg/1	19	0.8	
Free CO2	mg/1	2	2	
Dissolved Solids	mg/1	208	246	26
Suspended Solids	mg/1			6
Total Solids	mg/1			32
Total Coliform Count	Coliforms/ml			0
Faecal Coliform Count	Coliforms/ml			0

* Sabaki raw water and treated water samples were analysed by the Water Quality Laboratory of Ministry of Water Development, Water Quality Monitoring Programme.

** Borehole water samples were analysed at the Industrial Research and and Consultancy Unit, Faculty of Engineering, University of Nairobi.

TABLE 1 WATER QUALITY OF SABAKI RIVER AT BARICHO

GUIDELINES FOR DRINKING WATER QUALITY

FOR KENYA AND WORLD HEALTH ORGANISATION

WATER CONSTITUENT	UNITS	GUIDELINE VALUE	
		KENYA	WHO
Colour	mg Pt/1	< 25	TCU 15
Turbidity	NTU	15	5
Odour	TON		inoffensive
Electrical Conductivity	uS/cm	2000	
pH	pH	6.5–8.5	6.5–8.5
Total Alkalinity (CaCO3)	mg/l (ppm)	500	
Chloride (C1)–	mg/l (ppm)	250	250
Sulphate (SO4)=	mg/l (ppm)	400	400
Nitrate (NO3)–	mg/l (ppm)	10	10
Nitrite (NO2)–	mg/l (ppm)		
Flouride (F)–	mg/l (ppm)	1.5	1.5
Sodium (Na)+	mg/l (ppm)	200	200
Potassium (K)+	mg/l (ppm)		
Calcium (Ca)++	mg/l (ppm)		
Magnesium (Mg)++	mg/l (ppm)		
Iron–Total (Fe)+++	mg/l (ppm)	0.3	0.3
Manganese	mg/l (ppm)	0.1	0.1
Ammonia–Free and Saline (NH4)+	mg/l (ppm)		
Phosphate (P)	mg/l (ppm)		
Carbonate Hardness as CaCO3	mg/l (ppm)		
Non–Carbonate Hardness as CaCO3	mg/l (ppm)		
Total Hardness	mg/l (ppm)	250	250
Free Carbon Dioxide	mg/l (ppm)		
Silica as SiO2	mg/l (ppm)		
Oxygen Absorbed 4hr. at 27c PV	mg/l (ppm)		
Total Dissolved Solids residue at 180c	mg/l (ppm)	1000	1000
Suspended Solids (S.S.)	mg/l (ppm)	Free of SS	

Source:

1 Water Quality in Kenya–Ministry of Water Development, Kenya

2 Water Quality for WHO–Guidelines for Drinking Water Quality, Vol. One, WHO Geneva, 1971

TABLE 2 GUIDELINES FOR DRINKING WATER FOR KENYA AND WHO

SABAKI RIVER WATER (AT BARICHO)

LEVELS OF PESTICIDES, HEAVY METALS AND NUTRIENTS

PARAMETER	UNITS	CONCENTRATION
PESTICIDES [1]		
Malathion	ug/l	< 0.1
Parathion	ug/l	< 0.1
Diazinon	ug/l	< 0.1
Aldicarb	ug/l	< 0.1
Carbofuran	ug/l	< 0.1
Lindane	ug/l	< 0.1
Heptachlor	ug/l	< 0.1
Dimethoate	ug/l	< 0.1
Gramaxone	ug/l	< 0.1
Mancozeb	ug/l	< 0.1
DDT	ug/l	< 0.1
DDE	ug/l	< 0.1
Paraoxon	ug/l	< 0.1
Malaoxon	ug/l	< 0.1
P-Nitrophenol	ug/l	< 0.1
P-Aminophenol	ug/l	< 0.1
Aldrin	ug/l	0.45
Captan	ug/l	3.8
op'DDE	ug/l	0.13
Dieldrin	ug/l	1.3
pp'DDD	ug/l	4.2
HEAVY METALS [2]		
Lead (Pb)	ug/l	33.9
Cadmium (Cd)	ug/l	< 10.0
Iron (Fe)	ug/l	1024
Managanese (Mn)	ug/l	201
Cobalt (Co)	ug/l	< 0.1
Zinc (Zn)	ug/l	368
Copper (Cu)	ug/l	28.2
Arsenic (As)	ug/l	< 0.1
Selenium (Se)	ug/l	< 0.1
Mercury (Hg)	ug/l	< 0.1
Nickel (Ni)	ug/l	< 0.1
Chromium (Cr)	ug/l	6.8
Titanium (Ti)	ug/l	21
NUTRIENTS [3]		
Total Nitrogen	mg/l	0.46
Total Phosphorus	mg/l	0.26

Samples Analysed At:

[1] National Agricultural Laboratories, Nairobi
[2] Centre for Nuclear Science Techniques,
Faculty of Engineering, University of Nairobi
[3] Chemistry Department, University of Nairobi

TABLE 3 LEVELS OF PESTICIDES, HEAVY METALS & NUTRIENTS IN SABAKI

TABLE 4

MAXIMUM ALLOWABLE CONCENTRATIONS

HEAVY METALS, NUTRIENTS AND PESTICIDES FOR DIFFERENT USES.

VARIABLE	DRINKING WATER					FISHERIES AND AQUATIC LIFE		
	WHO	EC	CANADA	USA	USSR	EC	CANADA	USSR
HEAVY METALS								
Aluminium (mg/l)	0.2	0.2					0.005-0.1	
Arsenic (mg/l)	0.05	0.05	0.05	0.05			0.05	
Barium (mg/l)		0.1	1.0	1.0				
Boron (mg/l)		1.0	5.0	5.0				
Cadmium (mg/l)	0.005	0.005	0.005	0.01	0.001		0.0002-0.0018	0.005
Chromium (mg/l)	0.05	0.005	0.05	0.05	0.1-0.5		0.002-0.02	0.001-0.5
Cobalt (mg/l)					0.1			0.01
Copper (mg/l)	1.0	0.1	1.0	1.0	1.0	0.005-0.112	0.002-0.004	0.001
Iron (mg/l)	0.3	0.3	0.3	0.3	0.5		0.3	0.05
Lead (mg/l)	0.05	0.05	0.05	0.05	0.03		0.001-0.007	0.03
Managanese (mg/l)	0.1	0.05	0.05	0.05				
Mercury (mg/l)	0.001	0.001	0.001	0.002	0.0005		0.0001	0.0005
Nickel (mg/l)		0.05					0.025-0.15	
Selenium (mg/l)	0.01	0.01	0.01	0.01			0.001	
Zinc (mg/l)	5.0	0.1-3.0	5.0	5.0	1.0	0.03-2.0	0.03	0.01
NUTRIENTS								
Nitrates (mg/l)	10		10	10				
Phosphorus (mg/l)		5						
PESTICIDES								
Total Pestcidies (mg/l)		0.5	0.1					
Individual Pesticides (ug/l)		0.1						
Aldrin (ug/l)	0.03		0.7					
Dieldrin (ug/l)	0.03		0.7				4 ng/l	
DDT (ug/l)	1.0		30.0				1 ng/l	
Lindane (ug/l)	3.0		4.0	0.4				
Methoxychlor (ug/l)	30		100	100				
Phenols (ug/l)		0.5	2.0		1.0		1.0	1.0

PRINCIPLE DISEASES IN KILIFI AND MOMBASA

DISTRICT	KILIFI		MOMBASA	
YEAR	1986	1987	1986	1987
DISEASE				
Malaria	353086	293880	160369	335139
Resp. diseases	203893	170552	96975	88180
Skin diseases	105927	83222	63272	56560
Diarrhoeal	74570	62472	21772	16479
Intestinal worms	72911	50619	11753	11305
Eye infections	37263	19047	26529	11117
Anaemia	25683	22641		
Bilharzia	20031	13681		
Gonorrhoea			28395	17446

Sources:
1. Mombasa District Development Plan 1989–93
2. Kilifi District Development Plan 1989–93

TABLE 5 PRINCIPLE DISEASES IN KILIFI AND MOMBASA

KILIFI DISTRICT NOTIFIABLE DISEASES

	1980	1981	1982	1992
Chicken Pox	520	337	589	1345
Infectious Hepatitis	1236	56		563
Malaria	29086	31924	57403	6315
Meningitis	9	19		0
Upper Respiratory Tract Infections	20083		915	42244
Leprosy	39	3		27
Pneumonia	1538	797	107	1548
Rabies	0			42
T.B.	38	14	43	22
Diarrhoeal	10385	7029	10745	19160
Intestinal worms	8127	5991	6202	17310
Acute Poliomyelitis	91	2916		7
Bilharzia	852	430	5323	6955
Measles	1520	2299	1103	2205
Gonorrhoea	2518	1812	2040	1803
Mumps	60	38		694
Tetanus	19	49		4
Wooping Cough	53		21	
Urinary T. Infection				20816
Eye Infection			2128	5938
Ear Infection				3652
Skin Diseases			130	20845
Anemia			116	5652
Malnutrition			33	1478
Cholera				
Dental Disorders			272	
Mental Disorders			1006	
TOTAL	76174	53714	88176	158625

Source: Ministry of Health

TABLE 6 NOTIFIABLE DISEASES IN KILIFI DISTRICT

NWCPC COAST REGION:
TOP CONSUMERS, 1992

7.1 SUPPLIED FROM SABAKI WATER WORKS ONLY

	AVERAGE CONSUMPTION [M3]	
	MONTHLY	ANNUAL
NORTH MAINLAND		
Whitesands Hotel	17,182	206,184
Department of Defence	15,000	180,000
Bamburi Portland Cement	14,033	168,396
Silver Beach Hotel	7,000	84,000
Kenya Police	6,793	81,516
African Safari Club	6,243	74,916
Travellers Beach Hotel	6,000	72,000
Mombasa Beach Hotel	4,000	48,000
Equatorial Beach Hotel	3,500	42,000
Holiday Centre	3,468	41,616
Bamburi Beach Hotel	3,233	38,796
Agricultural Society of Kenya	3,083	36,996
SUB-TOTAL	89,535	1,074,420
KIKAMBALA		
Sun & Sand Hotel	?	?
Wispering Palms Hotel	?	?
SUB-TOTAL		
KILIFI		
African Safari Club	2,082	24,984
Coast Inst. of Agriculture	1,832	21,984
Kenya Cashewnuts Ltd.	1,093	13,116
SUB-TOTAL	5,007	60,084
MALINDI/WATAMU		
Blue Bay Beach Hotel	11,700	140,400
Watamu Bay Beach Hotel	3,480	41,760
Turtle Bay Beach Hotel	3,030	36,360
Hemingways Beach Hotel	2,300	27,600
Blue Marline Hotel	2,260	27,120
Eden Rock Hotel	1,875	22,500
SUB-TOTAL	24,645	295,740
TOTAL	119,187	1,430,244

7.2 SUPPLIED FROM MZIMA SPRINGS ONLY

	AVERAGE CONSUMPTION [M3]	
	MONTHLY	ANNUAL
MAZERAS		
Kilimanjaro Mineral Water	32,795	393,540
SUB-TOTAL	32,795	393,540
WEST MAINLAND		
Kenya Petroleum Refineries	75,000	900,000
Mombasa Textiles Ltd	21,000	252,000
KPA	20,000	240,000
Kenya Railways	15,000	180,000
Kenya Cooperative Cremeries	12,500	150,000
Mombasa Airport	11,000	132,000
Kenya Power & Lighting	7,118	85,416
SUB-TOTAL	161,618	1,939,416
TOTAL	194,413	2,332,956

7.3 SUPPLIED FROM BOTH SABAKI AND MZIMA

	AVERAGE CONSUMPTION [M3]	
	MONTHLY	ANNUAL
MOMBASA ISLAND		
Kenya Ports Authority	70,900	850,800
Kenya Breweries	30,000	360,000
Ministry of Public Works	21,500	258,000
Kenya Police	7,000	84,000
Pan African Insurance	6,212	74,544
Coastal Bottlers	6,009	72,108
Bamburi Portland Cement	4,300	51,600
SUB-TOTAL	145,921	1,751,052
TOTAL	145,921	1,751,052

ENVIRONMENTAL IMPACT ANALYSIS:
Socio–economic criteria

AREA OF IMPACT\CRITERION	IMPACT SCENARIO	ORDER	IMPACT RESULT
PROJECT AREA:			
LAND			
Land/Capita	Decrease	First	Indefinite
Land use intensity	Increase	First	Indefinite
Land values	Increase	NA	Positive
Average farm size	No change	NA	
PEOPLE			
Land ownership	Increase	First	Positive
Land distribution	Increase	Second	
POPULATION			
Numbers	Increase	First	Indefinite
Households	Increase	First	Indefinite
Density	Increase	First	Indefinite
Health	Increase		Positive
Education	Increase	First	Positive
Out migration	Decrease		Positive
In migration	Increase		Negative
WATER SUPPLY			
Domestic	Increase	First	Positive
Livestock	Increase	First	Positive
Utility value			
Cost/unit	Decrease	First	Positive
AGRICULTURE			
Crop production	Increase	First	Positive
Crop diversification	No change	Second	Positive
Crop yields	Increase	First	Positive
Tree crop yields	Increase		Positive
Consumption	Increase	First	Positive
Sales/marketing	No change	Second	Positive
Livestock production	No change	Second	Positive
WOODFUEL			
Tree cutting	No change		None
COMMERCE			
Trade volume	Increase		Positive
INDUSTRY			
No. of establishments	Increase	First	Positive
Turnover	Increase	Second	Positive
Diversification	Increase	First	Positive

TABLE 8

Table 8 (cont.) (pg 2 of 2)

AREA OF IMPACT\CRITERION	IMPACT SCENARIO	ORDER	IMPACT RESULT
MINING			
New projects	Increase	First	Negative
TOURISM			
Visitor numbers	Increase	First	Positive
FISHERIES			
Informal	No change		None
Commercial	No change		None
Sportfishing	No change		None
EMPLOYEMENT			
Job creation	Increase		Positive
Wage levels	No change		
TRANSPORT			
Road network	No change		
Service levels	Increase	Second	Positive
Costs	Decrease	Second	Positive

NA = NOT APPLICABLE

Source: Environmental Impact Assessment Study Team

APPENDIX 1. PARTICIPANTS

The Study Team comprised four persons:-

Professor G-M. Mutiso	Institutional Specialist & Team Leader
Mr J. Tomlinson	Hydrologist & Deputy Team Leader
Dr. F. Muthuri	Ecologist
Mr P.V. Byrne	Resource Economist

They interviewed:-

4/5/93

Baraza, L. W.	HP Gauff.

5/5/93

Baker, David	HP Gauff.
Dongen, van P.	Senior Consultant, Groundwater Survey (Kenya) Ltd.

6/5/93

Ciira, R.M.	Researcher, Kenya Wildlife Society.
Gachukia, Catherine	Rural Design Programme Projects Coordinator, Kenya Wildlife Society.
Kioko, J.M.	Deputy Director, Kenya Wildlife Society.
Keter, J.K.	East African Wildlife Society.
Rotich, N.K.	East African Wildlife Society.

7/5/93

Bahemuka, J. Mbula	Dept. of Sociology, UON.
Kinya, Moses	National Water Conservation and Pipeline Corporation.
Komutho, B.O.	Deputy Director, National Environment Secretariat.
Mangala, Michael	Centre for Nuclear Science Technique.

10/5/93

Else, Jim	Deputy Director Research, Kenya Wildlife Society.
Price, Mark Stanley	Director, African Wildlife Foundation.
Inamdar, Amar	African Wildlife Foundation.
Namoya, Fadhili	Greenfields.

11/5/93

Kilele, W.	Managing Director, Agricultural Development Corporation.
Maritim, O.C.	Technical Manager Engineering.
Musa, Jasto	Microproject Officer, European Economic Community.
Ndeti, K.	Chakama Ranch.
Njeru, E.N.	Chief Economist, Dept. of Rural Planning
Omburu, G.O.	Senior Economist, Dept. of Rural Planning.
Kimoni, Z.O.	Rural Development Fund.
Price, Stanley Mark	Director, African Wildlife Foundation.

12/5/93

Almassy, Balint	World Bank
Kiss, Angela	World Bank.
Musango, Peter	H.P. Gauff
Musau, K.	Engineer, H.P. Gauff.

13/5/93

Robertson, Anne	National Museums.

15/5/93

Gichangi, S.M.	Senior Warden Tsavo East.
Kasiki, S.M.	Officer in charge of station.
Wilhem, van Wijgaarden	Consultant
Njoroge, Ngure	African Wildlife Foundation.

17/5/93

Nderu, Ephrahim	District Range Officer, Kilifi.
Piko, F.	District Agricultural Extension Officer Malindi.
Ngonde, A.N.	Deputy Warden, Malindi Marine National Park.
Mukholi, P.J.	District Irrigation Officer Kilifi
Makondia, J. A.	Irrigation Officer Malindi
Rashid, R.M.	District Environment Officer Kilifi
Ruoya, P.K.	District Surveyor, Kilifi.
Bonaye, ???	Assistant Water Engineer, Kilifi.
Githitho, A.	District Forest Officer, Kilifi.
Kirui, S.N.	Warden, Arabuko-Sokoke Forest Reserve, Kilifi.

18/5/93

Bekuto, Balozi K.	Assistant Research Officer, Kilifi.
Ndirangu, C.N.	Forest Assistant, Kilifi.
Goodwin, Uta	Orchard Owner
Kuyoh, W.	Assistant Manager, Sabaki Tropical Fruits Ltd, Malindi
Kivatsi, S.	Sales Representative, Sabaki Tropical Fruits Ltd, Malindi
Kagau, Ruguru N.	Fisheries Officer, Kilifi.

Abuodha, J.	Research Scientist, Moi University.
19/5/93	
Korane, A.B.	D.C. Mombasa.
Kasera, D.	D.O. II Mombasa.
Andwana, Paul	NWCPC Mombasa.
Njiru, C.	NWCPC Mombasa
20/5/93	
Gicheru, P.K.	District Water Engineer - Kilifi.
21/5/93	
Barnato, Joseph	Sabaki Tropical Fruit Farm
Kuyoh, Willie	Assistant Manager, STFF.
Kivatsi, Stephen	Sales Representative, STFF.
Mbwana, Ronald Chandugu	Chief, Mwahera Location
Six Elders	Mwahera Location
Yaa, Julius	Chief - Jilore Location
Nguga, Stephen	Subchief - Lango Baya, Jilore.
Mwamure, Wewson	Subchief - Kakoeneni, Jilore.
22/5/93	
Hare, Erastus	Former Chief Sokoke Location
Sanita, Benson	Chief Sokoke, Sokoke Location
Six Elders	Sokoke, Location.
Pasi, Charles	Former Chief Sokoke Location Councillor Sokoke.

24/5/93

Mutiso, J.M.	Land Adjudication Officer - Kilifi
Gicharu, D.M.	Land Adjudication Officer 1.
Sinoti, Erastus	Public Health Officer - Bahari Division, Kilifi.

25/5/93

Lugogo, Juma	Coast Development Authority
Musembi, J.	Director, Coast Development Authority.
Thoya, M.S.	DIDC Library Assistant for locations.

26/5/93

Farah, M.A.	Area Manager Baricho
Abuya, M.O.	Laboratory Technologist.
Robertson, Ian	Private Consultant Agriculture.
Robertson ,Ann	National Museums.

8/6/93

Baker, David	HP Gauff
Wangombe, K. B.	HP Gauff
Mahamud, Mohamed	National Water Conservation and Pipeline Corporation (NWCPC).

14/6/93

Ndili, Stephea, Aswa	District Statistical Officer, Mombasa District.
Jalenga, Stephen, M.	Provincial Planning Assistant, Coast Province.
Tsuma, Martin, M.	Provincial Planning Officer, Coast Province.

TABLE 3

MAXIMUM ALLOWABLE CONCENTRATIONS

HEAVY METALS, NUTRIENTS AND PESTICIDES FOR DIFFERENT USES.

VARIABLE	DRINKING WATER					FISHERIES AND AQUATIC LIFE		
	WHO	EC	CANADA	USA	USSR	EC	CANADA	USSR
HEAVY METALS								
Aluminium (mg/l)	0.2	0.2						
Arsenic (mg/l)	0.05	0.05	0.05	0.05			0.005–0.1	
Barium (mg/l)		0.1	1.0	1.0			0.05	
Boron (mg/l)		1.0	5.0	5.0				
Cadmium (mg/l)	0.005	0.005	0.005	0.01	0.001		0.0002–0.0018	0.005
Chromium (mg/l)	0.05	0.005	0.05	0.05	0.1–0.5		0.002–0.02	0.001–0.5
Cobalt (mg/l)					0.1			0.01
Copper (mg/l)	1.0	0.1	1.0	1.0	1.0	0.005–0.112	0.002–0.004	0.001
Iron (mg/l)	0.3	0.3	0.3	0.3	0.5		0.3	0.05
Lead (mg/l)	0.05	0.05	0.05	0.05	0.03		0.001–0.007	0.03
Managanese (mg/l)	0.1	0.05	0.05	0.05				
Mercury (mg/l)	0.001	0.001	0.001	0.002	0.0005		0.0001	0.0005
Nickel (mg/l)		0.05					0.025–0.15	
Selenium (mg/l)	0.01	0.01	0.01	0.01			0.001	
Zinc (mg/l)	5.0	0.1–3.0	5.0	5.0	1.0	0.03–2.0	0.03	0.01
NUTRIENTS								
Nitrates (mg/l)	10		10	10				
Phosphorus (mg/l)		5						
PESTICIDES								
Total Pesticides (mg/l)		0.5	0.1					
Individual Pesticides (ug/l)		0.1						
Aldrin (ug/l)	0.03		0.7					
Dieldrin (ug/l)	0.03		0.7					
DDT (ug/l)	1.0		30.0				4 ng/l	
Lindane (ug/l)	3.0		4.0	0.4			1 ng/l	
Methoxychlor (ug/l)	30		100	100				
Phenols (ug/l)		0.5	2.0		1.0		1.0	1.0

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H P GAUFF KG — CONSULTING ENGINEERS — P.O. BOX 49817 NAIROBI/KENYA.

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JBG

2nd September, 1993
DB/bn/1063/970

Prof. G.M. Mutiso
Mutiso Consultant
P.O. Box 14333
NAIROBI

RE: SECOND MOMBASA & COASTAL WATER SUPPLY
ENGINEERING AND REHABILITATION PROJECT
REHABILITATION AND AUGMENTATION OF
SABAKI WATER WORKS
CONTRACT WW/C/D/01

Environmental Impact Assessment
Comments on Draft Report

Dear Prof. Mutiso,

Thank you for your letter of 1st September, 1993 on these.

However your response is not sufficient to forward to the Client. Please deal sub-item by sub-item in Sections 4 and 5 indicating specifically the alterations incorporated between advance draft and draft copies.

In particular your attention is drawn to 5(iv), 5(v), and 5(vi) and 6(p/9) all of which require a response even in terms of the revised draft.

Yours Sincerely
H.P. Gauff KG
Consulting Engineers

L. Laubert
GENERAL MANAGER

D. Baker
HEAD, WATER SECTION

cc: Dr. Muthuri

TABLE 4

PESTICIDE LEVELS IN SABAKI RIVER & AQUIFER AT BARICHO

SUBSTANCE	UNIT	RIVER <1> jun'93	RIVER <2> apr'94	RIVER <1> jun'94	RIVER <3> jun'94	BOREHOLE No. 1 <2> apr'94	BOREHOLE No. 1 <1> jun'94	BOREHOLE No. 1 <3> jun'94	CANADA MAX. PERM.	EU MAX. PERM.	WHO MAX. PERM.
CAPTAN	µg/l	3.80	2.00	nd	nd	1.03	nd	nd		0.1	-
ALDRIN	µg/l	0.45	<0.02	0.01	nd	<0.02	nd	nd	0.7	<0.01	0.03
DIELDRIN	µg/l	1.30	<0.02	0.45	1.5	0.03	0.09	0.07	0.7	<0.01	0.03
opp'DDE	µg/l	0.13	0.03	0.05	0.01	<0.01	0.02	0.06	} 30		} 1.0
pp'DDT	µg/l	4.20	0.32	0.08	1.8	<0.01	0.08	0.09			
ALDECARB	µg/l	-	-	nd	nd	-	nd	nd			
RIVER FLOW	m³/s	<20	- 40			40					

<1> National Agricultural Laboratories, Nairobi
<2> SGS, Mombasa
<3> University of Nairobi

nd = not detected

Prof. Muhso, ~~which one of these~~ Fax. 860771

SABAKI REHABILITATION/AUGMENTATION-ACTION PLAN FOR ENVIRONMENTAL PROTECTION

19/6/98
12:20 pm

TABLE 1

GUIDELINES FOR DRINKING WATER QUALITY FOR KENYA AND WORLD HEALTH ORGANISATION

WATER CONSTITUENT	UNITS	GUIDELINE VALUE	
		KENYA	WHO
Colour	mg Pt/1	< 25	TCU 15
Turbidity	NTU	15	5
Odour	TON		inoffensive
Electrical Conductivity	uS/cm	2000	
pH	pH	6.5–8.5	6.5–8.5*
Total Alkalinity (CaCO3)	mg/l (ppm)	500	
Chloride (C1)–	mg/l (ppm)	250	250
Sulphate (SO4)=	mg/l (ppm)	400	250
Nitrate (NO3)–	mg/l (ppm)	10	50
Nitrite (NO2)–	mg/l (ppm)		3
Fluoride (F)–	mg/l (ppm)	1.5	1.5
Sodium (Na)+	mg/l (ppm)	200	200
Potassium (K)+	mg/l (ppm)		
Calcium (Ca)++	mg/l (ppm)		
Magnesium (Mg)++	mg/l (ppm)		
Iron–Total (Fe)+++	mg/l (ppm)	0.3	0.3
Manganese	mg/l (ppm)	0.1	0.1 [0.5(p)]
Ammonia–Free and Saline (NH4)+	mg/l (ppm)		
Phosphate (P)	mg/l (ppm)		
Carbonate Hardness as CaCO3	mg/l (ppm)		
Non–Carbonate Hardness as CaCO3	mg/l (ppm)		
Total Hardness	mg/l (ppm)	250	
Free Carbon Dioxide	mg/l (ppm)		
Silica as SiO2	mg/l (ppm)		
Oxygen Absorbed 4hr. at 27c PV	mg/l (ppm)		
Total Dissolved Solids residue at 180c	mg/l (ppm)	1000	1000
Suspended Solids (S.S.)	mg/l (ppm)	Free of SS	

*Preferably less than 8.0

p=Provisional health guideline valve.

Source:

1 Water Quality in Kenya–Ministry of Water Development, Kenya
2 Water Quality for WHO–Guidelines for Drinking Water Quality, Second edition 1993

MOEIATBS.WR1

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H P GAUFF KG — CONSULTING ENGINEERS — P.O. BOX 49817 NAIROBI/KENYA.

24th August, 1993
DB/bn/1063/934

Prof. G.M. Mutiso
Mutiso Consultants
P.O. Box 14333
NAIROBI

Dear Prof.

RE: SECOND MOMBASA & COASTAL WATER SUPPLY
ENGINEERING AND REHABILITATION PROJECT
REHABILITATION AND AUGMENTATION OF
SABAKI WATER WORKS
CONTRACT WW/C/D/01

Environmental Impact Assessment
Comments on Draft Report

Kindly receive a copy of the comments on the EIA report, together with a copy of the report & annex as formally submitted.

Please study and provide your written reaction as quickly as practicable, particularly on aspects of the report for which you were directly responsible.

Yours Sincerely,
H.P. Gauff KG
Consulting Engineers

D J Baker

D. BAKER
HEAD, WATER SECTION

cc: Dr. F. Muthuri
Mr. P. Byrne
Mr. J. Tomlinson

Encls

SABAKI RIVER WATER (AT BARICHO)
LEVELS OF PESTICIDES, HEAVY METALS AND NUTRIENTS

PARAMETER	UNITS	CONCENTRATION
PESTICIDES [1]		
Malathion	ug/l	< 0.1
Parathion	ug/l	< 0.1
Diazinon	ug/l	< 0.1
Aldicarb	ug/l	< 0.1
Carbofuran	ug/l	< 0.1
Lindane	ug/l	< 0.1
Heptachlor	ug/l	< 0.1
Dimethoate	ug/l	< 0.1
Gramaxone	ug/l	< 0.1
Mancozeb	ug/l	< 0.1
DDT	ug/l	< 0.1
DDE	ug/l	< 0.1
Paraoxon	ug/l	< 0.1
Malaoxon	ug/l	< 0.1
P-Nitrophenol	ug/l	< 0.1
P-Aminophenol	ug/l	< 0.1
Aldrin	ug/l	< 0.1
Captan	ug/l	0.45
op'DDE	ug/l	3.8
Dieldrin	ug/l	0.13
pp'DDD	ug/l	1.3
	ug/l	4.2
HEAVY METALS [2]		
Lead (Pb)	ug/l	33.9
Cadmium (Cd)	ug/l	< 10.0
Iron (Fe)	ug/l	1024
Managanese (Mn)	ug/l	201
Cobalt (Co)	ug/l	< 0.1
Zinc (Zn)	ug/l	368
Copper (Cu)	ug/l	28.2
Arsenic (As)	ug/l	< 0.1
Selenium (Se)	ug/l	< 0.1
Mercury (Hg)	ug/l	< 0.1
Nickel (Ni)	ug/l	< 0.1
Chromium (Cr)	ug/l	6.8
Titanium (Ti)	ug/l	21
NUTRIENTS [3]		
Total Nitrogen	mg/l	0.46
Total Phosphorus	mg/l	0.26

Samples Analysed At:

[1] National Agricultural Laboratories, Nairobi
[2] Centre for Nuclear Science Techniques, Faculty of Engineering, University of Nairobi
[3] Chemistry Department, University of Nairobi

TABLE 3 LEVELS OF PESTICIDES, HEAVY METALS & NUTRIENTS IN SABAKI

MAXIMUM ALLOWABLE CONCENTRATIONS

HEAVY METALS, NUTRIENTS AND PESTICIDES FOR DIFFERENT USES.

VARIABLE	DRINKING WATER					FISHERIES AND AQUATIC LIFE		
	WHO	EC	CANADA	USA	USSR	EC	CANADA	USSR
HEAVY METALS								
Aluminium (mg/l)	0.2	0.2					0.005-0.1	
Arsenic (mg/l)	0.05	0.05	0.05	0.05			0.05	
Barium (mg/l)		0.1	1.0	1.0				
Boron (mg/l)		1.0	5.0	5.0				
Cadmium (mg/l)	0.005	0.005	0.005	0.01	0.001		0.0002-0.0018	0.005
Chromium (mg/l)	0.05	0.005	0.05	0.05	0.1-0.5		0.002-0.02	0.001-0.5
Cobalt (mg/l)					0.1			0.01
Copper (mg/l)	1.0	0.1	1.0	1.0	1.0	0.005-0.112	0.002-0.004	0.001
Iron (mg/l)	0.3	0.3	0.3	0.3	0.5		0.3	0.05
Lead (mg/l)	0.05	0.05	0.05	0.05	0.03		0.001-0.007	0.03
Managanese (mg/l)	0.1	0.05	0.05	0.05				
Mercury (mg/l)	0.001	0.001	0.001	0.002	0.0005		0.0001	0.0005
Nickel (mg/l)		0.05					0.025-0.15	
Selenium (mg/l)	0.01	0.01	0.01	0.01			0.001	
Zinc (mg/l)	5.0	0.1-3.0	5.0	5.0	1.0	0.03-2.0	0.03	0.01
NUTRIENTS								
Nitrates (mg/l)	10		10	10				
Phosphorus (mg/l)		5						
PESTICIDES								
Total Pestcidies (mg/l)		0.5	0.1					
Individual Pesticides (ug/l)		0.1						
Aldrin (ug/l)	0.03		0.7					
Dieldrin (ug/l)	0.03		0.7				4 ng/l	
DDT (ug/l)	1.0		30.0				1 ng/l	
Lindane (ug/l)	3.0		4.0	0.4				
Methoxychlor (ug/l)	30		100	100				
Phenols (ug/l)		0.5	2.0		1.0		1.0	1.0

MAXIMUM ALL…
HEAVY METALS, NUTRIENTS AND PESTICIDES …

VARIABLE	DRINKING WATER					[illegible] AND AQUATIC LIFE		
	WHO	EC	CANADA	USA	USSR	EC	CANADA	USSR
HEAVY METALS								
Aluminium (mg/l)	0.2	0.2					0.005-0.1	
Arsenic (mg/l)	0.05	0.05	0.05	0.05			0.05	
Barium (mg/l)		0.1	1.0	1.0				
Boron (mg/l)		1.0	5.0	5.0				
Cadmium (mg/l)	0.005	0.005	0.005	0.01	0.001		0.0002-0.0018	0.005
Chromium (mg/l)	0.05	0.005	0.05	0.05	0.1-0.5		0.002-0.02	0.001-0.5
Cobalt (mg/l)					0.1			0.01
Copper (mg/l)	1.0	0.1	1.0	1.0	1.0	0.005-0.112	0.002-0.004	0.001
Iron (mg/l)	0.3	0.3	0.3	0.3	0.5		0.3	0.05
Lead (mg/l)	0.05	0.05	0.05	0.05	0.03		0.001-0.007	0.03
Managanese (mg/l)	0.1	0.05	0.05	0.05				
Mercury (mg/l)	0.001	0.001	0.001	0.002	0.0005		0.0001	0.0005
Nickel (mg/l)		0.05					0.025-0.15	
Selenium (mg/l)	0.01	0.01	0.01	0.01			0.001	
Zinc (mg/l)	5.0	0.1-3.0	5.0	5.0	1.0	0.03-2.0	0.03	0.01
NUTRIENTS								
Nitrates (mg/l)	10		10	10				
Phosphorus (mg/l)		5						
PESTICIDES								
Total Pesticides (mg/l)		0.5	0.1					
Individual Pesticides (ug/l)		0.1						
Aldrin (ug/l)	0.03		0.7					
Dieldrin (ug/l)	0.03		0.7				4 ng/l	
DDT (ug/l)	1.0		30.0				1 ng/l	
Lindane (ug/l)	3.0		4.0	0.4				
Methoxychlor (ug/l)	30		100	100				
Phenols (ug/l)		0.5	2.0		1.0		1.0	1.0

SABAKI RIVER WATER (AT BARICHO)

LEVELS OF PESTICIDES, HEAVY METALS AND NUTRIENTS

PARAMETER	UNITS	CONCENTRATION
PESTICIDES [1]		
Malathion	ug/l	< 0.1
Parathion	ug/l	< 0.1
Diazinon	ug/l	< 0.1
Aldicarb	ug/l	< 0.1
Carbofuran	ug/l	< 0.1
Lindane	ug/l	< 0.1
Heptachlor	ug/l	< 0.1
Dimethoate	ug/l	< 0.1
Gramaxone	ug/l	< 0.1
Mancozeb	ug/l	< 0.1
DDT	ug/l	< 0.1
DDE	ug/l	< 0.1
Paraoxon	ug/l	< 0.1
Malaoxon	ug/l	< 0.1
P-Nitrophenol	ug/l	< 0.1
P-Aminophenol	ug/l	< 0.1
Aldrin	ug/l	0.45
Captan	ug/l	3.8
op'DDE	ug/l	0.13
Dieldrin	ug/l	1.3
pp'DDD	ug/l	4.2
HEAVY METALS [2]		
Lead (Pb)	ug/l	33.9
Cadmium (Cd)	ug/l	< 10.0
Iron (Fe)	ug/l	1024
Managanese (Mn)	ug/l	201
Cobalt (Co)	ug/l	< 0.1
Zinc (Zn)	ug/l	368
Copper (Cu)	ug/l	28.2
Arsenic (As)	ug/l	< 0.1
Selenium (Se)	ug/l	< 0.1
Mercury (Hg)	ug/l	< 0.1
Nickel (Ni)	ug/l	< 0.1
Chromium (Cr)	ug/l	6.8
Titanium (Ti)	ug/l	21
NUTRIENTS [3]		
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TABLE 3 LEVELS OF PESTICIDES, HEAVY METALS & NUTRIENTS IN SABAKI

15/6/93

Kutto, F.C.	Water Engineer, Kilifi.
Mwebi, S.B.	Water Engineering Assistant, Kilifi.
Mwangi, J.G.	Assistant Hydrologist, Kilifi.
Maithya, R.M.	Assistant Hydrologist, Kilifi.

APPENDIX 2. REFERENCES

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APPENDIX 3. RECORD OF MEETINGS IN MOMBASA AND KILIFI

SECOND MOMBASA AND COASTAL WATER SUPPLY PROJECT REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS

Present:

Mr. E.G. Munyi	D.O.I Rep. DC (Chairman)
Eng. C. Njiru	Regional Manager - NWCPC
Mr. J. Tomlinson	Hydrologist (Gauff)
Mr. D. Baker	Project Manager H.P. Gauff
Prof. C.M. Mutiso	Institutions/Team Leader (Gauff)
Mrs. P.A. Odhiambo	DAO - Mombasa
Mr. Veria Samia	KATO
Mr. S.H. Galugalu	CDA
Mr. B.W. Kavu	KWS
Prof. J.A. Lugongo	CDA
Mr. S.M. Mwaguni	Government Chemist's Dept.
Dr. Mweu Nguta	KMFRI
Mr. M. Ntohijira	DDO - Mombasa
Mr. G. Monor	District Fisheries Officer
Mr. H. Mohammed Hassan	Fort Jesus Museum
Mr. P.V. Byrne	Economist (Gauff)
Dr. F.M. Muthuri	Ecologist (Gauff)
Mr. J. Muthamia	MCTA

D.O.I introduced himself and his role to facilitate meeting on behalf of the DC. He introduced Mr. Njiru, Regional Manager of NWCPC, Coast Region.

Mr. Njiru introduced Mr. Baker as he felt it more appropriate that the team present their work.

Mr. Baker: Provided project background and then described team's tasks. He indicated that this was the first of several engineering consultancies funded by World Bank for Second Mombasa and Coastal Water Supply. This study was to:

(i) Assess existing system and see to its rehabilitation and
(ii) Augment to the planned record stage to mid 1980s projection.

Existing system has several problems:
Sabaki river has bed load (sand) and sediment causing severe problems with pumps. There are problems along pipeline and at intake and treatment to be dealt with.

Second stage of the Mombasa and Coastal Water Supply was to increase intake at Baricho, but significant quantities of ground water have now been confirmed and is available in the old sand bed below the Sabaki. Very significant quantities of water are available in this 50 m bed of old sediments, so it may be better to use this source rather than pump directly from the river. This is still to be confirmed.

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Initial studies on the ground water supply options were funded by Germany Government for a project aimed at supplying Malindi - Watamu with more water. Two large boreholes have been sunk and pump tested. A Contractor is now equipping and laying pipes to pumping station. This should be completed by end 1993, and supply Malindi - Watamu with another 20,000 m^3/day

Main increment of water supply will probably come from a second wellfield area now being assessed by the Consultants for the Mombasa and Coastal System. By the end of 1994 there should be a doubling of water at Nguu Tatu from 34,000 m^3 to 70,000 m^3 which is the design capacity of the pipeline. Pumps and refurbishment of pipeline are to be financed under the World Bank.

The enhancement of water to fully supply Mombasa and Coastal beyond this level is under another study, which will also consider Mzima Springs and other sources.

One of requirements of World Bank is to undertake environmental study to assess positive and negative consequences of projects. Funds will not be released unless the impacts are believed to be minor or can be rectified. The team members present here are responsible for the environmental impact assessment study.

Mr. Baker introduced Prof. Mutiso, the team leader.

Mutiso: The team is looking for comments and advice on environmental issues. We request your comments and information. Each consultant will outline what work has been done, to invite your comments. He introduced Mr. Tomlinson first, on hydrology.

Tomlinson: There are two features of the hydrology:

(i) Sabaki carries large sediment load, so whatever happens at Baricho there will be very little impact in terms of silt/sediment removal.

(ii) There is an effect of alum on down river ecosystem, as a result of sediment recovery. Therefore any project to reduce the need to reduce sediments would be good i.e. such as groundwater source.

(iii) Effect of low flows by removing twice as much water if Baricho is to be rehabilitated is to be mitigated.

There is a feeble data base for this project, so it has been difficult to get adequate data. Part of the intention of this study will be to establish a permanent measuring station, probably at Baricho.

Conclusions on low flows are speculative, but sometimes Athi dries up and the only water in the Sabaki is from Mzima Springs overflow. In very dry periods Sabaki might have $2^1/_2$ m^3/sec from Mzima, and with downstream losses an extraction of 100,000 m^3/day would remove a very significant quantity of water during the low (dry) season flows.

Therefore the team is looking at measures such as taking river water during peak flows and storing the water near Chakama in an off-river storage reservoir. The purpose of Chakama reservoir would be to mitigate the possible environmental effects of drying-up the river from approximately 2 km downstream under exceptional (dry) conditions.

There is no environmental effect from Baricho redesign in terms of sedimentation from the river water on the beaches of Malindi. In a separate and important subject, that is under study by Mr. Abuodha of Moi University, the impacts of the silt on beach/delta and estuary structure and chemistry will be covered.

Muthuri: No baseline study has been previously made on ecology, so we are working now on the following ecological systems:

(i) Marine
(ii) Riverine
(iii) Terrestrial

The Sabaki supports an interesting and unique ecosystem. Abstraction of water should leave a minimal flow necessary to support aquatic flora and fauna especially in dry periods. Salt intrusion could be a problem but the project will not effect this as the proposed extraction will not sufficiently affect flows and the estuary will withstand intrusion.

In connection with sedimentation it is believed the rate of silt deposition is increasing but this project is unimportant in this respect, it is a separate national environmental issue.

The treatment works has the potential for impacting the riverine and marine ecosystems in terms of pollution, so the levels of aluminium outflow will have to be measured to ensure they remain below danger levels. Bioaccumulation may also be a problem. The chemicals concerned will be monitored, as there is no baseline data. Sludge emanating from the use of tropical (TCL) chloride of lime will be disposed of in disused quarries near the treatment works.

The other impact is the effect of the pipeline itself on the terrestrial environment. However, the pipeline is already in situ, so any effect is already in place. However, the pipeline passes through dry woodland and does not traverse any critical habitats. It does however cross Rare Gorge, for example, which has important plant species, but the effect of the pipeline itself and the access road is minimal.

The main impact is "colonisation" of the pipeline area, and the concern is that important plant species will be lost due to over-exploitation and cultivation.

Byrne: Highlighted the problem with the absence of a previous baseline study against which to measure changes such as:

(i) the road especially the community supply to population 3 km on both sides of the pipeline
(ii) increased agriculture or erosion
(iii) new people into new land
(iv) direct cost of inadequate supply of water (eg. hotel tankers, storage)
(v) water borne diseases data

Benefits to people that are being evaluated include:

(i) business - commerce, industry, mining
(ii) tourism
(iii) private citizens more time

Mutiso: I am covering institutional issues, such as population movements. We have established clearly that no people have moved in because of the pipeline, with the exception of Lango Baya, in Jilore area. In Mombasa there is a great deal of settlement in Mashomoroni area, but this is not driven by the pipeline. These movements are caused by other more substantial factors, partly political.

We were able to interview three generations of Chiefs in Jilore, and this was very useful as Jilore - Sokoke Settlement schemes from as early as 1931 provided information on these movements. There has been a lot of population movement in Kilifi. Firstly people moved from hinterland into Gede, Teso and Roka. The key factor was that the families were not moving en masse. Instead, families split to take advantage of up to three ecological areas.

The major finding is that the pipeline has not been a key factor in influencing settlement and land use.

The second area of study is that there may be changes in the pattern of land use. Kilifi agriculture is traditional, without heavy use of external inputs of particular note is the poor soil conservation. Some areas have become much more intensively used, but there is nothing unusual going on along the pipeline.

However there is a move to large-scale and more commercial agriculture by a few people who have come into the area. They bring in new techniques and have an influence on other farmers.

One possible conclusion is that the area along the pipeline will become very important in the near future. That phenomena has not yet started but there is the potential to displace present owners.

There is the emphasis in our work on studying the pipeline and its road, rather than the distributional effects in Mombasa itself, which is beyond the terms of reference. Nevertheless, we are concerned with environmental effects of the water use itself.

Lugongo: I wonder if we are doing justice to the exercise in regard to Mr. Baker's comments on the team's objectives. Perhaps part of the investment should be directed to the source of the erosion problem i.e. Mt. Kenya area. In terms of cost/benefit Kenya would benefit greater in terms of unit cost of water if this was addressed. I would also like to hear more on the effects of using groundwater, as the environmental effects have to be discussed in terms of community impact.

KEMRI and JICA have been working in Kilifi and have baseline data on water-related diseases.

Mutiso: There are three comments here. Firstly for our immediate work we are constrained by our TOR and it does not include the Athi catchment erosion problem. Secondly one of the problems in Kenya is that there are so many authorities with overlapping responsibilities. In any catchment there are very many ministries involved and co-ordination and action is very difficult and leads to inaction. Thirdly we believe there may be enough groundwater to make Baricho surface water abstraction redundant so that the siltation problem is removed as far as the pumping problems are concerned.

Lugongo: Is it part of your TOR to consider revamping Baricho, as the Sabaki can be utilised for other purposes as well?

Mutiso: The utilisation of existing investments is a choice for the future, should groundwater be sufficient, and the pumping works and intake not required.

Baker: It is not yet certain that the Baricho surface water works can be phased out; we should know in 8 months, once all the resource assessment is complete.

Tomlinson: It should be understood that the water is the same as the water in the river; the technique of extracting groundwater is a matter of convenience (to avoid silt). On the issue of sediment it cannot be concluded that land use is the cause of silt. The processes on the Athi - Kapiti Plains creating erosion are largely natural processes that cannot be changed. Also on the Galana, the silt load created by the rains is natural. There have been improvements in Machakos, leaving perhaps Kiambu and other small areas to affect erosion and siltation. It is a correct approach to regard the problem to be addressed at source, but it is not part of this study. There will be more monitoring and measuring and in the future it may be possible to determine cause - effect factors.

Byrne: We have discussed with KEMRI their data but they are considering the actual diseases at present not cause and effect. There is no data that can be used for our study.

Muthuri: Groundwater is of high quality and therefore suits the communities. Pesticides and heavy metals are being evaluated, and there will be monitoring in the future. We do not believe there are any negative effects on the communities coming from use of groundwater.

Mwaguni: A new concept has been introduced of using groundwater. What effect will there be on the shallow wells used by the local people? A second issue is the disposal of sludge. But transporting this is problematic; could this sludge be analysed for other uses?

Baker: There will be no effect on shallow wells, because the water is coming only from the narrow bed and alluvial deposits under the Sabaki. The first two wells are located only 100 m apart. The first was pumped at 24,000 m^3/day and the drawdown was less than 5 m. The drawdown in the second well was only 15 cm. This is because the sources are apparently a sub-surface flow, and the recharge from the Sabaki itself. Therefore the impact is very localised. There is expected to be no long-term change. There will be retained a stable groundwater environment if the extraction is confined to the bed of the Sabaki.

Muthuri: The disused quarry where we want to dispose the sludge is within 200 m of the sludge source, and 100 m from present site of disposal. Because of its location and the small quantities it is produced hard to imagine what economic use could be made of it, because of transport costs to town.

Kavu: Quantity of water flow will be less downstream of the intakes. We are concerned about the impact on wildlife if dry season flows are substantially reduced. There is also a species of tilapia

Mweu: I get the impression that the statement that there is a "feeble data base" could be used to excuse the project. Perhaps it would be useful to circulate the draft report, to enable us to properly assist the consultants. For example, there are other experts at KMFRI who could contribute.

Mutiso: It is important to note that the data base is feeble in some areas, not all. Mr. Tomlinson was referring to hydrology. One constraint is that we are working for the Corporation and what the Corporation does with the report is its concern, so we are not in a position to circulate it. This is the usual consulting practice.

Njiru: What the Corporation is doing is to partly solve the water supply problem and has gone to World Bank for assistance. One of the steps is to look into the Environmental Impact of increasing water pumping from the Sabaki to get the supply up to 70,000 m^3 for Mombasa and 20,000 m^3 for Malindi - Watamu.

Odhiambo: Mutiso mentioned land use and therefore compensation is involved; will there be compensation if there is disturbance?

The second issue I wish to raise is protection of the catchment. It is important that the problem be solved and therefore it is important to identify the catchment areas contributing to the problem. This would at least identify the problems for additional effort to be focussed by relevant organisations.

Baker: If there are affected parties there will be compensation. In all cases where land is required or crops destroyed then the local chiefs are involved and proper compensation is assessed and made. We have done this during the drilling programme, for example.

Tomlinson: The first National Water Master Plan established that the greatest cost of erosion is farmers themselves, and the emphasis should be on the fact that farmers cannot afford to lose the soil, not on the nuisance value of the sediment. If is unlikely that any connection can be made between the catchments concerned and Baricho's problems or siltation on Malindi with regard to the present study.

Lugongo: Is it possible for you Mr. Chairman to suggest that such a study be done on the issue as a separate exercise?

Tomlinson: Can I suggest that the most important thing would be to motivate Corporation staff to properly measure and monitor the river. It is of great importance to ensure under the Corporation's new operational powers. This would provide the data to determine where the sources of the problem are and what could be done.

Muthamia: What will be done to handle the waste water, since water coming into Mombasa will be greatly increased.? At present disposal of waste water and sewage is very problematic.

Njiru: There is another project on drainage and waste water disposal.

Muñyi: Could there be any additional uses or benefits from the possible Chakama reservoir?

Baker: This is a side arm of the Sabaki, and if there were a dam it would be used as an off-river clean water storage that does not silt-up. If it is used as a storage system its levels will alter, sometimes drastically. To allow for other uses or benefits, such as irrigation, would involve extra costs. It is not within our scope of work.

This scheme is only likely to be effected if the Client agrees that the extra costs are justified.

Lugongo: Have the team members discussed with Mr. Abuodha?

Team: Yes, he has been extremely helpful to us.

Odhiambo: Will the disposal of sludge in the quarry be a permanent solution?

Muthuri: Yes, we are only using one quarry which is very large and it will take many years to fill. It is close to the existing disposal site.

Munyi: Would Prof. Mutiso like to comment, before winding up, on the proceedings?

Mutiso: The only comment is that you should please send us any further comments, if you think about these later. Please also note that we are also concerned with the wider environmental issues, (such as erosion) but are constrained by our narrow terms of references.

I would like to thank you for coming along and assisting us. We are very grateful and would greatly appreciate any information you can send us. There are many "grey" areas where we need help; the example is the issue of chemicals in the water.

Munyi: Closed the meeting by thanking all present. Members of the public are very much looking forward to the project.

SECOND MOMBASA AND COASTAL WATER SUPPLY
REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS
KILIFI MEETING (15TH JUNE 1993)

Present

Mr. H.N. Mung'asia	Acting DC Kilifi (Chairman)
Mr. G.C.M. Mutiso	H.P. Gauff/W.B. Water Ass.
Mr. D. Baker	H.P. Gauff KG
Mr. F.M. Muthuri	H.P. Gauff - Environment Assistant Team
Mr. J. Tomlinson	H.P. Gauff - Hydrologist
Mr. P. Byrne	H.P. Gauff - Economist
Mr. M.A. Mwakileo	DSCO - Kilifi
Mr. F.C. Kutto	AG. DWE, - Kilifi
Mr. R. Kachula	Consultant - CDA
Mr. H.M. Mwarumba	Administrative Officer I - Kilifi
Mr. M. Ndoro	Technical Officer - CDA
Mr. J. Musembi(mbe)	Director CDA - Kikambala
Eng. C. Njiru	Regional Manager - NWCPC
Mr. E.O. Sinoti	PHO - Kilifi
Mr. C.D. Mwatete	Livestock Production - Kilifi
Mr. D.M. Nzure	District Information Officer - Kilifi

Mung'asia: Introduced the purpose of the meeting with apology for the misunderstanding concerning the meeting and its delayed start. He was deputing for the DC, who was away, and had not been informed. He introduced Mr. Baker.

Baker: Discussed. History of the Baricho Water Project and NWCPC, and its efforts to enhance water supply for the coast and Mombasa. There are three components of the project:

(i) rehabilitate and augment Baricho Water Works
(ii) new project to augment supply
(iii) Improved distribution

The rehabilitation and augmentation study to cover engineering and environmental aspects to achieve full potential water supply to Malindi and Mombasa started in late August 1992. There is a major groundwater resource at Baricho determined by the studies since August 1992. This will be used for Malindi - Watamu and add to the Mombasa supply by the end of 1993. Our project includes sourcing water and the wellfield approach has been used. This work has located a second wellfield area that will be adequate for Mombasa augmentation to bring the supply from Sabaki up to 70,000 m^3/day from the present level of half this.

The environmental impact assessment (EIA) study is a World Bank requirement for financing the project to rehabilitate and augment Sabaki.

The team is required to hold meetings to receive comments from relevant district-based personnel. This is the second meeting following the Mombasa meeting yesterday.

Mr. Baker introduced Prof. Mutiso, the team leader.

Mutiso: The team is looking for comments and advice on environmental issues. We request your comments and information. Each consultant will outline what work has been done, to invite your comments. He introduced Mr. Tomlinson first, on hydrology.

Tomlinson: There are two features of the hydrology:

(i) Sabaki carries large sediment load, so whatever happens at Baricho there will be very little impact in terms of silt/sediment removal

(ii) There is effect of alum on down river ecosystem, as a result of sediment recovery. Therefore any project to reduce the need to reduce sediments would be good i.e. such as groundwater source.

(iii) There is need to consider the effect of low flows by removing twice as much water if Baricho is to be rehabilitated to pipeline design capacity for Mombasa and North Mainland of 80,000 m^3 and Malindi 20,000 m^3. This is a very difficult question to answer because there is very little data on the discharge of water in the Athi - Sabaki river.

There is a feeble hydraulic data base for this project, so it has been difficult to get adequate data. Part of the intention of this study will be to establish a permanent measuring station, probably at Baricho.

Hydraulic conclusions are speculative, but sometimes Athi dries up and the only water in the Sabaki is from Mzima Springs overflow. In very dry periods one might have $2^1/_2$ m^3/sec flow from Mzima, and with downstream losses, an extraction of 100,000 m^3/day would remove a very significant quantity of water during the low (dry) season flows.

The team is looking at measures such as taking river water during peak flows and storing the water near Chakama in an off-river storage reservoir. This will add to the cost. The purpose of Chakama reservoir would be to mitigate the possible environmental effects of drying-up the river from approximately 40 km downstream under exceptional (dry) conditions. But it is not essential to the project, which at present is to take the extra water from a wellfield.

There is no environmental effect from Baricho water works in terms of sedimentation from the river water on the beaches of Malindi, although it is a separate and important subject that is under study by Mr. Abuodha.

Muthuri: No baseline study has been previously made on ecology, so we are working on impacts on the following ecological systems:

(i) Marine
(ii) Riverine
(iii) Terrestrial

The Sabaki supports an interesting and unique ecosystem but this can be sustained with a minimal flow. Salt intrusion could be a problem but the project will not effect this as the proposed extraction will not sufficiently affect flows and estuary/delta will withstand intrusion.

In connection with sedimentation it is believed the rate of silt deposition is increasing but this project is unimportant in this respect, it is a separate national environmental issue.

The treatment works has the potential for impacting on the riverine and marine ecosystems in terms of pollution, so the levels of alumina outflow will have to be measured to ensure they remain below danger levels. Bio accumulation may also be a problem. The chemicals concerned will be monitored, as there is no baseline data. Sludge, with chloride of lime, will be disposed of in disused quarries near the treatment works.

The other impact is the effect of the pipeline itself on the terrestrial environment. However, the pipeline is already in situ, so any effect is already in place. The pipeline passes through dry woodland and does not traverse any critical habitats. It does however cross Rare Gorge, for example, which has important plant species, but the effect of the pipeline itself and the access road is minimal.

There is impact by "colonisation" of the pipeline area by limited new settlement, and the concern is that important plant species will be lost due to over-exploitation and cultivation.

Byrne: Highlighted the problem with the absence of a previous baseline study against which to measure changes such as:

(i) the road and the water supply - impacts on 3 km on both sides of the pipeline
(ii) increased agriculture or erosion
(iii) limited numbers of new people who are opening land
(iv) direct cost of inadequate supply of water (eg. hotel tankers, storage)
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Benefits to people that are being evaluated include:

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We were able to interview three generations of Chiefs in Jilore, and this was very useful as Jilore - Sokoke is controversial for land use settlement schemes from as early as 1931 provided information on these movements. There has been a lot of population movement in Kilifi. Firstly people moved from hinterland into Gede, Teso and Roka. The key factor was that the families were not moving en masse. Instead, families split to take advantage of up to three ecological areas.

One major finding is that the pipeline has not been factor in influencing settlement and land use.

The second area of study is that there may be changes in the pattern of land use. Kilifi agriculture is traditional, without heavy use of external input of particular note is the poor soil conservation. Some areas have become much more intensively used, but there is nothing unusual going on along the pipeline.

However there is a move to large-scale and more commercial agriculture by a few people who have come into the area. They bring in new environmentally positive techniques and have an influence on other farmers.

One possible conclusion is that the area along the pipeline will become very important in the near future. That phenomena has not yet started but there is the potential to displace present owners.

There is the emphasis in our work on studying the pipeline and its road, rather than the distributional effects in Mombasa itself, which is beyond the terms of reference. Nevertheless, we are concerned with environmental effects of the water use itself.

Mwakileo: Is there a draft report that we can consider, together with our own field trips to project sites. Is there a paper we should have seen?

Mutiso: As Consultants we are working for the Corporation, and it is their choice and responsibility of what is done with the report. We cannot distribute our findings as is general practice.

Njiru: Apologised for his lateness in arrival at the meeting. The Corporation has employed the team to evaluate the impact of the rehabilitation of the pipeline and enhancement of the water supply to pipeline capacity. The team called this meeting for the purpose of introducing the subject and inviting comments or issues from those present at the meeting. This meeting is actually part of the study and will contribute to the findings and conclusions.

Mwakileo: As far as agriculture is concerned there are areas of erosion. As a ministry we will prioritise the areas along the pipeline and enhance soil and water conservation efforts in these areas. Since these efforts will be new they are not budgeted for the 1993 - 94 financial year. Funding is not available. What can be done about this?

Mutiso: There is a lead time to enable the ministry(ies) to take action and budget. The three critical erosion areas are:-

(i) km 26 from Baricho
(ii) Rare Gorge
(iii) Ndzovuni River

These are small areas and are not adjudicated so that action can easily be taken as it is not private land. In the long-term you do need to get into the planning cycle.

Njiru: It is strongly recommended that departmental heads drive along the pipeline and inspect the project area. It would familiarise you with the project and project area.

Mutiso: To what extent do you believe the adjudication can be achieved quickly? This may contribute to stabilising land use and avoid further erosion?

Njiru: Please understand that there will not be any further disturbance for land acquisition for the pipeline. Also, there will be no provision of water for irrigation. It is only a domestic supply to people along the pipeline.

Mutiso: We are looking for a stable land use system around the pipeline.

Mung'asia: It is a policy matter for the Lands Department. They have their agenda to get the work done.

Baker: I would like to address the team in asking what has been the impact of the pipeline road on the environment?

Mutiso: Part of the pipeline road does have a matatu and bus service and the road provides a N - S link in the interior. But the momentum does not yet exist to make it a viable transport route. Our findings suggest that the pipeline and the road have not had an impact on settlement nor land use.

Byrne: The road would probably have been built anyway as part of the natural development of transport corridors. As Prof. Mutiso points out it has not as yet had a major impact. For mitigation, it will be necessary to look at long-term design and management of the road, and maintenance budgeting under Ministry of Works.

Kachula: We are interested in sources of water for irrigation and agro-industrial projects.

Baker: In 1974 Mowlems investigated the possibility of the existence of the wellfield. However, it was not further explored until 1980/81 when JICA investigated sources to answer the question of where Mombasa would obtain water next. JICA suggested a diversion of the Sabaki to a storage dam on the Rare River. In the mid 1980s the groundwater potential was again considered by MOW/GTZ/BGS. Boreholes were sunk but results were inconclusive. In 1989 Gauff resumed investigations for the Malindi supply. Seismic and borehole surveys located the old river bed and it was established that it exists south of the existing south bank. It is confirmed that it is river water that has percolated into the underground reservoir. These are deep sand beds of the Sabaki river up to 50 m.

Tomlinson: The underground channel probably begins at the Galana Causeway some 70 - 80 km upstream of Baricho. Above this there is no suggestion of underground rivers or flows. In the sections where deposits exist there will be major water resources that are recharged from the river. If you want water for a project you apply to MOWD for an extraction licence in the normal way.

Njiru: The question is getting beyond the scope of this meeting as there is another consultancy to consider new sources of water for Mombasa. This is considering all relevant hydrology.

Tomlinson: All data on extraction licences is available in the 1978 Water Master Plan; the information will also be updated in the Second Master Plan by JICA which has not yet been released.

Kachula: CDA is looking for possible sources of surplus water for potential agricultural development projects.

Mutiso: Mr. Njiru - with respect it does come within our TOR to consider these major development projects. Where are these projects to be developed?

Tomlinson: There are two main water source systems based on the volcanics of Kilimanjaro and Chyulu. For water abstraction the CDA would apply in normal circumstances. It would require a permit to take the necessary water at times when water is above a certain level of flow in the river. You would need storage for an irrigation system due to dry season low flows.

Kachula: Assuming the pipeline can be developed to full capacity, will the Corporation still go for the Second Mzima Pipeline? Could there be surplus water from Mzima?

Baker: The answer is that there will be no surplus water. The present projects will not be adequate, and further water is still required. The other consultancy is considering the most appropriate source and all the water will be required for domestic consumption.

Ndoro: Is it possible to have a second pipeline for untreated water for sewage, etc. rather than treat all water?

Baker: It is not possible because of the danger of connecting systems to the wrong supply and the very high cost of having a dual system.

Mung'asia: The meeting can now be concluded if there are no other comments.

Mutiso: The team is very grateful for your presence, contributions and comments. The Corporation is a member of DEC and DDC, so comments and materials can be obtained through those sources. We request you to send us any further contributions you might have.

Mung'asia: Thanks to the team. There have been extensive problems, especially in the tourism zone. The DEC is prepared to assist in any involvement on issues concerned with the pipeline and its rehabilitation.

REPUBLIC OF KENYA

National Water Conservation & Pipeline Corporation

SECOND MOMBASA & COASTAL WATER SUPPLY

ENGINEERING & REHABILITATION PROJECT

REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS

COMMENTS ON THE ENVIRONMENTAL IMPACT ASSESSMENT DRAFT REPORT SUBMITTED BY M/S GAUFF

Prepared by:
BCEOM,
Technical Assistance to
NWCPC,
NAIROBI.

July, 1993

SUMMARY

1. Purpose

2. Background on Environmental Policy and Trends in Kenya

3. Terms of Reference (TOR)

4. General comments on the EIA Draft Report Structure and Content

5. Discussion on major issues and shortcomings

6. Detailed remarks on the draft report

SECOND MOMBASA AND COASTAL WATER SUPPLY
REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS
COMMENTS ON THE ENVIRONMENTAL IMPACT ASSESSMENT DRAFT REPORT SUBMITTED BY M/S GAUFF (JULY 1993)

1. Purpose

The purpose of this report is to comment on the conformity and content of the Environmental Impact Assessment (EIA) draft report with regards to:

- The terms of references;
- The recommended format for an EIA report;
- The reliability of collected data and identified impacts;
- The relevancy of the proposed mitigating measures.

The evaluation report will present successively:

(i) general considerations regarding environmental policy in Kenya, TOR and EIA report structure and presentation;

(ii) a discussion on major findings, issues and short-comings;

(iii) a detailed review of report text, tables and figures.

During its evaluation mission, BCEOM's expert visited the Sabaki Water Works facilities, the proposed water field areas and the Sabaki river delta. Meetings were also organised with the Manager of Baricho water treatment plant, the NWCPC sub-area manager of Malindi and the District Agricultural Office in Malindi. In Nairobi World Bank Office, the expert met with the representatives in charge of environmental aspects of Bank operations, A. Kiss and C. Cornelius.

2. Background on Environmental Policy and Trends in Kenya

At present, there is no environmental policy defined in Kenya. No specific regulations on EIA procedures have been established yet. As a result, only international funded projects are environmentally screened for impact assessment, in accordance with funding organisation requirements and guidelines, local projects being implemented without any control.

Like other African countries, Kenya has been strongly suggested by the World Bank to initiate a National Environmental Action Plan (NEAP). This process is intended to provide a framework for integration of environmental considerations into the nation's economic and social development.
It is a "demand driven" process, i.e. initiated in response to requests from the concerned countries. As a systematic rule, the NEAP is supported by a group

of donors led by the Bank, and the process is managed by the country itself, the donors being only the sponsors and the catalyst of the process.

The major components to address generic issues in a NEAP include:

i) Establishing environmental policy and legislation,

ii) Establishing the institutional framework for dealing with the environment (environmental policy body, mechanisms for coordination, public/private sector involvement...),

iii) Building a national capacity for environmental assessment,

iv) Establishing environmental monitoring and information systems,

v) Developing human resources.

Funds from the Bank are already available to support the elaboration of the Kenya NEAP. Several preparatory meetings and workshops have already been held, involving multi-sectoral participation (government bodies, Universities, Donors, NGOs, private sector), in order to organize working groups and task forces.

The Kenya NEAP should be hopefully initiated soon, mainly if we consider the deadline fixed by the Bank, to refuse lending to any African country which has not fulfilled its NEAP by July 1st, 1994.

3. Terms of References (TOR)

The TOR discussed here exclusively concern the Project component related to the Augmentation and the rehabilitation of the existing Sabaki/Baricho bulk supply system.

Draft TOR have been elaborated by the Bank staff and presented in the Staff Appraisal Report (Annex 11, Part C). The Project component is classified as B-category according to the Bank Operational Directive 4.00, thus requiring limited EIA.

Draft TOR are extremely detailed, express the good perception of the Bank Staff about the expected and most probable impacts of the project and define clearly the scope of work for M/S GAUFF and the tasks to be achieved. Draft TOR suggest an EIA report outline according to recommendation of O.D. 4.00.

TOR for the EIA study, as included in the agreement between the National Water Conservation and Pipeline Corporation (NWCPC) and the Consultant are almost the exact replication of the draft TOR. Nevertheless it must be mentioned that a part of the draft TOR is missing in the contractual TOR. This missing part, roughly equivalent to one page, concerns Task 4 (partly) and Task 5 (fully). According to the fact that these missing tasks are more or less covered by the EIA report, it is most probable that the problem results from word processing deficiency. This point must be cleared between NWCPC and M/s GAUGG.

4. **General comments on the EIA Draft Report Structure and Content.**

The following comments have been made on the draft document submitted by M/S GAUFF on 5th July 1993 (acc. letter ref. 1063).

In general, the study report answers the main requirements expressed by the TOR. Nevertheless, some important aspects stressed by the TOR have been insufficiently covered in the EIA report: for example aspects related to land-use, impacted areas, hydrological balance of the river, competitive use for water, clear distinction between impact types (construction/operation, long/short term,..), description of recommended studies, etc... All these points are discussed in following section 5.

The draft report structure consists of a main report to which the individual reports elaborated by each participant have been attached as appendices. The main report has not been re-written but produced through cutting-pasting of sections or paragraphs from individual reports. This approach results in a strong confusion feeling for the reader: objectives of the study are not clearly stressed, presented data lack homogeneity, overlapping of information in different parts of the report, lack of clear conclusions and synthesis, duplication of text between report and appendices. Most of these deficiencies could be cleared away by the elaboration of a unique document re-structured and re-written by one of the experts from the individual reports.

For these reasons, we recommend the Consultant M/S GAUFF **to restructure the whole report in order to produce a unique and understandable final document**, fully based on the individual reports of the experts. While re-organizing the report structure, we recommend the Consultant, M/s GAUFF to take into consideration the followings:

i) To keep the **same outline** than that of the draft report, which satisfies Bank's O.D. 4.00

ii) To screen baseline data in order to maintain into the text figures and maps which are deemed necessary for the understanding of the problem, because directly related to the project area or indirectly providing a comparison support to the discussion. Raw data (ex. statistical tables) should be put into appropriate appendices. For all tables and maps, source of information and year should be provided.

iii) To make a clear distinction between the **Project area**, directly concerned by project components, and the **Project region** which can be indirectly affected by the project (or which can affect the project), but which has not immediate physical links with it. For ex. the vegetation cover on the future well fields is related to the project area, but the Sokoke forest reserve must be presented in the project region. This aspect is very confusing in the draft report. Also, as a clarification for the reader, mention always on regional thematic maps the proposed location for project development (the "project area").

iv) To add a sub-section on **impact identification** at the beginning of section 5 (Environmental Impacts). This could simply be done through a presentation **matrix** which crosses intended project actions with detailed environmental fields. Project actions should be clearly distributed according to the project life period: **pre-construction** (ex. exploratory drilling), **construction** and **operation**. This approach will also helps to screen all potential impacts before assessment of the most significant ones.

v) To recapitulate all proposed measures of the mitigation plan in terms of investment costs, operation costs and implementation schedule. This must be included also into the executive summary.

5. Discussion on major issues and shortcomings

i) **Section 2** of the draft report (Policy, legal and administrative framework) must be reviewed. Indeed the framework to be described here in accordance with the report outline suggested by the Bank, is not the framework for the development project, as done in the draft, but the institutional framework within which the EIA is prepared: specific requirements of donor agency(ies) and/or of national legislation in the sector. For the present project, the framework is limited to that defined by the Bank in OD 4.00.

The framework described by M/s GAUFF in the draft report must be removed from this section either to a sub-section in the Baseline Data Chapter or in an Appendix.

ii) **Water balance** is a major component of the EIA study, as it should help to advise on the sustainability of the project regarding the resource and also to identify potential water use conflicts with other users. This component is almost neglected in the draft report (Section 4.3.2. "Water balance at Baricho", about 15 lines without relevant information).

It is obvious that a detailed water balance for the system can hardly be developed at present, mainly because some basic parameters are still unknown like the actual water exchange rates between the river and the related aquifers. Nevertheless, M/s GAUFF should try to provide a minimum of information on this matter, elaborating on the present existing knowledge, or expected from the hydrogeological investigations presently on-going on the potential well fields. At least, a rough assessment of water requirements along the Sabaki river downstream Baricho area is deemed necessary.

Information on irrigation is available in the socio-economic report (section 4.6.7.3),but was unfortunately not exploited in terms of water requirements and even not mentioned in the main report. For the final report, this aspect should be analyzed. These data on irrigation schemes should be checked, because several projects (under implementation or just proposed under IFAD or CEC funding) mentioned by the Malindi Agricultural Office to the BCEOM's Expert were not listed in the draft report.

In the same range of consideration, the computation made by M/S GAUFF on the aquifer pumping (Section 6.2.2 and Fig. 6.4) is either doubtful or inadequately explained. According to the result of the simulation, some years almost 18 MCM are extracted from the 20 MCM estimated total capacity of the aquifer, for a maximum steady yield of 290,000 m^3/day. This looks hardly believable, the depletion of an aquifer by a significant percentage of its capacity resulting generally in serious limitations and problems: reduction of pumping discharge, intrusion of silts and clay in the aquifer, clogging around the well, subsidence phenomenon,... M/s GAUFF must clarify his approach.

Also, the possible impact of the pumping on shallow wells (if any, to be confirmed) looks under estimated (page 6 of the Mombasa meeting minute). Water static level is only about 2.5 m bgl. Pumping tests showed a draw down of about 3 m for 24,000 m3/d pumping yield. Considering the high transmissivity of the aquifer, permanent pumping during the dry season could have effects on water table level at significant distances from the wells and possibly affect shallow wells.

iii) **Land use** aspect is almost missing from the draft report. Page 12, the Consultant mentions that it used SPOT satellite imagery to map the land-use along the pipe-line. No information nor map as results were presented in the draft report. This should be included in the final report.

Also, the report does not provide any detailed land-use of the area anticipated for underground water production. This information is deemed necessary to estimate the compensation budget which could be required if production wells are located in farmland areas. In fact, the two production boreholes already implemented upstream of Baricho are located on farmland, in a coconut plantation. Their construction led to compensation for the farm owner. It is recommended that M/s GAUFF estimates a compensation budget for the development of the well fields, based on an expected number of wells to be implemented, a realistic area required as protection perimeter for each of the production wells and a reasonable compensation basis per unit area. M/s GAUFF should also recommend measures to protect the well field area in the future.

iv) **Fisheries** have been studied, but the draft report provides information on sea fisheries only. These are certainly the most important in the region, but river fishing activities should also have a basic role in protein supply to small villages, as soon as we move 10 or 20 km upstream the river estuary. This role has been stressed by the representative of the Kenya Wildlife Services (Mombasa meeting records, p.6). Few information on the subject is required, at least to support the estimate for a minimum guaranteed discharge in the Sabaki river downstream Baricho.

v) **Impacts of project in Mombasa and Malindi** have not been identified in the draft report. At least two types of impacts could be anticipated from the augmentation of supply:

- Firstly, the limited capacity of the sewerage system which could not be able to absorb the increased production of sewage. In Malindi, there is no sewerage network, waste water being discharged in individual septic tanks (high class residential areas), or simply in infiltration pits (old town). Malindi is already badly affected by a deficient drainage because of local topography, which results in severe flood occurrence in several areas during the rainy periods. Excess of waste water could overflow in flood-prone areas with prejudicial effects regarding health and sanitation. M/s GAUFF should at least mention this potential impact, recommend mitigating measures or make sure that the point is fully covered by on-going studies on water supply.

  This is only one aspect of a wider issue which concerns the **general management of the water resource:** Mobilisation of water resource is great, but of same importance is to consider at the same time what to do with the waste water and which measures can control over-use and reduce spoiled water. M/s GAUFF should made some recommendations in this field or, at least, mention on-going or committed studies which will cover these aspects.

- Second, the project could have effects on water quality, at least in Malindi. At present, the chlorination of water is done at Baricho WTP. After 40 to 50 km in the pipe-line, the chlorination level is very low in the service tank. To day, this point is not actually prejudicial to health, because water is totally distributed within 24 hours. With augmentation of supply, the residence time in the tank should increase, with higher risks regarding water quality. M/s GAUFF should stress the point, propose mitigating measures (post chlorination facilities in Malindi) or make sure that the risk is fully assessed in other on-going studies.

vi) **River water quality** has been studied, but some issues involve few remarks and require may be some supporting information.

M/s GAUFF considers that **discharge of alum in the river** could be harmful to the environment, and proposes a monitoring of river quality but without assessing the actual level of the potential problem. What must be stressed is:-

- the daily average consumption of alum mentioned in the report is not useful for the understanding of the problem. Consumption can vary by as much as 2 t/day in dry season to more than 10 t/day in flood period. So, the dilution factor of alum in the river is perhaps maintained at a reasonable value all year long. To be checked.

- since early 1993, the Sabaki Water Works is experiencing the use of cationic polymers (Catfloc-T) to reduce the use of alum because of cost and irregular supply. Mixed with alum, the polymer can reduce alum requirement by almost half. (see also Report Gauff on "Optimisation of chemicals used in coagulation/flocculation, Sabaki WW case study" of May 1993)

- M/s GAUFF mentions that alum has an increased solubility in water when the pH is low, resulting in increased concentration and potential toxicity. Is it actually a potential hazard, considering that Sabaki water pH is alkaline (almost 8, see table 4.20)?

- No chemical analysis was made (or related data collected) during the study to check the present and natural level of Aluminium in the Sabaki and the purification (absorptive) capacity of the water system.

We think that all these elements tends to minimize the risk of detrimental impact linked to Alum discharge in the river as stressed in the draft report. A full monitoring of Al as proposed by M/s GAUFF is may be not justified. What should be a better proposal is a more specific investigation on Alum release: Sampling of water should be carried out, when sludge is released in the river, at the same time upstream the outfall (to check natural Al content), at the outfall site and at few sites downstream (i.e. 100 m, 200 m, 500 m, 1 km, 5 km).

It is strongly recommended, if possible, to include some results of Al content of Sabaki river water in the final report.

Pesticide residues have been identified by M/s GAUFF in the Sabaki river. On this basis, a river water monitoring programme has been proposed as the major component of the mitigation plan. The anticipated cost for the next two years of monitoring is estimated over US$ 400,000. This approach calls for two major remarks.

The first one concerns the reliability of the data. Table 4.22, which dispatch the results of the chemical analysis does not provide source of data, date of sampling, and in the main text, no information is provided on sampling and analytical procedures. Only one result is provided in the draft report, and anyone knows that results of micro pollutant analysis can be strongly affected by several parameters: sampling method, storage and preparation of sample, quality and calibration of the analytical equipment, measurement method,...

It doesn't look realistic to draw a conclusion on the pollution by pesticides of the Sabaki river and to elaborate such a costly monitoring programme on the basis of only one sample analyzed. It is recommended to improve the information by complementary analysis before concluding.

The second remark concerns the mitigation plan, limited to monitoring activity. No recommendation on the problem itself and how to deal with is provided in the draft report. M/s GAUFF should provide a rapid analysis of the problem, establish terms of references for specific studies to be undertaken in a further step and propose a water quality plan for the first years more conceived as an adapted survey (target is to identify problem and solutions, and to elaborate an action plan) rather than as a monitoring programme (target is to control the efficiency of any action plan at long term).

For example, it is doubtful that pesticides will be found in water all over the year. Pesticides are generally sprayed during dry periods, and if there is any pollution in the catchment, it is most probable that peak pollution in river (the most easy to detect) will occur with the first floods (the first rains have in general an important run-off and wash out pollutants on the dry soil surface). So, it is necessary to organize sampling in accordance with these observations, in order to increase efficiency of the sampling and to reduce costs.

Also, a better screening of pesticide marketing in Kenya, and pesticide use according to crop type, cropping pattern and land-use should help to identify quickly the most problematic areas in the watershed and thus to reduce the monitoring stations. Such aspects should be mentioned in the TOR for recommended studies.

An additional remark concerns the proposal made in the draft report to consider that monitoring of pesticides in the catchment area after 2 years will become part of the routine work of NWCPC (section 7.5 p.40). We think that this type of monitoring should be more considered under a national environmental programme (Ministry of Agriculture ?) than under a Corporation task. What should be the responsibility of the Corporation is the control of pesticides at treated water level during the periods identified as the most critical for these micro pollutants.

vi) In the monitoring plan elaborated by M/s GAUFF (Chapter 9, section 9.1), it is proposed an **hydrological monitoring** of the river at Baricho, with quite heavy installation like cable way. Water level is already recorded at the intake structure and other places several times a day. The presence of the weir just downstream the intake could provide a good basis for establishing a calibrated and quite stable section of the river. According to these 2 elements, couldn't it be possible to propose a study for the setting up of calibration curves rather than a monitoring? If feasible, gauge reading at intake (or any other suitable place) could provide directly the related river discharge. Also, which is the interest to have accurate data on flows over 20 to 25 m3/s (those for which the cable way or other heavy equipment is required) as it is known that in normal situation (i.e. water is not spread over wide flood plain), the recharge of alluvial aquifer is not actually higher than with medium flows. The scientific value of what is proposed by M/S GAUFF is not disputable, but we consider that it exceeds the direct interest of NWCPC, more limited to water availability and aquifer recharge. Such a monitoring should be proposed under the responsibility of another Government Agency (Min. of Water Resources, Min. of Agriculture, Dept Of Hydrology ?).

6. Detailed remarks on the draft report

P.1 Section 2.1.1. There are no effluent standards in Kenya. What about ambient standards ?

P.4 Section 2.3. This section should be better considered under the Impact analysis chapter.

P.13 Section 4.2. Support description of the river system with relevant figures. In last para, compare comparable figures: Tana catchment at Garissa, which area, which flow ?

P.14 Second para, river records up to 1992 (instead of 1972) ? Para 4: make a section to present climate.

P.15 Section 4.3.1 para 5: Penetration of sea water into the Sabaki estuary seems very limited. For which reasons ? Low tide amplitude ?

P.17 Transmissivity of aquifer is 8000 m2/day. In report on pumping tests (p11), transmissivity is about 7000 m2/day. Check figure. Elaborate on the meaning of this high value in terms of aquifer static level fluctuation, sensibility to pollution,...

P.18 Section 4.4 Title should be "Ecological conditions". Section 4.4.1 Develop

P.19 Para 5 and related table 4.24. Check unit for total pesticides in table: ug/l instead of mg/l Also, Canadian standards (in same table): more stringent (almost 5 to 10 times) for fisheries and aquatic life than for drinking water? doubtful. Check. It should be more suitable to compare with standards from tropical countries than those from Canada where rivers are frozen several months per year. UNEP should have this type of data. In last section, try to provide some inf. on pesticide regulation in Kenya.

P.20 Section 4.5.1 Develop. Section 4.5.2 and Section 4.5.3. To be developed in the impact analysis chapter.

P.23 When presenting agricultural sector, try to focus on facts and figures which will be used later in the study: Farm budget (for compensation purpose), irrigated area (for estimating water requirements)...

P.24 Section 4.6.3 Develop some aspects on river fisheries.

P.25 Section 4.6.4 Try to link data on mining to project: risk of excavation close to the pipe-line, risk of river pollution upstream the water intake... Last para, figures on labour are too old to be usable (1982, 1984) Possible to update?

P.27 Para 4: Intake modification will not affect the river system during operation, but which impacts during the construction works? Para 6: In term of impact on the downstream water resource, pumping in the aquifer should not be disconnected from getting water from the river, because the more water is pumped, the more river water will be mobilised to recharge the aquifer. Para 8: aspects related to alum release in the river already discussed (see section 5 of present evaluation report).

P.28 Para 1: Sewage from staff house; check number of oxidation ponds (8 or 10 ?); M/s GAUFF should also mention that the main sewer going to the ponds is badly broken in its upper part, the waste water being discharged in the open space and along the track to the closest village. Recommend immediate rehabilitation.

P.30 Section 5.2.2. Too old data on water demand per capita (1948-62!). Average figures are also of limited interest in those tourist areas which show generally huge consumption discrepancies between connected household, unconnected one and hotel bed.

P.33 Section 5.2.8. As already discussed, elaborate on river fisheries.

P.34 Section 5.5 and related Table 4.15 "Environmental impact cost-benefit matrix". The purpose of the matrix is not clear, as is its content. Explain order of impact: For example, increase of population is first order, when report stress that the project should not attract many peoples. Criterion seem redundant: population number, household, density obviously vary similarly, and if density increase, land per capita decrease. In section 5.5, it is mentioned that where values or quantities can be provided, these are included in the matrix. No figures are given in the matrix.

P.37 Last para and related figure 6.4. Already discussed in a general comment on water balance.

P.42 Chapter 8: Environmental management and training. We agree on the general role and functions of an Environmental Monitoring Unit within NWCPC as proposed by M/s GAUFF. Regarding water quality monitoring, which should focus at certain periods of the year on special aspects like pesticides, the proposed environmentalist should be able to carry out the sampling. Provide for a special professional training programme which covers this aspect.

P.45 Chapter 9: Monitoring Plan. Review in accordance with previous comments.

REPUBLIC OF KENYA

DRAFT

HARAMBEE

MAJI NI UHAI

National Water Conservation
& Pipeline Corporation

SECOND MOMBASA & COASTAL WATER SUPPLY

ENGINEERING AND REHABILITATION PROJECT

REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS

ENVIRONMENTAL IMPACT ASSESSMENT

ANNEXES

JBG Gauff Ingenieure
FRANKFURT AM MAIN., GERMANY
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BASELINE DATA

To fulfill the requirements of the Terms of Reference for this Environmental Impact Assessment, it has been necessary to compile a Data Base of Baseline Data that will serve as a benchmark for any future assessment in the impact area.

This is explicitly not to be included in the main report which is to "... be concise and limited to significant environmental issues." (World Bank Operational Directive OD 4.--Annex A1 of October 1989.)

It is therefore presented as five annexes.

In reading these annexes, it is important for the reader to distinguish between the project area, the study area, and the impact area. **The project area** should be taken to mean that part of the upper Sabaki - Athi river watershed that impacts upon the Sabaki Water Works; together with that part of the catchment that is in the vicinity and downstream, including the marine environment in the vicinity of the river mouth and bordering Kilifi District. Added to this is the North Mainland area that receives water or is influenced both directly by the Baricho- Nguu Tatu Pipeline and lies between the pipeline and the Indian Ocean. **The study area** includes that part of the Sabaki River catchment in the vicinity and downstream of the Sabaki Water Works, the marine environment in the vicinity of the river mouth and bordering Kilifi District to the south; and the North Mainland area between the Sabaki River and Mombasa Island. Essentially this is Kilifi District south of the Sabaki River. **The impact area** is but a part of the study area and involves that part of the Sabaki River catchment in the vicinity and downstream of the Sabaki Water Works; the immediate marine environment at the river mouth; and the strip of land that straddles the pipelines, set at a 3 km. wide strip on either side of the main and subsidiary pipelines. This is the estimated distance that people will normally travel during both rainy and dry seasons to utilise water supplied by the pipelines.

Annexe 1 deals with background information on the Policy, Legal and Administrative Framework, and has been prepared by Professor G-M Mutiso.

Annexe 2 deals with the Water Sector Environment in the project area and has been prepared by Mr J. Tomlinson.

Annexe 3 deals with the Biological Conditions within the study area and its environs, and has been prepared by Dr. F. Muthuri.

Annexe 4 sets the scene on the social infrastructure within the study area, and in particular deals with the problems being faced by the local people in the modem world. It has been prepared by Professor G-M Mutiso, and Mr P. V. Byme.

Annexe 5 is concerned with the current economic situation in the study area with some background on the situation pertaining prior to the commencement of the first Mombasa and Coastal Water supply Project in the late 1970's. Its author is Mr. P. V. Byme.

ANNEXE 1

POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

1.1. The Water Sector Environment

This project is in the general water sector environment. This has been dominated by issues of the history of the water sector in Kenya, water engineering professional standards and management problems, policy making constraints, and since the late 1970's, the primacy of donor projects in the sector.

1.2 Water Sector History

Generally speaking, all the projects related to the Coast Water Supply originate in the colonial period where the main objective was to supply the port of Mombasa and not necessarily the population of the region. Mombasa was not seen as a major industrial city and tourism had not become as important as it is today. Little concern was expressed for serving the rural populations.

The last ten years of colonial rule saw the water sector begin to claim its separate identity from agriculture. Water Affairs were under the Ministry (formerly Department) of Agriculture. Within this ministry, some water specialists, who were to dominate thinking of the sector into the seventies, were of the opinion that the most important developments for the country would be in building small schemes at low levels of technology. Therefore there was little effort put into the training of engineering and management professionals in the water sector. The few indigeneous engineers who graduated in the sixties were posted to the Water Department where, according to them, they were given little responsibility in design, hydrology or construction supervision. The department was dominated by colonial expatriates at the design, supervision, hydrology and administrative levels.

At the beginning of the 1970's, it became politically impossible to continue without locals in the highest administration levels. The Ministry of Agriculture still dominated the major water policy issues of the day. Offices continued to be dominated by expatriates, with basic thinking for the sector set by British consultant engineering firms.

By the mid seventies the picture was beginning to change rapidly. New donors, particularly the Scandinavians and Germans, were entering the rural and urban water sectors unexpectedly and the political situation required Africanisation of the next level of engineering administrators with engineers with little field and design experience. New short term expatriates, mostly from Western Europe, had taken over from the British expatriates and new European and North American consultants had entered the field.

Towards the end of the seventies and during the decade of the eighties, there was major expansion in the design and construction of water projects pushed essentially by donors, for this sector could absorb a lot of funds. The Water Ministry was established as a separate entity. Nationally, the projects were supported by politicians for the emerging urban conglomerates were demanding services. The rural population, in turn, was pushing for self help water projects to cut down the time invested in looking for water. The sector saw an increase in the number of local engineers entering the profession. Since construction was booming, one found an increasing number of the local engineers, with limited experience, in charge of major projects without design and supervision experience. The ministry's top administrators gave them these responsibilities mainly as a counter weight to the expatriate design teams who they saw as impeding their promotions. There emerged many marauder construction firms, frequently with monopoly access to their country donor funds. Others had linkages to the higher Kenyan political levels, which protected their self interest.

In this heady setting, design and supervision standards fell. Some key decisions were made on projects based on bypassing the major design office of the ministry, which was still expatriate dominated, because the lower levels of the ministry and the highest administrative levels, both manned by local engineers, had political reasons for doing so. After all, it had not tolerated them well.

By the close of the eighties, donors and the government were extremely unhappy about the construction cost overruns, lack of provisions for maintenance, mismanagement and misuse of funds and the lack of coherent approach to the sector. Indeed, many donors ceased to fund the sector.

1.3. Professional Standards

The issue of standards is tied to local engineering numbers, and their entry into the field. Less than ten local water engineers went into the ministry in the sixties. They rose up under Africanisation to man the administrative posts, which are the apex, without much experience. Those who followed them were again very few, less than twenty. They were promoted into administrative responsibilities again without much time for developing their professional skills. Even more serious is the fact that they ended up in managerial levels without any significant management training.

Currently, it can be argued that in terms of numbers there are enough engineers for the sector in country. However, they are not in the ministry or its agencies. Many of the brightest and most aggressive have left the ministry and are found in private consulting, on donor projects, in municipal government and in the private sector in general. A lot of them look askance at the power fights in the sector, where different public institutions vie for supremacy, not in terms of legal frameworks, but in terms of political access, which has led to fragmentation of policy and staffing and nepotism. In this atmosphere, some of the major sector activities, like the First National Water Master Plan and the Second National Water Master Plan or national water resources assessment are left to donor projects.

Those entering the field now concentrate on getting some marketable skills so that they can exit the public institutions. Fortunately, there are bright engineers graduating into the sector. It is to be hoped that with the retirement of the first generation, and over the next few years, the second generation of local engineers from the sector, alternative leadership and professionalism will spread in the sector for the numbers now are big enough for the profession to begin policing itself.

1.4. Policy Constraints

The brief placing of water development matters in one ministry, in the late seventies, is currently over. In the eighties, water policy matters were scattered between the Water Ministry, Ministry of Agriculture, Ministry of Local Government and by the eighties into the Ministry of Reclamation and Development of Arid and Semi Arid Lands and Wastelands, which systematically argued that it was responsible for all water affairs in 84% of the country's land mass. In 1993, the independent Water Ministry, handling only water affairs is no more. It has responsibilities for other concerns, among them development of the arid areas, and supervision of regional authorities. It also has a National Water Conservation and Pipeline Corporation whose powers are similar to it. There are many regional authorities which claim some supremacy over water in their regions. Municipalities and their parent ministry also claim some water responsibilities.

On major technical matters, specifically who has national responsibility for water supply construction and distribution and for sewerage is unclear and there are competing claims by different public institutions. In the long term these need resolution.

These conflicting policies and approaches to developing the water sector are symptomatic of other structural and political problems of the nation but they are relevant in evaluating how some actions for this particular project seem not to get the policy support they deserve. Decisions were made on the original Sabaki system within this confused policy arena as discussed elsewhere.

1.5. Donor Influence in the Sector

Those donors, who have been interested in funding in the sector, have got a preponderant influence in some sub-sectors because the sector is so fragmented at policy, administration and professional standards level. They have created niches for themselves. For example, one donor dominates water resource assessment and small scale irrigation and another dominates urban water supply for small towns. The World Bank, on its part, has been identified with the large pipeline supplies to the large urban centres. This donor programming specialisation continues the fragmentation of the sector for each donor takes a part of the normal ministerial operation and locks significant numbers of staff into projects. It is difficult for whoever is in charge of the sector to coordinate and set up long term national integrated policy. This fragmentation leads to projects being evaluated on a very narrow basis without any long term structure plan for water supply to regions not to speak of national environmental concerns about planning and sustaining the water resource. Consequently one can end up with programmes which do not fit the national water resources base.

1.6. Public Health and Safety

Most public health and safety issues are regulated by the Public Health Act. There are related Acts like Malaria Prevention, Poisonous Drugs, Mental Health, Chiefs Authority etc. The main agency responsible for enforcing this is the Ministry of Health. Worker safety is regulated under the Factories Act. Oversight responsibilities are with the Ministry of Labour.

Conceptually, there should be one law or a set of legal provisions which are found in different laws to set standards for pesticide and other forms of pollution. This is not the case currently for the water quality standards in the country are adaptations of the WHO standards and are not even incorporated into the Water Act. Regulation of pollution control is therefore scattered between the Water, Agriculture, Plant Protection, Fertilisers, Pest Control Products, Malaria Control, Public Health, Factories and Poisonous Drugs Acts.

After a study of the specific areas where the pesticide pollution which was detected in Sabaki River water originates, the NWCPC will have to determine which of the agencies, responsible for enforcing the various acts, will be called upon to put into place control measures. It will be useful if NWCPC, can initiate discussions with all parties concerned to agree on which standards to use and get them enacted into law immediately. Conceivably such standards could be included in the NWCPC Act so as to facilitate its enforcing them since in the final analysis, it is the premier water undertaker on the Athi-Sabaki Catchment at present.

For the waterworks assessment, the main issue is public health which is driven by the availability of water and its misuse. Where the piped water has been made available to communities and it is being used irregularly, eg water being taken from flooding air valve chambers, or where waste water is allowed to pond and breed mosquitoes or snails, or where contamination is introduced because of faulty maintenance, there is need to invoke the Public Health and the Chiefs Authority Acts to compel communities to obey the law on public health. Although the rehabilitation and augmentation proposals have sought to address some of the issues, clearly more will have to be done by the local public health officials and chiefs to ensure that water misuse does not lead to increase of waterborne diseases.

On its part, the Pipeline Corporation will have to put into place better maintenance for it is its negligent maintenance which is leading to water collecting in places at times and thus leading to threats on public health. Similarly, consumers in Mombasa and elsewhere have complained about polluted or contaminated water out of the pipeline. The existing water throughput control, purifications and pipeline maintenance systems are such that it is plausible that on occasions, untreated or contaminated water gets through the system. It is also plausible that the unsystematically controlled treatment chemicals introduce their own contamination as some consumers complain. The rehabilitation and augmentation designs intend to deal with controls and maintenance. It will be necessary for the Public Health officials of the Ministry of Health to monitor the water.

In the waterworks proper, there is need for public health officials to enforce the Factories Act properly for the workers handling chemicals are put at risk by the inappropriate building and equipment design. Although some of the issues of design are taken into account in the redesigns, regular inspection by the factory inspectors and public health officials should be mandatory and part of the monitoring scheme. This will be normal work for district based staff and has no budgetary implications.

ANNEX 2
ATHI- SABAKI RIVER ENVIRONMENT

2 The Athi/Sabaki Watershed

2.1 Catchment Description

There are two major rivers, the Tana river and the Athi river, draining in a south-easterly direction from the central highlands of Kenya into the Indian Ocean. Of these two, the Tana which lies to the north of the Athi, is the larger river in both catchment area and runoff. The Athi river, however, includes Nairobi and its surroundings in its upper catchment.

The Athi river rises over 500 km. from the ocean on the southern slopes of the Nyandarua range (Aberdares), where average annual rainfalls are about 1200 mm. These headwaters represent only a few percent of the catchment, most of which lies in the semi-arid plateau foreland of Kenya that separates the highlands from the coastal belt. In this dry part of the country, annual rainfalls are from 400 to 800 mm.

The total catchment area of the river, from headwaters to the Indian Ocean, near Malindi, is 38,000 sq. km. There are 35,000 sq. km. above Baricho which is about 65 river kms. from the coast. Baricho is the village on the north bank near the intake site from which the river intake derives its name, although the water works themselves are located adjacent to the village of Lango Baya.

The river above its confluence with the Tsavo river is known as the Athi River. Just below the confluence, that is from Lugard's Falls to the ocean, the river is known as the Sabaki River, the upper parts of which are also called the Galana River.

The whole of Kenya has been hydrologically divided into separate drainage areas which have been numbered from 1 to 5. The Athi/Sabaki river is the major river in drainage area No. 3, which is divided from its headwaters to its outflow to the ocean into basins and sub-basins designated by letters of the alphabet as shown in Fig. 2.1: DRAINAGE BOUNDARIES.

The Tsavo river is partly fed from the Mzima Springs, which derives flow from a very substantial aquifer under and to the south east of the geologically recent volcanic Chyulu Hills. The Mzima Springs outflow is rather constant from season to season but varies slowly when there are periods of high or low rainfalls sustained over several years (British Geol. Survey et al., February 1988).

The surface flow of the Athi River, above the Tsavo confluence, sometimes ceases for short periods during spells of dry weather sustained over one or more seasons. During such periods the Sabaki river flows are derived from Mzima Springs outflows. There are substantial channel losses along the Tsavo and Sabaki rivers (Mansell-Moullin M., November 1973; Gauff, September 1989). However, the Sabaki River outflow to the ocean has not been observed to dry up in living memory (Mansell-Moullin M., November 1973).

From the headwaters to the ocean the river brings down large quantities of silt and sand during periods of heavy rainfall and high flow. Erosive action is principally in areas where the density of surface drainage is greatest. These are:

1. The upper Athi basins, 3B and 3C, which consist of steep sided narrow valleys in deep red coffee soils that erode easily when the vegetative cover is disturbed or removed by cultivation.

2. Basin 3A includes the Athi-Kapiti plains where erosion is a naturally occurring process, accelerated by grazing animals that both remove vegetative cover and reduce infiltration of rainfall by trampling (Dunne T., 1977).

3. Machakos and the surrounding heavily populated rural area, basin 3E, lose a lot of soil by erosion although soil conservation measures have been much promoted.

4. The Chyulu and other volcanic hills in the middle catchment comprise large areas where the surface drainage network is either poorly developed or absent. In these areas most rainfall infiltrates directly downwards (British Geol. Survey et al., February 1988) and there is little or no surface runoff to transport erosion products.

5. The National Parks of Tsavo West and East, basins 3G and the upper parts of 3H, are periodically denuded of protective vegetative cover after sustained dry periods. If these periods are followed by heavy rainfall there is severe erosion and the associated flood waters are effective in transporting huge loads of sediment downstream to the ocean.

The annual sediment transport for the Sabaki river has been estimated (Tippetts Abbett McCarthy Stratton, 1980) at just under 10 million tonnes, equivalent to 400 tonnes per sq. km. or about 0.3 mm. depth of soil when averaged over 25,000 sq. km, which is the proportion of the total area in which erosion processes may be significant. This can be compared with erosion processes in the Tana catchment.

In Kitui and in Embu, cropped land sheet erosion studies (Daines S.H. et al., April 1978) indicated annual rates of over 20,000 tons per sq. km. Over 4,590 sq. km. of cropped land, it was estimated that there was an average soil loss of 4,600 tons per sq. km. per year. The Tana river at Garissa is estimated to carry over 35 million tons of sediment per year (Tippetts Abbett McCarthy Stratton, 1980). These estimates, when compared with the estimates for the Athi river, indicate that the difficulties with erosion in the catchments, and sediment transport in the Athi/Sabaki river, are in line with difficulties experienced in other parts of the country. Accelerated erosion is a country-wide concern. The very considerable nuisance caused by waterborne erosion products in the ocean at Malindi and at the Sabaki water works near Baricho is not considered a sufficient reason for treating the Athi catchment as a special case.

Annual streamflow changes in Kenya were apparent from multiple correlation study of gauged streamflow against year serial number, basin precipitation, antecedent gauged flow (Tippetts Abbett McCarthy Stratton, 1980). The period of record spanned in this study was 1935 to 1972. Seven river gauging stations (RGS) were selected as having sufficient reliable data for analysis, unfortunately this did not include any stations in the Athi/Sabaki catchment, but one or more in each of the other four main drainage areas.

The results suggested strongly that there is a trend to higher annual runoff as the years go by. For the Tana river at Garissa, for the period 1935 to 1970, the trend amounted to a net annual increase in runoff of 4 mm. per year, equivalent to an 84 percent addition to the 1935-70 mean flow by the year 1985. This increase in flow was occurring while water diversions were increasing and is attributed mainly to massive changes in vegetation, such as replacement of indigenous forest by other trees or crops. This change in vegetation has resulted in a reduction of actual evapotranspiration. There was evidence that the dry weather flows had also increased, and this is attributed to increased ground water recharge because the replacement vegetation is shallow rooted compared with the original vegetation.

These results run contrary to the widely accepted assumption that forests are essential to sustain dry season river flows. The river flow data series for the Athi river were not considered sufficient to be included in the study, which was conducted in stage 1 of the Kenya National Master Water Plan. Master Water Plan Stage 2 results, which may include an updating of trend analysis, have not yet become available. In default of any recent nationwide review of trends in streamflow, and for the purposes of this report, it can be assumed tentatively that a similar positive trend would be found in Athi river flows, if sufficient data were available.

Another positive trend in Athi river catchment runoff is as the result of increasing volumes of effluent from Nairobi, all of which must find its way into the Athi river. This can be expected to continue to increase. The Nairobi water supply is at present and for the immediate future obtained largely from the Tana river catchment, which in the form of effluent discharge amounts to a net transfer from the Tana to the Athi river systems. This trend will cease when and if the proposed Munyu dam project on the Athi river is implemented. Additional water for Nairobi will then come from the Athi. Nairobi effluent will continue to be discharged into the Athi. The result would be a reversal; and a weak negative trend in the Athi flows, in respect of Nairobi water use, could result.

2.2 Climate

The climate is tropical over the watershed but varies from the coast to the headwaters. Conditions at the coast are humid with a very weakly bimodal rainfall distribution. The rest of the catchment varies from sub-arid/arid in the plateau foreland to sub-humid in the upper part of the catchment with a strongly bimodal rainfall distribution in all parts. The rainy seasons are associated with the north and south movements of the intertropical convergence zone.

The distribution of rainfall over the catchment is indicated by isohyetal mapping as shown in Fig. 2.2: MEAN ANNUAL RAINFALL. The seasonal distribution is shown by selected hyetograms located on a map of the southern part of Kenya in Fig. 2.3: DISTRIBUTION OF MONTHLY RAINFALLS.

The other important water-related climate parameter is evaporation. Isopleths of annual potential evaporation rates are mapped for the southern part of Kenya and are shown in Fig. 2.4: MEAN ANNUAL POTENTIAL EVAPORATION. These indicate annual evaporative water loss expected from an open water surface.

A monthly comparison of rainfall and evaporative demand gives an indication of climate in terms of whether there is sufficient moisture available in that month to sustain vegetative growth. For this purpose, a humid month is defined as a month in which rainfall is greater than 44 percent of the potential evaporation. The distribution of humid months is shown for the southern part of Kenya in Fig. 2.5: DISTRIBUTION OF HUMID MONTHS.

Earlier studies in climate trends (Tippetts Abbett McCarthy Stratton, 1980) found no trend in annual rainfalls for 61 long term rainfall stations in Kenya. Recent investigations (Ogallo L.J., 1992) confirm that rainfall in Kenya shows no systematic trend to date. The evidence of some change in climate can be found in the retreat of the glaciers on Mount Kenya.

2.3 River Flows

River flows in the Athi/Sabaki river have been estimated from records obtained at river gauging stations (RGS). The earliest records are from 1949. Since then new stations have been opened, and some closed and abandoned. In the first comprehensive study of the Sabaki river in 1973 (Mansell-Moullin M., November 1973), 41 RGS are listed. However, most of these were sited in unstable reaches of the river and insufficient flow measurements by current meter had been made to make much use of these records. Several subsequent reports are available (Tippetts Abbett McCarthy Stratton, 1980; and Ertuna G., 1979; Gauff, September 1989), mainly working over the same data series.

There is a recent report that is intended primarily as an assessment of the low flow regime at the Baricho intake site on the Sabaki river (Gauff, 1990). After careful inspection of available data, only records from four stations were used. These are:

1. RGS 3DA2 at Munyu	1956 to 1989
2. RGS 3F2 at Thwake	1965 to 1989
3. RGS 3F5/3F9 at Bushwackers	1980 to 1989
4. RGS 3G3 at Mzima Springs	1956 to 1986

The Mzima Springs record is continuous. The other stations are intermittent. However, it proved possible, by noting the characteristics of the flow during periods of concurrent records at two or more gauges, to piece together a near continuous estimate of monthly river flows at Baricho for the period 1956 to 1989. This very useful result is further considered in the following paragraphs.

For hydrology, river records are basic data for catchment studies. For the engineer, they are useful for planning water resource development and as a basis for the design of hydraulic structures. Monthly flow records provide a sufficient basis for estimating yields and for sizing major components of a water development, such as intakes, reservoirs, conveyance channels and associated works. Dam spillways usually need records with shorter time steps than a month.

Further analysis of the historical record to reconstruct a sequence with shorter time steps than a calendar month is probably not justified since the assumption made in design is that the future flows will be similar to the recent past. This assumption creates an uncertainty in the validity of the design that cannot be overcome by greater precision in defining the past, only by allowing some margin in the adopted design to allow for the future. Consequently, the monthly flow record for 1956 to 1989, (Gauff, 1990) for Baricho, can be considered to be the best use that can be made of the historical river records in respect of Sabaki river water resource development. For present purposes, these records are presented as monthly flow duration curves and are shown in Fig. 2.6: FLOW DURATION CURVE. Two curves are shown. One is for the flow expected at Baricho allowing for present Mzima pipeline abstraction from Mzima Springs, which, in fact, only commenced in 1957. The other is for 'natural' river flows, such as would be expected without abstraction at Mzima Springs.

Flood flows have not been well recorded. The largest floods within the period of record were in 1951 and 1961 (Mansell-Moullin M., November 1973). The peak discharge for a 100-year return period is estimated at 7,500 cu. m/sec. Flood waters at Baricho in 1968 were reported to be over 9 m. deep (Scott Wilson Kirkpatrick & Partners, July 1972). An interesting, and so far unexplained, feature of the flow regime of the Athi/Sabaki river is that no overbank flooding has occurred in the Baricho valley during the last decade (Gauff, September 1989), although Tana river floods have overtopped river banks in their habitual fashion during that period.

The recent construction of a road embankment out across the south bank flood plain just upstream of the Baricho intake for the purpose of constructing a bridge across the Sabaki river severely restricts the flood plain at this location. During future major floods, this will cause the river to back up and increased flooding will occur on both south and north bank flood plains upstream. Flood levels at the intake site itself will be unaffected or even slightly reduced as a result.

2.4 Catchment Water Balance

For the whole of the catchment above Baricho, the rainfall can be reckoned at 600 mm. in an average year, and the mean annual runoff at 40 mm. (Tippetts Abbett McCarthy Stratton, 1980). The difference of 560 mm. is accounted for largely by actual evapotranspiration.

For the Athi/Sabaki basins, as depicted diagrammatically in Fig. 2.7: DRAINAGE PATTERN, the average annual basin water balance (Tippetts Abbett McCarthy Stratton, 1980) can be summarized as follows:

Basin	Principal river	Catchment area (sq. km.)	Rainfall (mm.)	Runoff (mm.)
3A	Mbagathi	3,333	701	61
3B	Nairobi	1,920	1,120	212
3C	Ndaragua	361	1,253	357
3D	Athi	1,614	720	55
3E	Thwake	2,935	842	72
3F	Athi	14,382	513	19
3G	Tsavo	6,214	441	45
3H	Sabaki	7,150	560	33

These tabulated results were obtained (Tippetts Abbett McCarthy Stratton, 1980) with a rainfall/runoff model using daily rainfalls recorded at sites where records extended over a long period. The model results were verified by comparison with river gauge records for much shorter periods. The results obtained are shown graphically by mapping isopleths of mean annual runoff in Fig. 2.8: MEAN ANNUAL RUNOFF, and of the difference between rainfall and runoff in Fig. 2.9: RAINFALL MINUS RUNOFF.

2.5 The Sabaki River

2.5.1 Geology and Hydrogeology

A thick wedge of Mesozoic sediments covers bedrock at and near the coast. The bedrock is dislocated along several north-south trending faults. This coastal section of Kenya has been alternately elevated and depressed above and below sea level over a period of perhaps the last 250 million years. The great depth of sedimentary rocks, which dip gently east seawards, are therefore of both marine and continental origin.

In general terms, seismic data for Kenya is considered insufficient for a good definition of risk. The seismic risk for the coastal area is, however, reckoned to be slight, and normal engineering practice in design considered appropriate (private communication, S.J.Gaciri, Department of Geology, University of Nairobi). In this connection the following points should be noted:

1. There was an earthquake felt in the Mombasa area on 13 March 1990 with epicentre at about 4 S, 40 E, 18 km. below the oceanic crust. The magnitude was slightly above 5.2 on the Richter scale (Gaciri S.J. and Macharia H.T., May 1990). The event was succeeded by some aftershocks and faint tremors until the end of March.

2. The March 1990 earthquake caused no damage to the Sabaki water works or transmission pipelines. It is believed to have cracked a thrust block on the water supply pipe that crosses the new Nyali bridge, which eventually caused a flexible bellows type pipe coupling to fail.

3. Geologically very recent volcanic activity in the region of the Chyulu hills is of interest in connection with long term sustainability of Mzima springs outflows. Risk of interruption of the flow regime by renewed volcanic activity is perceived as slight (British Geol. Survey et al., February 1988).

Sea level fluctuations in Pleistocene times and their possible hydrogeological implications for Kenya have been the subject of considerable speculation and some investigation since the turn of the century. The existence of palaeochannels associated with Kenya's coastal rivers was the subject of a review by the hydrogeologist working on the preparation of Kenya's first stage National Master Water Plan (Logan J., April 1978). He recommended geophysical investigations to define the groundwater development potential.

Investigations of the Sabaki river were commenced in 1988 (Gauff 1989) in connection with abstracting groundwater from the sediment filled palaeochannel near Baricho. The following are details of the investigations:

1. In 1988 there were seismic investigations (Halse J.E.P., 1988).

2. An exploratory borehole on the north bank was tested in 1989.

3. By mid-1990 exploratory drilling at three sites upstream of the intake on the south bank was completed. The two sites that gave good results were developed in 1992 into the two existing production wells.

4. In 1991 the geology of the Lango Baya fault and surroundings were mapped (Halse J.E.P., August 1992).

5. In September 1992 a river survey was carried out (Halse J.E.P. and Hutchinson P.J., November 1992) from Lugard's Falls to the Lango Baya Fault near the Baricho intake.

6. The second set of seismic investigations started on the north bank upstream of the intake in November 1992 and moved downstream to the south bank in early 1993. Currently (June 1993) the 5th exploratory borehole of the current investigations is being completed.

7. An extension eastwards, downstream of the intake, of the geological mapping was completed in 1993, to cover a further 5 sq. km. of potential wellfield (Hutchinson P.J., March 1993).

8. Currently (June 1993) geophysical investigations and exploratory drilling are continuing in order to locate the sites for three production wells on the south bank downstream of the intake.

The course of the Sabaki river (Halse J.E.P. and Hutchinson P.J., November 1992) runs through the Basement system from Lugard's Falls to about 2 km. upstream of the Galana Causeway. Downstream of this point the river traverses Permo-Triassic sediments, mainly shales and sandstones, as far as the Lango Baya fault, downstream of which the later Jurassic marine limestones are encountered. Upstream from the Galana Causeway the river regime is erosional, downstream depositional.

The erosional river regime is characterised by regular rock bars, a relatively steep gradient and little sedimentary deposition other than in the channel and on the sandy river terraces on the banks. It is the resistant nature of the Basement rocks that gives the river its steep gradient.

The Galana Causeway is a rock bar, downstream of which no more rock bars are to be found, although bedrock may be found sometimes on one side of the channel or sometimes the other, but never on both simultaneously, until in the vicinity of the Lango Baya fault, where the channel has found a way through a sandstone/siltstone/mudstone barrier. Three and a half kilometres downstream of this barrier, the river course passes through and out of a sandstone sided valley and begins to meander across an extensive flood plain.

Because the ocean level was some 40 to 60 m. lower at an earlier time, the river channel was incised below its present level from downstream of the Galana Causeway to the ocean. When sea levels rose to the present levels then the deeper palaeochannel was infilled with erosional products brought down by the river. Where these depositional materials are sufficiently coarse, high potential aquifers are to be found.

The site for the surface water intake, near Baricho, was selected principally for the favourable topography just downstream of the Lango Baya fault. The river section here is relatively stable where it is confined by the sides of the valley that the juvenile river cut through the sandstone/siltstone/mudstone barrier. It is precisely this relatively steep section of the palaeochannel, where flow velocities would have been high, that is the location where the deposited alluvial material is coarse with the finer sediments washed out. There may be a number of other favourable upstream sites for wellfields along the Sabaki, where the transmissivity of the aquifers is high. However, it may turn out that Baricho, selected for other reasons as a water supply intake site, is also the location of the best aquifer in Kenya.

Generally the character of the Sabaki river channel changes little as it approaches the ocean. The river is typically about 80 m. wide, and shallow. For flows below 20 cu. m/s, that is for about half the time, the water is about 0.2 m. deep for most of the width, with usually a single deeper channel of 0.5 m. or more that is only a few metres in width.

A survey was conducted with the assistance of J. Abuodha of Moi University, as part of the present study, of the Sabaki river from its mouth near Malindi for 8 km. upstream to the ferry at Kwa Alenya (Abuodha J. and Tomlinson J.J., June 1993). Four cross-sections were taken and stream velocities observed. The sand bar at the river mouth was inspected. The tidal effect at the Sabaki bridge was measured. The conclusion is that the tidal wedge, or volume of sea water entering the river at high tide, is either absent or very small, therefore the Sabaki cannot be said hydraulically to have an estuary. There is a small deltaic deposit of sand usually to be found at the bar. Salt water is occasionally detected at low flow during high tide at the Sabaki bridge. This can be assumed to occur when the river flows are of the order of 3 cu. m/sec or less. This would be expected for about two months in the year, on average. A condition of zero discharge in the Sabaki river would allow sea water to enter about 1 km. upstream of the bridge at high tide.

Currently, (June 1993) a research project is being undertaken by J. Abuodha of Moi University on the development of beach and dunes from Malindi to Mambrui. In his unpublished work the aggradation of the beaches at the Sabaki river mouth is illustrated by a comparison of several aerial photographs of different dates. A simplified mapping on the same lines has been prepared for this report and is shown in Fig. 7 (main report): BEACH AGGRADATION, 1969 TO 1989.

The southern beach was eroding somewhat at some time between 1954 and 1969 (Abuodha, J. private communication, evidence supported by an inspection of erosion features, just below the terraces of the Eden Roc Hotel), but has been aggrading rapidly since the late 1960s. The northern beach was slowly aggrading prior to 1969, and has aggraded rapidly since then. Any satisfactory explanation of the processes forming beach and dunes and the apparent changes over the last four decades is likely to be quite complex.

2.5.2 Water Balance at Baricho

Baricho and its surrounding area receive water inputs from:

a. the Sabaki river flows (inflows from upstream, surface and sub-surface); and
b. and from rainfall.

Water outputs from the same area are from:

a. onwards Sabaki river flows (outflows, surface and sub-surface);
b. water pumped to Mombasa and the north coast down the pipelines;
c. water lost by evaporative processes from vegetation and any open water surfaces;
d. local runoff into the river, including treated effluent;
e. and water percolating downwards to provide local groundwater recharge.

The mean annual flow of the Sabaki river at Baricho is 39 cu. m/sec, equivalent to 1,230 million cubic metres per year, of which 12.5 million cubic metres are currently pumped from the Baricho water works into pipelines. By contrast, the local rainfall amounts to 800 mm. annually, equivalent to 80 million cubic metres per year over, say, a local area surrounding Baricho extending over 100 sq. km.

The local water budget has been estimated, as part of the present study, by comparing Baricho measured rainfalls for the period 1968 to 1973 with estimated average monthly rates of evapotranspiration, using daily time steps. The results, for nine different values for the maximum moisture holding capacity of the soil, are presented graphically in Fig. 2.10: WATER BALANCE, BARICHO AREA. It can be seen that the average annual water surplus, that is rainfall that is not lost by evaporation, diminishes as the moisture holding capacity of the soil increases. Such increases can be expected in areas covered by forest or dense vegetation.

An upper limit for annual recharge to groundwater for the area surrounding Baricho, excluding the Sabaki river palaeochannel, is estimated, as shown in Fig. 2.10, as the excess of surplus water over mean annual runoff. The value for the mean annual runoff is derived for the Baricho area from the map showing the distribution of mean annual runoff as shown in Fig 2.8. These results indicate that for soil moisture storage capacities above 100 mm., recharge to groundwater, is absent or negligible. Useful recharge may be expected where soil moisture storage capacities are below 75 mm., that is zones where vegetation is light and shallow rooted and the soils are sufficiently permeable to allow excess water to percolate downwards. Under forest or dense bush in the Baricho area, recharge is likely to be negligible. In comparison with other parts of Kenya, the recharge potential in this area has been classified as relatively fair. This is shown in Fig. 2.9.

For the palaeochannel aquifer, the water balance for the Sabaki river flows indicates that the annual average recharge is of the order of a hundred times greater than the likely amounts of groundwater abstraction from a pumped wellfield. The current state of knowledge indicates that horizontal subsurface flows in the palaeochannels are very small compared with surface flows, so long as there is flow in the surface channel. If surface flow ceases, then the subsurface groundwater movements become of significance.

2.5.3 Groundwater Abstraction at Chakama-Baricho

The present state of knowledge regarding groundwater development at Baricho has been summarized in recent communications from the hydrogeologists who are undertaking the current investigations (Van Dongen P., May 1993, and Gauff, March 1993) as follows:

1. The two production boreholes on the south bank upstream of the Baricho intake have been successfully test pumped at 1000 cu. m/hr.

2. The quality of the pumped water is good. Initially the water smelt of H_2S, but not after several days pumping.

3. The transmissivity of the aquifer is in the range of 8,000 m2/day, which is an exceptionally high value for Kenya.

4. There appears to be a direct hydraulic connection between the surface flow in the river and the aquifer.

5. A very large quantity of water can be pumped without significantly lowering the water table. The pumped water was free of fine suspended particles.

Currently, (June 1993), investigations continue in order to better define:

1. aquifer dimensions;
2. permeability and storage capacity;
3. recharge mechanism;
4. groundwater flow pattern;
5. water quality distribution pattern.

A successful outcome of these investigations would render it possible to set up a groundwater management computer model to evaluate the various possibilities and constraints for groundwater development of the palaeochannel.

It can be estimated that the present wellfield will pump from an aquifer with a storage of several tens of millions of cubic metres of groundwater, say, 20 million cubic metres. It can be further assumed that this aquifer is in good hydraulic connection with the surface water flows in the Sabaki river. It is expected that more locations along the river will be identified where similar wellfields can be established. What cannot be assumed is that the process that yields clean water from the muddy Sabaki flows can be exploited without constraint in perpetuity.

The present investigations, together with experience gained from the operation, expected later in 1993, of the two existing production wells to supply water to Malindi, will provide the information needed to develop a management plan. Careful monitoring of various aspects of the development of groundwater are needed to assist in decision making. In particular, surface water flows in the Sabaki should be measured in a regular and reliable manner.

Two ground water development options are considered for the purposes of the present study. These are:

1. A pumped storage scheme, where water is pumped from groundwater to an off-river natural reservoir site near Chakama. Pumping constraints assumed are that there is no pumping when Sabaki river flows are very muddy, above 100 cu. m/sec, or very low, that is below 2 cu. m/sec. Water from the reservoir would gravitate to the present intake site from where it would be pumped to the existing treatment works for onward pumping to transmission pipelines.

2. A scheme where the aquifer is pumped continuously, and therefore depleted during those periods when the Sabaki flows are less than the rate of abstraction. During such periods the river flows would be expected to dry up in the vicinity of the wellfield. Flow would be restored downstream to an agreed compensation level by introducing pumped groundwater into the downstream river channel.

These options are described in more detail below. Both of them mitigate one of the significant negative environmental impacts of the rehabilitation and augmentation of the Baricho water works, namely, the reduction in downstream Sabaki dry season flows when more water is diverted from the river at Baricho.

Where groundwater is used for village supplies from shallow wells in the area surrounding Baricho or downstream near the river, the current state of knowledge indicates that groundwater development of the palaeochannel will have no effect outside of the immediate vicinity of the palaeochannel. This is because the transmissivity of locally occurring aquifers is so much lower than that of the palaeochannel that any changes in water levels in one will not affect the other. Expected changes in water levels away from the river channel are not expected to occur as a result of changes in the Sabaki river flows. Recharge to locally exploited groundwater resources is from rainfall, as described in 2.3.2 above.

2.6 Storage Schemes

The suggestion that off-channel storage should be considered for the augmentation of the coastal water supplies from the Sabaki river during periods of dry weather flow was made during the earliest investigations (Mansell-Moullin M., November 1973).

2.6.1 The Off-channel Reservoir Site near Chakama

The Consultant (Gauff, September 1989) identified a very promising off-channel storage site near Chakama as shown in Fig 8 (main report):OFF- RIVER STORAGE NEAR CHAKAMA. Two alternatives were originally proposed for using the Chakama reservoir site for water abstraction schemes so that there would be no water diverted from the river at low flow:

- By gravity flow from a new surface water intake on the Sabaki river upstream of Chakama, with onward gravity flow to the Baricho intake.

- A pumped storage scheme with water pumped up from Baricho during periods of moderate river flow to augment the dry weather supply when river flow was insufficient.

In the light of the recent success of the ground water pumping tests at Baricho, with yields from each borehole of about 1000 cu m/hr, a pumped storage scheme from groundwater is a third alternative. This third alternative, which is chosen for consideration for the purposes of this report, has the advantage that the requirement for treatment of the water would be minimal, and no dead storage is required in the reservoir for sediment deposition.

Any of the three alternatives would give a yield that can be estimated by a simulation of reservoir operation. Although the present study only considers pumped storage from groundwater, the computer simulation of reservoir operation is set up so that it could conveniently estimate performance for the other options.

The data inputs to the model are:

- Sabaki river monthly flows (Gauff, 1990). The sequence is almost complete but there is a gap in the sequence between 1972 to 1974. By joining the record from February 1972 to March 1974 a continuous 31 year record has been created for use as a primary input to the model.

- The average monthly rainfalls at Baricho Chief's Camp, Station No 93 39 027, are input to the model to estimate the water balance over the surface of the proposed reservoir at Chakama.

- The average monthly open water evaporation which is assumed at the Chakama site to be 2200 mm annually.

- The topography of the reservoir site near Chakama (Gauff, September 1989).

The computer program for the simulation of the operation of pumped storage:

- Sets the initial storage volume in the reservoir.
- Reads the data inputs.
- Performs a monthly calculation of the water depth and surface area, derived from the volume in storage.
- Performs a water balance at the end of each month.

For each time step the storage equation is:-

Storage = previous month's storage
+ water pumped from river
+ (rain - evaporation - seep) x surface area
- draft

The simulation uses an upper and lower limit for the river flows of 100 and of 2 cu m/sec., beyond which limits the pumping stops. The seepage rate has been set at 0.2 mm per day per metre of water depth. These parameters could be varied as required for investigating other operating conditions.

The results are presented graphically as flow duration curves (Fig 2.11) for six drafts from 50,000 to 300,000 cu m/d and also a graph showing how the required pumping capacity increases with draft (Fig 2.12).

The simulation was also run with an extended (Markov) flow series and found to give about five to ten failures in a 200 year sequence. This tends to confirm that the period of record at Baricho of 31 years gives a useful estimate of the 95% reliable requirements.

2.6.2 Paleochannel Storage Scheme

The aquifer for the current two production wells at Baricho has been tentatively estimated to have a storage capacity of 20 million cubic metres (20 Mcm). If investigations indicate that there is no constraint on pumping at high river discharge, that is no risk of drawing muddy water into the wells, then the storage available in the paleochannel is available for a pumping scheme that would provide water for the transmission pipelines and, during low Sabaki river flows, provide additional water for compensation downstream of the wellfield.

In this scheme it is envisaged that the river channel at the wellfield would dry up whilst Sabaki river flows were insufficient to fully recharge the paleochannel aquifer. The pumping rate during these low flows would be increased as required to provide extra water to reintroduce sufficient into the Sabaki river channel, say 2 km downstream of the production wells, to maintain flow in the Sabaki river channel into the ocean.

A simulation, using an adapted version of the computer program as above, has been performed. The results, for a downstream compensation flow of 2000 l/s, are presented graphically Fig 2.13: SIMULATION OF AQUIFER PUMPING. This graph shows the drawdown of the aquifer, in terms of the water remaining in storage, for the 31 years of flow records at Baricho. For the assumed storage capacity of 20 Mcm, and a compensation flow of 2000 l/s, the maximum steady yield without failure during the period of record was found by trial to be 160,000 cubic metres per day. As indicated in the preceding section, this can be taken as an estimate of the 95 percent reliable yield.

ANNEX 3

BIOLOGICAL CONDITIONS

3 Biological Conditions

3.1 Introduction

The present rehabilitation and augmentation works will take place in an ecologically complex area traversing a wide range of ecosystems. To ensure the sustainability of the project, the study team was required to identify impacts of the project on the terrestrial, riverine, and marine ecosystems and propose measures to mitigate any negative impacts.

In order to achieve the above objective it was pertinent that the study team assemble the baseline information on ecological conditions of the North Mainland study area ecosystems and the interactions that exist among them before presenting mitigation plans. Of particular importance in establishing the ecological baseline are variables such as soils, climate, vegetation, fauna and habitats in each ecosystems of the study area. These are covered in annexe 2 and below:

3.2. Soils

The underlying geology of Kilifi District basically comprises sedimentary rocks of various properties ranging from consolidated sand, silt and clay to limestone exposures (Jaetzold and Schmidt, 1983). Along the coast, coral rock forms the soil parent material while extensive alluvial plains are found along the Sabaki River.

Going from west to east, the soils occur in a broad Southwest - Northeast orientated pattern more or less parallel to the coastline. This is due to the fact that the underlying rocks in Kilifi District are mainly derived from marine sediments which were deposited at various stages of geological history.

The soils of Kilifi District fall into the following three broad categories: Coastal Upland Soils; Erosional Plain Soils; and Coastal Plain Soils;.

3.2.1. Coastal Upland Soils

These soils fall under five broad categories. These are:

a. Soils Developed on Magarini Sands. They are well drained, very deep, red to dusky red, very friable, sandy clay loam to clay soils.

b. Soils Developed on Jurassic Shales. These are very heavy clay soils.

c. Soils Developed on Kambe Limestone. These are well drained, deep, dark reddish brown, friable, fine sandy clay soils.

d. Soils Developed on Mazeras Sandstone. These are variable ranging from shallow to very deep, generally coarse sand soils characteristic of southern Kilifi. North of Kaloleni, however, they range from loamy sand topsoil to sandy clay subsoil.

e. Soils Developed on Mariakani Sandstone. These are well drained, deep, dark brown to yellowish brown, firm, very fine sandy clay loam soils.

3.2.2. Erosional Plain Soils

These soils are mainly developed on Pleistocene bay sediments. The soils range from sandy to clayey in texture. Included in this category are also riverine flood plain soils developed on sediments from various sources.

3.2.3. Coastal Plain Soils

These soils have developed mainly on coral limestone and coastal sands (Kilindini sands). Soils developed from the coral limestone are generally well drained and are of loamy sand to sandy clay in texture. Those developed from the coastal sands are also well drained but are sandy to sandy loam.

The sand dunes and the mangrove swamp sediments are also included among the coastal plain soils. The soils of the dunes are excessively drained, very deep, loose, sandy to loamy sand. The mangrove swamp sediments are very poorly drained, very deep, soft, excessively saline and moderately to strongly sodic, loam to clay often with sulfidic material.

3.2.4. Soil Quality and Agriculture

Most of Kilifi District has generally poor soils, which, combined with adverse rainfall conditions, create a difficult environment for small-scale farming over most of the district. Soil distribution and fertility along the pipeline can be described as follows:

Near the Baricho intake (Lango Baya), soils have developed from alluvial sands from former river deposits (Magarini sands) They are excessively drained, very deep, yellowish red to pale yellow, loose, loamy sand to loamy. This area has low to very low fertility.

South from here, the soil group is well drained, very deep to deep, red to dusky red, friable sandy clay loam to clay, with low to very low natural fertility. It is interspersed and forms a complex with a similar group of stony and rocky sandy clay loams and clays that are evident south of the Rare gorge to Magogoni. This complex exists along the traverse of the road to approximately Magogoni, north-west of Kilifi town, where soil changes to imperfectly drained, moderately deep, dark grayish brown very firm, slightly cracking clay, with humic topsoil of moderate fertility. There are local variations, with heavier and lighter soil deposits.

Closer to Mombasa, over the final 15 km., along the Nguu Tatu pipeline, the soils have developed on shales which have produced an association of well drained to imperfectly drained, shallow to moderately deep, yellowish brown to very dark grey, firm to very firm clays. In valleys, along the pipeline, the soils are imperfectly drained, deep, dark grey to olive grey, very firm clays, with humic topsoil and sodic deeper subsoil, or interfluves.

These generalised types (after Siderius, 1978) indicate low fertility status, and indicate the need for husbandry techniques that increase organic matter, nutrients (manures, fertilizers) and erosion protection in respect of the light textures on slopes. In areas of intense use, south-west and north-west of Kilifi Creek, it is clear how easily eroded these soils are.

3.3. Climate

A description of the climate is given in Annexe 2, section 2.2

3.4. Vegetation

The vegetation of Kilifi District and environs falls into three broad categories. These are terrestrial, riverine and marine vegetation types.

3.4.1 Terrestrial Vegetation

Along the coast, the original vegetation has been greatly modified by agriculture and other human interferences. Before this modification the vegetation cover was a mosaic dependent on available moisture, soil type and elevation. Several broad terrestrial vegetation types including the coastal dunes, forests, woodlands, bushlands and savannas are encountered from the shoreline to the inland. The terrestrial vegetation of the coastal region was extensively described by Moomaw (1960) and the following account is adapted from his work to take account of the dramatic changes in the vegetation that have occured since then.

3.4.1.1. Dune Vegetation

Sand dunes are a common feature of the coast north of Malindi. The dunes are unstable formations. They are covered with salt tolerant vegetation of strand plants which protect the unstable substrate. Common plants of the dunes include *Ipomoea pes-caprae, Cyperus maritimus, Hyphaene parvula* and *Garcinia livingstonei*. Removal of this vegetation leads to severe erosion of the sand dunes.

3.4.1.2. Lowland Dry Forest on Coral Rag

This type of a forest occurs on the narrow strip of land, usually less than 5 km. wide, extending inland from the coast where old raised coral reef is the land surface. Remnants of this forest are found around Mtwapa and near Gede. Some of the indigenous trees include *Combretum schumannii, Ficus bussei* and *Cassipourea euryoides.* At present the coral rag vegetation is currently under severe threat of clearance for hotel and other tourist related developments.

3.4.1.3. Lowland Dry (deciduous) Forest

This forest is found in areas with annual rainfall of between 600 and 1000 mm. and well drained soils. The Arabuko-Sokoke Forest Reserve is the only major remnant of this type of vegetation. The most dominant trees of this forest include *Cynometra webberi, Manilkara sulcata, Brachylaena huillensis, Brachystegia spiciformis* and *Afzelia quanzensis.* This forest supports some population of elephants, buffaloes and other types of wildlife some of which are quite distinctive species.

3.4.1.4. Lowland Rain Forest

This forest is found in coastal areas with high rainfall especially in southern Kilifi. Today, however, only scattered remnants of this forest remain along the coastal range where they are referred to as the "Kayas" or original homesteads by the Miji Kenda peoples. The common trees of the rain forest include *Sterculia appendiculata, Chlorofora excelsa* and *Ficus spp.* The lowland rain forests are under great human pressure for they are agriculturally useful.

3.4.1.5. Lowland Woodland

This is a more or less an edaphic vegetation which develops only on freely drained sands. It is found in the relatively dry parts of Kilifi and Kwale districts. In the study area there are well developed woodland stands north of Adu, at Marafa, Garashi and around Mwangea Mountain. A broad band of the woodland used to extend from north of Bamba to Gotani behind the Sokoke Forest. This type of vegetation is also found on the relatively drier parts of Mazeras and Mariakani.

The dominant trees of the lowland woodland are *Brachystegia spiciformis, Afzelia quanzensis* and *Lannea stuhlmannii.* This vegetation has been observed to be under threat from human activity in the region. In the seventies it was a major source of export charcoal. Currently the woodland is destroyed by creation of farmland and removal of building poles.(NEHSS, 1984).

3.4.1.6. Lowland Savanna

This is a lowland grassland with scattered trees and bushes. Lowland savanna is the characteristic vegetation of the foot plateau. The major savanna trees are *Manilkara densiflora, Dalbergia melanoxylon, Acacia mellifera* and the species of *Terminalia, Commiphora* and *Diospyros.* The common grasses are *Hyparrhenia rufa, H. filipendula, Themeda triandra, Digitaria mombasana* and *Heteropogon contortus*. In this vegetation type the slash and burn agriculture is still practised.

3.4.1.7. Acacia - Euphorbia Bushland

The extent of this vegetation type, generally called the Nyika, is vast and its boundaries stretch to the interior of the country. Bushland vegetation, however, occurs over the whole coastal hinterland where rainfall is less than 600 mm. per annum.

In the study area, the *Acacia-Euphorbia* Bushland lies to the west of Bamba and Mwangea Mountain, while north of Sabaki River, it swings eastward approaching the coast north of Mambrui. These are important areas for ranching. However, activities such as overgrazing and charcoal burning threaten the productivity of this arid ecosystem.

This arid vegetation type is dominated by species of *Acacia* and *Euphorbia.* The *Acacia* species include *A. lahai, A. seyal, A. zanzibarica* and several others. The *Euphorbia* species are *E. nyikae and E. tirucalli.* Other common plants include the species of *Commiphora, Grewia, Newtonia* and *Terminalia.*

3.4.2. Riverine Vegetation

The Sabaki is the only perennial river in the study area. It supports a gallery forest the extent of which is subject to varying degrees of inundation and human influence. The dominant tree of the gallery forest is *Acacia eliator.* Other trees include *Hyphaene compressa* and the *genera* of *Ficus, Albizia* and *Terminalia.*

Phragmites mauritianus forms a luxuriant development beside the river. The floor of the floodplain is dominated by grasses such as *Echinochloa pyramidalis, Panicum maximum* and *Cynodon dactylon*, a variety of sedges (*Cyperaceae*) and *Typha domingensis.*

Towards the Sabaki river mouth there is some development of mangrove swamp. This is composed of *Rhizophora mucrunata, Avicennia marina* and *Sonneratia alba.* However the mangrove species were found to be in a poor state. This may be attributed to human pressure including cutting, grazing and trampling by livestock.

3.4.3. Marine Vegetation

The marine vegetation of the study area comprises of the mangroves, the sea grasses and the marine algae.

3.4.3.1. Mangrove

The mangrove swamps are distinct coastal ecosystems. They are basically estuarine and mainly occur in protected habitats where the sea water and freshwater from inland mix. In the study area the mangroves forests are well developed around the Tudor Creek, Mtwapa Creek, Kilifi Creek, Mida Creek and Ngomeni. Mangrove forests cover an area of 6,378 ha. in Kilifi District.

The mangrove species occur in distinct zonation as they have different requirements for shade, salinity and other environmental variables. The most important mangrove species of the study area are the *Rhizophora mucrunata, Sonneratia alba, Avicennia marina, Ceriops tagal* and *Bruguiera gymnorrhiza.*

The mangrove swamps are very productive ecosystems and yield large quantities of fish, crabs, prawns and oysters. They are also valuable sources of fuelwood, building poles, timber, tannins and other natural products (Kokwaro, 1985).

The mangroves form critical nursery grounds for numerous marine species. In addition, they provide important habitats for both resident and migratory birds and other forms of wildlife.

3.4.3.2. Seagrasses

The seagrasses or the marine angiosperms are a group of flowering plants that are a prominent feature of the intertidal zone of the Kenya coast (Isaac, 1968). The seagrass beds occur in lagoons between the fringing reefs and the shore as well as the creeks.

Common seagrasses of the study area include *Cymodocea ciliata C. serrulata, Syringodium isoetifolium, Halodule wrightii, Thalassia hemprichii* and *Halophila ovalis.* The seagrasses form extensive beds around Watamu and Mida Creek. They are also common around Malindi.

The seagrass beds form a highly productive system, providing nursery grounds for marine fauna. They also play an important role in marine food chains in various habitats including the lagoons, creeks, coral reefs and open sea.

3.4.3.3. Marine Algae

The Kenyan coast has a rich diversity of marine algae. The marine algae are represented in the following groups: green algae (*Chlorophyceae*), red algae (*Rhodophyceae*) brown algae (*Phaeophyceae*) and blue-green algae (*Cynophyceae*). The most common genera encountered in the study area are: *Ulva* (*chlorophyceae*) *Turbibaria* (*Phaeophyceae*), *Caulerpa* (*Chlorophyceae*), *Padina* (*Phaeophyceae*), *Gracilaria* (*Rhodophyceae*) and *Halimeda* (*Chlorophyceae*).

3.5. Wildlife

The wildlife of the study area falls into three major categories. These are the terrestrial, freshwater and marine wildlife.

3.5.1. Terrestrial Wildlife

The terrestrial wildlife in Kilifi District is mainly distributed into two major areas. These areas constitute the dry hinterland bordering the Tsavo East National Park and the Arabuko-Sokoke Forest Reserve.

Detailed animal censuses for Kilifi District have been carried out through aerial surveys by DRSRS between 1977 and 1989 and the results presented in Table C.2: ESTIMATES OF WILDLIFE POPULATION OF KILIFI DISTRICT by DRSRS. A great percentage of the animals occur mainly in Galana and Kulalu ranches. There are some wildlife in Chakama and Giriama ranches while the other ranches attract only a few wild animals.

Although the aerial survey of 1977 showed the presence of elephants in Kilifi, there were no elephants recorded in the 1988 and 1989 surveys (DRSRS, 1989). This is attributed to poaching which reduced the population of elephants in Kilifi from 10,000 in 1973 to effectively 0 by 1989 (Gesicho, 1991).

In 1993, the situation has improved and the elephant population in Kilifi is on the increase. Interviews with Mr. Stephen Gichangi, Senior Warden, Tsavo East National Park revealed an estimated elephant population of 130 individuals in Galana and Kulalu ranches in Kilifi District.

It is important to note that the aerial surveys by DRSRS could not detect, forest animal populations due to low visibility. Consequently the elephants and other large herbivores in the Arabuko-Sokoke forest remained uncounted during the above censuses. Recently however, the elephant numbers and distribution in Arabuko-Sokoke forest have been obtained by using dung density as indicator of elephant presence (Gesicho, 1991). Using the above technique, it has now been determined that the elephant population in Arabuko-Sokoke forest is rather small ranging between 78 and 90 elephants.

A list of common terrestrial fauna found in the Arabuko-Sokoke forest and the surrounding areas is presented in Table. C.3: TERRESTRIAL WILDLIFE SPECIES COMMON IN ARABUKO-SOKOKE FOREST AND THE SURROUNDING AREAS. In addition to the above list there are many more species of birds, reptiles, amphibians, molluscs, insects and other forms of faunal life contained in diverse natural terrestrial habitats of the study area.

As a whole the settled areas of the study area were found to support very few wildlife species. The baboons and the sykes monkeys were however, common along the river valleys. Among the large mammals, we recorded the presence of two buffaloes in the Marikano forest patch of Kakoneni sublocation in Jilore Location.

3.5.2. Riverine Fauna

Virtually all the freshwater fauna are confined to Sabaki river, the only permanent river system in the study area. The Sabaki supports important fish species including *Labeo gregori, Oreochromis spirulus, Clarias sp* and *Clarotes sp.* Freshwater prawns are also common in the Sabaki. These include *Macrobrachium lepidactylus, M. rude* and *M. scabrinsculum.* Other riverine fauna include the crocodile (*Crocodylus niloticus*) and the hippopotamus (*Hippopotamus amphibius*) while the baboon (*Papio cynocephalus* and the Sykes monkey (*Cercopithecus albogularis*) are found in the gallery forest.

Among the bird species, the herons, sacred ibises, fish eagles, plovers, egrets, terns and kingfishers, among others are common along the Sabaki River. A list of the birds species encountered along the river during the field survey (May, 1993) is shown in Table. C.4: BIRD SPECIES RECORDED ALONG THE SABAKI IN MAY 1993.

3.5.3. Marine Fauna

A host of vertebrate and invertebrate marine fauna are found in the coastal waters. Some of the most prominent marine groups in the study area include crustacea, molluscs, fish, reptiles, avifauna and mammals.

3.5.3.1. Crustacea

A wide diversity of crustacea occur along the coast of the study area. The most important are the prawns (*Penaeidae*), the crabs (*Portunidae*), the spiny *lobsters* (*Palinuridae*) and the shrimps (*Caridae*).

Six families of prawns are represented along the coast. The most common prawn species (*Panaeus indica, P. monodon* and *P. semisulcatus*) occur in the in-shore areas including the sheltered bays, inlets and the river mouths.

The portunid crabs (*Scylla serrata, Portunus pelagicus* and *P. sanguinotentus*) are common along the north coast. *Scylla serrata,* an edible crab, is found in the muddy estuaries and mangrove swamps of the study area.

The shrimps have been heavily fished and the lobsters are now rare in Kilifi and its environs.

3.5.3.2. Molluscs

The molluscs common in the marine habitats are the gastropod, giant clam bivalve, octopus, the squid and the cuttlefish. Many shelled molluscs such as the triton (*Charonia tritonis*), helmet shell, (*Cypraecassis rufa*), cowrie (*Cypraea sp.*), spider conche (*Lambis sp.*) occur along the coast of the study area.

3.5.3.3. Marine Fish

The marine fish of the study area are conveniently divided into two broad categories: the demersal and the pelagic fish. The demersal are common in the inshore waters while the pelagic fish are normally found in the open sea.

The demersal fish of the inshore waters of the study area include the rabbit fish (*Siganidae*), parrot fish (*Scaridae*), scavengers, (*Lethrinidae*), snappers (*Lutjanidae*) and the surgeon fish (*Acanthuridae*). The common pelagic fish are the kingfish (*Scombroidae*) cavalla jacks (*Carangidae*) barracuda (*Sphyreanidae*) and the sail fish (*Istiophoridae*) among others.

3.5.3.4. Reptiles

Several species of turtles are believed to nest along the Kenyan coast. The two most widely distributed are the green turtle (*Chelonia mydas*) and the olive Ridley turtle (*Lepidochelys olivacea*). The Hawksbill turtle (*Eretmochelys imbricata*) is however, less frequent. These turtles are greatly threatened due to disturbance on the beach habitats where the females lay their eggs.

3.5.3.5. Avifauna

Over a hundred species of water birds are associated with the Kenyan coast. The most common bird species encountered during the field survey are the plovers, terns and the sea gulls. These birds were abundant in the Sabaki river mouth area where they feed on the crabs, molluscs and the fish.

3.5.3.6. Mammals

The marine mammals along the coast are represented by the dugong (*Dugong dugon*) which feeds mainly on seagrasses. The dugong population in the study area has greatly decreased to the point of extinction.

3.6. Critical Habitats and Significant Natural Sites

These are areas of unique or outstanding value because of their inherent ecological or geological attributes and include:

1. Areas of high biodiversity.
2. Habitats for endemic (in ecological terms found nowhere else in the world) , rare or endangered species.
3. Areas of intense scenic beauty
4. Areas with aesthetic and sacred value.

Areas with the above characteristics in the study area cover a wide range of habitats including forests, groves, gorges, creeks, coral reefs, beaches, estuaries, areas with monuments and historical sites. Some of these areas are now protected by the government.

3.6.1. Arabuko-Sokoke Forest

The Arabuko-Sokoke Forest, with an area of 372 km2, is situated between Kilifi Creek and the Sabaki River. This is a forest with high biological diversity. The forest is one of the most important sites in Kenya for bird conservation (Kelsey and Langton, 1984). Six species of birds listed as rare in the ICBP/IUCN Bird Red data Book occur in this forest. Two of these bird species, the Sokoke Owl (*Otus ireneae*) and the Clarke's Weaver (*Ploceus golandi*) are found nowhere else in the world.

In addition to the endemic bird species, the Arabuko-Sokoke forest is of great importance for other wildlife. It is the only known locality for the rare Ader's Duicker (*Cephalophus adersi*). The frog *Leptopelis flavomacculatus* is only known elsewhere in the Shimba Hills. Two butterflies, *Charaxes lasti* and *Charaxes protocles azota* are endemic. Although this important forest is in the study area, it is not affected in any way by the present project.

3.6.2. The Kaya Forests

The Kaya Forests are relic patches of the once very extensive lowland rain forests of Eastern Africa. The word "Kaya" means homestead to the Miji Kenda people. Historically the Kayas sheltered small fortified villages and functioned as places for refuge in times of the war. Today the Kayas are still respected as holy places for burying elders and offering sacrifices and prayers (Robertson, 1987).

The main Kayas in the study area are the Kaya Kauma, Kaya Chonyi, Kaya Jibana, Kaya Kambe, Kaya Ribe, Kaya Rabai and Kaya Giriama. These forest patches have a high biodiversity and contain rare and unique flora. The forests protect the many small but important watersheds. They also form suitable habitats for the remnants of rainforest trees such as *Sterculia appendiculata* and *Chlorofora exelsa*. The Kayas, like Arabuko- Sokoke Forest are not threatened by this project.

3.6.3. Sacred Groves

The sacred groves are small patches of forests and woodlands that have developed in areas with unique geological formations such as caves and rock outcrops. These are areas of great scenic beauty. The sacred groves are used for offering prayers, rain-making and other traditional practices by the Miji Kenda.

Most prominent among the sacred groves of the study area are the Cha Simba, Pangani and Kambe Rocks in Kaloleni and Mulungu wa Mawe in Ganze. The rock outcrops contain many rare, endemic and botanically unique plants. Striking plants to be seen in sacred groves include *Euphorbia wakefieldii, Pandanus rabaiensis* and *Ficus wakefieldii.* The endemic *Saintpaulia* *rupicola*, and the rare *Cola octobaloides* and *Savia fadenii* are among other unique plants found in the sacred groves. The sacred groves are also not threatened by the present project.

3.6.4. Gorges and Creeks

The Rare and Ndzovuni Rivers have cut deep gorges in some sections of the study area before discharging their waters into Kilifi Creek. The gorges cut by the above rivers are colonized by unique flora including the succulents and cycads. The gorges were found to be suitable sites for species such as *Encephacartos hilderbrandtii* (*Cycadaceae*), *Gonotopus bolvinii* (*Araceae*) *Cissus quandrangularis* (*Vitaceae*) among other spectacular plant species. Like the sacred groves, the gorges were also sites of great scenic beauty.

The creeks are critical habitats for a wide range of marine organisms. The creeks are important breeding, nursery and feeding grounds for marine fish and crustaceans such as prawns, crabs, oysters, shrimps and lobsters. The study area has several creeks including Tudor, Mtwapa, Kilifi and Mida Creeks.

3.6.5. Coral Reefs

The coral reefs roughly run parallel to the Kenyan coast at distances ranging from 500m to 2 km. from the shoreline. The coral reefs, however, do not occur at the mouths of streams and rivers. This is attributed to the low salinity of the river mouths, the absence of hard substrate at these sites, and possibly to the high silt load of some rivers. There are ten coral reef areas along the Kenya coast of which Bamburi reef, Vipingo-Kanamai reef and Watamu-Malindi reef are found along the shore of the study area.

Corals belong to the fairly large group of animals known as coelenterates. The living corals are colonies of polyps which secrete a calcareous sheath around themselves. About 140 different species of hard and soft corals have been identified along the Kenyan coast (UNEP, 1989). The most common coral genera found along the coast of the study area include *Pocillopora, Acropora, Montipora, Astreopora, Porites, Playtgyra, Echinopora* and *Galaxea*.

The coral reefs are one of the finest examples of a biologically productive and taxonomically diverse ecosystems. A coral-reef forms through a system of intricate inter-relationships among a multitude of organisms, a very complex ecosystem, which rivals the complexity of the tropical rain forests.

The coral reefs are critical habitats for a host of marine organisms. The reefs are utilized as feeding, spawning, nursery grounds and shelter for a wide range of marine life including marine fish, sponges, echinoderms, molluscs, annelids, crustacea and other coelenterates.

3.6.6. Beaches

Beach habitats are widely distributed along the shoreline of the study area. Although the beaches are often inhospitable to marine and strand plant species, they provide a number of important ecological values. These include dissipating wave energy and stabilizing and protecting other aquatic and terrestrial systems. Many beaches in the study area serve as nesting habitats for marine turtles.

3.6.7. Estuaries

Ecologically, an estuary is a semi- enclosed coastal body of water within which the sea water is diluted by freshwater from land drainage (Correll, 1978). Estuaries are critical sites as spawning and nursery grounds, for migratory species of marine fish. In addition, they are important feeding and resting habitats for many species of water birds.

The Sabaki river mouth, is the only estuary of significance in the study area. This is an important habitat for the water birds where large concentrations of terns and gulls were encountered during the field survey of May, 1993.

3.7. Protected Areas

In recognition of the ecological importance of the coastal ecosystems, the Government of Kenya has protected several areas as National Parks, National Reserves and National Forest Reserves. Along the coast there are four Marine National Parks and five Marine National Reserves and one National Forest Reserve. The following is a list of the National Parks and Reserves found along the coast of the study area.

1. Mombasa Marine National Park (1000 ha.) and Mombasa Marine National Reserve (20000 ha.)

2. Malindi Marine National Park (600 ha.) and Malindi Marine National Reserve (21300 ha.).

3. Watamu Marine National Park (1000 ha.) and Watamu Marine National Reserve (3200 ha.).

The protected coastal forests in the study area are the Arabuko-Sokoke Forest Reserve and the Gedi National Monument Forest. The Kaya forests are increasingly gaining recognition and several forest patches have been proposed for conservation as shown in Figure 3.1: PROPOSED FOREST AREAS FOR GAZETTEMENT KILIFI DISTRICT.

3.8. Rare and Endangered Species

The study area harbours a significant number of threatened species, the major categories of which are: mammals, birds, reptiles, amphibians, molluscs, crustacea, insects and plants. The list of the most threatened species is presented in Table C. 5: INVENTORY OF THE MOST THREATENED SPECIES in the Study Area. Fortunately, very few of these threatened species normally inhabit the impact area of the project.

3.8.1. Mammals

Three mammals, the African elephant (*Loxodonta africana*), the dugong (*Dugong dugon*) and the Ader`s duicker (*Cephalophus adersi*) are now threatened in the study area. None were found in the impact area, or are likely to normally reside there.

Aerial survey in Kilifi District rangelands indicated a decline of elephants from 10,000 in 1973 to 0 in 1989 (Gesicho, 1991). Very few of the elephant population in the Arabuko-Sokoke forest also survived during this time. The present population (78-90 elephants) is thought to be the young survivors of a highly fragmented and socially disrupted population. The decline of elephants population is attributed to the poaching for ivory and the loss of habitat due to agriculture and human settlements.

Dugong, a herbivorous mammal was last seen along the coastal zone of the study area during the census of 1975 (NEHSS, 1984). Since then the dugong population has greatly decreased and must now be considered a seriously endangered species.

The Ader`s duicker is a rare mammal species which is endemic in Arabuko-Sokoke Forest.

3.8.2. Birds

Six bird species found in the study area are listed as rare in the ICBP/IUCN Bird Data Book (Kelsey and Langton, 1984). Two of these species, the Sokoke Scops Owl (*Otus ireneae*) and the Clarke`s Weaver (*Ploceus golandi*) are endemic. The Sokoke Pipit (*Anthus sokokensis*) is a near endemic species. The Amani sunbird (*Anthreptes pallidigaster*) only occurs in Arabuko-Sokoke forest and the Usambara Mountains in Tanzania. Other rare bird species, found in the study area are the Coast Akalat (*Sheppardia gunningi*) and the Spotted Ground Thrush (*Turdus fischeri*).

3.8.3. Reptiles

Three species of turtles, the Green Turtle (*Chelonia mydas*), Hawksbill Turtle (*Eretmochelys imbricata*) and Olive Ridley Turtle (*Lepidochelys olivacea*) are threatened along the Kenyan coast. These species have now become rare due to human exploitation and interference. The turtles nesting sites along the coast are often raided for eggs and the mothers killed for meat when coming ashore to lay. Some turtle beaches have also been disturbed and are no longer suitable nesting sites.

3.8.4. Amphibians

The frog, *Leptopelis flavomacculatus* is a rare species found only in Arabuko-Sokoke forest and Shimba Hills.

3.8.5. Molluscs

Many large and beautiful shelled molluscs are heavily collected for sale to tourists. The giant triton (*Charonia tritonis*) and the bullmouth helmet shell (*Cypraecassis rufa*) have now become rare species due to over collection.

3.8.6. Crustacea

The demand for lobsters, crabs and prawns has caused a decline of these species on the Kenya coast. Due to overfishing the Spiney lobsters (*Palinurus spp.*) have become rare species in the study area.

3.8.7. Insects

Two rare butterflies, *Charaxes lasti* and *Charaxes protocles azota* are endemic to Arabuko-Sokoke Forest.

3.8.8. Plants

Several indigenous trees from the coastal forests have experienced great losses due to exploitation. Wood carving activities have reduced the African ebony (*Dalbergia melanoxylon*), *Brachylaena huillensis* and *Combretum schumannii* to rare species. *Warburgia stuhlmannii* has now been over collected for medicinal purposes. Other rare plant species found in the study area include *Euphorbia wakefieldii, Aloe kilifiensis, Saintpaulia rupicola* and *Oxystigma msoo* among others.

ANNEXE 4

SOCIAL CONDITIONS

4. Social Conditions

4.1. Introduction

The current social conditions of Kilifi district people, where the project is located, are determined by their historical development of an extensive land use system. Population density has increased to the extent that this land use system is now counter productive. As a result, the people are poor. Poverty is exacerbated by lack of skills to make the people productive in modern agriculture or other sectors of the economy. Consequently they continue to mine the natural resources at the expense of the environment.

It is clear from field work that the project will have minimal impacts on their social conditions since fundamentally it is not designed to improve their production capacities but to provide potable water for a limited number of the population. However, the labour saved from looking for water and health benefits accrued from availability of potable water will be important additions to the welfare of a significant number of people in Kilifi.

4.2. Land Use in Historical Perspective

4.2.1. Kayas and the Origins of Land Use

Land use is a function of history, social organisation and competition for acquisition of production resources. Kilifi District is populated by a section of the wider Mijikenda group with nine subgroups. Two of the subgroups, the Digo and the Duruma, are found in Kwale District. The other seven, the Rabai, Ribe, Chonyi, Jibana, Kauma, Kambe and Giriama are found in Kilifi District. Their settlement, during the sixteenth century, was originally in Kayas to the interior of Mombasa, in areas which form part of Kilifi District today. Then, Kayas were only settlements. Today they are ritually holy places of origin. (Spear. 1978, Porter, 1991, Were, 1988, Martin, 1973.). The Kayas were located on densely forested and fortified hills, the richest ecotones.

Social control in the seventeenth and eighteenth century was under the elders who also had economic control over the society through rituals. The populations were limited and farming was essentially of millet and livestock.

By the end of the eighteenth century, the Kaya population had increased. The Kayas could not accommodate all the people. There was rebellion about control by the ritual gerontocracy. Various individuals began to live outside the Kayas and to build their lineages. Production was diversified with livestock and cultivation of maize being adopted. Trade, between the coastal Arab sultanates and the interior, developed as a major source of wealth for households being built into lineages. Trade items were mainly wildlife products, especially ivory, and maize.

4.2.2. Population Explosion and Extensive Land Use

As trade became the important source of wealth, the Giriama subgroup, estimated to be 20,000 people, at the turn of the nineteenth century, and the largest part of Kilifi District population today, literally left Kaya Giriama and exploded north eastward. They crossed the Rare river by the 1840's and entered the Jilore area, on the south bank of the Sabaki River, and Gede by the 1880's. They crossed the Sabaki River into Marafa by 1895. The Giriama developed a land use system which was based on buying wildlife products from their neighbours, partly hunting the abundant wildlife, trading in livestock products, especially ivory, as well as keeping livestock and farming maize. They became the intermediaries between the interior people and the coastal Arab sultanates. Land was fired to develop grasslands for livestock. More favourable spots were slashed and burned to develop gardens for tree crops and maize again to be sold to Arabs at the coast.

On reaching the rich alluvial flats of the Sabaki River, major expansion in maize production was undertaken and the Giriama dominated maize trade along the whole coastal area to such an extent that it took the British colonial government's punitive taxes to break this monopoly in 1930's; this being done to keep the maize monopoly in the hands of white farmers (Zwanenberg. 1972, 1975, 1975.).

Whilst the Giriama expanded, the other Kilifi Mijikenda largely remained within their original areas. As a result their own populations stagnated. Their land asset deteriorated as fallow periods shortened. They, by the middle of the nineteenth century, were increasingly drawn into christian churches and the colonial economy of Mombasa as labourers, and clerks the petty functionaries. In Goran Hyden's term they became a captured peasantry (Hyden.1983), who farmed coconut palm's mainly for selling the toddy to the emerging urban population of Mombasa over and above their subsistence slash and burn agriculture producing maize.

Since land in the north east and into the interior was available for claiming, the Giriama organised to continue expanding. The social organisation and production unit remained the extended family living in one compound. This institution splintered as the dictates of trade and farming required. Social control could not be by the kaya ritual elders but passed to the diviners who, to date, still exercise enormous control over Giriama society. Parts of families would, in the late nineteenth century, split to squat on the large run down estates owned by Arabs in the coastal strip. This was to be repeated in the twentieth century when European estates were established and still goes on today (meeting of the District Development Committee of 26/5/93). The large estates have been replaced by small land lots owned by locals other than for two or three owned by multinationals.

In attempts to control this squatting strategy, the British colonial government set up the Gede Settlement Scheme as early as 1931 to deal with the "Giriama squatter problem". It was to be expanded, under ALDEV, in 1951. Infrastructure was developed along the coast, first to support Arab and British plantations and lately to support tourism. As a result the coast has always been a more attractive place to live, mainly through squatting, and also to earn a living from. Since they have never owned it, Giriama participate in all this as portions of households but sociologically speaking really not part of it for they have resisted Christianity and Islam more than any of the other Kilifi Mijikenda. It is estimated that only 25% of Giriama are non-traditional believers. In 1979, only about 27% had received formal education compared to 49% nationally (CBS. 1979). They present a paradox therefore since their explosion from the kayas, their adaption of maize and trade and their ability to coexist with Arab and British colonial production systems show that they have adopted major changes both in social and production organisation in the past. Driving the paradox is the need to always diversify to deal with the limitations of production in one zone. In Section 4.5.2. it is discussed in detail how current Giriama populations in three locations split the household to straddle different ecological zones.

The technology for opening land, both for livestock keeping and crop farming, is to slash and burn. For grazing lands, repeated burning led to pest control as well as forcing the creation of grasslands where woodlands previously existed. On farm land, cultivation continues until the land is exhausted. It is then fallowed. Elders claim that fallow periods used to be about 10 years in the past. Other than in the really dry parts of the district, it is doubtful whether land is allowed to stay fallow for more than four seasons now. In the coconut/cashew and cassava zones, populations are such that there is no land being rested.

The reasons are strictly demographic. As shown in Table. A.1: KILIFI DISTRICT POPULATION 1989, the densities are approaching a level where resting land is a luxury. Figure 4.1: KILIFI DISTRICT ADMINISTRATIVE BOUNDARIES shows the 1999 administrative organisations of the district. In Bahari division, where the bulk of the land is in these land use zones, the 1989 population density was 196 people per square kilometre (p/km^2). In Kaloleni Division, with a much more dry interior than Bahari, the density was 171 p/km^2. It is only in Ganze and Malindi divisions, where the densities are 28 and 25 p/km^2 respectively, that fallowing is possible. Even in these divisions, the more favoured pockets such as hilly areas, bottom land and alluvial flats have populations which do not allow the fallow systems to continue. For example, Ganda location density is 142 p/km^2 and two of its sublocations, Ganda and Msabaha have densities of 277 and 229 p/km^2 respectively. There was no evidence of fallowing observed in these two sublocations during the field work for this study.

4.2.3. Current and Future Land Use Structural Problems

If the technology for opening up land is slash and burn, it should also be noted that households have access to different pieces of land and use the land in complex ways. They own some plots for cash crops, usually coconuts and cashew nuts, some for subsistence crops, maize mainly, for as children go to school their labour is not available for the bird scaring necessary for production of millet. Farming is low technology and hardly uses any modern inputs (Kihu. 1984). Other pieces of land are for livestock although the bulk of the population does not have any livestock now, an index of the relative overpopulation and impoverishment.

Land use is also being affected by the system of land registration. The overall distribution of land by legal type is shown in Table. B.1: KILIFI DISTRICT LAND BY LEGAL CATEGORY. The bulk of the land is unregistered trust land. Hence, people use traditional land claiming techniques to privatise this land. The current status of land registration is shown in Table. B.2: LAND ADJUDICATION STATUS 24/5/93. What is clear in this table is the fact that it is the better land, found in the coastal

Bahari Division, which also is being speculated on for non agricultural development, mainly tourism, which has received priority in the past. The second area of registration of land is in Kaloleni Division, where the more educated and more politicised non- Giriama groups have demanded the service. The effects of adjudication on land use are, first, that the people in the adjudicated areas will be able to invest in land improvements because they have secure title in law. At the same time, the poor of the adjudicated areas will be thrown out of the better land and will move to drier and poorer land to eke out a living. Also, those in the better areas will be capitalised by getting title and will be able to buy land in other parts of the district either by mortgaging the title or selling small titled plots to use the proceeds in buying larger but poorer land in other parts. Since the actors on titled land are mainly the non- Giriama, who are moving to what are perceived as Giriama lands, there will be mixing of the Kilifi Miji Kenda to a higher degree than in the past. Since some of the seve are supposed to be better agriculturalists, as a result of their having become overcrowded and reaching the land frontier at existing technology in the past and as a result learning soil fertility enhancement techniques, this mixing may have positive environmental impact on land use.

4.2.4. Land Use Along the Baricho Nguu Tatu Pipeline

During field work, the study team visited the Baricho Nguu Tatu pipeline and established the following categories of land use as a bench mark for future monitoring.

1. Baricho Intake to Km. 5

This is an area of recent (less than five years) farming. 30% of the land has been cultivated. There is livestock.

2. Km. 6

There is localised tramping by livestock as they go to water in a local stream.

3. Km. 6 to Km. 10

There is minimal opening of land as only less than 10% seems to have been cultivated. This area seems to be an extension of the Mwahera 10 ha. haraka settlement pattern. There is very dense bush developed after repeated firing.

4. Km. 10 to Km. 12

This is a mixed area with old settlements and new ones established by the maturity of the cashew and coconut palms. About 40% of the land is cultivated. The rest is grazing land.

5. Km. 12 to Km. 15

There has been cultivation for about two years. There are a lot of young coconuts and cashews. About 40 % of the land is farmland. Livestock are tapering off.

6. Km. 16 to Km. 25

This area is 90% plus cultivated and there is absolutely no evidence of livestock.

7. Km. 26 to Km. 29

There is secondary bush on both sides and the horizon and absolutely no livestock evidence was seen.

8. Matano Mane to Rare Gorge

Cultivation is 40-50% and has been going on for more than 20 years given the maturity of the orchards. There is infilling with new lands opened for maize and some new settlers who are buying from old owners with established farms.

9. Rare Gorge

There is cultivation on the bank lip both on the eastern and western side. There also is cultivation on the small flood plain with coconuts less than three years old. There is extensive bush clearing especially on the western bank. The study team was told that the clearing is to keep baboons and monkeys away from the shambas. Cultivation is about 50%. There is evidence of goats but not cattle. The study team was told that cattle succumb to diseases for there were buffaloes in the region until recently.

10. West of Rare River to Kachororoni

There is recent limited farming 20% and evidence of livestock.

11. Km. 41

There is irrigation of horticultural crops from the pipeline supposedly since there is a break in the pipeline. The fact of the matter is that the air valve chamber is vandalised.

12. Silala to Km. 53

There is cultivation in about 40% of the land. The vegetation is of a more dry area type. There is evidence of livestock.

13. Km. 54 to Mwapula Primary

This is essentially livestock area with less than 20% of the land newly cultivated.

14. Ndzovuni River to Km. 58

This is the boundary area between the Giriama and the Kauma. The Ndzovuni River channel is pristine forest. No evidence of charcoal burning. The study team was told by local people that the area was not settled for up to ten years ago there were still large game, elephants and buffalo. This presented disease problems as well as putting any cultivated crops at risk.

15. Jaribuni Area

After Km. 58, there is evidence of recent settlement and farming. This area is also the historical area of Kaya Kauma. There is extensive mining of iron ore and land reclamation by the mine owners. The uncultivated land is bush and thicket, evidence of historical burning.

16. Dziani to Mesheta River

This is the Kauma heartland and has been continuously farmed for centuries. Cultivation is over 90% of the land area.

17. Jibana Area

Surprisingly this area is not as cultivated as expected for there is about 40% forested patches of bush.

18. Kambe Area

This is totally cultivated where there are no rock outcrops, about 10% of the land. Cropping comes to the stone bases. These are old farms and the plots are small. There is variety in crops unlike all other previous areas where maize, coconuts, pigeon peas, and cowpeas were seen on some farms. There also is sugar cane and arrow roots on bottom land.

19. Ribe Area, Jomeka/Kinyume Tanks area

Although this area seems to be as dry as the area east of Rare River, there is very high population density and more than 80% of the land is cultivated. It is clear these farmers are cultivating for lack of better land. The 20% thickets seem to have been repeatedly burned.

20. Km. 93 to Km. 98

This area is still in the Ribe area. During the colonial period there used to be ranches in the area. The population has moved in and cleared the land for farming. It is poor cropland. About 80% of the land is cultivated.

21. Km. 99 to Nguu Tatu

This is former ranch land. Very intensive farming has replaced livestock. There are no permanent tree crops for the squatters know that the land really does not belong to them. The strategy is therefore to produce a maize crop and establish usufruct rights with the hope that the state will acquiesce to the squatting.

22. Nguu Tatu to Bamburi, Shomoroni and Utange

This are is currently attracting squatters from Mombasa. Giriama and other Seve squatters seem to be encouraged by some local politicians to occupy the land which belongs to the state, the cement factory, some ranchers and private estates. This squatting is supposed to assure especially the Giriama some access to Mombasa urban land. The DC's office Mombasa states that this settlement is one of the major political problems for the district.

4.2.5. Land use along Kilifi North Pipeline

The study team similarly investigated the Kilifi North Pipeline to establish current land use for future monitoring. This one was selected since maps and planning documents of the district and central government show forestry land use. The land has been privatised by the Giriama. It falls into three distinct areas.

1. Silala to Sokoke Chiefs Camp/Town

This embraces the northern and western slopes of the Reru River. Historically it was grazing land for Sokoke households who used to send cattle outposts there and lived on the more endowed foot slopes nearer Kilifi. It is being sold to landless people especially from the south west where densities are high. There is evidence of very poor farmers. About 40% of the land is under cultivation. According to the Chief, the settlers have only started permanent farming in the last two years and thus there is no evidence of the settlement having been influenced by the construction of the pipeline or they would have settled more than ten years ago.

2. Sokoke Chief's Camp to Foot Plateau Top

This is undulating land to the southern and south eastern slope of Rare River and the hinterland side of the foot plateau. It has higher rainfall than land to the west and north. It has deep soils. It has always been the maize growing area of the Sokoke people whose households are on top of the foot plateau in Sokoke, Tezo and Roka locations. In government documents this is supposed to be county council forest. Yet the land is under adjudication now and is cultivated up to 85%. There are few permanent homesteads for it is farmed by split households mainly. Those who are there permanently have only settled in the past five years.

3. Foot Plateau Top to Kilifi Town.

These are old settlements with mature tree gardens forcing the households to split and move to areas where they can grow maize, the subsistence crop.

4.2.6. Impacts of Pipelines on Land Use: Conclusions

The terms of reference were specific on requiring the study team to comment on the land use impacts of the pipeline. The population distribution has been reviewed and the land use seen on the ground described. It is clear to the study team that it is not the pipeline which is driving land use now. Land use is driven by historical processes of the Giriama especially. Specifically, land use is driven by the household coping strategies developed in historical times of slash and burn agriculture, building households, and splitting them to exploit production in different zones. There is a veneer of non-Giriama influences as the other Kilifi Mijikenda, who face tremendous land hunger, move into some of the Giriama areas and buy land. The pipeline has made life easier in Lango Baya and Makobeni sublocations of Jilore location for people who claimed the land historically and who moved back for economic reasons.

The comments above should not be used to deny the potential for the pipeline making a difference in terms of the kind of people who will move next to the pipeline in the longer term. On the Nguu Tatu pipeline, there are three farmers who are large scale operators and they have bought land next to the pipeline since it assures them comfortable operations. One has a fruit plantation of close to 50 ha. He is very busy buying land and is reputed to have bought close to 1,000 ha. at the Mwengea Hill base. On the land abutting the pipeline he is careful not to make an individual connection but rather uses local labour to draw water for his orchard from the public supply. The second large scale operator has bought more than 100 ha. and planted it with sisal, orchard and casuarinas for poles. The third has a completely modern mixed farm with improved livestock.

The point is simply that non-Mijikenda are beginning to speculate on the land next to the pipeline. It is expected that this will grow. Its environmental impacts are likely to be positive for they new operators use modern farming techniques and conserve the land and forest resources. Whether the social impacts are positive is doubtful for in the long term these settlers will be throwing poor people out of this land who in turn will go to exploit drier lands with negative environmental consequences. It is not clear that the Kilifi Mijikenda, and the Giriama in particular, have an answer to this social threat for their squatting strategies, developed to assure access to different ecological areas, were honed for transient settlers, the Arabs and the British, whilst the local large scale operators are here to stay.

4.3 Population Served by the Pipelines

Kilifi district population has grown very fast in the past thirty years. Table. A.2: KILIFI DISTRICT POPULATION 1962 TO 1989 refers. There was a 21.1% increase between 1962 and 1969. Between 1969 and 1979 it again increased by 40.1% and in the next decade increased again by 37.3%. Total Fertility rates were 2.8, 1.7 and 5.6 for 1962, 1969 and 1979 respectively. The population almost doubled between 1962 when it was 247,822 and 1977 when it was 430,986. In 1989 it was 591,903. Given the high fertility rate, the youthful district population is set to go on exploding.

During the rehabilitation and augmentation design, design demands for the population along the pipeline was established by counting households in the three kilometres on both sides of the pipelines based on mapping developed from 1989 aerial photography, it being estimated that people will walk three kilometres for water, even during the rainy season. This methodology was adopted because most of the areas are inaccessible. Data on this exercise is presented in Table. A.5: SIX KILOMETRE SWATH POPULATION SERVED BY PIPELINES, which is based on 1989 Aerial Photography. The population from this counting shows that a total of 47,256 people would be served continuously since they are within three kms. of the pipelines. This is about 8% of the 1989 Kilifi district population. Mombasa District population was not included in this exercise since it is part of the distribution network after the pipeline reaches Nguu Tatu.

It is difficult to establish the number of people who existed in the particular environs traversed by the various pipelines in Kilifi District from past census data. There are two key problems, varied enumeration units and mobile splintering households. The first problem is that to date Kilifi District, not unlike other less developed districts in Kenya, has had different enumeration units, the sublocations, for census taking in 1948, 1962, 1969, 1979 and 1989. A typical example is Jilore location, one of the oldest, where the Baricho intake is located. In the 1962 census it had two enumeration units. In 1969 it had three. In 1979 it had four. By the 1989 census, the four enumeration units had been transferred to a new location, Gede, although some of the population remained in Jilore. During this census four new enumeration units, sublocations, were created for Jilore. These are Jilore/Ziani, Lango Baya, Makobeni, Kakoneni and Arabuko Sokoke Forest. There is no rational way of determining what the proportions of population were in these areas before the 1989 census. Consequently, the study team offers the data from the 1989 census on the existing sublocations which are traversed by the pipeline as the baseline data for future monitoring.

To test the reliability of this approach, field interviews with two retired chiefs, three current chiefs, three subchiefs and twelve elders were conducted in three locations where there has been fluctuating population movements over the past thirty years. These are Jilore, Mwahera and Sokoke. Over and above the reason of fluctuating populations, the locations were also selected so as to capture the problem of populations downpipe from the Sabaki Waterworks, population exploitation of and relationships with wildlife and the Arabuko Sokoke Forest and the privatisation of nominally public lands by settlement.

The second problem is the extremely mobile splintering of households first, during any year; second, during major droughts and third, as settlement schemes are created, since populations seek to exploit different ecological zones in the district for production. These problems are discussed below. The Sabaki- Nguu Tatu Pipeline is considered first in analysing the populations. Later, the Kilifi North Pipeline is dealt with as a sample of the branch pipelines.

According to field interviews, before construction of the Sabaki Waterworks, only five households lived all year in the Lango Baya sublocation of Jilore location. In 1993, there are 270 households with a population of about 4,000 people found there. Two hundred and nine households are splinters of old households which used to live there in the 1930's and who first moved to Ganda location between 1936 and 1938 to avoid the ravages of drought in Lango Baya (Njaa ya Ndugu Si Mtu - A Brother is not a Human Being!). Ganda location is in the cashew nut -cassava ecological zone while Lango Baya is in the dry livestock -millet zone as shown on Figure 4.2: KILIFI DISTRICT SIMPLIFIED ECOLOGICAL ZONES. From Ganda this group again split households and entered into the Gede Settlement scheme in the 1950's. The motivation this time was to get land in the coastal coconut and cassava zone. They came back to the area once there was work related to the construction of the Waterworks between 1979 and 1982. They have stayed because of the economic opportunities including availability of water. It is members of these Giriama households who have now sold land to the 60 Chonyi households in Lango Baya area. The Chonyi are buying land in the area since land adjudication is apace in their locations and densities are high. Their motivation is not availability of water but availability of land.

On most Kilifi maps and even in current development documents, the area covered by Mwehera location is shown as forest. So is 75% of Sokoke location. Mwahera location with 1,400 households and about 19,600 people in 1993, was settled completely between 1961 and 1965 as an informal "haraka" settlement scheme. The parent households were in Dida and Kakajuni in the high rainfall areas. This was not formally planned settlement but it has not been opposed by the state for in the rest of Kenya, forest land was being privatised in the same manner during the first years of independence. In this location, only 35 households with an estimated population of 490 people, have moved into the area since 1982. They are buying less developed land away from the pipeline. These new buyers are Chonyi, Jibana and Kauma coming from the high density south western parts of the district. The motivation is thus clearly land and not water.

Sokoke location is the third location for detailed field work. The hundred households found between Matano Mane and Bale, (Km. 26 on the Nguu Tatu pipeline) had a population of about 1,200 in 1993, but have been there since the turn of the century. They have split households in Tezo and Roka locations in the coconut and cassava zone next to Kilifi Town. Between Bale and Kachororoni, in the dry livestock and millet zone, there has not been a permanent population since the early 1960's for the upper Rare river, during the dry season, the only source of surface water before the pipeline and all ground water is extremely saline. The surface dams constructed by the Hinterland Programme of ALDEV in the 1950,s, using forced labour, washed out by the sixties forcing populations to move. The area was always used for seasonal grazing by households from the wetter foot plateau in the same location.

Eighty two households, with about 986 people in 1993, have now permanently settled in the area from Tezo, Dzoni and Chasimba in the wetter coastal zone and from Bamba and Mwarakaya in the drier interior. This is the only group where settlement appears to be driven by the availability of pipeline water on the main pipeline. From Kachororoni to Silala there are 75 households who have been there for more than fifty years. They used to get their water from the lower reaches of the Rare River and the Ndzovuni River which are not saline.

West of Ndzovuni River the populations were established by the turn of the century. There is no evidence of the pipeline attracting new populations.

Of the branch lines, the Kilifi North Pipeline was sampled for it traverses some of the more contentious areas in terms of centrally planned land use. In public planning documents, maps and donor project proposals, this area is shown as having county council forest. Yet all the land east of Rare River is being adjudicated under individual title! All of Sokoke location has always been populated this century. Households have split and exploited the wetter coconut -cassava area between the foot plateau and the coastline, farmed cashew and maize in the transition zone and kept livestock in the livestock and millet areas of the north. Since the foot plateau is steep to the north and west, where the Rare river also cuts deep channels, it has appeared to many as if the land was unclaimed and should remain forest reserve. This is far from the truth for two past chiefs, the current one and elders have narrated to the study team how the population historically has exploited all areas.

Starting from Silala to Sokoke Chief's camp, in 1993, there are 200 households with more than 2,400 people. They have been in the area for more than fifty years. These households were such important cattle keepers in this region that the African Land Development Programme of 1938-1961 developed dams and Sokoke town to facilitate their operations as early as 1948. It should be noted that these families are split households from the more endowed areas of the location. From Sokoke Location Chief's camp, established in 1942 to serve the existing population, to the top of the foot plateau there is land belonging to 500 households with about 6,000 people, who live on top of the foot plateau in Sokoke location and in coastal areas of Tezo and Roka locations. They move to cultivate maize on the slopes at various seasons since the trees in the more ecologically endowed areas are mature and maize cannot grow under them. Homesteads are on top of the foot plateau in the coconut -cashew nut -cassava zones. Mainly there are temporary structures in the maize farms. This area is intensively cropped as more than 90% of the land is opened up. It is important to note that on the plateau and up to the edge of the location, towards Kilifi, are found about 30 homesteads with about 3,600 people who intensively cultivate tree crops and move to other zones for other crops and livestock.

The conclusion is then simply that no new people have been attracted to the Kilifi North Pipeline. Intensification of land use has taken place as population has grown with households still practising production systems which depend on different agro-ecological zones. This is not to deny that the piped water has direct impacts in reducing water collection labour and time, increasing the value of land and in the long term, impacting on the health of the people as they reduce consumption of highly contaminated water.

From the field work, it is also clear that many more people than those covered by the six kilometre swath, in the district are beneficiaries of the water provided for various reasons. First, information obtained showed that the people, who live more than three kilometres from the pipelines, take advantage of the available water especially during dry periods. Second, the land use practices are such that households split at different times of the year to ensure that they exploit the different ecological zones where they own land or have usufruct rights. Since they build only temporary structures, the pattern could not be detected by using mapping techniques. From this perspective then it is logical that most of the people in the various sublocations abutting the pipelines benefit from the pipeline water some of the time. This has positive long term ecological impacts on their health for the more distant populations exploit the piped water resource during the dry season when available alternatives are more than likely to be contaminated.

If these arguments are taken into account, significant numbers of the district population are likely to enjoy positive environmental advantages from the water provided. As shown in Table. A.6: SUBLOCATIONS SERVED BY SABAKI -NGUU TATU AND SABAKI -MALINDI PIPELINES and in Figure 5 (main report): PIPELINE AND SUBLOCATIONS SERVED, the sublocations which are covered by the Sabaki- Nguu Tatu pipeline and its branches had a total population of 282,206 in 1989 out of a Kilifi District total of 591,903. This is about 48% of the Kilifi District population. The population of the sublocations served by the Malindi Pipeline, excluding those sublocations also served by the Sabaki- Nguu Tatu pipeline, that is Lango Baya and Makobeni, is 88,425.

In the 1989 census, the population of the sublocations which abut the river and are served by the Malindi pipeline from the Waterworks to Malindi Town was 26,288. It is guess estimated that those who live nearer the banks of the river than the pipeline, about 7,000 people, depend on the river water totally. This guess estimate was arrived at based on interviews with chiefs and water department personnel. During field interviews comments like "why should people walk to the pipeline when they can draw water in the river?", were made by field officers. In any case the various proposals for augmentation will leave sufficient flows in the river to assure the local populations access to water.

It can therefore be seen that the two main pipelines and their branches traverse sublocations which had a total population of 370,631. If it is assumed that 7,000 of these rely on Sabaki River since it is nearer their homes than the pipeline, then a total of about 363,000 people, out of the District total of 591,903 in the 1989 Census had access to pipeline water. This is about 60% of the Kilifi District population. It does not mean that all these people normally utilise the pipeline water all year round. Field interviews showed that in the dry seasons most of the population utilise this water for it is more reliable and less contaminated than other sources.

Augmentation of the water supplied will have positive environmental health impacts on the population of all sublocations of Mombasa District which according to the 1989 census was 461,753 for it will reduce reliance on some contaminated wells, ponds and rivers.

Since there has not been a distribution study of Mombasa district, the study team is not in a position to make further comments other than that it is the unconnected low income groups who will benefit from increased supply from two points of view. First, they cannot afford to buy scarce water and rely on surface or ground contaminated water. Increase in supply is more than likely to reduce the water selling price possibly bringing it within their reach. Second, increase in supply will necessarily lead to increased access by the poor. This will be through individual connections and public distribution points in poor neighbourhoods which generally are the first to loose supply during water shortages. This will positively impact on the health of the poor.

In summary then, the final task on this section is to estimate the population impacted positively by the Sabaki water works in the two districts. It is estimated to be just under a million, approximately 965,000. This figure is arrived at by computing the population in the sublocations served in 1989 and assuming a growth rate of 4% per annum.

4.4. Community Structures

In Sections 4.2., and 4.3. on land use and population, the historical evolution of the social structure and its production organisation was covered. In summary, the majority of Kilifi District population are the Giriama. Furthermore, their paradoxical social -cultural strategy of maximising resource extraction across ecological zones, by building large households, has led them to remain the un-captured peasantry. This denies them participation in the modern transactional economy for the households cannot buy the education, training and capital goods to make them competitive. They are therefore of a low income status.

In an extensive study for the Food and Nutrition Planning Unit of the Ministry of Planning and National Development (Foeken 1989) 150 households in the three ecological zones in Kilifi District were studied as part of a wider study which also covered Kwale District. Each household was visited six times over a two year period. This study stands out as the most systematic on community structure as well as on utilisation of resources by households in Kilifi.

Foeken et. al. found that Kilifi households are polygamous, patrilocal and large with an average of 23 people per household. Only 26% of the households were nuclear and the rest, 74%, were extended households. Significant also was the fact that half of the adult males are not living in the household as they migrate to find work, and the number of absentee males tends to be higher where households are large. These facts reinforce the Giriama paradox adduced before. More than half of the population has not received any formal education. Of the adults, 60% have partially or completely finished primary education. 75% of the women have absolutely no education. Only 10% of the men and 3% of the women have post-primary education.

On average households have 2.7 pieces of land and total household holdings are 3.3 ha. although in the livestock -millet zone the average holding is 8.4 ha. However, about 40% have less than 1.2 ha. in all zones. One third of all land is used for farm crops with the rest on tree crops and in the drier areas for fallow. There is no fallowing in the densely populated and better endowed coconut -cassava and cashew and cassava zones. The scattering of land and its size underscores the fact that the district has passed the slash and burn agricultural frontier. It is poor based on the land resource. Households are therefore not self sufficient on food and have to depend on cash crops, livestock and off farm employment.

However, only 18% of the household own more one or more head of cattle, whilst 41% own goats or sheep. Sixty percent and 54% of the households own coconut palms and cashew nut trees.

Twenty five percent of the adult population is employed off farm, with 42% of all adult males and 7% of adult females so employed.

The average annual income is Ksh. 10,000 per household, 60% percent of which comes from wages, 15 % from livestock and cash crops, and 25% from food production. Significantly, being in the different ecological zones does not seem to make a difference in terms of household income. For all zones and most households survival is depended on wage employment. Close to half of the households therefore live in poverty.

If the production structure is problematic, so is the social control structure. The extended household stands as the social and economic control mechanism. It is dominated by the owner of the homestead who is more than likely uneducated and a believer and practitioner of the diviner's social psychological control model. During field work, the study team explored this issue by asking the elders and Mijikenda officers what the role of the young and educated was. Uniformly the answer was that social control is with the old who use the diviners to control the households. Each function and major decision for the household majority has to be sanctioned by the household gatekeeper, the old man, and the community gatekeeper, the diviner. Thus change is slow whether it is production technology or ideological.

4.5. Cultural Properties, Sites and Monuments

The relevant cultural properties in the area are the Kayas, which are traditional religious sites and historical sites and monuments along the coastal strip. It is estimated that there are a total of 70 historical sites and monuments along the coast, 58 of which have been gazetted as national monuments (NEHSS, 1984). These include the Gedi Ruins, Vasco da Gama Pillar, Jumba la Mtwana and Mnarani Ruins. The built up historical monument sites in the coastal towns and region have already been protected under the National Parks and the Museums. The pipelines do not touch on any of them. There are proposals tied to forestry expansion for protecting the Kayas as shown in section 4.6.7. on planned development activities.

4.6. Population and its Impact

4.6.1. Settlement

Kilifi settlement patterns have been historically determined and populations in areas abutting the pipelines have generally been in the area long before the advent of the pipelines as argued in Sections 4.2., and 4.3.

4.6.2. Agriculture

Agriculture is mainly slash and burn but as argued under land use, this type of agriculture is reaching/has reached its frontier at existing technology. Clearly then land will degrade fast in the future if soil conservation measures are not introduced. Generally the pipeline traversed areas show no imminent erosion. However, areas needing immediate attention are specified under land use, Section 4.2.4.

4.6.3. Poaching

There is extensive low technology poaching for subsistence. This has been systematically documented for the Arabuko Sokoke Forest (Mogaka. 1991.) and significantly for selling to restaurants serving the Malindi and Watamu tourism market. The poaching trade routes stretch to the interior of the district to the areas around the Kulalu and Galana ranches mainly and traverse the pipeline. Since poaching is illegal, the study team could not quantify the amounts. However, local officials know the bicycle routes of the poachers as well as the restaurants providing game meat in the tourism sector. The later would not discuss the game meat sources. It is this Malindi driven poaching which casts doubt on the plans for game ranching in the district.

4.6.4. Pollution

The only pollution seen on the ground was the possible contamination of pipeline water from broken air valve chambers which are used as wells for drawing water as well as cattle troughs and marshes resulting from leaking washouts where mosquitoes can breed and which also create possibilities for other waterborne diseases. Of course spilling and splashing of water at collecting points tends to pool and becomes breeding ground for mosquitoes and snails. These are to be taken care by the rehabilitation and augmentation design. No fertiliser, pesticide or acaricide pollution exists for little of these chemicals are used in Kilifi District where agriculture is underdeveloped.

4.6.5. Charcoal Burning and Fuel Gathering

Historically, much of the study area has been a source of charcoal, especially in the 1970's, when commercial operators came from Mombasa to fill international orders. This was stopped by the Kenya Government. There is no evidence of current charcoal burning or trade for during the field work period, no charcoal for sale was seen. On fuel wood needs of the population, there is no shortage at this time for there is a lot of natural growth in most of the areas along the pipeline other than the south west part of the District, in Chonyi and Ribe areas, where population densities are such that almost all the land is cultivated.

The second variable is the Kilifi farming system which includes trees, mainly coconut, mango and cashew nut trees and to a limited degree citrus species. The wood products of these farm trees provide fuel. Thirdly, along the pipeline and in other parts of the district planting of casuarina for poles is already commercialised. Smallholders have begun to plant this species. After the sale of poles, the remains become fuel wood.

Basically then, there is no shortage of fuel wood that would leadg to major ecological problems. The district's farming system includes production of wood resources for fuel.

4.6.6. Recreation

Poor communities do not usually create extensive infrastructure for recreation. The main recreational activities of the indigeneous Kilifi population is dancing, usually organised in most homesteads or significant ritual places. In general there are no organised recreation facilities in the study area other than school soccer pitches. The Arabuko Sokoke Forest, the Marine Parks and Reserves are available for local populations but given the economic poverty it is doubtful they avail themselves of the facilities. Beaches are still accessible other than in a few places in Malindi, Watamu, Mombasa and Kilifi towns where developers have blocked public access. This is an issue receiving national attention. There, as recognised in the design, is need to create recreation facilities at the Waterworks for workers and the local community.

4.6.7. Major Planned Public Development Activities

4.6.7.1. Dams

Proposals for a dam at Munyu on the Athi River have been in the national water development plans for at least fifteen years. It is supposed to impound water in the upper reaches of the Athi, near Nairobi, to be used to primarily supply water to Nairobi, generate limited amounts of power and support irrigation in limited downstream areas. It is not, expected that this dam will be built in the near term. It will possibly come on stream when the third Nairobi water supply scheme under construction that will draw water from the Ndakaini river, a tributary of the Tana River is exhausted and Nairobi has to look for extra water. Its construction is therefore guess estimated as not occuring before the second decade of the twenty first century.

Construction of this dam will have major effects on the flow patterns of the river especially by assuring dry season flow downstream. This will be a positive environmental impact on the river ecosystem. Secondly construction of the dam, may lead to more systematic regulation of pollution in the greater Nairobi area to assure that the water will be acceptable for Nairobi water supply. Although this will be positive environmentally, it is important that the monitoring of greater Nairobi pollution, especially heavy metals, be systematised now. Thirdly, it is possible the dam will lead to expansion of irrigation activities downstream on the Athi. There will therefore be need to monitor possible pesticide and fertiliser pollution on the river to establish long term trends.

4.6.7.2. Ranches

Several ranches are planned in the area abutting the major pipelines as shown in Figure 4.4: KILIFI RANCHES. These are Weru Group Ranch, which is in the waterworks and intake area, Chakama Ranch, which is upstream of the intake, and Kulalu and Galana Ranches which are upstream also. Giriama Ranch, almost in the middle of the district is the other one. Weru group ranch is bedeviled by quarrels about membership, solvency and management problems to such an extent that it is doubtful it will ever develop as a group ranch. Two private groups are making offers to different factions within the group ranch with the objective of buying it and making it into a private ranch. The judgement of district officials was that this is not probable in the short term. Consequently no operations with environmental impacts are expected from it for little ranching takes place now.

Chakama ranch is owned by a company with 43 shareholders. Four years ago it went into a joint venture with an American multinational to set up extensive irrigation of bananas for export. Since then the American multinational has gone bankrupt. The proposals for irrigation with water from the Sabaki River is therefore currently a non-starter, for financing was to be external. However, since they have irrigation rights based on flood water abstraction of the order of 25 cubic meters per second, their future plans and operations should be closely monitored as extraction of this amount of water during normal or low flows would have a major environmental impact. Monitoring Chakama ranch long term plans, is important for the difference between normal flow water rights and flood flow rights is often imperfectly understood, and the owners may try to develop irrigated operations upstream from the intake not according to the water right they hold.

Kulalu and Galana ranches are run by the Agricultural Development Corporation, a government parastatal. They estimate that they only take about 1,000 cubic metres of water daily from the Sabaki River for Kulala, as Galana, the bigger ranch, has a lot of surface water sources. This amount is set to be reduced as Kulalu develops its own preferred surface water sources. On Kulalu, there was a lease for 100 acres of irrigation which was terminated at the beginning of 1993. There are no plans for irrigating on these ranches in the future. Their key proposals are to go into game ranching. A proposal for a project costing Ksh. 300 million plus has already been put to the Commonwealth Development Corporation. Given the macro-economic pressures to divest parastatals, it is not likely that this project will proceed in the near term. Besides the ranches already offer very lucrative sources of subsistence poaching and market poaching for Malindi tourist culinary exotica.

4.6.7.3. Irrigation

In the middle reaches of the Athi, in Machakos District, it is estimated that close to 5,000 ha. are irrigated for horticultural crops and flowers by a number of small scale farmers and a few companies. It is not expected that this will expand for private investors see other areas in Kenya and Tanzania as better sites for expansion of the production of these export crops. In any case the major source of Sabaki River low flow is not the Athi, where they are taking irrigation water, but Tsavo River. Of special concern to the Kenya Wildlife Services is the irrigation activity concentrated on the Athi Rivber between its branch, Mutito Andei, and Tsavo East National Park. There are two ecological issues here. One is in assuring that a stretch of Tsavo East Park receives low season flow from the stretch of the Athi river before Tsavo river contributes its waters. The second is in minimising clearing on the western bank of the Athi river so as to preserve the integrity of the park on the eastern bank. Kenya Wildlife Services is discussing these issues with the farmers. It has proposed that a two kilometre swath of the Western bank be left uncleared. This would however marginalise many of the small scale irrigators.

On the Sabaki river, there is a private 300 ha. irrigated banana plantation on land leased from the Agricultural Development Corporation, downstream from the intake. This scheme has lost significant portions of its plantation as the river changed its course in early 1993. They do not plan to expand. Further downstream is a small 20 ha. orchard growing grapes along the Sabaki river bank. The owner is moving to an area abutting the pipeline in the interior for the grapes performed badly on the Sabaki bank. The Coast Development Authority has made proposals to the Kilifi County Council to get land on the north bank for irrigated seed production and pineapple growing. Their application is for less than 500 ha. The site is downstream from the intake. The Coast ASAL Development project is planning 10 small irrigation schemes on yet un-designated areas (Coast ASAL, nd.). The Smallholder Irrigation project of the Ministry of Agriculture, funded by the Dutch Government, is to irrigate 80 ha. in Chakama location.

4.6.7.4. Water Supply

The biggest water supply project, apart from the subject of this study is the Malindi Water Supply, which uses the same waterworks, and is being financed by German aid funds (Kilifi DDC. 1993). GTZ has for a long time operated the Kilifi Water and Sanitation Programme (KIWASAP), which has assisted in construction of wells, expansion of subsidiary pipelines and perhaps most importan,t has trained communities in water technologies and hygiene. In the short term the programme is to construct the Kapecha pipeline and to rehabilitate the Bamba pipeline and construct water pans in Ganze division. Its previous work was concentrated in Bahari division (Kilifi DDC, 1993). The Coast ASAL Development Project is set to develop some limited water supply for livestock in Ganze Division. The Water Resources Assessment Project, funded by the Dutch Government, which is a planning project, is currently operating in Kilifi and will in the long term indicate the potential water resources of the District.

4.6.7.5. Mining

Kilifi District has always had limited mining for various minerals eg. iron, marble, limestone etc. There has been a proposal for a cement factory in Kaloleni Division (Kilifi DDC. 1993). This is opposed by environmentalists in the district for it could destroy the Pangani area limestones. The company has, as of the District Development Committee meeting of 26/5/93, stated that it is relocating. Clearly, if it proceeds with the cement factory, not only will there be environmental impacts in terms of mining for the resource but considerable amounts of water will be taken from the pipeline. Bamburi cement factory has existed in Mombasa for a long time. Over the past twenty years it has developed a systematic land reclamation system which is so successful that it has become a tourist attraction although its dust pollution is still a problem. There is no doubt that its future expansion will be in the framework of rehabilitating the land in environmentally acceptable ways. It needs to improve its dust collection methods.

4.6.7.6. Forestry

Under the National Forestry Masterplan, jointly funded by the Bank, FINNIDA and ODA, Kilifi District has developed its forestry masterplan (Kenya Forestry Masterplan, 1992.). It proposes to set aside an extra 120,000 ha. of natural forest reservation. Table. C.1: PROPOSED FOREST RESERVES IN KILIFI DISTRICT and Figure 4.5: PROPOSED FORESTS IN KILIFI DISTRICT shows the proposals. The existing Arabuko Sokoke Forest Reserve is shown in Figure 4.6: LOCATION OF ARABUKO-SOKOKE FOREST RESERVE IN KILIFI DISTRICT. The proposals are environmentally significant since they will protect some important local watersheds, protect cultural areas, mainly Kayas, thereby assuring sources of medicinal plants and assure biodiversity. However, the study team noted that assumptions about availability of natural forest areas in Sokoke, Vitengeni, Mwahera and Kauma locations are not realistic given the numbers of people actually on the ground as shown in the sections on population and land use. For the Arabuko Sokoke Forest, the only gazetted forest in the District, Kenya Wildlife Services and the Forest Department have already agreed to develop the forest for tourism for it is close to the tourism centre of Malindi. This is part of its wider concern with integrating back beach tourism with wildlife (KWS. 1990).

4.6.7.7. Fisheries

The only major planned project is the joint project on interactive and adaptive research on fisheries to be undertaken by the Kenya Wildlife Services and the Kenya Marine Fisheries Research

Institute. This will develop strategies for utilising marine areas for tourism and fisheries in ecologically sound ways. The Kwale -Kilifi Development Programme, funded by IFAD, is supporting artisanal fishing by training in fishing and boat repair; machinery repair; and institutional support to the Fisheries department.

4.6.7.8. Manufacturing

Two export processing zones are proposed for both Mombasa mainland and southwest Kilifi. Their environmental impacts have been assessed positively. They will draw water from the greater Mombasa supply system. There is no systematic data to show forward plans for factories in Kilifi. However, it is expected that the spill over from Mombasa will be into Kilifi District especially on the Mombasa -Nairobi Road axis in the south west part of the district and on the Mombasa -Kilifi Road axis. The Kilifi District Development Committee has an active programme of environmental assessment of all factory proposals. Strengthening it will assure future monitoring of environmental impacts.

There is a proposal for a sisal estate in the Kibwezi area which would need 6,000 cubic meters of water daily for paper pulp making. This proposal has been around for more than ten years. If it ever comes off the drawing board, a serious environmental assessment will need to be made for such processing operations will generate heavily polluted waste water.

4.7. Fresh Water Supplies and Impacts on Health

There are three hospitals in the district, forty dispensaries and six health centres. These services are very unevenly distributed and large sections of the population have little access to them.

The most important endemic diseases in Kilifi District are malaria, bilharzia and diarrhoea (Katui-Katua et al, 1985). Studies in Kilifi District (Wellcome Trust) show that disease patterns vary considerably from one location to another. The ongoing KEMRI/JICA work is highlighting the need to better understand and identify causal agents. The principal causes of morbidity in the Kilifi and Mombasa districts are shown in Table. 5 (main report): PRINCIPAL DISEASES IN KILIFI AND MOMBASA DISTRICTS 1986, 1987.

Annual totals do not provide a clear indication of trends in water-related diseases. For example, the total number of out-patients diagnosed with diarrhoeal diseases at the Coast General Hospital in 1981 was 53,594. This fell to 27,461 in 1987, and in 1991 rose to 29,174. However, 1981 was a very dry year and it is thought that many people were obtaining water from depleted, contaminated sources. In Malindi, there is a very seasonal and intense diarrhoeal disease problem in the wet season when the poor town drainage is unable to cope with the rainfall. This is coupled with heavy population density, especially in the unplanned settlements without sanitation infrastructure.

There is little evidence to show that there will be any significant change in disease incidence which is related to water. Although water-borne diseases are of great importance, many factors contribute to their transmission and impact. Enhancing supply is a prerequisite for reduction in disease problems, but practices such as poor storage and handling within the household units are more important. Water is rarely boiled, and during acute shortage periods, traditional wells and dams are being used for consumption. These are usually contaminated. In Mombasa, seepage from pit latrines, that exist in close proximity to wells, is known to occur (Ministry of Health, pers comm.). Dams in the hinterland have also been tested and are heavily contaminated (Katui-Katua et al,1985).

It is clear that the link between water supply per se and the incidence and intensity of disease and parasite problems is insufficiently known to provide a basis for estimating the impact of improved water supply. Other, more important factors are: the use of water, storage, sanitation, personal habits and attitudes. However, isolated events such as cholera outbreaks in Kayafungo and Bamba areas, in the early 1980's, during the driest periods, suggest that surface water sources used at these times were probably contaminated. The close proximity of shallow wells to pit latrines in Mombasa apparently provides a link in the faecal-oral routing of some diseases. An estimated 70% of all Mombasa residents use pit latrines, 20% have septic tanks. Only 10% are connected to the mains sewerage system. Finally, other diseases such as respiratory diseases will continue to cause high morbidity in rural areas.

Health benefits usually rely on high rates of water usage that are typically provided only by household connections. There is a sharp decline in the quantity consumed when the source is outside the house or compound, and there is a direct relationship between distance to water and consumption per capita (above minimum requirements). Water supply alone is not sufficient to mitigate against disease, but it is recognized that it is essential to "..provide adequate quantities (of water) near to the home to encourage and facilitate regular washing by all." (Katui-katua et al, 1985). Hygiene education, improved sanitation, disposal of waste water and enforcement of regulations are other essential inputs.

Kilifi District water resources are only now being comprehensively studied by the Dutch funded Water Resources Assessment Programme. The situation described by the Appraisal Mission on the Kilifi Water and Sanitation Programme, that there was no data to evaluate the impact of water on water borne diseases still obtains (Katui-Katua.1985, KIWASAP 1991, various). It is not possible to establish the impacts on the health of the population as a result of supplying fresh water for the basic data on the health of the district is missing. Table 6 (main report): KILIFI DISTRICT: NOTIFIABLE DISEASES 1981 TO 1992, shows the diseases which by law have to be reported. There is no pattern to the data.

From discussions with health, water and administration field personnel and previous WHO work, (WHO/UNEP. 1982.), the study team concludes that the majority of the people of the district have mixed water strategies whereby they use pond, pan, well and river water if it is nearer their homes than piped water. Consequently, it is unrealistic to expect the impacts of piped water to be clear. There is a second data collecting problem. It is estimated that only 20-40% of the district population have at one time or other attended a health facility. Most of the district population get their health needs taken care of by the traditional medicine system. Consequently it would be impossible to develop realistic parameters for the impacts of an improved water supply system. The developed pipeline supply, as argued elsewhere, occasionally reached about 363,000 people or 60% of the districts population in 1989. Since this coverage is episodic, it is not possible to conclusively show its impacts. As the WRAP data becomes available and sets up a baseline, it will be possible to better specify these impacts in the future.

Water is however a very definite "felt need", due to the district's semi-arid nature, and improved supplies undoubtedly produce benefits in terms of time savings and reduced physical effort. For example, at present women have to carry water up to 12 km. in the dry season in the Bamba area and all non-piped sources have been determined to be heavily contaminated.

One of the key activities in the district is the water hygiene programme of the Kilifi Water and Sanitation programme which has been operating since 1988. It seeks to improve handling of water in the home and at limited sources. In the long term, this activity, more than perhaps pipelines, will have positive health impacts for the major environmental health issue are contaminated sources and handling contamination and not contamination of the piped supply.

ANNEXE 5

RESOURCE - ECONOMICS

5.1. Economic Setting

Access to piped water in urban areas in Kenya is estimated to be approximately 70 % of the total urban population which is supplied through metered connections. Approximately 8 % additional to this are people supplied through communal water points and water kiosks. The remaining 22 % of the population has limited access to potable water. In Mombasa per capita consumption is estimated at between 160 to 180 l.p.c.d. This is higher than elsewhere in the country due to the high number of tourist hotels in the coastal strip.

In the study area the majority of people have to carry water over considerable distances from either natural sources which are normally polluted, inadequate and dry for long periods of the year or from water points along the pipelines.

Scott Wilson Kikpatrick & Partners (1971) did some investigative work on future water consumption for areas to be served by the pipeline. This involved developments within areas already served and forecasts for future consumption. It was then estimated that in the early 1970's approximately 1,000 people would be served along the pipeline.

Availability of reliable data from the time of development of the pipeline road is virtually non-existent, hence a comparison can only be done through local knowledge and photographs. The Coast Province Regional Development Plan (1971) indicates that at the time there were no urban centres along the pipeline route and only two 'rural centers', the townships of Malindi and Kilifi. Even at a lower level such as 'market centres' there were only 8 in the whole province and only 21 'local centres' of which the majority were situated close to the coast line. The lack of information and data was due to the scattering or dispersing of the limited developments outside identifiable centres. The table below shows the growth in urban, rural, market and local centres since the early 1970's.

Places such as Lango Baya were never classified even as a local centre until the waterworks was built and other areas along the pipeline such as Vitengeni, Ganze, Ribe and Sokoke only now classify as rapidly growing population areas. There are several small trading centres along the pipeline road; these centres trade mainly in a small quantity surplus cash crops such as fruit and vegetables mainly to generate some funds in order to purchase other household goods and essential items such as cooking fat, sugar, tea, soft drinks and cigarettes. Since many of the family members work in Malindi, Kilifi or Mombasa with transport to and from being fairly good, trading is often done there.

The Ministry of Water Development and Scott Wilson Kikpatrick & Partners produced an Aerial Photographic Mosaic in 1975 over the entire pipeline route. These photographs indicate that there was very little development at the time in the area. Apart from few scattered areas of cultivation (shambas), there was virtually no development whatsoever in the proximity (1.5 km either side of the pipeline road) of the main pipeline for the first 22 km from the Waterworks; at which point there were then a few scattered developments for the next 10 km. It was not until near Sokoke that any development became clearly visible on the aerial photography.

CENTRES SELECTED FOR EMPHASIS IN PLACING INFRASTRUCTURE IN KILIFI AND MOMBASA DISTRICTS 1989

DISTRICT	URBAN CENTRES	RURAL CENTRES	MARKET CENTRES	LOCAL CENTRES
MOMBASA	MOMBASA		SHANZU	UTANGE BAMBURI
KILIFI	MALINDI KILIFI MARIAKANI	KALOLENI MARIAKANI BAMBA MAZERAS	GONGONI MAMBRUI GEDE WATAMU VITENGENI GANZE TAKAUNGU VIPINGO MAJENGO RABAI KINAGONI FUNDISHA HADU NGOMENI MARIAKANI MARAFA GARASHI BARICHO CHAKAMA DAGAMRA JILORE KAKUYUNI	GANDA MSABAHA ROKA MTONDIA SOKOKE DIDA JARIBUNI JUNJU JEURI RIBE JIMBA KIDUTANI KWADEMU GOTANI KIBAONI MITANGONI GONGONI TSAGWA

There is considerable evidence today along the pipeline road that new developments are taking place and have been since the pipeline was built; however, the evidence of development from observation is mainly agricultural (i.e scattered development) apart from main junctions along the road were shops schools and other facilities have been built. Due to large tourism developments, private houses and commercial enterprise by the coastline it is believed that a large number of people whom were previously living nearer to the sea have been relocated further inland either by exchange of property or by selling their property near the sea and purchasing land further inland at a lower price. In view of this it is believed that the population increases along the pipeline is due to relocation of people and opening up of the area by the pipeline road giving people far better access, as well as the more obvious availability of water. The existing availability of water and new concentration of people and infrastructure such as schools, shops, churches and other facilities have been encouraged and developed along most of the pipeline route. It should be noted that most of the people along the pipeline road are sub-sistence farmers and rely mainly on rainfall for their crop production rather than on water derived from the pipeline.

The fact that a considerable number of small holdings have developed in the project area due to or because of the construction of the pipeline indicates there is a need for an evaluation of environmental impacts and of environmental assets which is different from the idea of sustainable development. The project despite being an efficient development with efficient policies still requires some form of valuation. Little or no impact assessment has been done previously in the area, however if transfer of resources (i.e extensive development in the area) are made then what will be the future benefits being lost for the sake of present gain. The majority of the people living in the study area are subsistence farmers; this is not a sustainable form of development. Since most of the people in the project area live their lives from hand to mouth suggests that the rate of resource use is greater than the rate of resource regeneration. With current population growth in the area, an increase in infrastructure will automatically follow, which may in the long run have a positive effect on the surrounding environment as more goods and services become readily available.

Due to the spread out nature of the developments along the pipeline road most of the facilities aree not immediately visible from the road itself. The latest Kilifi District Inventory of Infrastructure indicates that there are 76 primary schools and 4 secondary schools in Ganze division; and 87 primary schools, 17 secondary schools and 6 service and training institutions in Kaloleni Division. In 1970 there were only 442 primary schools in the whole of coast province.

Coastal region economics falls predominantly into three main categories:

i. Primary sector (this includes agriculture, fisheries, forestry and mining)

ii. Secondary sector (this includes manufacturing, construction,distribution and services)

iii. Tourism

This categorizing has been based on the fact that there are two distinct economies in the area; the first being that of the small subsistence farmer, herdsmen and fishermen which embraces over 90 % of the people outside Mombasa, equivalent to 70 % of the total population. The second economy covers the balance of the population which includes the commercial sectors such as commercial farmers, ranchers, industrial and service occupations.

It can be argued that nationally, the tourism sector surely must be the most important sector; however, it employs only an estimated 5 - 8 % of the population.

The fact that the subsistence agricultural sector embraces such a large portion of the population should indicate that government programmes should concentrate more in this sector; this has not been the case to date. Although recent reliable figures are not available the following government development expenditure per sector can be estimated:

Primary Sector:	5 %
Social services:	60 %
Infrastructure:	35 %

Household economics is determined to a large extent by the potential of the agro-ecological zones. In the project areas the relatively harsh climate has resulted in mixed subsistence farming and livestock activities.

In addition to the general environment, seasonal out-migration of males seeking outside employment affects the occupational structure. It is estimated that there are only approximately 30 percent of male-headed households in the project areas with cultivation as their main economic activity compared with 60 percent of households headed by women.

Most of the households practice subsistence activities. As such markets tend to cater to local needs only. Information gathered from talking to local people shows that most of the areas do not genertate any surpluses, from livestock or crops. Cash cropping is thus seen by the subsistence farmer as a high risk activity.

The are indications that in the study area the main constraint affecting households is food security, and the main production constraint is cash, especially for items such as tools, labour and other production inputs.

The percentage distribution of household cropping areas, are currently estimated as follows:

Acres	**Percentage of Households**
1 - 5	58
5 - 10	28
10 - 15	7
15 - 40	5
40+	2

Living standards, infrastructure and income will only increase in the study area with the introduction of soil conservation practices, row cropping, water harvesting, mulching, agro-forestry, and the use of improved seed and crop rotation.

People who lack water often indicate that they would be more than willing to pay for improved water facilities, in reality this rarely works. One of the main reasons for this is that the people living in the area believe it is the Government's responsibility to supply water; this is irrespective of operating and maintenance costs which rarely is even considered. (It should be noted that in years of drought most people cannot properly feed themselves, never mind paying out for water supply). Secondly, water is a pressing need (especially to donor agencies) but not a prime requirement for the rural people. In rural areas such as this, the most predominant (pressing) requirement is food security and cash, not water. Thirdly, to the rural people, when a aid agency helps towards the improvement of water and sanitation supply they feel it does not belong to them but to the donor. This fact discourages proper use, and maintenance of any equipment and little attention is given to operating costs.

5.2.1. Agriculture

5.2.1. Agro-Ecological Zones and Land Use

There are three different agro-ecological zones in the study area. These are described in summary below (Jaetzold and Schmidt, 1983).

Coconut-Cassava Zone (L3)

This zone has a medium to long cropping season, intermediate rains and short growing season thereafter. It has good yield potential for crops with an average yield of over 60%. First rains usually starts mid-April with best yield from hybrid maize, white sorghum, mat sorghum, cowpeas, sweet potatoes, sunflower, chilies, soya-beans and nearly all vegetables. Crops which can be grown the whole year are coconuts, bananas, bixa, mangoes, papaws, avocados, sisal, guavas, senna and castor with fair yield potential crops with an average of 40-60% of the optimum. During first rains rice in seasonal flooded grasslands, beans and sim-sim. Second rains, usually start mid-October with best yield from sorghum, sweet potatoes and green grams.

There is potential whole year agriculture for cassava, citrus, pine-apples and cashew nuts. Poor potential areas have 20 - 40% potential yield. Second rains are only good for coast maize. The coconut-cassava zone has nearly no grasslands for pasture and forage, although there is some grazing under coconut trees. Carrying capacity is 0.7 ha/LU, with Mimosa pudica 0.4 ha/LU, down to about 0.15 ha/LU feeding Napier or Bana grass and legumes.

Cashewnut-Cassava Zone (L4)

This zone has a short cropping season, intermediate rains, and a weak very short rains. It has good yield potential during first rains usually starting mid April. The main crops are sorghum, bulrush millet, cowpeas, green grams, sim-sim, sunflower, soya bean and chilies. Whole year growing potential exists for mangoes, castor and sisal. It has fair yield potential for maize, finger millet, beans, sweet potatoes, groundnuts, onions, tomatoes, peppers, okra, and cabbage for the first rains. For the second rains, usually starting mid-October, crops which can be grown are foxtail millet, green grams, cow peas and spinach. Whole year potential exists for cashewnuts, drought resistant cassava, papaws and pineapples. Some marginal crops with poor yield potential during second rains only are coast maize, local maize and sweet potatoes. Pasture and fodder require more than 2 ha/LU on woodland; feeding bana grass and legumes like siratro down to about 0.35 ha/LU. Tsetse fly are found near rivers or thickets.

Lowland Livestock-Millet Zone (L5)

This zone has a short to medium cropping season, and a second season with intermediate rains. Small areas in the zone have as good potentials as zone L4. Cashew nuts are very marginal in this zone. Cowpeas and sim-sim, planted towards the end of the first rainy season do well.

5.2.2. Land Use and Farming Systems

The immediate impact area along the pipeline to Mombasa lies almost entirely within the Cashewnut-Cassava zone, L4. The areas closer to the coast, served by the water subsidiary pipelines fall under the Coconut-Cassava Zone, L3. In general, agricultural land use can be summarised as traditional, with a low degree of modernization. The cultivation of food crops for home consumption predominates (Hoorweg, 1991; Foeken, 1989)). Mixed cropping is the normal strategy. Yields are low. However, the farming system is complex, although land use practices and farming tools appear simple. Slash and burn farming is still employed in some areas, notably closer to the Kilifi Creek area. This form of land use requires long fallow periods which are no longer possible under present population densities, and will have to be abandoned in favour of resource-conserving practices. The farming system employed by any extended family unit typically straddles all three ecological zones described, as a risk aversion strategy.

Average farm size is approximately 3.2 ha., but this statistic conceals the strategy families adopt in owning and farming more than one plot. Households usually have two and sometimes three and four plots in different agro-ecological zones. On average house-holds have 2.7 plots (Foeken, 1989). Plots vary in size down to 1.5 ha. Main crops are cereals, cassava, legumes and bananas. There is only one reliable cropping season, although cassava acts as a food storage crop and is harvested in the dry season. Maize and cassava are the main food crops. Food crops cover 70% of the land in Kilifi district.

In general food production is low and covers only half the family's energy requirements. Only 15% of households succeed in covering their total food requirements. Coconuts, cashews and mangos or citrus are grown by more than half of all farmers, and cover approximately half their farm areas although inter-cropping is normal. Pests and diseases are principal constraints. Mosaic virus is particularly bad for cassava.

There is an average of 4.3 adult labour units per household, of which 1.2 units (25%) is engaged in off-farm employment. Off-farm employment plays a vital role in the agricultural economy of the study area, accounting for two-thirds of household income on average Ksh. 6,560 in 1985. Over 60% of all families obtain income from employment. Less than 10% restrict themselves to farming only. A diversified household economy is the norm, involving off-farm income, through wage employment or the informal sector.

Tree crop and livestock sales provided only Ksh. 1,258 per household in 1985 on the Kenya Coast, and Ksh. 820 in Kilifi in Zone 4. The value of food crops was estimated at Ksh. 2,207 in the wider Kenya Coast and Ksh. 3,815 in Kilifi in Zone 4. The total value of household agricultural production represented a return of Ksh. 2,200-2,900 per hectare in the Kilifi Zone 4 sample (Foeken, 1989). This was equivalent to US $ 137-180.

Even so, some 40% of rural households in Kilifi district live below the food poverty line, although variation in income and income composition is considerable. Location and access to labour markets is of vital importance in determining non-farming income opportunities. There is no significant difference in household income among the agro-ecological zones represented. This may be construed to suggest that most households are living at or near to basic subsistence level. There is very limited ability to create surpluses and invest in human capital (education) and the farming system. Agricultural credit is not available, in practice, and technical support negligible, so agricultural households in the study area have limited scope to make the economic transition to greater prosperity and food security.

5.2.3. Livestock Production

Livestock production in the district is mainly undertaken in the marginal and rangeland areas. The total cattle population of Kilifi district was estimated by the Ministry of Agriculture and Livestock Development at 213,000 head in 1986. In 1988, District Socio-Cultural Profile (Were, 1988) argued that the population was spread out among the divisions as follows: Kaloleni 410,000; Malindi 70,000; Ganze 35,000 and Bahari 10,000. These figures should be treated with caution for it is not clear why the overpopulated Kaloleni has more cattle than other divisions. They may just reflect the easier access to Kaloleni division.

The main breed is the East African Zebu and there are a limited number of herds of improved milk production cattle on some small-holdings and at Vipingo and Kilifi plantations along the coast.

Livestock ownership is particularly skewed, with only 18% of families owning cattle and 41% some sheep/goats. Nearly all households have poultry. There are an average 4.3 cattle and 2.9 sheep/goats per household according to Foeken.

The main constraints facing animal production are:

a. climatic conditions, affecting water availability and pasture quantity and quality;
b. disease, such as trypanosomiasis and East Coast Fever and foot and mouth;
c. poor husbandry techniques that have not improved due to a weak extension service, inadequate and inefficient veterinary services.

With the exception of improved water supply for livestock close to the pipeline, these are not factors that the Baricho project will affect in any way.

5.3. Tourism

Tourism is the dominant commercial sector in Kilifi District and has stimulated activities in all spheres of the economy especially agriculture, manufacturing, road and air transportation, and construction.

There are more than 7,200 hotel beds on Mombasa Island and the north coast to Malindi. A further 800 beds are planned or under construction. This estimate does not include cottages and flats and boarding houses used for tourism.

In 1993, occupancy rates on the coast have fallen 12% by comparison to the same period last year, but is still in excess of 58% overall. The peak occupancy period was 1991, with a an average of 78% room occupancy. In 1992, it fell to 71%, probably due to Kenya's adverse international publicity. The industry has entered an uncertain stage. There is world-wide recession and Kenya's image was tarnished by insecurity and political changes, and strong competition is being presented from alternative destinations for travellers. South Africa has offered a new market, but Kenya's success in capturing this market has been limited by economic and political constraints at home in South Africa. There was a decline in the industry in 1992, and the trend is a further fall in 1993, although sales to agencies housing staff involved in the Somalia and Sudan relief activities will bolster a flagging industry.

The Malindi and Watamu Marine National Parks and the Malindi Marine National Reserve are vital tourist attractions for the industry. The Arabuko-Sokoke Forest is in its early stages of development as an attraction, but is a focus of conservation concern for its unique avifauna. It is an important lowland dry forest.

5.4. Fisheries

In 1992, total fish catch was 1,005 tons as recorded at seven landing stations in Kilifi District. The informal fishing industry is not a large employer. It covers approximately 475 fisherman using 160 boats. However, it is economically important for the total value of catch was Ksh. 22 million in 1992. The extent of the catch that goes unrecorded is not known, but undoubtedly would add significantly to the income, subsistence value and employment from the industry.

There is extensive commercial trawling off Malindi and north to Lamu, in Ungwana Bay. The catch is landed in Mombasa, or processed at sea and transferred to motherships, and it is not possible to identify the catch component relevant to the study area offshore from Malindi. Data on production is sketchy and under-reporting is believed to be rampant.

There is no noticeable trend in total fish catch, at least in the artisanal sub-sector. Production has varied from a low of 629 tons in 1990 to 1,390 tons in 1991. The data may reflect the extent of reporting, rather than accurate production trends, in any case. Netting with fine gauge nets and traps within the estuary of the Sabaki may be important in affecting catch potential.

Sportfishing for tourists and residents is an important sub-sector and there has been a strong growth in the number of registered charter boats operating out of Malindi, Watamu, Kilifi Creek and Mtwapa Creek. There are 23 charter and 10 private game fishing boats in Kilifi district. The main season is August through to March. In 1992, just over 150 tons of game fish were landed. The majority of fish were released after tagging, a trend that is being strongly promoted by game fishing organizations.

5.5. Commerce, Industry and Mining

5.5.1. General Profile

There is limited industrial and commercial development in the study area. The main towns of Mombasa, Malindi and Kilifi form the central economic places, in a hierarchy of urban centres, rural, market and local centres. The economic linkages are weak beyond these, except in terms of repatriation of wages and supply of essential foodstuffs. The main agricultural cash crop production is along the coastal strip, and the hinterland, where the pipeline is situated, is a substantial net food importer. In addition, agro-processing; oil extraction, cashewnut processing, cotton ginning and copra making; is confined to the main towns. There is virtually no saw-milling potential from natural woods in the impact area.

Commerce is typically trading in food crops and consumer trade goods, and follows closely the administrative structure of centres.

Mining is limited to Bamburi Portland Cement (limestone), Vitengeni Mines in Ganze, gypsum at Roka, south of Malindi, extraction of rock for building and decorative use on the pipeline road by Athi River Mining, and the Associated Battery Manufacturers lead mine near Mombasa. Sand and stone, hard and limestone, is locally important but not recorded in district statistics. Other minerals in the study area include limestone in the Jaribuni area and manganese and galena in the Kivara area near Jaribuni, but these are limited in potential. Once water becomes more available it is thought that more mining in the area will occur. The construction industry is also locally important but restricted in its impact to the coastal area; value added accrues in the principal urban areas, especially Mombasa.

Salt production and shrimp farming are conducted north of Malindi, outside the impact area.

5.5.2. The Tourism Sector in Perspective

Although hotels and the service industries are an important employer in the study area, over 90% of the population remains dependent on agriculture as the main economic pursuit. The tourist industry is vital to rural families as an important source of off-farm income.

5.5.3. Charcoal Production

A large area of land lying just west of the pipeline route, and south of Baricho, was an important charcoal exporting area in the 1970's (National Environment and Human Settlements Secretariat, 1984). The area is no longer an important source of charcoal. The study team found no production going on during field work. No evidence of transport vehicles carrying charcoal or firewood from the area was collected. However reports to members of the study team in the field indicate that forest reserves such as Arabuko-Sokoke are now sources of subsistence charcoal and fuelwood.

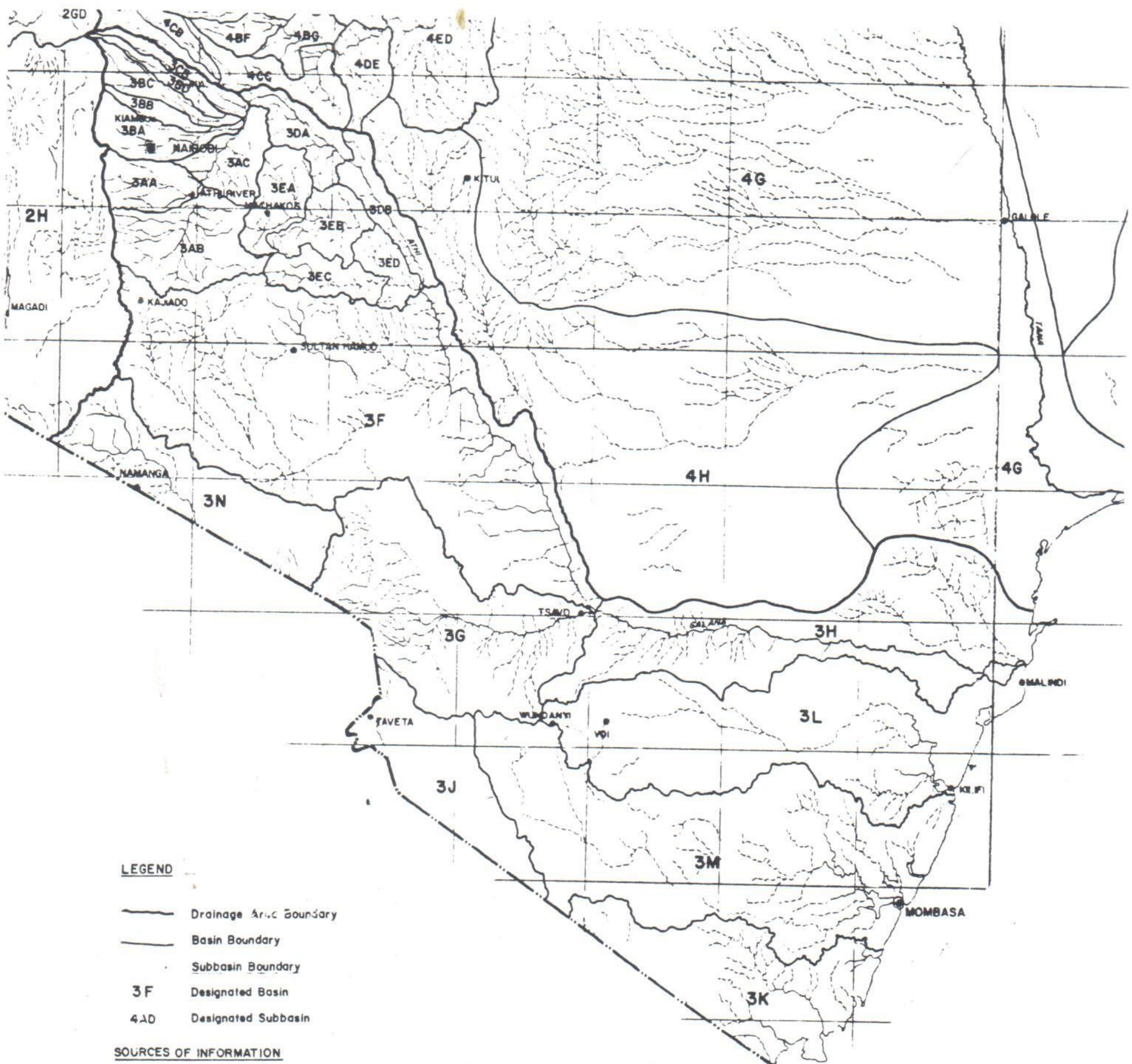
5.5.4. Employment and Incomes

It is possible that 15-20% of the potential labour force of Kilifi District is engaged in wage employment, with a rate of job creation of 8-10% per annum (National Environment and Human Settlements Secretariat, 1984). In the early 1980's over 60% of all employees at Kilifi hotels were from the district, and a total of 74% were from Coast Province (Migot-Adholla et al, 1982). Agriculture provides wage employment for only about 4% of the potential labour force. Locally the

Kilifi Plantations and Vipingo Estates are important employers with a labour force of approximately 3,500.

Off-farm employment is primarily a male activity, involving 60% of adult men (Foeken, 1989). There are few opportunities for wage employment in the farming areas, so those seeking labour must move to sites of work opportunity. Off-farm employment provided an average wage of Ksh. 10,000-12,000 in 1985 (US $ 625-750) in a sample of 324 rural households. An estimated 60% was available for repatriation to families, after housing and subsistence costs at the place of work. Where agricultural production is more than adequate there is less off-farm labour.

About 70% of the income of the district is thought to originate in the coastal belt (Kilifi District Development Plan 1989-1993).

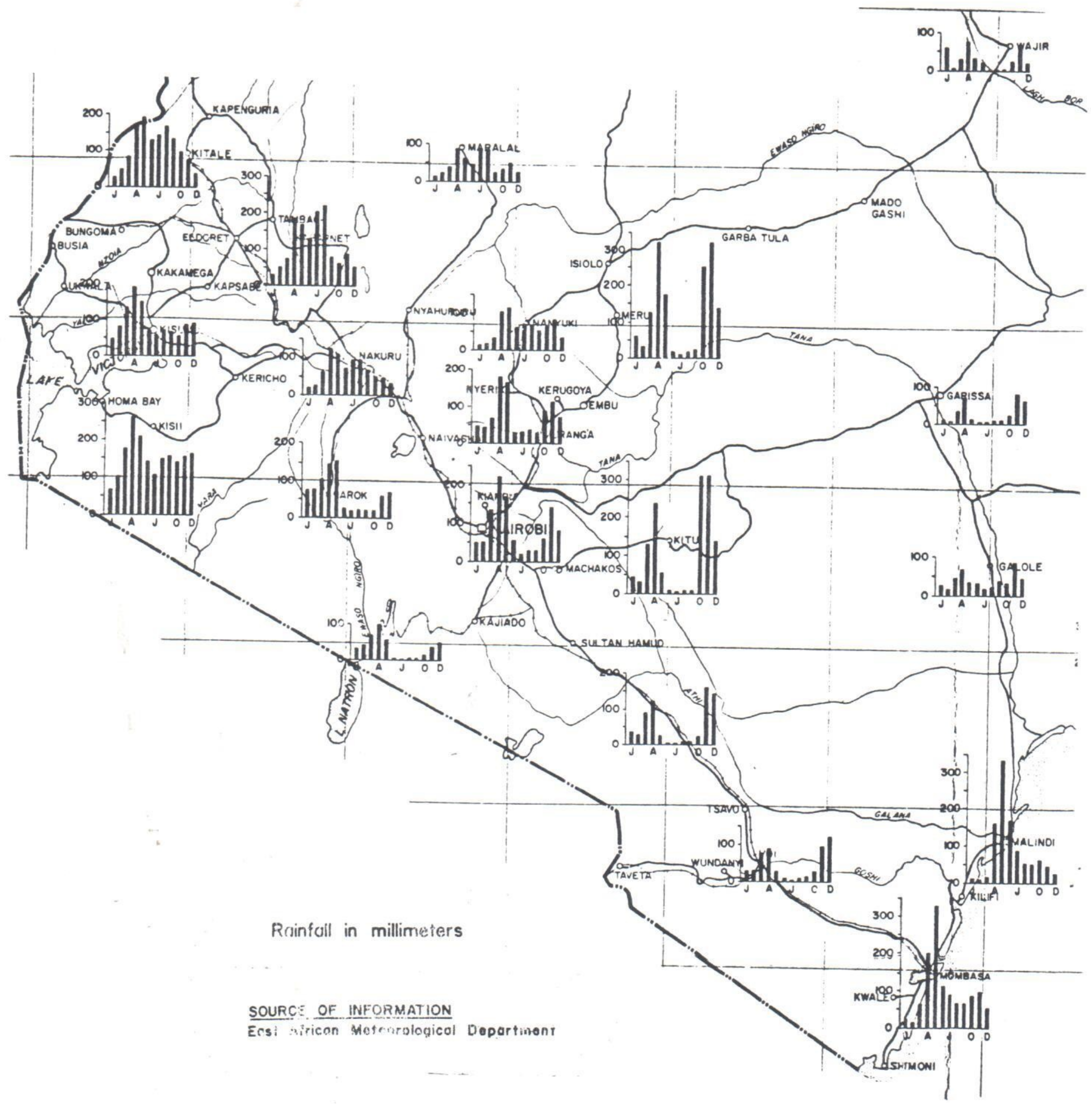


SOURCES OF INFORMATION

1. Water Department drainage Boundary maps at 1:50,000 and 1:100,000 Scales.
2. Survey of Kenya topographic mapping
3. PWD Drawing No. 26006 prepared in 1943

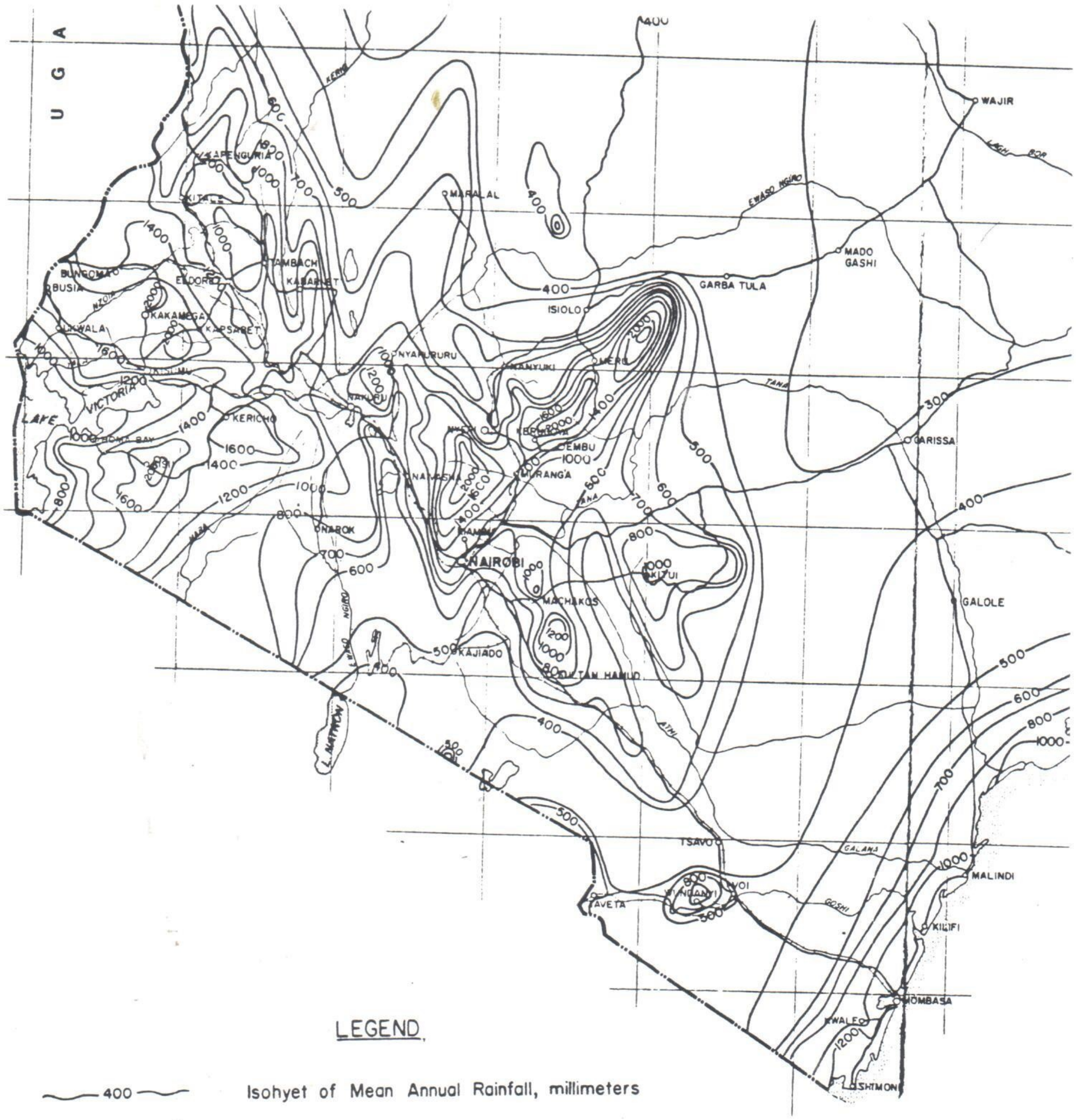
Adapted from Kenya National Master Water Plan, Stage I (Tippetts Abbetts McCarthy Stratton, 1980)

Drainage Boundaries Figure 2.1



Adapted from Kenya National Master Water Plan, Stage I (Tippetts Abbetts McCarthy Stratton, 1980)

Mean Annual Rainfall Figure 2.2



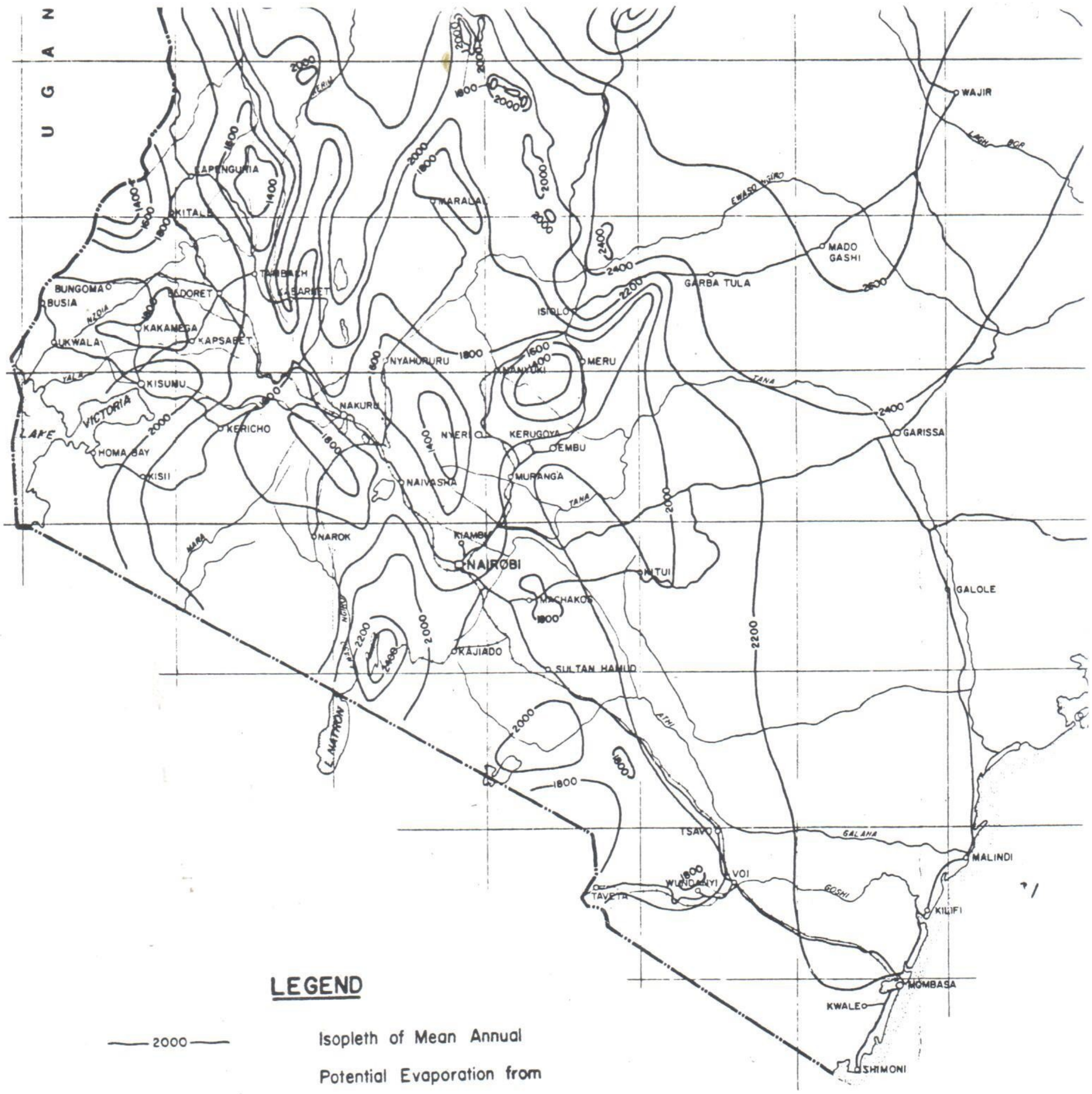
LEGEND

—— 400 —— Isohyet of Mean Annual Rainfall, millimeters

SOURCE OF INFORMATION
Survey of Kenya Maps, 1966, compiled by East African Meteorological Department

Adapted from Kenya National Master Water Plan, Stage 1 (Tippetts Abbetts McCarthy Stratton, 1980)

Distribution of Mean annual Rainfall Figure 2.3



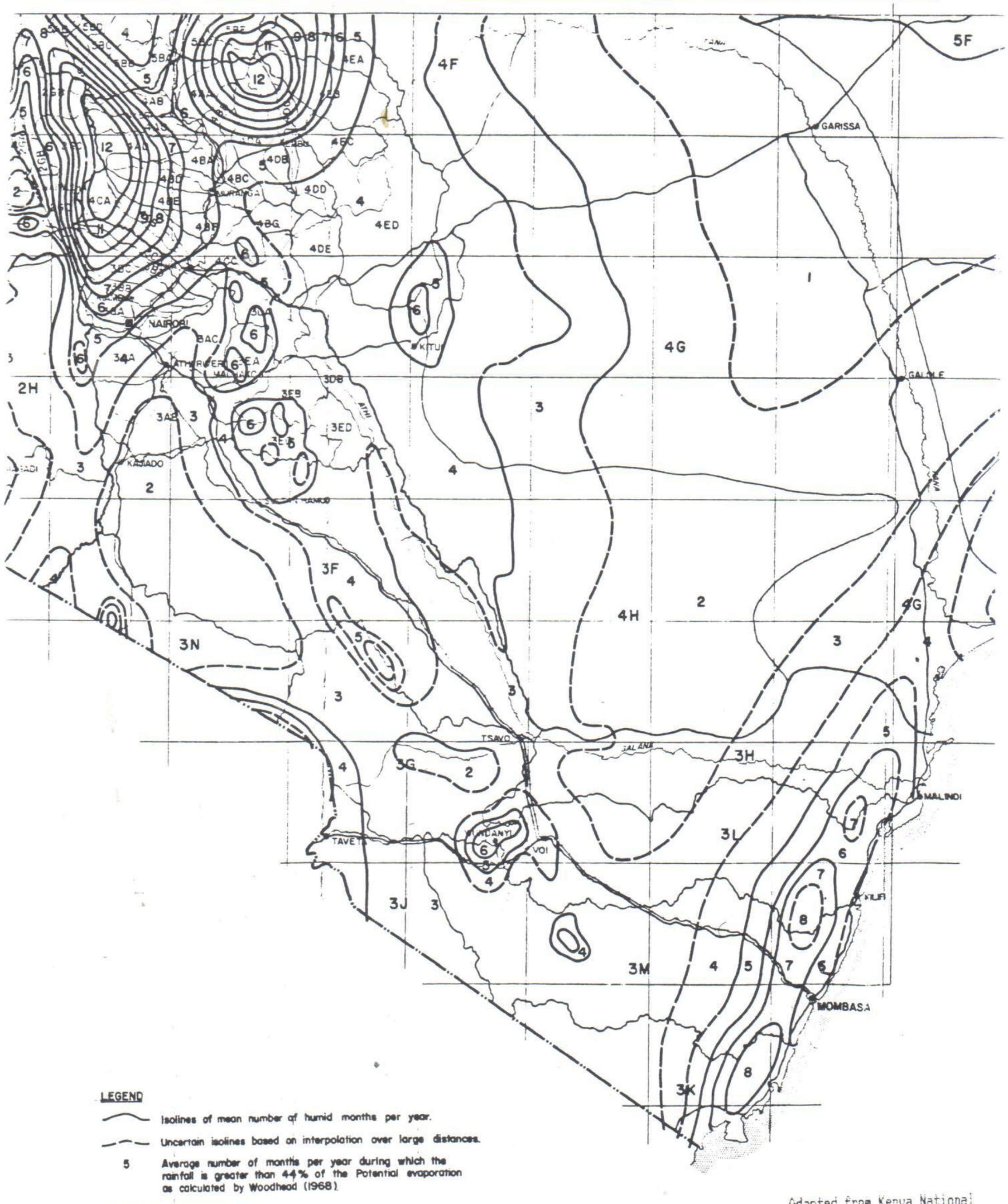
LEGEND

—— 2000 —— Isopleth of Mean Annual Potential Evaporation from Open Water, millimeters

SOURCE OF INFORMATION
T. Woodhead, East African Agriculture And Forestry Research Organization, 1968

Adapted from Kenya National Master Water Plan, Stage 1 (Tippetts Abbetts McCarthy Stratton, 1980)

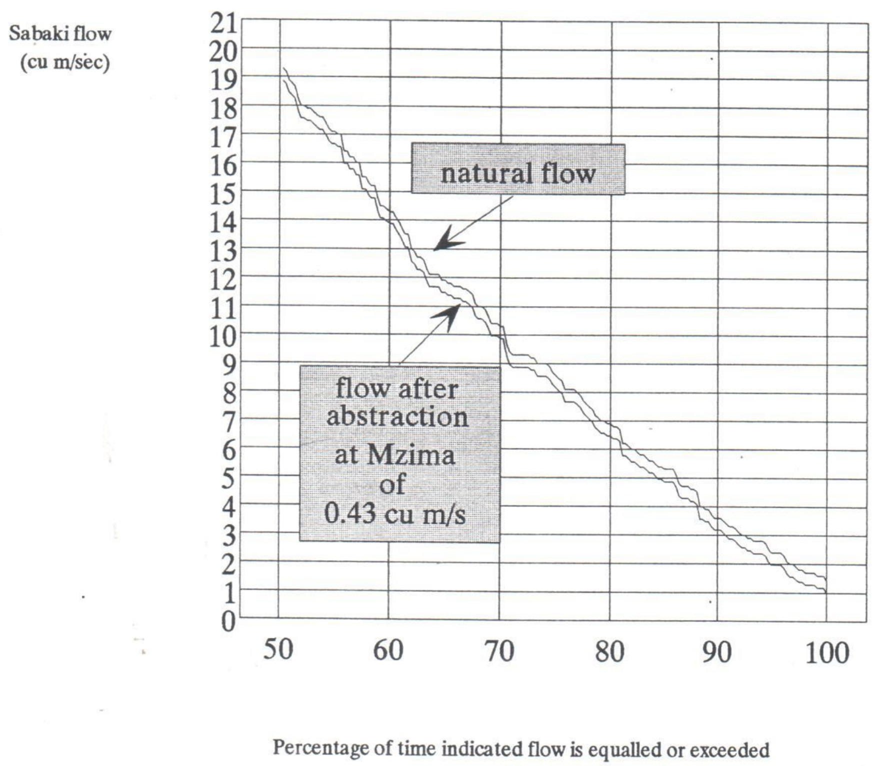
Mean Annual Potential Evaporation Figure 2.4



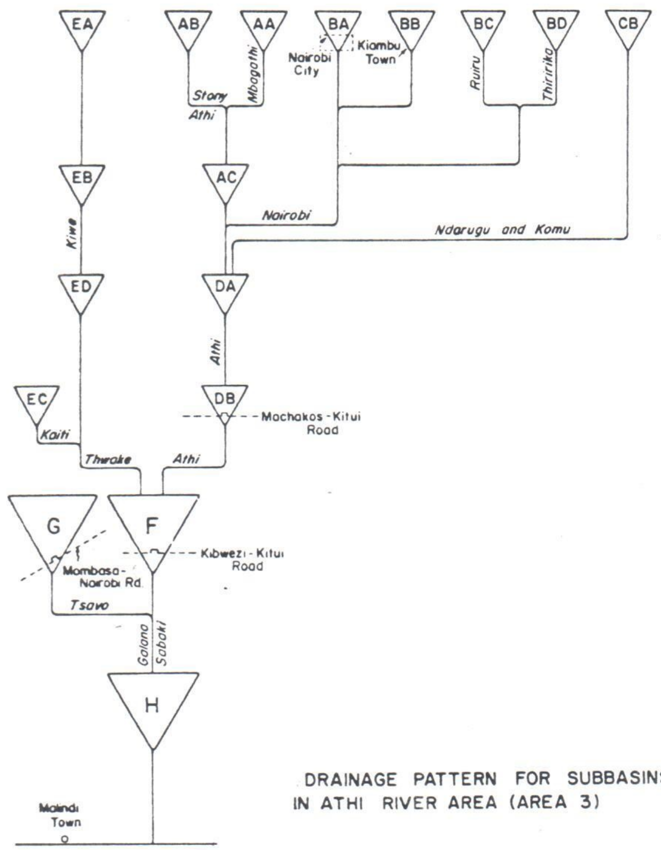
Adapted from Kenya National Master Water Plan, Stage 1 (Tippetts Abbetts McCarthy Stratton, 1980)

Distribution of Humid Months Figure 2.5

Monthly flow duration curve, reconstructed natural Baricho flows

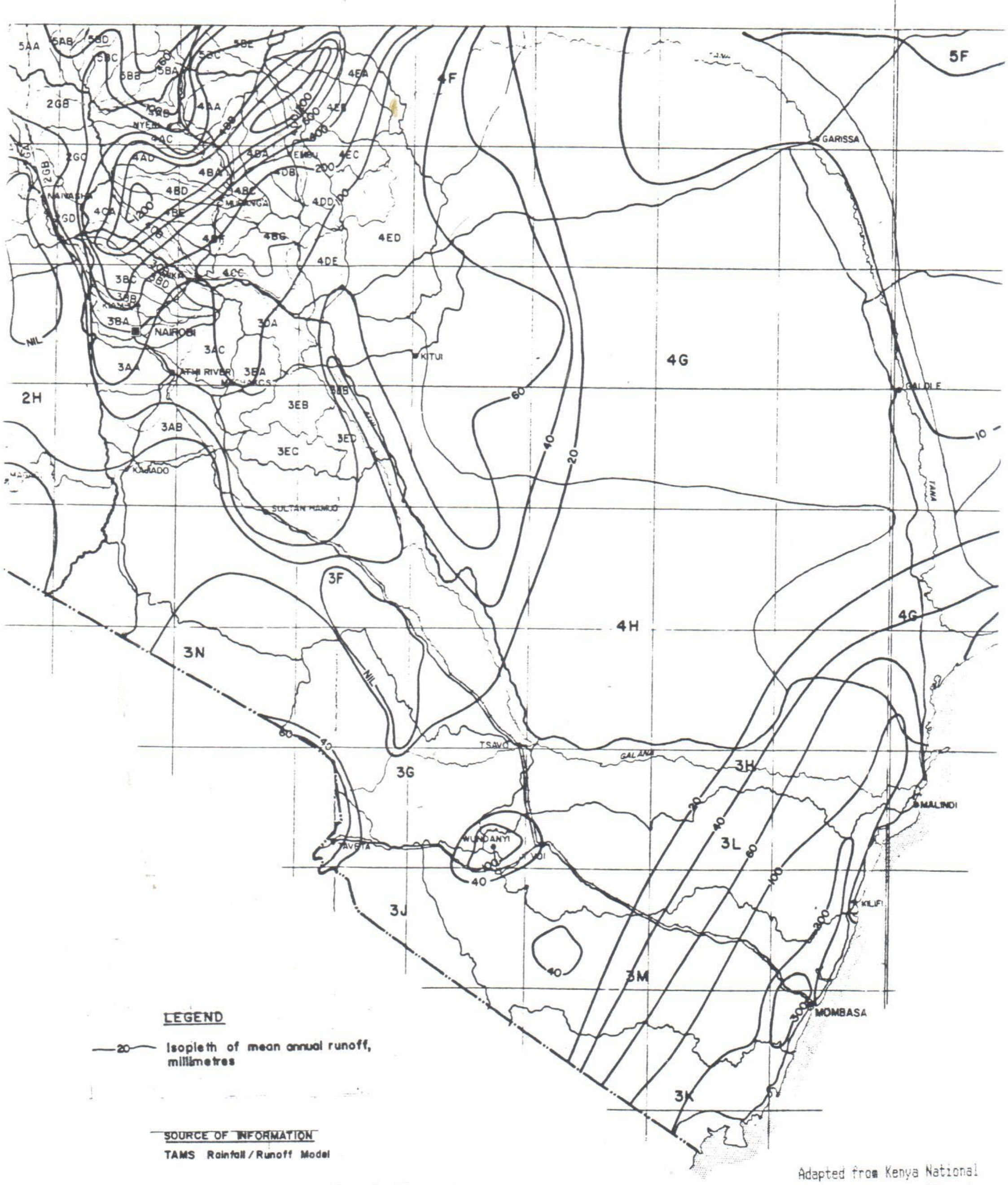


Flow Duration Curves Figure 2.6



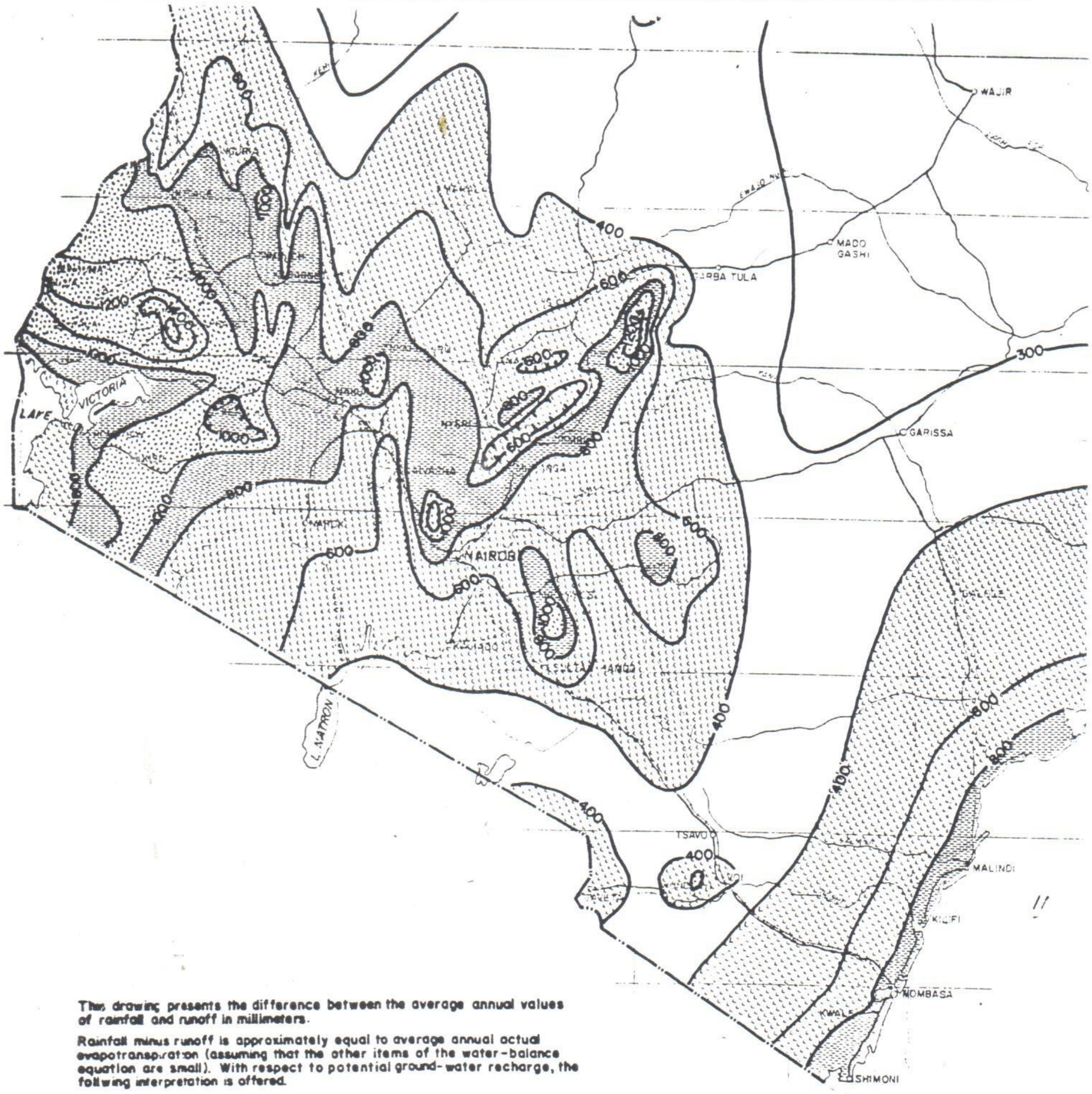
DRAINAGE PATTERN FOR SUBBASINS IN ATHI RIVER AREA (AREA 3)

Drainage Pattern Figure 2.7



Adapted from Kenya National Master Water Plan, Stage 1 (Tippetts Abbetts McCarthy Stratton, 1980)

Mean Annual Runoff Figure 28



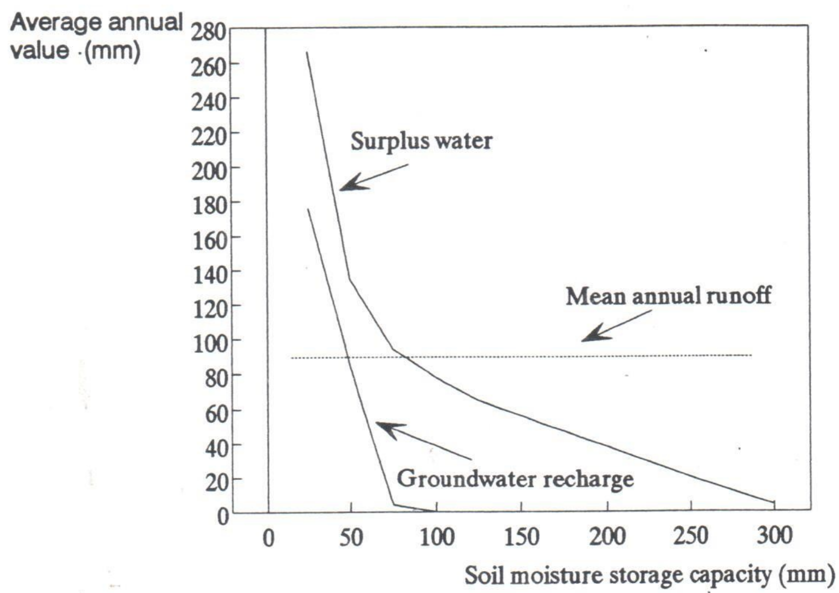
This drawing presents the difference between the average annual values of rainfall and runoff in millimeters.

Rainfall minus runoff is approximately equal to average annual actual evapotranspiration (assuming that the other items of the water-balance equation are small). With respect to potential ground-water recharge, the following interpretation is offered.

RAINFALL MINUS RUNOFF	RECHARGE POTENTIAL
> 1000mm	The highest in the country
600-1000mm	Relatively good
400-600mm	Relatively fair
< 400 mm	The lowest in the country

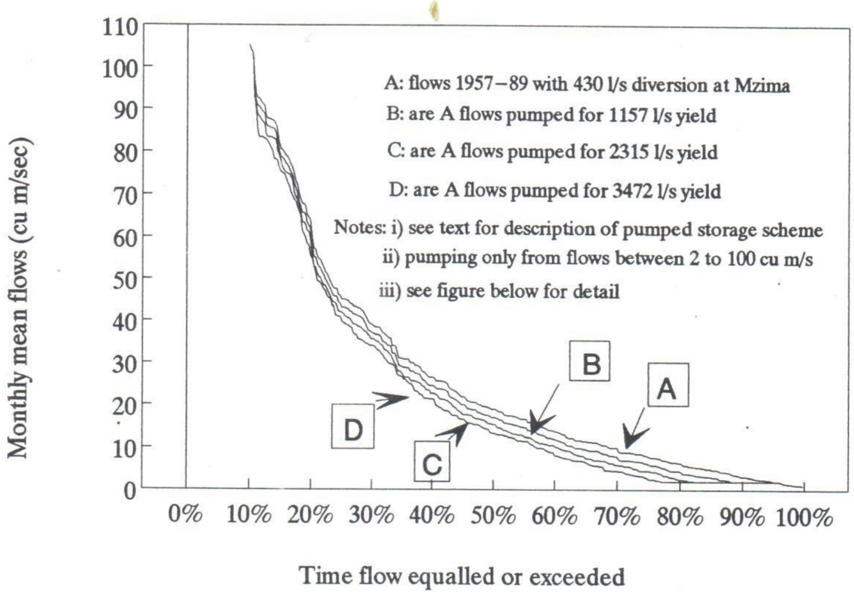
Adapted from Kenya National Master Water Plan, Stage 1 (Tippetts Abbetts McCarthy Stratton, 1980)

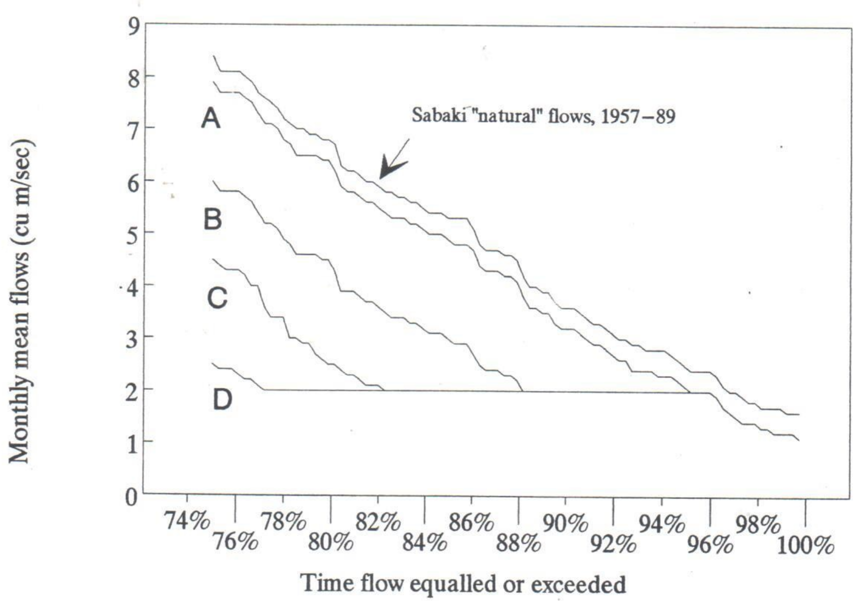
Rainfall minus Runoff Figure 2.9



Water Balance, Baricho Area Figure 2.10

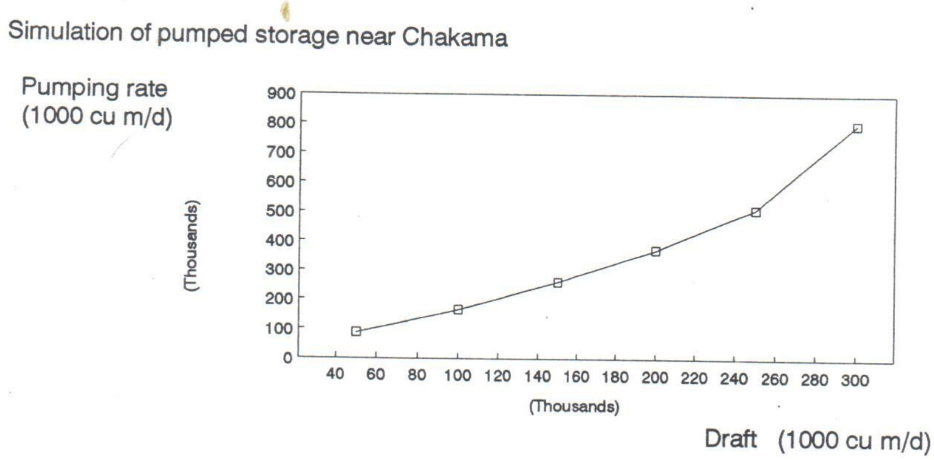
Monthly flow duration curves, Sabaki river near Chakama
–these figures show the effect on the flow regime of a pumped storage scheme



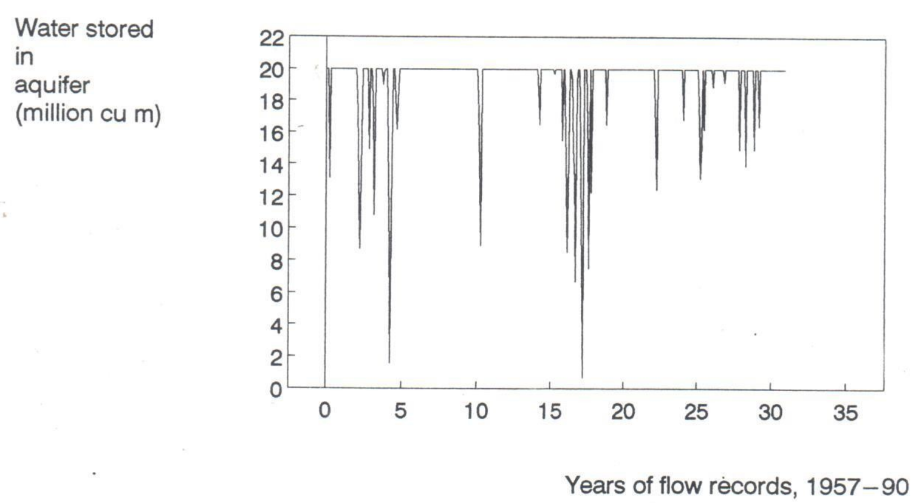


LOWER FIGURE IS ENLARGEMENT OF BOTOM RIGHT HAND CORNER OF UPPER FIGURE

Flow Duration Curves Figure 2.11

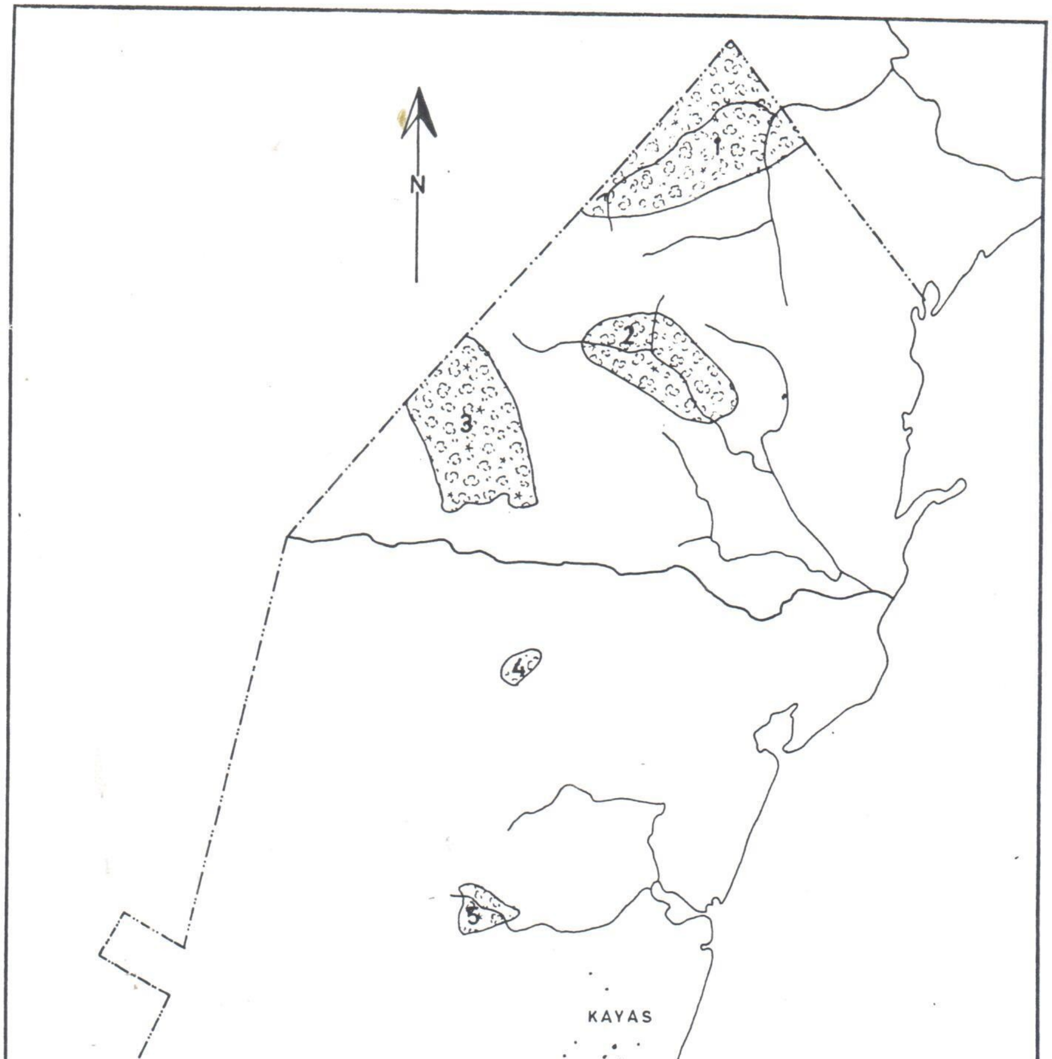


SIMULATION OF PUMPED STORAGE SCHEME NEAR CHAKAMA



SIMULATION OF PUMPING FROM 20 MCM BARICHO AQUIFER AT 333,000 CU M/DAY
(DOWNSTREAM COMPENSATION FLOW = 2.0 CU M/SEC
DRAFT = 160,000 CU M/DAY)

Simulation of Aquifer Pumping Figure 2.12

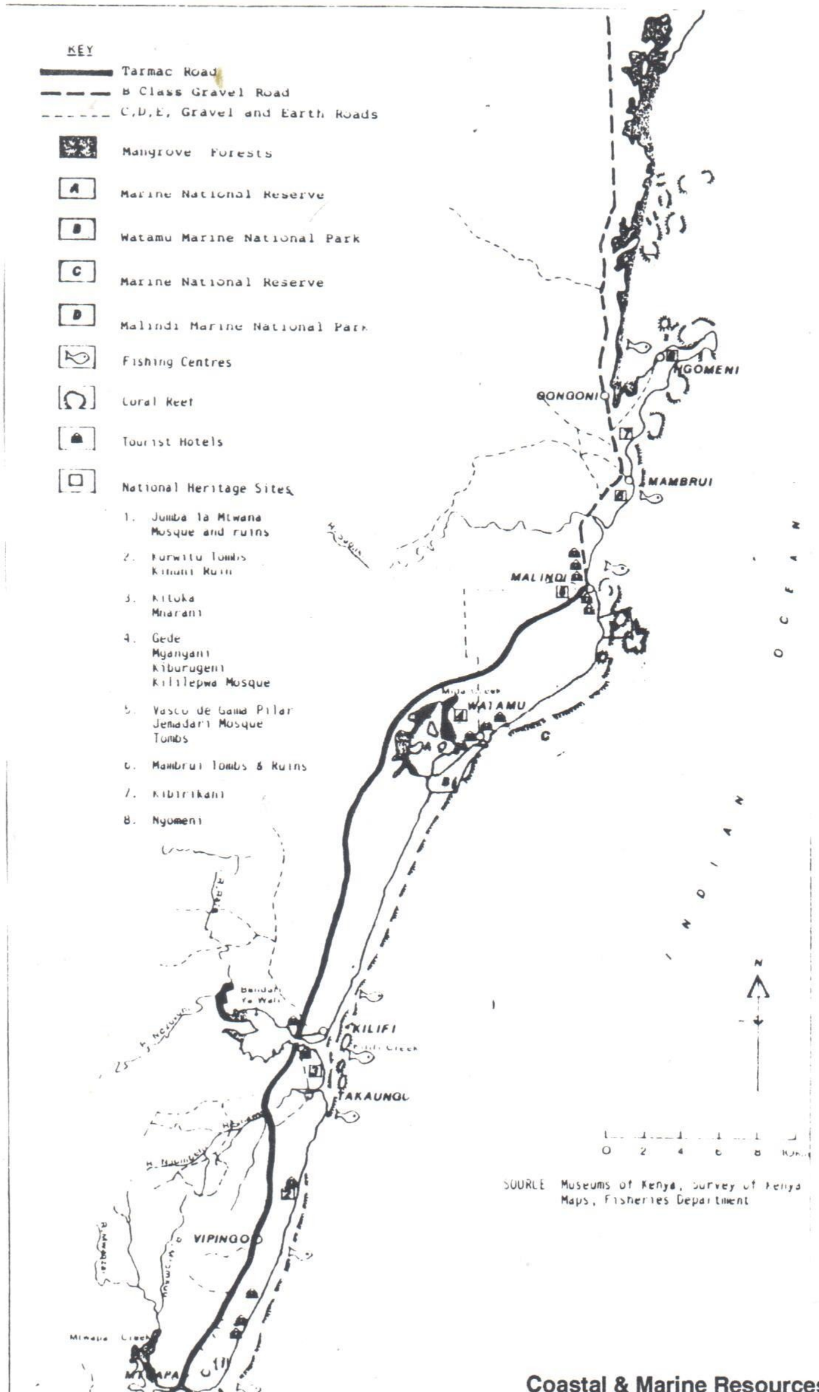


LEGEND

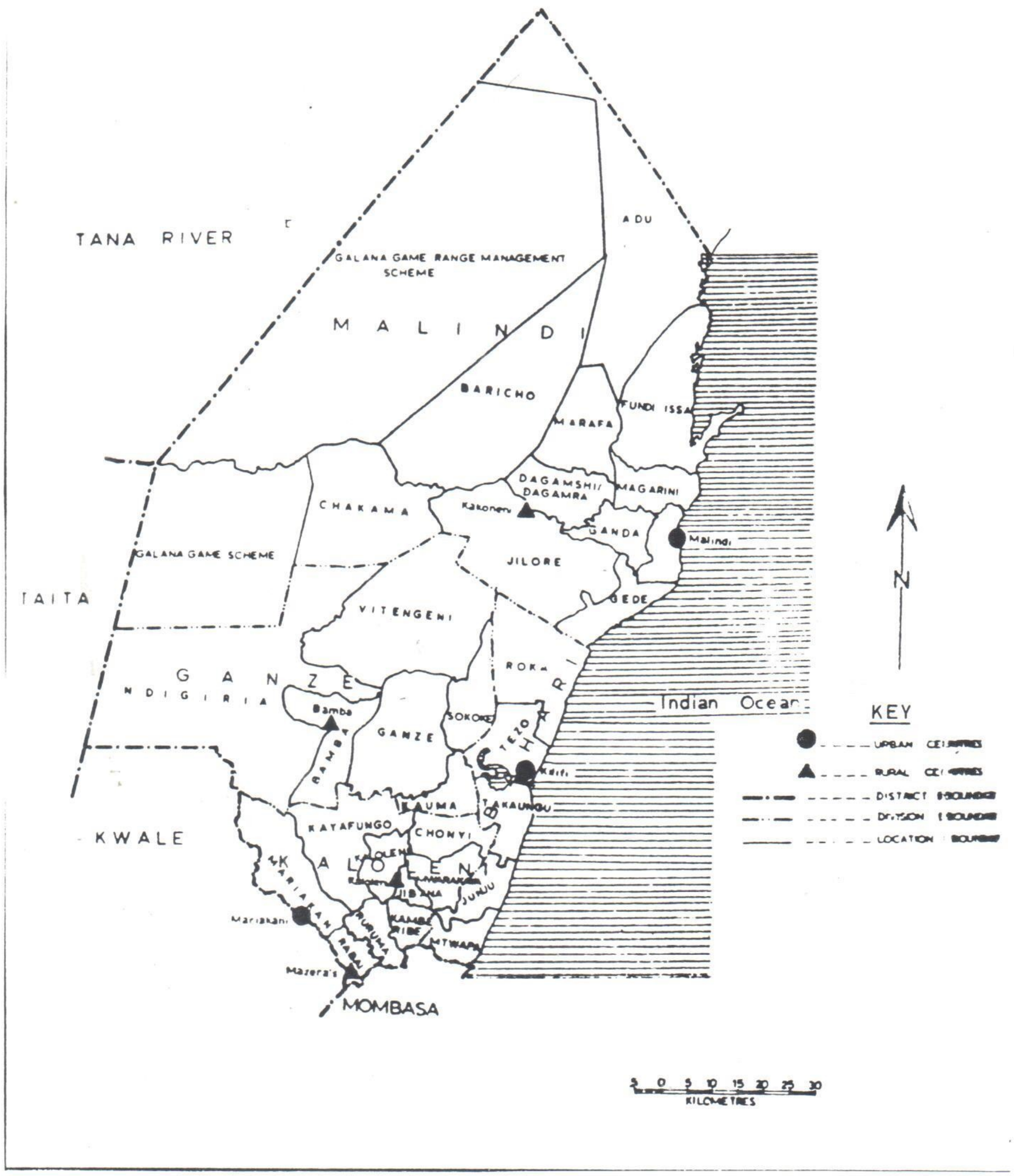
No.	NAME	AREA (HA)
1	ADU	15,000
2	BUNGALE (A)	7500
3	BUNGALE (B)	7500

FOREST AREAS

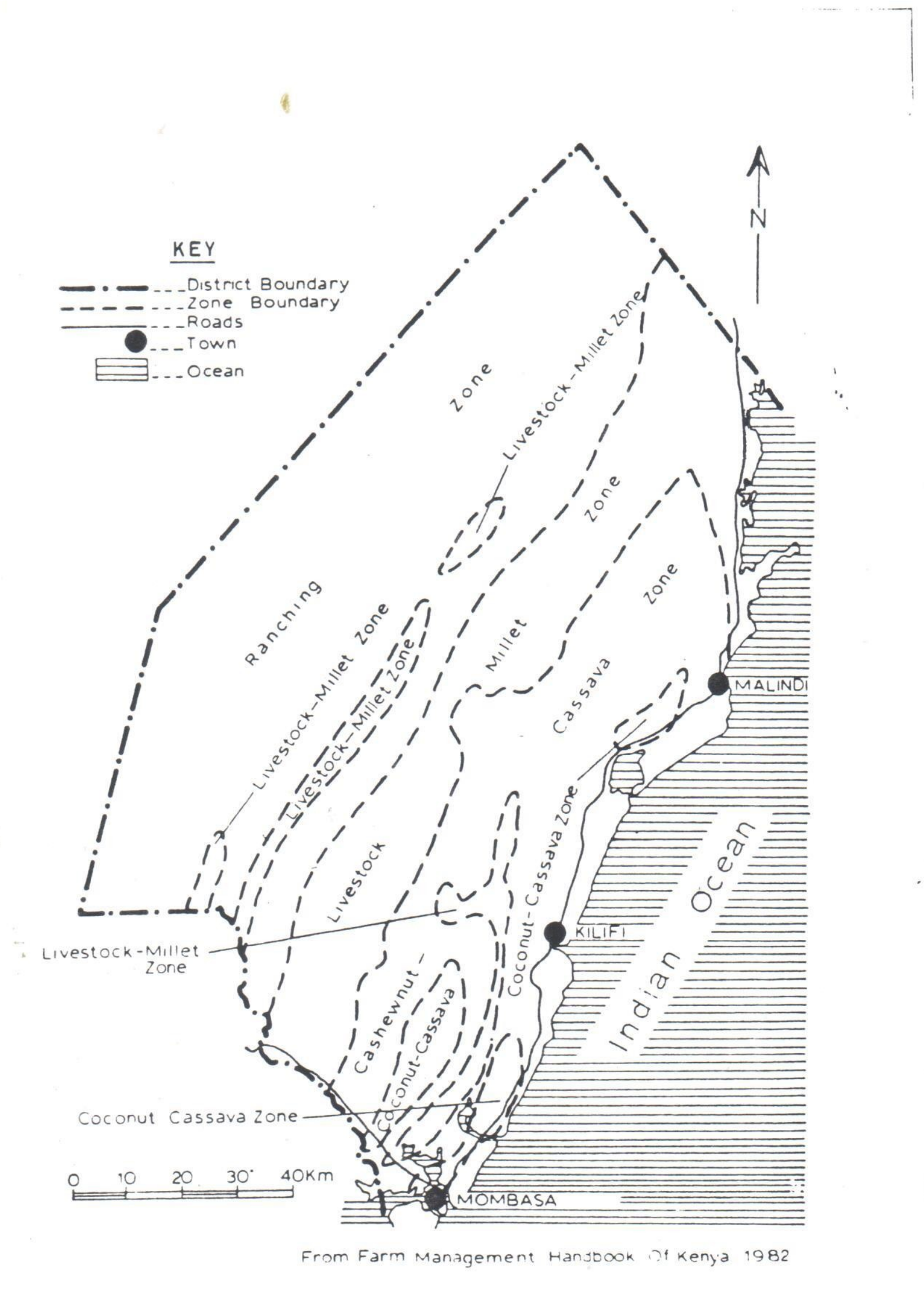
Proposed Forest Areas for Gazettment, Kilifi District Figure 3.1



Coastal & Marine Resources, Kilifi District Figure 3.2



Kilifi District Administrative Boundaries Figure 4.1



Kilifi District Simplified Ecological Zones Figure 4.2

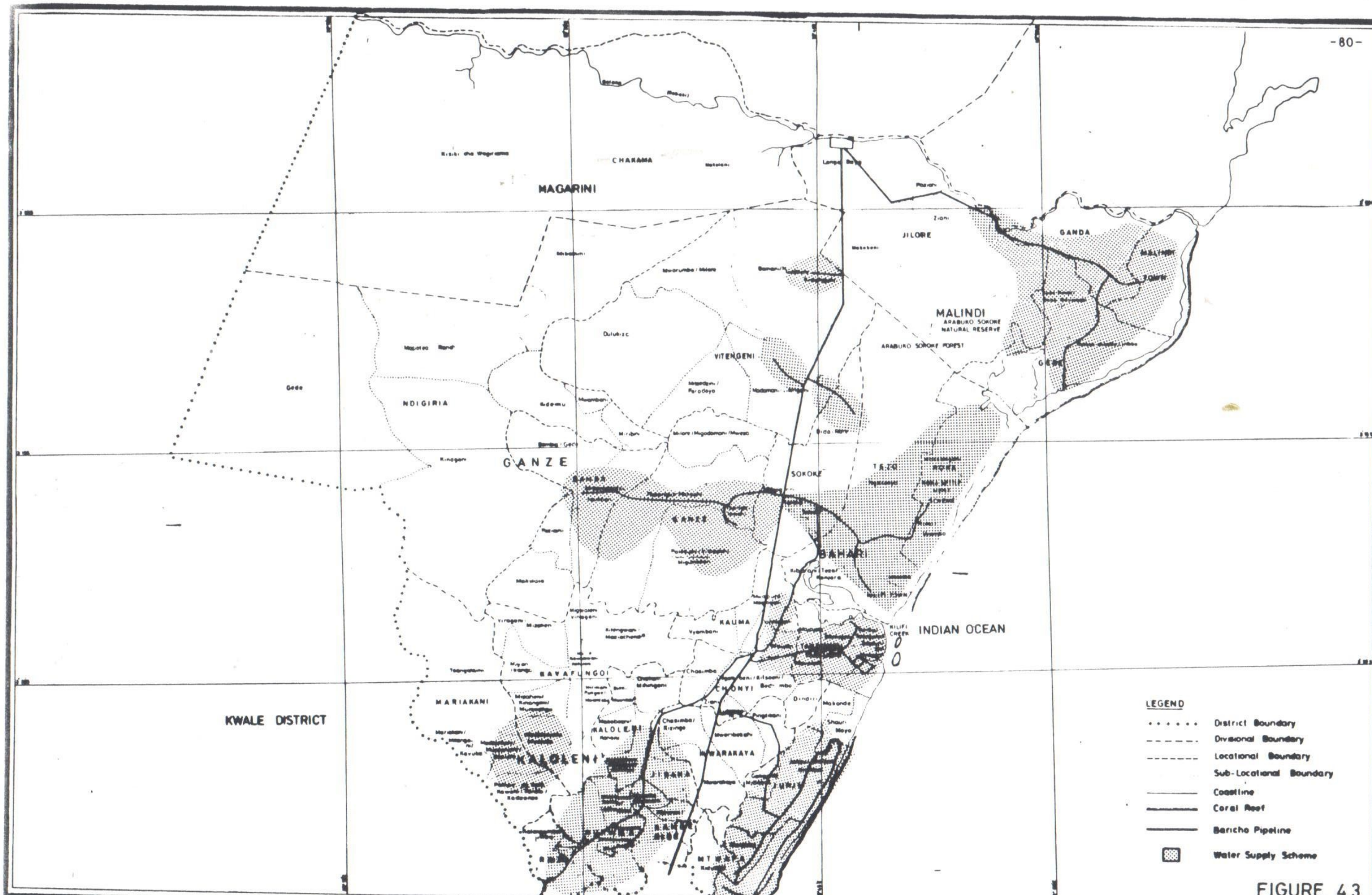
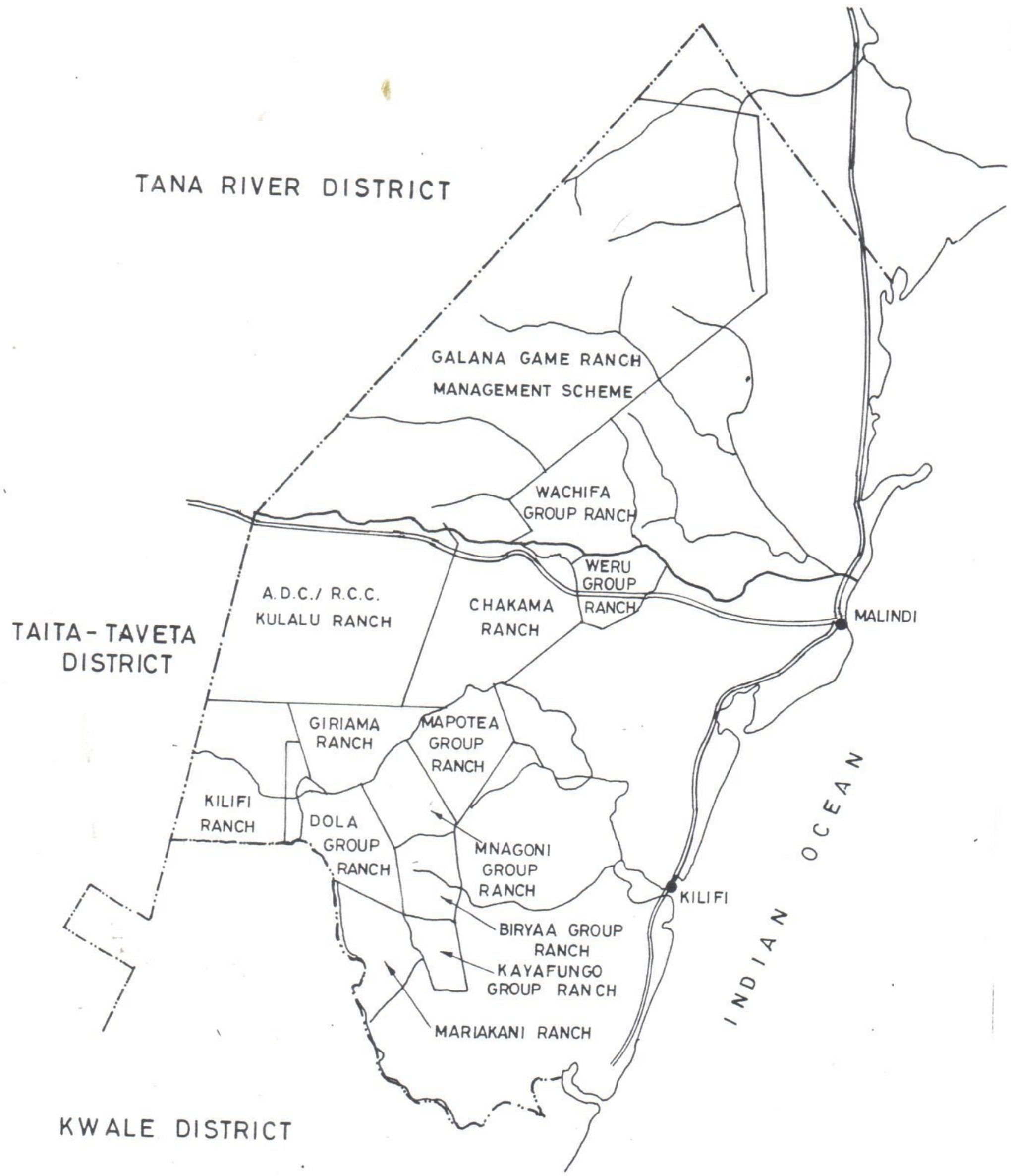
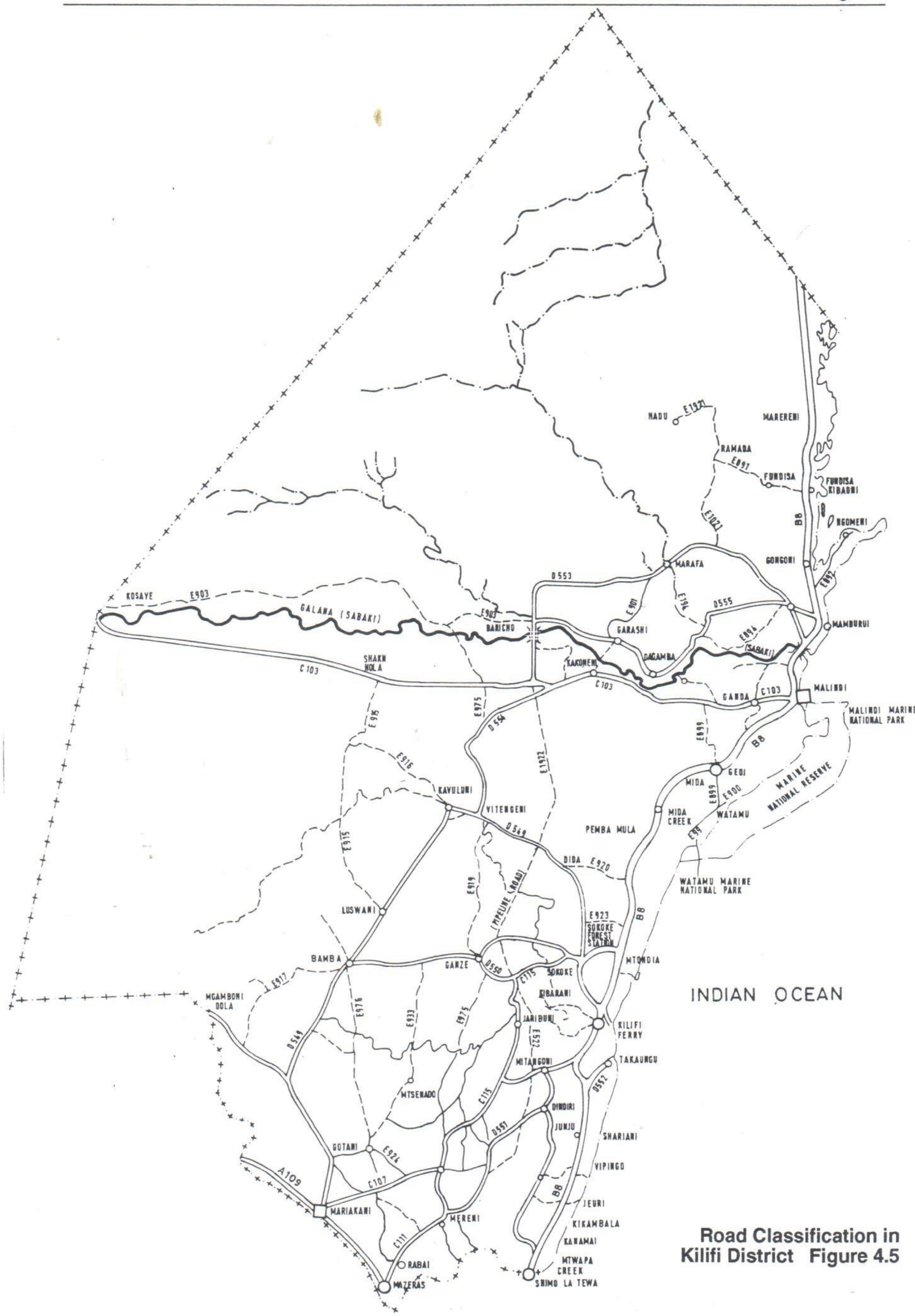


FIGURE 4.3

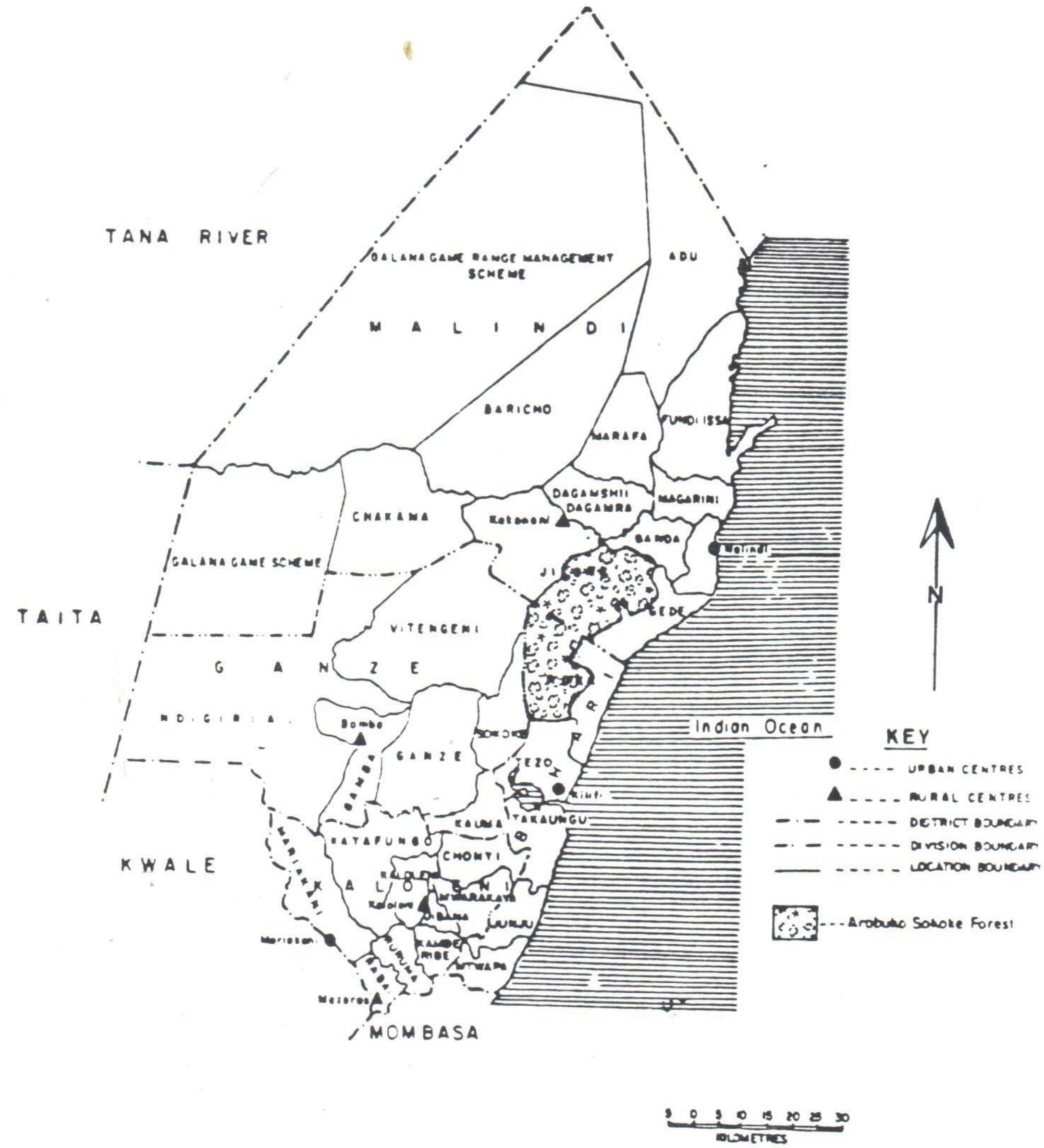
SECOND MOMBASA & COASTAL WATER SUPPLY ENGINEERING AND REHABILITATION PROJECT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION P. O. BOX 30173 NAIROBI	H. P. GAUFF K. G. CONSULTING ENGINEERS P.O. BOX 49817 NAIROBI	LOCATION BY SURVEYED BY DESIGNED BY DRAWN BY CHECKED BY	SCALES A1 SIZE 1 200,000	REHABILITATION AND AUGMENTATION OF SABAKI WATER WORKS PIPELINE AND SUBLOCATIONS SERVED



Kilifi Ranches Figure 4.4



Road Classification in Kilifi District Figure 4.5



Source : Base map extracted from District Development Plan 1989/93

Location of Arabuko- Sokoke Forest Reserve Figure 4.6

TABLE A1

KILIFI DISTRICT POPULATION 1989

Population by Sex; Number of Households; Area; Population Densities: For all Administrative Areas.

AREA	POPULATION			HOUSE HOLDS	AREA (sq. km)	POPULATION DENSITY
	MALE	FEMALE	TOTAL			
KILIFI DISTRICT	**282382**	**309521**	**591903**	**89876**	**13006**	**46**
BAHARI DIVISION	**60022**	**61383**	**121405**	**23250**	**620**	**196**
Roka Location	**7688**	**8836**	**16524**	**2338**	**106**	**156**
Roka	3910	4283	8193	1176	54	152
Uyombo Matsangoni	3778	4553	8331	1162	52	160
Tezo Location	**16424**	**16686**	**33110**	**6971**	**130**	**255**
K. Township	7292	6907	14199	3882	12	1183
Kibarani Konjora	4320	4934	9254	1392	78	119
Mtondai Majaoni	4812	4845	9657	1697	40	241
Takaungu Mavueni Location	**8927**	**9147**	**18074**	**3225**	**141**	**128**
Mavueni Majajani	2139	2415	4554	630	22	207
Kiriba Wangwani	1269	1311	2580	420	39	66
Takaungu Mnarami	3561	3275	6836	1422	38	120
Mkwajuni Mkomani	1958	2146	4104	753	42	98

Table A1 (cont.) (pg 2 of 8)

AREA	POPULATION			HOUSE	AREA	POPULATION
	MALE	FEMALE	TOTAL	HOLDS	(sq. km)	DENSITY
Junju Location	**8084**	**8452**	**16536**	**3421**	**109**	**152**
Vipingo	3208	3171	6379	1574	40	159
Bomani/Junju Mtomkuu	2596	2832	5428	962	43	126
Kuruwitu	2280	2449	4729	885	26	182
Mtwapa Location	**14777**	**13516**	**28293**	**6049**	**89**	**318**
Mtwapa	2406	1984	4390	990	10	439
Kidutani	1783	1837	3620	515	15	241
Shimo la Tewa	4190	3456	7646	2021	19	402
Kanamai	3420	3207	6627	1479	15	442
Mawamba	714	784	1498	223	8	187
Jeuri	2264	2248	4512	821	22	205
Ngerenya Location	**4122**	**4746**	**8868**	**1246**	**45**	**197**
KALOLENI DIVISION	**88697**	**103074**	**191771**	**26167**	**1121**	**171**
Kambe/Ribe Location	**5783**	**6426**	**12209**	**1788**	**62**	**197**
Chauringo	1613	1778	3391	490	29	117
Mbwaka Kikomani	2267	2553	4820	716	12	402
Pangani Maereni	1903	2095	3998	582	21	190
Rabai Location	**12087**	**13167**	**25254**	**3564**	**62**	**407**
Kisurutini Mwele	2548	2811	5359	831	14	383
Kisimani Buni	2844	3019	5863	751	20	293
Kaliangombe Jimba	3049	3359	6408	922	18	356
Mazeras Mugumowa Pasta	3646	3978	7624	1060	10	762

Table A1 (cont.) (pg 3 of 8)

AREA	POPULATION			HOUSE HOLDS	AREA (sq. km)	POPULATION DENSITY
	MALE	FEMALE	TOTAL			
Kayafungo Location	**6801**	**8427**	**15228**	**1572**	**116**	**131**
Mbalamweni	2635	3214	5849	617	54	108
Kinagoni	824	1079	1903	173	22	87
Miyani	1121	1388	2509	268	23	109
Murimani	2221	2746	4967	514	17	292
Mwanamwinga Location	**6219**	**7890**	**14109**	**1452**	**179**	**79**
Kibwabwani	1325	1685	3010	338	37	81
Kithengwa M. Chenda	2502	3134	5636	565	72	78
Viragoni	2392	3071	5463	549	70	78
Mariakani Location	**12653**	**14290**	**26943**	**4422**	**287**	**94**
Munyenzeni	1669	2093	3762	423	57	66
Kawala	2144	2546	4690	601	30	156
Tsangatsini	2193	2638	4831	551	128	38
Mariakani	6647	7013	13660	2847	72	190
Ruruma Location	**11352**	**13333**	**24685**	**3421**	**83**	**297**
Mwamtsunga	2548	2999	5547	802	16	347
Jimba	2500	3068	5568	805	26	214
Mwawesa	2694	3004	5698	738	20	285
Mleji	3610	4262	7872	1076	21	375
Chonyi Location	**9319**	**11146**	**20465**	**2964**	**119**	**172**
Kitsoeni	2824	3288	6112	886	54	113
Ziani Ng'ombeni	3653	4408	8061	1108	31	260
Chasimba	2842	3450	6292	970	34	185
Mwarakaya Location	**8043**	**9692**	**17735**	**2670**	**88**	**202**
Mwarakaya	3160	3820	6980	1042	35	199
Pingilikani	1684	2068	3752	607	34	110

Table A1 (cont.) (pg 4 of 8)

AREA		POPULATION		HOUSE	AREA	POPULATION
	MALE	FEMALE	TOTAL	HOLDS	(sq. km)	DENSITY
Kizingo	3199	3804	7003	1021	19	369
Kaloleni Location	**11390**	**13128**	**24518**	**2952**	**96**	**225**
Chalani Mihingoni	1934	2147	4081	382	13	314
Kaloleni Vishakani	5371	6082	11453	1641	36	318
Birini Mwamleka	819	908	1727	206	16	108
Makomboani Kinani	1458	1854	3312	261	15	221
Mikiriani	1808	2137	3945	462	16	247
Jibana Location	**5050**	**5575**	**10625**	**1362**	**29**	**366**
Kwale Nyalani	2920	3303	6223	852	16	389
Chilulu	1284	1439	2723	310	4	681
Tsagwa	846	833	1679	200	9	187
GANZE DIVISION	**39776**	**47870**	**87646**	**10166**	**3137**	**28**
Ganze Location	**6874**	**8546**	**15420**	**1644**	**345**	**45**
Mweza	1070	1294	2364	284	72	33
Petanguo	1824	2394	4218	412	72	59
Palakumi	2009	2510	4519	457	125	36
Tsangalaweni	1971	2348	4319	491	76	57
Kauma Location	**4065**	**4646**	**8711**	**997**	**164**	**53**
Vinagoni	1738	2003	3741	432	72	52
Ng'ombeni Vyambani	1274	1477	2751	301	33	83
Magogoni Mwapula	1053	1166	2219	264	59	38

Table A1 (cont.) (pg 5 of 8)

AREA		POPULATION		HOUSE	AREA	POPULATION
	MALE	FEMALE	TOTAL	HOLDS	(sq. km)	DENSITY
Vitengeni Location	**4853**	**5653**	**10506**	**1286**	**252**	**42**
Vitengeni Madamani	2725	3254	5979	796	80	75
Mitsedzini	398	453	851	105	42	20
Dulukiza	906	1107	2013	202	76	26
Milore	824	839	1663	183	54	31
Sokoke Location	**4712**	**5449**	**10161**	**1371**	**585**	**17**
Rare/Dida	2229	2573	4802	685	519	9
Sokoke Magogoni	2483	2876	5359	686	66	81
Bamba Location	**8680**	**10481**	**19161**	**2204**	**1233**	**16**
Mwakala	1876	2225	4101	432	75	55
Paziani	1611	1828	3439	474	52	66
Midoina Gede	1034	1282	2316	268	817	3
Nambani Mtsarawatsatsu	2884	3494	6378	611	122	52
Mnagoni	1275	1652	2927	419	167	18
Ndigiria Location	**5794**	**7044**	**12838**	**1377**	**387**	**33**
Mikamini	1482	1853	3335	326	39	86
Mwambani	2066	2431	4497	378	254	18
Mirihini	948	1148	2096	339	52	40
Kidemu	1298	1612	2910	334	42	69
Mwahera Location	**4798**	**6051**	**10849**	**1287**	**171**	**63**
Mwahera	4798	6051	10849	1287	171	63

AREA	POPULATION			HOUSE HOLDS	AREA (sq. km)	POPULATION DENSITY
	MALE	FEMALE	TOTAL			
MALINDI DIVISION	93777	97084	190861	30243	7605	25
Ganda Location	8785	10067	18852	2559	133	142
Ganda	2104	2332	4436	577	16	277
Kakuyuni Malimo	2362	2727	5089	642	61	83
Msabaha	2185	2392	4577	736	20	229
Madunguni	1063	1263	2326	321	20	116
Paziani Kavunyalalo	1071	1335	2424	283	16	152
Magarini Location	10689	12080	22769	2484	242	94
Mambrui	3943	4318	8261	984	40	207
Bomani	2314	2663	4977	577	83	60
Pumwani	2027	2401	4428	423	78	57
Marikebuni	2405	2698	5103	500	41	124
Malindi Location	27407	23964	51371	11204	87	590
Shella	9133	7924	17057	3848	15	1137
Kijiwetanga	3477	3490	6967	945	18	387
Barani	9789	7909	17698	4818	14	1264
Sabaki Ngurureni	5008	4641	9649	1593	40	241
Bungale Location	3376	3736	7112	761	532	13
Dakacha	2219	2443	4662	479	427	11
Baricho	761	861	1622	180	74	22
Gandini	396	432	828	10	231	27

Table A1 (cont.) (pg 7 of 8)

AREA	POPULATION			HOUSE HOLDS	AREA (sq. km)	POPULATION DENSITY
	MALE	FEMALE	TOTAL			
Garashai Location	**4428**	**5237**	**9665**	**1138**	**166**	**58**
Singwaya	524	596	1120	143	59	19
Mikuyuni	781	898	1679	236	13	129
Bura	907	1112	2019	245	56	36
Masindeni	548	675	1223	139	10	122
Batte	1668	1956	3624	375	28	129
Fundi–Issa Location	**10829**	**11691**	**22520**	**3268**	**487**	**46**
Gongoni	5583	5891	11474	1731	124	93
Fundi–Issa	3306	3649	6955	859	121	57
Marereni	1940	2151	4091	678	242	17
Chakama	1410	1541	2951	488	4603	1
Makongeni	1035	1153	2188	369	1401	2
Matolani	375	388	763	119	3202	0
Gede Location	**12470**	**12659**	**25129**	**3667**	**142**	**177**
Mbarakachembe Jimba	3623	3775	7398	935	52	142
Watamu/Dabaso Mida	6084	5799	11883	1957	58	205
Mijomboni	2763	3085	5848	775	32	183
Adu Location	**3432**	**3926**	**7358**	**900**	**626**	**12**
Ramada	1667	1969	3636	414	274	13
Adu	1765	1957	3722	486	352	11
Marafa Location	**4063**	**4454**	**8517**	**1179**	**293**	**29**
Mambasa	1127	1242	2369	308	130	18
Bore	1220	1519	2739	326	76	36
Madina	1716	1693	3409	545	87	39

Table A1 (cont.) (pg 8 of 8)

AREA	POPULATION			HOUSE HOLDS	AREA (sq. km)	POPULATION DENSITY
	MALE	FEMALE	TOTAL			
Jilore Location	**6888**	**7729**	**14617**	**2595**	**294**	**50**
Jilore Ziani	1078	1271	2349	378	33	71
Lango Baya	1870	1963	3833	783	67	57
Makobeni	2828	3266	6094	1082	161	38
Kakoneni	1112	1229	2341	352	33	71
Arabuko Sokoke Forest	110	110	220	50	523	0

Source: 1989 Population Census (unpublished estimates)

TABLE A2

KILIFI DISTRICT POPULATION 1962 TO 1989

YEAR	POPULATION	% CHANGE
1962	247822	
1969	300568	21.1
1979	430986	40.1
1989 *	591903	37.3

Source: Population Census 1962 to 1989 * Unpublished Estimate

TABLE A3

POPULATION BY DIVISION 1979 AND 1989

DIVISION	YEAR	KM SQ	POP	DENSITY
Kaloleni	1979	1057	151544	143
	1989 *	1121	191771	171
Ganze	1979	2917	65437	22
	1989 *	3137	87646	28
Malindi	1979	7414	129081	17
	1989 *	7605	190861	25
Bahari	1979	615	84924	138
	1989 *	620	121405	196

Source: Population Census 1979 and 1989 * Unpublished Estimate

TABLE A4

TOTAL FERTILITY RATES

Year	1962	1969	1979
Fertility Rate	2.8	1.7	5.6

Source: Population Census 1962, 1969 and 1979.

TABLE A5

POPULATION ALONG PIPELINES

SIX KILOMETRE SWARTH POPULATION SERVED BY PIPELINES
BASED ON 1979 MAPPING, AND ASUMMING 8 PERSONS PER HOUSEHOLD

A5.1 BARICHO–NGUU TATU MAINLINE

AREA NAME	GRID IDENTIFICATION	ESTIMATED HOUSES	ESTIMATED POPULATION
Galana/Sabaki	55.56	16	128
Lango Baya	54.55	16	128
Lango Baya	53.54	15	120
Lango Baya	52.53	22	176
Lango Baya	51.52	10	80
Lango Baya	50.51	17	136
Lango Baya	49.5	10	80
Lango Baya	48.49	1	8
Kijego	47.48	0	0
Sosoni	46.47	12	96
Ganze/Vitengeni	45.46	3	24
Makobeni	44.45	8	64
Malanga	43.44	12	96
Malanga	42.43	6	48
Girimacha	41.42	7	56
Viriko	40.41	62	496
Makobeni	39.4	68	544
Malanga	38.39	74	592
Kaembeni	37.38	71	568
Kaembeni	36.37	65	520
Kidunguni	35.36	44	352
Kidunguni	34.35	70	560
Kaembe	33.34	49	392
Mwahera	32.33	50	400
Mwahera	31.32	57	456
Vitengeni	30.31	53	424
Mwahera	29.3	41	328
Madamani	28.29	47	376
Vigengeni	27.28	51	408
Ganze	26.27	75	700
Ganze	25.26	66	528
Matano Mane	24.25	53	424
Matano Mane	23.24	73	584
Matano Mane	22.23	57	456
Dida/Rare No. 2	21.22	67	536
Sokoke Dida	20.21	92	736
Sokoke	19.2	67	536
Sokoke	18.19	64	512
Magogoni	17.18	50	400
Magogoni	16.17	68	544
Magogoni	15.16	46	368
Magogoni	14.15	36	288
Magogoni	13.14	46	368
Magogoni Rare	12.13	71	568
Tsangalaweni	11.12	22	176
Rare No. 1	10.11	41	328

Table A5 (cont.) (pg. 2 of 4)

AREA NAME	GRID IDENTIFICATION	ESTIMATED HOUSES	ESTIMATED POPULATION
Sokoke	9.1	37	196
Magogoni	8.09	35	280
Magogoni	7.08	66	528
Mizijini	6.07	70	560
Magogoni	5.06	42	336
Kirumbe	4.05	27	216
Bahari Tezo	3.04	24	192
Kibarani Tezo	2.03	19	152
Kaya	1.02	41	328
Kauma	0.01	73	584
Magogoni Mwapula	99	23	184
Vinagoni	98.99	40	320
Vinamgoni	97.98	58	464
Vingamgoni	96.97	52	416
Kauma Vyambani	95.96	57	456
Vyambani/Mbudzi	94.95	139	1112
Vyambani	93.94	105	840
Kitsoeni	92.93	136	1088
Dztisoni	91.92	128	1024
Chonyi	90.91	62	496
Chonyi	89.9	110	880
Galanema	88.89	77	616
Mwele	87.88	49	392
Mwarakaya	86.87	53	424
Kitsoeni	85.86	72	576
Pingilikani	84.85	61	488
Mlembe Mitsano	83.84	39	312
Mwembe Kati South	82.83	35	280
Mwembe Kati South	81.82	25	200
Mwarakaya North	80.81	31	248
Mbuyuni	79.8	17	136
Mbuyuni	78.79	19	152
Jibana	77.78	64	512
Kwale/Nyalani	76.77	50	400
Maadani	75.76	41	328
Kwa Loa	74.75	26	208
Mbwaka	73.74	16	128
Pangani	72.73	19	152
Ribe	71.72	22	176
Chauringo	70.71	23	184
Chauringo	69.7	45	360
Chauringo	68.69	12	96
Mitsajeni	67.68	12	96
Mafigani	66.67	8	64
kinunguna	65.66	6	48
Mwakirunge	64.65	14	112
Marimani	63.64	12	96
TOTAL		**4143**	**33144**

A5.2 SOKOKE SUBSIDIARY LINE

AREA NAME	GRID IDENTIFICATION	ESTIMATED HOUSES	ESTIMATED POPULATION
Magogoni	84.85	21	168
Rare	85.86	60	480
Dida	86.87	36	288
Sokoke Rare	87.88	11	88
Sokoke Rare	88.89	4	32
Sokoke	89.9	37	296
Upper Sokoke	90.91	50	400
Upper Sokoke	91.92	72	576
TOTAL		**291**	**2328**

A5.3 MAVUENI SUBSIDIARY LINE

AREA NAME	GRID IDENTIFICATION	ESTIMATED HOUSES	ESTIMATED POPULATION
Mitangoni	85.86	49	392
Mitangoni	86.87	115	920
Mavueni Majajani	87.88	100	800
TOTAL		**264**	**2112**

A5.4 UBAONI SUBSIDIARY LINE

AREA NAME	GRID IDENTIFICATION	ESTIMATED HOUSES	ESTIMATED POPULATION
Pingilikani	85.84	22	176
Kaloleni	84.83	20	160
Mwarakaya	83.82	50	400
Pingilikani	82.81	52	416
Kasidi	81.8	65	520
Mbuyuni	80.79	55	440
Mikaoni	79.8	25	200
Gongoni	78.79	50	400
Viringo	77.78	18	144
Bahari	76.77	50	400
Mwembe wa Sungu	75.76	21	168
TOTAL		**428**	**3424**

A5.5 BARICHO – MALINDI LINE

AREA NAME	GRID IDENTIFICATION	ESTIMATED HOUSES	ESTIMATED POPULATION
Kwa Upanga	14.15	75	600
Kakuyuni	13.14	93	744
Kakuyuni	12.13	68	544
Kakuyuni	11.12	60	480
Kakuyuni	10.11	30	240
Madungoni	9.1	42	336
Madungoni	8.09	7	56
Madungoni	7.08	12	96
Madungoni	6.07	27	216
Mugumoni	5.06	12	96
Bate	4.05	35	280
Mongoti	3.04	47	376
Mongoti	2.03	35	280
Mongoti	1.02	27	216
Jilore	99	54	432
Jilore	97.98	50	400
Mikuyuni	96.97	20	160
Kakoneni	95.96	15	120
Kanoneni	94.95	25	200
Jilore	93.94	10	80
Makobeni	92.93	5	40
Mwenga	91.92	5	40
Pishimwenga	90.91	20	160
Kirashini	89.9	7	56
TOTAL		**781**	**6248**
GRAND TOTAL			**47256**

A5.6 SUMMARY

LINE	ESTIMATED CONSUMERS
Baricho – Nguu Tatu	33144
Mavueni Subsidiary Line	2112
Sokoke Subsidiary Line	2328
Ubaoni Subsidiary Line	3424
Baricho – Malindi	6248
TOTAL	**47256**

Source : H.P. Gauff

TABLE A6

POPULATION IN SUBLOCATIONS SERVED
BY NGUU TATU AND MALINDI PIPELINES

DIVISION	LOCATION	SUBLOCATION	POP. 1989
A. BARICHO NGUU TATU PIPELINE			
Malindi	Jilore	Lango Mbaya	3833
		Makobeni	6094
Ganze	Mwahera	Mwahera	10849
	Vitengeni	Madamani/Vitengeni	5979
	Sokoke	Dida/Rare	4802
		Maganoni	5359
	Bamba	Bamba/Gede	2316
		Nambani	6378
		Paziani	3439
	Ganze	Petanguo Maryani	4218
		Tsangalaweni	4319
		Palakumi	4519
	Kauma	Mwapula/Magogoni Vingangoni Mbudzi	3741
Kaloleni	Chonyi	Nyombeni/Kitsoeni/Bedzombo	6112
		Lutsangani/Ziani	8061
	Mwarakaya	Pingilikani	3752
		Mwarakaya	6980
		Chasimba/Kizingo	7003
	Jibana	Tsaawa/Chilulu	2723
		Jibana/Kwale	6223
	Kambe Ribe	Mbwaka/Kikomani	4820
		Marereni/Pangani	3998
		Forodhani/Makobeni/Chauringo	3391
	Ruruma	Mwamutsunga	5547
		Maweza	5698
		Jimba	5568
	Rabai	Kalongombe/Jimba	6408
		Kisurutini/Simakeni/Mwele	5359
		Rabai/Chisimoni/Buni	5863
		Mazeras	7624
Bahari	Ngerenya	Ngerenya	8868
	Tezo	Kibarani/Tezo/Konjara	9254
		Kilifi Town	14199
		Mtondia	9657
	Roka	Matsangoni	8331
		Roka/Uyombo	8193
	Takaungu/ Mavueni	Majajani	4554
		Mkongani	4104
		Kiribo/Wangwani	2580
		Takaungu/Mnarani	6836
		Mavueni	4554

Table A6 (cont.) (pg 2 of 2)

DIVISION	LOCATION	SUBLOCATION	POP. 1989
Bahari (cont.)	Junju	Vipinae	6379
		Junju/Bomani/Kireme	5428
	Mtwapa	Mwambe	1498
		Kidutani	3620
		Mtwapa	4390
		Kanamai	6627
		Shimo la Tewa	7646
		Jeuri	4512
	TOTAL		**282206**
B. BARICHO MALINDI PIPELINE			
Malindi	Ganda	All	18852
	Malindi	All	51371
	Gede	All	25129
	Subtotal		95352
	Less	Lango Baya Sublocation	3833
	Less	Mkobeni Sublocation	6094
	TOTAL		**85425**
GRAND TOTAL			**367631**

Source: Consultant's Calculations Based on 1989 (unpublished estimates) Census Data

TABLE B1

KILIF! DISTRICT: LAND BY LEGAL CATEGORY 1976

Government Land	5043 sq km
Freehold	233 sq km
Trustland	498 sq km
Registered Land	511 sq km
Unregistered Land	6238 sq km

Source: Kilifi District Lands Office

TABLE B2

KILIF! DISTRICT LAND ADJUDICATION

Status as on 24 May 1993

B2.1 REGISTERED

LOCATION	SECTION	HA.	PLOTS	ORIGIN
Kaloleni	Vishakani	2355	819	TL
	Kinani	3300	804	TL
	Chalani	2930	795	TL
Jibana	Myalani	2112	1489	TL
	Chilulu	1120	515	TL
Kambe Ribe	Chauringo	683	362	TL
	Forodhani	1106	335	TL
	Mbwakamaereni	986	631	TL
Chonyi	Chasimba	1500	418	TL
	Galenema	2930	480	TL
	Bandarasalama	2469	878	TL
Mwarakaya	Mwarakaya	1407	523	TL
Gede	Dabasu	1380	332	TL
	Mijomboni	4300	805	TL
	Jimba	1450	440	TL
	Chembe Kibabamshe	1850	440	TL
	Mbaraka Chembe	4100	308	TL
	Mida/Majauni	1500	782	GL
	Kirepwe B	140	113	GL
Ganda	Kakuyuni/Madunguni	1400	315	TL
	Maduguni B	300	95	TL
Roka	Masangoni	1309	719	TL
	Madeteni	1114	623	TL
	Uyombo	1532	619	GL
Tezo	Mtondia/Roka	310	210	GL
	Majauni Old Settlement			
	Aldev Settlement	810	289	GL
	Tezo Madukani	127	47	GL
	Majaoni	100	65	GL
Jilore	Weru Ranch	12015	18	PU
Kayafugo	Kayafugo G. Ranch	10720	19	PU
Bamba	Mnagoni G.R.	15137	38	PU
	Dola G.R.	20000	18	PU
Ganze	Birya G.R.	14195	38	PU
	Mapotea G.R.	23600	56	PU
TOTAL		140287	14438	

KEY:
GL = Government Land
TL = Trustland
PU = Public Utilities

Table B2 (cont.) (pg 2 of 3)

B2.2 UNDER DEMARCATION

LOCATION	SECTION	HA.	PLOTS	ORIGIN
Kambe Ribe	Kikomani/Makombeni	984	787	TL
	Kinunguna	1119	299	TL
	Pangani	1334	709	TL
Jibana	Mwedeje	350	207	TL
Ruruma	Changombe	1136	323	TL
	Mawesa	1325	1818	TL
	Mikaani			
	Mwamwebomu/Chonyi	942	939	TL
Rabai	Mazeras	1500	936	TL
	Buni/Kisimani	1650	979	TL
Chonyi	Bedzombo/Kisoeni	3250	1092	TL
Kauma	Vyambani	1363	298	TL
	Vingagoni	1255	566	TL
	Mwapula/Magogoni			TL
Kayafungo	Mwijo/Mlimani			TL
Sokoke	Rare		867	TL
	Dida		1612	TL
Ganda	Msongoleni			
	Kikambetele	1905	530	GL
	Madunguni A.	1400	618	TL
Jilore	Kakoneni	1981	520	GL
Mavueni	Takaungu	1400	806	GL
	Mavueni 3B	2582	403	GL
	Mavueni 3A	2171	1009	GL
Malindi	Takaye/Musoloni	1038	733	GL
Magarini	Masheheni	720	108	GL
	Mambrui/Sabaki	1040	136	GL
TOTAL		30445	16295	

KEY:
GL = Government Land
TL = Trustland
PU = Public Utilities

Table B2 (cont.) (pg 3 of 3)

B2.3 SETTLEMENT SCHEMES

LOCATION	SECTION	HA.	PLOTS	ORIGIN
Mtwapa	Mtwapa	3035	607	TL
	Kijipwa	148	355	TL
Roka	Roka/Tezo	5595	1119	TL
	Mtondia	1165	233	TL
Mavueni	Vipingo	520	260	TL
Ngerenyi	Ngerenyi	4750	950	TL
Tezo (Proposed)	Kibarani	2250	750	TL
TOTAL		17463	4274	

B2.4 PROPOSED

LOCATION	SECTION	HA.	PARCELS	ORIGIN
Vitengeni	Shononika	0	0	TL
	Dzikunze	0	0	TL
Jilore	Malanga	0	0	TL
Rabai	Jimba/Kawala	0	0	TL
	Kawala/Mureji	0	0	TL
Ganze	Tsangazini	0	0	TL
	Petanguo	0	0	TL
	Palakumi/Visapuni	0	0	TL

KEY:
GL = Government Land
TL = Trustland
PU = Public Utilities

Source: Kilifi District Lands Office

Table B3

INFRASTRUCTURE INVENTORY

ALONG BARICHO TO NGUU TATU PIPELINE ROAD

CENTRE	COMMERCIAL FACILITIES				ELECT- RICITY	INSTITUTIONS AND GENERAL										
	URBAN CENTRE	RURAL CENTRE	MARKET CENTRE	LOCAL CENTRE	AVAILABLE	POLICE STATION	HOSPI- TAL	HEALTH CENTRE	DISPEN- SARY	SCHOOLS HIGHER	SCHOOLS SECOND	SCHOOLS PRIMARY	BANKS	BUS SERVICES	CATTLE DIPS	COOP. SOCIETIES
1974																
Lango Baya																
Bamba											■	■		■		
Vitengeni			■					■				■		■		
Sokoke				■					■			■		■		
Ganze			■					■				■		■	■	
Jaribuni				■					■			■		■		
Kakuyuni					■				■			■		■		
Kaloleni		■					■				■	■		■		■
Ribe						■					■	■		■		
1990																
Lango Baya												■		■		
Bamba											■	■		■		
Vitengeni			■					■		■		■		■	■	■
Sokoke				■					■			■		■		
Ganze			■					■			■	■		■	■	■
Jaribuni				■	■				■			■		■		
Kakuyuni					■				■		■	■		■	■	
Kaloleni		■					■				■	■		■	■	■
Ribe						■					■	■		■	■	

TABLE C1

PROPOSED FOREST RESERVES

AREAS PROPOSED TO BE SET ASIDE AS FOREST RESERVES IN KILIFI DISTRICT:- STATUS AS AT 24 FEBRUARY 1993.

DIVISION / Location	FOREST	STATUS	AREA (Ha)	FORUM
KALOLENI				
Kambe-Ribe	Kaya Kambe	Trustland	100	DEC,DDC,CC
Kambe-Ribe	Kaya Ribe	Trustland	100	DEC,DDC,CC
Jibana	Kaya Jibana	Trustland	150	DEC,DDC,CC
Rabai	Kaya Rabai	Trustland	600	DEC,DDC,CC
Rabai	Kaya Kivara	Trustland	150	DEC,DDC,CC
Kayafungo	Kaya fungo	Trustland	100	DEC,DDC,CC
Jibana	Tsoba Forest	Trustland	?	Sub DDC (Kal)
Mariakani	Katolani	Trustland	?	Sub DDC (Kal)
Mariakani	Matongoni	Trustland	?	Sub DDC (Kal)
Kayafungo	Nzovuni	Trustland	1200	D.F.O.
TOTAL			2400	
GANZE				
Kauma	Kaya Kauma	Trustland	100	DEC,DDC,CC
Mwahera	Mwangea Hill	Trustland	2500	DEC,DDC,CC
Ganze	Nzovuni	Trustland	1200	D.F.O.
TOTAL			3800	
BAHARI				
Mwara Kaya	Kaya Chonyi	Trustland	200	DEC,DDC,CC
Junju	Tsolokero	Trustland	50	DEC,DDC,CC
Mavueni	Mavueni	Trustland	?	D.F.O., DLAO
TOTAL			250	
MALINDI				
Madunguni	Sabaki	Trustland	1000	D.F.O.
TOTAL			1000	
MAGARINI				
Baricho	Adu	Trustland	15000	D.F.O.
Marafa	Bungale	Trustland	7000	D.F.O.
Baricho	Dakatcha	Trustland	25000	D.F.O.
TOTAL			47000	

KEY:

DDC = District Development Committee

DEC = District Executive Committee

CC = County Council

DFO = District Forest Officer

Source: Kilifi District Forestry Office

TABLE C2

ESTIMATES OF WILDLIFE POPULATION
FOR KILIFI DISTRICT

ANIMAL SPECIES	Feb-Mar 1977		April, 1988		November 1989	
	Population	Std. Error	Population	Std. Error	Population	Std. Error
Elephant *Loxodonta africana*	1553	921				
Giraffe *Giraffa camelopardalis*	1071	526	565	274	313	113
Burchell Zebra *Equus burchelli*	428	294	2789	2355	816	514
Impala *Aepyceros melampus*	268	210	3251	2623	191	86
Buffalo *Syncerus caffer*	54	51			330	125
Eland *Taurotragus oryx*	375	284	548	523	695	522
Ostrich *Struthio camelus*	107	68	120	68	313	136
Warthog *Phachocoerus aethiopicus*	2838	1143	582	246	973	401
Oryx *Oryx beisa*	1178	473	565	240	1077	515
Lesser Kudu *Tragelaphus imberbis*	107	69	188	82	191	111
Waterbuck *Kobus ellipsiprymnus*	482	461	308	234	17	17
Gerenuk *Litocranius walleri*	107	108	86	40	226	92
Grant Gazelle *Gazella granti*			1215	688	799	273
Kongoni *Alcelaphus buselaphus*			120	91		

Source: Department of Resource Survey and Remote Sensing

TABLE C.3

TERRESTRIAL WILDLIFE SPECIES COMMON IN ARABUKO- SOKOKE FOREST AND THE SURROUNDING

Elephant	(*Loxodonta africana*)
Buffalo	(*Syncerus caffer*)
Bush Pig	(*Potamochoerus porcus*)
Civet	(*Civettictis civetta*)
Porcupine	(*Hystrix oristata*)
Spotted Hyaena	(*Crocuta crocuta*)
Leopard	(*Panthera pardus*)
Sykes Monkey	(*Cercopithecus albogularis*)
Olive Baboon	(*Papio cynocephalus*)
Genet	(*Genetta genetta*)
Golden-rumped Elephant Shrew	(*Rynchocyon cirnei*)
Dwarf Mongoose	(*Helogale parvula*)
Red Squirrel	(*Funisciurus ochraceus*)
Aders Duicker	(*Cephalopus adersi*)
Bushbuck	(*Tragelaphus scriptus*)
Bush Baby	(*Galago crassicaudatus*)
Giant Gambian Rat	(*Cricetomys gambianus*)
Bristle-tailed Elephant Shrew	(*Petrodromus tetradactylus*)
Blue Dricker	(*Cephalophus monticola*)
African Wood Owl	(*Ciccaba woodfordii*)
Yellow-bellied Greenbul	(*Chlorocichal flaviventris*)
East African Beaded Scrub Robin	(*Cecrcotrichas quadrivirgata*)
Red-capped Robin Chat	(*Cossupha natalensis*)
Black-headed Apalis	(*Apalis melanocephala*)
Grey-backed Camaroptera	(*Camaroptera brachyrus*)
Collared Sunbird	(*Anthreptes collaris*)
Olive Sunbird	(*Nectarinia olivacea*)
Python	(*Python sebae*)
Puff Adder	(*Bitis arietans arietans*).

TABLE C.4

BIRD SPECIES RECORDED ALONG THE SABAKI RIVER, MAY, 1993

White necked Cormorant	(*Phalacrocorax carbo*)
Night Heron	(*Nycticorax nyoticovax*)
Green-backed Heron	(*Butorides striatus*)
Little Egret	(*Greetta garzetta*)
Yellow-billed Egret	(*Mesophoix intermedius*)
Goliath Heron	(*Ardea goliath*)
Blacked-headed Heron	(*Ardea melanocephala*)
Grey Heron	(*Ardea cinerea*)
Sacred Ibis	(*Threskiornis aethiopicus*)
African Spoonbill	(*Palatea alba*)
Osprey	(*Pandion halietus*)
Pale-chanting	(*Melierax poliopterus*)
Spur-winged Plover	(*Holopterus spinosus*)
Crab Plover	(*Dromas ardeola*)
Kittlitz's Plover	(*Charadrius pecuaris*)
Water Dikkiop	(*Burhinus vermiculatus*)
Caspian Tern	(*Hydropgne caspia*)
Swift Tern	(*Sterna bergii*)
African Fish Eagle	(*Haliaeetus vocifer*)
Common Pratincole	(*Glareola pratincola*)
Sooty Gull	(*Larus hemprichii*)
Mourning Dove	(*Streptopellia depiciens*)
White-browed Coucal	(*Centropus supercilisous*)
Speckled Mousebird	(*Colius striatus*)
Fischer's Lovebird	(*Agapornis fischeri*)
Lilac-breasted Roller	(*Coracias caudata*)
Pied Kingfisher	(*Ceryle rudis*)
Malachite Kingfisher	(*Corithornis cristata*)
Little Swift	(*Apus affinis*)
African Pied Wagtail	(*Motacilla aguimp*)
Yellow-vented Bulbul	(*Pycnonotus barbatus*)
Fiscal Shrike	(*Lanius collaris*)
Pin-tailed Whydah	(*Vidua macroura*)
Golden Palm Weaver	(*Ploceus ocularis*)
Indian House Crow	(*Corrus plendens vicillot*)
Pink-backed Pelican	(*Pelecanus rufescens*)
Mangrove Kingfisher	(*Halcyon senegaloides*)
Hadada Ibis	(*Bostrychia hagedash*)

TABLE C5

INVENTORY OF THE MOST THREATENED SPECIES IN THE REGION NEAR THE PROJECT AREA

SPECIES	CRITICAL HABITAT	STATUS*	THREATS
Elephant *Loxodonta africana*	Arabuko-Sokoke Forest	Endangered	Poaching/Habitat Loss
Ader's Duicker *Cephalophus adersi*	Arabuko-Sokoke Forest	Rare/Endemic	Habitat Loss
Dugong *Dugong dugon*	Creeks	Endangered	Exploitation
Clarke's Weaver *Ploceus golandi*	Arabuko-Sokoke Forest	Rare/Endemic	Habitat Loss
Sokoke pipit *Anthus sokokensis*	Arabuko-Sokoke Forest	Rare	Habitat Loss
Amani Sunbird *Anthreptes pallidigaster*	Arabuko-Sokoke Forest	Rare	Habitat Loss
East Coast Akalat *Sheppardia gunningi*	Arabuko-Sokoke Forest	Rare	Habitat Loss
Spotted Grand Thrush *Turdus fischeri*	Arabuko-Sokoke Forest	Rare	Habitat Loss
Green Turtle *Chelonia mydas*	Beaches	Endangered	Exploitation/Loss of Habitat
Hawkshill Turtle *Eretmochelys imbricata*	Beaches	Endangered	Exploitation/Loss of Habitat
Olive Ridley Turtle *Lepidochelys olivacea*	Beaches	Endangered	Exploitation/Loss of Habitat
Giant Triton *Charonia tritonis*	Coral Reefs	Vulnerable	Overcollection
Bullmouth helmet shell *Cypraecassis rufa*	Coral Reefs	Rare	Overcollection
Spiney Lobsters *Palinurus spp.*	Creeks	Rare	Overfishing
Butterfly *Charaxes lasti*	Arabuko-Sokoke Forest	Rare/Endemic	Loss of Habitat
Butterfly *Churaxes protocles azota*	Arabuko-Sokoke Forest	Rare/Endemic	Loss of Habitat
Arican Violet *Saintpaulia rupicola*	Kayas/Sacred Groves	Endangered	Loss of Habitat

Table C5 (cont.) (pg 2 of 2)

SPECIES	CRITICAL HABITAT	STATUS*	THREATS
Euphorbia Wakefielddii	Kayas/Sacred Groves	Endangered	Loss of Habitat
Aloe kilifiensis	Kayas/Sacred Groves	Endangered	Loss of Habitat
Savia fadeni	Kayas/Sacred Groves	Endangered	Loss of Habitat
Cola otolobiodes	Kayas/Sacred Groves	Endangered	Loss of Habitat
Oxystigma msoo	Kayas	Endangered	Loss of Habitat/ Exploitation
Brachylaena huillensis	Arabuko–Sokoke Forest	Rare	Over harvesting for wood carving
Dalbergia melanoxylon	Woodlands	Rare	Over harvesting for wood carving
Warburgia stulmanii	Bushlands	Rare	Over collection for herbal medicine

*

Endangered Species: Taxa in danger of extinction and where survival is unlikely if the causal factors continue operating.

Vulnerable Species: Taxa believed likely to move into endangered category in the near future if the causal factors continue operating.

Rare Species: Taxa with small populations that are not at present endangered or vulnerable but are at risk.

Sources:
NEHSS,1984
UNEP, 1989
Robertson, 1987
Gesicho, 1991
Kelsey and Langton, 1984

Table D1

NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION
OPERATING AND EXPENDITURE SCHEDULE

COAST REGION

ITEM	UNITS	1991	1992
Overheads and Administration	KShs.	2,152,487	1,864,897
Cost of Employment	KShs.	79,040,520	56,315,519
Electricity Consumed	*KWH*	*31,232,164*	*33,671,496*
Cost of Electricity	KShs.	52,737,984	57,595,392
Cost of Fuel	KShs.	3,146,584	2,887,447
Production Supplies			
Aluminium Sulphate	*TON*	*3,470*	*3,900*
Cost of Aluminium Sulphate	KShs.	38,777,250	46,710,300
Soda Ash	*TON*	*540*	*740*
Cost of Soda Ash	KShs.	1,566,000	2,874,900
Chlorine	*TON*	*20*	*20*
Chlorine Gas	*TON*	*260*	*272*
Cost of Chlorine	KShs.	4,553,120	5,894,080
Cost of Transport	KShs.	2,346,281	2,945,436
Repairs and Maintenance	KShs.	7,993,156	8,322,048
TOTAL	**KShs.**	**192,313,382**	**185,410,019**

Table D2

NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION
OPERATING AND EXPENDITURE SCHEDULE

ESTIMATES FOR SABAKI WATER WORKS: SURFACE WATER

ITEM	ROUNDED AVERAGE ANNUAL EXPENDITURE FOR THE COAST REGION IN 1991/92 (KSHS)	PERCENT. ASSIGNED TO SABAKI	ROUNDED ESTIMATE OF ANNUAL EXPENDITURE FOR SABAKI IN 1991/92 (KSHS)
Overheads and Administration	2,010,000	47%	950,000
Cost of Employment	67,700,000	15% Treat. & Pump.	10,160,000
		40% Distribution	27,080,000
Cost of Electricity	55,200,000	75%	41,400,000
Cost of Fuel	3,020,000	65%	1,960,000
Production Supplies			
Cost of Chlorine	5,230,000	50%	2,620,000
Cost of Alum	42,800,000	95%	40,660,000
Cost of Soda Ash	2,220,000	95%	2,110,000
Cost of Transport	2,650,000	55%	1,460,000
Repairs and Maintenance	8,170,000	60%	4,900,000
TOTAL	**189,000,000**		**133,300,000**
Annual Operating Cost per Cubic Metre	**6.09**		**9.13**

NOTE: Daily water production assumed to be 40,000 cu.m/d for Sabaki Works and 85,000 cu.m/day for NWCPC Coast Region in total.

Table D3

NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION
OPERATING AND EXPENDITURE SCHEDULE

ESTIMATES FOR SABAKI WATER WORKS: GROUND WATER

ITEM			COST
Overheads and Administration		KShs.	2,000,000
Cost of Employment	Treatment & Pumping	KShs.	7,000,000
	Distribution	KShs.	27,080,000
Cost of Electricity	*Electricity Consumption 51,000,000 KWH*	KShs.	122,400,000
Cost of Fuel		KShs.	1,000,000
Production Supplies			
Cost of Salt for Chlorine Production		KShs.	2,079,000
Cost of Transport		KShs.	1,200,000
Repairs and Maintenance		KShs.	4,000,000
TOTAL		**KShs.**	**166,759,000**
Annual Operating Cost per Cubic Metre		**KShs.**	**5.64**

Notes:

1. The above assumes the same price levels as applied to the costs incurred using surface water in 1991/92
2. Total water production is assumed to be 81,000 cu.m/day

TABLE E1

SABAKI WATER WORKS STAFF

	PLANNED	EXISTING
Subarea Manager	1	1
Deputy Subarea Manager	1	1
Operation Maintainance Inspectors	6	2
Mechanical Inspectors	4	2
Electrical Inspectors	4	2
Laboratory Technologists	4	2
Assistant Lab. Technologists	2	0
Chemical Attendants	10	0
Electrical Technician I	2	1
Technicians II/III	2	0
Plant Maintenance Technician	2	0
Plant Maintenance Technician II/III	2	0
Motor Vehicle Inspector	1	0
Motor Vehicle Technician	1	0
General Maintainance Foreman	1	0
Operators	4	2
Pipefitters	6	6

Source: NWCPC, Baricho

TABLE E2

ANALYTICAL METHODS
FOR DETERMINATION OF MAJOR VARIABLES

VARIABLE	GRAVI-METRIC	TITRI-METRIC	PHOTO-METRIC	ELECT-ROCHEM. PROBE	FLAME PHOTO-METRY	LC	AES	AAS	GC	GC/MS	BIOLO-GICAL
Residual	■										
Suspended Matter			■								
Conductivity				■							
pH				■							
Acidity & Akalinity		■									
Redox Potential				■							
Dissolved Oxygen		■		■							
Carbon Dioxide		■		■							
Hardness		■									
Chlorophyll a			■								
Nutrients			■								
Organic Matter (TOC,COD,BOD)		■									
Major Cations					■			■			
Major Anions		■	■								
Silica			■								
Fluoride			■								
Heavy Metals			■				■	■			
Pesticides						■			■	■	
Bacteria											■
Algae											■
Flora and Fauna											■

TOC - Total Organic Carbon
COD - Chemical Oxygen Demand
BOD - Biochemical Oxygen Demand
LC - Liquid Chromatography
AES - Atomic Emission Spectrophotometry
AAS - Atomic Absorption Spectrophotometry
GC - Gas Chromatography
GC/MS - Gas Chromatography/Mass Spectrometry

Sources:
Chapman, 1992
APHA, 1989
Golterman et al., 1978