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REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT



# FEASIBILITY STUDY ON WATER SUPPLY AUGMENTATION PROJECT OF MOMBASA - COASTAL AREA - HINTERLAND

# FINAL REPORT



SEPTEMBER 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

## PREFACE

In response to the request of the Government of Republic of Kenya, the Japanese Government decided to conduct a feasibility study on water supply augmentation project of Mombasa coastal area and hinterland and entrusted the survey to the Japan International Cooperation Agency (JICA). The JICA sent to Kenya a survey team headed by Mr. Takao Ichimiya from March to September, 1980.

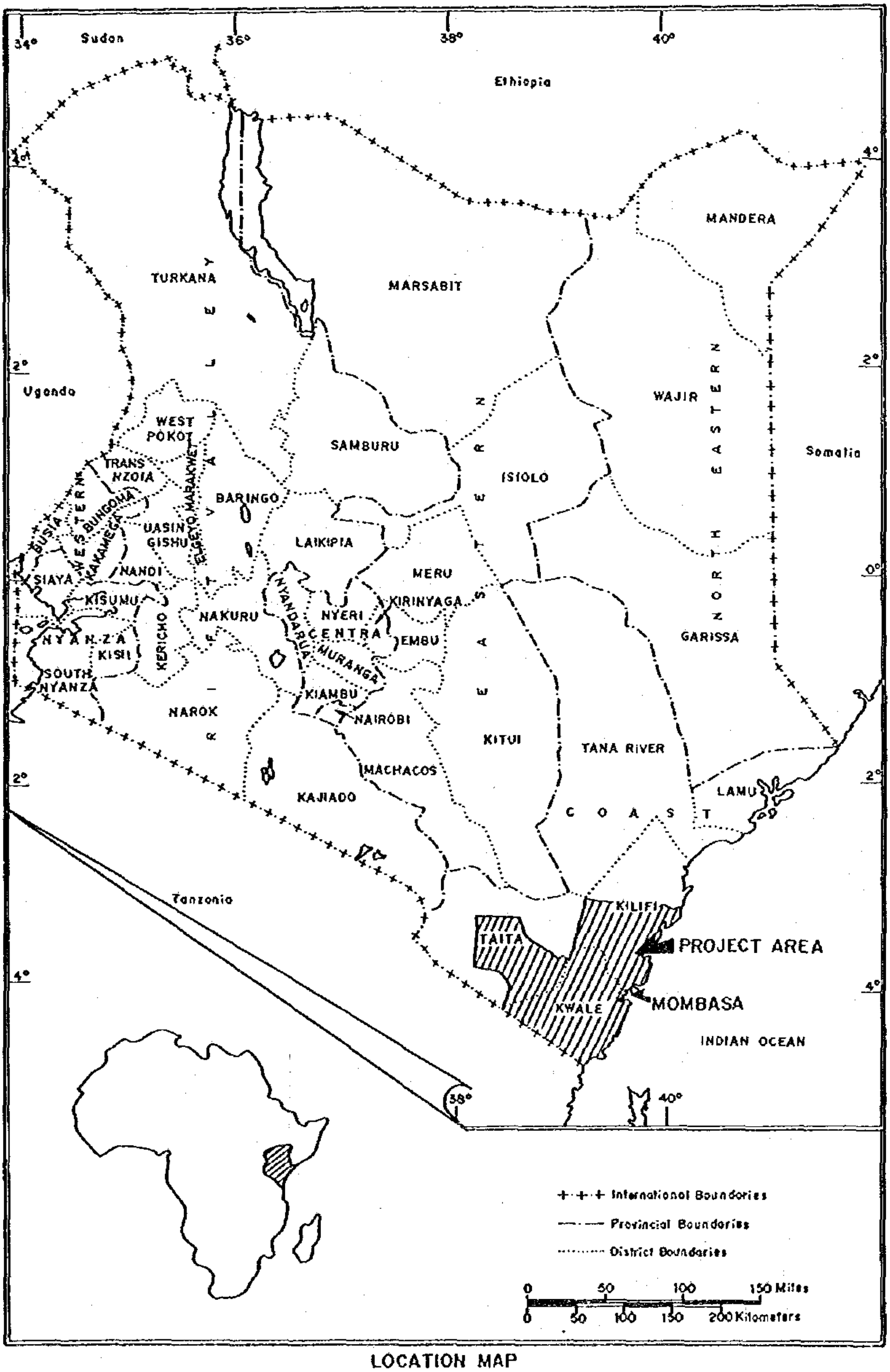
The team exchanged views with the officials concerned of the Government of Kenya and conducted a field survey in Mombasa coastal area and hinterland. After the team returned to Japan, further studies were made and the present report has been prepared.

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

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

September, 1981

Keisuke Arita
President
Japan International Cooperation Agency




LOCATION MAP

FEASIBILITY STUDY ON WATER SUPPLY
AUGMENTATION PROJECT OF
MOMBASA-COASTAL AREA-HINTERLAND

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## ABBREVIATIONS

| | | |
|---|---|---|
| BPT | : | Break Pressure Tank |
| CMD | : | Cubic Metre per Day |
| CMS | : | Cubic Metre per Second |
| CPWB | : | Coast Province Water Branch |
| CWP | : | Communal Water Point |
| E&E | : | Ecology and Environment |
| EIRR | : | Economic Internal Rate of Return |
| FIRR | : | Financial Internal Rate of Return |
| GDP | : | Gross Domestic Product |
| G/S | : | Gauging Station |
| ha | : | Hectare |
| IBRD | : | International Bank for Reconstruction and Development |
| IC | : | Individual Connection |
| JICA | : | Japan International Cooperation Agency |
| JWWA | : | Japan Water Works Association |
| km | : | kilometre |
| lpcd | : | litre per capita per day |
| MGD | : | Million Imperial Gallon per Day<br>1 MGD = 4,545.96 $m^3$/day |
| mm | : | millimetre |
| MOWD | : | Ministry of Water Development |
| MPB | : | Mombasa Pipeline Board |
| O&M | : | Operation and Maintenance |
| p.a. | : | per annum |
| P/L | : | Pipeline |
| ROI | : | Return on Investment |
| RWS | : | Rural Water Supply |
| TRDA | : | Tana River Development Authority |
| WED | : | Water Engineering Department |

## CURRENCY

US$1 = KSh 7.5
K£1 = KSh 20

# SUMMARY

S01 Circumstances: In the foregoing Inventory Report submitted in September 1980, the future demand for water supply augmentation in the project area for a middle term up to around 2000 was projected. The project area encompasses the south-eastern corner of Kenya consisting of Mombasa, the seven urban centres and the rural areas. The demand was projected to be 1.8 $m^3/s$ in 2000 in addition to the total supply capacity by the existing and on-going facilities.

S02 On the other hand, the studies of water supply source to cope with the demand were made extensively by means of raising every conceivable plans, and sieving the less favourable ones until the best plans remained. Of twenty plans raised as conceivable, three plans were remained for further study. They were the Second Mzima P/L with Tsavo Reservoir Plan (the Mzima with Tsavo Dam Plan), the Rare Reservoir with Rare P/L Plan (the Rare Plan), and the Mwachi Reservoir with Mwachi P/L Plan (the Mwachi Plan).

S03 As a whole, the availability of the hydrologic data for the study of each plan is poor. Almost every plan is formed based on the hydrologic data estimated on particular assumptions. After the Inventory Report was submitted, it was informed that the data used for planning the Mwachi Plan included incorrect information about the datum elevation of the gauge staff. Re-study made based on this information reveals that the probable scale of the Mwachi Plan would become too small to an extent that this plan can not cope with the scope of the projected demand. But this plan would function as an auxiliary to fulfil the local needs and the industrial demand.

S04 Situation being as such, the study of the Mwachi Plan has to be suspended. The remaining two plans are further studied putting use of the results of the field survey. In this report, therefore, treated

are the particular results of the further study on the two plans including their economic and financial aspects, and the results of studies on the order of development by which the difference of the benefits and the costs (B-C) is maximized in the long run.

S05 Second Mzima P/L with Tsavo Reservoir Plan: is a combination of the pipeline with related structures from the Mzima Springs to Mombasa, and the Tsavo dam and reservoir on the Tsavo River purposed to compensate the abstracted flow from the Springs so as to secure the intake discharge for the Sabaki P/L as well as to maintain the ecological and environmental conditions along the full stretch downstream from the dam. The maximum supply capacity of this plan is 1.2 $m^3/s$.

S06 The water supply facilities are studied with the accuracy required for the bankable feasibility study. These facilities consist of the intake structures at the Springs, the pipeline therefrom to Mombasa for 219 km, the related structures and the distribution reservoirs located near Mombasa. The Tsavo dam is located on the Tsavo River near the confluence with the Athi River. Due to the absence of the hydrologic data on the lower stretch, the amount of release of flow from the dam is treated to be equivalent to the amount abstracted from the Springs. Hence, the scale of the dam is subject to review for the feasibility study when the sufficient hydrologic data on the lower stretch become available.

S07 Total cost of this plan is estimated at US$270 million on the economic cost basis and US$421 million on the financial cost basis. The latter amount is composed of US$214 and 207 million respectively of local and foreign currency portions. The return on investment (ROI) of the Plan is derived at 5.5% when the estimated current water rate of 5.6 KSh/$m^3$ at the outlet of distribution reservoir is applied. The financial internal rate of return (FIRR) of the Plan is derived at 3.4% when the water rate of 13.6 KSh/$m^3$ which is derived by assuming a water tariff increase of 15% per annum, is applied.

S08 Rare Reservoir plus Rare P/L Plan: is based on a concept to utilize the rainy season flow of the Sabaki River stored and regulated in the reservoir on the Rare River. The water source feature of the plan consists of the intake weir on the Sabaki River, the waterway therefrom to the Rare reservoir for 40 km and the dam on the Rare River. The water supply feature consists of the intake and treatment plant near the reservoir, the pipeline with pumping station to Mombasa for 70 km, and the distribution reservoirs near Mombasa. Flow is by gravity from the Sabaki River to the Rare reservoir, and by pump thereafter. This plan has physically a larger capacity but a scale of 2.5 $m^3/s$ is taken. The scale of the dam is subject to review for the feasibility study when sufficient hydrologic data on the Sabaki River become available.

S09 The cost of this Plan is estimated at US$274 million (economic) and US$452 million (financial). The latter amount is composed of US$288 million and US$164 million respectively of local and foreign currency portions. The ROI of the Plan is derived at 8.3% when the estimated current water rate of 5.6 $KSh/m^3$ at the outlet of distribution reservoir is applied. The FIRR of the Plan is derived at 4.0% when the water rate of 13.6 $KSh/m^3$ which is derived by assuming a water tariff increase of 15% per annum, is applied.

S10 Up-to-date Information Concerning the Project: After submitting the Draft Final Report in February 1981, the Study Team was informed that the Munyu scheme was taken up as a priority scheme in the Athi River basin development study and was also informed that a feasibility study of the Munyu scheme would start from May 1981.

S11 There may be two cases concerning the result of the Munyu Study so far as it may affect the Mombasa water supply augmentation project:

Case A: Available water is sufficient for the Mombasa Water Supply by the year 2000

Case B: Available water is not sufficient for the Mombasa Water Supply by the year 2000

There will be alternatives of water supply plans for Cases A and B. The best plan will again have to be selected out of all of the plans conceivable. Some examples of alternatives for Cases A and B are given below and their conceptual figures are presented in ANNEX 1115.

Case A: When the available water is sufficient:

A1: Combination with the 2nd Sabaki P/L, and

A2: Combination with the 2nd Mzima P/L.

Case B: When the available water is not sufficient, the deficit will have to be supplemented by other reservoir or water source(s).

Examples are as shown below:

B1: Combination with Rare reservoir plus Rare P/L (deficit is supplied by Rare reservoir),

B2: Combination with 2nd Mzima P/L plus Tsavo reservoir (deficit is supplied by Tsavo reservoir), and

B3: Combination with 2nd Sabaki P/L plus Tsavo reservoir (deficit is supplied by Tsavo reservoir).

There may be other means of supplementing the deficit such as the combination with other water sources like coastal rivers or groundwater.

As the feasibility study on the Munyu dam scheme is proceeding, the selection of the best alternative for the Mombasa water supply is suspended until the feasibility study on the Munyu dam scheme is finished to confirm the availability of water to Mombasa water supply.

S12 *Conclusion:* *After the Munyu feasibility study is completed*, this Final Report would be reviewed and updated, if necessary, incorporating the result of the Munyu study. The results of the present study on the two plans of the Second Mzima P/L with Tsavo dam Plan and the Rare reservoir with Rare P/L Plan are summarized as follows:

(1) Both of the plans are technically possible though the scale of the Tsavo dam and the Rare dam should be subject to further investigations.

(2) The result of economic evaluation shows the ROI values of 5.5% for the Second Mzima P/L with Tsavo dam Plan and of 8.3% for the Rare reservoir with Rare P/L Plan, based on the current water rate (wholesale price) of 5.6 $KSh/m^3$ in both cases. Although these values are not so satisfactory, whether to implement such a project that is urged by basic human needs like the Mombasa water supply augmentation cannot be determined only by the ROI value.

(3) The result of the study on the financial aspects of the two plans commonly anticipates a serious deficit of CPWB for a long period. The financial impacts to be brought by implementing either one of the two plans should be carefully treated.

(4) The result of the study on project priority by means of Dynamic Programming indicates that in technical and economic aspects, the Rare Plan be implemented first. However, if the future electric power constraints in Kenya were anticipated and if the Kenyan Government should make every effort to prevent the economic and social problems caused by the power shortage, the merits of the Second Mzima Plan, such as gravity conveyance and no requirement for treatment, would be emphasized.

S13 When the Second Mzima Plan should be allowed as the promising alternative plan for Mombasa water supply augmentation, the following conditions will have to be fulfilled first:

(1) Considering the significance of the huge amount of cost, the terms of foreign loan(s) required for financing the capital fund should be sufficiently soft; low interest rate and long repayment period.

(2) The serious financial burden of CPWB expected from implementing this Plan should be shared by non-beneficiaries of this plan through the Government account.

S14 When the Second Mzima P/L with Tsavo Reservoir Plan would be implemented, this plan would meet the water demand in the Project area leaving some years before 2000. Then, the Rare Plan would be conceived before 2000 as one of the promising alternatives to follow.

S15 Recommendation: For more dependable planning, hydrologic observation has to be reinforced and continued on the Sabaki, the Mwachi and the Rare Rivers. The future growth of demand for water supply has to be observed carefully to up-date the planning.

# 1. INTRODUCTION

## A. History

1101 Mombasa is one of the most important cities in the Republic of Kenya as a sole international seaport of the country, as well as the centre of transportation, trade, manufacturing and tourism. This city is the second largest in the country. The coastal area in the south of the Sabaki River, along which Mombasa is located, is a rather densely populated area supported by agriculture, fishery and tourism. The hinterland of the coastal area is dry and sparsely populated and progressing slowly.

1102 These areas, against their growth in the recent decades, have not been favoured with adequate water supply. Particularly in Mombasa, the shortage of water supply had become chronic. In the recent years, the water supply in Mombasa has had to be rationed for 12 hours a day. Such shortage has not only been an inconvenience to the development in these areas, but also a most serious constraint factor to the development of these areas.

1103 The water supply in these areas is being made by the existing water supply facilities consisting of the Mzima Pipeline (P/L) and other systems. The total capacity is insufficient so that the said shortage had been caused. For the augmentation, the Sabaki P/L scheme is under construction, and the scheme is expected to be put to comission within 1981. However, it is foreseen that thus augmented capacity will soon be caught up by the growing demand.

1104 To cope with this situation, the Government of Kenya intends to augment further the water supply to these areas, and in June 1979 requested the Government of Japan to conduct a feasibility study on the water supply augmentation project for Mombasa, the coastal area and the hinterland (the Study). In response to this request, the Government of Japan decided to provide a technical assistance for this study.

1105 The Government of Japan through the Japan International Co-operation Agency (JICA) organized a preliminary survey mission which was sent to Kenya in October 1979. The mission made a brief survey and clarified the scope of work (S/W). Then JICA organized an advisory committee and a study team (the Team). The Team accompanied by a member of the advisory committee was sent to Kenya in early March 1980. The S/W for the Study was agreed and signed in March 1980. The executing agency of the Government of Kenya is the Ministry of Water Development (MOWD). The study was commenced and is continued since then.

1106 The Study consists of Part I and Part II. The objectives of Part I are (1) to project the water demand for the supply augmentation for Mombasa, the coastal area and hinterland for about 20 years after the total capacity of the existing and on-going supply facilities will have been met by the demand, and (2) to clarify the water sources to cope with the said demand. In Part II, further study is made on the most promising plans as defined in Part I.

1107 Before the start of the Study as well as during the early stage of the Study, the study work was proceeded in expectation that more abstraction of water from the Mzima Springs was possible without jeopardizing the intake discharge for the on-going Sabaki P/L Project. It was later revealed by the Team that this expectation was not feasible, and other means of providing water sources had to be looked for. This revelation caused many changes in the scope and schedule of the Study.

1108 In accordance with the S/W, the Initial Report which deals mainly with plan of operation and schedule of the Study work was submitted in April 1980. However, against the original schedule shown in this report, the preparation of the Inventory Report which is an outcome of Part I to be conducted entirely in Kenya was postponed by a few months due to the said facts. This report was submitted in late September 1980.

1109 Part II consists of the field work to be conducted in Kenya and the home work to be made in Japan. The field work was performed on schedule from June to September 1981. At the end of the field work for Part II, the work progress was reported by the Interim Report which was submitted in late September. The Team in which twelve member joined left Kenya for Japan for the home work in early October 1980.

1110 The home work of Part II has been continued in Japan since early October 1980 and the results have been compiled in the Draft Final Report. In this report two plans are treated as the candidates for the water supply augmentation of the subject area. These two plans are (1) Second Mzima P/L with Tsavo reservoir plan and (2) Rare reservoir and P/L plan. These plans had been selected as the results of the Part I work as reported in the Inventory Report, as well as taking into account the new information concerning the hydrologic data obtained in course of the Part II work.

1111 In February 1981, the JICA Study Team visited Kenya and submitted to MOWD the Draft Final Report. During this visit, the Team had meetings with the concerned staffs of MOWD and TRDA and discussed with them several issues including MOWD's comments to the Inventory Report. The Team also met high officials of MOWD concerned to the Study and reported the results of the study.

1112 The MOWD's comments to the Draft Final Report arrived at JICA Head Quarters, Tokyo in the middle of June, 1981. The reply to the said comments dated July 22, 1981 was prepared by the JICA Study Team and sent to MOWD through the Embassy of Japan in Nairobi. The Final Report is submitted to MOWD in September 1981.

1113 Meanwhile, in March 1981, Mr. C. N. Mutitu, Director of Water Engineering Department of MOWD and Mr. W. J. Odhiambo, Head of Implementation Branch of MOWD visited Japan. During their stay in Japan, meetings were held twice between these Kenyan officials and Japanese officials concerned together with the JICA Study Team. In the course of these meetings, it was revealed that the Munyu dam scheme in the upper Athi River would be taken up for a feasibility study in the near future.

1114 Although the Munyu scheme would be worthy of consideration in the study on the Mombasa water supply augmentation, it is not appropriate to start reviewing and updating the present study immediately. The reason is that the feasibility study on the Munyu scheme is informed to have been just started in May 1981 and the features on this scheme are not available until the completion of the said study. Therefore, the Final Report would, if necessary, be reviewed and updated only after the feasibility study on the Munyu scheme is completed.

1115 However, considering the significance of the Munyu scheme, a note on this scheme is prepared based on the limited data and information obtained from the "Technical resume from a meeting held with TRDA regarding dams on Athi River and its tributaries" which was attached to the MOWD's comment to the Draft Final Report. Also incorporated in this note is a view of the geologist of JICA Study Team through the Munyu site reconnaissance survey carried out during his stay in Kenya in August 1980. The said note on the Munyu scheme is attached to this Final Report (ANNEX 1115). It comprises some issues on the Munyu scheme, some considerations to be taken in the Munyu study and some alternative plans conceivable for the Mombasa water supply augmentation after the Munyu study is completed.

1116 The situations related to the Munyu scheme being as stated above, several paragraphs are newly drafted and added to this Final Report; they include the paras. from 1110 to 1116 in Chapter 1 INTRODUCTION, the para. 7105 and paras from 7107 to 7113 in Chapter 7 CONCLUSION AND RECOMMENDATION, and the paras from S 10 to S 14 in SUMMARY (all the number of paragraphs are those of the Final Report). In some paragraphs, minor amendments are made including improvement in wording and in report arrangement, which do not affect the context of the Report. The other paragraphs than the above are all retained as they were in the Draft Final Report.

1117 This Final Report has been prepared with the intention of providing the materials for judgement of selection for the decision maker of the Government of Kenya to take the necessary steps for the implementation. Regardless of the decision, it is needed to reinforce the hydrologic observation at necessary points along the rivers concerned for the purpose to raise up the precision of the study to follow.

1118 In this Final Report, historical description is principally based on the results of the field study carried out from March to September 1980. Hence, the "present" conditions mean those as of September 1980. For example, the Sabaki P/L is described in this report as being under construction, though it is already completed and being operated since February 1981.

## B. Technical Circumstances

1201 It had orginally been expected by most of the persons concerned that the water supply augmentation for the subject area could be achieved by abstracting water from the Mzima Springs in addition to the abstraction by the existing Mzima P/L. This expectation had been conceived by a fact that a perennial outflow of water of excellent quality is gushing out from these Springs throughout the year. The quantity of the outflow was studied and confirmed by MOWD./1 The preliminary Survey Mission and MOWD agreed upon the S/W based fundamentally on this expectation. The Study was commenced under this circumstance.

1202 After the start of the Study, the following facts became clear as the hydrologic study progressed.

(1) the outflow from the Mzima Springs is ample and perennial as studied previously by MOWD, but

(2) there exist a great amount of loss of flow along the downstream stretch of the Sabaki River to which the outflow from the Mzima Springs joins, and

(3) the flow of the Sabaki River on the lower reaches becomes very small especially in the dry season in comparison with the size of the catchment area.

1203 The Sabaki P/L project is under construction under such hydrologic condition. The intake discharge of this project had been designed to accord with the minimum dry season flow of the Sabaki River at Baricho. Hence, there is no hydrologic possibility to further increase the intake discharge from the Sabaki River at Baricho.

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/1 Master Planning Section, Water Dept., MOWD, "Flow Regeme of the Mzima Springs", Aug. 1979.

1204 It was, therefore, clarified that the additional abstraction of water from the Mzima Springs would jeopardize the intake discharge of the Sabaki P/L. When more water is abstracted from the Springs, the dry season flow of the Sabaki River at Baricho will decrease to an extent to be below the designed capacity of the Sabaki P/L, hence there will be some periods of time when the Sabaki P/L will not be able to function fully. The probability study indicated that such periods will extend to about 20 % of days of a year on an average.

1205 Thus, the original expectation to abstract more water from the Mzima Springs was not clarified to be feasible. An original alternative expectation to seek water from the lower Sabaki River was neither feasible. The water sources, therefore, for the supply augmentation had to be looked into others than those expected above. As methodology, an elimination method was adopted.

1206 The water sources looked into were (1) the Sabaki River system including the Tsavo River with the seasonal flow regulation reservoir, (2) the coastal rivers with the seasonal flow regulation reservoir, (3) other conceivable water sources such as groundwater and (4) their combination. From these investigations, twenty alternative plans were conceived. Out of these twenty plans, the less favourable plans were eliminated, and three plans were finally remained. They are:

The Second Mzima P/L plus Tsavo Reservoir plan,
(abr. Second Mzima and Tsavo plan, scale 1.2 $m^3/s$)

The Rare Reservoir and P/L plan, and
(abr. Rare plan, scale 2.5 $m^3/s$)

The Mwachi Reservoir and P/L plan
(abr. Mwachi plan, scale 3.0 $m^3/s$).[/1]

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Remarks: /1 Not adopted in this study due to the new information.

1207 In the Inventory Report submitted in September 1980, the subject area for the water supply augmentation was delineated and the future demand in the area was projected. On the other hand, the availability of water was hydrologically studied. Then in view of the magnitudes of demand and water availability, the aforementioned three plans were selected. Preliminary study was made on these three plans and the comparison was dealt with. In parallel, the field survey of Part II consisting of the topographic survey and the surface geological survey was made on these three plans. The progress thereof was reported in the Interim Report submitted in September 1980.

1208 After the shift of the Study team from Kenya to Japan, the home work of Part II has been continued for the purpose to make further studies on the selected three schemes. In course of these studies the Team was informed that the hydrologic data of the Mwachi River collected from the MOWD during the Part I work involved incorrect information about the datum of the water gauge staff. Taking these new information into consideration, the hydrologic study on the particular gauging station (3MA3) was made again. The results showed that (1) the availability of water became far smaller than it was once estimated and that (2) the accuracy of the hydrologic data of this gauging station is insufficient to make sound study on this plan.

1209 In view of the new results, it is understood that it is difficult to decide an exact development scale and that a would-be scale is too small to meet the size of full demand. Hence, the Mwachi Plan has to be put aside from the present study as a main plan to meet the total demand. However, this plan may be useful as an auxiliary scheme to support a partial demand or as a source solely for the industrial demand. In this concern, the hydrologic observation on the Mwachi River would have to be reinforced and continued.

1210 With the omission of the Mwachi plan, two plans, that is, the Second Mzima and Tsavo plan, and the Rare plan are dealt with in this report.

## C. Hydrologic Data

1301 It is needless to say that the hydrologic data having sufficient accuracy and a long coverage period of time are required for a feasibility study of a project which is concerned to the water resources development. The present states of the hydrologic observation and data on the Sabaki River system and the coastal rivers which are located in the "Drainage Area 3" of the whole Kenya are rather poor to meet the said requirement.

1302 On the upper reaches of the Athi River (the upper part of the confluence of the main Sabaki River with the Tsavo River), the hydrologic observation has been continued properly. The same is said on the lower part of the Tsavo River (the largest tributary of the Sabaki River). Whilst on the rest of the stretch of the Sabaki River, there is no reliable existing gauging station with an exception at Baricho (3HA3) which had been abandoned in as early as 1957 after seven years' observation with many blanks. There are gauging stations on the coastal rivers, one each on three rivers (the Pemba, Mwachi and Rare), but it is less accurate except for the one on the Pemba River. Hence, very little is known on the discharge of the lower part of the Sabaki River system as well as on most of the coastal rivers.

1303 As aforementioned, the loss of flow along the lower reaches of the Sabaki River causes serious loss of water source. However, the behaviour of the loss is hardly known in location and quantity. Accordingly, in the present study, the planning has to depend mostly upon the estimation and assumption to supplement the scantiness of the existing hydrologic data.

1304 For a reliable planning of the water resources development of the Sabaki River system and the coastal rivers, it is required to reinforce and to continue for future the hydrologic observation.

## D. Intention

1401 This Final Report deals with two plans; the Second Mzima P/L plus Tsavo Reservoir plan and the Rare Reservoir plus Rare P/L plan. Though water supply facilities including the P/L of the former plan are studied in a precision of a feasibility study, the rests are not to be treated as those studied in the precision of a feasibility study. This is due to the fact that the available hydrologic data are below the requirement for a feasibility study both in accuracy and coverage period.

1402 It is hence intended by this report to provide the decision maker with the materials to decide for taking the necessary future steps.

# 2. THE PROJECT AREA

## A. Delineation and Geography

2101 Delineation: The project area is defined in this study as an area whose bulk water supply augmentation is to be studied. The project area basically comprises Mombasa, the coastal area to the south of the Sabaki River on which Mombasa is situated, and the hinterland located to the west of the coastal area. The project area is bounded by the Sabaki River in the north, by the coast in the east, by the Tanzanian border in the south and by the boundary of the Tsavo National Parks in the west.

2102 The project area extends to an area of about 19,900 $km^2$ encompassing four Districts (administrative sub-division of Province) in the Coast Province. Included in the project area are the Kilifi District of the southern bank of the Sabaki River, the entire Mombasa District, the entire Kwale District, and the Taita Taveta District excluding the Taveta Division (administrative sub-division of District).

2103 In the four Districts of the project area, included are ten Divisions. Nine of them are entirely included in the project area except the Malindi Division of which three Locations (administrative sub-division of Division) of Gede, Ganda and Jilore Madunguni are only included.

2104 Geography: The project area is generally flat declining to the ocean with undurations. In the west the elevation is about 600 m with independent hills. The coastal area is low, and a series of independent hill range runs parallel with the coastal line. The project area located approximately between 3°S and 5°S latitudes is in a tropical zone.

2105 The coastal area is relatively wet, but the inland area is dry. Annual precipitation is about 1,200 mm along the coast, but decreases going to inland and becomes finally less than 500 mm. In the coastal area, temperature ranges between 35°C and 24°C, but in the west of the project area the range narrows down between 32°C and 22°C.

2106 The vegetation in the project area is also zonally influenced by rainfall and temperature. There are three climatological zones such as the coastal savanna, the coastal forest along the hill ranges, and dry bushland and thicket which occupies the largest area in the project from the coast to the west in order.

2107 Mombasa is located approximately in the middle of the coast in Kenya with heavy population of 342,000 (1979 census) which is ranked second in Kenya. The coastal area is rather densely populated in isolated middle to small towns like Malindi, Kilifi and Kwale. Population of the coastal area is 51,000. The hinterland is sparsely populated, but owing to the huge size of the area, the population amounts to 730,000. Total population of the whole project area is estimated at 1,123,000 (1979). This population will grow to 2,315,000 in 2000 including 716,000 of Mombasa.

2108 Socio-economy: Agriculture, fishery and forestry are the dominant means of livelihood in the whole project area. In this primary sector, there are two distinct economies, one is the economy of small substance farmers, herdsman and fisherman to embrace more than 90 % of the population outside Mombasa. The other is the monetary economy to embrace the balance of the population.

2109 Mombasa is the centre of transportation, trade, manufacturing industry and tourism. Mombasa is a sole international seaport of Kenya as well as of some adjoining land-locked countries of east Africa, and equipped with necessary seaport facilities. Mombasa is linked with Nairobi and coastal towns with highways and roads. The railroad links

Mombasa to Nairobi and further to Kisumu. Also the air-service is available to Nairobi and Malindi.

2110 The manufacturing industries in Mombasa are the second largest in the country. Main products are refined oils, cement, steel, aluminium wares, beverages, etc., with many other items by light industires. The total wage employments in Mombasa amounted to 86,300 (1979) occupying more than one quarter of that of the whole country.

2111 Existing industrial factories are concentrated in the Mombasa Island and expanding to the West Mainland. The Municipal Council of Mombasa prepared a blue print of future industrial development. This plan demarcated 1,990 ha of industrial area, of which more than one half is concentrated in the West Mainland (856 ha in Changamwe area and 143 ha in Mazeras area).

2112 For the tourism, Mombasa functions as one of the two gate towns for the international tourists in Kenya and a centre of the tourism of the coastal area. Among the tourism resources of this area, the beach resort which offers the eternal summer attracts any tourist. There are nearly 100 hotels in the project area, of which one half are in the beach area, one third in Mombasa and rests in the hinterland. Total available beds amount nearly to 10,000. The hotel night-beds sold in 1979 amounted to 2 million. This number will be nearly doubled in the year 2000 if the available beds with smooth water supply are increased.

## B. Present Water Supply

### a. General

2201 The Ministry of Water Development (MOWD) is the sole government agency with technical expertise in water affairs and the largest water supply undertaker of the country. The Water Engineering Department of the MOWD is in charge of water supply, and the Coast Province Water Branch (CPWB) is the executing agency of the Department for water supply in the Coast Province area. The organization chart of the Department, which was proposed to be put in force within 1980, is presented in ANNEX 2201.

2202 Apart from the MOWD, there is a statutory body, the Mombasa Pipeline Board (MPB), which controls two major pipelines, the Mzima/Mombasa Pipeline and the Marere/Mombasa Pipeline, which are bulk suppliers. The CPWB acts as an agent for the MPB in the Coast Province. Actual operation and maintenance as well as the budgetary measurement including construction are undertaken by the above mentioned Water Engineering Department.

2203 In the project area there are a number of independent water supplies including urban water supply, rural water supply, ranch water development and self-help water schemes. Out of them, 19 large-scale supplies are operated under the MOWD as listed below. Other water supplies are operated by other different agencies.

<u>Water Supplies Operated under MOWD</u>

1. Mombasa Island
2. West Mainland
3. North Mainland
4. Malindi
5. Kaloleni
6. South Mainland
7. Voi
8. Mariakani
9. Gede-Watamu
10. Kilifi
11. Msambweni
12. Wundanyi
13. Tezo-Roka
14. Kwale
15. Mazeras-Rabai
16. Kinango
17. Dembwe-Wusi
18. Mwajika-Teri
19. Mackinnon Road

2204 Water supply in the project area is characterized by the system of bulk water supply, as mentioned in the sections to follow. The bulk water supply under a water agency involves, in principle, water production and conveyance up to the supply area. The service of supplying water for consumers is undertaken by another water agency. In the project area, this system is widely practiced.

b. Water Works Facilities

2205 There are two major bulk water supplies, in terms of supply capacity, which are presently serving in the project area; namely 1) Marere Pipeline and 2) Mzima Pipeline. The Sabaki Pipeline now under construction will soon come into operation. These bulk water supplies including other existing supplies are listed in ANNEX 2205-1 and their locations are shown in ANNEX 2205-2.

2206 Marere Pipeline is the first potable water supply system for Mombasa constructed initially in 1916. This system has presently an expanded capacity of 13,500 CMD. The water sources are the Marere Springs and the Pemba River. After a simple treatment the system supplies water to Kwale and Kinango as well as the southern coastal area of Mombasa.

2207 Mzima Pipeline is the main bulk water supply system for the coastal area serving 36,000 CMD. The water source is the Mzima Springs. The distance between the water source and the supply area is as far extended as 219 km, and the elevation difference is as big as 505 m. The system was put in service in 1956 after the construction works since 1951.

2208 The intake facility at the Springs is characterized by its long sheet piling works of 600 m. The sheet piles compose a cut-off in the lava to intercept and to collect groundwater to the intake chamber. The intake works were designed to a capacity of 72,000 CMD, but presently the intake quantity is limited to 36,000 CMD with surplus water being returned into the Mzima River. Therefore, the Mzima Pipeline can be doubled with an additional pipeline without further extension work at the intake, when required.

2209 The transmission pipeline from the water source to Mombasa consists of a prestressed concrete pipeline ranging from 530 mm to 760 mm in diameter over the distance of 219 km; ten break pressure tanks protecting the pipeline; and three prestressed circular reservoirs, each 27,000 $m^3$ in capacity at the end of the pipeline at Mazeras. Flow in the pipeline is by gravity. Because of the elevation difference of 505 m, the pipeline is sectioned to a number of spans together with the break pressure tanks. Discharge is metered at two points: one downstream from the intake and the other just before the reservoirs. Since the pipeline was installed, there have been a number of shortcomings in construction and operation of the pipeline, but they have been gradually remedied. Some sections have been replaced with steel pipes.

2210 To distribute water received into the reservoirs, twin 530 mm pipelines are installed from Mazeras to the service reservoirs at Changamwe, from which the West Mainland area is supplied by a ring main. Mombasa Island is served by twin trunk mains, 600 mm and 900 mm in diameter. In addition, some portion of water is conveyed to outlying areas including areas as far north as Kilifi with the branches from the Mazeras - Changamwe pipelines.

2211 Sabaki Pipeline is under construction as of September, 1980 with its completion target at the end of the same year. When it is put into operation, it constitutes a principal part of water supply in Mombasa and the coastal area with a supply capacity of 54,000 CMD for the first phase and 72,000 CMD in total for the second phase.

2212 The water source of this system is the Sabaki River. The intake is located about 100 km north of Mombasa at Baricho. Close to the intake, a new water treatment plant is being constructed with treatment facilities completely equipped including presettling tanks, sedimentation basins and filters. The main transmission pipeline is to convey the treated water to Changamwe reservoirs, and on the way the pipeline will have distribution mains to serve for the northern coastal area of Mombasa and areas along the transmission main. Together with the construction of the system, the distribution facilities are being built in addition to the existing facilities.

c. Water Use

2213 The average daily consumption in the Mombasa Water Supply was 48,000 CMD in 1979, the details of which are shown in ANNEXES 2213-1 and -2. This amount shows the water consumption under the currently practiced rationing for 12 hours a day from 6 a.m. to 6 p.m. due to the chronic water shortage. If fully supplied, the consumption is considered to rise somewhat above this figure. As regards the supply rationing, some consumers in the area have private tanks to secure their water, and especially the industrial firms and hotels have storage facilities for a few days use of their own.

2214 The number of connections on consumer classification as of February 1979 is shown in ANNEX 2214. As to the kiosks as mentioned in the said ANNEX, there are two types: the government kiosks and privately owned kiosks licensed by the Government. There are many application for new connections, but they are not accepted owing to the shortage of supply capacity.

2215 The water rates of the CPWB are established according to the classifications of the consumers. The average rates are 8.00 KSh/$m^3$ for the urban water supply and 2.00 KSh/$m^3$ for the rural water supply in 1980. The individual water rates are presented below.

(1) Where a meter is installed, a monthly charge, according to the reading of the meter, for the first 9 cubic meters, per cubic meter ...... KSh 3.60

(2) Where water is sold in excess of 9 cubic meters, through one meter in any one month, per cubic meter ........................ KSh 9.05

(3) Where water is sold to a licensed retailer, per cubic meter ..................... KSh 1.10

(4) Retail charges for water sold by licensed retailer or at a kiosk per unit of 20 litres (0.02 cubic meter) or part thereof ..................... KSh 0.05

(5) Minimum charge for water at a metered connection per month ........................... KSh 32.40

2216 In addition to the water charge, the customers pay the meter rental charge on the monthly basis which is determined by size. Rental charge is KSh 3.50 for a meter up to 20 mm and KSh 6.00 for a meter 25 mm and the charge rises in proportion to the size. The customers are also required to make a security deposit, which is currently KSh 200 per customer for new connections. All customer payment is made on the monthly basis.

2217 System loss and leakage of the transmission pipelines are rather small as shown in ANNEX 2217. The figure on 1979 was 2.1 %. On the other hand, loss and leakage in the distribution system cannot be indicated by accurate figures from the distribution and consumption records, but according to a study made in the past, the total leakage and unaccounted-for water was estimated at 20%. The present loss and leakage may be similar to this figure, as there have been no prominent change in the supply condition.

## C. Present Sanitary Facilities

### a. General

2301 Sanitary services such as sewerage, drainage and solid waste collection are generally poor in Mombasa area. Around 180,000 persons, almost a half of the existing population in Mombasa have to rely on the most primitive and insanitary excreta disposal method - pit latrines. Sullage is often allowed to lie on the ground outside the Swahili house where solid waste is accumulated. After rainfall, sullage is putrefied in puddles. The nuisance is creating severe health hazards to the inhabitants and spoiling amenity and aesthetic appearance of the area.

2302 Groundwater of the Island is now highly contaminated by sewage infiltration from septic tanks and soakage pits. Groundwater was previously used for water supply, but this important water resource has become unsuitable drinking in the recent years.

2303 The creek areas are not much polluted from sewage. Organic matters disposed into the creeks from sewage seem to be carried away by the tidal current, which is rather swift due to a large tidal range of 2.3 m, but floating matters tend to collect on the shore. A considerable oil pollution is observed in Port Kilindini and Port Reitz smearing the water front with oil.

2304 As the population in the area is ever increasing and the built-up area is steadily expanding, detrimental conditions due to insufficient sanitary facilities and services are always being aggravated. The living environment and amenity of the area will be perilled if no effective measures are quickly taken. It is necessary to review the present condition of sanitary services and to expeditiously start remedial actions so as to check the environmental pollution.

b. Sewerage

2305 As for the sewage disposal, there are five sewerage systems in addition to the very widely used pit latrines and septic tanks in Mombasa. These systems in use cover 1) two small residential areas on the north-west side of the Island serving 4,000 people, 2) the residential and commercial areas in Old Town serving 33,000 people, 3) the town centre with 5,000 people served, 4) a residential and industrial area in Changamwe with 13,000 people served, and finally 5) the Shimo-la-Tewa Prison on the North Mainland serving 1,000 people, which is owned and operated by the Government through the Ministry of Works. Existing systems are shown in ANNEX 2305.

2306 These systems, constructed during the last 20 years, are still in use. The physical condition of sewers, structures, tunnels, etc. is good, the design and construction are generally satisfactory.

2307 On the other hand, maintenance and operation of existing works are poor. The two oldest treatment works 1) and 3) consisting of septic tanks and simple trickling filters are completely broken down. The Mombasa Island Treatment Plant 2) which treats sewage from the Old Town functions as a pre-treatment unit only, as sludge is discharged directly to the sea at ebb tides. The outfall system is inadequate, as sewage surfaces above the outfall and is transported by tides and surface currents into Mombasa Harbour and Tudor Creek.

2308 The oxidation ditch at Changamwe 4) is not in operation and raw sewage is discharged directly into the sea at Port Kilinoini. However, this plant will, if operated as intended, produce an effluent of high quality.

2309 The stabilization ponds at Shimo-la-Tewa Prison 5) are overgrown with weeds, and the transfer pipe from the first to the second pond is completely blocked, forcing the effluent to by-pass into the outfall pipe.

c. Pit Latrines

2310 Pit latrines serving 60 % of the population in Mombasa are in use in the most congested Swahili type housing areas where there is no space for additional pits. The latrines are therefore constructed as an integral part of the house. Although pit latrines used in Mombasa are large and well constructed, they will be eventually filled up and have to be regularly emptied. Pits are manually cleaned and the labour force involved is directly exposed to excreta. Spilling of excreta on the ground during emptying operation is inevitable. There are no health ordinance covering the emptying operation.

2311 Pits are often flooded by the storm water, and frequently collapse. Whenever pits are dug to the groundwater table, gross contamination of the groundwater results.

d. Septic Tanks

2312 Sewage disposal by means of septic tanks and soakage pits is the system most widely used where piped water is available. These serve 24% of the population covering all the tourist hotels along the coast, and most of the industrial and commercial areas. The system depends on infiltration of the liquid phase into the surrounding ground. Soakage pits inevitably clog up, and if not emptied, cause flooding, odour problems and considerable nuisance. This system has been adopted for large developments and the results have been constant clogging. The soakage pits are generally excavated to the ground water table, and as a consequence the groundwater in the Island is widely contaminated with existing water wells being abandoned.

2313 Regular emptying of septic tanks is a prerequisite for proper functioning of this system. However, they are only emptied whenever the system fails and problems arise. Even then it is often only the soakage pit which is emptied. A manual procedure for emptying septic tanks and soakage pits is normally adopted, resulting in the same unsanitary conditions, as described for pit latrine emptying. Occasionally the liquid pit or tank content is simply poured on the ground surface where it finds its way to the nearest storm water drain. Septic tanks and soakage pits function satisfactorily in the low density residential areas in the coastal strip.

e. Storm Water Drainage

2314 Areas with a proper storm water drainage system cover the most densely developed parts on the Island, parts of the Changamwe area on the West Mainland and the Kisauni housing Estate on the North Mainland.

2315 Other less developed areas, such as the coastal tourist resorts, the high standard, low density housing areas on Nyali, Famburi, Shanzu, Kizingo, Tudor, Port Reitz, Likoni and Shelly Beach depend on natural drainage for disposal of runoff water. Drainage is of no particular problem, as these areas are either situated on coral ground with very good permeability, or close to the water front.

2316 The existing drainage systems are generally well designed and constructed and being in good conditions. However, street flooding is common due to insufficient street sweeping and inadequate maintenance of gratings, gullies, pipes and catch pits.

2317 Nonetheless, as roughly half the population of Mombasa live in the low standard Swahili type housing areas with inadequate or no drainage facilities, the present conditions for the city as a whole must be termed unsatisfactory.

f. Solid Waste Disposal

2318 Present refuse collection is far from regular on the Island, and large areas of the mainland are not serviced at all. Of particular concern is the lack of adequate collection of refuse in the low standard Swahili housing areas. Collection of solid waste from several tourist hotels and the more peripheral residential areas on the mainland is sporadic. The total quantity of refuse collected and disposed on the Municipal landfill has, it is said, drastically declined during the last few years, in spite of a rapidly increasing population.

2319 This situation is due to the fact that collection equipment is quite insufficient including vehicles, which frequently break down because of poor maintenance and inadequate servicing. When breakdowns occur, the vehicles are out of operation for a long time, owing to a lack of spare parts.

2320 Littering around dust bins and collection batteries in residential areas, hotels, etc. is quite common, and is caused by broken or too small dust bins and by negligence on the part of the public and the refuse collectors. On the refuse dumped on the landfill, it is often observed that insects breed and animals scavenge, because all refuse piles are exposed without any covering.

g. Operation and Maintenance of Sanitary Facilities

2321 Operation and maintenance of all the afore-mentioned sanitary facilities are unsatisfactory. Regarding the sewage treatment plants there are two plants which are already not in operation owing to the lack of effective maintenance. As regards the storm water drainage, floods occur because of failure of street sweeping and cleaning of gratings, gutters, etc. As for solid waste disposal, collection is far from satisfactory, mainly from inadequate maintenance of all equipment.

## D. Water Demand Projection

### D-1 Factors of Water Requirements

#### a. Population

2401 The population of the whole project area is estimated at 1,123,000 as a provisional result of the census made in August 1979. The population of Mombasa totals 342,000, and the population of the other urban centres is 51,000. The population of the rural area is 730,000. The urban centres include the towns of Malindi, Kilifi and Mariakani in the Kilifi District, Kwale and Kinango in the Kwale District, Voi and Wundanyi in the Taita Taveta District. The rural area, though it has a large population, is very sparsely populated, with inhabitants mainly engaged in agriculture and fishery.

2402 The population growth rate was 3.3 % in Mombasa, 5.3 % in urban centres and 3.1 % in rural areas, when compared with the 1969 population census. Only urban centres showed higher growth than that of whole Kenya of 3.4 %. It is observed from the above that population increase in Mombasa is becoming stagnant, and that in contrast the urban centres are still attracting population.

2403 To estimate future population which is one of the basic factors of water requirement, the 1979 census is used as the most up-to-date demographic data. The method employed for the population projection is the "ratio method" which is summarized as follows:

(1) In principle, a jurisdictional level of district is taken as the unit of projection when such districts are included entirely in the project area. In the cases of Kilifi and Taita-Taveta districts, which are included partly in the project area, these districts are broken down into division and location levels.

(2) Changes in the jurisdictional boundaries are adjusted as far as possible based on inquiries at the Central Bureau of Statistics and the census map available.

(3) Based on the population census figures of 1962, 1969 and 1979, the ratio of each district toward the whole nation's population is plotted on a section paper to obtain the past trend (ANNEX 2403-1).

(4) The above trend is first extrapolated simply and adjusted later taking account of the future changes in the socio-economy of each district (ANNEXES 2403-2 and -3).

(5) After determining the future trend of ratio to the whole nation, the future population of each district is derived by multiplying each ratio to the future national population independently estimated, as shown in ANNEX 2403-4.

2404 Population projection of the urban centres is made independently of that of the project area. The procedures are summarized below.

(1) Seven urban centres have been selected in accordance with the indications in the Fourth Development Plan. In principle, these urban centres are defined as those having a population of 2,000 people or more. The economic potential and the spatial distribution are considered as well. Selected urban centres are Malindi, Voi, Kilifi, Mariakani, Wundanyi, Kwale and Kinango.

(2) In order to obtain the past trend of the urban centres, the population of the seven urban centres in the population census of 1962, 1969 and 1979 is aggregated (ANNEX 2404-1) and its ratio to the province population is plotted on a section paper.

(3) The ratio thus obtained is extrapolated to get the future trend. The future population of urban centres is obtained by multiplying the ratio by the future province population that has been estimated in the preceding paragraph 2403 (ANNEX 2404-2).

2405 Future population of the rural area has been derived deducting the future populations of Mombasa and urban centres from the total population of the project area.

2406 The result of population projection of the project area is presented in ANNEXES 2406-1 and -2. The population of the whole project area is anticipated to reach 2.3 million in the year 2000. The average growth rate is estimated at 3.5 % per annum, which is slightly higher than that of the whole nation. The population of Mombasa is predicted to reach 716,000 in the year 2000. The average growth rate in the same period is estimated at 3.6 % per annum. The total population of the seven urban centres is projected to increase at a high growth rate of 4.5 % per annum to reach 128,000 in the year 2000. It is estimated that the rural population will increase at the same growth rate as the average of the whole nation to reach 1.5 million in the year 2000.

2407 The high and low growth of population projection in the project area has been made separately from the adopted one. To obtain the high and low projection, the projected percentage to the nation population of Mombasa, other urban centres and rural areas has been applied to the high and low growth of projection of the nation population, respectively. The result is tabulated in ANNEX 2407.

b. Industries

2408 Manufacturing industries in the project area are concentrated in Mombasa. In the past, industrial development took place mainly on Mombasa Island, but it is recently expanding to West Mainland. Heavy industries including East African Oil Refinery, Bamburi Portland Cement Company, East African Breweries and others, are all in Mombasa, and in addition there are many light industries, such as furniture and house fixtures, textile and textile goods, metal industries, cardboard and paper products and others. The scale of industries in terms of the number of employees is as listed below.

| Number of Employees | Number of Industries |
| --- | --- |
| Over 500 | 2 |
| 200 - 499 | 12 |
| 100 - 199 | 18 |
| 50 - 99 | 27 |
| 20 - 49 | 41 |
| 15 - 19 | 97 |

2409 Apart from Mombasa, there are not many industries in the project area. They are, in Malindi, a furniture manufacturer, a cotton spinner and two bakeries; in Kilifi, Kenya Cashewnuts Limited, a modernized factory with 1,800 employees; in Voi, an edible oil manufacturer and a sisal factory; in Mariakani, a milk processing factory; and in Ramisi, a sugarcane factory.

2410 Water for the industries is supplied by the municipal water supply, and there is no specific industrial water supply. Because of the supply rationing, many of the industries have their own storage facilities, for example, the East African Oil Refinery has a tank with a capacity of 10,000 $m^3$, and the Kenya Breweries Limited a tank of 1,700 $m^3$. Capacities of the storage are enough to cover a few days consumption.

2411 Mombasa has an advantage for the industrial development due to its excellent position as the sole international seaport of the country, while Mombasa has some disadvantages for the industrial development, that is, its location is far from the centres of domestic market such as Nairobi and others and many industries are developing in and around Nairobi and the western highland. Mombasa will, nevertheless, develop as an industrial district in line with the national industrial policy of shifting from import-substitution to export-orientation, and taking full advantage of the sole, good seaport and will become a centre of bulk import of materials and bulk export of manufactured products.

2412 For the industrial development of Mombasa, the Municipal Council of Mombasa has broadly demarcated four areas as shown below.

| | |
|---|---|
| (1) Mombasa Island | 153 ha |
| (2) West mainland | |
| Changamwe area | 856 |
| Mazeras area | 143 |
| (3) Nyali area (north mainland) | 342 |
| (4) South area | 497 |
| TOTAL | 1,991 ha |

The above demarcated areas are already partially occupied by some existing factories. Out of the four areas, the Nyali area in the north mainland has a further detailed plan.

| | |
|---|---|
| Nyali industrial area | |
| Existing factories: | |
| Bamburi Portland Cement | 41.4 ha |
| Bamburi Portland Cement (Silos) | 0.8 |
| Kenya Asbestos | 19.0 |
| SUB TOTAL | 61.2 ha |

| | | |
|---|---|---|
| Planned: | | |
| Light Industries | 53.3 ha | |
| General | 227.5 | |
| SUB TOTAL | 280.8 ha | |
| TOTAL | 342.0 ha | |

2413 Apart from Mombasa, within the project area, industrial areas delineated for town plannings by the Municipal Councils are as shown below.

| | | | |
|---|---|---|---|
| (1) | Malindi | 3 blocks | 8.4 ha |
| (2) | Voi | 4 | 8.9 |
| (3) | Kilifi | 1 | 14.1 |
| (4) | Mariakani | 1 | 6.0 |
| (5) | Wundanyi | 2 | 6.6 |
| (6) | Kwale | 2 | 43.1 |
| (7) | Kinango | 4 | 2.2 |
| | TOTAL | | 89.3 ha |

2414 Industrial expansion in the project area outside Mombasa is being encouraged with some successful results, and it is imperative to secure water together with expansion of the primary sector's production for realization of the industrial development.

c. Tourism

2415 The tourism resources in the project area are beaches, wildlives and buildings of historical interest. At present, hotel facilities are largely restricted to Malindi, Watamu, Kilifi, Kiambala, Mombasa, Tiwi, Diani and Shimoni.

2416 In 1978, there were 51 hotels in the beach area, 33 hotels in Mombasa Island and 11 hotels in the coast hinterland, as shown in ANNEX 2416. The daily average beds available in 1978 were estimated at 6,900 in the beach area, 1,500 in Mombasa Island and 700 in the coast hinterland.

2417 Present water supply for the tourist hotels is not necessarily satisfactory. There are many hotels which have provision of water storage against the regular suspension of water supply or wells for self supply.

2418 According to the latest study on beach tourism development, it is concluded that future tourism development will be principally in the southern coast. On the other hand, tourist projection which is essential for water demand projection is made employing the following procedures.

(1) To analyze the historical data on hotel-beds occupied in the coastal area, excluding 1973 data (ANNEX 2418-1).

(2) To project the future night-beds by a logistic curve, which was found most fitted (ANNEX 2418-2).

The result indicates that 3.9 million hotel-beds will be required in 2000 with 10,800 tourists a day on an average.

## D-2 Water Demand Projection

2419 Water demand projection in this section is undertaken to obtain a basis for a medium term water supply plan until the year 2000. After projecting the total water requirement, the net requirement, i.e., the total demand less the existing supply capacity, is determined.

2420 Future water demand is projected by categories of water use and locations of demand centres. The categories adopted are 1) domestic, 2) industrial, 3) tourism and 4) commercial, public and other water demands. Water for livestock breeding is independently projected from the above. The locations adopted for projection are Mombasa, other urban centres and rural areas. The urban centres include Malindi, Voi, Kilifi, Mariakani, Wundanyi, Kwale and Kinango.

2421 Historical consumption data are not taken as the representative water demand, because the current supply network does not cover all the demand area and demand in the pipe-served area is even surpassing the supply capacity. Therefore, potential demand at present is considered.

2422 For water demand projection, the gross requirement basis is employed with all the losses and leakage in the trunk main or in the distribution facilities included. Intake and treatment losses, however, are not counted in the demand volume; it will be considered in the capacity of the intake/treatment facilities.

b. Domestic Water Demand

2423 Domestic water is defined as water to be used in households for drinking, cooking, bathing, washing, etc. In estimating domestic water demand, a study made by the City Council of Nairobi for water demand projection is referred in which emphasized are GDP growth as well as population growth as the influential factors for water consumption.

2424 In the usual water supply engineering practice, the future per capita water demand is estimated based on the past trend with any necessary reasonable adjustments taken in. In the present case, however, no reliable data on the past trend of per capita consumption are available on the water supply currently practiced. Therefore, the future per capita water demand is estimated from a viewpoint by assuming that the increase of per capita consumption is in proportion to the growth rate of GDP. Based on this concept, the structure of income groups which corresponds to the growth rate of GDP is sought for. Employing the income group structure and assuming per capita consumption for individual groups, the average per capita water demand is estimated.

2425 All the projections for the above procedures are presented in ANNEX 2425. First, the income composition in 1979 and the weighting factors are estimated. Applying these factors, the total average income for 1979 is obtained in the form of index. By the same method, the total average income for 2000 is estimated. The income growth rate for 1979 - 2000 ranges between 5% and 6% in accordance with the national target. The income groups to satisfy this condition are determined by trial and error. The structure of income groups corresponds to the growth rate of 5.4% per annum.

2426 On the other hand, per capita demand is estimated based on the Design Manual of MOWD. Based on this, the per capita demands are taken as 200 lpcd, 100 lpcd and 50 lpcd for the high income, the medium income and the low income groups, respectively. As is shown in ANNEX 2425, the average per capita demand is obtained as 80 lpcd a little higher than that estimated from the records available at the CPWB as presented in ANNEX 2426.

2427 In the same manner, the average per capita demand for 2000 is estimated for the above obtained income group structure. Per capita demands of the individual groups used for this estimation are 240 lpcd, 120 lpcd and 60 lpcd, respectively. The average per capita demand obtained is 126 lpcd. The figure 240 lpcd for the high income group is equivalent to about 200 lpcd in net consumption, which corresponds approximately to the present consumption level in developed countries.

2428 The per capita demand in the intervening years is interpolated as shown below:

| | 1979 | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| Per capita demand (lpcd) | 80 | 82 | 91 | 101 | 113 | 126 |

2429 The domestic water demand in Mombasa and the urban centres is projected multiplying the per capita demand determined above by the projected population. The projected demand is shown in ANNEX 2429. The growth rate in the period of 1979-2000 will be 5.9 % per annum for Mombasa and 6.8 % per annum for the urban centres.

c. Industrial Water Demand

2430 Industrial water is defined as water required in the process of manufacturing products such as cooling, processing, cleaning and so forth. As the existing industries appear to be using water as much as required despite the present water rationing, historical data on consumption is used for water demand projection. The current demand is estimated at 4,670 CMD and 140 CMD for Mombasa and urban centres, respectively. Based on these figures, the future water demand is estimated by applying a growth rate of 12 % per annum which is comparable to the historical growth rate of manufacturing sector in Kenya. The results are presented in ANNEX 2429. Based on the estimated factory area occupied of 273 ha in Mombasa in 1978 and the planned one of 1,991 ha in 2000, the industrial water demand per hectare of factory area is estimated to be 17 CMD/ha in 1978 and 24 CMD/ha in 2000.

d. Tourism Water Demand

2431 Tourism water demand is defined as water required in the tourism hotels for all purposes. The water demand per hotel-bed occupied is taken at 1.0 CMD based on a consensus with CPWB that an international level of a tourist water demand of 1.0 CMD should be applied.

Taking the unit water demand at 1.0 CMD per hotel-bed occupied and assuming it unchanged through the year 2000, the present (1979) potential demand for hotel use is estimated to be 4,540 CMD in Mombasa and 1,520 CMD in the urban centres. Assuming the growth rate as 3.0 % through 1979-2000, the demand is anticipated to be 8,480 CMD in Mombasa and 2,480 CMD in the urban centres as presented in ANNEX 2431.

e. Commercial, Public and Other Water Demand

2432 This category of water is defined as water used in shops, restaurants, business offices, government offices, schools, hospitals, airports, seaports, railways, fire fighting and so on. The present (1979) potential demand is estimated at 13,840 CMD in Mombasa and 2,050 CMD in the urban centres, all of which are estimated based on the present consumption under rationing. Assuming the growth rate as 6 % per annum comparable to that of the GDP, the water demand of this category for the year 2000 is estimated at 47,050 CMD in Mombasa and 6,960 CMD in the urban centres, as shown in ANNEX 2429.

f. Rural Water Demand

2433 The rural water comprises such water used in rural areas as 1) domestic use, 2) livestock use and 3) commercial, public and other uses. For the estimation thereof, the Design Manual of the MOWD, the National Master Water Plan and further the field survey carried out for the present study are referred to and taken into consideration.

2434 The domestic water demand is projected as product of the estimated per capita demand and the estimated population. For the per capita demand, the figures in the Design Manual, 50 lpcd for the population with individual connections and 25 lpcd for the population using communal water points and kiosks are adopted as the potential demand and not changed through the year 2000. The percentage of population with the individual connections is assumed as 20 % for present and 80 % in the year 2000. On the contrary, the percentage of population using communal water points and kiosks is assumed as 80 % for present and 20 % in the year 2000. Based on the above, the per capita demand for domestic use is projected as shown below.

| | 1979 | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| Per capita demand (lpcd) | 26 | 27 | 31 | 34 | 39 | 44 |

2435 Livestock water demand is projected based on the number of grade cattle per person multiplied by the estimated rural population. In this projection, the study made by the National Master Water Plan shown below is adopted.

Projected Number of Grade Cattle per Person by District

| District | 1979 | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| Kilifi | 0.20 | 0.20 | 0.19 | 0.18 | 0.17 | 0.16 |
| Kwale | 0.78 | 0.77 | 0.73 | 0.68 | 0.65 | 0.61 |
| Taita Taveta | 0.46 | 0.46 | 0.44 | 0.42 | 0.39 | 0.36 |

Water demand per grade cattle is estimated at 75 lpcd based on the Design Manual of MOWD.

2436 On the water demand for commercial and public use, and for industries, no reliable data is available. Therefore, the water demand for the above category is assumed as 15 % of the total water demand in the rural area, considering the results of the present field survey and other available studies. On the other hand, tourism water demand is not counted in the rural water demand, because it is already included in the foregoing tourism water demand.

g. Total Water Demand

2437 The consolidated projection of annual average water demand for the whole project area is shown below (ANNEX 2437-1) and graphically depicted in ANNEX 2437-2.

| Year | Mombasa District (CMD) | Urban Centres (CMD) | Rural Area (CMD) | Total (CMD) | ($m^3$/sec) |
|---|---|---|---|---|---|
| 1980 | 54,010 | 8,440 | 54,440 | 116,890 | (1.35) |
| 1985 | 74,000 | 11,630 | 66,870 | 152,500 | (1.77) |
| 1990 | 100,960 | 15,580 | 80,220 | 196,760 | (2.28) |
| 1995 | 139,020 | 20,680 | 99,850 | 259,550 | (3.00) |
| 2000 | 193,980 | 27,380 | 123,560 | 344,920 | (4.00) |

2438 The growth rates between the years 1979 and 2000 are 6.6 %, 6.2 % and 4.2 % for the total water demand in Mombasa, urban centres and rural areas respectively. The overall annual average daily per capita demands for each demand centre are as tabulated below.

| Year | Mombasa (lpcd) | Other Urban Centres (lpcd) | Rural Areas (lpcd) |
|---|---|---|---|
| 1980 | 152/1 | 156/1 | 72 |
| 1985 | 175 | 171 | 75 |
| 1990 | 200 | 183 | 77 |
| 1995 | 231 | 197 | 80 |
| 2000 | 271 | 214 | 84 |

2439 Apart from the above water demand projection, high and low growth estimations are made incorporating the high and low growth population projection and varying the key factors on which the projection depends, results of which are presented in ANNEXES 2439-1 and 2439-2. Factors used for these estimations are as follows.

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/1 When the tourism demand is excluded, the per capita demand will be 138 lpcd in Mombasa and 125 lpcd in urban centres.

| Factors | Adopted | High | Low |
| --- | --- | --- | --- |
| Income growth rate(%) | 5.4 | 5.6 | 5.1 |
| Per capita demand lpcd | 126 | 129 | 120 |
| Industrial growth rate(%) | 12 | 14 | 10 |
| Adjustment for tourism water, more or less(%) | | +10 | -10 |
| Commercial and other uses growth rate(%) | 6 | 7 | 5 |
| Per capita demand for rural areas 1979 and 2000 (lpcd) | 26 - 44 | 26 - 47 | 26 - 35 |

h. Net Water Demand

2440 Net water demand to be met by the present project is obtained by subtracting the following categories from the projected total water demand so far estimated.

(1) demand to be met by the existing and planned water supply schemes, and

(2) demand to be met by water supply schemes independent of the present project.

2441 The former includes not only the existing schemes, but also Sabaki Pipeline which is under construction and those whose improvement is being planned by the MOWD. They are listed in the next page.

Existing and On-going Water Supply Capacity (CMD)

| | | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 1. | Mzima Springs | 36,000 | 36,000 | 36,000 | 36,000 | 36,000 |
| 2. | Marere Springs | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| 3. | Pemba Water Works | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| 4. | Tiwi Borehole Nos. 1 & 4 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| 5. | Tiwi Borehole Nos. 2, 3 & 5 | 4,500 | 4,500 | 4,500 | 4,500 | 4,500 |
| 6. | Sabaki P/L System | 54,000 | 72,000 | 72,000 | 72,000 | 72,000 |
| | TOTAL | 109,000 | 127,500 | 127,500 | 127,500 | 127,500 |
| | ($m^3$/s) | (1.26) | (1.48) | (1.48) | (1.48) | (1.48) |

2442 The latter category includes self supply schemes in rural areas and independent supply schemes like that of Wundanyi Division. Their total supply is shown below.

Self Supply Water Schemes Capacity (CMD)

| | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| Total | 36,390 | 43,700 | 50,860 | 56,550 | 61,820 |
| ($m^3$/s) | (0.42) | (0.51) | (0.59) | (0.65) | (0.72) |

2443 The net water demand to be met by the present project is determined after deducting the above mentioned water supply capacity from the total water demand in the project area. The net water demand in 2000 will amount to 155,600 CMD or 1.80 CMS as shown below.

Net Water Demand (CMD)

| | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| Total | -28,500 | -18,700 | 18,400 | 75,500 | 155,600 |
| ($m^3$/s) | | | (0.21) | (0.87) | (1.80) |

2444 As presented in ANNEX 2444-1, it is anticipated that the water demand can be fulfilled by 1988 on the basis of annual average demand. However, an occasional deficit is anticipated to occur early in 1986 when the afore-mentioned existing capacity with some expected expansion will be exceeded by the peak monthly demand (ANNEXES 2444-2 and 2444-3).

E. Requirement for Water Supply Augmentation

2501 The existing bulk water supply systems have some serious shortcomings as described in the following paras below, and even when the Sabaki Pipeline project is put into operation in the near future, water shortage will again occur within a rather short time. To cope with this anticipated adverse situation, a most effective measure has to be expeditiously taken, especially considering the required time to construct a new project.

2502 Due to shortage of bulk water supply, rationing of water has been practiced for 12 hours a day. As most of large consumers have private storage tanks for their own use, the rationing is barely endured by the public. However, the cost of such provisions is burdened by the consumers as extra expenses. Further, unhygienic conditions of storing facilities and water use caused by the intermittent supply cannot be overlooked. When 24 hours-continuous supply should be practiced, it is anticipated that the water demand would increase by about 20 percent, namely, potential water demand for such a big amount is currently left unsatisfied.

2503 No new connections have been allowed in the recent years due to the said chronic water shortage. When the Sabaki Pipeline project is commissioned in the very near future, the supply capacity is to be doubled. However, new connections, coupled with the extension of supply hours, will soon exhaust the supply. The results of the present study indicate that the demand of water will catch up with the supply capacity in the period of 1985 to 1990. In terms of monthly maximum demand, the year 1986 will be the limit (ANNEX 2444-2).

2504 Industrial development for Mombasa is steadily under way, and demarcation of the industrial areas have already been made by the Municipal Council of Mombasa. On the whole, the industrial development policy of Kenya is now in the process of transition from import-substitution to export-oriented. Particularly in Mombasa, bulk import of materials and bulk export of products are envisaged. The transition of industrial policy and the industrialization of the project area require an urgent expansion of the water supply capacity.

2505 Tourism has been a major foreign exchange earning industry in Kenya, and this will not change in the future as well. According to the estimation of the present study, the number of hotels is to be doubled by the year 2000. Presently the water rationing is giving difficulties to hotel management leading to possible stagnation of tourism. This situation must be rectified by as early realization as practicable of augmentation of the supply capacity.

2506 In estimating the future water demand, a number of assumptions have been made and the most realistic values have been selected out of the estimates. Actual development of the water demand, however, may deviate from the estimation to a higher or lower side. In case the actual development takes place more rapidly than assumed, the augmentation of the supply capacity must be expedited and the scale of the project may also need reconsideration, to catch up with the requirement.

2507 In planning a future water supply project for Mombasa, Coastal Area and Hinterland, the followings, among others, must be taken into consideration, as will be surmised from the descriptions in the preceding sections.

1) Facilities of least cost operation and maintenance are preferable, such as requiring least electric power and less sophisticated equipment.

2) Import materials will be allowed in the current stage of national economy and industrial development, but in the future they should be minimized according to the national policy.

3) The project to be planned should be such one as to be completed by 1985 and to commence water supply in 1986 when the present water supply capacity runs short.

# 3. ALTERNATIVE PLANS

## A. Inventory Study

3101 The amount of water required for the augmentation of water supply in the whole project area in the year 2000 is estimated at 155,600 $m^3$/day or 1.8 $m^3$/s. On the other hand, the total supply capacity of the existing and on-going facilities including the second stage development of the Sabaki P/L will meet the growing demand upto 1986. Hence the said 1.8 $m^3$/s will be met by the growing demand after 14 years.

3102 The original expectations to seek the additional abstraction of water from the Mzima Springs or from the Sabaki River at Baricho are not feasible. The reasons are that (1) the driest flow of the Sabaki River at Baricho will be exhausted by the Sabaki P/L project leaving no remainder, that (2) more abstraction of water from the Mzima Springs in addition to the abstraction by the existing Mzima P/L (0.43 $m^3$/s) would decrease the flow at Baricho so that the Sabaki P/L will not be able to take full discharge for 20 % of days of a year on an average, and accordingly that (3) the ecological and environmental conditions would be affected on the lower reaches of the Sabaki including the Tsavo National Parks.

3103 Therefore, the necessary water for the augmentation of water supply had to be found elsewhere. In finding water sources, an elimination method was adopted in which all of the plans conceivable were enumerated and the ones less favourable than the others were eliminated until the promising plans remained.

3104 Possible sources for additional water can be found as follows:

(1) to increase the dry season flow of the Sabaki River with a reservoir which has a capacity large enough for seasonal flow regulation in or near the Sabaki River system,

(2) to do the same on the coastal rivers,

(3) to look for water from other sources than the above such as the Tana River, groundwater or even desalinized sea water, and

(4) to combine some of the above.

3105 Every conceivable plan to meet the requirement was looked for. Finally, twenty plans were raised altogether as shown in ANNEX 3105. In the process of raising, the members of the MOWD, the advisory committee and the Team joined. Of the twenty plans, the water source was in the Sabaki River system on ten plans, the coastal rivers on five plans, the Tana River on two plans, and groundwater and desalinization on three plans as mentioned in Chapter 7 of the Inventory Report.

3106 On these twenty plans, the sieving process was made to eliminate the plans which were less favourable than the rests until the best plans were remained. The respects of comparison through the sieving process were on the quantity and quality of water available, the easiness of operation and maintenance, the effects to the ecological and environmental conditions, the possibility of future extension, and the cost.

3107 After careful sieving, three best alternative plans were remained. They were;

- Second Mzima P/L with Tsavo reservoir plan,
- Rare P/L with Rare reservoir plan,
- Mwachi reservoir with Mwachi P/L plan.

3108 Brief studies were made on these three plans in respect to the hydrology, planning of structures, optimum development scale for the construction cost and water rate. In the Inventory Report, the above-mentioned studies were described, and it was proposed that the selection of a plan to be developed first was to be made by the Government of Kenya, but that further study work in Part II was evenly made on the said three plans.

B. Hydrologic Issues

3201 The hydrologic work in the whole Kenya has been conducted exclusively by the hydrologic section of the MOWD. In general, the availability of the hydrologic data for the current study is limited in the coverage period of observation and accuracy of gauging stations (G/S). Available data for the aforementioned three best alternatives are insufficient for the bankable feasibility studies.

3202 The hydrologic observation network or the location of G/S in the basin of the Sabaki River system is maldistributed to the upper reaches of the Athi River and the lower reaches of the Tsavo River leaving the rest of the basin nearly uncovered. There is no reliable existing G/S on the stretch downstream from the middle reaches of the Athi River (G/S 3F9 near the Road B-7 bridge) until the estuary for nearly 300 km. Hence, there is no sufficiently long reliable data to clarify the behaviour of losses of flow along the Athi-Sabaki Rivers which is in problem.

3203 In the Second Mzima P/L plus Tsavo reservoir plan, the Tsavo reservoir is an indispensable element of the plan to secure the full intake discharge of the Sabaki P/L scheme as well as to maintain the ecological and environmental condition on the lower reaches. This reservoir is needed in order to compensate the flow on the lower stretch. Hence, exact dimensions of the dam and reservoir can be determined only when the behaviour of the flow loss is known and thence accurate amount of flow to be released from the dam is assessed. Due to the scantiness of the hydrologic data of the lower stretch, the present planning had to be made on an assumption that the existing flow regeme would be maintained if the amount of flow equivalent to that abstracted from the Mzima Springs is supplemented by the release from the dam.

3204 For the Rare reservoir plus Rare P/L plan, it is essential to know the flow of the rainy season on the Sabaki River near the point where the eastern boundary of the Tsavo East National Park comes across the Sabaki River. However, no hydrologic data are available on this stretch. Hence, in the planning of the Rare dam and reservoir, a simulation model was made using hydrologic data at G/S 3F2 on the Athi and 3G2 on the Tsavo. The policy of the simulation model is that the diversion of water to the Rare reservoir is made only when there is surplus after ensuring the intake amount at Baricho. On the Rare River on which the dam and reservoir are located, there is one G/S, but the data do not indicate that the Rare River carried flow required for the water supply augumentation.

3205 On the coastal rivers, the hydrologic observation is generally poor except for the Pemba River on which the existing intake for water supply is in operation for long, and the flow gauging has been made since 1932. On the Mwachi River, there is a G/S (3MA3) which was opened in 1972, and the hydrologic data covering more than seven years were available and used for the planning of the Mwachi dam and reservoir as reported in the Inventory Report.

3206 During the Part II work, however, the Team was informed that the datum (zero point) of the gauge staff of the G/S 3MA3 has once been changed by 1.06 feet and the exact timing of this change was not detectable, and that only the data after September 1979 was reliable.

3207 Re-studies were made on the hydrologic data of the Mwachi River (G/S 3MA3). The results indicated that the average of flow would become far smaller than it was treated in the Inventory Report.

3208 Thus, for accurate planning of the plans for the water supply augmentation for the project area, it is necessary to reinforce and continue the hydrologic observation.

## C. Plan Studies

3301 In this report, two alternative plans such as;

- Second Mzima P/L plus Tsavo reservoir plan, and
- Rare reservoir plus Rare P/L plan

are treated. The former is treated in Chapter 4, and the latter in Chapter 5. Of the three plans raised in the Inventory Report, the Mwachi reservoir plus Mwachi P/L plan is not treated because of the results of re-study on the hydrologic data.

3302 The Second Mzima P/L plus Tsavo Reservoir plan consists of two features, one on the water supply and the other on the compensation of flow to the lower reaches. The former is composed of the intake structures, the pipe line with appurtenant structures and the distribution reservoir. They are studied in the accuracy required for the bankable feasibility study. The latter feature is composed of the Tsavo dam and reservoir. This feature is studied as accurately as possible on the available hydrologic data. However, for the aforementioned reasons this feature is not to be treated to have the accuracy required for bankable feasibility study. It is necessary for attaining the same accuracy to supplement the hydrologic data of the lower stretch.

3303 The Rare Reservoir and Rare P/L plan consists of two features, one on the water resources development and the other on the water supply. This plan is studied as accurately as possible, but for the aforementioned reason, it is necessary to supplement the hydrologic data of the lower Sabaki River for the purpose to attain the accuracy required for the bankable feasibility study. However, as the water source of this plan depends upon the rainy season flow of the Sabaki River, it is less influenced than the dry season flow by the loss of flow in problem.

3304 As for the Mwachi Reservoir plus Mwachi P/L plan which was raised in the Inventory Report, the results of the re-study on the available hydrologic data indicated that the average flow would be far smaller than it was treated in the foregoing report to an extent not to be able to provide sufficient water in view of the middle or long term planning of the supply augmentation. In this context, the study on this plan has to be suspended in the present study.

3305 The Mwachi plan had been raised in 1972/1 for the first time as one of five alternative plans for the immediate augmentation for Mombasa. At that time, there was no G/S on the Mwachi River, and the proposed development scale was assessed taking analogy to the adjoining Pemba River whose water had long been used for the water supply for Mombasa. This plan was not taken up as the Sabaki P/L project was taken up for the augmentation purpose. The hydrologic observation on the Mwachi River was being commenced since this proposal.

3306 Since then, the Mwachi plan has not been considered up to now. This plan, though its study is suspended in this study, would have some significances for the water supply augmentation. As a water source of sizable scale, this river is the one located nearest to Mombasa, hence the transmission distance is as short as 10 km from the West Mainland of Mombasa in which the industrial area of Mombasa is located on the city planning. Hence, the Mwachi plan will be suited as the supplemental means of the whole augmentation to cover the local water supply in the South and West Mainlands of Mombasa or to fulfill solely the industrial needs. In this concern, it is desirable to reinforce and continue the hydrologic observation on the Mwachi River.

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/1 Scott-Wilson Kirkpatrik and Partners, "Report on an Investigation into an Additional Source to Provide the Necessary Immediate Augmentation of the Mombasa Pipeline Board Supplies", Draft..

# 4. SECOND MZIMA P/L WITH TSAVO RESERVOIR PLAN

## A. Planning

4101 Purpose: The Mzima Springs located at 680 m above sea level and 220 km to the north-west of Mombasa yields potable water without treatment. The spring water has being used partly by 0.43 $m^3/s$ for the water supply of Mombasa by the existing Mzima P/L since 1956. The Second Mzima P/L plus Tsavo Reservoir Plan is purposed to make full use of the remaining spring water for the water supply augmentation of the project area without using the power for transmission. As the additional abstraction of the spring water will cause some adverse effects to the lower reaches of the Sabaki River, the compensation of flow is to be made by the Tsavo reservoir.

4102 Rivers: The outflow of the Mzima Springs is very stable having the minimum flow of 2.2 $m^3/s$ in addition to the existing abstraction of 0.43 $m^3/s$. The outflow of the springs is collected by the Mzima River and joins into the Tsavo River. About 50 km downstream from the junction of the both rivers, the Tsavo River joins into the Athi River and becomes the Sabaki (Galana) River. The intake of the Sabaki P/L at Baricho is located about 160 km downstream from the confluence of the Athi and Tsavo. Of the total flow distance from the springs to the estuary, nearly 60 % is in the Tsavo National Parks.

4103 Compensation of Flow: Due to the loss of flow along the Sabaki River, the dry season flow of the Sabaki River at Baricho is considerably small. The capacity of the Sabaki P/L (0.83 $m^3/s$) is designed to coincide with the lowest flow. Hence, when more water is abstracted from the Springs, the flow at Baricho will decrease below the said capacity. The vegetation and wildlife along the Sabaki River which depend on the river water will be jeopardized. Also, when flow on the dry season is extremely low, there will be a possibility of intrusion of saline water into the river. Therefore, compensation of flow is required when more abstraction of water from the Springs is made.

4104 The Tsavo River carries ample flow in the rainy season. This flow is used for the compensation purpose by means of storing it in a reservoir, and releasing necessary amount in the dry season.

4105 The Plan: Under this plan, it is planned to take 1.2 $m^3/s$ of water from the Mzima Springs to transmit this flow to Mombasa and to compensate the flow of the Sabaki River by providing a dam and reservoir on the Tsavo River. The structures required are the underground intake structures at the Mzima Springs, the pipeline from the intake to the distribution reservoir located near Mombasa for 219 km, the appurtenant structures of the pipeline, and the Tsavo dam.

4106 Dam and Reservoir: As the quantitative behaviour of the flow loss along the Sabaki River is almost unknown, it is almost impossible at present to assess the effective amount of flow that reaches downstream out of the amount of flow that is released from the dam. Hence, the amount of release is treated in the present study as an amount of flow equivalent to that abstracted from the Springs. After the behaviour of the flow loss is clarified by the hydrologic observation, the amount of the release will have to be restudied and modified, if necessary, and the dimensions of the dam and reservoir will have to be reviewed.

4107 Adverse Effects: The sites of the dam and reservoir are located entirely in the Tsavo west National Park. The noises and movements caused by the construction activities of the dam will give adverse effects to the wildlife and vegetation during the construction period, while, the reservoir will provide a new water surface which will have good effects newly on the vegetation and wildlife. The Mombasa-Nairobi fuel pipeline runs across the upstream part of the reservoir area, so that the re-location thereof is required to avoid a contamination of impounded water in an emergency.

4108 Intake: The existing intake of the Mzima P/L has been constructed underground because of the water level as well as of the needs for the environmental protection. This intake needs to be expanded for additional abstraction. Construction of new intake on the separate place is impossible because the six springs which compose totally the Mzima Springs, are concentrated in a small area.

4109 P/L: Abstracted water is transmitted to the destination by gravity, and the pump-boosting method is not adopted to avoid power use and noises created by large pumps in the National Parks, and also from the viewpoint of cost. The pipeline runs parallel with the existing pipeline for the same distance of 219 km to Mombasa. The distribution reservoirs are located at Samburu and Mariakani in addition to the existing ones at Mazeras. The pipe is 1,000 mm in diameter for the majority of its length.

4110 Development Scale: Possible maximum amount of abstraction from the Mzima Springs is 1.2 $m^3/s$ which is smaller than 1.8 $m^3/s$ required for the supply augmentation in the year 2000. Hence, the full availability has to be developed. Assuming that this plan is put to commission in 1986 when the existing capacity including the second phase of the Sabaki P/L becomes full, the supply capacity will be met by the growing demand in 1995 leaving five years till 2000. The deficit after 1995 will have to be filled by other plans.

## B. Water Sources

### a. General

4201 Monthly mean discharge at the gauging stations of the Tsavo River and the Mzima Springs (3G2 and 3G3, respectively) is collected to estimate the availability of abstraction from the Mzima Springs to Mombasa as shown in the Inventory Report. It is, moreover, mentioned in it that further development of Mzima Springs menaces the intake amount of 0.83 $m^3/s$ on the Sabaki pipeline system at Baricho without the Tsavo reservoir.

4202 The capacity of the Tsavo reservoir required for the compensation of intake amount at Baricho was simply estimated in the Inventory Report based on the criteria that the contribution of the Tsavo River to the Sabaki River is kept same even if the abstraction from the Mzima Springs is directly made to Mombasa, that is, the release in the dry season from the Tsavo reservoir is the sum of inflow to the reservoir and the amount corresponding to the abstraction.

4203 The impounding capacity required for the Tsavo reservoir is restudied by making a simulation model using hydrologic data at 3F2 on the Athi River and 3G2, since these two stations keep the reliable data for a long time period while there is no gauging station from which reliable hydrologic data are available on the Sabaki River.

b. Simulation Model

4204 The simulation model is made using the continuity at the reservoir under the conditions that there are losses along the Sabaki River and that mandatory release is established between Baricho and the estuary and between the Tsavo dam and the confluence of the Tsavo and Athi Rivers as shown in ANNEX 4204. As the abstraction of 1.2 $m^3/s$ is directly made from the Mzima Springs, inflow data to the reservoir are arithmetically calculated by subtracting the abstraction of 1.2 $m^3/s$ from the discharge data at 3G2.

4205 Operation rules of the Tsavo reservoir to warrant downstream requirements are summarized as follows;

1. when the discharge of the Athi River is greater than the sum of requirement for losses, intake amount at Baricho and the requirement between Baricho and the estuary, the release from the Tsavo reservoir is kept as small as the ecological requirement between the Tsavo dam and the confluence of the two rivers,

2. when the downstream requirements can not be met by discharge of the Athi River, the release from the Tsavo reservoir is made so as to meet the requirements, and

3. when water level of the reservoir reaches to the low water level and requirement of release from the reservoir to downstream is greater than inflow to the reservoir, outflow is equal to inflow.

4206 The mandatory release between Baricho and the estuary is taken into account because of the needs for protecting the Sabaki River from the intrusion of saline water. The mandatory release to the Tsavo River is assumed to be 1.0 $m^3/s$ from the ecological viewpoint. The losses along the Sabaki River are taken to be 5.85 $m^3/s$ between 3F2 and 3HA3 as estimated in the Inventory Report. The requirement at Baricho is 0.83 $m^3/s$, because the treatment losses are returned to the river.

4207 Evaporation of 4 mm/day from the reservoir surface is taken into account in the continuity, because the mean annual free-water evaporation is estimated to be 2,500 mm in areas below 300 m/1 and because evaporation from the reservoir surface would be around 60% of the pan evaporation.

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/1 Master Planning Section, Water Department, MOWD, Rainfall Frequency Atlas of Kenya, Jan. 1978.

c. Simulation Results

4208 For the effective reservoir storage chosen arbitrarily, the deficit volume that the requirement and mandatory release are not satisfied in a year is shown in ANNEX 4208. If the reservoir has the effective capacity of 34 million $m^3$, all the requirements are satisfied. However, the most efficient point of the effective storage is the tangent to the curve with 45 degrees to the abscissa. Thus, the Tsavo reservoir is determined to have the effective storage of 21 million $m^3$.

4209 The study without the Tsavo dam is separately made changing the abstraction from 0 $m^3/s$ to 1.2 $m^3/s$ as shown in ANNEX 4209. The average deficit volume of 7.2 million $m^3$, when the abstraction is 1.2 $m^3/s$, corresponds to 12.3% of the total requirement volume a year at Baricho and between Baricho and the estuary. In other words, the Sabaki River becomes dry successively for 1.5 months a year if the abstraction is 1.2 $m^3/s$ and the deficit occurs intensively in the dry season.

4210 The main reason why the abstraction is directly made from the Mzima Springs providing an underground intake is that the taken water is adequate as potable water without any treatment. However, there is a disadvantage that groundwater to the Mzima Springs can not be well trapped.

4211 Another simulation model that the abstraction is made from the Tsavo reservoir is studied. The conditions such as losses along the Sabaki River and mandatory releases are not changed. As the results of simulation show in ANNEX 4211, the deficit volume on the Sabaki River is a little greater than in the case when the abstraction is directly made from the Mzima Springs, if the effective storage is 21 million $m^3$ and abstraction is 1.2 $m^3/s$. Thus, it can not be considered that there is an advantage in the abstraction from the Tsavo reservoir.

## C. Reservoir and Dam

### a. Reservoir

4301 The prediction of sediment accumulated into the reservoir is made by preparing a rating curve of suspended load. Though the measurement of load at 3G2 was tried according to MOWD, the data necessary for the estimate of sediment load into the Tsavo reservoir were not well obtained.

4302 The estimate of sediment trapped by the Tsavo dam is made based on the measurement records of sediment at the Kamburu reservoir by Dr. George Ongweny and et al.[/1] that sediment of 5.6 million tons is entering into the Kamburu reservoir a year[/2]. The entering volume of sediment into the Tsavo reservoir for 100 years is estimated at 16 million $m^3$ which corresponds to the low water level of El.482.500 m.

4303 As the effective capacity required is 21 million $m^3$, the high water level is determined to be El.486.500 m by reading the reservoir storage curve shown in the Inventory Report. The crest of dam is 5 m higher than the high water level so that flood water can be controlled with allowance.

4304 As the existing fuel pipeline between Mombasa and Nairobi runs across the reservoir, the cost for relocation of the pipeline is included in the cost of the Tsavo dam.

### b. Dam

4305 Though the Tsavo dam was designed as the rock-fill dam with a centre core in the Inventory Report, it is mentioned in the Interim Report that it is hard to obtain the materials available for the impervious core near the dam site. As the laterite distributed near the dam

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/1 Department of Geography, University of Nairobi

/2 The daily newspaper "Nation" dated May 1980 published in Nairobi site does not contain good amount of silt, the laterite is not suitable as core materials.

4306 The Tsavo dam is changed to the rock-fill dam with upstream asphaltic membranes, because the rock-fill dam is still cheaper than the concrete gravity dam, since rock materials are easily obtained near the dam site. Moreover, the Kindaruma and Kamburu dams on the Tana River have been constructed with upstream asphaltic membranes. The plan and cross section of the Tsavo dam are shown in ANNEX 4306-1 and -2. Main parameters are as follows;

| | |
|---|---|
| height above river bed | 34 m |
| length | 370 m |
| volume | $450 \times 10^3 m^3$ |

4307 At the upstream foot of the dam, the curtain grout is designed as the anti-leakage measure, because there is a slight possibility that water leaks from the bottom of the reservoir.

c. Spillway

4308 It is necessary to estimate floods for the design of spillway and diversion facilities. According to the studies, the design flood and the probable maximum flood for the spillway are 1,550 $m^3/s$ and 1,990 $m^3/s$, respectively. Flood estimates at the dam site are discussed in ANNEX 4308.

4309 The ungated overflow spillway is selected as the type of spillway, because the control of ungated spillway is easy and power supply is not stable owing to the location of the Tsavo dam. As shown in ANNEX 4306-1, the width of spillway is 220 m long. The energy of flow is dissipated by the hydraulic jump as shown in ANNEX 4306-2. Though the spillway was designed at the saddle of the left bank in the Inventory

Report, the spillway is attached to the main dam, because the front of saddle is high and wide.

d. Diversion Tunnel and Cofferdam

4310 The design discharge for the diversion tunnel and cofferdam is 650 $m^3/s$ which corresponds to a 10-year flood. If the flood is passed by pressure flow through the diversion tunnel, the crest elevation of the cofferdam is required to be higher than El.480.000 m. Thus, the diversion tunnel is designed so that the flood can pass by free flow.

4311 The diversion tunnel is used as the river outlet for the mandatory release and emergency drawdown of water level after completion. The river diversion facilities are equipped in the plugging concrete of the diversion tunnel.

D. Water Supply Facilities

a. Description of the System of the Plan

4401 The plan is designed to draw additional 1.2 $m^3/s$ (103,680 $m^3$/day) ground water at a maximum rate from the Mzima Springs. With this development the total system capacity available for the project area would be about 231,500 $m^3$/day which is expected to be adequate to meet the project's demand on a peak month daily demand basis until the end of the year 1995 (ANNEX 4401).

4402 A water supply study for all the project area with the proposed 2nd Mzima P/L system is made based on the demand projection which is described in the preceding chapter of the Project Area and available sources of supply including on-going Sabaki P/L system. Water demand by area and sources of supply planning in 1990 and 1995 are shown in the table in ANNEX 4402-1 and locations of the area and supply sources are shown in ANNEX 4402-2. The recommended system of the plan with the 2nd Mzima P/L is schematically shown in ANNEX 4402-3.

b. Design Criteria

4403 The basic concepts for preliminary designing of the water supply facilities are the technical soundness and the least coat of the plan. Principal items of design standard are prepared based mainly on the Design Manual of MOWD and partly on the Design Criteria for Water Works Facilities of JWWA supplementing the former.

4404 Design criteria for the plan is included in ANNEX 4404-1 and a study on fluctuations in demands and the system capacity for the plan is included in ANNEX 4404-2.

c. Major Facilities

4405 Spring Intake: The same method of abstraction from the Mzima Springs employed for the existing system is used to abstract the additional water of 1.2 $m^3/s$ in order not to devastate the natural appearance of the national park. Intake facilities required for the new plan are; (1) 2 km long sheet-piling and infiltration trench by doubling and expanding the existing facility, (2) an RC made collecting and overflowing chamber (ANNEX 4405-1) and (3) an overflow pipeline with 600 mm diameter pipe and approximately 1 km long from the collecting chamber to the long pool. Locations of the proposed facilities are shown in ANNEX 4405-2.

4406 Transmission main P/L: The new Mzima P/L will have a capacity to convey the spring water with a maximum rate of 1.2 $m^3/s$ by gravity flow and would be constructed in a single construction stage. The proposed pipes range 1,000 mm to 1,350 mm in diameter. The pipe material will be selected from ones to satisfy the specifications for tender which will be carried out in order to obtain the most competitive material(s).

The new pipeline is to be laid in parallel to the existing Mzima P/L with a total length of approximately 219 km from the Mzima Springs to the existing Mazeras reservoirs. At the Mazeras reservoirs, the new transmission main will be connected to the existing spare 600 mm inlet pipe to the reservoirs, which was previously installed for future use. General plan and profile of the proposed transmission main P/L are shown in ANNEX 4406-1 to -3.

4407 Although the initial capital costs of the gravity flow system are higher than the costs of an alternative plan of introducing pumping system, the gravity flow system is more preferable and reliable for the long life operation when future increase in energy costs for pumping is taken into consideration, as the economic evaluation of the alternative plans revealed (ANNEX 8207 in the Inventory Report, Sept. 1980).

4408 Operating storage reservoirs of a total capacity of 220,000 $m^3$ for the plan is proposed to be constructed at required places. With these additional storage reservoirs, the whole project area would be secured with 1-1/2 days for Mombasa and 2-1/2 days of storage for other areas respectively. The provisional storage capacity by areas in the project and the locations are shown in ANNEXES 4408-1 and 4406-1 through 4406-3. Standard reservoir structures are shown in ANNEX 4408-2.

4409 BPTs: On the proposed pipeline, six BPTs and reservoirs at three places are to be constructed to reduce the excess pressure in the pipeline. Distribution reservoirs at three places namely Voi, Taru and near Mariakani will act as both for storage reservoir and break pressure tank. The standard BPT structure is shown in ANNEX 4409.

4410 Subsidiary pipelines are proposed to deliver bulk water branched from the transmission main P/L to the remote area from the main as depicted in ANNEX 4410. In this plan, the subsidiary pipelines proposed are the following.

1. Taru reservoir to Banga area, approximately 40 km, with 300 mm pipe for an approximately supply of 2,500 $m^3$/day in 1995.

2. Main transmission P/L to Mariakani area, approximately 3 km, with 350 mm diameter pipe for supply of approximately 5,000 $m^3$/day in 1995.

3. Mazeras reservoir to Kaya Bombo reservoir, approximately 28 km, with 500 mm diameter pipe for supply of 16,000 $m^3$/day in 1995.

4. Marere P/L to Kaya Bombo reservoir, approximately 17 km, with 400 mm diameter pipe for supply of 9,000 $m^3$/day in 1995.

4411 Sizes and capacities of major components of the plan comprising the spring intake, main transmission P/L, BPTs storage reservoirs and subsidiary P/L are shown in ANNEX 4411.

## E. Cost Estimates

### a. General

4501 The project cost is estimated on both the economic and the financial cost bases. The criteria which are common to both the economic and financial cost bases are as stated below.

4502 The main features of the Project are shown in ANNEX 4502 for both the water supply facilities and the dam and reservoir.

4503 The base date for the cost estimate is set at the middle of 1980. The exchange rates applied are US$1 = KSh7.5 = ¥250.

4504 Land acquisition costs including compensation costs for dam and reservoir are considered to be nil assuming all the land required for the Project are owned by the Government.

4505 Costs for engineering and administration of the Project are assumed at 10% of the direct cost which comprises material, equipment and construction costs.

4506 The cost for physical contingencies is assumed to be 15 % of the total base cost which is composed of the direct and the engineering and administration costs.

### b. Economic Cost

4507 Based on the above criteria, the economic cost is estimated as shown in ANNEX 4507-1. The total capital cost of the Second Mzima P/L with Tsavo Reservoir Plan excluding the replacement cost amounts to US$270 million equivalent of which the foreign currency portion is US$163 million and the local currency portion is US$107 million equivalent. For estimating the economic cost, unit prices and work quantities for each component as shown in ANNEX 4507-2 are employed.

4508 The replacement cost is computed based on the economic life of each assets as shown in ANNEX 4508.

4509 The O & M cost of the Project is estimated dividing into staff salary, chemical cost and repair cost as shown in ANNEX 4509.

c. Financial Cost

4510 The financial cost of the Project is estimated by adding the sales tax and the price contingency to the economic cost as shown in ANNEX 4507.

4511 The sales tax is assumed at 10 % for both the foreign currency portion and local currency portion of the project cost. All of the tax amount is counted in the local currency portion of the project cost.

4512 The price escalation is considered by the rates of 6 % per year for foreign currency portion cost and 10 % per year for local currency portion cost for the period of 1980 - 1986. The price escalation thereafter is not considered and assumed to keep the price level of 1986 through the evaluation periods.

4513 The replacement cost and O & M cost are estimated based on the economic cost by applying the said price escalation.

4514 The total financial cost of the Second Mzima P/L with Tsavo Reservoir Plan excluding both the replacement cost and the interest during construction is estimated at US$421 million equivalent which is composed of the foreign currency portion of US$207 million and the local currency portion of US$214 million equivalent.

## F. Evaluation of the Plan

### a. General

4601 The evaluation of the Plan is made on the basis of return on investment (ROI). The ROI is defined in this study to be the discount rate at which the present worth of all capital cost, O&M cost and replacement cost (economic costs excluding duties and taxes) equals the present worth of all revenues attributable to the project investment over the evaluation period.

4602 It is noted that the said ROI does not represent fully the economic rate of return which would be higher due to health and other environmental and social benefits. However, the ROI can be considered an appropriate measure for a purpose of project comparison.

4603 The benefit is taken to be the sold water which is taken at the outlet of distribution reservoir. The loss rate of 5% is assumed in the course of intake and the outlet of distribution reservoir. The water is evaluated at a value which is 70% of the retail water tariff by discounting the balance of 30% of the estimated cost for distribution network. These assumptions are taken considering that the Project is a bulk water supply project and that the distribution network is not included.

4604 Since the water volume to be supplied by the Plan is determined by the development scale of the Plan, the present worth of the benefit is consequently determined by the three factors i.e. development scale of the Plan, water rate and discount rate to be applied.

4605 The cost used for the evaluation is the economic cost which is estimated in the preceding sub-Chapter E. The construction period for the initial stage is assumed to be 3 years in which 15%, 60% and 25% of the initial construction cost will be disbursed in the first, second and third year respectively.

4606 The present worth of the cost is determined by the two factors i.e. the development scale of the Plan and the discount rate to be applied.

4607 Consequently, the balance of benefit and cost (B-C) is determined by the three factors such as the development scale of the Plan, the water rate and the discount rate to be applied.

4608 The present worth of both the benefit and cost are computed on the basis of annual equivalent value. The evaluation period is taken to be 50 years starting from the year of commission of the Plan.

b. Evaluation of the Plan

4609 Among the three parameters which defines B-C value, first, the development scale is set at 1.2 $m^3/s$ which is considered to be the maximum development scale of the Second Mzima P/L with Tsavo Reservoir Plan. Then, the water volume to be supplied each year by the Plan is fixed as shown in ANNEX 4609.

4610 For the development scale of 1.2 $m^3/s$, the required capital cost, replacement cost and O&M cost are derived as shown in the same ANNEX 4609.

4611 The B-C value of the Plan is derived by applying various water rates to the water volume stream of each year. The B-C values derived are presented in ANNEX 4611 by varying water rates and discount rates.

4612 A water rate at which a straight line under a discount rate intersects the zero value of B-C gives the water rate by applying which the discount rate will give the ROI of the Plan (ANNEX 4611). By plotting these water rate and the ROIs which correspond to these water rates, a correlation curve is derived as shown in ANNEX 4612.

4613 Based on this correlation curve, a ROI value corresponding to a water rate can be obtained. As the figure shows, when the water is evaluated at the estimated current water rate of 5.6 KSh/$m^3$ /1, the ROI of the Plan will be 5.5%.

c. Sensitivity Test

4614 In this section, it is examined how the changes in the projected water demand and in the costs for the Plan will affect the ROI.

4615 The water demand of high growth projection and low growth projection shown in ANNEXES 2439-1 and -2 are applied for testing the sensitivity of water demand to ROI.

4616 The case in which the costs for the Plan is increased by 10% is also tested. The results of these sensitivity tests are as shown in ANNEX 4616. As shown in the figure, the case in which the demand follows the low growth projection and the costs increase by 10% will bring the ROI of 4.2%.

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/1 As the current (1980) average water rate on the retail water tariff is estimated at 8.0 KSh/$m^3$, the water value at the outlet of distribution reservoir is computed at 5.6 KSh/$m^3$ by assuming the 30% of the retail tariff constitutes the cost for distribution networks.

## G. Financial Aspects

### a. General

4701 The objective of the study on financial aspect of the Project lies in clarifying the financial impact to the CPWB, the expected executive agency of the Project. In the present study, the financial internal rate of return (FIRR) is computed and the income statement and cash flow are projected to estimate the financial impact of the Project.

4702 It is noted, however, that since this is a bulk water supply project excluding the aspects of water distribution system, the above financial statements are hypothetical in their natures. Therefore, the continuity with the preceding financial statements is not attempted and the project's own financial impact is tried to be clarified independently.

4703 The conditions for the financial study are stated hereunder. The water volume to be supplied by the Project is taken at the outlet of the distribution reservoir. The trunk main loss to be occurred in the course of water intake and distribution reservoir is assumed to be 5 % of the total water supply. The whole volume taken at the outlet of the distribution reservoir is evaluated by a hypothetical water rate, which will be explained in paras. 4709-4712.

4704 For projecting the income statement and cash flow, the local currency portion of the capital cost is assumed to be generated by the CPWB's equity and the foreign currency portion of the capital cost is assumed to be financed through foreign loan(s).

4705 The interest rate for the foreign loan(s) is assumed to be 7.45 % per annum and the repayment period is assumed to be 20 years including 2 to 3 years of grace period during the constructions. The above loan conditions are adopted referring to those applied for the Nairobi Water Supply Project II which was co-financed by IBRD, OPEC and Saudi Fund contributions. The interest during the construction period is capitalized and assumed to be paid after the operation starts.

4706 The financial study is made for 20 years from the construction start, which correspond to the assumed repayment period of foreign loan(s).

4707 The economic life of equipment and materials is assumed as shown in ANNEX 4508 and that of dam is considered to be 50 years. In calculating depreciation, the straight line method is applied. A composite rate of 3.3 % for the Second Mzima P/L with Tsavo Reservoir Plan is developed based on the individual items and applied.

4708 The price escalation is assumed at the rates of 10 % per year for local currency portion and 6 % per year for foreign currency portion respectively for the period from 1980 to 1986 and thereafter the price level of 1986 is assumed to be kept.

b. Water Rates

4709 For testing the financial impact of the Project, an average water rate of 13.6 $KSh/m^3$ or $US\$1.81/m^3$ (at current price) is adopted for evaluating the water value at the outlet of distribution reservoir. In determining the above water rate, the following factors are taken into considerations.

(1) The water rate should fall in such a range as is deemed reasonable in terms of the water rate itself. In other words, a water rate that is higher than the cost of a desalinated water cannot be adopted even if such a high water rate will bring a much surplus on the financial statements.

(2) In addition, the increase rate of water that will be required in the period of 1980-1986 to reach the level of water rate in 1986 should also fall in the range that is deemed reasonable and realizable. Namely, a water rate that requires such a high increase rate as cannot be realized when the ability of consumers to pay it is considered, is not to be adopted.

(3) Moreover, the water rate should be high enough to attain a sufficient level of ROI in the economic evaluation.

4710 First, considering the above factors, an annual increase rate of 15 % was set based on an assumed inflation rate of 10 % and an increase rate of real income of 5 % that was estimated in the Inventory Report

(ANNEX 5202 of the Inventory Report). This implies that, if the real income will increase at the rate of 5% per annum, the percentage share of the payment for water charge in the total household income will keep a same level in the future as in 1980.

4711 Second, the level of water rate of 13.6 KSh/m$^3$ at the outlet of distribution reservoir is deemed to be lower than the cost of desalinated water. The above water rate of 13.6 KSh/m$^3$ corresponds to a water rate of 19.4 KSh/m$^3$ (US$2.59/m$^3$) when converted to the retail water tariff. This is rather high but deemed to be less or comparable to the cost of desalination of sea water.

4712 Finally, the water rate of 13.6 KSh/m$^3$ will bring the ROI of 7.1 % for the Second Mzima P/L with Tsavo Reservoir Project when applied for economic evaluation after converted to the water rate at 1980 constant price (ANNEXES 4612 and 4712). This rate of return on investment can be considered to be above the minimum rates required for such a public investment aiming at fulfilling a basic human needs as a public water supply. The ROI and water rates at current prices in 1980 and 1986 are shown in ANNEX 4712.

c. Financial Internal Rate of Return (FIRR)

4713 The FIRR for the Second Mzima P/L with Tsavo Reservoir Plan are derived at 3.4 % as shown in ANNEX 4713.

4714 The revenues of CPWB accrued from the Project are assumed solely from water sales. The other revenues such as connection fees and labor billed for installing new connections are not considered. The volumes of water sold are consistent with the engineering estimates and the loss rate of 5 % in the course from the intake to distribution reservoir is assumed. The water rate of 13.6 KSh/m$^3$ at the outlet of distribution reservoir is applied (para. 4709).

4715 It is noted that the capital cost is taken comprising both the foreign loan (foreign currency portion of the capital cost) and the CPWB's own equity (local currency portion of the capital cost). Therefore the FIRR derived in ANNEX 4713 are the rates of return for the total investment of the Project.

d. Income Statements and Cash Flow Projections

4716 As mentioned in a preceding paragraph (para. 4702), the present financial study has the nature of hypothetical one. Therefore, the financial statements of both the income statements and cash flow are prepared in such a simplified form as can be allowed to observe the financial impact of the Project. The balance sheet is not projected in this study from the same reason as stated above.

4717 The conditions for the financial study such as terms of foreign loans, depreciation, replacement, financing sources are as stated before in paras. 4703-4708. The water rate of 13.6 KSh/$m^3$ (US$1.81/$m^3$) is assumed as mentioned in paras. 4708-4711. The financial projections are made for the period of 1983-2002 (para. 4706).

4718 Under the conditions stated above, the income statements and cash flow for the Second Mzima P/L with Tsavo Reservoir Plan are projected as shown in ANNEX 4718-1 and 4718-2.

# 5 RARE P/L WITH RARE RESERVOIR PLAN

## A. Planning

5101 Concept: The Rare Reservoir plus Rare P/L Plan functions by a combination of the rainy season flow of the Sabaki River, the reservoir on the Rare River, and the pipeline from the Rare reservoir to Mombasa. There is no site for reservoir on the Sabaki River due to possible leakage of water, but this river carries ample flow in the rainy season though the dry reason flow is no more available after the abstraction by the Sabaki P/L. It is, therefore, planned to divert the rainy season flow of the Sabaki River to the Rare reservoir in a trans-basin manner, to store and regulate seasonally the diverted flow in the reservoir, and to treat and transmit water to the demand area.

5102 The Plan: Required structures are an intake on the Sabaki River, a waterway therefrom to the Rare Reservoir, a dam on the Rare River, an intake and treatment plant and a pipeline, 70 km long, from the reservoir to Mombasa. Water is conveyed by gravity from the Sabaki River to the Rare reservoir, and by pumping from the reservoir to the destination.

5103 The intake weir is located on the Sabaki River near the point where the eastern boundary of the Tsavo East National Park runs across. This location has to be re-studied when the behaviour of the flow loss is clarified by the future hydrologic observation. It is because this intake weir should be located at the lowest location of the stretch in which the flow loss is not so much so that the waterway to follow can be shorter and the intake discharge is ample.

5104 The waterway with a capacity of 13.3 $m^3/s$ starts from the intake weir on the Sabaki River, runs to the south-east for about 40 km and opens on the Rare River at a point about 20 km upstream from the Rare dam. This 20 km stretch functions as waterway. The dam site is located near the Vitengeni Village. The reservoir is capable of the seasonal flow regulation, namely to store the rainy season flow and provide 2.5 $m^3/s$ of water throughout the year.

5105 The intake for the water supply, the pump house and the treatment plant are located on the right bank of the Rare reservoir. Purified water is fed by pumps to the P/L which runs in parallel with the Sabaki P/L for 70 km. The storage reservoir is located near Mazeras.

5106 Adverse Effect: As the flow is taken outside the Tsavo East National Park, there is no adverse effect on the ecology and environment of the Park. The dry season flow of the Sabaki River will be maintained, hence there is no change in the ecological and environmental condition on the lower reaches of the Sabaki River, and the intake discharge for the Sabaki P/L is secured.

5107 Development Scale: As the rainy season flow of the Sabaki River is ample, it is possible for this plan to provide water far more than the augmentation requirement in 2000. However, the optimization study indicated (ref. Inventory Report) that 2.5 $m^3/s$ scale was most economical. Hence, the current study deals with the plan of this scale. As the augmentation requirement is 1.8 $m^3/s$ in 2000, this plan will meet the demand beyond 2000. Assuming that the demand after 2000 will grow with the growth rate of 1999 - 2000, the capacity will meet the growing demand until 2003 or for 18 years after the existing supply capacity including that the Second stage of the Sabaki P/L will be met by the demand.

5108 Future Consideration: As there is no reliable gauging station of river flow on the Sabaki River, this plan depends on the hydrologic data of G/S 3F2 on the Athi River and G/S 3G2 on the Tsavo River. Hence, it is necessary to review this planning after sufficient hydrologic data are availed by the reinforced hydrologic observation.

## B. Water Sources

### a. General

5201 The Rare River origins from the Taita Hills and flows towards the east through the Tsavo East National Park. After passing the east boundary of the park, it is quite hard to see the trace of the river. The Rare River reappears near the village of Goshi named the Goshi River. However, flow of the river is only observed just after heavy rainstorms. Thus, it is judged that there is no available water as resources.

5202 As the Rare River penetrates hilly places, there are good places to construct dams for impounding water. Thus, it is planned to divert the flow of the Sabaki River to the Rare River. The basic policy of the diversion is as follows. When the runoff of the Sabaki River is remained after ensuring the intake amount at Baricho and the mandatory release between Baricho and the estuary including losses along the Sabaki River, the flow of the Sabaki is diverted into the Rare.

5203 For making a simulation model, it is required to have reliable hydrologic data for a long time period. However, as there is no reliable gauging station on the Sabaki River, the sum of runoff at 3F2 of the Athi and 3G2 of the Tsavo is considered as the runoff of the Sabaki River. It is assumed that losses along the Sabaki River between 3F2 and 3HA3 are 5.85 $m^3$/sec.

### b. Simulation Model

5204 The operation policies of the Rare reservoir are summarized as follows;

1. reservoir water level is kept as high as possible, that is, when water level goes down, it is tried to recover the water level without any delay,

2. diversion to the Rare reservoir is not allowed without ensuring the intake amount at Baricho (0.83 $m^3$/sec) and the mandatory release between Baricho and the estuary (1.0 $m^3$/sec) including losses along the Sabaki River (5.85 $m^3$/sec between 3F2 and 3HA3), and

3. storage capacity of the reservoir is determined so that abstraction is warranted by 100 % for the given data.

5205 The simulation model is made using the continuity at the reservoir including the conditions mentioned above. Evaporation of 4 mm/day from the reservoir surface is taken into account in the continuity as assumed para. 4207.

c. Simulation Results

5206 The reservoir gross storage required for the abstraction is shown in ANNEX 5206. If the abstraction is 2.5 $m^3$/sec, the reservoir storage required is 39.6 million $m^3$ and the high water level is El.84.2 m. As mentioned in the policy of simulation, the abstraction of 2.5 $m^3$/sec is warranted by 100 % for the data given.

5207 The flow capacity of the diversion canal is required as shown in ANNEX 5207. As the severe drought continues around for 5 months, the canal capacity required is 13.3 $m^3$/sec for the abstraction of 2.5 $m^3$/sec, that is, the canal capacity is around 5 times more than the abstraction.

5208 If the upper reaches of the Athi River are developed by the construction of the Munyu or Kiboko dam, river flow of the Sabaki River will become stable, so that the necessary flow capacity of the diversion canal becomes less than that designed at present, if the abstraction is fixed. In other words, the flow capacity of the diversion designed at the present situation is available for more abstraction, provided that the upper reach of the Athi is developed.

C. Reservoir and Dam

a. Reservoir

5301 The prediction of sediment into the reservoir is made by the procedure used for the Tsavo reservoir. The dead storage predicted for 100 years is 12 million $m^3$ which corresponds to the low water level of EL.79.0 m.

5302 There are mines near the village of Vitengeni, from which barytes and galena mainly composed of sulfate of barium and plumbum sulfide, respectively are quarried. The only problem of the mines to the project is that muddy water used for washing quarried ores flows into the reservoir without having sedimentation basins.

b. Dam

5303 The Rare dam is designed as the rock-fill dam with the centre core. Since the gorge at the dam site spreads dully and materials for rock-fill dam are available near the dam site, the concrete gravity dam is more expensive than the rock-fill dam. The plan and cross section of the dam are drawn based on the development scale of 2.5 $m^3$/sec as shown in ANNEX 5303-1 and -2. The main parameters are as follows;

| | |
|---|---|
| height above the river bed | 33 m |
| length | 554 m |
| volume | 380 x $10^3 m^3$ |

5304 As there is a slight possibility that water leaks from the bottom of the reservoir, the curtain grout is constructed from the bottom of centre core.

c. Spillway

5305 Flood estimates for the design of the spillway and diversion facilities are mentioned in ANNEX 5305. According to the studies, the design and probable maximum flood for the spillway are 1,305 $m^3$/sec and 1,905 $m^3$/sec, respectively.

5306 The ungated overflow spillway is selected as the type of spillway for the same reasons mentioned for the spillway of the Tsavo dam. The spillway has the bathtub shape as shown in ANNEX 5303-1. The crest length of the spillway required is 200 m long. The main part of the dam would become like a concrete dam. The overflow portion of the spillway is designed in a straight line because the diversion facilities are used as the spillway. The profile of the spillway is shown in ANNEX 5303-2.

d. Cofferdam and Diversion Facilities

5307 The design discharge for the diversion facilities and cofferdam is 260 $m^3$/sec which corresponds to a 10-year flood. In the Inventory Report, the diversion tunnel was designed at the left bank with the break of 90°. With consideration of the condition that river flow of the Rare is normally zero, the diversion facilities are designed in the less expensive way that the diversion channel is used as the spillway.

5308 The construction order of the Rare dam is discussed because of the use of the diversion channel as the spillway. The spillway facilities are, at first, constructed remaining the circle portion of the toe end and are used as the diversion facilities. Next, the cofferdam and main dam are embanked. Finally, the circle portion of the spillway is constructed during the dry season when flow is zero.

e. Diversion Canal

5309 The intake facilities and diversion canal for introducing water from the Sabaki to the Rare are designed as shown in ANNEX 5309 and 5303-2, respectively. The intake facilities which are located between the Sala gate of the Tsavo East National Park and the crocodile camp on the Sabaki River, consist of the overflow portion and the intake to the diversion canal. The diversion canal which has the trapezoidal shape is designed by stone pitching, because stone pitching is cheaper than concrete lining for the diversion canal.

5310 The geological reconnaissance survey has been only made for the intake site. It is required for the accurate cost estimate to make the topographic survey at the intake site and through the route of the diversion canal.

D. Water Supply Facilities

a. Description of the system of the plan

5401 A water supply study for all the project area with the 2.5 $m^3/s$ scale of development of the Rare P/L plan is herein carried out based on the demand by area and available sources of supply including on-going Sabaki P/L system. Water demand by area and supply plan in 2000 are developed as shown in the table in ANNEX 5401-1. Locations of the demand area and supply sources are shown in ANNEX 5401-2. The recommended system of the Rare P/L plan is schematically shown in ANNEX 5401-3.

5402 The Rare plan is to be implemented in two stages, each of which consists of two phases, to minimize investments. The approach for the above is carefully studied and the results thereof are included in Chapter 6 of this report.

5403 Facility development as for the bulk water supply program is based on the criteria that the system capacity shall meet the peak monthly daily demands which are about 113 percent of the annual average daily demands. Therefore, water production and transmission main capacity is to be adequate to meet the above peaks which will occur during the period of December through April. The design output from the proposed treatment plant will be developed by four steps of execution at 50,000 $m^3$/day each for the first and the second, 100,000 $m^3$/day in a single stage for the third and 50,000 $m^3$/day for the last development, (the total capacity being 250,000 $m^3$/day) each of which corresponds to the requirement in 1991, 1994, 2000 and 2003 respectively. This approach is presented in ANNEX 5403.

b. Design Criteria

5404 As already mentioned in the preceding chapter, principal items of design standard are prepared based on the Design Manual of MOWD and partly on the Design Criteria of Water Works Facilities of JWWA supplementing the former. Design criteria for the plan is included in ANNEX 4404-1.

c. Major Facilities

5405 General: The water treatment plant, pumping stations and pipelines necessary to implement the water supply program are designed to incorporate the optimal, technically and economically, methods of providing potable water from Rare reservoir to meet increasing demands of water in various areas of the project. Sizing and phasing of construction is determined by the criteria set forth in the previous sections. The proposed construction is described for its major facilities in the following paragraphs.

5406 Raw water intake: The plan proposes that initial construction of the intake works and installation of three pumps for the first phase-first stage requirements. The other pumps will be installed in stage of the second through the fourth. Sizes and elements of the plan are designed along with the criteria and included in ANNEX 5406-1. The proposed layout of the intake and these facilities are illustrated in ANNEX 5406-2 and 3.

5407 Raw water transmission main: The main will have a full capacity of 275,000 $m^3$/day flow with 1,500 mm diameter pipe from the intake pumping station to the proposed treatment plant.

5408 Treatment plant: The water impounded in the reservoir is subject to varying degrees of turbidity, organic polution, and bacteriological contamination. Such water has to be properly treated to become a potable supply, which shall conform to the drinking water quality standard as shown in ANNEX 5408. The proposed treatment plant will incorporate the following processes: chemical coagulation, sedimentation, filtration, and chlorination. The clear water reservoir at plant is sized to provide operating storage for pumping for transmission plus storage for back wash for filters.

5409 The plan provides for three units of treatment plants one in the first phase with a capacity of 100,000 $m^3$/day output and the second and the third for the second phase with a combined capacity of 150,000 $m^3$/day output with a provision of a 20 percent of the future expansion of the treatment capacity to the design output.

5410 Proposed plant design will provide for more stable treatment process in each single unit by separate basins for flocculation and sedimentation, plus gravity type rapid sand filters. The flow diagram for the proposed treatment plant is shown in ANNEX 5410-1 and the plant layout is presented in ANNEX 5410-2.

5411 Transmission pumping station: Transmission pumps to be installed in the pumping station adjacent to the clear water reservoir are sized according to the criteria presented in ANNEX 4404-1. Three pumps will be installed for the first phase-first stage construction, and the other pumps will be installed in the following stages as required.

5412 Transmission main P/L and system storage: New transmission mains and storage reservoirs are provided. The general location and the sizes of these pipelines and storage reservoirs are shown in ANNEX 5412-1. The required amount of system storage is discussed in ANNEX 5412-2.

5413 Subsidiary pipelines are proposed to deliver bulk water branched from the transmission mains to the remote area. Subsidiary mains proposed in the plan are as follows:

1. Taru reservoir to Banga area, approximately 40 km, with 350 mm diameter pipe for an approximate supply of 7,000 $m^3$/day in 2000.

2. Main transmission P/L to Mariakani area, approximately 3 km, with 350 mm diameter pipe for supply of approximately 5,500 $m^3$/day in 2000.

3. Mazeras reservoir to Kaya Bombo reservoir, approximately 28 km, with 600 mm diameter pipe for supply of 32,000 $m^3$/day in 2000.

4. Marere P/L to Kaya Bombo reservoir, approximately 17 km, with 450 mm diameter pipe for supply of 10,500 $m^3$/day in 2000.

## E. Cost Estimates

### a. General

5501 The project cost is estimated on both the economic and the financial cost bases based on the same criteria as mentioned in paras. 4502-4506.

5502 The main features of the Project are shown in ANNEX 5502 for both the water supply facilities and the dam and reservoir.

b. Economic Cost

5503 Based on the said criteria, the economic cost is estimated as shown in ANNEX 5503-1. The total capital cost of the Rare P/L with Rare Reservoir Plan (2.5 $m^3/s$ scale) excluding the replacement cost amounts to US$274 million equivalent of which the foreign currency portion is US$123 million and the local currency portion is US$151 million equivalent. For estimating the economic cost, unit prices and work quantities for each component as shown in ANNEX 5503-2 are applied.

5504 The replacement cost is computed based on the economic life of each assets as shown in ANNEX 4508.

5505 The O & M cost of the Project is estimated dividing into staff salary, chemical cost, repair cost and electricity cost as shown in ANNEX 5505.

c. Financial Cost

5506 The financial cost is estimated based on the same criteria mentioned in paras. 4511-4513.

5507 The estimated financial cost is shown in AANEX 5507. The total financial cost of the Rare P/L with Rare Reservoir Plan excluding both the replacement cost and the interest during construction is estimated at US$452 million equivalent which is composed of the foreign currency portion of US$164 million and the local currency portion of US$288 million equivalent.

F. Evaluation of the Plan

a. General

5601 The evaluation of the Plan is made on the same basis as being applied for the Second Mzima P/L with Tsavo Reservoir Plan mentioned in the preceding sub-Chapter F of Chapter 4. The conditions and assumptions are also the same as mentioned in paras. 4601-4608.

b. <u>Evaluation of the Plan</u>

5602 The development scale of the Plan is set at 2.5 $m^3/s$ despite the fact that around 5.5 $m^3/s$ would be the optimal scale from the point of view of the total economy (see Chapter 6). The reasons are: (i) this is not a long term plan but a medium term water supply plan with a target year of around 2000, (ii) the water demand is projected until the year of 2000 in this study and, thereafter the projected demand has only little significance considering an expected rapid change of social and economic aspects and (iii) the cost for the development scale of 5.5 $m^3/s$ will amount so large including a pre-investment for the big scale dam that a smaller scale is more realistic and realizable in terms of the resources to be committed to the Plan.

5603 The water volume to be supplied each year by the development scale of 2.5 $m^3/s$ is as shown in ANNEX 5603.

5604 For the development scale of 2.5 $m^3/s$, the required capital cost, replacement cost and O&M cost each of which is estimated on economic cost basis are as shown in ANNEX 5603. The said development scale of 2.5 $m^3/s$ is found to be most optimal when it will be constructed in four stages of 0.5 $m^3/s$, 0.5 $m^3/s$, 1.0 $m^3/s$ and 0.5 $m^3/s$ as will be mentioned in Chapter 6. The capital cost stream of the Plan is prepared following the above stagewise construction (ANNEX 5603).

5605 The B-C value of the Plan is derived by applying various water rates to the water volume stream each year. The B-C values derived are presented in ANNEXES 5605-1 to 5605-5 by varying water rates, development scales and discount rates.

5606 Following the same procedures as mentioned in para. 4612, a relationship of water rate and ROI is obtained as shown in ANNEX 5606. As the figure shows, when the water rate is taken at the estimated current water rate of 5.6 KSh/$m^3$, the ROI of the Plan will be 8.3%.

c. Sensitivity Test

5607 The sensitivity of the ROI to the water demand and costs is tested following the same procedures mentioned in para. 4614-4616.

5608 The results are shown in ANNEX 5608. As shown in the figure, the case in which the water demand follows the low growth projection and the costs increases by 10% will bring the ROI of 6.2%.

G. Financial Aspects

5701 The financial impact of the Rare P/L with Rare Reservoir Plan is studied under the same conditions as is applied to the financial study of the Second Mzima P/L with Tsavo Reservoir Plan. The nature of the financial study and the general conditions assumed are mentioned in paras. 4701-4712.

5702 The concerned figures which are proper to the Rare P/L with Rare Reservoir Plan are as stated below. A composite rate of 5.3% is developed and applied for computing depreciation based on the economic life of individual assets as shown in ANNEX 4508.

5703 The water rate of 13.6 KSh/$m^3$ or US$1.81/$m^3$ (at current price) is adopted for the financial study. This water rate will bring a ROI of 10.8% for the Rare P/L with Rare Reservoir Plan (Full Development Case) when applied for economic evaluation after converted to the water rate at 1980 constant price (ANNEXES 5606 and 4712).

5704 It is noted that, for financial study of the Rare P/L with Rare Reservoir Plan, two cases are taken up: the full development case and the first phase development case. The former is the case that the capacity of treatment plant will be developed up to the full scale of 2.5 $m^3$/s and the latter is the case that the capacity of treatment plant will be developed only to the yield of 1.0 $m^3$/s. The other conditions than the above such as the capacities of reservoir and pipeline remain the same. The result of the comparison shows that the full development case is better. Therefore, in this study, the full development case is taken up and the first phase development case is contained only for reference in ANNEXES 5704-1 to 5704-3.

5705 The FIRR is derived at 4.0% as shown in ANNEX 5705.

5706 The income statements and cash flow for the Rare P/L with Rare Reservoir (Full Development Case) are projected as shown in ANNEXES 5706-1 and 5706-2.

# 6. FUTURE DEVELOPMENT

## A. General

6101 Two plans namely the Second Mzima P/L plus Tsavo Reservoir Plan (the Second Mzima Plan) and the Rare P/L plus Rare Reservoir Plan (the Rare Plan) are given for the project. It is intended in the study of this Chapter to discuss the optimal development sequence and the scale of the plans for a long term period.

6102 The objective function is the balance of total benefit (B) attributable to the two Plans of the Second Mzima and the Rare Plans and the total cost (C) to be required for the same two Plans i.e. B-C. It is intended in this Chapter to find which combination of development sequences will maximize the value of B-C: the Second Mzima Plan first and the Rare Plan later, or the Rare Plan first and the Second Mzima Plan later. It is also intended to find how the development scale of the two Plans should be divided into several stages in order to maximize the B-C value.

6103 The above intension is schematically depicted in ANNEX 6103 for the case of a combination in which the Second Mzima Plan is constructed prior to the Rare Plan. The benefit is determined by the water volume to be supplied by the two Plans (shaded portion on the picture) which is subject to the total development scale multiplied by a water rate. Therefore the benefit is determined by three factors: development scale, water rate and discount rate.

6104 The cost is determined by two factors: development scale after considering stage development of the two Plans and discount rate.

6105 Consequently, the objective of the study in this Chapter is summarized to derive a combination of $S_1$, $S_2$, $S_3$, $S_4$ and $S_M$ (=1.2 $m^3/s$) which maximize the value of B-C.

6106 The development of the Rare Plan is assumed to be made in four stages and the total scale of each stage development should be less than or equal to 5.5 $m^3/s$ that is the possible physical maximum scale of the Rare Plan ($S_1+S_2+S_3+S_4 \leq 5.5$ in ANNEX 6103).

## B. Conditions and Input Data

6201 Since the factors to be considered and the possible combination of them are so many, a computer programme is developed and applied. The input data are: (i) the projected water demand curve used for economic evaluation, (ii) the cost tables for the two Plans, (iii) the water tariff ranging from 3.0 KSh/$m^3$ to 15.0 KSh/$m^3$ by 0.5 KSh/$m^3$ interval, (iv) the development scale of the Second Mzima Plan of 1.2 $m^3/s$ (=$S_M$) and those by the Rare Plan by 0.1 $m^3/s$ interval, and (v) the discount rates ranging from 6% to 14% by 2% interval.

6202 In inputting the demand curve that is projected up to the year 2000 is extrapolated up to the required period. The scale of the first stage development of the Rare Plan (=$S_1$) is set at not less than 0.5 $m^3/s$ to avoid a non-realistic solution.

## C. Output

6301 As the output of computer calculation is voluminous, some samples of them are presented in this report in ANNEXES 6301-1 to -7.

6302 The ANNEX 6301-3 shows the output sample for the case of 10% discount rate and of 7.50 KSh/$m^3$ water rate. The annual net benefit under the varying development scales is shown in the righthand-most column. In this column, only the maximum representative is picked up and presented from among many other annual net benefits under a corresponding development scale. Each scale of four stage developments of the Rare Plan is shown in four columns under the "RARE PLAN".

6303 Out of the four columns under the "MZIMA PLAN", the three columns of 2 to 4 are dummies for the convenience of computer programme. If the Second Mzima Plan is to be constructed prior to the Rare Plan, the scale of 1.2 $m^3$/s would appear in the first column under the "MZIMA PLAN".

6304 For the case of the development scale of 2.5 $m^3$/s, the ANNEX 6301-3 indicates that the annual net benefit of US$0.8 million will be attained by the stagewise construction of the Rare Plan under such a sequence as 0.5 $m^3$/s, 0.4 $m^3$/s, 1.0 $m^3$/s and 0.6 $m^3$/s in the four stages. The figure zero in the first column under the "MZIMA PLAN" indicates that the B-C (annual net benefit) value will be maximized with 0 $m^3$/s development of the Second Mzima Plan. This means that the Second Mzima Plan is not to be constructed prior to the Rare Plan.

6305 Searching through the ANNEXES 6301-1 to -7 which show all the output samples for the case of 10% discount rate, it is indicated that the Second Mzima Plan is not to be constructed if the annual net benefit (B-C) is to be attained in its maximum.

6306 All the calculations mentioned above are made by an electronic computer applying a method of Dynamic Programming, which is briefly explained in ANNEX 6306.

6307 The output tables shown in ANNEXES 6301-1 to -7 are shown in a group of curves in ANNEX 5605-3 for discount rate of 10%. For other discount rates, the similar group of curves are prepared as shown in ANNEXES 5605-1 to -5/1.

6308 As shown in the above ANNEXES 5605-1 to -5, the total development scale of the Rare Plan is indicated to become optimal at around 5.0 - 5.5 $m^3/s$ in every cases of varying discount rates.

## D. Result of Future Development Study

6401 The results of the study made in this Chapter indicate that the Second Mzima Plan is not to be constructed if the annual net benefit (B-C) should be attained in its maximum and that the Rare Plan is to be developed in the scale up to around 5.0 $m^3/s$ to 5.5 $m^3/s$ which is estimated to be its physical maximum scale.

6402 But, in this study report, the development scale of 2.5 $m^3/s$ for the Rare Plan is adopted for the reasons mentioned in preceding paragraph 5602.

6403 By scrutinizing the output tables shown in ANNEXES 6301-1 to -7, the stagewise construction of 0.5 $m^3/s$, 0.4 $m^3/s$, 1.0 $m^3/s$ and 0.6 $m^3/s$ is found to maximize the value of B-C for the total development scale of 2.5 $m^3/s$. Therefore, it is concluded in this study that the Rare Plan should be constructed in four stages of 0.5 $m^3/s$, 0.5 $m^3/s$, 1.0 $m^3/s$ and 0.5 $m^3/s$ after adjusted a little for the conveniences of the facilities and the actual daily operation.

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/1 Actually, the economic evaluation of the Rare Plan on the basis of ROI is made based on the results of the study made in this Chapter.

These development stages are designated as follows:

| Phase | Stage | Development | Accumulated Capacity |
|---|---|---|---|
| Phase 1 | Stage 1 | 0.5 $m^3/s$ | 0.5 $m^3/s$ |
| Phase 1 | Stage 2 | 0.5 $m^3/s$ | 1.0 $m^3/s$ |
| Phase 2 | Stage 1 | 1.0 $m^3/s$ | 2.0 $m^3/s$ |
| Phase 2 | Stage 2 | 0.5 $m^3/s$ | 2.5 $m^3/s$ |

The fund procurement will be made by phase, and the construction will be made by stage. (ref. ANNEX 6401)

6404 In order to meet the projected demand, the completion of each stage development is required in the years shown below.

| Phase | Stage | Completion in |
|---|---|---|
| 1 | 1 | 1986 |
| 1 | 2 | 1991 |
| 2 | 1 | 1994 |
| 2 | 2 | 2000 |

Provisional time schedule for the stage developments is shown in ANNEX 6404.

## E. Executive Agency

### a. Present Executive Agency

6501 MOWD: As already described in Chapter 2, the authority of water supply in Kenya is the Ministry of Water Development (MOWD), which is in charge of planning, design, construction and management of the water supply systems in the country. The organization of the MOWD is shown in ANNEX 2201.

6502 WED: MOWD has in its organization as executing agency, the Water Engineering Department (WED) which is responsible for all the functions of planning, design, construction and management of the water supply systems.

6503 CPWB: Under the WED, another organization, the Coast Province Water Branch (CPWB), is provided for the water supply for the Coast Province. It has four divisions: Operation and Maintenance (O&M), Engineering, Administration and Finance. Out of the above four divisions, the O&M Division has three local headquarters located in Changamwe, Mombasa and Malindi. (ANNEX 6503)

6504 MPB: Apart from the CPWB, another agency is involved in the water supply of Mombasa, i.e., the Mombasa Pipeline Board (MPB). This is an autonomous body established in 1958. The MPB presently belongs to the MOWD and responsible for operation and financial management of the Mzima and Marere pipeline systems. However, all the technical matters of operation, including planning, design, construction and daily operation and maintenance are vested in the CPWB. In addition, routine measurement of bulk water supply and collection of water charges are also entrusted to the CPWB.

6505 Historically, the MPB has been the sole owner and enterpriser of the bulk water supply systems in the coastal area, but its authority and scope of responsibility have been diminished. Presently the MPB owns two systems of Marere and Mzima Pipelines and the activities have come to be confined as stated above. The CPWB has been gradually taking over water supply systems and their management to collectively run all the water supply systems and their management.

6506 Other Agencies: A number of rural water supplies are operated by the county councils under the direction of the Ministry of Local Government in the project area. Most of them are taking water from the MPB system. In addition to them, there are some water supplies operated under the direction of other Ministries, which are also receiving water from the MPB system. Operation of those water supplies is entrusted to the CPWB. (ANNEX 6503 and 6506)

6507 Work Force of CPWB: CPWB employees in total are around 1,500, of whom 1,200 are in the O&M divisions. Out of 1,200 staff members of the O&M divisions, senior class engineers or qualified staff are as few as only two percent of the total number. As for O&M in Mombasa, some 260 personnel are engaged in routine operation and maintenance work. The personnel appear capable at present, both in number and qualification, to cope with the water supply to 20,000 service connections in the Mombasa area.

b. Considerations for New Development

6508 The new development is to be executed by the existing agencies concerned, i.e., the MOWD, the WED and the CPWB, and the organizations and their functions are considered generally appropriate. However, to carry out the project successfully and operate the completed facilities in a sound manner, the following is to be considered.

6509 Expansion of the System: The on-going programs of the Mombasa and Coastal Water Supply Project envisage an increase in the scope of operation in the system in the near future. The commissioning of the Sabaki Pipeline system will require the following actions.

1) To set up a special customer relation program to ensure prompt execution of service connections for new customers in accordance with the increase in supply.

2) To reinforce the staff for repair of leaks of the distribution network and routine maintenance work, in consideration that leakage will increase due to rise of water pressure and extension of supply hours.

3) To recruit operation staff required for the operation of the Sabaki Pipeline system including the treatment plant.

6510 In the meantime, the extension work of the distribution pipelines necessitated by the development of the Sabaki Pipeline system has already been designed for Mombasa Island, the West Mainland, the North Mainland, Kilifi, the Tezo-Roka settlements, Mnarani, Takaungu, Mtwapa and Vipingo, and now under way.

6511 As regards the implementation of the supply augmentation, there are two aspects of requirement; one for the implementation of the bulk water supply system, and the other for expansion of the distribution system required along with the expansion of the supply capacity. As for the latter, the same work force and system which have been developed for the Sabaki Pipeline system as described above (Para. 6509) will be applied.

6512 Regarding the implementation of the water supply augmentation project, a special task unit is desirable to be established in the WED. The line of authority of the task unit should be from the WED to the task unit and its power be similar to the CPWB. All staff, including the chief, of the task unit will be taken from among the staff of the WED and the CPWB. The task unit and the CPWB will be in full cooperation so far as the present project is concerned.

6513 Major tasks of the task unit will be as follows:

1) Planning and designing of the project,
2) Uses of consultant services,
3) Procurement of equipment and materials,
4) Prequalification of contractors, and tendering of civil works,
5) Construction supervision,

6) Commissioning of the completed works and transfer thereof to the CPWB,

7) All communications with authorities and agencies concerned.

6514 As has been practiced so far, centralization of all the water supplies in the project area is desirable to be further advanced. Presently wholesale and retail of water are separately carried out under several individual agencies, with partial operation and management of the water supply business entrusted to the CPWB. To attain more function-operation and management of all the water supplies in the project area, the comprehensive authority and responsibility of water supply is, of necessity, to be centralized in one sole agency.

## 7. CONCLUSION AND RECOMMENDATION

7101 For the water supply augmentation of the project area for the middle term up to around the year 2000 (demand 1.8 $m^3/s$), three plans were raised as the candidate plans in the Inventory Study. Of the three plans, the study on the Mwachi Plan is suspended owing to the new finding on the hydrologic records. Then the remaining two plans such as the Second Mzima plus Tsavo Plan (capacity 1.2 $m^3/s$) and the Rare Plan (capacity 2.5 $m^3/s$) have been studied in this report.

7102 The Second Mzima plus Tsavo Plan is a combination of the pipelines from the Mzima Springs to Mombasa, 219 km long, and the Tsavo dam and reservoir on the Tsavo River. The total cost is estimated at US$270 million (economic) and 421 million (financial). By applying the current water rate of 5.6 $KSh/m^3$, the return on investment (ROI) is derived at 5.5%. Financial internal rate of return (FIRR) is derived at 3.4% when the annual increase rate of wholesale water price of 15% is applied.

7103 The Second Mzima plus Tsavo Plan has the advantages that the water quality is very high and no treatment is needed, that the water is transmitted only by gravity and no power is needed, and accordingly that the operation and maintenance (O&M) are easy and cheap. On the other hand, the disadvantages are that the investment cost is huge owing to the long distance between the Springs and Mombasa, that the stage-wise development is impossible, and that the capacity is smaller than the projected demand in 2000, hence there is no possibility of further development in the future.

7104 The Rare Plan is a combination of the reservoir on the Rare River in which the rainy season flow of the Sabaki River is stored and regulated, and the pipeline to Mombasa, 70 km long. The total cost is estimated at US$274 million (economic) and 452 million (financial). The ROI is derived at 8.3%, and the FIRR at 4.0% under the same conditions as applied for the Second Mzima Plan.

7105 The Rare Plan has such advantages that the capacity is sufficient to meet the demand beyond the year 2000, that the future extension of capacity is technically possible, and that the stage-wise development is possible. The disadvantages are that the investment cost is also huge, that the quality of water is, like the case of the Sabaki P/L, not so favourable, and that the O & M will not be so easy and cheap in view of the quality of water and of the water transmission to be made by pumps. The comparison table of the two plans is shown in ANNEX 7105.

7106 The study of the Mwachi Plan which was raised once in the Inventory Report as one of the best alternative plans is suspended in the Final Report owing to the issues on the hydrologic data. In view of the accuracy of the data, it is difficult to decide exact development scale of this plan at present. The scale can be studied only after sufficient data are accumulated in future, but it is anticipated at present that the scale would become much smaller than that treated in the Inventory Report. Hence, this plan has to be put aside from the present study. However, this plan may be useful as an auxiliary plan to support partially the local demand or as a source for the industrial demand. Location of the Mwachi plan is favourable to supply the West mainland area of Mombasa.

7107 It can be said that, in technical aspects, both of the plans are possible though the scale of the Tsavo dam and the Rare dam should be subject to further investigations including those for loss of the Sabaki River (for Tsavo dam) and sedimentation (for Tsavo and Rare dams).

7108 The results of the plan evaluation show the ROI values of 5.5% for the Second Mzima with Tsavo Plan and of 8.3% for the Rare Plan, based on the current water rate (wholesale price) of 5.6 $KSh/m^3$ in both cases. Although these values are not so satisfactory, whether to implement such a project that is urged by basic human needs like the Mombasa water supply augmentation cannot be determined only by the ROI values.

7109 According to the results of the financial analysis of the two plans, a serious deficit of CPWB will be anticipated for a long period for both the cases. Therefore, the financial impacts to be brought by implementing either one of the two plans should be carefully treated.

7110 In Chapter 6 "Future Development", priority study of the two plans by means of Dynamic Programming Method is made solely from the technical and economic aspects for a long term period far exceeding the year 2000. The mathematical solution indicate that the Rare Plan is to be implemented first.

7111 However, if the future electric power constraints in Kenya were anticipated and if the Kenyan Government should make every effort to prevent the economic and social problems caused by the power shortage, the merits of the Second Mzima P/L with Tsavo Reservoir Plan, such as gravity conveyance and no requirement for treatment, would be emphasized.

7112 When the Second Mzima P/L with Tsavo Reservoir Plan would be allowed as the promising alternative plan for Mombasa water supply augmentation, the following conditions will have to be fulfilled first:

(1) Considering the significance of the huge amount of cost, the terms of foreign loan(s) required for financing the capital fund should be sufficiently soft; low interest rate and long repayment period.

(2) The serious financial burden of CPWB expected from implementing this Plan should be shared by non-beneficiaries of this plan through Government account.

7113 When the Second Mzima P/L with Tsavo Reservoir Plan would be implemented, this plan would meet the water demand in the Project area leaving some years before 2000. Then, the Rare Plan would be conceived before 2000 as one of the promising alternatives to follow.

7114 Due to the insufficient hydrologic information, all of the current studies on the water source has to depend on the values estimated on the assumptions. It is, therefore, recommended to reinforce and continue the hydrologic observation on the Sabaki River and the coastal rivers so that the planning work of the water source development could be made directly on the actual and accurate data.

7115 The future growth of demand for water has to be observed carefully taking into consideration such factors as the possible impact given by the supply increase from the Sabaki P/L, the increase in population and consumers' number accompanied by the anticipated release of the supply rationing, the development of the distribution network, the development of the sewage systems and possible raising of the water tariff.

# ANNEXES

## A Note for the Munyu Dam Scheme on the Athi River

During the Inventory Study, the Study Team made full consideration on the water resources development plans on the Athi River. At that time, such plans were proposed in the National Master Water Plan, and the pre-investment study on the Athi River basin was just started by TRDA. Among the twenty conceivable plans raised in the Inventory Report, four plans (Plans 1, 2, 3 and 4) are those combined with the dams on the Athi River; the Plans 1 and 2 being combined with the Munyu dam plan and the Plans 3 and 4 with the Kiboko (alias Thwake) dam plan (which was later altered by the Yatta dam plan by TRDA).

In fact, Plans 1 and 2 remained as two of the most promising plans in the course of sieving and were finally sieved out. The main reason for the sieving-out was that it was uncertain whether the Munyu dam scheme was to be materialized keeping pace with the Mombasa Water Supply Augmentation Project.

Situation turned recently centering around the Munyu dam scheme. According to the information attached to the comments of MOWD, the top priority of development was given to the Munyu dam scheme in the preinvestment study of the Athi River basin and the feasibility study of the Munyu dam scheme was started in May, 1981.

The contemplated scheme is informed to have the purposes of irrigation of 13,000 ha on the Kibuwezi area, hydro-power generation of 30 - 40 MW, and water supply to Nairobi and Mombasa. If the effects and the completion timing (mid 1986 in schedule) of the Munyu dam scheme are confirmed as they are contemplated, the Plans 1 and 2 in the Inventory Report would be worthy of the reconsideration. However, the following points have to be confirmed prior to the reconsideration of the plan to be adopted for the Mombasa water supply augmentation.

1. Storage Capacity of the Reservoir:

The Munyu site provides a topography favourable for a dam and reservoir. However, it is not informed to the Team whether the full advantage of such topography is usable to the dam and reservoir in view of the engineering geology. According to the view of the Team's geologist after the visit to the site, the higher parts of the both banks of the damsite seems to be composed of the Tertiary deposit in which some pervious layers are included. A possible height of the dam will have to be determined after thorough geological investigation by the test drillings and seismic exploration. Should the dam height bec-me lower than that contemplated, the amount of water available to the Mombasa area would become less and/or the commanding area of irrigation would become smaller.

2. Loss of Flow:

There is the loss of flow which is in problem on the Athi River and the Sabaki River. The estimation of the loss has been made, but the estimation has not been confirmed by the hydrologic data measured at the permanent stations. Possible benefits of the Munyu scheme will depend much on the Kibuwezi irrigation scheme and the Mombasa water supply of which available amounts of water are influenced by the loss of flow. The project scale can not be determined without obtaining the final value of the loss. Such value will have to be clarified in the feasibility study of the Munyu scheme.

3. Influence of Flow Regulation against the Loss of Flow:

The recharge to groundwater along the Athi and Sabaki Rivers is mainly made with the abundant flow in wet seasons under the natural condition without the reservoir. The flow in wet seasons will be impounded in the reservoir and released in dry season after the reservoir is completed. The recharge to groundwater along the Sabaki River might be decreased in wet seasons, that is, the loss of flow might be increased in dry seasons. This problem will have to be carefully treated in the feasibility study of the Munyu scheme.

4. Return Flow from Irrigation:

According to the hearing in Nairobi in February 1981, the Team is informed that the available water for Mombasa would be about 3 $m^3/s$ calculated through;

12 $m^3/s$ (flow from the dam or power station)

x 0.5 (irrigation efficiency)

x 0.5 (rate of return flow).

The value of 3 $m^3/sec$, if available as estimated, will be sufficient for the Mombasa water supply augmentation. However, as the Kibuwezi area lies in the dry area, the rate of return flow has to be confirmed through the feasibility study on the Munyu scheme. It is further informed that the irrigation commanding area is to be adjusted to make sufficient amount of flow available to the Mombasa water supply augmentation. Namely, it would be possible that the irrigation commanding area would be decreased to satisfy the water requirement to Mombasa. In this concern, a careful study on the available return flow from irrigation will have to be made in the feasibility study on the Munyu scheme.

After the points raised above are confirmed, the available amount of water to the Mombasa water supply will be clarified. At that time, there will be two cases regarding the sufficiency; namely, Case A: Available water is sufficient, Case B: Available water is not sufficient. "Sufficient" means that the available water is more than the water requirement for the Mombasa water supply augmentation by the year 2000.

At such stage, there will be many cases of water supply palns. The best plan will again have to be selected out of all of the plans conceivable at that time. Examples of each case are given below and their conceptual figures are presented in the attached sheet.