

**SURVEY AND PLAN FOR IRRIGATION DEVELOPMENT
IN THE PANGANI AND WAMI RIVER BASINS**

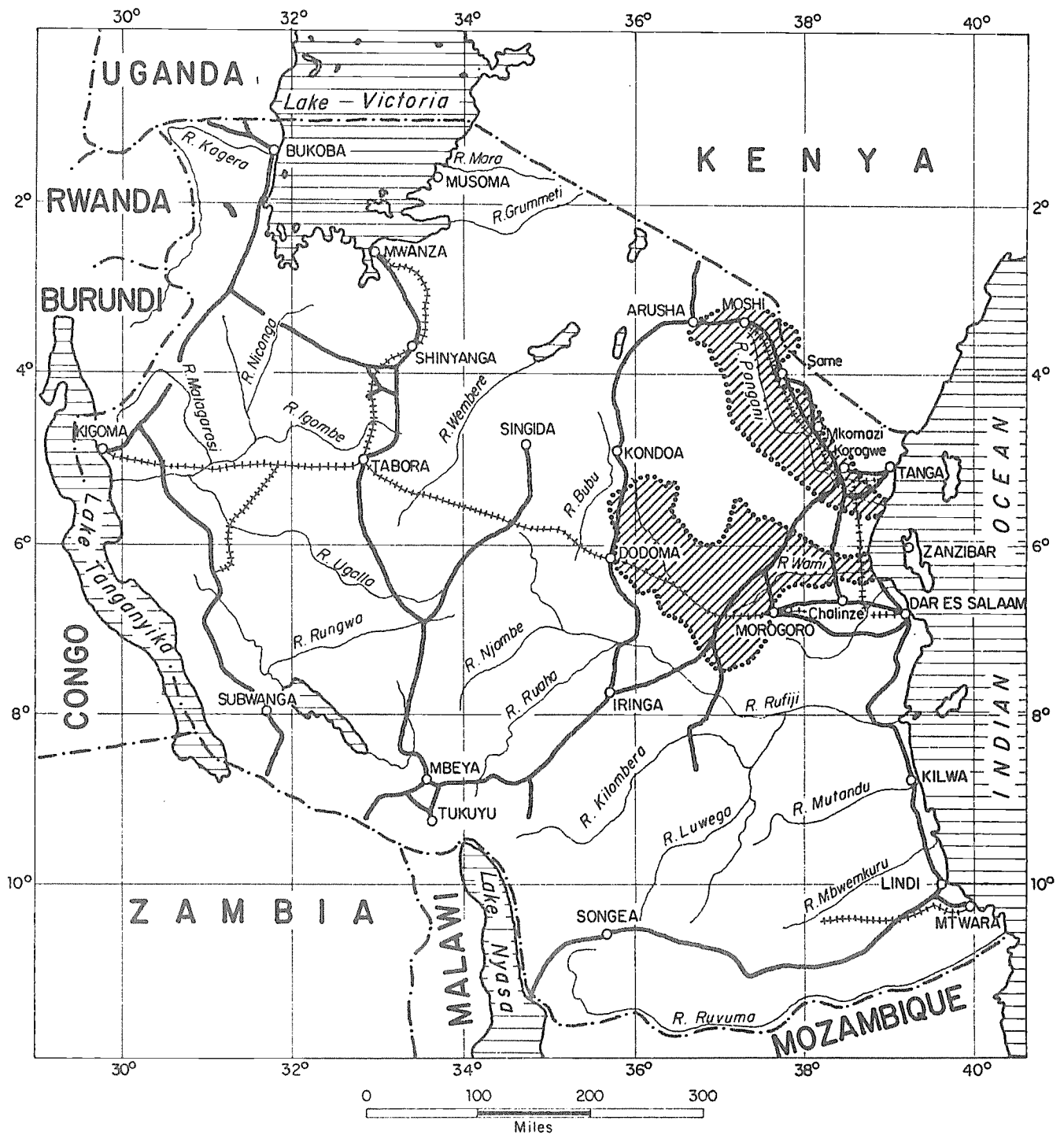
UNITED REPUBLIC OF TANZANIA

FINAL REPORT



**UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS**



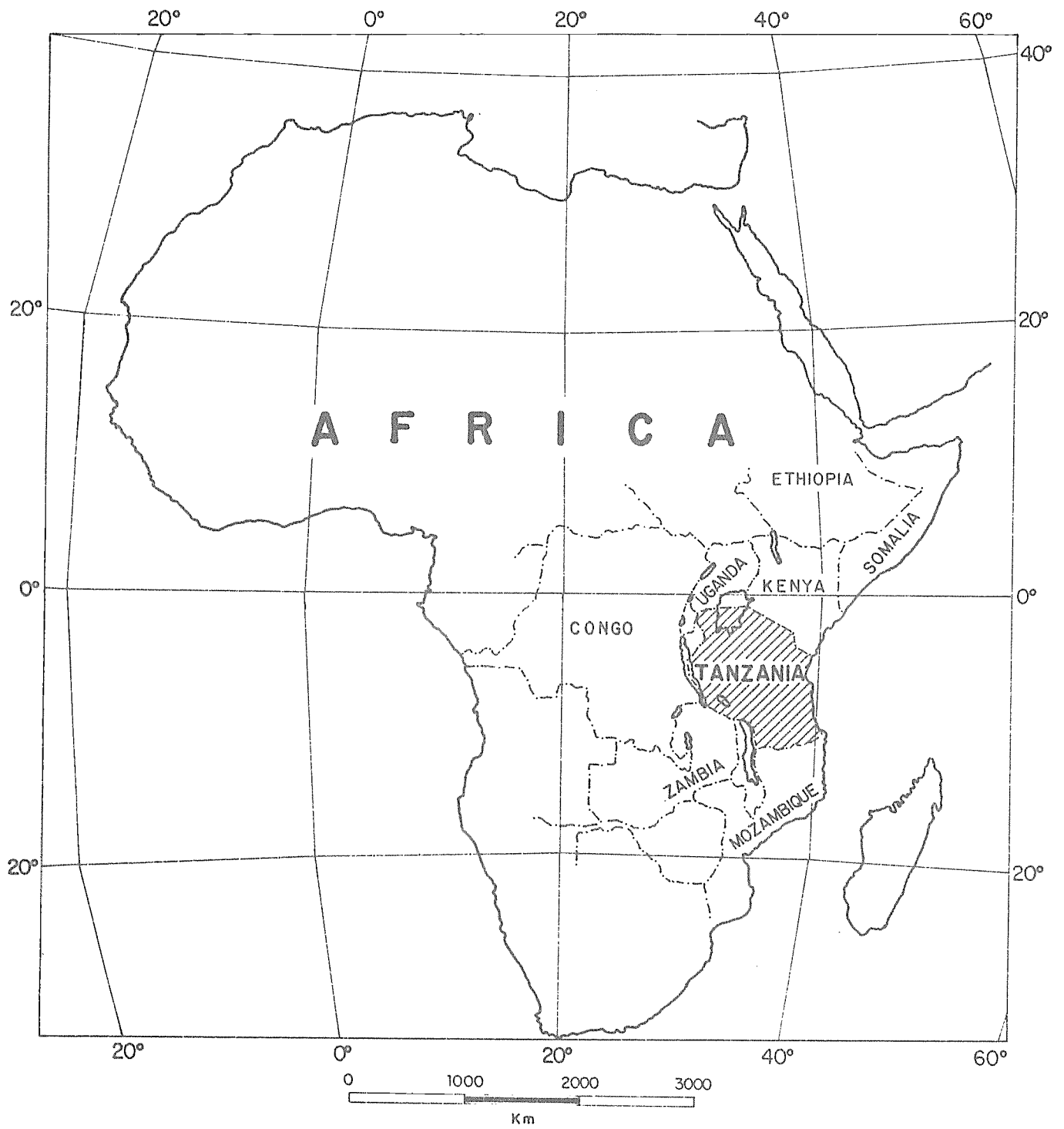


TANZANIA

PANGANI-WAMI RIVER BASINS

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IN THE PANGANI AND WAMI RIVER BASINS

UNITED REPUBLIC OF TANZANIA



LOCATION OF TANZANIA
IN AFRICA

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Survey and Plan for Irrigation Development
In the Pangani and Wami River Basins

UNITED REPUBLIC OF TANZANIA

Final Report

Report prepared for
the Government of Tanzania by
the Food and Agriculture Organization of the United Nations
acting as executing agency for
the United Nations Development Programme

UNITED NATIONS DEVELOPMENT PROGRAMME
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1969

ABSTRACT

The accompanying report describes a project undertaken by the Government of the United Republic of Tanzania, with the assistance of the United Nations Development Programme 1/, to investigate the potential for irrigation development in the Pangani and Wami river basins, to prepare detailed plans and work schedules for pilot areas, and to draw up a programme of irrigation development for execution in the seven years following the completion of the project.

The need for the development in the Pangani and Wami river basins is part of the need for improvement of the national and regional economy, but particularly arises from the pressure of population in the upper Pangani basin.

The Government's request for assistance was approved by the Governing Council of the United Nations Special Fund in January 1964. The Food and Agriculture Organization of the United Nations was appointed the Executing Agency, and the Ministry of Agriculture was appointed as the Government Cooperating Agency 2/.

The UNDP contribution to the project was in the form of professional and technical personnel, contractual services, equipment and supplies to the value of \$ 1 225 300, and this was matched by the Government counterpart contribution in kind estimated at \$ 921 000.

During the execution of the project aerial photography of part of the Wami coastal plain was carried out by contractors Aero-Precisa of Lebanon, and of the Wami escarpment area by Messrs. Story and Partners. The other surveys and investigations were carried out by internationally recruited experts and Government counterpart personnel.

- 1/ Assistance to the project was provided by the United Nations Special Fund until 1st January 1966. On that date the Special Fund and the Expanded Programme of Technical Assistance were merged into the United Nations Development Programme which continued to provide assistance to the project.
- 2/ Ministerial reorganization led to the Government Cooperating Agency being changed from the Ministry of Agriculture to the Ministry of Lands, Settlement, and Water Development.

It is estimated that in the headwaters region of the Pangani approximately 300 000 acres are under some form of irrigation and that about 500 000 acre feet of water are currently abstracted annually from various tributaries, largely for irrigation. Mainly due to unsuitable soils the potential for expansion of irrigation in the Pangani basin is limited. Four areas, totalling some 20 000 acres are proposed for development. The form of development proposed includes the improvement and intensification of existing irrigation farming, as well as development by settlement of unused, or largely unused, areas.

On the Wami coastal plain consideration is given to irrigation development on some 50 000 acres. Flood control, however, is essential before major irrigation development can take place, and land development costs for irrigation are too high for irrigation to bear any part of the costs of the necessary flood control reservoir. Major irrigation development, therefore, cannot take place unless and until a decision is taken to develop the hydroelectric power potential of the Wami.

An order of priority for irrigation development is suggested, and it is proposed that early attention should be given to those areas where improvements and intensification of existing irrigation can be effected. Pilot areas are recommended for each of the proposed main development areas, two of which have been established, and a detailed engineering design has been prepared for a third. Proposals for future work on the pilot areas are submitted, and it is stressed that development based on settlement should not commence until farming systems have been fully tested on the pilot areas, managerial and administrative problems studied, and the necessary infrastructure and supporting services can be provided.

Emphasis is given to the need for coordination of all with sectorial interests in water usage, and the desirability of a unified irrigation development authority to ensure full coordination.

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CHAPTER I

INTRODUCTION

1. The Background

The United Republic of Tanzania ^{1/} lies just south of the equator between Lakes Victoria, Tanganyika and Nyasa, respectively, and the Indian Ocean. The country is the largest and most populous in the East African region with nearly 10 million inhabitants living in an area of some 361 800 square miles. The population is concentrated in the higher rainfall areas along the coast, around the shores of Lake Victoria and in the northern and southern highland areas.

The economy of the country is heavily dependent on agriculture. Over 90 percent of the population obtain their living directly or indirectly from agriculture, which accounts for more than 70 percent of the gross domestic product. Some 81 percent of the country's total export earnings are derived from a range of agricultural products produced both by small holders and estates.

The Pangani and Wami river basins, lying in the northeast corner of the country, cover 28 000 square miles and contain a population of about 1.5 million people of whom 1.1 million live within the Pangani river basin with an area of some 11 600 square miles. The gross value of exported agricultural products from these two river basins is to the order of £10 million pounds, about one quarter of the total exports from Tanzania. The greatest contribution comes from the densely populated and relatively prosperous Pangani river basin.

^{1/} Formerly known as the Republic of Tanganyika and Zanzibar.

Densities of population in the Pangani basin are high and it is not uncommon to find localities on the mountain slopes with populations of two thousand people per square mile. Furthermore the average rate of growth of population within the Pangani basin is over 3 percent per annum, as compared to an estimated national average growth rate of 1.6 percent per annum. The need to intensify agricultural production and to reduce population pressures by resettlement is therefore apparent.

Primarily to meet the requirements of additional hydroelectric power development in the Pangani river basin, Messrs. Sir William Halcrow and Partners, Consulting Engineers, London, recommended to the Government that major storage of flood water of the Pangani should be effected by the construction of a high dam at Nyumba ya Mungu. This recommendation was submitted to the Government in 1962, in the Consultants' report "The Development of the Pangani Basin". In addition to serving the main purpose of hydroelectric power development, the dam, which is now completed, made available considerable quantities of water for irrigation purposes. Several alternatives on the use of the water were proposed by the Consultants.

In the case of the Wami river basin a preliminary survey of the water resources potential was carried out by FAO in 1963 and the results were submitted in publication No. 1626, "Water Resources Potential of the Wami Basin".

In 1963, the Government of the Republic of Tanzania requested assistance from the United Nations Special Fund (UNSF) ^{1/}, for a project designed to provide technical data on which to base irrigation development in the Pangani and Wami river basins, and to submit proposals for irrigation development that could be implemented in the period 1967-1974. The request was approved by the Governing Council of the UNSF in January 1964. FAO was appointed the Executing Agency and the Ministry of Agriculture was appointed as the Government Cooperating Agency ^{2/}. WHO was requested to consider the health implication of the project.

2. The Plan of Operation

A Plan of Operation entitled "Survey and Plan for Irrigation Development in the Pangani and Wami River Basins" was drawn up and signed by FAO as the Executing Agency for the UNSF on 10 April 1964, and by the Government of Tanganyika (now Tanzania) and the UNSF on 17 April 1964. The Plan of Operation was

- 1/ Assistance to the project was provided by the United Nations Special Fund until the 1st January 1966. On that date the Special Fund and the Expanded Programme of Technical Assistance were merged into the United Nations Development Programme which continued to render assistance to this project.
- 2/ Ministerial reorganization led to the Government Cooperating Agency being changed from the Ministry of Agriculture to the Ministry of Lands, Settlement and Water Development.

subsequently amended to take into account the formation of the United Republic of Tanganyika and Zanzibar, and the change in the Government Cooperating Agency.

The purpose of the project was to determine, through surveys and investigations, the technical and economic basis of design for irrigation development of the Pangani and Wami river basins. Based on the results of the investigations suitable pilot demonstration areas were to be selected, and detailed designs and schedules of work prepared for these areas. In addition, a programme of irrigation development in the two basins for implementation in the seven years following the completion of the project was to be established. The investigations included hydrological studies for both ground and surface water, engineering studies needed for the planning of storage dams and reservoirs, flood protection works as well as irrigation and drainage systems. In addition, investigations into the soils, suitable cropping patterns, irrigation practices, sociological conditions, health implications and economics were included in the terms of reference. The Plan of Operation is attached as Appendix I.

The UNSF contribution to the project was \$ 1 225 300 and covered the cost of international experts, subcontractual services, equipment and supplies. The Government contribution in kind was estimated at \$ 921 000. This covered the cost of counterpart technical and administrative personnel, local equipment and supplies, buildings and construction, and cost of transporting and handling project equipment.

3. Hydroelectric Power

During the investigations it became apparent that the area suitable for irrigation development in the Pangani basin was limited, and full use could not be made of the water regulation provided by the recently constructed Nyumba ya Mungu dam. In the Wami basin irrigation demanded major flood control storage which could only be economically justified, if at all, should a multipurpose scheme be developed involving the production of hydroelectric power.

The need to develop electric power to meet the rapidly growing demand in the Pangani basin, coastal and central areas of Tanzania was highlighted in an appreciation of the market for electricity in Tanzania carried out by Messrs. Merz and McLellan in 1964.

Although the Plan of Operation did not include investigations into the development of hydroelectric power, this was included in the work programme of the project for the foregoing reasons.

The areas investigated with a view to irrigation development and the provision of hydroelectric power in the Pangani and Wami basins are shown in Figures 1 and 2.

4. Brief Account of Execution

(a) General

The operations of the project commenced on 22 April 1964 and ceased on 15 February 1968. The Project Manager was appointed on 1 January 1964. The project headquarters which had originally been sited in Dar-es-Salaam were moved to Moshi, in Kilimanjaro Region, early in 1965. Shortage of housing, office and storage facilities in Dar-es-Salaam necessitated another site as project headquarters. In addition, early investigations in the Wami basin directed interest to the coastal plain area where lengthy preliminary investigations were required before a full investigational programme could be developed. In the meantime, activities could be extended in the Pangani basin and Moshi provided a suitable centre.

The international staff and staff assigned to the project by the Government of Tanzania are shown in Appendix II.

(b) Summary of field work carried out

The areas for irrigation development proposed in the Halcrow Report formed the basis on which the project planned its detailed pedological, topographical and engineering surveys in the Pangani basin.

In the Wami basin the basic data obtainable did not permit investigations of the central alluvial plain. An overall appraisal indicated that the area best suited for initial irrigation development was on the coastal plain and subsequent investigations therefore were limited to this area.

(i) Topographical surveys and mapping

Topographical surveys were carried out for water storage, flood control and irrigation schemes. In addition, survey work was carried out for reconnaissance purposes. In the Pangani basin all surveys were carried out by conventional survey methods. In the Wami basin the major part of the mapping was accomplished by photogrammetric methods.

The project arranged for aerial photography at a scale of 1:10 000 covering about 360 000 acres of the Wami coastal plains and along the middle reaches of the Wami river. This photography was undertaken by contractors Aero-Precisa, of Lebanon. Other aerial photography was borrowed from the Survey Division Dar-es-Salaam, Air Survey Division, Dar-es-Salaam and Messrs. Story and Partners, Dar-es-Salaam. On behalf of the Government the firm of survey contractors, Messrs. Story and Partners, had provided aerial photography cover of a further 150 000 acres of the Wami basin.

Photogrammetric plotting, at a scale of 1:10 000 with ten feet vertical interval contours and covering 22 000 acres was carried out for the main irrigation area in the Wami basin. In addition, Messrs. Story and Partners plotted a further 35 000 acres at the same scale and vertical interval in the area of the Wami escarpment.

Topographical surveys at a scale of 1:10 000 with contours at ten feet vertical intervals were carried out in the Pangani basin over 45 000 acres, and at a scale of 1:2 500, with contours at one foot intervals for four pilot irrigation areas.

The areas of topographical surveys are given in Figure 3.

(ii) Soil surveys

Soil surveys to determine suitability for irrigation were carried out at reconnaissance, semidetailed and detailed levels, within six major areas in the headwaters of the Pangani, the Middle Pangani region, and the Wami coastal plain. The areas surveyed at reconnaissance and semidetailed levels totalled some 280 400 acres. In addition, exploratory work and check surveys covering an area of 160 000 acres were carried out either at the request of the Government, or to appraise areas prior to more detailed investigation. Detailed soil surveys over some 4 500 acres were carried out in possible pilot scheme areas.

The areas of soil surveys are also shown in Figure 3.

(iii) Hydrology, climatology and water resources

Climatological and hydrological statistics were compiled and analyzed for application to studies of water availability, control and irrigation requirements in the Pangani and Wami basins.

(iv) Irrigation engineering

In the Pangani river basin preliminary assessments were made of the total seasonal water requirement for four proposed irrigation development areas. These requirements were well within the overall quantity available for irrigation after taking into consideration the requirements for other users, including hydroelectric power.

Preliminary investigations were carried out into flood protection works, and designs for storage reservoirs were prepared together with preliminary costs.

Detailed designs for three pilot irrigation areas were prepared for localities suitable for subsequent major development in the Pangani basin. The fourth project area in the Pangani basin is of low priority and no detailed design for a pilot area was prepared. Two of the three pilot areas were established, one at Miwaleni and one at Kahe.

Consideration was given to the design of irrigation layouts in all the selected project areas and preliminary estimates of cost were prepared.

In view of the limited irrigation potential of the area downstream of the recently constructed Nyumba ya Mungu dam, coupled with the finding that irrigation development in the Wami coastal area would not be economically justified as a single purpose project, consideration was given to the possibilities of hydroelectric power development in the Wami basin.

(v) Agronomy

Studies of existing experimental data and current cropping patterns in the project areas were carried out. A number of experiments were established in the Miwaleni and Kahe project areas in Moshi district in the upper Pangani basin. These experiments were designed to provide information on suitable crop varieties, cultural practices, fertilizer treatments, and frequency and method of irrigation, but the project ended before the full experimental programme could be developed.

No agronomical work was carried out in the Wami coastal plain, but preliminary suggestions for future work were submitted.

(vi) Sociology

Sociological sample surveys covering 255 families were carried out in the over populated highland and lowland localities surrounding areas proposed for irrigation development. The surveys were designed to obtain and assess factual information on the social, cultural, economic and other significant institutional characteristics, and to relate the effect of these characteristics to settlement on the proposed irrigation schemes.

Data was collected by five field assistants under close supervision following a period of intensive training.

The conclusions and recommendations were intended for application to the irrigation areas at Miwaleni, Kahe and Naururu, in the Pangani basin. The health aspects of irrigation development in the Pangani and Wami river basins were studied by WHO and a report prepared.

(vii) Economic appraisals

A preliminary economic appraisal of the Kahe scheme was carried out by Dr. Allbaugh early in 1966, and his report entitled "An Economic Appraisal of the Proposed Kahe Irrigation Project in the Pangani River Basin, Tanzania" was submitted to the Government at the end of that year. A further preliminary economic appraisal of the Kahe and Miwaleni upland schemes was prepared by Dr. Moes in 1967 and his report entitled "Economic Appraisal of the Kahe and Miwaleni Project Areas" was forwarded to the Government early in 1968. More detailed studies are required before a final economic assessment can be made.

A survey of the market prospects for various crops was carried out by Dr. Bauer in 1967 and a report entitled "Marketing Prospects for the Crops Grown in the Survey and Plan for Irrigation Development in the Pangani and Wami River Basins Project Area" was prepared.

5. Reports

The final report on the project is contained in a single volume. During the project a number of specialists and consultants reports were prepared and have been handed over to the Government. A list of these reports is contained in Appendix VII.

6. Acknowledgments

The assistance and cooperation received from many branches and officials of the Government and other authorities, as well as various companies and private individuals, are gratefully acknowledged.

In particular, the assistance from the following Ministries, Departments, Institutes and Organizations was appreciated:

Ministry of Lands, Settlement and Water Development, particularly:

- The Water Development and Irrigation Division;
- The Survey Division;
- The Ubunge Planning and Research Station;
- The Land Division.

Ministry of Agriculture:

- Agriculture, Veterinary and Forests Divisions;
- Agriculture Research Station, Tengeru;
- Agriculture Research Station, Ilenga.

Local Government Council

Regional and Area Commissioners and Officers, etc.

Tanganyika Electric Supply Co., Ltd., Dar-es-Salaam.

CHAPTER II

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

A. THE CONCLUSIONS OF THE SURVEY

1. General

The Pangani and Wami river basins, lying in the northeast corner of Tanzania, cover 28 000 square miles and contain a population of about 1.5 million people of whom about 1.1 million live in the Pangani basin with an area of some 11 600 square miles. As a result of the wide variation in soil and climatic conditions, the population of the Pangani basin is unevenly distributed and is largely concentrated in the northern mountain areas. The need for the development of irrigation in the two basins is, of course, part of the need for improvement of the regional and national economy, but particularly stems from the population pressure in the upper Pangani basin.

It is estimated that about a third of a million acres are under some form of irrigation in the upper Pangani basin, and that on mounts Meru and Kilimanjaro about half a million acre feet of water are abstracted annually, largely for irrigation purposes. Current irrigation practices are wasteful of water, and there is considerable room for improvement in water usage and intensification of production. Surveys in the upper and middle reaches of the Pangani river showed the limited availability of unpopulated, or only lightly populated, land suitable for irrigation development. Although a preliminary reconnaissance revealed a large, virtually unpopulated area suitable for irrigation development in the coastal plain of the Wami river basin, the area is some 250 miles from

the densely populated mountain areas of the upper Pangani basin, and offers a drastic change in environmental conditions to the mountain dwellers of the north. These facts indicate that effective relief of population pressures in the upper Pangani will be achieved more by the development of a systematic extension programme aimed at intensifying and improving existing irrigation in that region, than by the development of irrigation schemes in the limited areas which are unpopulated, or only lightly populated, and in which the soils are of fair or marginal suitability for irrigation. The irrigation development proposed as a result of the survey however, provides an opportunity to build up experience both in the improvement of existing irrigation and the establishment by settlement of new areas.

2. Land and Water Resources

Soils

The soil surveys carried out during the project at reconnaissance and semi-detailed level extended over a total area of 280 434 acres. In addition, broad reconnaissance and detailed surveys were carried out.

In the headwater region of the Pangani basin there are some 38 000 acres of good Class I soils, representing 56 percent of the area surveyed. Details regarding the existence of shallow phases of these soils and of saline and alkaline patches have yet to be determined however. A high proportion of the land is currently in use and some form of irrigation is practised over much of the land under cultivation.

In the middle region of the Pangani basin no irrigation Class I soils were identified although some 39 000 acres, or 43 percent of the area surveyed, are suitable for irrigation in Classes II and III. Salinity and alkalinity are major problems in this region; irrigation is currently being practised in localized areas.

In the area surveyed at reconnaissance level in the Wami coastal plain there are 57 000 acres of soils suitable for irrigation in Classes I and II. The area is only very sparsely populated (see Chapter IV).

Water resources

The completion of the Nyumba ya Mungu dam and reservoir on the Pangani river has removed the danger of frequent flooding in the central plains of the basin. Further, after meeting the commitment for hydroelectric power generation in the lower reaches of the river, the reservoir has made available an additional 233 000 acre feet of water for the expansion of irrigation upstream of the Hale power station. The Miwaleni springs are the main source of water for the largest

of the areas proposed for irrigation development in the headwaters region in Moshi district. In addition, a large aquifer, or aquifers, has been identified in the lower areas of Moshi. The extent of this groundwater supply, and the effect of substantial extractions on the flow of the Miwaleni springs, have not yet been determined.

The flow of the Wami river varies considerably both seasonally and annually. Annual discharges over a 10-year period varied from some 600 000 acre feet to some 3 000 000 acre feet. In order to control flooding and provide a sufficient base flow for irrigation throughout the year, a storage reservoir with a capacity of about 1.5 million acre feet is essential. It is estimated that the cost of construction of such a storage reservoir would be about £ 14 million (see Chapter V).

Crops

A wide range of crops are grown on estates and African owned small holdings in the Pangani basin and reflect the considerable variation in environmental conditions which can occur within a distance of a few miles. The crops grown include coffee, tea, bananas, sisal, sugar, cotton, maize, wheat, rice, a range of legumes, and various fruit and vegetables. There is a strong element of export crop production by African small holders in addition to the production of food crops for home use and local sale. This is particularly marked in the headwater region of the Pangani. In addition to shortage of water, poor cultural standards, use of unsuitable varieties, lack of pest and disease control, and lack of use of fertilizers contribute to the low yields currently obtained.

The agronomic studies carried out during the project were limited to the lower areas of Moshi district. The broad aim of these studies was to increase the yields of selected crops currently grown in the area, and to investigate the potential of new crops such as kenaf, for fibre, and various fodder crops including lucerne and berseem. The intensive production of high value vegetables, including onions and tomatoes, requires the development of a processing industry, an exacting standard of management, and involves a high degree of risk. In addition, current varieties and known cultivation techniques limit vegetable production to a certain time of the year only. Kenaf grows well, but owing to the intensive labour requirement for retting, the development of a more efficient method of mechanical decortication needs to be found before this crop can be developed. Lucerne and berseem also grow well, and there is considerable potential for dairy development. This is a long-term process however, and further studies in the economics of milk production and the production costs of a range of fodder crops are required. Development of irrigation in the early years will need to be based on the current major crops of the lower areas of Moshi, such as cotton, hybrid maize and seed beans, with limited production of vegetables including chillies. Sugar cane has a potential for early introduction into the cropping system if additional local factory capacity can be arranged.

No agronomic trials were carried out in the other areas proposed for irrigation development, but in the central Pangani region maize, cotton, beans, rice and possibly tobacco should provide the basis for early irrigation development.

In addition to the usual range of cereals, legumes, and root crops, coconuts, cashewnuts and various tropical fruits are grown on a small scale by the very sparse population living in the Wami coastal plain. Detailed studies are required before recommendations can be made for crops which should be included in an irrigation development programme. Due to the high tsetse population no cattle are kept in the area, and the lack of animal and tractor power, together with the lack of local market incentive, are major contributing factors to poor cultural standards and low crop yields (see Chapter IX).

3. Markets

Good export markets exist for a number of the crops under consideration including cotton, chillies, seed beans, and for fresh onions and various processed vegetables of the right quality. There is an internal market for sugar, maize, dairy products, and with the establishment of a bag factory at Moshi, also for kenaf fibre. Communications and primary marketing arrangements in Moshi are in general satisfactory for these products. The growing regional and national demand for liquid milk, and the inability of the recently completed dairy factory in Arusha to obtain adequate supplies locally, indicate the desirability of developing milk production.

Primary marketing facilities are not so developed in the central Pangani region as in Moshi, and communications are poor. In both areas cooperatives play a major part in primary marketing.

In the Wami coastal plain primary marketing is such that there is little production incentive for the small number of cultivators in the area. General development to date has been very limited and communications are extremely poor (see Chapter X).

4. Irrigation Development

High development costs or unsuitable soils ruled out much of the land investigated with a view to irrigation development in the Pangani river basin. Four areas are proposed for development. The acreages and preliminary estimates of engineering capital cost are given below.

A reservoir for flood control and the provision of a base flow to ensure irrigation water throughout the year is a prerequisite to large scale irrigation development on the Wami coastal plain. A preliminary estimate of irrigation development over 50 000 acres indicates an engineering cost of about Shs T 3 200 per acre, excluding the cost of the storage reservoir.

		Net Irrigable Area (acres)	Estimated Capital Cost (Shs T/ acre) <u>1/</u>	Annual Water Require- ment (acre feet)	Water Source
1.	Kahe (i) surface irrigation or (ii) overhead sprinkler	8 800 11 000	2 760 2 560	60 000 60 000	gravity from Miwaleni Springs
2.	Miwaleni upland	2 000	3 020	14 000	ground- water pumping
3.	Naururu	2 200	3 380	20 000	gravity diversion from river
4.	Marwa	7 000	3 500	36 000	pump diversion from river

1/ One US dollar is equivalent to 7.14 Tanzania shillings.

The estimated engineering costs per acre for the five schemes are based on full development of each area. In practice, development would take place over a number of years. The rate of development cannot be forecast at this stage, and will depend on the results obtained from pilot areas, the availability of experienced management and trained extension and cooperative staff, the readiness of settlers to come forward, the rate at which the settlers adapt themselves to new conditions, and the availability of funds. In the early stage of development capital costs per acre will be higher than the quoted estimates, as certain works will require to be completed in full from the outset, irrespective of the area initially brought under irrigation.

The rate of improvement in production is likely to be faster where the farmers are familiar with the development area, the crops included in the farming system, and have experience of irrigation however simple or inefficient their current practices may appear. These conditions will apply where development is based on the improvement of existing irrigation farming, as it does in part, at least, at Miwaleni upland and at Naururu. Experience gained in the development of these areas by means of intensive, coordinated rural extension programmes would be of wide application to the very extensive area currently under some form of irrigation in the Pangani headwaters, and middle regions. Where irrigation development is to be established on settlement, as at Kahe,

a simple farming system based on well tried and familiar crops should be developed and tested on pilot areas before settlement takes place. More remunerative and sophisticated farming systems may be introduced as they are developed and the necessary infrastructure is established.

Because of the soils and topography in the Marwa area overhead sprinkler irrigation is proposed. The engineering costs per acre are high, and apart from providing limited assistance to existing farmers, it would be advisable to await the outcome of the detailed studies of overhead sprinkler operation proposed for part of the Kahe pilot area, before any action takes place at Marwa.

Flood control is a prerequisite to irrigation development on the Wami coastal plain, and the cost of land development for irrigation is too high for irrigation to bear any part of the cost of the flood control reservoir. Major irrigation development can only take place if the cost of flood control and storage is borne by hydroelectric power generation. A decision as to whether hydroelectric power will be developed in the Wami basin has yet to be taken. The area is sparsely populated, and the conditions are so different from those of the overpopulated but cool and healthy mountain areas of the upper Pangani basin, that it is unlikely that significant numbers of people would be attracted to the coastal plain from the upper Pangani mountain areas in the foreseeable future. No alternative source of people for the major development of irrigation in this area has yet been investigated. For the foregoing reasons irrigation development on the Wami coastal plain is likely to proceed slowly and extend over many years (see Chapter VII, section 4 of Chapter IX, and Chapter XI).

5. Pilot Irrigation Areas

Of necessity, and in the interest of efficiency, irrigation development requires a high degree of control and supervision. Inevitably, land tenure and various administrative problems will arise which will be further aggravated if sound practical knowledge, together with the staff necessary for the dissemination of this knowledge, are not available. Moreover, the rate of adoption of recommended practices, and the level of yields obtained by family worked fields as compared with yields obtained from fields worked by labourers under direct control, should be assessed before a final economic judgement for full development is made. Pilot irrigation areas are, therefore, required in each main area proposed for irrigation development. In these areas agronomic investigations may be carried out on an experimental and field scale, the social and administrative problems of settlement may be studied, staff of various disciplines may receive practical training under field conditions, and a demonstration for future development may be established. In addition, data will be made available which will make possible a more reliable economic assessment of main developments to take place (see section 3 of Chapter IX).

6. Health

Bilharziasis is the principal medical problem associated with irrigation, although malaria, amoebiasis, and nematodes are present and care will have to be taken to ensure that irrigation development does not worsen the health situation. Currently no human trypanosomiasis has been recorded but in the Wami basin, where there is a high tsetse density and *Glossina brevipalpis* is present, human trypanosomiasis could be transmitted, should cases be imported.

7. Hydroelectric Power

The cost of land development for irrigation in the Wami coastal plain is so high that irrigation can bear no part of the cost of a flood control and storage reservoir on the Wami river. If the storage cost could be charged to hydroelectric power generation it would be a step forward in the development of large scale irrigation on the Wami coastal plain. It is understood that Government is considering the Wami basin, together with other areas, as a possible source of additional power to meet the forecast of load growth for the Moshi, Arusha, and Central/Coastal areas from about 1975/76 onwards.

As a follow up to the initial proposals by SWECO, Consulting Engineers and Architect, preliminary consideration was given to the alternative development of underground and surface power stations. The tentative cost of underground power development with an installed capacity of 165 megawatts and an estimated annual energy of 775 million Kwh is £ 36.2 million. For surface power development with an installed capacity of 73.5 megawatts and an estimated annual energy of 636 million Kwh the tentative cost is £ 28.76 million. Both cost estimates include the full estimated cost of the main storage reservoir on the Wami, which would also control the flood waters on the coastal plain (see section 5 of Chapter VI).

B. RECOMMENDATIONS

Based on the conclusions of the survey, the following recommendations are made.

1. Irrigation Development

Of the irrigation areas proposed, Kahe, Miwaleni upland and Naururu offer the best potential for early development. Although it would appear that priority attention should be given to Kahe, and full development of Miwaleni upland should depend on the effect of substantial groundwater abstraction by boreholes on the flow of the Miwaleni springs, in the light of present knowledge, it is recommended that early attention be given to the improvement and intensification of existing irrigation at Miwaleni upland and Naururu.

Pilot areas

Irrigation development should be based on experience gained in pilot areas established within each main area proposed for development. Initially each pilot area should aim at developing, testing and demonstrating a simple farming system based on well tried crops which are familiar to the people of the area. In those irrigation development areas such as Kahe, where development is dependent on settlement, part of the pilot area should be set aside in order that the proposed farming system could be further tested under conditions of family operated units, before large scale settlement is started.

Research into more intensive and remunerative farming system should be carried out concurrently with the development of the simple farming systems which will be adopted in the first years of main development.

Kahe and Miwaleni upland

Pilot areas have been established at Kahe and Miwaleni upland on 200 and 100 acres respectively. The main crops for inclusion in the simple farming system to be tested may well be cotton, hybrid maize, and seed beans with vegetables, including tomatoes, onions, and chillies, grown as minor crop.

Should Government policy support the expansion of sugar production by out-growers in Moshi district, and if factory capacity can be made available, then sugar cane should be tested for early inclusion as a major crop at Kahe.

In view of the demand for kenaf fibre in Moshi when the bag factory commence operation, investigations into the cultivation and decortication of kenaf should continue.

Because of the more efficient control of water applications by overhead sprinkler irrigation, it is recommended that this method be tried out on part of the Kahe pilot area, in view of the salinity and or alkalinity problems in parts of the main areas.

Investigations into the problems and economics of production and processing of the potentially more rewarding vegetable crops should also continue.

A dairy unit should be established at an early date so that the economics of milk production from grade stock fed on irrigated fodder crops can be studied, and experience gained in dairy management.

Naururu

A pilot irrigation area should be established at Naururu on about 250 acres as soon as funds and staff are available, and again early attention should be directed to the development and testing of a simple farming system based on crops well known to the people of the area.

Many of the soil units found in the main development area are contained in the proposed pilot area, and special consideration should be given to the irrigation development problems set by the intricate soil pattern prevailing in the main development area.

Marwa

It is recommended not to establish a pilot area at Marwa until the implications of the operation of an overhead sprinkler system have been studied in detail on the Kahe pilot area, and the financial and staffing commitments of Kahe, Miwaleni upland, and Naururu areas have been fully met.

Wami coastal plain

Flood control is essential before major irrigation development can take place on the Wami coastal plain. The cost of the flood control and storage reservoir can only be borne by hydroelectric power. No pilot irrigation area should be established unless and until it is decided to develop hydroelectric power in the Wami basin. There will be sufficient time between the taking of a decision to develop hydroelectric power and the construction of a flood control and storage reservoir for pilot area investigation to be carried out without delaying main development.

Main areas

Further studies should be carried out on the groundwater supplies in the lower areas of Moshi and on the effect of substantial borehole abstractions on the flow of the Miwaleni springs.

Detailed soil surveys are required at Kahe, Miwaleni upland and Naururu. These schemes should then be reappraised in the light of data from the pilot areas and the detailed soil surveys.

Development at Naururu and Miwaleni upland should aim at improving and intensifying existing irrigation as part of a full, coordinated rural extension programme. At Naururu this should include improvements to the intake and lead canal from the Pangani.

A schedule for phased settlement of Kahe should be prepared as soon as a satisfactory simple farming system has been fully tested on the pilot area, and staffing requirements can be met.

The introduction of potentially more rewarding farming systems, including intensive vegetable production for processing and dairy farming, should not take place until these systems have been fully tested on the pilot areas at Kahe and Miwaleni upland.

Even if a decision is taken to develop hydroelectric power in the Wami coastal plain, and a flood control and storage reservoir is constructed, major irrigation development is likely to proceed slowly in view of the lack of population in the area and other problems such as poor communications, lack of markets, associated with the development of the area.

Consideration should be given to the source of people who would develop the area, and a careful study should be made of the full implications of attracting large numbers of people to this unpopulated locality.

2. Processing

Vegetables are processed into various products. Varietal suitability to the various products varies considerably. More detailed agricultural research is required before consideration can be given to the type of product to be produced and the establishment of minimum economic processing facilities.

In the meantime consideration should be given to acquiring the unused pilot dehydration plant from the Tanganyika Farmers Cooperative Association in Arusha for the preparation of sample offers of dehydrated products and trial shipments.

3. Establishment of a Unified Irrigation Development Authority

The many interests involved in the development of water resources require close coordination of all with sectorial responsibilities for water usage, and an administrative organization with legal powers. Within the overall organization for the development of water resources, there is a need for a unified authority with specific responsibility for irrigation development. Such an authority would be responsible for coordinating and evaluating projects before authorizing their execution, and for preparing the plans, controlling, authorizing or

executing the individual projects. The authority would ensure that the infrastructure essential for successful irrigation projects, including communications, markets, extension, research, and social services were developed, and would arrange for the necessary training of all concerned. Although it may be said that this can be achieved by joint consultation and action by the various ministries, past experience elsewhere has shown the advantage to be gained from a unified authority.

4. Training

Irrigation development programmes will require the participation in varying degrees of various organizations and individuals including local authorities, influential leaders of the community, and cooperative societies in addition to the staff at all levels of a number of Government departments. It is essential that the training of all concerned should be closely coordinated.

In addition to the training of staff in the practical techniques of irrigation and farming and the provision of the necessary services, public opinion requires to be brought to understand the need for control and discipline in irrigation development programmes.

Full use should be made of the pilot areas when planning training programmes, and consideration should be given to short overseas practical training courses for selected intermediate and field level workers.

5. Health

Medical scrutiny of the settlers and treatment of all diseases which could be of epidemiologic importance (malaria, bilharziasis, ancylostomiasis), should be done before the settlers arrive on the scheme. Vaccination of all settlers and immunization of the children should be carried out. Treatment and follow-up on individual record cards should be established, and the region of the country from which the settler comes noted.

Malaria prophylaxis should be considered after the arrival of new, non-immune settlers.

The bilharziasis hazard, considered as one of the major health problems, requires the institution of molluscicide control methods in the water supply intake for the irrigation schemes. Intensive health education directed towards prevention of contact with water is indispensable. Observation of the ecological changes and surveillance of the irrigation system for snails should be instituted from the beginning.

CHAPTER III

DESCRIPTION OF THE PROJECT AREA

1. General

The Pangani and Wami river basins lie in the northeast corner of the United Republic of Tanzania, and cover a total area of approximately 28 000 square miles, or about 8 percent of the area of the country as a whole. Some 15 percent of the population of the country live in the two basins, with heavy concentration on the mountain slopes on the northern and eastern edges of Pangani basin. The gross value of exported agricultural products is some £ 10 million pounds or roughly 25 percent of the national figure, with the greatest contribution coming from the Pangani basin.

2. Location and Physical Description

(a) Pangani river basin

The Pangani river runs for a distance of about 330 river miles from the steep slopes of Mount Meru and the Kilimanjaro massif in the northwest to the Indian Ocean at Pangani in the southeast. The western edge is flanked by the Masai steppe, whilst the east is bounded by the North and South Pare Mountains and the Usambara Mountains. The basin covers an area of some 12 000 square miles and lies between longitudes 36° 30'E and 39°E and latitudes 3°S and 5°30'S.

The perennial streams from Meru and Kilimanjaro, and the flow from several springs emanating from the geological contact between the underlying basement complex and the superimposed volcanics merge into one single river, the Pangani, at the apex of the detrital fan a few miles south of Arusha Chini. From this point, for a distance of about 100 river miles, the Pangani becomes a "stranger" river running in a semidesert trough for 60 miles to Kirua, thereafter passing through a series of falls and rapids over a distance of 25 miles to Buiko, and then down a final fall at Mandera before reaching its confluence with the Mkomazi, its largest tributary. Below the Mkomazi the river enters a short cataract stretch and then, below Korogwe, receives much of the drainage from the Central Usambaras through the Luengera, an intermittent river. It then drops down the escarpment in a series of falls finally reaching its estuary through a short gorge and a sluggish, meandering course across the coastal plain.

The uppermost tributaries begin on tertiary-recent volcanics associated with Kilimanjaro and Meru, the basin itself lying almost entirely on Precambrian crystalline metamorphic rock. Recent and Pleistocene to Miocene lacustrine sheets, overlying the Precambrian basement, floor the valley between the lower Moshi area and Hedaru. Neocene fluvial and marine beds occur along the coast near Pangani and there are small patches of Palaeozoic and Mesozoic rocks near the river mouth.

By comparison with other African rivers, the Pangani is not a great river, but due to various factors its flow was relatively equable prior to the construction of the Nyumba ya Mungu dam, even though there was only one lake (Jippe) of any importance in its headwaters. The main reason for the comparatively equable flow of the Pangani is the porous nature of the soils in the upper catchment area which rapidly absorb the rain water. The absorbed water partly reappears as perennial springs on the southern flanks of Meru and the Kilimanjaro massif and accounts for about half of the total annual river discharge above the Mkomazi confluence.

(b) Wami river basin

The catchment area of the Wami river and its tributaries covers approximately 16 000 square miles and lies between latitudes $35^{\circ}30'E$ and $39^{\circ}E$ and longitudes $5^{\circ}S$ and $7^{\circ}S$. The basin is bordered by the Rufiji and Ruvu rivers on the south and by the Pangani, Msagesi and Mligazi rivers to the north and northeast.

The river rises some 60 miles north of the town of Dodoma, where it is known as the Kinyansungwe river. Near Mpwapwa it bears southeastwards and flows into Lake Gombo near Kidete. The area drained above Kidete, the western plateau, covers nearly 6 000 square miles. Only after heavy flooding in the catchment area does Lake Gombo overflow and river water from the western plateau enters the lower river system.

Below Kidete the river is known as the Mkondoa which, flowing southeastwards, penetrates the Nguru and Rubeho range of mountains and emerges at Kilosa onto an alluvial floodplain. Here, flowing initially eastwards and then northeastwards, it passes through an area of extensive swamp land known as the Mkata Plains and

Tendigo Swamp. In this area it joins three tributaries named the Mswero, Mkundi and Wami, the main river now taking the name of the Wami. The river continues to flow north/northeastwards until about 40 miles north of Morogoro. Here the river swings sharply east and shortly after this reaches the upper edge of the escarpment where it leaves the central plateau. Between the Mkondoa-Wami river confluence and the escarpment, the river is joined by the major tributaries Mkundi, Liwale, and Lukigura. The central plateau covers an area of approximately 7 100 square miles.

From the central plateau, the river falls rapidly down the escarpment. About five miles downstream of Mandera Bridge it levels out to enter the coastal plain and flows at a gentle gradient eastwards into the Indian Ocean.

The Wami basin is covered by sedimentary and metamorphic rocks formed in the Archean period. The right bank of the Kinyasungwe tributary in the western plateau is formed by a granite shield (part of a mantle which covers a large part of Tanzania, extending from Lake Victoria down to Lake Nyasa).

Alluvial sedimentary areas formed in recent periods are:

The central alluvial plain of alluvial deposits.

The coastal plain of the Wami basin, a continuation of the Pangani coastal plain, which is formed by marine sediments between elevations of sea level to 120 ft.

The basin may be divided into five main topographical areas:

- (i) The rolling country of the western plateau at elevations ranging between 3000' to 5000'.
- (ii) The broken and deeply gullied country of the Nguru and Rubeho Mountains through which the drainage system of the western plateau and of the southern part of Masailand passes.
- (iii) The central alluvial plain, gently sloping in a uniform gradient from the foothills of the mountains to the edge of the escarpment from an elevation of 1500' to 1100'.
- (iv) The area of the escarpment where the Wami river runs through narrows falling from 1100' to 100' within a distance of 60 miles.
- (v) The coastal plain, which includes the alluvial river valley broad flood-plain and a higher marine shelf through which the river valley is cut, near the coast. Unlike the Pangani the flow of the Wami ranges widely.

3. Climate

(a) Rainfall

Both basins may be divided into two broad zones lying east and west of longitude 37°20' (approximately).

In the coastal areas east of this line there are usually two clearly defined rainy periods, the short rains from November to December, and the long rains from March to May. Annual rainfall ranges between 40 inches to 50 inches.

West of this line, in the central area of the Pangani and in the western plateau of the Wami, rainfall is low, unreliable and may be restricted to a single period any time between November to May. Precipitation may be 20 inches or less.

Exceptions to this division occur in the mountain areas of Kilimanjaro, Pare, Usambara, Nguro and Rubeho where the pattern is often ill-defined and where rainfall reaches as high as 80 inches a year.

(b) Temperature

In most of the areas of interest to irrigation development temperatures fluctuate over a limited range. In the Pangani basin mean monthly temperatures range from a minimum of 68°F to a mean maximum of 77°F in the headwaters area, and a mean minimum of 76°F to a mean monthly maximum of 83°F in the coastal plain. The temperature conditions in the Wami basin are similar.

4. Communications

(a) The Pangani basin

The basin is well serviced by a small single track 1.06 m gauge railway line which runs from Tanga in the southeast, about 30 miles north of the Pangani river mouth, through Korogwe to Moshi and Arusha in the northeast. The northwest end of this line connects with the Nairobi-Mombasa line from Kahe, 17 miles south of Moshi, to Voi. The southern end of the Arusha-Tanga line is connected to Dar-es-Salaam at a junction 40 miles from Tanga.

A main road runs down the eastern side of the basin from Himo on the Arusha-Moshi-Mombasa road in the north, to Korogwe and Tanga. Access elsewhere in the basin is by secondary roads and tracks which are often impassable for one or two days after heavy rain. A single track of very low standard parallels the river on

the right bank. The river may be crossed at the Nyumba ya Mungu dam and at Toronto.

A scheduled air service calls at Tanga, Moshi and Arusha, and airstrips suitable for light aircraft, and as emergency landing grounds for others, are maintained at Engare Nairobi, Same, Mombo and Makanya.

(b) The Wami basin

The only two townships of major significance, Dodoma and Kilosa, are linked by the central railway line which runs from Dar-es-Salaam to Kigoma.

There is a network of reasonable main roads but the system of feeder roads is inadequate and of a low standard.

5. Land Use and the People

(a) The Pangani river basin

Of the total area of 12 000 square miles it is estimated that some 9 000 square miles are suitable for grazing and as game reserves only. Most of the grazing lies in the west of the basin and is used by the pastoralists Masai. Of the remaining 3 000 square miles, some 450 square miles or 288 000 acres, are taken up by estate agriculture in which sisal, coffee, tea, cereals and sugar are major crops. About 450 000 acres are occupied by forest reserves. Small holdings cultivated by the local people occupy the remaining utilizable land, estimated to be about 1.5 million acres. There is a strong element of cash crop production in the farming of the local people, particularly in the Kilimanjaro area and coffee and cotton are grown as major export crops in addition to food crops.

It is estimated that some form of irrigation agriculture is practised over nearly 320 000 acres on the southern slopes of Kilimanjaro and Meru, and in the Mkomazi valley. Apart from the highly skilled irrigation farming carried out on some of the estates, the local people in the mountain areas have practised primitive irrigation, using furrows, over many decades, and more recently in various localities in the low areas.

A wide range of crops are grown by the local people and reflect the considerable variation in environmental conditions. On the mountain slopes the main crops include coffee, bananas, maize, elusine, beans and a variety of vegetables including considerable tonnages of onions. On the lower plains common crops are maize, cotton, cassava, sweet potatoes and beans, with minor garden

planting of vegetables. In some of the valleys where irrigation is available such as southwest of Same, in parts of the Mkomazi valley, and in limited areas around Kahe, rice is cultivated.

The total population of the basin is approximately 1.1 million people, and it is made up of some ten different tribes. Although customs, habits and language vary, swahili is understood almost everywhere. Numerically the Wa Chagga are the most important, and together with the Wa Pare and Wa Kahe, are most directly concerned with the areas proposed for irrigation development. The intensive cash crop production, particularly in the Kilimanjaro area, has resulted in a relatively high standard of living. This is being threatened by the rapid growth in population as the system of inheritance leads to fragmentation of holdings, and employment opportunities in the urban areas are inadequate to satisfy the needs of the younger generation. Tribal affiliation, family ties, health conditions and personal attachment to the environment are the main barriers to population movement.

Chapter VIII of this volume describes in more detail the sociological conditions, and Chapter IX the current land use, in the areas selected for irrigation development. These areas, Kahe and Miwaleni upland in the headwaters region, and Naururu and Marwa in the middle region of the Pangani, were selected following investigation of a number of possible areas suggested by earlier surveys, particularly those contained in the report by Sir William Halcrow and Partners, 1962.

(b) The Wami river basin

Land use is much less intensive than in the Pangani basin, with large areas of the basin uninhabited and others only extensively grazed by cattle of pastoral tribes. The presence of tsetse fly in the central alluvial plain, along the escarpment and in the coastal plain, is a limiting factor to grazing development. Estate agriculture is more restricted than in the Pangani basin and is largely confined to sisal production along the railway line in the central alluvial plain. Small scale subsistence farming is carried on in various localities, particularly around Dodoma on the western plateau and on the southern foothills of the Rubeho and Nguru mountains.

There are several tribes dominated numerically by the Wagogo, who provide one quarter of the total population of some 400 000 people living in the basin. The Wagogo, on the western plateau, and the Masai are pastoralists. The other major tribal groups, the Wasangara, Wa Kagura and the Wa Nguru, live on the mountain slopes and obtain their livelihood by cultivation.

An early appraisal suggested that the coastal plain offered the best opportunity for irrigation development. Following on from further investigation a very sparsely populated area was proposed for irrigation development. The few inhabitants of this area are dependent on subsistence farming, fishing, or wages from the railway, sisal estates, and the Salt Works. A more detailed description of the area proposal for irrigation development is given in Chapter IX.

6. Health

Bilharziasis is the principal medical problem associated with irrigation development. Transmission of *S. mansoni* and *S. haematobium* exists in the Pangani basin and of the latter only in the Wami area. The vector snail of the intestinal form, *B. pfeifferi*, is present around the scheme in the lower Moshi area, and its prolific breeding under irrigation development is well known.

In the whole of both river basins, malaria is endemic, and the spread of malaria in new irrigation areas could constitute a real danger. Many of the settlers on new irrigation areas are likely to be relatively non-immune individuals from the mountains where malaria is absent.

Amoebiasis and nematodes are also prevalent and steps will need to be taken to prevent the situation deteriorating under irrigation.

Currently no human trypanosomiasis has been recorded, but in the Wami basin where tsetse densities are high and the more important *Glossina brevipalpis* is present, human trypanosomiasis could be transmitted, should cases be imported.

Although the nutritional status in the lower Moshi area is better than in the rest of the country, it is unsatisfactory in the Wami region - especially in protein consumption - and the population would certainly benefit from changes induced by irrigation, both by diversified cropping and higher food production and by higher per capita income.

CHAPTER IV

SOIL SURVEYS AND SUITABILITY FOR IRRIGATION

1. General Introduction

Between June 1964 and December 1966 soil surveys were carried out at different levels in parts of the two basins. A number of the areas to be surveyed had already been selected prior to the start of the project. In addition, broad reconnaissance and exploratory surveys were carried out during the life of the project to identify areas for further study. The location of the soil surveys is shown in Figure 3. Table 1 lists the different areas in which the surveys were conducted, together with the acreages and levels of the surveys.

The surveys were directly concerned with suitability for irrigation, and the soils were grouped according to the irrigation classes established by the United States Department of Interior, Bureau of Reclamation. The irrigation classes are briefly defined as follows:

- Class I - Land highly suitable for irrigation farming.
- Class II - Land moderately suitable for irrigation farming.
- Class III - Marginal land of fair suitability for irrigation farming.
- Class IV - Not irrigable, except under special conditions.
- Class V - Undetermined suitability for irrigation.
- Class VI - Non-arable land which cannot meet the minimum requirements of other classes.

Table 1: Areas of Soil Surveys Giving Acreages and Level of Survey

Areas	Reconnais- sance Soil Survey Acreage	Semi- detailed Soil Survey Acreage	Detailed Soil Sur- vey Acreage	Other Soil Sur- vey Acreage	Observations and Level of Survey
<u>Pangani Headwaters Region</u>					
Miwaleni	-	28 138	1 500	-	-
Kahe	-	39 506	1 727	40 000	General exploratory survey followed by semidetailed and detailed surveys.
<u>Middle Pangani Region</u>					
Marwa	-	-	-	15 286	Check survey.
Naururu.....	-	15 220	739	-	Semidetailed and detailed.
Ngage	-	39 950	-	40 000	Exploratory and semidetailed.
Hedaru	-	36 120	-	60 000	Broad reconnaissance and semidetailed.
<u>Wami Coastal Plain</u>	121 500	-	-	-	Intensive reconnais- sance.
<u>Miscellaneous</u>					
Upper Miwaleni ...	-	-	-	2 000	Broad reconnaissance.
Kileo	-	-	496	-	Detailed by Govern- ment request.
Mvungwe	-	-	-	?	General exploratory.
Ngage-Remiti	-	-	-	?	ditto
Buiko	-	-	-	?	ditto
Lake Manka	-	-	-	?	ditto
Mkomazi valley ...	-	-	-	3 000	Broad reconnaissance.
Lwengera valley ..	-	-	-	2 000	ditto
Lower Pangani	-	-	-	?	General exploratory.
Central Wami	-	-	-	?	ditto

2. Summary of Findings in Pangani Headwater Region

This section covers investigations carried out in the area above the Nyumba ya Mungu dam, and includes areas located between the Pangani river and its tributaries, the Kikuletwa, Rau, Mue and Soko rivers. The location and level of the surveys are shown in Figure 4.

(a) Miwaleni springs

A semidetained survey of 28 138 acres was carried out around and below the Miwaleni springs. The object was to ascertain the amount, nature, and distribution of the soils and to determine their suitability for irrigation agriculture with water derived from the springs. The area investigated included land lying to the north and east of the springs beyond command, as well as extensive areas to the south under command.

Much of the land under command between the Rau and the Mue rivers has salinity and alkalinity problems, and these problems increase in intensity southwards. A detailed soil survey carried out on 1 500 acres immediately south of the springs further confirmed this.

In all, some 12 500 acres of Class I land were mapped. Most of this land suitable for irrigation is on the alluvial slopes above command of the springs and water must be obtained either by pumping from the springs or from boreholes. The good irrigation land under command is restricted to narrow strips along the rivers and in the Kahe Forest Reserve, together with small scattered pockets.

Some 10 116 acres are completely unsuitable for irrigation due mainly to serious salinity and alkalinity problems. Adverse topography, flooding, shallowness and rockiness are additional inhibiting factors.

The remainder of the area includes only 710 acres of Class II land of moderate suitability for irrigation, and 4 713 acres of Class III land of fair or marginal suitability.

The distribution of land according to irrigation classes is shown in Figure 5.

Within the land classified, at semidetained level, as suitable for irrigation agriculture above gravity command of the Miwaleni springs, an area was selected for irrigation development.

The ground slope of the area is fairly steep, varying from 1:700 immediately above the springs to 1:100 on the northern edge of the area selected.

The soils are developed on alluvial material of volcanic origin. They are usually a dark reddish brown, and are of a heavy clay texture. When wet they become very sticky and plastic. Strong, medium granular surface structures are usual, with variations in the structural development of the subsoil. Deep cracking is prevalent during the dry season. Located on sloping land above the springs, the soils are free from flooding during the rains.

The pH is usually less than 8.5. Excess salinity occurs in localized areas, and requires corrective measures. Drainage, which is essential, is not expected to be a serious problem. On the whole the investigations show a reasonably productive soil, although further investigations are required to locate the saline areas and to define the remedial measures required.

(b) Kahe

A semidetalled survey was carried out over 39 500 acres in the Kahe area, and a total area of some 25 000 acres was considered suitable for irrigation development. The bulk of the remaining land was unsuitable because of excessively high salinity and alkalinity. The distribution of land according to irrigation classes is shown in Figure 6.

The soils in the area selected for irrigation development are developed in old alluvial-colluvial materials derived originally from the Kilimanjaro volcanics. They are mainly deep, well drained and permeable silt loams and clay loams of a weak structure, and are highly calcareous below 30 inches. There are however, irregular inclusions of shallow soils overlying gravels, cemented gravels and rocks. Drainage of these shallow soils under irrigation will depend upon the nature of the underlying gravels and their depth above slowly permeable material. The pH of the surface soil is generally high, above 7, and increases in depth in the subsoil. The values of electrical conductivity in the surface soils is not, in the main high, but in the subsoils it indicates varying degrees of salinity, and care is required to ensure that the water table, which is currently at a safe level, does not rise to the rooting zone under irrigation.

In general the soils are suitable for irrigation but a detailed soil survey of the whole area is required to locate the shallow inclusions, and to delineate areas of high salinity, before full development takes place.

3. Summary of Findings in the Middle Pangani Region

This section covers surveys carried out in the area extending from the Nyumba ya Mungu dam to the vicinity of Korogwe, and includes the areas influenced by the Pangani river and its tributaries, the Mkomazi and Lwengera. The location and levels of the survey are shown in Figure 7.

(a) Naururu

In general the soils in the central Pangani region are beset with problems including high salinity, high alkalinity, poor drainage, inclusions of shallow soils, and seasonal flooding although the construction of the Nyumba ya Mungu dam will now have controlled serious flooding. A reconnaissance survey of 230 000

acres carried out by FAO in 1957 in the Same district of the Pangani valley, revealed no Class I irrigation land, and less than 2 percent of the area reconnoitered was classed as moderately suitable for irrigation agriculture.

During the current investigations a semidetailed soil survey was carried out over some 15 000 acres, including all of the soils classed as moderately suitable for irrigation in the earlier reconnaissance by FAO. At this semidetailed level some 4 600 acres, or 30 percent of the area surveyed, was classed as suitable for sustained irrigation. This area contains, however, some inclusions of poor, and nonagricultural land, which will require a detailed soil survey to locate. These inclusions are occasionally saline/alkaline patches, but more frequently shallow phases of the soils mapped, overlying a calcareous hardpan. The fine texture of some of the soils requires special consideration of drainage.

A detailed soil survey, carried out over some 700 acres in the area proposed for a pilot scheme, further revealed the intricacy of the soil pattern, and although the selected soils are suitable for irrigation, crops and grasses adapted to salinity/alkalinity are recommended for investigation. These include cotton, rice, maize, sugar cane, and various vegetables in the deeper soils. The distribution of land according to irrigation class is shown in Figure 8.

(b) Marwa

The area is in the central Pangani region, about ten miles north of the proposed Naururu irrigation development area. It lies on rising ground to the east of the river from which it is separated by a highly alkaline and saline floodplain which varies from one to two and a half miles in width.

Previous surveys carried out in this area by FAO in 1957, and by Hunting Technical Services in 1961, failed to reveal any Class I or II soils. A broad check survey of the area covered by these earlier studies gave similar results, and the area proposed for development consists of some 9 300 acres of Class III soils, or soils of marginal suitability for irrigation.

Within the area selected for development neither salinity nor drainage are likely to present serious problems. The main difficulties lie in the steepness of the slopes, and the coarse texture of the soils. For these reasons Sir William Halcrow and Partners concluded that overhead irrigation would be necessary, and this conclusion is fully supported.

(c) Ngage

Some 39 950 acres were mapped, at semidetailed level, on the opposite bank to Naururu. Class II land amounted to 5 970 acres, and Class III to 14 450 acres. These irrigable soils do not occur in large blocks but are distributed in irregular areas on the floodplain.

The area is beset by problems related to development, especially high salinity and alkalinity, poor drainage, seasonal flooding, topographical limitations and an especially rich fauna that could be both destructive and dangerous.

(d) Hedaru

Following a brief reconnaissance 36 120 acres were investigated at semidetalled level. Of this some 9 370 acres of Class II land moderately suitable for irrigation were mapped. Fair or marginal lands account for 4 760 acres and 15 550 acres were separated into Class V as worthy of future investigations.

Unfortunately the area has a variety of problems relating to the economics of applying water, viz. length of canals, salinity and/or alkalinity and the inclusions of shallow soils. Much of the area can be eliminated on the basis of adverse topography and rockiness.

4. Summary of Findings in the Wami Coastal Plain

The area is bounded on the east by the coast line, and in the west by the Dar-es-Salaam to Tanga railway except on the Wami floodplain where surveys were extended upstream. The northern and southern boundaries are approximately the edges of the Wami river basin, although in the south the boundary is abrupt due to the drainage complexity of the area, and corresponds to a line marking the first tributaries draining into the Ruvu. The survey was based on aerial photographs with some ground control. In the north traverses were made every 1-2 miles for augering and inspection. In the south due to the difficulties of making direct traverses, ground control was more scattered. The location of this reconnaissance survey is shown on Figure 9.

The general area within which the area selected for development is proposed, is divided into two clearly distinguishable parts. These are the alluvial flats which comprise the old floodplain on both sides of the Wami river, and the higher shelf level of old sandy beach lines, clay flats and alluvial deposits, which slopes gently seawards. The Wami river cuts its way through this higher shelf, which may be regarded as the coastal plain proper, on its way to the sea.

The alluvial flats along the river are subject to annual flooding, especially in the lower reaches. Upstream, to the west, the flats are channelled by many old drainage lines, running roughly parallel to the river and marking former river courses. With such natural drainage lines and a gentle slope to the east, the western floodplain is inundated for shorter periods than the graded flats near the coast. The salinity influence of the coastal accumulation of salts extends inland into parts of the floodplain, in the groundwater. The precise boundaries of these transition areas have not been determined.

TANZANIA

Figure 9

LOCATION OF SOIL SURVEY IN THE WAMI COAST REGION

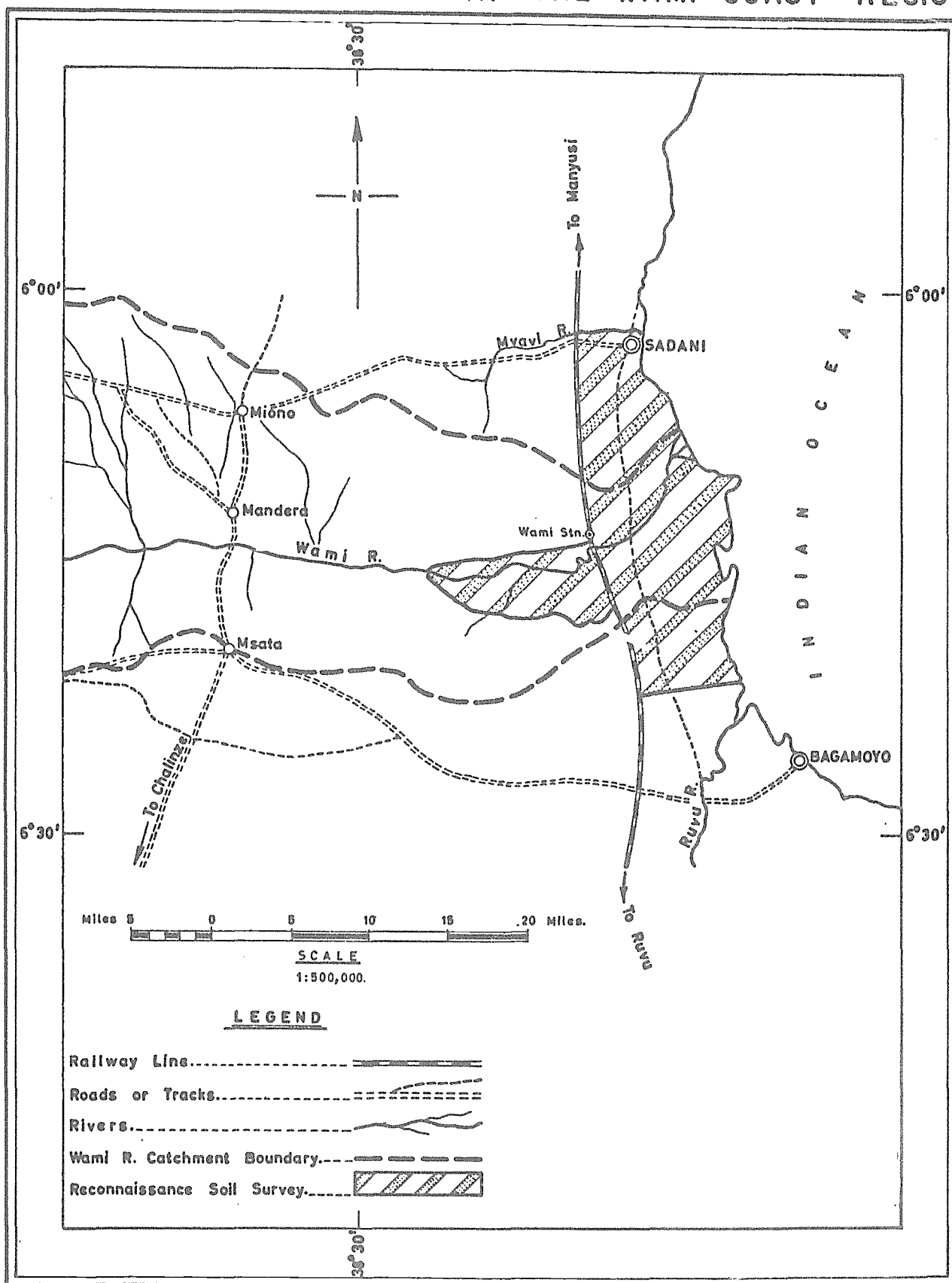
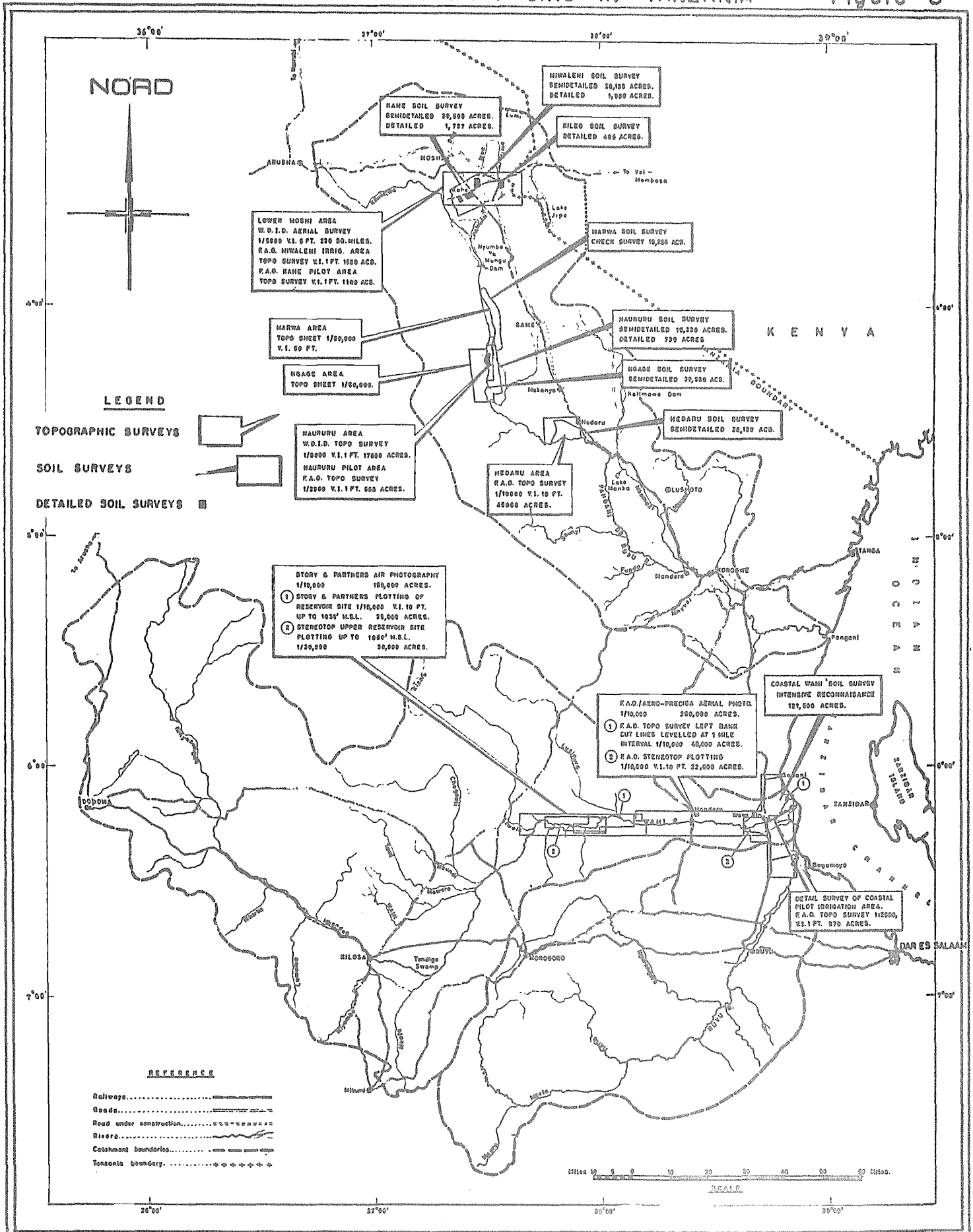


Figure 3



An escarpment of varying height and irregularity separates this alluvial floodplain from the higher coastal shelf, or coastal plain proper. This higher land is flooded in the wet season by accumulating water from the high, dissected land to the west.

A cross-section of the northern coastal plain shows generally high dissected land in the west, with long, low, regular, pedimentary outwash slopes below. These are partially dissected by narrow drainage lines that are dry most of the year, and occur at intervals usually greater than one mile, so that large, flattish areas are common. Below these colluvial slopes, the broad flat grassy, mainly black clay plain, extends eastward towards the coast, dominated by the recent sandy marine accumulation.

On the southern coastal plain the black clay flats are absent, or very local, and the topography is dominated by the regular slopes of the calcareous marine deposits, overlain by colluvial sands, and the discontinuous eroded remnants of old beach lines which mark higher, former sea levels.

During the survey the soils were classified according to the potential available after problems of flooding, drainage, irregular topography, forest density and low fertility have been brought under control.

The reconnaissance survey over 121 500 acres revealed an extensive area of land with good potential for irrigation. No less than 15 760 acres of Class I land and 41 720 acres of Class II land were mapped. A further 36 360 acres of fair or marginal land are available. Soils now included within Class V could be reclassified after forest clearance and further investigation.

The problems to irrigation development in the area relate mainly to the following:

- (i) Flooding. Floods are produced by overflow from the Wami river in the wet season and mainly cover the alluvial flats of the old floodplain. The northern coastal plain also floods, partly due to discharge from the hilly area west of the railway through numerous distributaries.
- (ii) Drainage. Many of the soils are of a heavy texture with associated poor internal drainage and are located in depressions.
- (iii) Topography. The topography is variable and occasionally irregular necessitating levelling in most areas.
- (iv) Bush and Forest Density. Much of the southern coastal plain and the alluvial plain is covered by dense bush.
- (v) Salinity. No serious problems are evident and saline soils are mainly confined to the nonagricultural "saline" and "seaside" complexes. High pH is usually coincident with calcium carbonate as either nodules, concretions or segregations within the profile. Careful water management is nevertheless necessary to avoid salinity problems developing on the heavy textured soils and clay flat inclusions, near the coast.
- (vi) Low fertility. No information is available on fertility levels. Experience with similar soils, under similar climatic conditions, suggest that those with sandy and medium textures may have a very low fertility level requiring heavy fertilization to produce good crops. The heavier soils are not so degraded and have a higher base content and better potential fertility.

Table 2: Summary of Areas Surveyed in the Pangani and Wami Basins Giving Irrigation Classes and Acreages

Irriga- tion Classes	Pangani Headwaters Region				Middle Pangani Region						Wami Coastal Plain		Total	
	Miwaleni acreage	%	Kahe acreage	%	Naururu acreage	%	Ngage acreage	%	Hedaru acreage	%	acreage	%	acreage	%
Class I	12 599	44.77	25 536	64.74	-	-	-	-	-	-	15 760	12.97	53 895	19.22
Class II	710	2.52	300	0.76	4 600	30.22	5 970	14.94	9 370	25.94	41 720	34.34	62 670	22.35
Class III	4 713	16.75	2 740	6.94	-	-	14 450	36.17	4 760	13.18	36 360	29.92	63 023	22.47
Class IV	2 190	7.78	70	0.17	9 420	61.89	8 890	22.25	2 450	6.78	-	-	23 020	8.21
Class V	1 005	3.57	10 150	25.69	1 200	7.88	4 160	10.41	15 550	43.05	4 530	3.73	36 595	13.05
Class VI	6 921	24.60	710	1.80	-	-	6 480	16.22	3 990	11.05	23 130	19.04	41 231	14.70
Total	28 138		39 506		15 220		39 950		36 120		121 500		280 434	

From these figures it can be seen that:

- (i) Approximately 64 percent of the total area surveyed or about 180 000 acres are included in the first three classes which are regarded as suitable for irrigation agriculture.
- (ii) Of this, 116 500 acres are in Classes I and II (highly suitable and moderately suitable) or 41.5 percent of the total. Some 63 000 acres or 22.5 percent of the area are Class III of fair and marginal suitability.
- (iii) To this irrigable land should be added 9 000 acres of Class III marginal land at Marwa (Middle Pangani) and suitable land in the Mkomazi valley, Lwengera valley, Ruvu basin and especially in the Central Wami where regular surveys were not carried out.

CHAPTER V

CLIMATOLOGY AND HYDROLOGY

1. Climatological and Hydrological Data

Climatological and hydrological data are essential in planning for irrigation development. The responsibility for the collection and publication of climatological data rests primarily with the East African Meteorological Department. This department operates a number of meteorological stations and, in addition, collects data from stations operated by other agencies, both Government controlled and private. The collection, processing and publication of hydrological data is almost exclusively carried out by the Water Development and Irrigation Department through the Hydrology Section.

The distribution of meteorological stations naturally reflects population densities and the degree of agricultural development, and is closely tied to communications and access. For the purpose of the Pangani/Wami Project this does not pose serious problems in the initial stages of development, as the current development areas are fairly close to present recording stations. As the work advances, however, it will be advisable to establish full meteorological stations in all future irrigation areas as and when they are identified.

In the Pangani basin there are six stations with a reasonable scale of meteorological equipment, and three in the Wami basin. In both river basins there are many more stations recording rainfall and temperature. In addition, the Dar-es-Salaam meteorological station gives a good representation of most climatological elements in the coastal plains of the two rivers.

There are more than 90 rainfall stations in the Pangani basin and over 60 in the Wami basin. Only 20 approximately were used as key stations because of the short periods over which records were available or because of the unreliability of many of the records for the rest of the stations. There is a definite need for autographic recorders particularly to obtain data on high intensity rainfall over short periods.

The Pangani and Wami river basins have received considerably more attention than any other region in Tanzania in recent years. As a result, the hydrological data available from a number of key stations are of a satisfactory level of reliability, not only for preliminary planning but also for project operational purposes.

Streamflow records have been maintained in the Pangani basin since the early forties, but recordings in the Wami were not started until about 1950.

2. Climatology of the River Basins

(a) Seasons

The seasons of the East African climate are controlled by the northward and southward movement of the sun. The area of greatest heating due to solar energy, referred to as the Heat Trough, experiences low atmospheric pressure. The movement of the Heat Trough, or low pressure centre, follows the sun with a lag of about four to six weeks behind the time of the sun's maximum elevation.

The sun is approximately overhead in Tanzania in early March and mid-October, so that the Heat Trough can be expected to have maximum effect about early April and mid-November. This trough of low pressure in the region produces a general movement of air mass from the surrounding high pressure belts. The result is a zone of convergence causing vertical upward movement of the air, condensation and precipitation. This continues from March to May causing the long rains, and from November to December with the short rains.

(b) Rainfall

On the coast, the mean annual rainfall occurs in two distinct seasons and is in the order of 40 inches. As the distance inland increases the rainfall decreases. Local topography produces considerable changes in the general pattern. A most noticeable variation is the merging of the two distinct rainfall seasons west of longitude 7°20'. In the mountainous areas of Kilimanjaro, the Pares, Usambara, Nguro and Rubeho, the rainfall pattern is ill-defined. The highest mean annual rainfall experienced in some parts of the mountain slopes is as high as 80 inches.

Rainfall distribution maps were compiled for the Pangani basin showing the pattern of the mean annual rainfall and the probable pattern once in every five and ten years. These showed that on the average the Pangani basin receives rainfall in excess of 30 inches on 30 percent of the total area of the basin. Once in every five years only 12 percent of the total area of the basin may receive rainfall in excess of 30 inches, and once in ten years this may be reduced further to 7 percent of the total area.

Populations are concentrated in the areas of high rainfall. Areas which receive a mean annual rainfall in excess of 30 inches generally contain a population in excess of 200 people per square mile. Where the mean annual rainfall ranges between 20-30 inches the population density is lower and varies between 75-200 per square mile. Below 20 inches the population density falls rapidly and may be less than 5 per square mile in areas receiving less than 15 inches.

Rainfall distribution maps for the Pangani basin showing the general pattern of mean annual rainfall and the probable pattern once in every five and ten years (20 percent and 10 percent probability), are shown in Figures 10, 11 and 12. Monthly distribution at selected stations are also given in Figure 10.

Similar rainfall distribution maps for the Wami basin were not prepared but it is anticipated that conditions will approximate to those in the Pangani. Mean monthly rainfall at selected sites in the Pangani and Wami basin is given in the following table.

Table 3: Mean Monthly Rainfall at Selected Sites (in Inches)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct.	Nov	Dec	Year
<u>Pangani basin</u>													
Kahe	1.30	0.89	1.68	3.63	2.56	0.16	0.28	0.12	0.32	0.64	1.14	1.22	13.94
Miwaleni	1.43	0.98	1.85	3.99	2.82	0.18	0.30	0.15	0.35	0.70	1.26	1.33	15.34
<u>Wami basin</u>													
Bagamoyo	2.65	2.60	4.33	10.17	8.85	1.54	1.01	1.47	1.34	2.24	3.29	4.33	43.82
Mandera	2.88	3.20	5.12	8.25	6.07	1.04	0.66	0.96	1.18	2.51	3.19	2.86	37.92
Morogoro	3.52	3.92	6.22	8.02	4.06	0.84	0.55	0.45	0.58	1.28	2.38	3.40	35.22
Dodoma	5.86	4.60	4.86	2.12	0.24	0.08	0	0	0	0.22	0.93	4.11	23.02

There are few stations equipped with automatic rainfall, gauges, and the instruments currently operating have only a short period of record. For this reason few records of rainfall intensity for periods of less than one day are available. Daily rainfall data are available from a large number of stations and records often cover a considerable number of years. The following data represent the maximum rainfalls in Dar-es-Salaam during a 40-year period of record:

<u>Duration</u>	<u>Total rainfall</u>
1 day	8.50 inches
2 days	10.10 "
3 days	10.89 "
4 days	13.06 "
5 days	16.55 "

Dar-es-Salaam may be regarded as representative of the coastal plains of both basins.

(c) Temperature, relative humidity, sunshine and evaporation

(i) Temperature, relative humidity and sunshine

Data for temperature, relative humidity, and sunshine for the lower Moshi areas, and for the coastal areas of the Wami, are presented in Table 4. In both areas it was necessary to combine data from a number of different stations to provide adequate information.

(ii) Evaporation

Evaporation losses from free water surfaces were computed from meteorological data obtained in the Wami coastal plain and the Pangani headwaters using Penman's formula. The evaporation losses are shown in Table 5. This table shows the computed evaporation, using Penman's formula, together with evaporation losses from a standard 'A' evaporation pan.

The climatological data collected during the project, in conjunction with tentatively proposed cropping patterns, provided a basis for determination of evapotranspiration and water requirements for irrigation projects.

Table 4: Summarized Climatological Data for the Lower Moshi Area of the Pangani and the Coastal Area of the Wami

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
<u>Lower Moshi Area</u>												
Mean temperature (°C)	25.3	25.5	25.5	24.3	22.6	21.3	20.7	21.1	22.2	23.8	24.7	24.8
Mean relative humidity (%)	65.8	62.3	65.4	74.1	71.4	65.2	63.7	64.3	62.4	61.7	63.3	63.6
Mean sunshine (hours)	273	255	239	204	146	153	136	171	207	248	237	257
<u>Wami coastal plain</u>												
Mean temperature (°C)	27.4	27.8	27.1	25.6	25.4	24.6	24.9	24.8	23.5	25.8	27.8	27.8
Mean relative humidity (%)	80.5	77.0	80.3	81.5	81.3	81.4	81.0	80.6	75.4	75.0	74.4	76.2
Mean sunshine (hours)	216	223	177	124	207	215	216	246	235	266	264	246

Table 5: Evaporation Losses (Expressed in Inches per Month Computed with Penman's Formula and Measured from Evaporation Pans)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
<u>Pangani</u>													
Evaporation pan	11.5	8.6	9.4	6.7	8.1	6.8	5.3	7.4	7.3	8.9	7.7	10.4	108.1
Penman's formula	7.5	6.6	7.4	6.6	6.9	5.5	4.2	5.3	5.3	5.7	5.9	7.1	73.0
<u>Coastal plains</u>													
Evaporation pan	7.7	8.7	6.4	4.6	4.7	4.4	6.0	5.1	6.1	7.5	8.2	7.0	76.4
Penman's formula	6.3	6.2	5.3	4.4	5.1	4.6	4.6	5.3	5.7	4.6	7.2	6.7	66.2

3. Hydrology

(a) General

In 1961, Sir William Halcrow and Partners were commissioned to formulate a comprehensive plan for the development of water resources in the Pangani valley, and particularly to prepare plans, specifications and estimates for a storage dam at Nyumba ya Mungu to impound about 900 000 acre feet. In their report of 1962, Sir William Halcrow and Partners recorded their extensive studies of the water resources and in March 1966 produced a supplement updating the hydrology of the Pangani to the end of 1964. Their report concluded that the construction of the dam would make available for irrigation development some 233 000 acre feet of water after meeting the requirements of existing users, including hydroelectric power. In the Pangani valley headwaters perennial springs previously unavailable to irrigation could be wholly diverted for irrigation purposes, while below the dam, controlled releases for irrigation could be guaranteed from storage. In addition to the water made available by the construction of the Nyumba ya Mungu dam, considerable quantities of groundwater reserves have been found in a large aquifer, or aquifers underlying the lower Moshi area. The effect of groundwater abstraction on the flow of the Miwaleni springs will need to be studied however. Hydrological studies carried out by the project were mainly directed towards assembling and analysing data for application to specific areas proposed for further investigation by the Halcrow Report or selected by the project for possible irrigation development. The results of the studies are discussed in subsequent paragraphs in this section.

Unlike the Pangani river basin, the Wami has not been subjected to any detailed investigation and survey until quite recently. The high potential for both agriculture and hydroelectric power development in the river basin, particularly east of the Nguru mountains on the central alluvial plains and down the escarpment, has been recognized for some time but no real interest was generated in this basin until the publication of FAO Report No. 1626 in January 1963.

The Wami is a typical spate-flow, rainfed river system with a low base flow and comparatively heavy peak flow for a short period of the year only. On average some 60 percent of the annual discharge occurs during the three months of March, April and May with peak flows often exceeding the base flow by some fifty to one hundred times. In consequence, extensive areas of the central alluvial and coastal plains are subjected to flooding for several months in the year, severely restricting agricultural development in those areas.

As stated in Chapter I of this volume, an early appraisal of the Wami basin indicated that the area best suited for initial irrigation development was on the coastal plain. Hydrological studies carried out were primarily concerned, therefore, with the provision of data which would assist in assessing the technical and economic feasibility of irrigation development in the Wami coastal plain. These studies are briefly discussed later on in this chapter.

(b) Hydrological studies in the Kahe, Miwaleni and central Pangani areas

The source of water for the Kahe irrigation scheme is the Miwaleni spring. A mean discharge hydrograph was derived by plotting measured discharge against dates of observation. Most discharge measurements were taken between January 1958 and March 1960. For the short period of observation, the base flow of the springs appears to average some 115 cu.ft/s throughout the year and deviates from this value by about ± 5 cu.ft/s. The maximum discharge generally occurs during November-December, and the minimum between April-June, although exceptions to this have been noted. Discharges as low as 106 cu.ft/s have been measured. The discharge flows down a stream into the Mue river.

Using a number of methods which combined climatological data with a tentatively proposed cropping pattern, an estimate of water requirement was made. After allowing for the lining of all canals and distributaries down to, but excluding farm ditches, the overall efficiency of the irrigation system was calculated to be 63 percent. This coupled with a large, unlined reservoir on the lead canal, and a small lined storage pond in the northern section of Kahe, allows for some 8 800 acres to be irrigated.

If mean water requirements are compared with mean discharges from the Miwaleni springs, there is an adequate supply of water in all months. However, to guard against the coincidence of a number of adverse conditions, it was considered necessary to supplement the water supply for the irrigation scheme by the inclusion of a series of boreholes in the proposed layout. In addition, the development of the irrigation area known as the Miwaleni upland area, north of the Miwaleni springs and above command, is entirely dependent on borehole water. Preliminary hydrogeological surveys were carried out to investigate the effect of borehole abstraction on the discharge from the springs, but the results were inconclusive and considerably more investigation is required before this can be determined. The extension of irrigation in the Miwaleni upland area will be partly dependent on the effect the extraction of groundwater has on spring flow.

In the 1962 Halcrow Report various areas were proposed as possible irrigation development sites. The areas proposed were examined and two, Naururu and Marwa, recommended for development using water from the Pangani river. A third proposal to develop irrigation in the lower Mkomazi valley requires detailed soil and topographical surveys to determine the extent of irrigable lands. It is suggested that this development, based on the partial diversion of the Pangani into the Mkomazi valley at Buiko, should be delayed until full control of the waters in the middle and upper Mkomazi is effected. It is thought that this will take up to 15 to 20 years. A summary of water requirements for irrigation development in the Pangani river basin is given in the table below.

Thus out of 233 000 acre feet available for irrigation development in the Pangani basin, 179 000 acre feet can be used by the above listed projects, and of these 130 000 acre feet are likely to be used in the next 15 to 20 years. Of the remaining 50 000 acre feet some 30 000 acre feet will be available for industrial development and normal expansion of private irrigation schemes in the Arusha and Moshi area, and 20 000 acre feet for power or future expansion of irrigation development.

Table 6: Summary of Water Requirement for Irrigation Development in the Pangani River Basin (in acre feet)

Miwaleni upland area	14 000
Kahe irrigation area	60 000
Naururu irrigation scheme	20 000
Marwa pump irrigation scheme	36 000
	Total
Mkomazi valley - Buiko diversion	130 000
	49 000
Total irrigation abstraction	179 000

(c) Hydrological studies in the Wami river basin

Streamflow records were available from 1953 in the case of the Dakwa gauging station on the central alluvial plain, and from 1954 in the case of the Mandera station on the coastal plain, below the confluence of the Lukigura river.

As stated earlier, the flow of the Wami is characterized by wide variation, both seasonally and annually. Maximum and minimum monthly flows for the month of January, as recorded at Mandera, were approximately 858 534 acre feet in 1962 and 6 264 acre feet in 1961. Annual discharges over the 10 year period of record varied from 616 000 acre feet to 3 275 000 acre feet. The annual discharge at the Mandera station is given in Table 7, and the monthly and annual discharges in Appendix III.

Table 7: River Wami Annual Discharge in Acre Feet at Mandera Gauging Station

	1954/55	55/56	56/57	57/58	58/59	59/60	60/61	61/62	62/63	63/64
Mean annual flow in 1 000 ac.ft.	892	1 122	1 665	1 207	660	1 074	616	3 275	1 590	2 343

Based on the flow figures for the 10 year period 1954-64, the floods that occurred in 1961 would appear to have a recurrence interval of between 12 to 18 years. The maximum recorded flow used for the rating curve was 27 000 cu.ft/s, but this is almost certain to have been exceeded outside of the observation times. A flood mark said to have occurred at the same period in 1961 would correspond to about 57 000 cu.ft/s on the extrapolated rating curve.

To provide an acceptable degree of regulation to meet irrigation, power development and flood control requirements, it is estimated that an impounding capacity of 1.5 million acre feet is required above the coastal plain.

Records of silt load in the Wami river have been made at Mandera in August 1965 and in May 1966. The indications are that the silt load is comparatively low. At a flow of 1 300 cu.ft/s the silt load was approximately 50 tons per day, and at 4 000 cu.ft/s, 700 tons per day. Based on the records the estimated annual silt burden would be about 150 000 tons or approximately 100 acre feet volume. If a flood control dam should be constructed as proposed in Chapter VI, most of the silt would settle in the reservoir created on the river. At the proposed capacity of 1.5 million acre feet, this would appear to be insignificant.

To ensure that the silt load has not been underestimated, more recordings should be taken, particularly during periods of high discharge.

CHAPTER VI

WATER CONTROL AND USAGE

1. Background and Present Situation

(a) Pangani river basin

The waters of the Pangani river basin are used more intensively for irrigation and power development than those of any other river system in Tanzania. In the headwaters of the Pangani, on the slopes of Mount Meru and Mount Kilimanjaro, a considerable quantity of water is abstracted annually. Even so, a large quantity averaging annually above 900 000 acre feet, flow down the river and is regulated by the Nyumba ya Mungu dam.

Below the Nyumba ya Mungu dam several small irrigation areas take water from the Pangani. The largest of these areas, Naururu, extends to about 1 000 acres. Downstream of the Buiko narrows, in the main Pangani valley, no major irrigation abstraction takes place. Water is used by the Pangani Falls hydroelectric power station, constructed in 1932, and the recently completed Hale hydroelectric power station, sited seven miles upstream of the Pangani Falls station.

The main tributary of the Pangani river is the Mkomazi and irrigation has been practised for many years in the Mkomazi valley. Currently there are seven irrigation areas, totalling some 3 000 acres in this valley.

Before the construction of the Nyumba ya Mungu dam the expansion of irrigation farming was limited for two reasons. Firstly, the lack of storage restricted the area under irrigation to that which could be irrigated from base

flows, and secondly, the demands of the hydroelectric power stations in the lower Pangani had to be met. These demands were laid down in Ordinance No.16 of 1961, often referred to as the Hale Ordinance. Briefly the Ordinance stipulated a flow of not less than 450 cu.ft/s. at the Grand Pangani Falls, and the maintenance of all naturally existing flows up to 700 cu.ft/s. at Hale, the site of the new hydroelectric power station. To safeguard the requirements of irrigation and the hydroelectric power stations, Sir William Halcrow and Partners were commissioned to draw up a comprehensive plan for the development of the Pangani basin and supply the necessary details for the construction of the dam at Nyumba ya Mungu. Work on the dam commenced in 1964, and was completed in 1966.

The construction of the Nyumba ya Mungu dam reservoir eliminated the danger of frequent floods in the central plain of the Pangani river, ensured that the water requirements of the Hale Ordinance would be fulfilled, and made available some 233 000 acre feet of water for irrigation development above or below the dam.

In 1955 a dam was built at Kalimawe in the Mkomazi valley. The dam is sited on a tributary, the Kisiwani river, about 60 miles upstream of the confluence of the Pangani and Mkomazi rivers. This dam, the capacity of which has recently been increased from 15 000 acre feet to 30 000 acre feet, assists in partially controlling the flow of the Mkomazi river. Sited high up in the catchment of the Mkomazi, and upstream of a major tributary, the Sessení, it provides limited flood control in the lower Mkomazi valley.

(b) The Wami river basin

In 1959, a small earth dam was constructed for irrigation at Ikowa on the Majenjeula river, a tributary to the Kinyasungwe. The original capacity was 3 100 acre feet but considerable silting-up subsequently occurred in the reservoir and the small irrigation scheme has not been a success.

Two further small dams were constructed in the western plateau. The first, Hombolo dam, on the Kinyasungwe, was completed in 1956, with a capacity of some 26 500 acre feet. The reservoir has been used for fishing with great success. The second, Dabolo dam, also on the Kinyasungwe, was completed in 1961 with a reservoir capacity of 5 200 acre feet.

Irrigation of small holdings is practised along the river banks in the Lumuma valley and in the Mkondoa valley. The area under such irrigation is small.

2. Water Control and Storage

(a) Pangani river basin

As stated earlier, the construction of the Nyumba ya Mungu dam removed the danger of frequent floods in the central plain of the Pangani, although uncontrolled major tributaries still lead to spillage losses at the hydroelectric power

stations in the lower Pangani, and flooding on the coastal plain. The areas still subject to recurrent flooding are the lower stretches of the Mkomazi valley, parts of the Luengera valley, and the coastal plain.

In their 1962 report, Sir William Halcrow and Partners included a scheme for irrigation development in the lower Mkomazi valley. Additional flow control measures are required before major development in this area can take place. The Water Development and Irrigation Department have selected and surveyed a site for storage upstream of the Kalimawe dam, and put forward proposals for hydroelectric power stations on the three main tributaries of the Mkomazi river, the Hingili, Yongoma, and Sessenii.

Possible irrigation areas in the Luengera valley require either the construction of a dam to control flooding or extensive river canalization and dyking.

As the Plan of Operation called for a programme of irrigation development over the seven years following on from the completion of the project, and as full development and control of the Mkomazi valley may take 15 to 20 years, consideration for irrigation development was largely confined to the headwaters and central reaches of the Pangani river.

(b) Wami river basin

The major areas suitable for possible irrigation development are on the central alluvial and coastal plains. Development of irrigation on the central alluvial plain in the area of the Mkata and Tendigo swamps is dependent on a system of flood control on the Wami river and its tributaries upstream of the plains. In addition, extensive river channel works throughout the area must be carried out to drain the swamp lands before agricultural development can take place.

It is considered that the area best suited to initial irrigation development is on the coastal plain, where an estimated net acreage of 50 000 acres of irrigable soils can be developed from a small diversion and regulating dam. Before any planned agricultural development of the coastal plain can take place however, it will be necessary to control the flood waters. A storage dam is necessary, not only to prevent extensive flooding of the alluvial floodplain but to provide sufficient base flow to irrigate the whole area throughout the year. From the hydrological data available the storage capacity necessary to ensure an acceptable degree of flood control is estimated to be 1.5 million acre feet. The cost of construction of a reservoir of this magnitude cannot be borne by irrigation, and consideration was given to the development of a multipurpose irrigation and power project. The development of hydroelectric power is discussed later on in this Chapter.

Of the alternative dam sites considered, the one immediately downstream of the Wami-Lukigura confluence was found to be the most economic. This is referred to as the upper Pongwe dam site. Before further design can be carried out, however, a thorough site investigation is required. Although indications are that silting-up of the reservoir is unlikely to be significant, additional data are required, especially during flood periods.

River training and dredging works for widening the channel are required in the coastal plain, as power and controlled spill release from the upper Pongwe dam would be in excess of the discharge capacity of the existing channel. The cost of design and construction of the upper Pongwe dam for flood control and power is given in the following table.

Table 8 : Estimate of Cost of Upper Pongwe Dam for Flood Control and Power

Description	Quantity	Unit	Rate (shillings)	Amount (£)
Site clearance and establishment				40 000
Excavation, including removal of top soil over dam area, and excavation of cut-off	800 000	cu.yds	8/-	320 000
Fill to dam embankment	12 130 000	"	15/-	9 097 500
Grouting			L.S.	1 700 000
Spillway and diversion works			L.S.	<u>480 000</u>
				11 597 500
			10% for contingencies	<u>1 159 750</u>
				12 757 250
			10% for design and supervision	<u>1 275 725</u>
			£	14 032 975

3. Proposed Irrigation Use

Of the various areas investigated in the Pangani and Wami basins five are proposed in this report for development in the first stage. Four of these areas are in the Pangani basin and total about 20 000 acres. The fifth area is on the Wami coastal plain and extends over about 50 000 acres. Proposals for the development of these areas are discussed in brief detail in Chapter VII.

During the course of the project a number of other possible irrigation areas in the Pangani river basin were considered and these are discussed briefly here.

(a) Pangani river basin

(i) Marwa right bank

The preliminary investigations revealed that the topography was such that only a very narrow, steeply sloping strip could be brought under economic pump lift. In addition, the terrain was broken making a uniform layout almost impossible. For these reasons, together with obviously high infrastructure costs and sociological problems, no further investigations were carried out.

(ii) Ngage

A semidetalled survey of some 40 000 acres revealed only about 6 000 acres of Class 2 irrigation land, and this was found to be dispersed within the area in irregular shaped blocks. Unsuitable topography limited the development of several thousand acres of Class 3 soils. This area was considered to be unsuitable for irrigation development.

(iii) Hedaru

A preliminary soil reconnaissance indicated that the area might be suitable for irrigation development. Engineering studies were carried out to determine suitable sites for river intake works, canal alignments and pumping station and a semidetalled soil survey extended over 36 120 acres. These studies revealed that the area of land suitable for irrigation under gravity command could not justify the high cost of canal construction, much of which would have to be cut from rock. In addition, the area of suitable irrigable soils which could be brought under pump lift command was inadequate. This area was considered to be unsatisfactory for further investigation.

(iv) The floodplains between Buiko and Mandera

Reconnaissance in the land under command on the floodplains on both banks showed the land to be uniformly saline and alkaline.

(v) Mkomazi river valley

Sir William Halcrow and Partners proposed the development of irrigation in the lower Mkomazi valley using water diverted from the Pangani into the Mkomazi, at Buiko. This proposal was examined. It is considered that more detailed soil and topographical surveys are required before the extent of the areas suitable for irrigation development can be determined. Further, as the lower stretches of the Mkomazi valley are subject to frequent flooding, river control measures are required. It is recommended that the diversion should not take place until full control and development of the waters in the middle and upper Pangani have been completed. In the light of existing knowledge it is estimated that some 50 000 acre feet may be abstracted by the diversion for the irrigation of about 6 000 acres in the lower Mkomazi valley.

Apart from a reconnaissance soil survey on some 3 000 acres no further investigations were carried out in the Mkomazi valley. The Water Development and Irrigation Department are investigating the possibility of several small schemes in the middle and upper reaches.

(vi) Luengera river valley

Possibilities exist for some 2 000 acres of irrigation in this valley but flood control or dyking will be necessary before the area can be developed. Further studies are required.

(vii) The coastal plain

Investigation showed the need for flood water control, or highly expensive river canalization and dyking. In addition, drainage water would need to be extracted by pump.

A proposal that 250 cu.ft/s should be abstracted from the Pangani between the Hale hydroelectric power station tail race and the Pangani Falls hydroelectric power station intake was examined. It was concluded that the area of suitable land was too small to justify the length of lead canal.

4. Water Use in the Pangani River Basin

Estimates for different uses in the Pangani basin are shown in Table 9.

Table 9 : Estimate of Water Use and Loss in the Pangani Basin
(in acre feet)

<u>Irrigation</u>		
Upstream of the Nyumba ya Mungu dam - Kahe and Miwaleni	-	74 000
Downstream of the Nyuma ya Mungu dam - Naururu and Marwa	-	56 000
Future diversion into the Mkomazi valley at Buiko	-	50 100
Total irrigation requirement		180 000
<u>Losses</u>		
Evaporation from the Nyumba ya Mungu reservoir	-	120 000
Evapotranspiration, and seepage along the central Pangani reach	-	135 000
Unregulated flood spills below the Hale power station	-	217 000
Total losses		472 000
<u>Power</u>		
Available at Hale power station site		508 000
Total		1 160 000

Thus it can be seen that the quantity of water required for irrigation is about 180 000 acre feet, for power 508 000 acre feet, and the balance lost in various ways is about 472 000 acre feet. It should be noted however, that the water, after use for power generation at the Hale and Pangani Falls stations, would still be available for irrigation development in the coastal region. However, as already pointed out, the coastal region is subject to flooding and pump drainage is required. Irrigation development in this area would involve expensive engineer works.

5. Hydroelectric Power Development

(a) General

Estimates of water requirements in the Pangani basin (see Table 9), show that of the total usable water nearly three fourths have been allocated to power generation in the overall development of water resources.

In the case of the Wami basin, the cost of the storage dam, which is required to prevent the extensive flooding in the coastal plain and to provide sufficient base flow to irrigate throughout the year, is so high as to make the project uneconomic if built solely for irrigation. If the storage cost in the Wami could be charged to hydropower generation, as in the case of the Pangani basin, it would be a great step forward for the purpose of starting large scale development of irrigation in the Wami basin.

In view of the high allocation of water for power in the Pangani basin, and because of the absolute necessity for power development to precede large scale irrigation development in the Wami basin, consideration was given during the project to various hydroelectric power schemes, although this aspect was not specifically included in the Plan of Operation. The details are contained in the Report, Irrigation and Power Development. Only a summary of the main considerations is given below.

(b) Potential hydroelectric power schemes in the Pangani basin

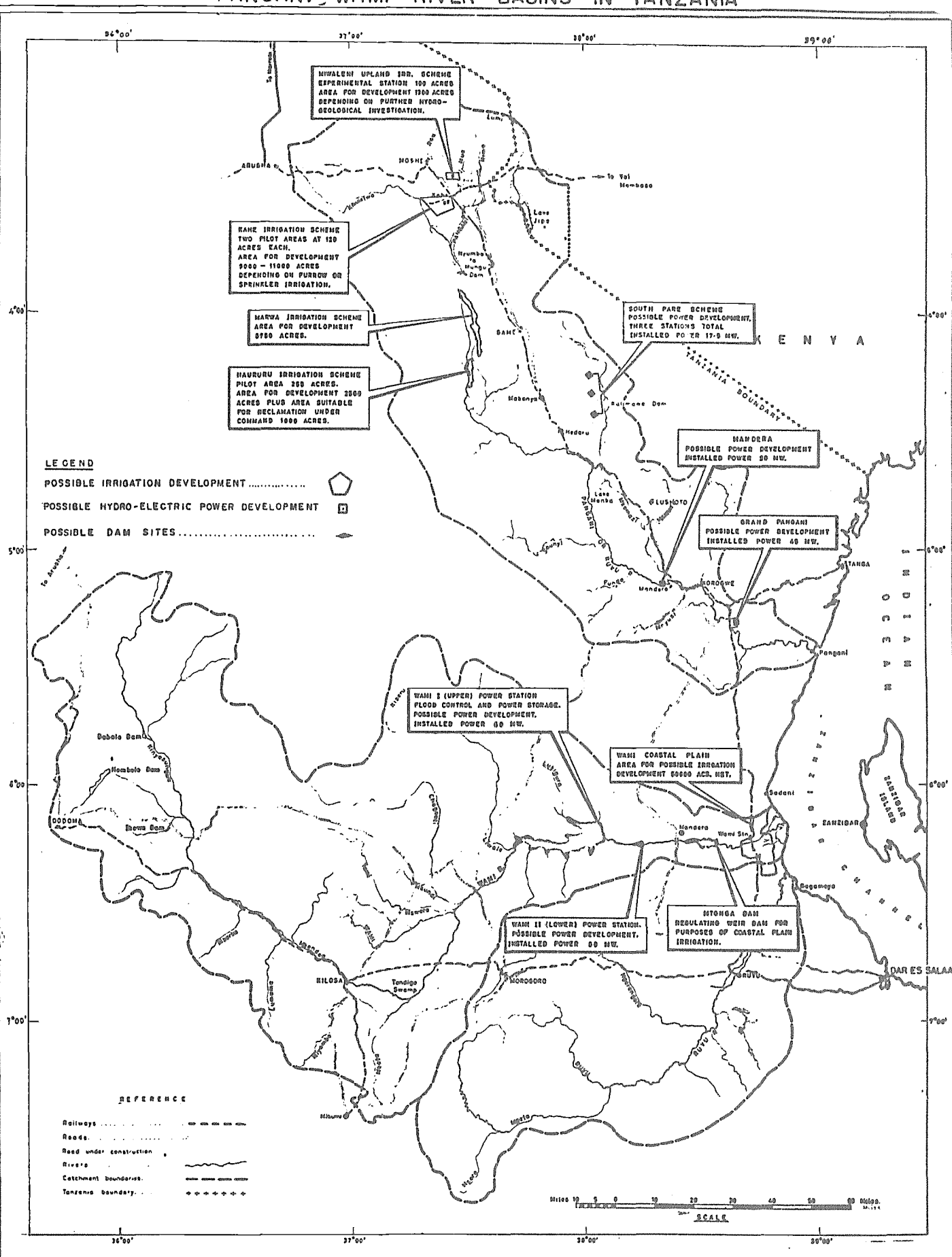
(i) Mandera hydroelectric power scheme

Balfour Beatty and Co. Ltd., Consulting Engineers to the Tanganyika Electric Supply Co. Ltd., proposed a power station at Mandera, 35 miles upstream of the Hale power station. The proposed installed capacity is 20 MW, with an annual energy of 64 million kWh. The Consultants estimated that with the Mandera station in operation the Hale and the Grand Pangani Falls power stations could operate at a more favourable load factor and produce an additional 26 million kWh. The site investigation was completed in 1965 but no further action has been taken to date.

(ii) Hydroelectric power on tributaries of the Mkomazi river

The Water Development and Irrigation Department has, under consideration in the South Pare area three small schemes on the Hingilili, Yongoma, and Sessenzi tributaries of the Mkomazi. The total installed capacity of the three schemes would be about 17.5 MW with an estimated annual energy of 92 million kWh.

Figure 13



(iii) Grand Pangani Falls power station

A small power station, known as the Pangani Falls power station, with an installed capacity of 17.5 MW has been in operation since 1932. Balfour Beatty and Co. Ltd. proposed the construction of a new power station at Grand Pangani Falls, and suggested that the old Pangani Falls power station should be taken out of commission. It was subsequently suggested that the old Pangani Falls station should remain in commission as long as possible at least until additional installed capacity to replace this station would become available.

The proposal was based on a regulated flow of 700 cu.ft/s for power generation. This requirement is met by the allocation of 508 000 acre feet per year for power, as shown in Table 9.

Summary of proposals and costs for hydroelectric power development in the Pangani Basin

The proposals and costs for power development are summarized in Table 10.

The total cost of the various proposals is £ 11.97 million for an additional installed capacity of 82.5 MW. The total estimated additional output is 405 million kWh.

The locations of the different power stations are shown in Figure 7.

It is suggested that all the hydroelectric power stations in the Pangani basin should be interconnected, making a continuous grid from Arusha through to Dar-es-Salaam. This would enable the interconnected power stations to operate on a more flexible schedule.

Table 10 : Summary of Data for Hydroelectric Power Schemes in the Pangani Basin

Station	Installed Capacity (MW)	Estimated Capital Cost (£ million)	Estimated Annual Energy (million kWh)
Mandera	20	3.22	64 + an additional 26 from Hale and Pangani Falls
Hingili Yongoma Sessen	17.5	2.40	92
Grand Pangani	45	6.35	223
Total	82.5	11.97	405

(c) Hydroelectric power development in the Wami basin

(i) Background

The river Wami in passing down the escarpment falls approximately 850 feet in a distance of some 32 miles. There are two basic methods by which this natural drop could be developed for power generation:

- Underground power stations could be constructed using vertical intake shafts and gravity tail race tunnels.
- The head could be concentrated at one or more penstocks using power canals and surface power stations.

In October 1966, SWECO, Consulting Engineers and Architects, submitted a preliminary proposal to the Government for a two-stage development with underground power stations, referred to as Wami 1 and Wami 2. The total proposed installed capacity was 160 MW which, under system load operation, would provide an annual average production of 745 million kWh. The total estimated cost of the preliminary proposals was about £29 million. The consultants proposed that their preliminary appraisal should be followed up with a comprehensive study to provide more accurate information on which the final cost figure could be worked out. The FAO team examined the preliminary proposal by SWECO in the light of topographic and hydrological information which was obtained subsequently, and during this examination gave consideration to the alternative of surface power development.

(ii) Underground power development

Based on the preliminary proposal by SWECO, a tentative scheme was worked out which includes two underground power stations, Wami 1 and Wami 2, with an installed capacity of 80 MW each, as proposed by SWECO, and which requires the construction of the upper Pongwe storage dam, a re-regulating dam for the Wami 2 power station, and a re-regulating and diversion dam for irrigation of the coastal plains. Two alternative sites were considered for the re-regulating and diversion dam, one at Lugoba and one at Matonga, but more detailed investigations are required before a final choice can be made. A small 5 MW power station could be established at the Lugoba (or Matonga) dam.

A summary of tentative costs for underground power stations operating on system load factor is given in Table 11.

Table 11 : Summary of Tentative Costs for Underground Power Development
Operating a System Load Factor (about 53 percent)

Station	Installed Capacity (MW)	Estimated Capital Cost ^{1/} (£ million)	Estimated Annual Energy (kWh million)
Upper Pongwe Dam	-	14.0	-
Wami 1	80	9.8	400
Wami 2 ^{2/}	80	10.9	345
Wami 1 and 2 including upper Pongwe dam	160	34.7	745
Lugoba ^{3/}	5	1.5	30
Total	165	36.2	775

^{1/} Including cost of transmission lines.

^{2/} Including the cost of re-regulating dam - the lowest Pongwe dam.

^{3/} Including the full cost of the re-regulating and diversion dam.

It needs to be stressed that the estimates are very tentative due to the lack of underground geological information and the resultant difficulty of estimating tunnelling costs. A careful geological exploration of the tunnel route is an essential part of any further consideration of this scheme.

(iii) Surface power development

As an alternative, to overcome the uncertainty of the geology, consideration was given to surface power development in two stages using canals and penstocks. This proposal envisages the construction of the first power station (Wami 1) at a site about nine miles downstream of upper Pongwe dam, and Wami 2 at the site about three miles downstream of Mandera bridge. A summary of tentative costs for this alternative, planned for base load operation, is given in the following table.

Table 12 : Summary of Tentative Costs for Surface Power Development
Operating at System Load Factor of 100 Percent

Station	Installed Capacity (MW)	Estimated Capital Cost ^{1/} (£ million)	Estimated Annual Energy (million kWh)
Upper Pongwe dam	-	14.00	-
Wami 1	25	5.85	215
Wami 2 ^{2/}	45	7.40	395
Wami 1 and 2 including upper Pongwe dam	70	27.25	610
Lugoba ^{3/}	3.5	1.51	26
Total	73.5	28.76	636

^{1/} Including cost of transmission lines.

^{2/} Including the cost of the re-regulating dam the lower Pongwe dam.

^{3/} Inclusive of full cost of the re-regulating and diversion dam.

(iv) Possible means of meeting the load growth

Forecasts of load growth for the Moshi, Arusha, and central coastal areas are shown in Figure 8, according to which the maximum demand of the system would grow approximately as follows:

end of 1968	about	65 MW
" " 1970	"	80 MW
" " 1975	"	150 MW
" " 1980	"	260 MW

The total generating capacity at present is about 75 MW, including 13 MW, including 13 MW at the Dar-es-Salaam thermal plant. This thermal station is now being enlarged to its full capacity of 30 MW which, together with the 8 MW plant currently being installed at the Nyumba ya Mungu dam, will meet the demand until 1972. (See Figure 8).

The load growth up to the end of 1974 could then be met by the hydroelectric plant proposed for Mandera, with an installed capacity of 20 MW, and the three small plants, totalling 17.5 MW, which are under consideration on the tributaries of the Mkomazi river. (See Figure 14).

The installed capacity of the hydroelectric plant proposed for Grand Pangani Falls is 45 MW, but the net addition to the system would only be 27.5 MW, if the old Pangani Falls power station, which has been in operation since 1932, is taken out of commission when the new plant comes into operation. The new plant, as indicated by the load curve, should come into operation by the end of 1974. The total installed capacity when all hydroelectric power schemes of the Pangani basin are completed would be 165 MW. This would meet the load growth up to 1975/76. (See Figure 14).

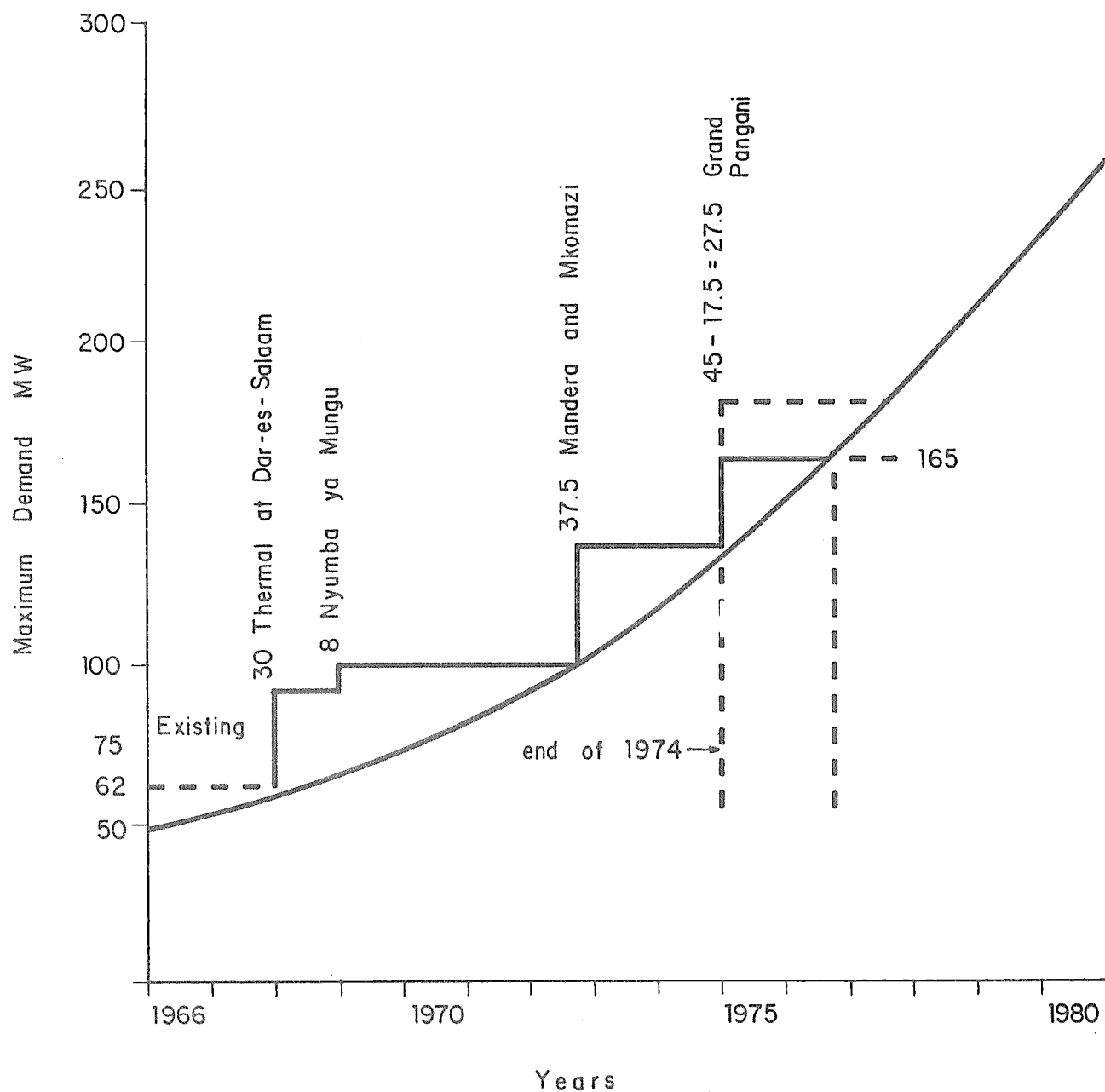
(v) An alternative possibility to meet the load growth

If power production should be developed as described above, the need for additional installations would arise in 1975/76. It is reasonable to expect that the hydroelectric schemes in the Wami basin would be considered for this purpose. Further, it would be most desirable to advance the time of commissioning the Wami power stations to a date earlier than 1975/76, if possible, in view of the most favourable impact it would have on the irrigation development of the coastal region in the Wami basin. This aspect was given some consideration during the project.

The suggestion is to defer the new Grand Pangani Falls power station to a future date and to replace it with the Wami power station. If it is possible to continue the operation of the present small Pangani Falls power station for a few more years, then it is desirable to do so. In such a case the above ground Wami 1 power station (25 MW) would be, more or less, able to replace the Grand Pangani Falls power station. On the other hand, if it is absolutely necessary to take the small Pangani Falls power station out of operation by 1974, then it would be necessary to go ahead with the above ground Wami 2 power station which will have an installed capacity of 45 MW. The annual energy output of this station is estimated at 395 million kWh which is considerably more than that of the Grand Pangani Falls power station, which has an annual energy output of 223 million kWh.

Considering the shortness of period available between now and 1974, it would be too much to expect completion of any more than the dam at upper Pongwe and one of the two above ground power stations (Wami 1 or Wami 2). Even this would perhaps be a tight schedule, but consideration of an underground power station would definitely add to the delay in view of the necessity of geological investigations which are not even started.

TANZANIA

LOAD GROWTH FOR THE MOSHI, ARUSHA AND
CENTRAL COASTAL AREAS

CHAPTER VII

IRRIGATION ENGINEERING

As a result of the studies carried out, four irrigation schemes are proposed for the Pangani basin. The schemes are referred to respectively as the Kahe (8 000 acres), Miwaleni upland (2 000 acres), Naururu (2 600 acres) and Marwa (8 000 acres) schemes, and cover a total irrigable area of some 20 600 acres. In the Wami river basin an area of some 50 000 acres is proposed for irrigation development on the coastal plains. The engineering aspects are discussed in detail in the Report Irrigation and Power Development, and are briefly summarized in this chapter. The general location of the irrigation schemes are shown in Figure 13.

In view of the lack of detailed soil information and of any firm decision as to which crop should be grown, various assumptions, especially with regard to water requirements and drainage, had to be made when preparing the preliminary designs for the engineering layouts. These initial designs and cost estimates will have to be modified in the light of experience, particularly agronomic, gained from pilot areas established within the areas proposed for irrigation development.

1. Kahe Irrigation Scheme

(a) General

The area selected for irrigation development is located some three and half miles to the south of the Miwaleni springs and to the west of the Moshi to Tanga railway line. The location of the scheme and boundaries of two alternative layouts, one for surface and one for overhead irrigation, are shown in Figure 15.

The area is well served with both road and rail communication. Kaho railway station is a junction where the line from Moshi branches, one branch going south to Tanga and Dar-es-Salaam, and one going east to join the Nairobi to Mombasa line at Voi. A private railway line connecting the Tanganyika Planting Company sugar estate at Arusha Chini with Kahe station runs through the northern half of the scheme area. A macadam road connects Arusha Chini to Moshi. The earth road connecting the scheme area to Arusha Chini requires to be brought up to all weather standard.

(b) Water supply

The water supply for development of the area is from the Miwaleni springs which have a mean flow of 115 cu.ft/s, deviating from this value by about $\pm$ 5 cu.ft/s. The quality of the water is suitable for irrigation purposes.

Comparisons between mean water requirements, based on tentative cropping systems, and mean discharges from the springs, show an adequate water supply throughout the year. To safeguard against a coincidence of adverse conditions however, the proposals include provision for the development of four boreholes already established. In general, the quality of groundwater is satisfactory, although at some points it may be on the unsafe side. In addition, about one hundred acres of water logged land around a spring in the southern section of the scheme could be reclaimed by using tube wells to lower the water table, and if of suitable quality, the water could be used to supplement the supply to the scheme during peak demands.

(c) General irrigation layout

The irrigation scheme has been designed to make use of some 60 000 acre feet of irrigation water. It is planned that the water supply for the Kahe scheme should come from the Miwaleni springs via a lead canal to a storage pond on the left bank of the Rau river. From this point two alternative distributional layouts were prepared. The first is for surface irrigation and the second for overhead sprinkler irrigation. The area under command may have to be reduced if an allowance of irrigation water is required to be set aside for continuous leaching and, as indicated in the Soils chapter, the application of gypsum in localized parts, together with continuous leaching, may well be necessary.

The area covered by the surface irrigation layout extends over 8 788 acres of which 7 806 acres are under gravity command, and 982 acres are commanded by a low lift pumping unit. The scheme is divided into two independently irrigated areas. One area is north of Tanganyika Planting Company railway line and amounts to 3 200 acres, and the other lies south of the railway line and totals 5 500 acres.

The most economic and feasible field unit is a block of 20 x 6 subunits in a gross area, including laterals, roads, windbreaks, etc., of about 145 acres. The shape selected for the subunits allows for regrouping for different acreages without affecting the ratio of net acreage to gross area commanded.

Storage ponds, canals, and all distributaries (excluding farm ditches) should be lined, and consideration was given to alternative lining materials, including earth, buried membrane, exposed prefabricated asphalt, soil cement, and synthetic rubber or rubber coated linings. Further studies are required before a final choice can be made. In view of the soil conditions particular attention was given to drainage in the engineering design.

Provision is made for access roads to all sides of each unit, minor roads on the south of all laterals, a main road on both sides of the main canal, and main ring road around the whole scheme.

The overall engineering costs total Shs T 24.3 million or about Shs T 2 760 per acre. The details of the estimate are given in Table 13. The requirements for foreign exchange in the capital cost are low.

In the case of overhead irrigation, the resultant economy in water usage, together with the more favourable ratio between gross and net area irrigated, enables the area under irrigation from the Miwaleni springs to be increased by some 25 percent, to 11 000 acres. The total capital cost for development of the 11 000 acres is estimated to be Shs T 27.9 million, but the cost per acre is estimated to be Shs T 2 550 as compared with Shs 2 760 for surface irrigation. This reduction is partly due to the spreading of certain overheads over a larger acreage, but mainly due to savings in the cost of the distribution and drainage system, land levelling, and water storage. In addition, overhead sprinkler irrigation has advantages in overcoming layout problems due to the irregular shallow soil inclusions. A preliminary economic assessment of surface and overhead irrigation indicated that the advantage lay with the latter method. The details of cost estimates are given in Table 14.

A detailed engineering layout was prepared for a pilot irrigation area of 200 acres and established on the ground, using boreholes to supply the water. During the design, particular attention was given to simple water control and measuring devices and to alternative canal lining materials. Special consideration was also given to minimizing earth movement. However, for various reasons the designs were not completely adhered to during the construction stage.

In view of the advantages to be gained from overhead irrigation, it is recommended that this method of water application should be included in the studies to be continued on the pilot area. Further studies of drainage and seepage are required.

2. Miwaleni Upland Irrigation Scheme

(a) General

The scheme is located some 11 miles east of Moshi, and lies immediately north of the Miwaleni springs and below the Arusha-Moshi-Tanga road. The ground slope of the general area is fairly steep, varying from 1:700 immediately above the Miwaleni springs to 1:80 in the north. The area selected for initial development was restricted to slopes not in excess of 1:100. For this reason the overall engineering layout proposed covers some 2 000 acres, although a semidetalled soil survey had revealed a block of some 8 000 acres of soils suitable for irrigation. As more experience is gained in the irrigation of these soils, the area could be extended northwards onto the steeper slopes, using contour terraces or other known techniques.

Table 13 : Estimated Cost of Layout for Surface Irrigation - Kahe

	Area under gravity command	Area under pump command	Total area
Net irrigable area in acres	7 806	982	8 788
..... Costs in Shs T			
Improvement of access roads	350 000	-	350 000
Diversion dam and headworks	96 260	-	96 260
Lead canal	1 569 460	318 000	1 887 460
Storage ponds (including pump station)	341 900	598 800	940 700
Main canal	1 345 000	-	1 345 000
Laterals and minor drains	4 092 775	518 000	4 610 775
Main drains	350 000	44 500	394 500
Sublaterals and field drains	4 920 850	620 000	5 540 850
Land clearing	1 880 000	240 000	2 120 000
Land levelling	2 185 680	274 960	2 460 640
Farm ditches and drains	78 060	9 820	87 880
Internal bridges and culverts	48 000	10 000	58 000
Pump house (including drill- ling and equipment)	160 000	-	160 000
	17 417 985	2 634 080	20 052 065
Engineering design and supervision (10%)	1 741 799	263 408	2 005 207
	19 159 784	2 897 480	22 057 272
Contingencies (10%)	1 915 978	289 748	2 205 727
Total in Shs T	21 075 762	3 187 230	24 262 999
Price per acre in Shs T	2 700	3 246	2 761

Table 14 : Estimated Cost of Layout for Overhead Sprinkler Irrigation - Kahe

Net irrigable area in acres 10 976	
	<u>Costs in E.A. Shs</u>
Improvement of access road	350 000
Diversion dam and headworks	96 260
Lead canal	1 400 000
Storage pond	265 000
Main canal	1 400 000
Laterals, pipes, minor drains	3 000 000
Main drains	400 000
Sprinkler system	13 203 000
Land clearing	2 400 000
Land levelling	240 000
Setting out of farm units	110 000
Internal bridges and culverts	50 000
Pump houses (including drilling and equipment)	180 000
	23 094 260
Engineering design and supervision (10%)	2 309 426
	25 403 686
Contingencies (10%)	2 540 369
Total price in E.A. Shs	27 944 055
Price per acre in E.A. Shs	2 550

(b) Water supply

The scheme lies above gravity command of water from the springs, and water for irrigation development will be obtained from underground reserves by means of boreholes. The effect of substantial groundwater abstraction of the flow of the spring, and hence on the water supply to Kahe, is not known, and further hydrogeological studies are required. The quality of the groundwater has been tested and was found to be satisfactory and similar to that from the springs.

(c) General irrigation layout

A preliminary engineering layout was prepared for some 2 000 acres, and the design makes provision for the use of some 14 000 ac.ft of irrigation water.

The full development proposal envisages the establishment of 15 boreholes, including the two already in existence, with a total abstraction capacity of 26 cu.ft/s. It is proposed that the boreholes should be interlinked to reduce the need for stand-by boreholes and pumping equipment, and should be powered by electricity from a central diesel generating center with a capacity of 0.7 MW. Provision is made for lined storage reservoirs of sufficient capacity to provide week-end storage.

Along the northern boundary of the scheme, where the slope is about one percent, a terrace layout is proposed. Low down on the more gentle slopes the field furrows are off-set at about 15 degrees to the contour.

The engineering development costs are estimated at Shs T 5.9 million, or about Shs T 3 020 per acre. Details of the estimate are given in Table 15.

A tentative estimate for pumping costs for an average pump lift of 100 ft is between Shs T 360 to Shs T 400 per acre per annum, including amortisation of capital.

A topographical survey at 1 ft-vertical interval is required before the final design, modified in the light of data from the pilot area, can be prepared. This pilot area, which uses borehole water, was established on about 100 acres.

3. Naururu Scheme

(a) General

The area lies approximately 25 miles south of the Nyumba ya Mungu dam, and is on the floodplain close to the left bank of the Pangani river. It was included amongst the areas recommended for further investigation by Sir William Halcrow and Partners in 1962. The general location is shown in Figure 16.

Table 15 : Estimated Cost of Layout for Surface Irrigation Miwaleni Upland Irrigation Scheme (1 966.5 acres)

	Capital costs in Shs T
Access roads	170 000
Boreholes	230 000
Pumps and ancillary equipment	300 000
Power station - 0.7 MW (2 x 350 kW diesel alternators)	500 000
Storage reservoirs at Shs T 10 000/-per ac.ft	1 440 000
Lead and main canal system inclusive of structure	800 000
Main drainage system	300 000
Site roads, bridges, culverts	100 000
Land clearing at Shs T 100 per acre for 2 400 acres	240 000
Land levelling at Shs T 400/-per acre for 1 966.5 acres	786 600
Setting out field units at Shs T 10/-per acre	19 665
Construction of field ditches and drains at Shs T 10/-per acre	19 665
	4 905 930
Contingencies (10%)	490 593
	5 396 523
Engineering and supervision (10%)	539 652
Total	5 936 175
	or Shs T 3 019/-per acre

Included within the proposed scheme is an area of some 1 000 acres which is under a simple form of irrigation command although only a proportion, estimated to be some 400 acres, is under irrigated crops. The lead canal to this area has been dug from a primitive intake on the Pangani river. From gaugings of flow it was found that about 20 cu.ft/s reached the start of cultivation area due to heavy losses in the canal.

Communications to Naururu from Same are poor, especially during the wet season when large stretches of the existing dirt road on the floodplain are impassable. Considerable work is required to bring the new road, at present under construction from Same direct to Naururu, up to standard.

(b) Water supply

The water supply to the scheme is by gravity from a simple fish-mouth intake on the Pangani river.

(c) General irrigation layout

The general area considered suitable for irrigation development consists of about 4 600 acres in a narrow and irregular strip bounded by non-saline alkaline soils. The shape of the irrigable area complicates the design of a regular layout, and the area covered by the preliminary engineering layout has been reduced to a gross area of 3 400 acres. This gives a net irrigable area of 2 600 acres.

The engineering survey work was limited to the determination of the location and extent of the area under locally developed irrigation; a detailed survey of the proposed intake site; and a main canal trace survey from the intake site and back to the river.

The preliminary layout makes provision for the use of about 20 000 acre feet of irrigation water. The main canal has been designed to provide all the necessary irrigation water during an eight-hour period. The alignment of the main canal is taken, wherever possible, to avoid contamination with salts. A short section will require lining to prevent the movement of groundwater into the canal, and depending on results of further seepage tests, and additional stretch may require lining.

The soil conditions required a deep drainage system, and pumps will be needed to extract some of the drainage water. Detailed topographic and soil surveys, together with data from a pilot area, are required before a final design can be prepared.

Although, with the completion of the Nyumba ya Mungu dam, the changes of the recurrence of floods which occurred in 1964 are greatly reduced, it is proposed to protect the scheme area with a dyke and interceptor drain.

A preliminary estimate of the total cost of the scheme is Shs T 7.5 million or about Shs T 3 380 per acre.

An engineering design was prepared for a pilot area of 255 acres, located so as to include a representative selection of the problem soils identified in a detailed soil survey of 700 acres. The layout has not yet been established on the ground.

4. Marwa Scheme

(a) General

The area is in the central Pangani region, about 10 miles north of the proposed Naururu scheme. It lies on rising ground to the east of the river from which it is separated by a highly alkaline and saline floodplain which varies from one to two and a half miles in width.

Previous surveys carried out in this area by FAO in 1957, and by Hunting Technical Services in 1961, failed to reveal any Class 1 or 2 soils. A broad check survey of the area covered by these earlier studies gave similar results, and the area proposed for development consists of some 9 300 acres of Class 3 soils, or soils of marginal suitability for irrigation.

Within the area selected for development neither salinity nor drainage are likely to present serious problems. The main difficulties lie in the steepness of the slopes and the coarse texture of the soils. For these reasons Sir William Halcrow and Partners concluded that overhead irrigation would be necessary. This conclusion is fully supported, and the proposed development of Marwa is based on an overhead sprinkler layout on a gross area of 8 900 acres.

Within the area proposed for development there are three villages, Kiriya, Marwa and Kwa Pateli. Of those Kiriya and Marwa are little more than fishing and cattle grazing centres with some small scale farming carried out along the river bank. Roads or tracks connect Kiriya with Lembeni on the main road and railway, and Marwa and Kwa Pateli with Same. Extensive improvements are required for the access roads to the scheme and to roads within the scheme.

(b) General layout

In the preliminary design provision has been made for the use of about 36 000 ac.ft of irrigation water. Water for the scheme is to be taken from the Pangani river at three points using simple fish mouth intakes. From these intakes the water will be taken, by canal, across the floodplain to the edge of the rising ground from where it will be lifted by pumps to the irrigable land. A provisional overhead sprinkler layout together with cost estimates was prepared. The overall development cost is estimated to be approximately Shs T 25 million or Shs T 3 566 per acre.

This scheme is allocated a low priority in the development of irrigation in the Pangani basin and more detailed investigations are required before a pilot scheme for the area can be established. Details of the engineering considerations are contained in the Report - Irrigation and Power Development.

5. The Coastal Plain of the Wami River

(a) General

Before any significant irrigation development can take place on the Wami coastal plain, it is necessary to control the flood waters of the Wami river, and to provide sufficient base flow to irrigate the proposed development area throughout the year. The construction of the upper Pongwe flood control and storage dam with a reservoir capacity of 1.5 million ac.ft is therefore a prerequisite to irrigation development in the coastal plain. As already stated, the cost of the storage dam estimated at £ 14 million is so high that it cannot be borne by irrigation, and irrigation development must await the development of hydroelectric power on the Wami river.

Preliminary consideration was, however, given to the selection of an area for irrigation development, and to the preparation of provisional estimates of the capital costs involved. In addition, an outline of a pilot irrigation scheme of some 100 acres was prepared. The location of the proposed development area is shown in Figure 6.

Communications in the area are not good. The principal road crossing the area is the old route from Bagamoyo to Tanga. This dirt road connects with the new Dar-es-Salaam to Korogwe highway along minor dirt roads from Bagamoyo to Msata, Sadani to Miono, Mkwaja to Kwamsisi and Mwera-Amboni. After rain most of these roads are in a poor condition and often impassable. A regular passenger train service connects Wami to Dar-es-Salaam, Korogwe, and Tanga.

(b) The proposed irrigation development area

A soil reconnaissance of 121 500 acres placed 93 840 acres in a category suitable for sustained crop production under irrigation. Because of the salinity of the soils at the coast and the saline nature of the groundwater below the floodplain near the coast, it was decided to leave a buffer area between the saline complex and the area to be irrigated upstream. For this reason, together with engineering and economic consideration, the gross area of the proposed development area was reduced to 68 100 acres, giving a net area of about 50 000 acres. Of this acreage, 15 400 acres are on the alluvial flats which comprise the floodplains on both sides of the river, 18 800 acres are on the higher northern coastal plain and 15 800 acres are on the southern coastal plain.

The water supply requirements for irrigation of the area throughout the year, estimated to be about 480 000 ac.ft, together with the necessary flood control, are met by the proposed upper Pongwe reservoir. This reservoir will have a mean annual discharge of about one million ac.ft, which will be available for power development on the escarpment, as well as irrigation development on the coastal plain.

A small re-regulating and diversion dam with a reservoir capacity of about 50 000 ac.ft is required. From this, nine tenths of the irrigable area would be under gravity command, and a single pumping station would lift the water to the remaining 5 000 acres. Two potential sites for this re-regulating dam were investigated, one at Mtonga and one at Lugoba, but no final choice was made. A lead canal from the dam, along the northern coastal escarpment would convey water to the northern coastal plain, and an inverted siphon from this canal would take water across the floodplain to the southern section.

A preliminary irrigation layout was prepared for an area on the floodplain for which adequate topographical data was available. Based on this, it is estimated that the cost for irrigation development would be about Shs T 3 200 per acre, or about Shs T 160 million for the 50 000 acres. No portion of the estimated cost of the upper Pongwe flood control and storage dam is included in this figure.

A suitable site for a pilot scheme was selected on the alluvial floodplain on the north bank of the river, about one mile downstream of the railway line. The area requires flood protection by a dyke and interceptor drain and it is proposed that the water supply should be by pump direct from the river into the canal system. An outline for one hundred acres was prepared, but a detailed soil is required before a final pilot area design can be drawn up.

CHAPTER VIII

SOCIAL CONSIDERATIONS AND IMPLICATIONS FOR SETTLEMENT

1. Introduction

In all too many planned settlement schemes results are discouraging. Costs are high and achievements small. Inadequate surveys and investigations, together with excessive speed in planning, have often resulted in premature implementation. The major unknown factors in most agricultural development schemes and, unfortunately, the least carefully assessed, are not what crops to grow, what varieties to select, how much water is required or what modern farming practices to apply, but how the human element will react since the farmers are the ultimate users for whom the technical development is planned. People do not vary their customary behaviour unless they feel some need which existing ways do not satisfy, and resist changes which they do not understand, or find difficult.

Farmers who have spent their lives in a community with its established social, cultural and economic patterns find great difficulty in moving to a new area where they are cut off from the familiar pattern. By the continuation, as far as possible, of the necessary social institutions in the environment of the new area, the farmer is more likely to accept the desirable social changes and adapt himself to the new conditions. The term 'social institutions' is used to cover the social habits established by groups, and the range of institutions is as wide as are the interests and activities of the people. Social institutions include such primary institutions as family, tribe, and religion; and secondary institutions such as those of education, economics and marketing, formal control and administration, health, and communication.

This chapter briefly summarizes the main findings of a study of these social institutions together with recommendations as to how these findings may be used to assist farmers to adapt themselves to irrigation development schemes at Kahe, Miwaleni, and Naururu. The recommendations should be taken as a basis only for further development in the Pangani and Wami basins, and in these areas they should be subject to modification in the light of experience gained from the schemes proposed for initial development.

2. Main Findings

The Village Development Committees, Village Chairman, and the elected 'balozi' ^{1/} proved to be the most effective agents in introducing new ideas to the existing communities.

The average age of the farmers is found to be surprisingly high, and not in general accord with the quoted national average. In addition, it is found that farmers have a high degree of basic knowledge about improved farming methods, even though many are not in a position to put their knowledge into practice. In contradiction to many other parts of the world, it is found that the older farmers are ready to adopt improved methods more quickly than their equivalent age group elsewhere, and that literacy has little significant bearing on their state of progressiveness.

The average family is from seven to eight members. This includes husband, wife and one adult dependant, two or three partially productive dependants and two full dependants. There is, therefore, a high proportion of available farm labour per family, which is significant in determining the size of the cultivated farm, the gross farm income, and the productivity per acre.

More than 50 percent of the population is found to be in the young age dependency group, which includes all under 15 years of age, the fertility and dependency ratios being amongst the highest in the world.

The average size of the farm holding is higher on the plains than on the mountains, and there is an inverse relationship between the size of the holdings and the returns per acre.

Although the average of total family income in the Pangani basin is nearly Shs T 1 500, there is a very considerable range in family incomes. Similarly the estimated average returns per acre of Shs T 260 on the mountain, and less than half of this figure on the plains, are subject to very great variations. The reasons for variation in land productivity between neighbours include:

^{1/} The elected representative of some 10 households.

- The farmer's relative state of progressiveness.
- The size of family labour.
- The size of farm holding.
- The withdrawal of the young active farmers from farms to urban centres leaving the burden of farming on low productive parents in the old age dependency group.
- The values which the farmer attributes to leisure and work.

The traditional laws of inheritance amongst the WaChagga, where both the first and the last born sons inherit the farm, has led to fragmentation, which is now being increased as population pressure is resulting in land division amongst all the sons. Property rights of women do not exist in the Pangani basin, except in parts of the Usambara mountains.

On the farm there is a definite division of family labour: male jobs; strictly female jobs; and some which overlap. Farm wives take an active role in farm labour. The keeping of farmer's accounts is usually carried out by the farmer's schoolchildren.

Farming is valued highly by most farmers, and despite the uncertainty of present farming, they would not exchange their present occupation. Mechanization, especially of ploughing, is greatly desired. Although there is considerable production of cash crops, food crop production, especially the staple foods, has prior claim on production resources. Of greatest importance to the farmers are sufficiency of food, education of their children, and the provision of suitable clothing for their wives.

Livestock, despite its inferior quality, is numerous, being a yard-stick of wealth and social standing, an insurance in old age and a security in times of want.

The main causes of farmers' dissatisfaction with their present localities are lack of capital and shortage of land and water. Farmers with large families are found to have a more favourable attitude towards resettlement. In the Moshi district, the age of farmers and dissatisfaction with their present locality is found to be inversely correlated.

A noticeable decline in the previously widespread belief in tribal curative methods is found, and increasing faith is being placed in modern medicine.

The structure and function of a number of institutions were examined in order to determine their role in creating, or changing social values.

The family, as the central core of all social institutions, was considered, together with the problems associated with it, such as polygamy, divorce, separation and desertion. Strong dislike is found with any attempt to try to reduce or eliminate polygamy.

The influence of the tribe on the individual is found to be greater than both family and religious influence. Tribal identification and group solidarity are very noticeable. Tribal inter-marriage although not forbidden is discouraged.

Cooperatives are a major economic institution and have a vital role in the development and change taking place in the country. The high percentage of membership shows that farmers are cooperatively minded. The Village Development Committees proved to be the most effective channel in reaching the individual farmer, and were the most effective source of information on farmers' needs and problems.

Age and tribal affiliation are not considered important in those who are working to effect changes, although their familiarity with the area, local conditions and problems is of great importance. Traditional sources such as the Village Development Committee have the greatest influence in spreading new ideas, whereas informal sources, such as leading farmers of the community, are the most effective in influencing the application of the ideas.

The radio is found to have a very large effect in breaking down the traditional isolation of the rural people, and programmes related to agriculture are the most popular. The peak listening time is in the evening.

3. Application of the Main Findings to Irrigation Settlement

In order to help farmers to accept and adjust themselves to new environments it is suggested that Village Development Committees, and 'balози' should be established at the start of the development stage.

Stability of the social aspects, and a progressive influence, are likely to be provided by the inclusion of some elderly men and families, although priority should be given to the recruitment of mature persons between 30-40 years with large families. This age group, in addition to providing the family labour necessary for high productivity, tends to adopt recommended farming practices relatively quickly. The whole family should be brought together on the scheme just as soon as it is practicable to present them as a unit to the new farming practices. The influence of the tribe, or the individual, suggests that a sizeable group of farmers of similar type and outlook, and chosen from the same locality, should be made neighbours on a scheme. It is not expected that the bringing together of different religious groups is likely to cause any major friction. Selection within the young unmarried and immature age groups is inadvisable.

Adequate housing is necessary to make settlement on the scheme acceptable, and sufficient loan facilities should be provided to enable farmers to construct their own houses. The engineering layouts do not make provision for houses to be established on individual plots within the irrigated area, and it is suggested that villages and community centres should be established outside the perimeter of the irrigated land. Health requirements demand the separation of field canals from homes, and indicate the undesirability of home gardens, which inevitably will mean some irrigation. However, the need to avoid a sterile, desolate village environment, together with the need to provide a sense of individuality to the settlers, may require that some modification to this principle should be considered, and the growing of vegetables and fruit in home gardens under irrigation may have to be permitted. Any modification will, however, require very special attention to the resultant health hazards.

The consideration at Kahe and Miwaleni which is being given to the development of a farming system which incorporates dairy production is highly desirable from a social security viewpoint, as well as from technical and economic considerations. Although from an economic aspect it is essential that the cropping system should aim at the maximum production of high value commercial crops, it is recognized that the system may well have to include the growing of staple food crops in view of the importance attached to staple food crop production by the people.

The size of the individual family unit has yet to be determined after further agronomic and soil studies have enabled a firm cropping system to be recommended, but the rights of the individual to the family unit should be recognized within the system of land tenure in order to enable the farmer to develop a feeling of personal interest in the land. It is suggested that the need to levy water charges should be fully explained to the farmers and this aspect should be dealt with as part of the overall training programme. A multipurpose cooperative should be built up on each scheme, and after a number of years should be in a position to take over the management of the scheme.

A degree of mechanization should be introduced, and the major operations such as ploughing should be fully mechanized. In other farm operations the level of mechanization should be fixed so that maximum use can be made of family labour. Provision for this has been made in the preliminary irrigation layouts.

The establishment of new, or expansion of existing schools and dispensaries is of the greatest importance as is the provision of adequate medical, social, and recreational facilities.

It is suggested that settlement should be in two stages, the first of which should extend over a period of about four years. The aims of the first stage should be:

- To train the farmer in the techniques of irrigation farming.
- To develop and train a cooperative organization which will increasingly take over responsibility of management of the scheme in the second stage.
- To ensure, as far as is possible, that the farmer intends to be a genuine settler and is reasonably adaptable to the requirements of irrigation settlement, before he is granted a right of occupancy over the land provisionally allocated to him.

At an early date during this probationary training stage the settlers should be encouraged to bring their families, and should be provisionally allocated an area of land. It will be necessary to provide credit facilities so that the settlers can build their own houses, preferably as a community development self-help project. Initially, assistance will need to be provided to the settlers until adequate returns are obtained from the irrigated fields. As far as is possible this should be in kind in preference to cash.

Close control and supervision of all aspects of training, including ultimate management, will need to be supplied by a competent salaried manager during this first stage, but at all time there should be the maximum consultation possible with the settlers.

In the second stage, the settler having demonstrated his desire to remain on the scheme, and shown a reasonable aptitude for irrigation farming, should be granted a long-term right of occupancy over his land, and the management of the scheme should gradually be handled over to the cooperative.

CHAPTER IX

AGRONOMIC INVESTIGATIONS

1. Current Land Use

(a) Miwaleni springs area

This general description applies to an area of some 28 000 acres on the lower slopes of Kilimanjaro, lying between the Moshi to Himo road in the north, and the Moshi to Tanga railway line in the southwest. The Pangani river, known in this area as the Ruvu, forms the eastern boundary. This area included the proposed Miwaleni upland scheme of some 2 000 acres. For the location refer to Figure 4.

The dominant vegetation is Acacia thorn bush, but the pattern is variable. To the south, in the saline areas, mature palms are particularly common. There are frequent forest clumps and two forest reserves, and the river banks usually support a high gallery forest. Open thorn bush with much grassland is the common pattern on the slopes below Kilimanjaro, and grasslands also occur in the wetter areas between the Rau and the Mue river.

It is estimated that about 50 percent of the area is under crops, although the percentage is higher in the northern section where the proposed irrigation scheme is located. The local people irrigate a proportion of the land, using water from various streams. The water available is limited, and with a low, erratic rainfall of some 15 inches per year, crop yields are poor.

The following crops are common in the area:

- Food crops - maize, beans, cassava, paddy, bananas, pidgeon pea, sweet potatoes and vegetables.
- Cash crops - cotton, vegetables (tomatoes, cabbages, onions and curcubits) and bananas.

Of the crops grown maize and beans occupy about half of the area under cultivation. The cultivation of bananas, vegetables and paddy is restricted to areas irrigated by furrows from the Rau river. Cotton, pidgeon pea and cassava are grown throughout the area and are largely dependent on rain. Although a proportion of the maize and an increasing area of cotton are grown in pure stands, most of the crops are interplanted. The main cropping season is during the long rain season commencing in March. In general, crop yields are low and although no reliable figures are available it is estimated that average yields per acre of maize are about 800-1 000 lbs, of cotton about 500 lbs of seed cotton, of beans about 400 lbs, and of onions no more than about 3'000 lbs. Lack of water is the major limiting factor to higher yields. Other limiting factors are poor cultural standards, including lack of timeliness of planting and weeding, lack of use of fertilizers, and use of unsuitable crop varieties.

The size of holdings varies considerably, but the average may be about 5 to 6 acres. Hired tractors, supplied by the cooperative union, are used to plough a proportion of the land, but ox cultivation is not practiced. Some of the farmers are resident in the area, and some live on the higher slopes of the mountain where the main crops are coffee and bananas, but hold annual cultivation rights on land in the lower areas. The number of permanent residents in the lower areas is growing as the population density on the higher mountain slopes increases.

Cotton, and maize surplus to requirements, are sold through cooperatives which have been established for a number of years.

(b) The Kahe area

This general description applies to an area of some 39 000 acres south-west of the Miwaleni springs, and contains the proposed Kahe irrigation scheme of some 9 000 to 11 000 acres. It is situated between the Kikuletwa and Rau rivers. The location is shown in Figure 4.

The natural vegetation is open thorn bush dominated by Acacia. Coarse grasses occur in some parts but bare patches sometimes occur on shallow soils overlying cemented gravel.

Excluding the sugar and sisal estates, continuous cultivation is confined to the river banks of the Rau, where supplementary irrigation water can be supplied to a range of crops. Particularly common are maize, bananas, beans and cotton. The rest of the area is mainly uninhabited, with only localized

attempts, in favourable years, to grow maize or cotton. Lack of water is the main limiting factor to agricultural production in the non-saline non-alkaline areas, the rainfall being highly erratic and averaging about 14 inches.

(c) Naururu

This description applies to some 15 000 acres on the left bank of the Pangani river, and includes about 2 200 acres proposed for irrigation development. The general location is shown in Figure 5.

The vegetation is variable with large grassy plains in those areas with highly saline and alkaline soils, and trees dominant along old water courses and the river. A parkland vegetation is common on the non-saline non-alkaline soils, the trees being particularly dense in parts. To the east, close to the edge of the floodplain, large areas are almost completely bare of vegetation due to over-grazing of the very alkaline soils. A variety of wild animals, including a high baboon population, are present.

The population is located mainly in the villages of Naururu and Mferigini, and is largely dependent on irrigation agriculture based on water obtained from the Pangani river through a simple off-take. The total area under irrigation command is some 1 000 acres, although it is estimated that no more than 400 acres are cultivated. The gross area of each holding varies from about five to fifteen acres.

Annual, biennial and perennial crops are grown in mixed stands, although it is estimated that about 75 percent of the area is under annual crops. The most common mixtures include maize/cotton, maize/cassava, and maize/cotton/sweet potatoes. In addition, a few plants of beans, chillies, sugar cane, pawpaw, bananas and pidgeon pea are frequently included in the mixed stands. Tobacco is grown in small plots.

The local cooperative society provides limited assistance for cultivation by tractors, and in the main all cultivation is carried out by family labour. Poor irrigation and cultural practices, combined with a wide range of pests, are major limiting factors to increased crop production.

(d) Marwa

This general area, in which some 8 000 acres are proposed for development of overhead irrigation, is located in the central Pangani region, some ten miles north of Naururu and is shown in Figure 7. Within the area are three small villages mainly dependent on fishing and cattle grazing and a limited amount of irrigation farming, which is confined to the river banks.

(e) Wami coastal plains

The general area is located on both sides of the Wami river, and on the floodplain extends about six miles upstream of the Tanga to Dar-es-Salaam railway line. The location is shown in Figure 9.

The vegetation is very variable and ranges between large areas of grassland on the northern coastal plain, to large, very dense forest clumps in the south, on both the coastal plain and the Wami floodplain. Other areas are dominated by Acacia thorn bush, tall mature palms, or salt bush. The grassland vegetation in many parts of the area is subject to annual burning and large areas, especially on the northern coastal plain, have a grassy fire climax cover. The mean annual rainfall is about 40 inches, but this is badly distributed with some 50 percent falling in April and May-June and July being the driest month. Rainfed agriculture is hazardous despite the mean annual rainfall of 40 inches.

The total population is small. It is estimated that in the 120 000 acres to which this description applies the total population will not exceed 5 000. A large proportion is centred on the sisal estate, the salt works and the railway. Farming and fishing occupy the remainder.

In this general area of some 120 000 acres, within which about 50 000 acres are proposed for irrigation development, only about 1 000 acres is under cultivation, excluding a 4 000 acre sisal estate. This cultivation is scattered along the river and beside stretches of the railway line and various roads and tracks. Holdings are small and average less than three acres per family.

Most of the fields are grown with a mixture of at least four to five crops, although maize and beans usually dominate the mixtures. A few fields of pure stands of tobacco are grown, and this is usually followed by maize or vegetables.

Other crops grown include bananas, coconuts, cashew nut, tobacco, beans, cowpeas, gram, cassava and sweet potatoes. During the long rains, and in areas prone to limited flooding, rice is grown.

In general, the standard of cultivation is very poor. A large proportion of the staple foods grown is consumed by the family. Cash requirements are met mainly from the sale of crops like bananas, pineapples, coconuts, mangoes and cassava.

Due to the presence of tsetse, no cattle are kept in the area, and neither animal nor tractor power is available. All cultivation is carried out manually. No reliable figures of family income are available; but it is estimated that the average income is about Shs T 300 per family. Improved cultivation, the use of higher yielding crop varieties, the provision of a source of power to supplement hand labour, and irrigation, are necessary to raise production and the standard of living of the people.

2. Experimental Work

A programme of agronomic investigations was started which was limited to the Miwaleni upland and Kahe areas. The broad aim was to investigate ways of increasing the yields of crops currently grown in the area, and to examine the potential of such new crops as lucerne, berseem, kenaf and sunhemp. The programme commenced with some simple observation plots on the Miwaleni upland area in 1965, and with the termination of FAO's participation, ended with the harvest of the 1967 long rain trials. A programme of investigations for 1967/68 was handed over to the Government.

In the initial stages of the agronomic investigations stress was placed on studies of the varietal, manurial, and cultural aspects of the crops selected for study. It was intended that more attention should be given to the study of the water requirements of crops, in combination with such related factors as manuring and plant population, from the short rain season of 1967 onwards.

(a) Summary of agronomic investigations at Miwaleni upland

A pilot irrigation area was established on about 100 acres, water for irrigation being obtained from boreholes. In addition to the limited area under experimental and small observation plots, certain crops were planted on a field scale by direct labour. These bulk plantings provided information on yields, labour requirements and practical problems of irrigation under field conditions. The results of the trials and observations are presented under the following grouping of crops: food crops, fodder crops, fiber crops, vegetable crops and oil crops.

(i) Food crops

Maize

During the long rains of 1965, 1966 and 1967 various varieties of maize were planted on a field scale. In all cases the plant population was around 15 000 plants per acre, and ammonium sulphate nitrate was supplied at the rate of $1\frac{1}{2}$ cwts per acre, half of which was given at the time of planting, and half as a top dressing 6-8 weeks after planting. The yields obtained are summarized in Table 16.

Table 16 : Yield of Maize Varieties from Bulk Plantings
(lbs/acre)

Variety	1965		1966		1967	
	Total area (acres)	Yield per acre	Total area (acres)	Yield per acre	Total area (acres)	Yield per acre
M6 <u>1/</u>	3	1 606	2	2 037	-	-
Early pearl <u>1/</u>	3	1 933	-	-	-	-
Kenya hybrid 622	-	-	2	4 343	-	-
Karanga local <u>1/</u>	-	-	14	2 626	-	-
Kenya hybrid	-	-	-	-	4. $\frac{1}{2}$	4 725 <u>2/</u>
623	-	-	-	-	4. $\frac{1}{2}$	3 492 <u>2/</u>

1/ Local varieties of open pollinated maize.

2/ During the process of land levelling the top soil was removed from a section of the land to a depth ranging between 8 inches to 21 inches. The average yield of 4 725 lbs per acre was obtained from the undisturbed section, and the average yield of 3 492 lbs per acre came from the section where the top soil had been removed. The variation in yield reduction ranged from a minimum of 264 lbs per acre to 2 128 lbs per acre, giving an average reduction of 1 233 lbs per acre. This illustrates the need to reduce top soil movement to a minimum.

A number of trials designed to provide information on varietal suitability, rate and time of fertilizers application and spacing, were carried out during both the long and the short rain growing season. The yields obtained during the short rains were consistently lower than those obtained from the long rain crop. This was partly due to climatic conditions and partly due to difficulties in irrigation.

Varietal comparisons showed the marked superiority of the hybrids over the open pollinated varieties. Kenya Hybrid 632 gave more than double the yield of M6, the lowest yielder, and exceeded other varieties by some 33 percent.

Although there was little response to phosphate, and none to potash, nitrogen at the rate of 80 lbs per acre, in two applications, gave significantly higher yields. Further trials are required on spacing and nitrogen requirements at different levels of plant population as trials to date have provided inconclusive results.

Beans

A number of varieties of beans were grown on a field scale during the long rains of 1965, 1966 and 1967, and during the short rains of 1966. They included varieties grown locally for food and for export as seed beans. Only during the long rains of 1965 did two varieties, Canadian Wonder, and a white haricot bean, exceed 1 000 lbs per acre. In general, yields were low throughout, particularly during the short rain season.

Trials were carried out to investigate the effect of fertilizers and various inoculants during 1966 and 1967, yielded poorly, with only one trial producing yields in excess of 1 000 lbs per acre. Again, in accordance with general experience, yields from the short rain crops were highly unsatisfactory with stunted growth and poor setting of pods.

There were indications of a response to phosphate at the rate of 40 lbs of nutrient per acre and to inoculation with soil from old bean fields.

Sorghum and finger millet

Observation plots of these two cereals were grown in 1965 and 1966. Promising yields were obtained but grain-eating birds can cause considerable damage in this area, and provide an ever present threat to small grains, particularly when concentrated on a relatively limited area in an irrigation scheme. The damage caused by grain-eating birds is illustrated in the yields from the sorghum variety plots given in Table 17.

Table 17 : Yield of Grain of Four Varieties of Sorghum
(lbs/acre)

Variety		Year	
		1965	1966
SB	68	1 758	834
H	78	3 708	954
H	726	-	Nil
H	6 060	-	Nil

In 1965 the damage by birds was relatively little. In 1966 it was so severe that the harvesting of the varieties H 726 and H 6060 was abandoned, and only a small proportion of the other two varieties was saved from the birds.

(ii) Fiber crops

Cotton

This is a major cash crop of the small local farmer in the low areas of Kilimanjaro region, and has been grown for many years. A long established gin-nery is in existence in Moshi, and arrangements for local marketing and export are satisfactory. Yields obtained on observation plots at Miwaleni were unsatisfactory however, and ranged between 1 200 and 1 500 lbs per acre of seed cotton. With effect from 1967 a comprehensive research programme has been initiated by the Central Regional Research Centre, Ilonga. Although current levels of yield are low, the fact that the crop is well known to the farmers and that it is a non-perishable commodity for which a well understood marketing system is in existence, justifies further investigation. It should be noted that yields in the order of 2 500 lbs of seed cotton have been consistently obtained from 2-4 acre plots grown in the past, under close supervision, in the lower areas of Moshi. These yields were obtained from the variety BP 52 then in general use in the Kilimanjaro region.

Kenaf

Observation plots planted in 1966 and 1967 yielded approximately 600-700 lbs per acre of fiber. This is well below yields obtained elsewhere, including Kahe, where fiber yields of up to one and three-quarter tons per acre were obtained. Decortication was carried out by machine on a local sisal estate, and the resultant product, due to the short fiber length, was classified as grade C. The price for grade C is about Shs.T. 800 per ton as against Shs. 1 600 per ton for grade A. In recent years considerable interest has been taken by Government in this crop, there being a ready market in Kenya, and plans for establishing a bag factory in Moshi. Further investigations into the agronomy and processing of this crop are necessary, but despite the low yields obtained on the Miwaleni upland plots, the much higher yields at Kahe, Arusha and elsewhere in the region justify further work.

Other fiber crops

Small observation plots of roselle and sunhemp were grown. The results indicated that there may well be a place for sunhemp either as a fiber crop, depending on the suitability of the fiber to the requirements of the bag factory to be established at Moshi or as a green manure crop, which would be of special benefit to the soils of Kahe which have a weak structure.

(iii) Forage crops

Lucerne

This crop was grown on a field scale of 16 acres using the variety "Hairy Peruvian". Planted in June 1966, the first cut was taken in September. Over a twelve-month period some eight cuts yielded an average of about seven tons of semidry hay per acre, or about 0.8 tons per cut per acre. The feeding quality of the hay was very satisfactory. Drying is a problem during the rainy season and investigations into drying techniques are required. Further research should be carried out on varieties, spacing, manuring, irrigation requirements and weed control.

Production of lucerne hay from the Miwaleni upland pilot area has found a ready outlet amongst the cattle owners on the mountain.

Berseem

This fodder crop has also shown considerable promise and on an observation plot 34 400 lbs green material was obtained in four cuts over a period of five months. A general manuring of 40 lbs of nitrogen and 60 lbs of P_2O_5 was used, and a subsequent fertilizer trial confirmed the marked response to fertilizer at this level, applied at the time of sowing.

The water requirement of this crop is higher than that of lucerne, but it has a number of advantages. As a five to six month crop, cultivation of berseem permits a more intensive rotation to be followed. In addition to a high yield potential, it is easier than lucerne to convert into hay and there is less loss of leaf during the process. A further possible advantage is that it is more tolerant of alkali conditions and may, therefore, be more suited to the condition of Kahe and Miwaleni upland.

Other fodder crops

A number of legumes and grasses were tried, all of which gave good results.

(iv) Vegetable crops

A wide range of vegetable crops was grown, particular attention being given to tomatoes and onions. Most of the vegetables showed excellent growth and yielded well during the cool, long rain growing season, but in accordance with general experience, with few exceptions, yields were poor during the short rain season.

Onions

This crop was grown under experimental and field conditions and the results show that yields of about 20 tons per acre can be achieved during the long rains from varieties such as Texas Grano. This variety consistently outyielded all other varieties, but its keeping quality is not as good as the locally grown Bombay Red, and its lack of pungency makes it less popular with the local consumer. The varieties recommended for dehydration processing gave unsatisfactory yields. All varieties yielded poorly during the short rain growing season.

A problem to be overcome before large scale cultivation of onions becomes practicable is the development of a suitable technique for either direct sowing or transplanting in fields, preferably the former.

Tomatoes

These were grown under field and experimental conditions and excellent results were obtained during the cool long rain season. Under field conditions, given a high standard of management, average yields of around 10-18 tons per acre can be expected from market varieties such as Money Maker, and a little less for the paste varieties like San Marzano. As already stated, a high standard of management is necessary. Fertilizers are required and particular attention must be given to pest and disease control.

No suitable variety has yet been found which will thrive during the short rain season. As all the year round supply of tomatoes is necessary if the main outlet for the crop is to be a processing plant, further investigations into varieties suitable for the short rain period and which meet the qualities demanded by the processor are required.

Chillies

These are grown on a garden scale by the local people, and are sold both for local consumption and for export. No yield figures are available of current local production, but yields in excess of 2 000 lbs per acre were obtained on the observation plots. The crop was practically free from insect pests and diseases, had a fairly low water requirement and appeared to be one of the few crops capable of yielding well during the short rain growing season.

(b) Agronomic investigations at Kahe

(i) Food crops

Beans

In general, the results obtained with this crop, both from extensive field scale plantings and from experimental plots, were similar to those obtained at Miwaleni upland, and were disappointing. Yields rarely exceeded 1 000 lbs per acre and were often appreciably lower. There was no significant response to fertilizer application.

Maize

In both field scale and experimental plantings the variety Kenya Hybrid 632 again proved to be the outstanding variety. Yields obtained in the long rain growing season were in the order of 5 000 lbs per acre as compared with an average yield of about 2 500 lbs per acre from a local variety. Experimental work on fertilizer responses and frequency of irrigation was inconclusive.

(ii) Fodder crops

Lucerne

Approximately 44 acres were sown to lucerne in 1966, a basal dressing of 20 lbs of nitrogen and 40 lbs P_2O_5 being applied at planting time. Yields were disappointing and with eight cuts per year averaged about half a ton of hay per cut per year, as compared with 0.8 tons per cut at Miwaleni upland. Before any large scale cultivation can take place at Kahe, the suitability of lucerne to the area and its yield potential require further investigation. The problems of salinity, alkalinity and concretionary layers mentioned in the Soils chapter may limit the potential of this crop.

(iii) Fiber crops

Cotton

During the long rain season of 1967, twenty four acres were sown to the local variety IL 58. The average yield was a very unsatisfactory 657 lbs of seed cotton per acre. Part of the crop was not harvested due to heavy stainer

damage. Other possible contributory factors to the low yield were the unsuitability of IL 58, too severe a restriction of irrigation water in order to restrain excessive vegetative growth, and possible effects of salinity/alkalinity.

In addition to the field scale plantings, a number of trials were established by the Central Regional Research Station at Ilonga, but results are not available.

Kenaf

Experiments to determine the effect of fertilizers' application on different row spacings gave inconclusive results. The average yields obtained, however, suggest that, under field conditions, fiber yields around three quarters to one ton are obtainable. This is a highly satisfactory yield, and with the plan to establish a bag factory at Moshi requiring the importation of 800 tons of fiber a year from Kenya, the crop warrants more detailed investigation. Particular attention is required to be given to finding a suitable mechanical method of extracting the fiber without loss of quality.

(iv) Vegetable crops

A range of vegetables can be grown successfully in the long rain growing season, but with few exceptions the short rain season is unsuitable. More attention was given to onions and tomatoes, and the results in general were similar to those obtained at Miwaleni upland.

(v) Conclusions

No firm recommendations for an intensive cropping system can yet be made. The production of vegetables, particularly tomatoes, on a major scale for processing poses a number of problems, not the least of which is the regular, all the year round supply to the processing plant of vegetables of the right quality for processing. Certain fiber crops, notably kenaf, show promise but require further investigation into processing techniques. The fodder crops also show promise, particularly lucerne and berseen, and it is suggested that serious consideration be given to investigating the implications of developing a farming system based on cattle and their products, especially milk.

Dairy production by smallholders on the mountain has been developing slowly over a number of years, and increased attention has been given to the provision of improved animals since 1964. Although standards of management are generally low, the management of cattle under intensive conditions is not a new concept to the people. With good communications and a ready outlet for milk to the UNICEF-assisted dairy factory in Arusha, in addition to the settlers and local people, a market is assured. From an agronomic viewpoint the effect of lucerne

and berseem, together with animal manure, on the soils of Kahe in particular, would be very beneficial. The economic and marketing aspects are discussed in more detail in Chapter X.

3. Pilot Irrigation Areas

Of necessity, and in the interest of efficiency, settlement schemes based on irrigation involve a high degree of control and supervision. Inevitably, land tenure and managerial problems will arise, which will be further aggravated if sound, practical knowledge, together with the staff necessary for the dissemination of this knowledge, is not available. Pilot irrigation areas are therefore required to be planned, taking into consideration these difficulties. There are three main purposes served by pilot areas. Firstly, as has already been shown, there is a need for considerably more agronomic work. This requires a relatively small acreage, which is unlikely to exceed 10 to 20 acres, and a larger area, possibly to the order of 60 to 80 acres, where more realistic assessments of yields, farming systems and practical problems associated with irrigation farming can be studied on a field scale. These areas should be operated by direct labour.

Secondly, there is a need for extension staff to be fully trained and experienced in the practical requirements of irrigation farming. This training and experience can be gained in the areas under field scale irrigation.

Thirdly, in addition to investigating the technical and practical problems of irrigation farming there is the need to investigate the human reaction to irrigation settlement, and the many land tenure and managerial problems which will arise. Moreover, the rate of adoption of recommended practices and the level of yields actually obtained from family units, as compared with yields from fields worked by direct labour, must be assessed before a final economic judgement for full development can be made. This requires that the pilot area should contain an area of land for settlement of a relatively small number of family units, once sufficient practical technical knowledge and trained staff are available to proceed to this stage of pilot area operation. Where irrigation development takes the form of improvement of existing irrigation this last stage may not be necessary, but is necessary where development is to be based on settlement, as at Kahe and the Wami coastal plain.

Miwaleni upland is an area already under cultivation, and simple irrigation is practised now. Development of this area will largely be based on improvements of existing irrigation by people already settled in the area. The pilot irrigation area of 100 acres which has been established serves the purpose of providing technical information and practical experience for extension workers, and is the basis for an extension development programme.

At Kahe, little cultivation takes place and development will be dependent on settlement. A pilot irrigation area which has been established there on 200 acres, and which like Miwaleni upland is supplied by borehole water, will need to incorporate a number of family units into the later stages of operation.

Within the Naururu area there are approximately 1 000 acres of cultivation under a simple form of agriculture, and development will partly be based on improvements to existing practices by local residents, as in the case of Miwaleni upland and partly on settlement from elsewhere. An engineering layout for a pilot area of some 250 acres has been prepared, but is not yet established on the ground.

No engineering layouts for pilot areas were prepared for Marwa or the Wami coastal plain, although a site was selected and an outline for a 100 acre pilot area, together with the necessary flood control measures, were drawn up for the latter scheme. The pilot area in the Wami coastal plain will need to be extended in future to include a limited number of settlers, but in view of the lack of data on the area, experimentation and field scale observations will be required for some years first.

A pilot area may well need to be in operation for a period of about five years from the commencement of agronomic experimentation before further development takes place. The period will obviously vary considerably between Miwaleni upland, which is based on improvement to existing irrigation and for which some agronomic information is available, and the Wami coastal plain scheme, which is based on settlement, and for which little agronomic information is to hand.

4. Priorities for Irrigation Development

The initial capital cost of the engineering layout for an irrigation scheme, and the potential return from the farming system recommended, are only two of several factors to be taken into account when considering priorities for development. Of considerable importance is the rate at which the farmers are likely to adopt recommended practices and raise yields towards the potential established by experimentation, and on this will depend the full cost of development. The rate of improvement of production is likely to be faster where the farmers are familiar with the development area, the crops included in the farming system, and have experience of irrigation, however simple or inefficient the current practice may appear. These conditions will apply where development is based on the improvement of existing irrigation farming, as it does in part, at least, at Miwaleni upland and at Naururu. In both of these areas a wider range of crops is grown, and shortage or inefficient use of water is a major reason for low yields. It is suggested therefore that in the Pangani basin prior attention should be given to the improvement of existing irrigation within an intensive, coordinated rural development programme in these two areas. The pilot areas at Miwaleni upland and Naururu would be primarily concerned with providing technical data from experimental and field scale plantings, and the training of extension staff to implement the irrigation development extension programme.

The final engineering layout, which will be modified in the light of information from the pilot area, may well take some time to complete and should be installed with the minimum disturbance of existing land rights and with capital expenditure consistent with the level of production. In the case of Naururu, improvements to the existing intake and the lead canal, as proposed in the engineering section, can be carried out immediately. Improvements to communications to this area should also be effected.

In the case of Kahe, very little cultivation takes place and development will be based on settlement of cultivators drawn from elsewhere. Agronomic investigations which have been carried out to date have been disappointing in general. Although kenaf yields were promising there are problems of processing to be solved as it is a crop which will be completely new to the settlers. There may well be a strong possibility for dairy development but this must be assessed over a period of years, and adjustment to commercial milk production will be a lengthy process. It is suggested that work at Kahe should remain concentrated on the pilot area, within which family-operated units should be established as soon as there is enough technical experience gained to proceed with reasonable confidence. The social and managerial problems should also be studied in the pilot area before systematic expansion of settlement takes place.

No engineering layout has been prepared for a pilot area at Marwa, although such an area, based on an overhead sprinkler irrigation system, will be required before full development can be considered. Initially, development should be restricted to improving the limited irrigation practised by the few people resident in the area, and to improving communications.

In the Wami coastal plain, flood control is essential before any major irrigation development can take place. The cost of flood control is high and can only be borne by hydroelectric power. No pilot irrigation area should be established unless and until it is decided to develop hydroelectric power in the Wami river basin. There will be sufficient time between the taking of a decision to develop hydroelectric power and the construction of a flood control and storage reservoir for pilot area investigations to be carried out without delaying main development, once flooding has been controlled.

Initial investigations in the pilot area should be directed towards improving the yields of selected crops which are grown in the area, and the integration of rain-fed and irrigated agriculture. A limited number of family operated units should be included in the pilot area after farming systems have been tested using directly employed labour.

The coastal plain is very sparsely populated and the environment presents a drastic change to the conditions in the overpopulated northern mountain areas of the Pangani basin. Considerable thought will have to be given to the source of future settlers to develop the area, as it is unlikely that significant numbers will come from the headwaters region of the Pangani.

CHAPTER X

ECONOMIC AND MARKETING CONSIDERATIONS FOR THE MIWALENI
UPLAND AND KAHE IRRIGATION SCHEMES

1. Introduction

Economic viability requires that the schemes should be capable of paying their way without subsidy, and it is essential to base economic considerations on a true and complete assessment of costs. Should wider policy issues require that certain cost elements be excluded from the accounting system adopted, the extent of the consequent charge to general revenue must be clearly visible. Although it may be possible to obtain a soft loan for a particular project, the expansion of public expenditure will make it necessary eventually to seek loans on hard terms. In the preliminary considerations given to the economic viability of these schemes, the annual service charge on capital investment has been based on an amortization period of 20 years and an interest rate of 6 percent, giving an annual service payment of approximately 8.7 percent.

In view of the population pressure in the Kilimanjaro region it is desirable to settle as many families as possible on the schemes. In principle therefore, and to meet the needs of the region, the schemes should be capable of bearing the full amortization charges, together with costs of administration and management, and still leave the intensively settled farmers in a position to obtain a reasonable net income. In the light of prevailing income pattern of the region a net disposable family income of Shs T 2 000 per year is considered to be a fair target. Regional family incomes are indicated in Table 18.

Although the final engineering designs will be modified in the light of further soil surveys and additional data to be obtained from the pilot areas, the estimates of capital cost provide a reasonable basis for computing the annual service charges. Estimates of total production costs, gross and net revenue

per annum are severely limited however, by the lack of agronomic information available from investigations carried out at Miwaleni upland and Kahe, and the need to use yield and production costs obtained from elsewhere. In addition, the meaningful estimate required is the net return per acre per annum from a farming system in which the individual components are integrated so as to make full use of the land, water, and labour which is available. It is not possible at this stage for any such farming system to be firmly recommended and any reference to crop rotations can only be tentative.

The high capital cost of irrigation development requires that the aim should be to devise a farming system which maximizes revenue. For social reasons however, it may be necessary initially to include the production of staple food crops for domestic consumption. However, illogical this may appear from a purely economic viewpoint, the fact remains that despite the substantial development of a cash economy in Moshi district there is a strong reluctance to be dependent on purchased staple foods. This attitude can no doubt be overcome in time, but will need to be taken into consideration in the early stages of development.

Table 18 : Distribution of Average Family Income and Farm Size

District area	Average farm size	Average family income			
		Net farm income	Supplement-ary earned income	Aid by second family earner	Total family income
	(acres)	 shillings			
<u>Moshi district</u>					
Highlands	3.3	758	760	13	1 531
Lowlands	6.5	594	400	26	1 020
<u>North Pare districts</u>					
Highlands	3.2	334	406	108	848
Lowlands	4.4	212	1 512	21	1 745

The people of Moshi district have demonstrated their ability to adapt themselves to many of the requirements of the day. The period of adaptation to more sophisticated production techniques under irrigation therefore, may not be as long as might be expected elsewhere. Nevertheless it will take time to adjust to new crops and farming systems, especially to the sophisticated production techniques demanded by crops such as tomatoes and other vegetables grown on a commercial scale to meet the requirements of a processing plant. Initially

therefore, it is advisable to give consideration to basing the major production on crops which are familiar to the people, and develop more complex systems as experience is gained.

2. Cost of Overheads for Irrigation Development

The total cost of the engineering layout for surface irrigation of 8 788 acres of Kahe is approximately Shs T 24.3 million and for the irrigation of 2 000 acres at Miwaleni upland is Shs T 5.9 million. Including investment in storage and buildings, not shown in the engineering estimates, the capital cost per acre is Shs T 3 061 and Shs T 3 319 for Kahe and Miwaleni upland respectively.

Estimates of the annual cost of overheads per acre for the Kahe and Miwaleni upland irrigation schemes are summarized in Table 19.

Table 19 : Estimates of Annual Cost of Overheads (Shs T per acre)

	Kahe	Miwaleni upland
	Shs. T.	Shs. T.
Annual service charge at 8.7 percent in capital invested	266	289
Maintenance, operation and renewal charges	52	350
Supervision and management	140	140
Total	458	779

Maintenance, operation and renewal charges include an estimate of the annual operating costs of the low lift pumping at Kahe of Shs T 7 per acre, and a very preliminary estimate of the borehole pumping costs of Shs T 300 per acre at Miwaleni upland.

It should be noted that, while the Kahe area is presently barren and uncultivated, the Miwaleni upland area is under fairly intensive cultivation at present, and the net annual value of current agricultural production is tentatively estimated to be Shs T 100 per acre. With the steady expansion of the acreage under cultivation due to population pressure, and the possibility of increasing yields at relatively little expense by extension work, this figure of Shs T 100 is considered to be conservative. As the aim is to assess the additional value of crop production resulting from the proposed investment in irrigation development in the Miwaleni upland area, the value of existing production must either be deducted from the estimates of total returns from the scheme area, or added to the estimated costs. If the value of existing crop production is added to the cost of overheads, the apparent difference between Kahe and Miwaleni upland overhead costs of Shs 321, would be increased to Shs 421.

3. Returns and Variable Costs of Production

In order to assist in assessing the merit of various crops and their potential for inclusion in a crop rotation the expected returns are set against the variable costs of production. The variable costs are those which are specific to the production of a particular crop. They include cost of seeds, fertilizer, insecticide, machine operating costs, and labour. In the summary given in Table 20 the variable costs are given including and excluding labour. Labour provided by the family would be excluded from the cost calculations and only the cost of hired labour required at peak times would be included, but this is not possible to estimate until the crops are assessed within a complete farming system. The yield figures used in the calculations are estimates based on local consultation and observation. They assume the use of known varieties of crops and good standard of management.

The returns from various crops and the variable costs are summarized in Table 20.

Table 20 : Estimates of Returns and Variable Costs 1/ for Various Crops - Kahe

Crop	(1)	(2)	(3)	(4)		(5)	
	Yield lbs	Ex farm price Shs per lb	Total return Shs per acre	Variable costs Shs per acre		Returns over variable costs	
				exclud. labour	includ. labour	exclud. labour	includ. labour
Cotton	1 300	.41 ^{2/}	533	215	480	318	53
Kenaf	1 400 (fibre)	.62 ^{3/}	868	193 ^{12/}	326 ^{12/}	675	542
Maize	3 500	.195 ^{4/}	683	231	355	452	328
Lucerne	17 600 (semidry hay)	.073 ^{5/}	1 280	484	731	796	549
Tomatoes	22 000	.06 ^{6/}	1 320	281	853	1 039	467
Onions	22 000	.06 ^{7/}	1 320	317	799	1 003	521
Berseem	20 000 (semidry hay)	.073 ^{8/}	1 460	544	859	916	601
Chillie	2 000	1.0 ^{9/}	2 000	137	659	1 863	1 341
Sugar cane	88 000	.018 ^{10/}	1 600	276	976	1 324	624
Food beans (local)	1 200	.255 ^{11/}	270	165	327	105	-57
Food beans (export)	1 000	.35 ^{11/}	350	165	327	185	23
Seed beans (export)	800	.7 ^{11/}	560	180	342	380	218

Footnotes: see next page

- 1/ The variable costs include cost of seed, insecticide, fertilizer, machine operating costs, and are shown both with and without labour costs. In the case of tomatoes an additional supervision cost of Shs T 20 per acre has been added in view of the strict management required for the production of this crop to meet processing requirements.
- 2/ Weighted average prices for cotton paid in 1966 by the Cotton Lint and Seed Marketing Board assuming an average percentage of 80 percent Grade A and 20 percent Grade C.
- 3/ Weighted average price of kenaf fibre based on Kenya factory prices of Shs T 1 600, Shs 1 400, and Shs 1 000 per ton for Grades A, B and C respectively and after deduction of estimated handling and delivery costs to the bag factory to be constructed in Moshi.
- 4/ Based on the National Agricultural Products Board's price for maize of Shs T 39 per 200 lb bag.
- 5/ This is the price at which the small quantities of lucerne produced by the schemes have been sold to the relatively few farmers keeping high grade cattle on Kilimanjaro. This price is less than half the price paid by Kenya dairy farmers.
- 6/ The price of tomatoes is based on local estimates of the price it would be necessary for a processing factory to pay in order to be competitive both within Tanzania and in the export market.
- 7/ This is a tentative estimate of the price for onions which a dehydrating plant, established near to the scheme, could afford to pay and maintain a competitive position in the world market.
- 8/ There being no local production on market for berseem, the price is estimated on the basis of the price obtained locally for lucerne. This crop is usually cut and fed in the green state.
- 9/ The price for chillies is based on the price offered by an export firm for the variety Long Red Cayenne.
- 10/ Based on data supplied by the sugar estate at Arusha Chini. The labour rates are those paid by the estate and are considerably higher than the Shs T 4.5 paid elsewhere.
- 11/ The local market price for good quality food beans in recent years has fluctuated around Shs T 45 per 200 lb bag. Exporters pay up to Shs T 80 per 200 lb bag for export food beans, but the average price, allowing for up to 15 percent rejects, transport and handling, is about Shs T 70 per 200 lbs. Seed bean prices vary between Shs T 160 to Shs T 180, but allowing for up to 25 percent rejects in addition to handling and storage, the average ex farm price is taken as Shs T 140 per 200 lbs.
- 12/ As variable costs are those specific to the production of a particular crop, the cost of machinery employed only for that crop must be included. Little is known about the mechanical decortication of kenaf, and the variable costs for this crop may be substantially underestimated.

4. Other Considerations

On the basis of returns over variable costs per crop acre chillies, sugar cane, tomatoes, and onions appear to offer the greatest promise. Appreciably below, but still appearing to be capable of supplying a reasonable return are the fodder crops of berseem, and lucerne, and the fibre crop of kenaf. Maize, cotton, seed and food beans for export are towards the bottom of the list. Food beans for local sale show no economic potential for inclusion. Other factors however, require consideration, and these are briefly discussed below.

(a) Marketing

There appears to be a good export market for chillies and this crop is currently being exported in substantial quantities. In the case of sugar there is no free capacity at the factory on the Tanganyika Planting Co. Ltd. sugar estate some 2 miles from the Kahe scheme area and connected to it by a private railway line. Tanganyika is however, a net importer of sugar, and the current consumption of 7 kg per head is low in comparison with Kenya and Uganda. A policy decision to aim at self sufficiency may influence the expansion in factory capacity at Arusha Chini particularly if, as is quoted, the Tanganyika Planting Co. Ltd. is the cheapest producer in Tanzania. In view of the good experience with outgrowers for the Kilembero Sugar Co. Ltd., it may be possible to develop a similar arrangement for Kahe.

There is no significant regional market for fresh tomatoes, and although with suitable packing and transport arrangements there is a national market for fresh tomatoes, the main market outlet for any significant production would be a processing factory producing paste and juice for internal consumption as well as export. Currently some 400 tons of tomato paste and juice are imported. The region is, and has been for many years, a major producer of onions. There is a limited seasonal import of fresh onions of some 300 tons per year, but the main outlet lies in the export field either as dehydrated onions for Europe, or as fresh onions.

Although small quantities of lucerne produced on the pilot areas are sold locally at a price of Shs 4 per 55 lb bale, and there are possibilities of building up a regional market for lucerne, this is too unpredictable to justify the production of lucerne and berseem as cash crops. The most promising use of these fodder crops is as feed for dairy cattle kept on the schemes. This is discussed later.

The Coffee Curing Co. of Moshi plan to start a bag factory at Moshi in 1969 and import some 800 tons of kenaf fibre from Kenya. This will provide a ready local market in addition to the existing Kenya market.

Cotton has been the major cash crop produced by small holders in the low areas of the regions for many years, and the marketing of this crop through well established channels in, for all practical purposes, unlimited quantities, is a strong point in favour of cotton production. Maize is purchased by the National Agricultural Products Board (N.A.P.B.) although considerable quantities

are sold or exchanged locally. It should be investigated whether the N.A.P.B. could increase maize prices to the amount of money saved on storage, when receiving off-season maize grown in the short rains. This is of some importance as maize is one of the few crops which will yield reasonably well during the short rain growing season. Tanzania is a major world producer of seed beans and a well organized marketing arrangement exists for the export of this crop, as it does for the export of food beans.

(b) Field requirements

Of the crops under consideration maize, beans and cotton are the most widely grown on a large scale, although there is a significant production of onions. Chillies and tomatoes are grown widely but on a garden scale, and sugar cane production by small holders is limited to very small areas. Kenaf, lucerne and berseem are completely unfamiliar to the people. Although farmers can be taught the production of new crops and the use of improved techniques, this will take time and where highly specialized forms of production are required, considerable risks are involved. This applies especially to the production of vegetables of suitable quality and in regular quantities to meet the requirements of processing plants. Apart from the fact that it has not been found possible to produce satisfactorily short rain season onions and tomatoes, and hence ensure a regular supply of these vegetables to a processing plant throughout the year, the very high standard of pest and disease control which is absolutely essential for commercial scale production of tomatoes, militates against the introduction of these crops as major earners of cash. Chillies are remarkably free from pests and diseases with the possible exception of bird damage, but are extremely unpopular to harvest. This again suggests that chillies should be limited to small scale production. Kenaf is a crop which is new to the people but is a relatively simple one to grow. A problem which has not yet been solved however, is a cheap and efficient method of extracting the fibre by mechanical means and still retain quality. Kenaf appears to have excellent potential for inclusion in the crop rotation but this cannot be realized until the problem of processing has been solved. No trials on sugar cane production have been carried out, but the level of production on the nearby estate is a reasonable indication of the yield potential. Experience of commercial scale sugar production is limited largely to former employees of the sugar estate who have subsequently settled in the lower areas of Moshi. This is a relatively straightforward crop to grow and in case that factory capacity can be provided warrants consideration as a major crop. It is understood that Government policy did not favour the inclusion of sugar production at Kahe, but it is not known if this policy still stands. From the foregoing sections it may be seen that in the early stages of development cotton, seed beans and maize cannot be excluded entirely on the basis of their comparatively lower returns over variable costs.

The fodder crops of lucerne and berseem can best be considered in conjunction with milk production.

5. Dairy Production

The agronomic advantages to be gained from the growing of leguminous fodder crops and the use of animal manure have already been noted. Preliminary examination of the economics of milk production suggest a return per acre from milk comparable to that of the more valuable crops.

There is an assured market for milk through the dairy factory established at Arusha with UNICEF assistance. This factory was built with a capacity of 6 000 gallons per day. Milk supplies to the factory have consistently dropped as estate production has fallen, and are now below the level of 2 500 gallons per day required for economic operation. It is intended to import supplies from Kenya. In addition, there is a requirement of some 700 gallons per day by employees on the nearby sugar estate, and of course, the needs of the farmers and their families on the schemes.

The preliminary assessment of the economics of dairy production assumed the good management of grade stock fed on home grown irrigated fodder crops, together with roughage and supplemented by purchased concentrates and minerals. The calculations were based on a high carrying capacity of 4 beasts to the acre producing an average of 564 gallons per head over a lactation period of 282 days. A price of Shs. 2.75 per gallon was assumed for revenue estimation purposes. The estimated return over variable costs per acre for milk production is about Shs T. 1 400, excluding labour costs of fodder crops, and about Shs T. 800 if labour costs are included. It should be noted that production costs are very high and errors in management can rapidly result in substantial losses.

The supply of suitable grade dairy cattle is likely to be extremely limited, and the build up of a large dairy unit as a major economic enterprise will extend over many years. Particular care will have to be taken when building up the herd to prevent the introduction of disease, and a quarantine centre will be required. In addition, the dairy herd will need to be protected from local cattle. Stock movements, particularly by butchers and traders on the mountain, will have to be studied and measures taken to avoid contact between the herd and the trade stock.

The lack of reliable information on production costs, including fodder crop production, and on returns, requires that dairy production should be limited to the pilot area for a period of at least five years. At the end of this period, during which additional fodder crops should be tried, the economics of dairy production can be more reliably assessed.

6. Crop Rotation

Agronomic factors other than the availability of irrigation water limit crop production. Of the crops listed onions, tomatoes, beans and cotton can only be grown during the period extending from February/March to September/October. New varieties of techniques may be developed to overcome this problem

but at present none is known. Further, in order to prevent the build up of cotton pests the Cotton Ordinance requires the uprooting and burning of cotton plants by a specified date in the latter part of the year. Kenaf may prove suitable for short season production if planted before mid-August, but this has yet to be proven, and the seasonal suitability of berseem has to be further investigated. Of the annual crops only maize, with a reduced yield in the order of 3 000 lbs per acre, and chillies can be relied upon to produce reasonably well during the short rain hot growing season commencing in October.

Under irrigation intensive production with the minimum of fallow period must be aimed at. The extent to which this aim can be met by the crops under consideration is limited to their adaptability to different seasons of the year. As has been pointed out, with the exception of the perennial crops of lucerne and sugar cane, and the annual crops of maize and chillies, the growing of the remaining crops is limited to the long rain growing season. The period which the crops occupy the ground ranges from some 4 1/2 months in the case of beans, to up to 7 months or more in the case of cotton.

(a) Cropping patterns for immediate consideration

In view of the points considered in sections 3 to 5 and in the early part of this section, any early development of irrigation outside the pilot area would need to be based on a simple rotation of cotton, maize and seed beans. In addition, vegetables, including onions, tomatoes and chillies, would be grown in a garden plot. Assuming a family unit of 4 acres plus 1/3 of an acre of vegetables, and a degree of mechanization, a basic rotation may be as shown in Table 21.

Table 21 : Basic Rotation for Early Implementation

Crop	Area in acres		Return/Variable Costs Excluding Labour (Shs T)		
	Long rains	Short rains	Long rains	Short rains	Total
Cotton	2	-	636		636
Maize	1	3	452	1 356	1 808
Seed beans	1	-	380	-	380
Vegetables	1/3	1/3 (chillies)	420	600	1 000
					3 824

The basic rotation gives an estimated return over variable costs per acre of approximately Shs T. 900. If the estimated annual cost of overheads of Shs T. 458 per acre for Kahe are deducted, the net return to the farmer per acre could be in the order of Shs T. 442 or Shs T. 1 815 per family unit. In the case of Miwaleni upland the overhead costs are appreciably higher and amount to Shs T. 779 per year, excluding the value of current production tentatively estimated to be Shs T. 100 per acre. The net return per family unit at Miwaleni upland, after deduction of full annual overhead costs, would therefore only be in the order of Shs T. 520. It should be noted that it may be necessary to hire some labour for peak seasonal work, such as cotton picking.

On account of the market for kenaf fibre shortly to be established in Moshi and the higher potential revenue from this crop, kenaf could profitably replace cotton as soon as a suitable method of mechanical decortication has been established. In the case of Miwaleni upland this would increase the net return per 4 1/3 acre unit to about Shs T. 1 000 which is still too low to justify the capital cost of development.

If factory capacity could be made available at the sugar estate, the replacement of 2 acres of cotton by 2 acres of sugar cane at Kahe would increase the returns over variable costs from the family unit to about Shs T. 1 250 per acre. After deduction of annual overhead costs the net return per family unit of 4 1/3 acres would be about Shs T. 2 400.

The returns over variable costs per acre for the basic rotation, or variants which could be expected to be implemented in the reasonably near future, would appear to justify the capital outlay estimated for irrigation development at Kahe but not at Miwaleni upland.

(b) Cropping patterns for future considerations

The development of a farming system based on milk production is highly desirable in view of the existing and growing demand for liquid milk within easy reach of the area, and the apparent profitability of such an enterprise. Such development however cannot take place at an early date due to lack of reliable data on production costs and returns, together with various management problems. A pilot dairy unit should therefore be established as soon as possible. The unit, based on zero grazing, should be supplied with fodder grown on the irrigated pilot area. Detailed studies should be carried out on the costs and returns of milk production, including the production costs of alternative fodder crops. Such investigations may extend over a five-year period before dairy development can commence and progressive farmers participate in a cooperative dairy unit. The rate of subsequent build up of a full dairy herd is likely to be limited by the availability of suitable stock and it is unlikely that milk production can assume a major role in under 10-15 years.

The need for an intensive and high revenue earning farming system has been stressed. Despite the problems associated with intensive vegetable production for processing, the potential high returns, together with the desirability of diversifying exports and developing local industry, justifies continued investigation into agronomic problems and the economics of vegetable production for processing. In view of the high production risks, this enterprise should be introduced on a small scale in the development areas after it has been fully tested on the pilot areas. The small vegetable dehydration plant available from the Tanganyika Farmers Association might well be used during the period of investigation.

CHAPTER XI

MANAGEMENT AND DEVELOPMENT OF THE PROPOSED IRRIGATION AT
KAHE AND MIWALENI UPLAND

1. Kahe

The overall concept of the scheme is one of participation by Government, management and tenant. The main functions of Government are the supply of initial capital and development effort, and the provision of public services such as research, education, health and welfare. Its share of the benefits will be derived from direct and indirect taxation. As stated in Chapter X, the cost of management and supervision has been included in the overheads of the scheme. The management initially established will be responsible for the direction and control of the development of the project, including the training of a cooperative to assume, eventually, full managerial responsibility. In addition, it must, in agreement with tenant committees, set aside money out of profits as a reserve fund. The tenants, as members of a cooperative, will share directly in the profits from the farms, and proportionately, according to their contribution, in the profit of any subsidiary activity. The management and operation of the scheme when fully developed is illustrated in Figure 17.

As Figure 17 shows it is proposed that the total irrigated area should be divided into 5 blocks for administration and management purposes. Each block should then be divided into units which will support 20 families, and each unit subdivided into fields of about 20 acres. Each settler should be allocated one acre in each field, the whole of which should be planted to a single crop. The full scheme should ultimately accommodate some 2 000 families. Two or three villages will be required for each block, and these should be sited to reduce the walking distance to a minimum. The staffing required for the overall management of the full scheme and for the daily operations within each block is given in Appendixes IV and V.

(a) Rate of development

In Chapter X the annual cost of the overheads of Shs T 458 assumed the implementation of the full irrigation layout from the outset. This will not occur in practice. The rate of development will depend on the results obtained from the pilot area, the availability of experienced management and trained extension and cooperative staff, the readiness of settlers to come forward, the rate at which the settlers adapt themselves to new conditions, and the availability of funds. The implementation of full development will extend over a period of several years. Approximately Shs T 2.8 million, or 13 percent of the total estimated capital requirement for irrigation, will be needed at the commencement of the main development for such works as the diversion dam and headworks, the lead canal and storage pond, and improvements to communications. The remaining capital expenditure will be roughly proportional to the acreage developed each year. The annual overhead costs per acre will therefore be significantly higher than Shs T 548 in the initial years.

(b) Procedure for development

The logical sequence of research, pilot area development study, and phased implementation of the main irrigation project should be followed. It is advocated that an officer of sufficient authority should be appointed in order to ensure continuity of the field work which was carried out during the period of the project and the later follow up action by the Government.

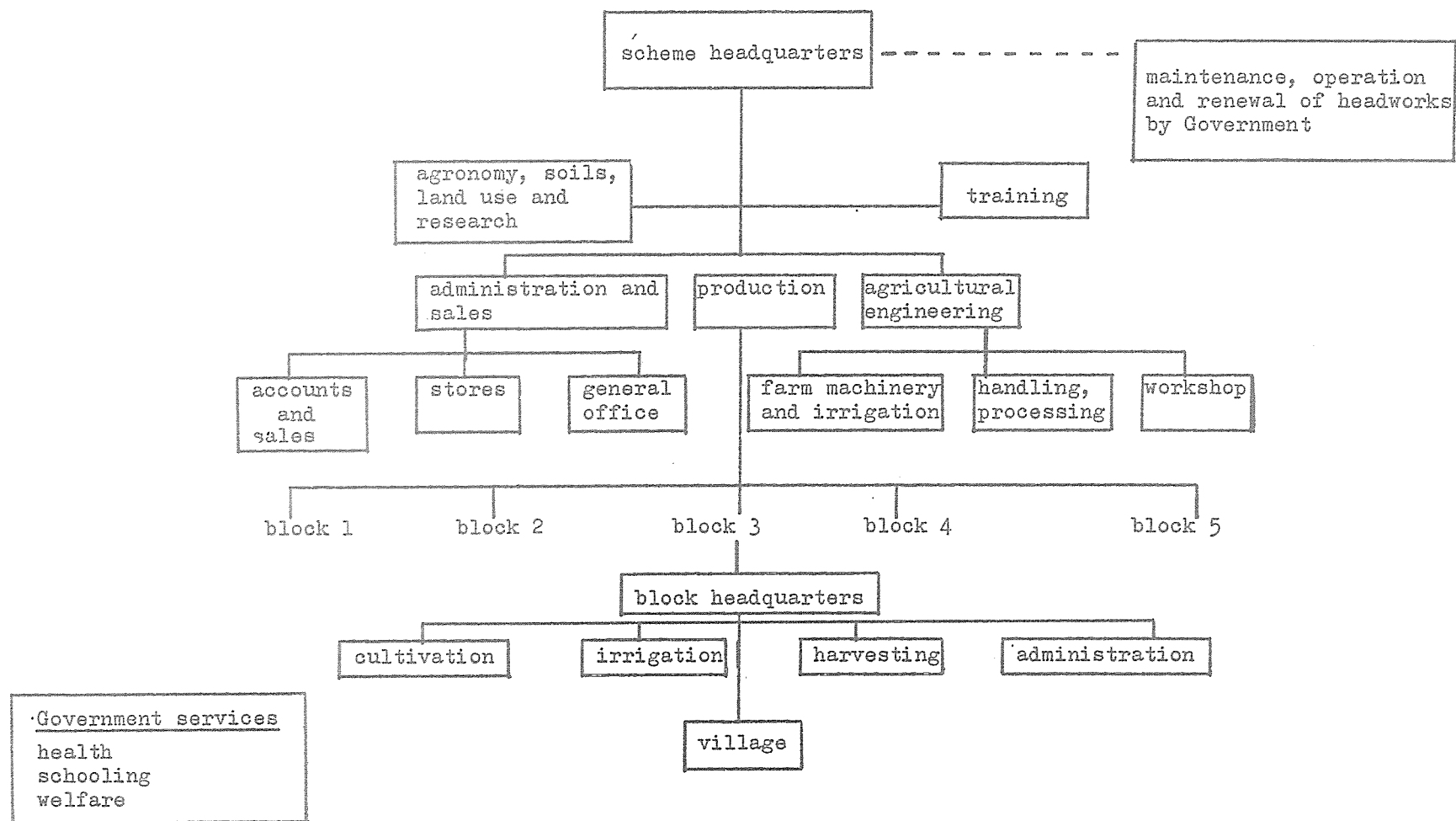
A detailed soil survey of the whole of the Kahe irrigation scheme should be carried out as soon as possible and studied together with the groundwater and subsoil investigations already completed.

Agronomic studies on the lines already discussed should continue on the pilot area, both on an experimental and a field scale. A training programme for extension staff should be developed and use made of the field scale operations on the pilot area to provide staff with some practical training in irrigation techniques. When it has been shown that the practical requirements of a simple basic cropping system can be fulfilled by the use of labour under direct control, a limited number of families should be established on the remaining land in the pilot area. This should be done in order to obtain a more reliable assessment of crop yields obtained by family units, and the various problems of management which will arise.

A final engineering design and revised estimates can be prepared in the light of the detailed soil survey and data from the field area, and a schedule for development prepared.

Figure 17

Management and Operation of Kahe Irrigation Scheme when Fully Developed



2. Miwaleni Upland

As indicated in Chapter X the returns per acre from Miwaleni upland will not justify high development costs in the near future. This situation may change if and when the way should be cleared for dairy development or the production of vegetables for processing, but this is likely to take a number of years. In view of the fact that the area is already under relatively intensive cultivation, it is proposed that the development should take the form of an intensive, coordinated rural extension programme. In the context of irrigation development the aim should be the intensification and improvement of the existing irrigation which makes use of water from streams and where practicable, supplementing the water supply from boreholes with a relatively low pump lift. The coordinated rural extension programme would aim however at the maximum participation by the local people in all aspects of rural development including social, health and educational improvements as well as improvements to the existing irrigation farming. In view of the very considerable area of land currently under some form of irrigation in the headwaters of the Pangani river particularly in the lower area of Moshi, and the large potential for increases in crop production resulting from intensification and improvements to existing irrigation, Miwaleni upland could well be developed as an example for wide application elsewhere. It is proposed that detailed consideration should be given to the development of such an extension programme.

The training programme for irrigation development should include a number of overseas fellowships in simple theory and practical techniques for field level workers.

APPENDIX I

PLAN OF OPERATION

UNITED NATIONS SPECIAL FUND PROJECT IN THE REPUBLIC OF TANGANYIKA

Survey and Plan for Irrigation Developments in the
Pangani and Wami River Basins

<u>Special Fund Allocation:</u>	US \$ 1,225,300
Consisting of:	
Special Fund Contribution:	US \$ 1,117,300
Government Contribution towards local operating costs:	US \$ 108,000
<u>Government Counterpart Contribution in kind:</u>	US \$ 921,000
Duration	3 years
<u>Executing Agency</u>	Food and Agriculture Organization of the United Nations
<u>Co-operating Government Agency</u>	Ministry of Agriculture

For the purpose of the Survey and Plan for Irrigation Developments in the Pangani and Wami River Basins to be undertaken by the FAO of the United Nations acting as Executing Agency for the United Nations Special Fund, this Plan of Operation shall be the Plan of Operation provided for in Article 1, Paragraph 2 of the Agreement signed on the 17th day of July, 1962, by the Government of the Republic of Tanganyika and the United Nations Special Fund.

I. PURPOSE AND DESCRIPTION OF THE PROJECT

A. Purpose of the Project:

1. The overall purpose of the project is to determine, through surveys and investigations, the technical and economic basis of design for irrigation development of the Pangani and Wami River Basins. These surveys and investigations will permit the selection of the most suitable locations for pilot demonstration projects to prepare detailed designs and the schedules of work for the pilot areas and to draw up a program of irrigation development in the two basins for execution in the seven years following the completion of the project.
2. Training of local personnel in the various aspects of irrigated farming is one of the main purposes of the project.

B. Description of the Project:

3. To achieve the above objectives the project will consist of:
 - (i) aerial photography of about 250 sq. miles in separate areas at a height suitable for mapping at a scale 1:10,000 with contours at vertical intervals of 5 ft.;
 - (ii) contour mapping by photogrammetry at a scale of 1:10,000 with contours at vertical intervals of 5 ft. over areas totalling about 70,000 acres;
 - (iii) ground surveys of specific areas for the location of the major works and structures such as dam sites, pumping stations canal headworks, etc. at scales of 1:2,500 or larger with contours at vertical intervals of 3-5 ft. over areas totalling about 4,000 acres;
 - (iv) reconnaissance soil surveys of about 500,000 acres in the Pangani and Wami basins to define priority areas within this total;
 - (v) semi-detailed soil surveys over the areas of higher priority so defined, expected to total about 120,000 acres;
 - (vi) detailed soil surveys of areas expected to total about 16,000 acres in order to select definitely the areas most suitable for the establishment of four pilot schemes, each of 500 acres net cultivable area. Three of these pilot schemes will be in the Pangani basin and one in the Wami basin. In addition a semi-detailed soil survey will be made of a selected area of about 160,000 acres in the Ruvu basin in order to enable the Government to obtain assistance from other agencies for the early development of this project;

- (vii) hydrological observations of the river-flows in the Pangani and Wami basins as required to supplement the data already existing. Based on this data, the amount of water which can be made available for irrigation in the conditions to be expected in the future will be defined. It is expected that about 8 additional hydrological stations will be required, of which most will be in the Wami basin;
- (viii) agronomical studies including analysis of data of the various existing crop experiments, study of suitable cropping patterns and crop rotations, layout of fields, methods and rates of irrigation. The investigations should cover also problems of farming in combination with livestock raising;
- (ix) sociological surveys, study of institutional solutions suited to the conditions including tenure, settlement, operational methods and the means to achieve active participation of the cultivators in all aspects of irrigation farming;
- (x) assessment of the total seasonal water requirements for the projects under investigation, based on the assumed cropping pattern and climatic conditions. Preparation of water management plans for individual projects and for each of the two river basins, taking into consideration both power and irrigation interest and the requirements of effective flood control;
- (xi) engineering studies needed for planning and design of storage dams and reservoirs, flood protection works as well as irrigation and drainage systems. These studies will be of preliminary natures for the river basins and in detail for selected areas where they will include design of field irrigation systems and drains. Geological investigation needed for the design of dams and major structure, study of ground water behaviour in relation to irrigated soils will form part of the studies for the pilot projects and projects selected for early development;
- (xii) preparation of estimates of the capital and annual cost for these priority projects;
- (xiii) feasibility studies for the same projects including comparative studies for various solutions against the background of regional and national development;
- (xiv) preparation of detailed designs and schedules of work for the four project areas;
- (xv) preparation of a definite program of development in the basins of the two rivers as recommended for implementation in the seven years following the completion of the project;
- (xvi) preparation of a comprehensive project report with all necessary maps, plans drawings and diagrams to cover all aspects and phases of the project.

II. WORK PLAN

A. Participation and Contribution of the Special Fund:

4. The Special Fund shall provide the following through the Executing Agency:

- (a) Experts. A total of 402 man months of expert services as detailed in Appendix I below. Within the total of 402 man months of expert service minor adjustment of individual post assignments may be made by the Executing Agency, if this is found to be in the best interest of the project.
- (b) Equipment and Supplies. Equipment and Supplies at a cost not exceeding US \$ 301,000 as detailed in Appendix I and Table II below. A more detailed list of equipment and supplies will be drawn up later.
- (c) Sub-contracts. Sub-contracts at a cost not exceeding \$85,000 for aerial photography, contour mapping and test pits and borings as detailed in Appendix I below.
- (d) Miscellaneous. Miscellaneous services and facilities as detailed in Appendix I below.

B. Contribution and Participation of the Government:

5. The Government shall provide the following as a counterpart contribution in kind:

- (a) Personal services comprising:

Professional staff: A total of 145 man months of professional staff service as detailed in Appendix II below. Within the total of 135 man months of professional staff service, minor adjustments of individual post assignments may be made by the Government if this is found to be in the best interest of the project.

Other staff: An estimated total of 2,422 man months of other personal services as detailed in Appendix II below.

- (b) Buildings and Construction: Establishment of the four pilot schemes as detailed in Appendix II below.
- (c) Equipment and Supplies: Equipment and supplies as detailed in Appendix II below.

- (d) Miscellaneous: Miscellaneous service and facilities as detailed in Appendix below.
 - (e) Cost of transporting and handling of equipment. The cost of import and customs clearance of project equipment, its transportation, handling storage and related expenses within the country, its insurance after delivery to the project site.
6. The estimated cost of the counterpart contribution as detailed in Appendix II below is based on the most realistic information available at the time of drafting this Plan of Operation. It is understood that price fluctuations during the period of execution of the project may necessitate an adjustment of said contribution in monetary terms; the latter shall at all times be determined by the value of the services and facilities required for the proper execution of the project.
7. The Government shall make available to the project all the records and information necessary for the implementation of the project under Article III, paragraphs 1 and 4 of the Agreement between the Government and the Special Fund and referred to in the preamble to this Plan of Operation, irrespective of whether the material has been published or not. This will include all reports, soil maps, texts, records, in particular all such information dealing with previous work, on the subject matter of the project, all available topographical or other maps or charts at suitable scales and any other information which in the opinion of the Executing Agency would facilitate the operation of the project.
8. Privileges and Immunities:
- The Executing Agency's contractors and their personnel (except Government nationals locally) shall have the right to the following:
- (a) Immunity from legal process in respect of all acts performed by them in the execution of the project;
 - (b) immunity from national service obligations;
 - (c) immunity from immigration restrictions;
 - (d) the privilege of bringing into the country reasonable amounts of foreign currency for the purposes of the Project or for personal use of such personnel, and of withdrawing any such amounts brought into the country, or, in accordance with the relevant foreign exchange regulations, such amounts as may be earned therein by such personnel in the execution of the project; and
 - (e) the same repatriation facilities in the event of international crises as diplomatic envoys.

9. All personnel of the Executing Agency's contractors shall enjoy inviolability for all papers and documents relating to the project.
10. The Government shall either exempt from, or bear the cost of, any taxes, duties, fees, or levies which it may impose on any foreign firm or organization which may be retained by the Executing Agency and on the foreign personnel of any such firm or organization in respect of:
 - (a) the salaries or wages earned by such personnel in the execution of the project;
 - (b) any equipment, materials and supplies brought into the country in connection with the Agreement or which, after having been brought into the country, may be subsequently withdrawn therefrom; and
 - (c) as in the case of concessions currently granted to the United Nations experts, any property brought, including one privately owned automobile per employee, by the firm or organization or its personnel for their personal use or consumption or which, after having brought into the country, may subsequently be withdrawn therefrom upon departure of such personnel.
11. The privileges and immunities to which such firm or organization and its personnel may be entitled, referred to in paragraphs 8, 9 and 10 of this Plan of Operation, may be waived by the Executing Agency where, in its opinion or in the opinion of the Special Fund, the immunity would impede the course of justice and can be waived, without prejudice to the successful completion of the Project or to the interest of the Special Fund or the Executing Agency.
12. The Executing Agency shall provide the Government with the list of personnel to whom the privileges and immunities enumerated above shall apply.
13. Local Operating Costs:

With reference to the payments to be made by the Government under Article V, paragraph 1(a) and (d) of the Agreement referred to in the preamble to this Plan of Operation, excepting the cost within the country for transportation of project supplies and equipment, which is a counterpart contribution, the Government shall pay to the Special Fund in local currency the equivalent of US \$ 108,000 towards local operating costs. This amount represents 15 percent of the total estimated cost to the Special Fund of foreign project personnel, including cost of foreign personnel of sub-contractors.

14. The contribution towards local operating costs, the equivalent of US \$ 108,000 shall be deposited by the Government in local currency to the credit of the Special Fund Account with in accordance with the following schedule:

Equivalent of US \$	25,900	on signature of Plan of Operation
" " " "	35,000	on 1st January 1965
" " " "	32,300	on 1st January 1966
" " " "	14,800	on 1st January 1967

The amount payable in each instalment is determined on the basis of the United Nations operating rate of exchange at the time of payment; payment of the above amounts, on or before the dates specified, is pre-requisite to operation.

C. Organization:

15. Overall responsibility for the organization and execution of the project rests with the Executing Agency, which will plan and direct operations through the Project Manager who will be selected and appointed by the Executing Agency in consultation with the Government.
16. The Government Co-operating Agency for the project shall be the Ministry of Agriculture which shall provide the necessary technical and administrative support to the project and shall ensure the cooperation of other Government agencies in the project.
17. The project Headquarters will be located in Dar-es-Salaam. However, duty station of some of the experts might be established in Moshi Arusha or in other suitable localities. The Government will also provide accommodation in other regions of Tanganyika when required for the purposes of the project.
18. The Government shall designate a Co-Manager acceptable to the Executing Agency. He shall be the counterpart of the Project Manager and will be responsible for all policy matters relating to the project and for the organization, the administration and the scheduling of the Government's participation in the project, in accordance with the provisions of the Plan of Operation on subsequent Work Plans.
19. The Project Manager shall be responsible for the detailed planning administration and execution of the project including timing and budgeting of the various elements, the preparation of technical reports and the organization and supervision of related training programs. In undertaking these responsibilities the Project Manager shall work closely with the Co-Manager.

20. The technical terms of reference of the Project Manager and of the other members of the Special Fund team are given in Table I.
21. The Executing Agency shall appoint an Administrative Officer acceptable to the Government who will work under the supervision of the Project Manager and in close cooperation with the Co-Manager.
22. The Administrative Officer and other administrative staff provided by the Government shall be responsible for servicing the project on administrative matters such as accounting, storekeeping, purchase of material and supplies, maintenance of equipment, payrolls and servicing of the experts and will perform such other duties as are assigned by the Project Manager.
23. The duties of the project personnel provided by the Government and called for in paragraph 5(a) and Appendix II of the Plan of Operation, will be to carry out whatever duties may be assigned to them in connection with the operation of the project under the administrative and technical supervision of the Comanager in cooperation with the Project Manager.

Sequence of Operation

24. The Executing Agency will commence operation of the project upon receipt of written authorization to do so from the Managing Director of the United Nations Special Fund.
25. The Project Manager will be appointed as soon as possible after 1 January 1964 and during the period between his appointment and the project becoming operational shall apply himself to the task of drawing up lists of urgently needed equipment for ordering and other preparatory work in connection with the project.
26. The Soil Survey shall start with reconnaissance surveys in both the Pangani and Wami Basins in the first half of 1964 as soon as the rains are over and the condition of the terrain are suitable for field work. This should be completed both for the reconnaissance and the semi-detailed survey (500,000 acres and 120,000 acres respectively) before the rains at the end of 1964. Maps should be prepared and detailed investigation completed before March 1965. The detailed survey of the selected 16,000 acres shall be completed before June 1965 in order to have sufficient time for the completion of the main structures of the 400 to 500 acre pilot project before the rains at the end of 1965. Operation of the farms shall start at the beginning of 1966.

27. The Hydrologist shall join the team in April/May 1964. During the first month of his assignment he will study existing hydrologic material and the existing hydrologic stations and participate in the establishment of additional hydrologic stations, most of them in the Wami basin.
28. The two Irrigation Engineers shall join in April/May 1964 together with the Engineering Surveyor. They should participate in the reconnaissance surveys and in the selection of the pilot areas and start with actual design as soon as the areas have been selected and the topographic maps prepared.
29. Before the selection is made, both Irrigation Engineers should study dam sites and prepare a design for storage dams and reservoirs and flood protection work, together with preliminary design for irrigation systems for a general plan for irrigation development in the two basins. The Survey Engineer shall join in May 1964. The Survey Engineer, together with the counterpart survey technicians and draftsmen shall assist the Irrigation Engineers with the preparation of contour maps.
30. The Chief Draftsman should join in mid-1964 to assist the engineers in the preparation of dam designs and irrigation systems and all other works.
31. The Agronomists shall join in July 1964 and should use the first period of their assignment in the study of existing irrigation farms, including experimental stations.
32. The Irrigations Technician (distribution and control of water on the fields) shall join at the end of 1965.
33. The Rural Sociologist should join in November 1964 to assist the Project Manager and the Agricultural Economist in planning the extensional work of the project.
34. The Agricultural Economist should join the team in November 1964 for a six month assignment and should return to the Project in early 1966 to participate in the feasibility studies.
35. The joining dates of the consultants have to be decided later in accordance with the progress of work in the various fields.

III. BUDGET

36. The estimated cost of the services and facilities to be provided for the project is detailed in the Plans of Expenditure appended to this Plan of Operation. Funds will be provided by the Special Fund and the Government as indicated below:

1. Allocation by the Special Fund (Appendix I) \$ 1,225,300
Consisting of:

Special Fund contribution	\$ 1,117,300
Government contribution to-	
wards local operating costs	\$ 108,000

Counterpart contribution in kind by the Government \$ 921,000

IV. REPORTS

37. The Government and Executing Agency will exchange financial and progress reports. The form, content and frequency of these reports will be agreed upon from time to time between the Government and the Executing Agency.
38. The Government and the Executing Agency shall at the end of each calendar year submit a joint certified inventory of project equipment purchased from the Special Fund allocation and for which title remains with the Special Fund.
39. Within 6 months following the conclusion of project operations the Executing Agency will submit a final comprehensive report on the project to the Managing Director of the Special Fund for presentation to the Government.

V. REVISION

40. The Project will be subject to periodic review by the Special Fund. Any substantial deviation from the Plan of Operation will require a careful evaluation of the problems encountered by the three parties to the project in order to determine the future course of action.

VI. STEPS TO BE TAKEN AT THE COMPLETION OF
SPECIAL FUND ASSISTANCE TO THE PROJECT

41. The Government intends to continue irrigation development within the two river basins, based on the information and experience gained in the pilot schemes. This development would be along the lines recommended by the team, which would be expected to set up a 10-year program.
42. At the successful conclusion of the project, the Government, the Executing Agency and the Special Fund will consult with a view to transferring the title to part or all of the equipment provided by the Special Fund in whose name it has been held by the Executing Agency, to the Government or to an Agency nominated by the Government.

VII. SIGNATURE

Agreed, on behalf of the parties, by the undersigned:

P. Bomani
Government of the Republic of Tanganyika

A.L. Adu
United Nations Special Fund

Date: 17 April 1964

Date: 17 April 1964

Pierre Terver
Food and Agriculture Organization of
the United Nations

Date: 10 April 1964

Explanatory Note to Amendment No.1

UNITED NATIONS SPECIAL FUND PROJECT IN THE REPUBLIC OF TANGANYIKA

Survey and Plan for Irrigation Developments in the

Pangani and Wami River Basins

The formation of the United Republic of Tanzania and Zanzibar on 26.4.1964 and the subsequent change of the Co-operating government agency, has necessitated adjustments in the existing title and text of the Plan of Operation.

The title had to be amended to state the Government Counterpart as the Government of the United Republic of Tanganyika and Zanzibar.

The Government Co-operating Agency for the project would be the Ministry of Land, Settlement and Water, and not the Ministry of Agriculture which would provide the necessary technical and administrative support to the project and would ensure the Co-operation of other Government Agencies in the project. Therefore, this necessitated an adjustment in the Organization of the Project.

AMENDMENT No.1 TO THE PLAN OF OPERATION

UNITED NATIONS SPECIAL FUND PROJECT IN THE REPUBLIC OF TANGANYIKA

Survey and Plan for Irrigation Developments in the
Pangani and Wami River Basins

The Plan of Operation signed by the Government of the Republic of Tanganyika on 17 April, 1964, by the United Nations Special Fund on 17 April, 1964, and by the Food and Agriculture Organization of the United Nations on 10 April, 1964, has been amended as per the attached.

Agreed on behalf of the Parties by the undersigned:

Government of the United
Republic of Tanganyika
and Zanzibar

United Nations Special
Fund

Food and Agriculture
Organization of the
United Nations

Date:

Date:

Date:

AMENDMENT No. 1

PLAN OF OPERATION

UNITED NATIONS SPECIAL FUND PROJECT IN THE REPUBLIC OF TANGANYIKA

Survey and Plan for Irrigation Developments in the

Pangani and Wami River Basins

In pursuance of the Plan of Operation signed by the Government of the Republic of Tanganyika on 17 April, 1964, by the United Nations Special Fund on 17 April, 1964, and by the Food and Agriculture Organization of the United Nations as the Executing Agency on 10 April, 1964.

Whereas it is considered necessary, due to the formation of the United Republic of Tanganyika and Zanzibar and due to the subsequent change of the Cooperating Government Agency, to amend the above Plan of Operation, the following modifications are made:

Page 1:

The title is amended as follows:

PLAN OF OPERATIONS

UNITED NATIONS SPECIAL FUND PROJECT IN THE

UNITED REPUBLIC OF TANGANYIKA AND ZANZIBAR

.....
Cooperating Government Agency

Ministry of Land, Settlement
and Water

.....

Page 6:

C. Organization:

.....

16. The Government Cooperating Agency for the project shall be the Ministry of Land, Settlement and Water which shall provide the necessary technical and administrative support to the project and shall ensure the cooperation of other Government agencies in the project.

APPENDIX II

LIST OF STAFF ENGAGED AT VARIOUS PERIODS ON THE PROJECT
- END OF APRIL 1967 -

Headquarters:

Project Manager	- D. Dolfi	(FAO)
Project Co-Manager	- W. Swinson	(Government Counterpart)
Administrative Officer	- C. Esposito	(FAO)
Administrative Officer	- A.N. Ozkan	(FAO)
Secretary	- Mrs. M.A.I. Fernandes	(FAO)
Office Supervisor	- S.S. Rashid	(Government Counterpart)
Accounts Assistant	- J. Shimba	do.
Clerical Officer	- L.S.Z. Sarumbo	do.
Typist/Stenographer	- Mrs. C. D'Souza	do.
Typist/Stenographer	- Miss J. Walli	do.
Typist/Stenographer	- Miss K.A. Bhimani	do.
Typist/Stenographer	- Mrs. A. Poole	do.
Typist/Stenographer	- Mrs. Z.K. Hassam	do.
Accounts Assistant	- B. August	do.
Accounts Assistant	- S. Singh	do.
Office Supervisor	- S. Chande	do.
Higher Clerical Officer	- P. Kangombe	do.
Clerical Assistant	- M. Mziray	do.
Clerical Assistant	- N.B.M. Tairo	do.
Clerical Assistant	- C. Dede	do.
Executive Officer	- J. Shimba	do.
Clerical Officer	- M. Mkisi	do.
Clerical Officer	- P. Mringi	do.
M.T. Clerk	- R.J. Laswai	do.
Assistant Stores Officer	- J.H.G. Alfanyes	do.
Stores Assistant	- W. Magembe	do.
Stores Assistant	- F.K. Kyamell	do.
Stores Assistant	- R.A. Malisa	do.

Headquarters (Cont'd)

Stores Assistant	- M. Issa	(Government Counterpart)
Stores Assistant	- G. Mlingi	do.
Stores Assistant	- J. Jonas	do.
Site Clerk	- R.M. Msangi	do.
Site Clerk	- G. Poliani	do.

Topographical Survey Team:

Engineer Surveyor	- G. Heathcote	(FAO)
Engineer Surveyor	- F. Tiani	(FAO)
Engineer Surveyor	- A. Hellstrom	(FFHC)
Photogrammetrist	- J.G. Rijsdijk	(FAO)
Technical Assistant	- A.E. Lyamuya	(Government Counterpart)
Technical Assistant	- S. Kafunya	do.
Technical Assistant	- P. Lihundi	do.
Technical Assistant	- R. Matanda	do.
Technical Assistant	- S. Mjwahuzi	do.
Technical Assistant	- B. Mwakibaba	do.

Soil Survey Team:

Soil Chemist	- K.N. Satyapal	(FAO)
Soil Chemist	- R.G. Menon	(FAO)
Soil Chemist	- J.W. Dewis	(FAO)
Soil Chemist	- T. Otienowski	(Government Counterpart)
Soil Laboratory Assistant	- Miss H. Hansen	(Danish Govt. Volunteer)
Laboratory Assistant	- S.R. Seneilwa	(Government Counterpart)
Laboratory Assistant	- M.M. Mtandala	do.
Technical Assistant Laboratory	- V.T. Kanabar	do.
Senior Soil Surveyor	- G.R. Robinson	(FAO)
Senior Soil Surveyor	- N. Mikenberg	(FAO)
Soil Surveyor	- G.R. Suggett	(FAO)
Soil Surveyor	- A. Hoekstra	(FAO Associate Expert)

Irrigation Engineering Team:

Hydrologist	- T.H. Mather	(FAO)
Irrigation Engineer	- J.J. Hearnshaw	(FAO)
Irrigation Engineer	- Y.H. Djang	(FAO)
Irrigation Construction Engineer	- M.R. Abdou	(Government Counterpart)

Irrigation Engineering Team (Cont'd)

Irrigation Engineer	- W.A. van Tuijl	(FAO Associate Expert)
Irrigation Engineer	- D. Baker	(U.K. Volunteer)
Irrigation Engineer	- P.T. Gilchrist	(U.K. Volunteer)
Senior Technical Assistant	- H.M. De Silva	(Government Counterpart)
Drilling Superintendent	- B. Rainer	do.
Assistant Inspector (Works)	- J.J. Reesaul	do.

Irrigation Agronomy Team:

Irrigation Agronomist	- F.B. Brown	(FAO)
Irrigation Agronomist	- R.D. Verma	(FAO)
Irrigation Agronomist	- M.F. El Ebrashy	(FAO)
Irrigation Agronomist	- F.J. Ijserinkhuijsen	(FAO Associate Expert)
Senior Agronomist	- D.K. Lwehabura	(Government Counterpart)
Assistant Field Officer	- B.F. Lwenyagira	do.
Field Assistant	- G. Rutatenekwa	do.
Field Assistant	- T. Faraji	do.
Field Assistant	- H. Mohaki	do.

Drawing Office Staff:

Chief Draughtsman	- F. Bullaty	(FAO)
Senior Draughtsman	- D. Miranda	(Government Counterpart)
Senior Draughtsman Assistant	- M.P. Jagatia	do.
Draughtsman Assistant	- P. Babili	do.
Draughtsman Assistant	- C.G. Msowoya	do.
Junior Draughtsman Assistant	- S. Gasper	do.

Sociology Team:

Rural Institutions Officer	- S.A. El Shishtawy	(FAO)
Sociology Assistant Trainee	- P. Baruti	(Government Counterpart)
Sociology Assistant Trainee	- W. Sebaya	do.
Sociology Assistant Trainee	- J. Maganga	do.
Sociology Assistant Trainee	- J. Jastin	do.
Sociology Assistant Trainee	- Miss H. Lema	do.
Sociology Assistant Trainee	- A. Mushi	

Consultants:

N. Allan	Irrigation Development	{FAO}
G. Allbaugh	Economist	{FAO}
P. Schroeter	Hydrogeologist	{FAO}
J. Silveira	Sanitary Engineer	{WHO}
B. Velimirovic	Epidemiologist	{WHO}
N. Bauer	Economist (Marketing)	{FAO}
J.E. Moes	Economist	{FAO}

APPENDIX III

MONTHLY AND ANNUAL DISCHARGES IN ACRE FEET

RIVER WAMI AT MANDERA STATION No.IG2

* Indicates values wholly or partly estimated

Year	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Annual Total
1953/4									23 783	17 954	10 068	12 145	
1954/5	8 271	11 877	10 545	162 345	80 642	232 304	*171 890	113 452	42 848	27 543	17 084	13 155	* 891 956
1955/6	14 204	27 239	62 284	133 696	82 079	264 714	279 453	124 159	50 809	42 637	23 235	17 810	1 122 319
1956/7	20 505	29 992	57 133	84 122	52 509	406 731	759 623	108 192	56 833	41 804	27 218	20 608	1 665 270
1957/8	29 236	59 007	35 520	41 336	174 088	315 948	320 728	113 764	48 065	31 809	22 350	15 596	1 207 447
1958/9	11 076	28 059	31 144	40 223	125 579	116 882	187 346	31 557	24 632	26 225	19 684	17 910	660 317
1959/60	16 036	25 819	48 653	39 016	84 909	539 125	164 646	58 915	38 916	25 407	17 286	14 813	1 073 541
1960/1	12 679	7 343	6 264	64 890	62 720	90 132	138 762	32 414	61 806	32 131	31 109	75 452	615 702
1961/2	586 308	385 955	858 534	*221 466	323 519	*291 604	303 680	93 135	66 561	61 950	48 888	33 890	*3 275 490
1962/3	35 657	51 081	97 493	84 376	241 114	541 876	280 350	85 610	68 159	47 757	32 577	*24 103	*1 590 153
1963/4	120 656	183 779	216 317	162 584	277 055	720 907	315 682	111 814	74 427	67 925	47 116	44 511	2 342 773
Max.	586 308	385 955	858 534	*221 466	323 519	720 907	759 623	124 159	74 427	67 925	48 888	75 452	3 275 490
Min.	8 271	7 343	6 264	39 016	52 509	90 132	138 762	31 557	23 783	17 954	10 068	13 155	615 702
* Mean	85 463	81 015	142 389	*103 405	150 421	*352 022	*292 216	87 301	53 306	40 519	28 655	*27 785	*1 444 497
Mean % Annual	5.92	5.61	9.86	7.16	10.41	24.35	20.22	6.04	3.69	2.81	2.01	1.92	100.00

* Means calculated on 10 years only (1954/5 to 1963/4)

APPENDIX IV

HEADQUARTER STAFFING - KAHE

Management	Numbers	Maintenance, operation and repair	Numbers
General Manager	1	<u>Workshop</u>	
Cultivation Manager	1	Superintendent	1
Assistant Cultivation Manager	1	Foremen fitter/mechanics	3
Agronomy/Soils Manager	1	Fitter/mechanics	10
Agricultural Engineering Manager	1	Fitter mates	10
Assistant Agricultural Engineering Manager	1	Time keepers/cost clerks	2
Secretary/typist	1	Storekeepers	1
General duty clerks and typists	4	Assistant storekeepers	2
Accountant	1	Motor transport drivers	2
Assistant accountants	2	General duty labour pool	20
Bookkeepers	4	<u>Building yard</u>	
Storekeepers	4	General foremen	2
Assistant storekeepers	4	Tradesmen	6
Motor transport drivers	3	Storekeepers	2
General duty labour pool	15	Time keepers	1
		Motor transport drivers	3
		General duty labour pool	20

APPENDIX V

PROPOSED STAFFING FOR BLOCKS - KAHE

Staff	Block				
	(1)	(2)	(3)	(4)	(5)
	982 acres	2 230 acres	2 069 acres	1 828 acres	1 679 acres
<u>Field Management</u>					
Field Officers	-	1	1	1	1
Assistant Field Officers	1	-	-	-	-
Crop Supervisors	5	11	10	9	8
<u>Agricultural Engineering Field Staff</u>					
Fitters/mechanics	1	1	1	1	1
Assistant fitter/mechanic	-	1	1	1	1
Tractor operators	14	32	29	26	24
Irrigation supervisors	1	1	1	1	1
<u>Office Staff</u>					
Clerical	2	3	3	3	3
Motor transport drivers	1	1	1	1	1
Station hands	1	2	2	2	2
Night watchmen	1	1	1	1	1

APPENDIX VI

BIBLIOGRAPHY AND REFERENCES

Sir William Halcrow and Partners	The Development of the Pangani River, 1962 and Supplement. 1966.
SWECO	Study of Hydroelectric Power Potential of the Lower Wami. 1966.
Balfour Beatty and Co.	The Potential of Hydroelectric Power Development. 1964.
Merz and McLellan	Report on Market for Electricity.

APPENDIX VII

LIST OF SPECIALISTS AND CONSULTANTS REPORTS PRODUCED DURING
THE PROJECT OPERATIONS IN THE PANGANI AND WAMI RIVER BASINS

J. J. Hernshaw Irrigation Engineer	Irrigation and Power Development
T. H. Mather Hydrologist	Climatology, Hydrology and Water Resources
Project engineering surveyors	Topographic surveys
N. Mikenberg G. R. Suggett Soil Surveyors	Soils
R. D. Verma Irrigation Agronomist	Agricultural
S. A. El. Shistawy Rural Sociologist	Social Aspects
Leland G. Allbaugh FAO Consultant - Economist	An Economic Appraisal of the Proposed Kahe Irrigation Project in the Pangani River Basin, Tanzania 1966.
U. Bauer Marketing Consultant	Marketing Prospects for the Crops Grown in the Survey and Plan for Irrigation Development in the Pangani and Wami River Basins Project Area, 1967.
J. E. Moes FAO Consultant - Economist	Economic Appraisal of the Kahe and Miwaleni Project Areas. 1967.
B. Velimirovic and J. Silveira WHO Consultants	Report on the Health Aspects of the Survey and Plan for Irrigation Development in the Pangani and Wami River Basins, Tanzania 1966.
P. Schroeter Hydrogeologist	Hydrogeological Investigations of the Miwaleni Spring, near Moshi, Northern Tanzania.

TANZANIA
PANGANI - RIVER BASIN LOCATION OF IRRIGATION AND HYDRO-ELECTRIC POWER INVESTIGATIONS

Figure 1

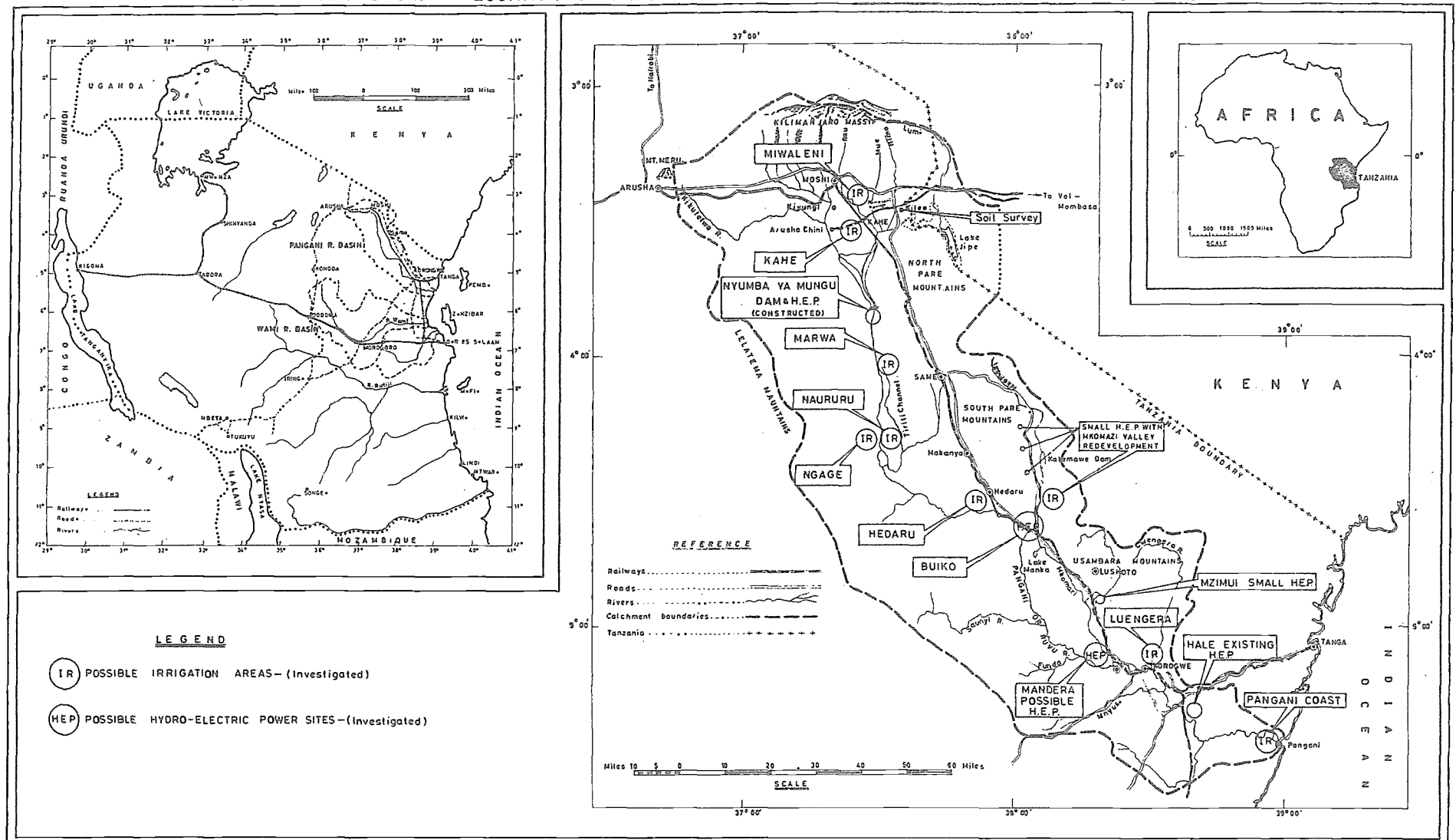
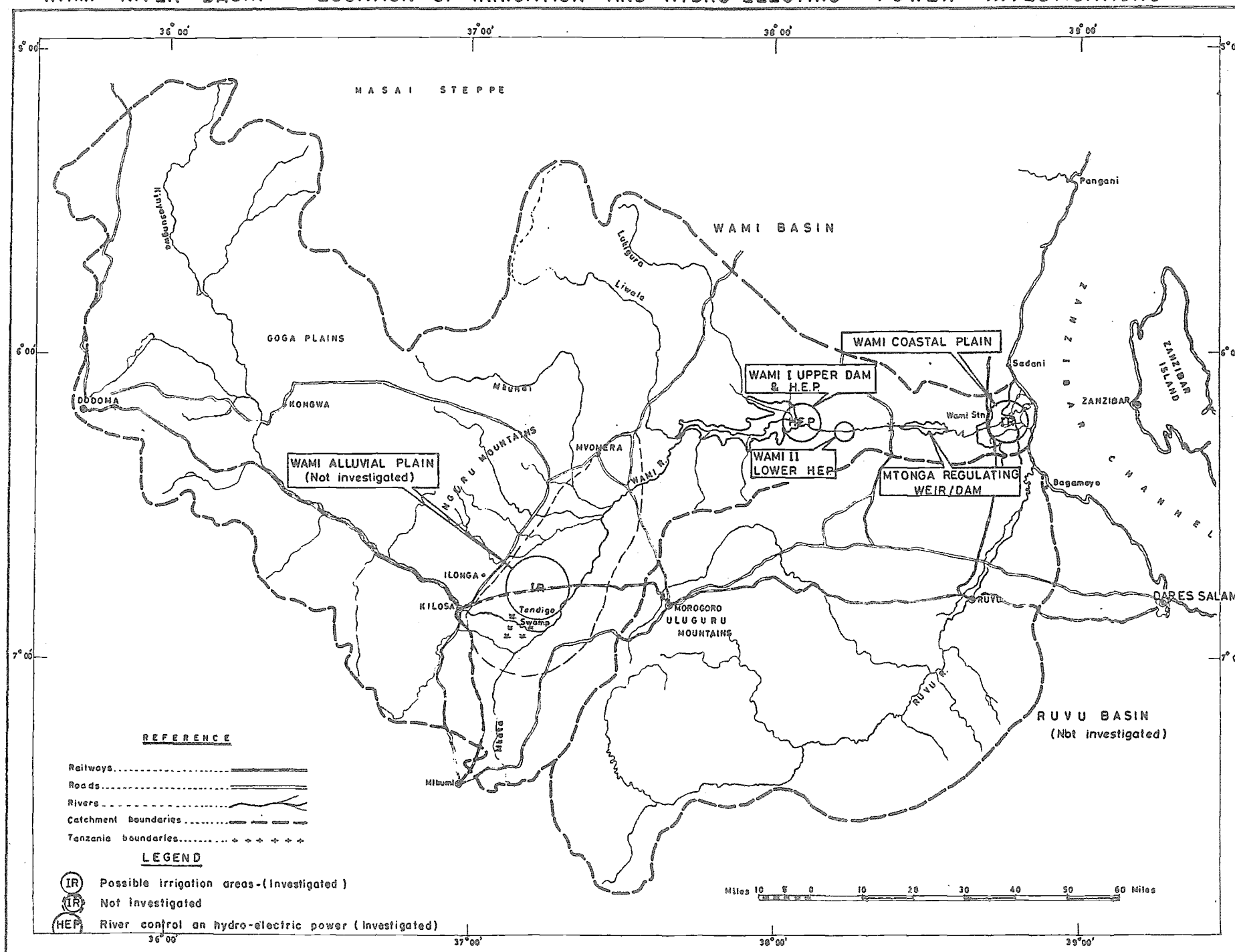


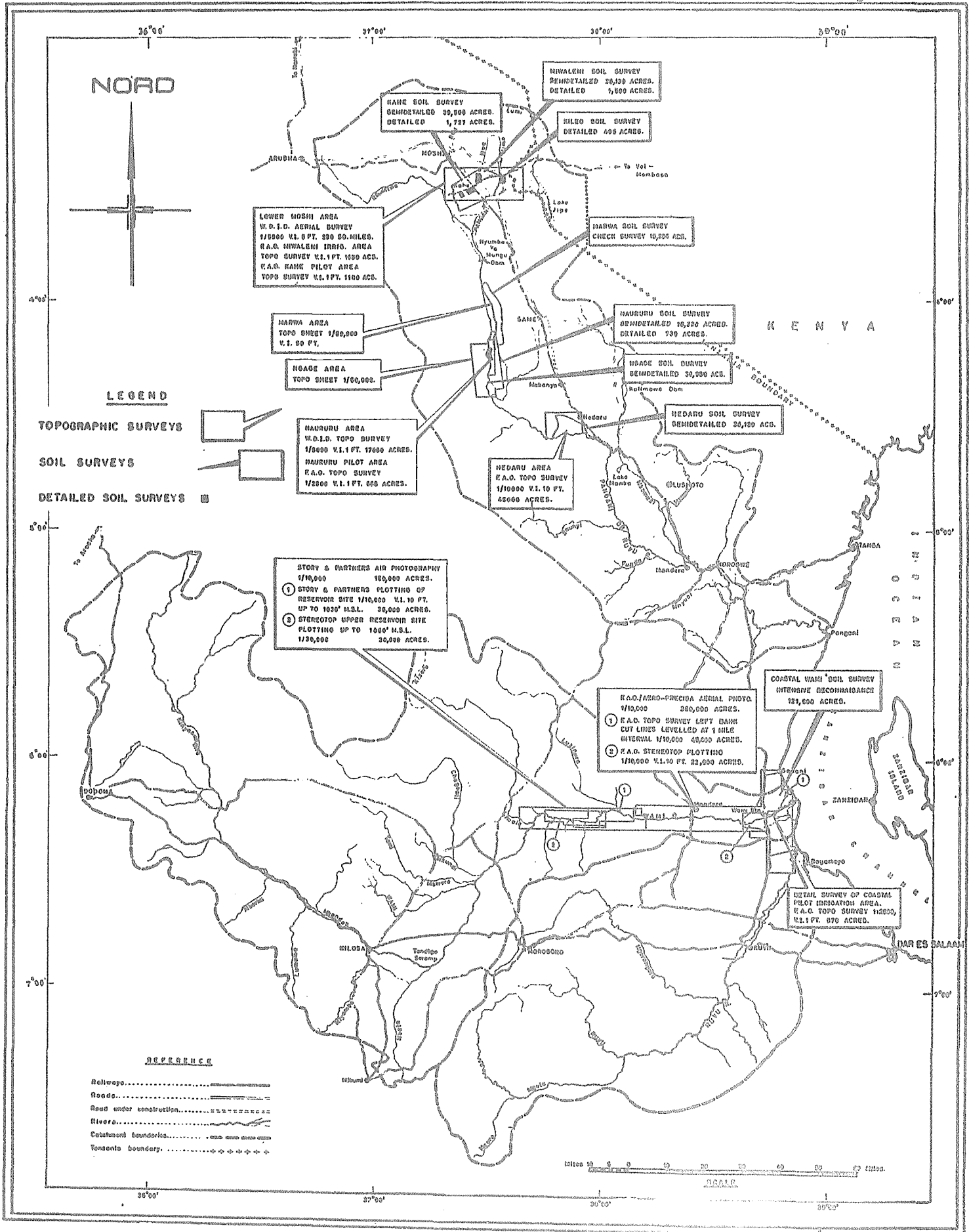
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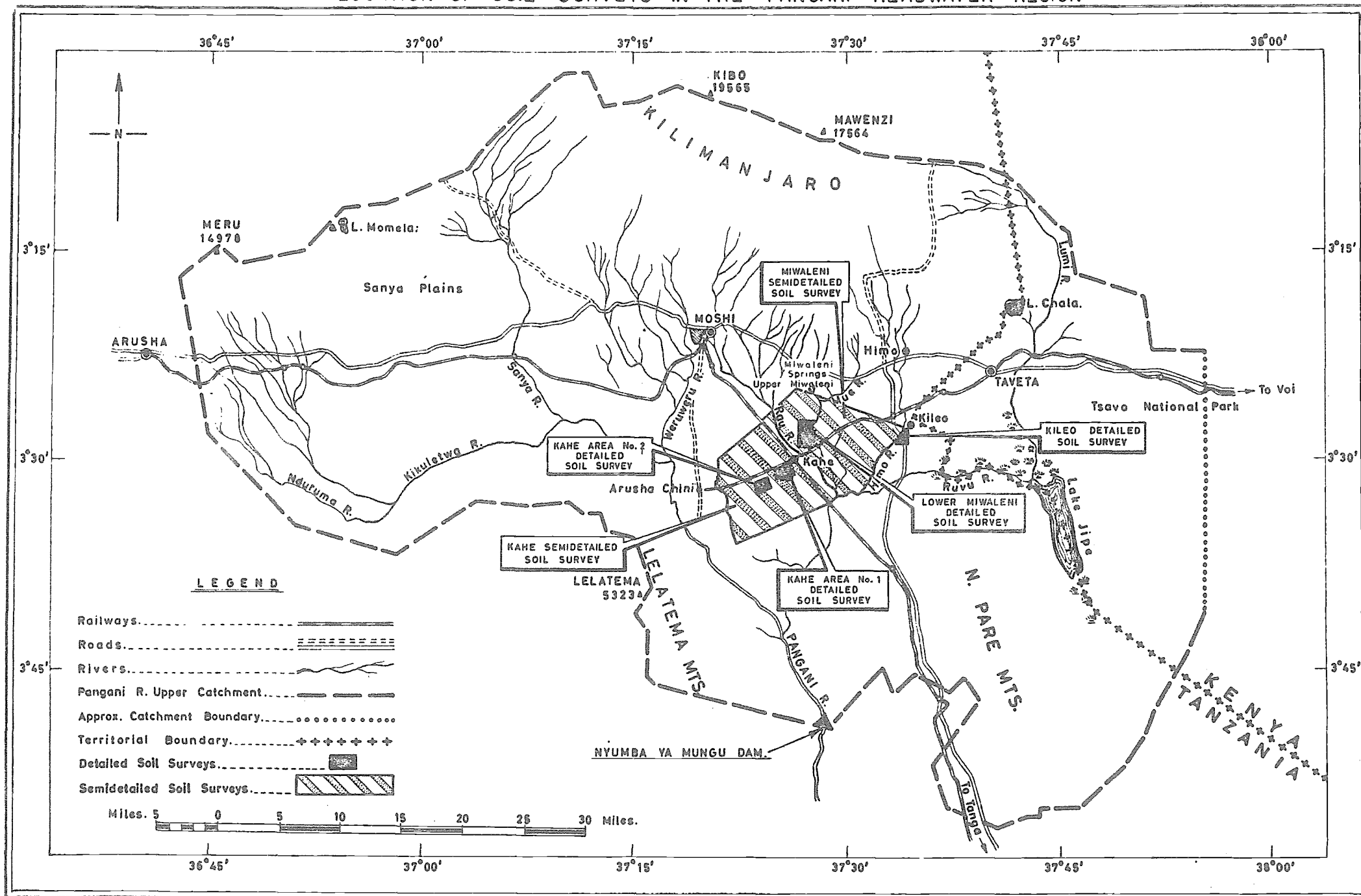
TANZANIA WAMI - RIVER BASIN LOCATION OF IRRIGATION AND HYDRO-ELECTRIC POWER INVESTIGATIONS

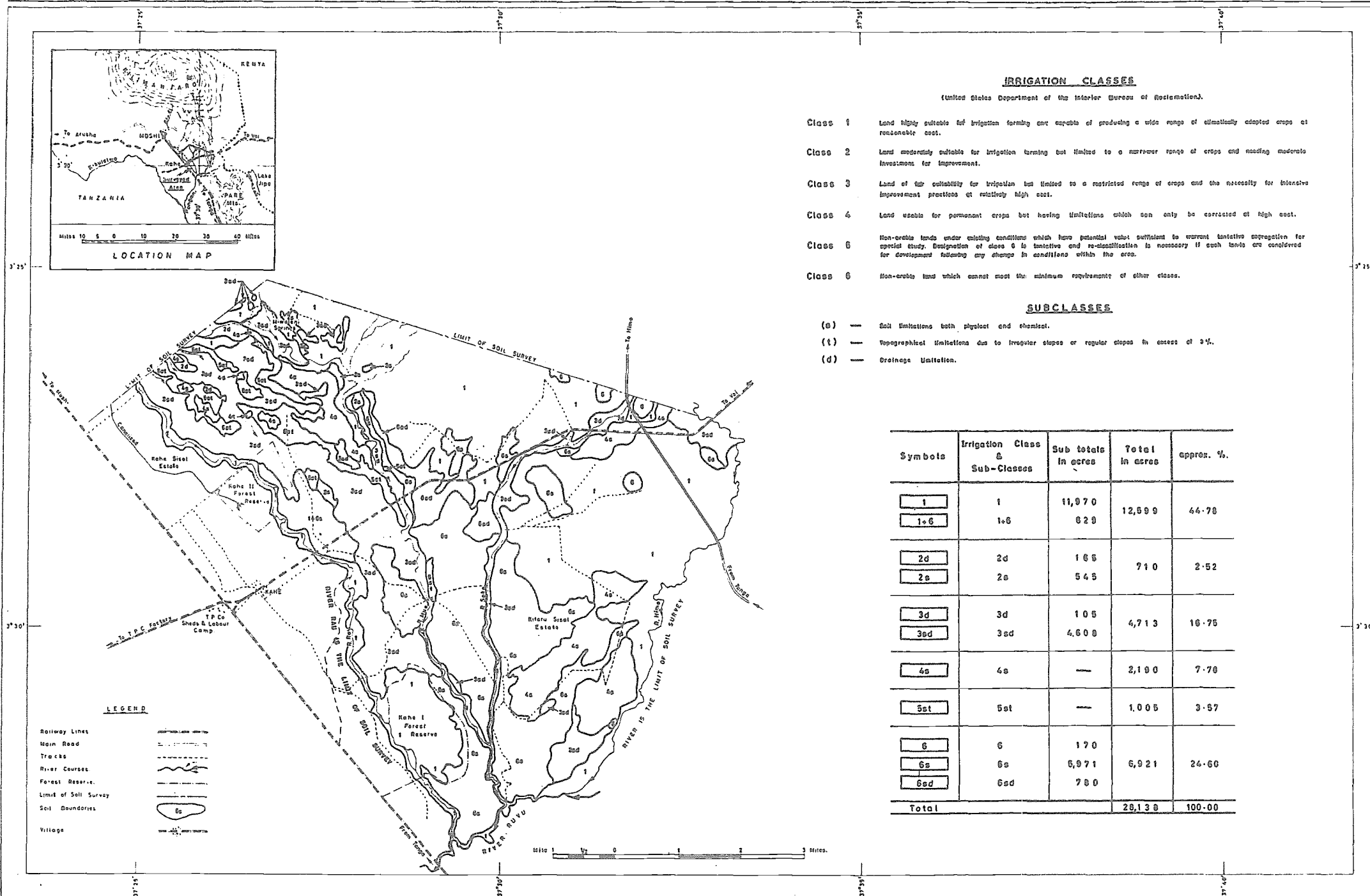


AREAS OF TOPOGRAPHIC AND SOIL SURVEYS of PANGANI-WAMI RIVER BASINS IN TANZANIA

Figure 3

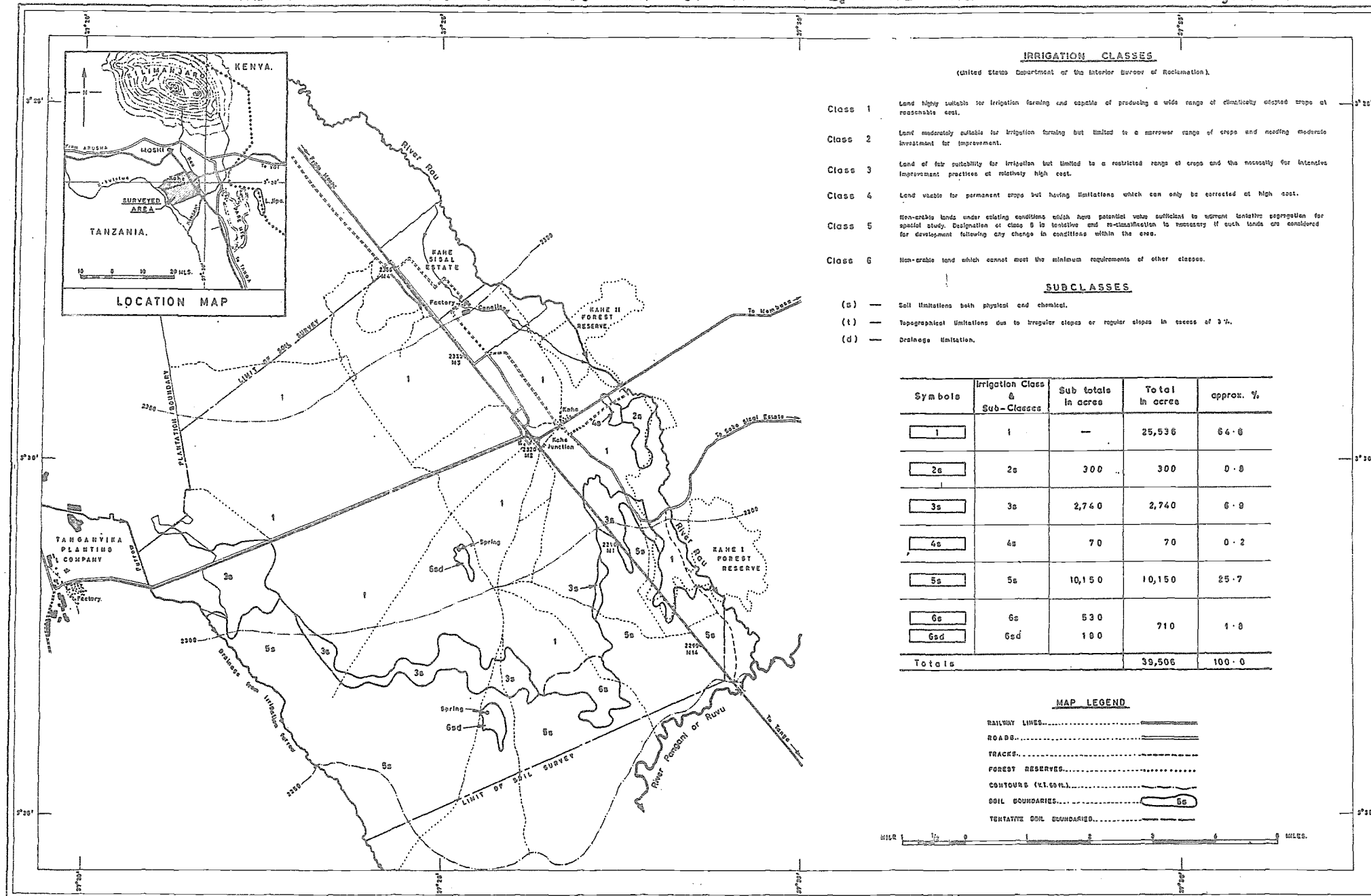


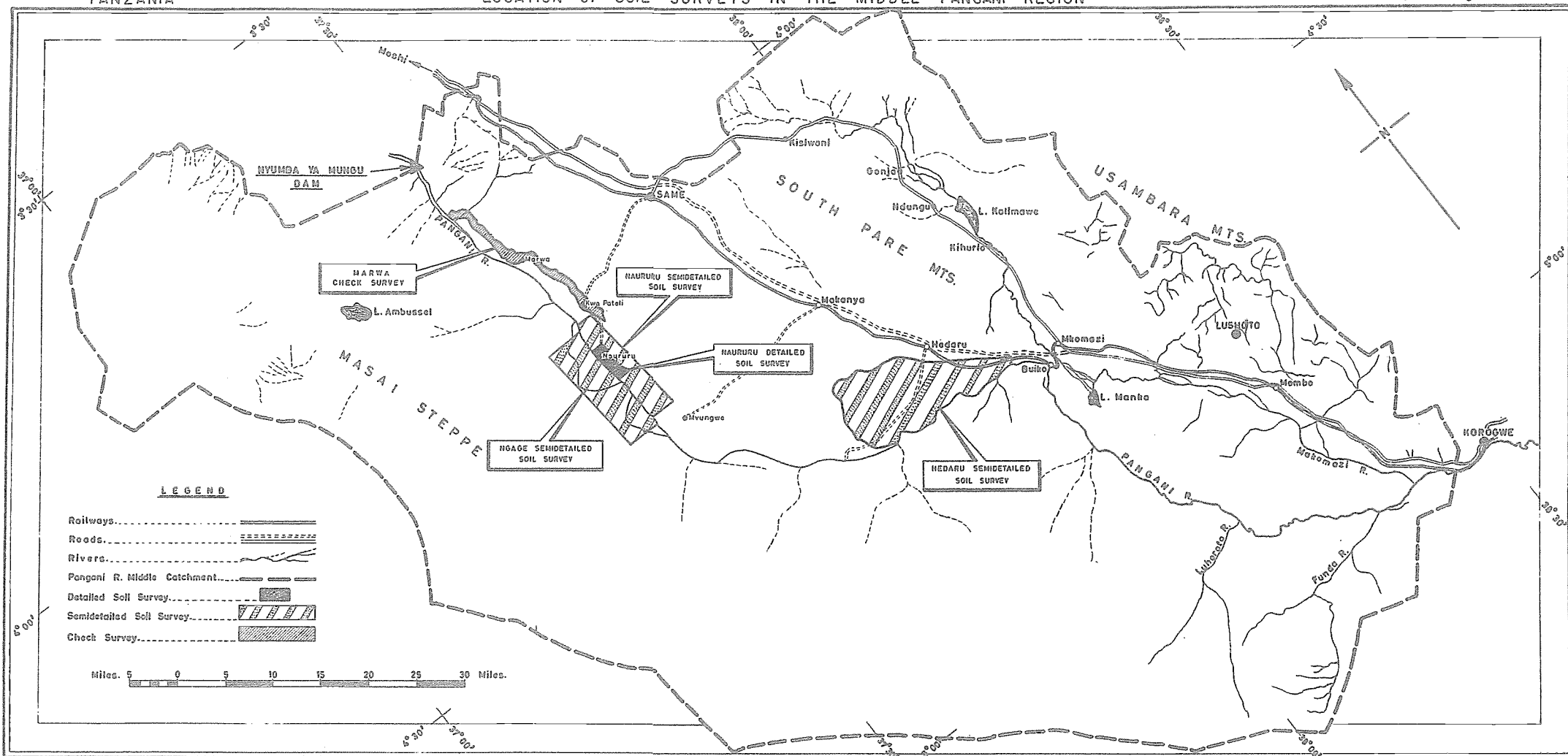


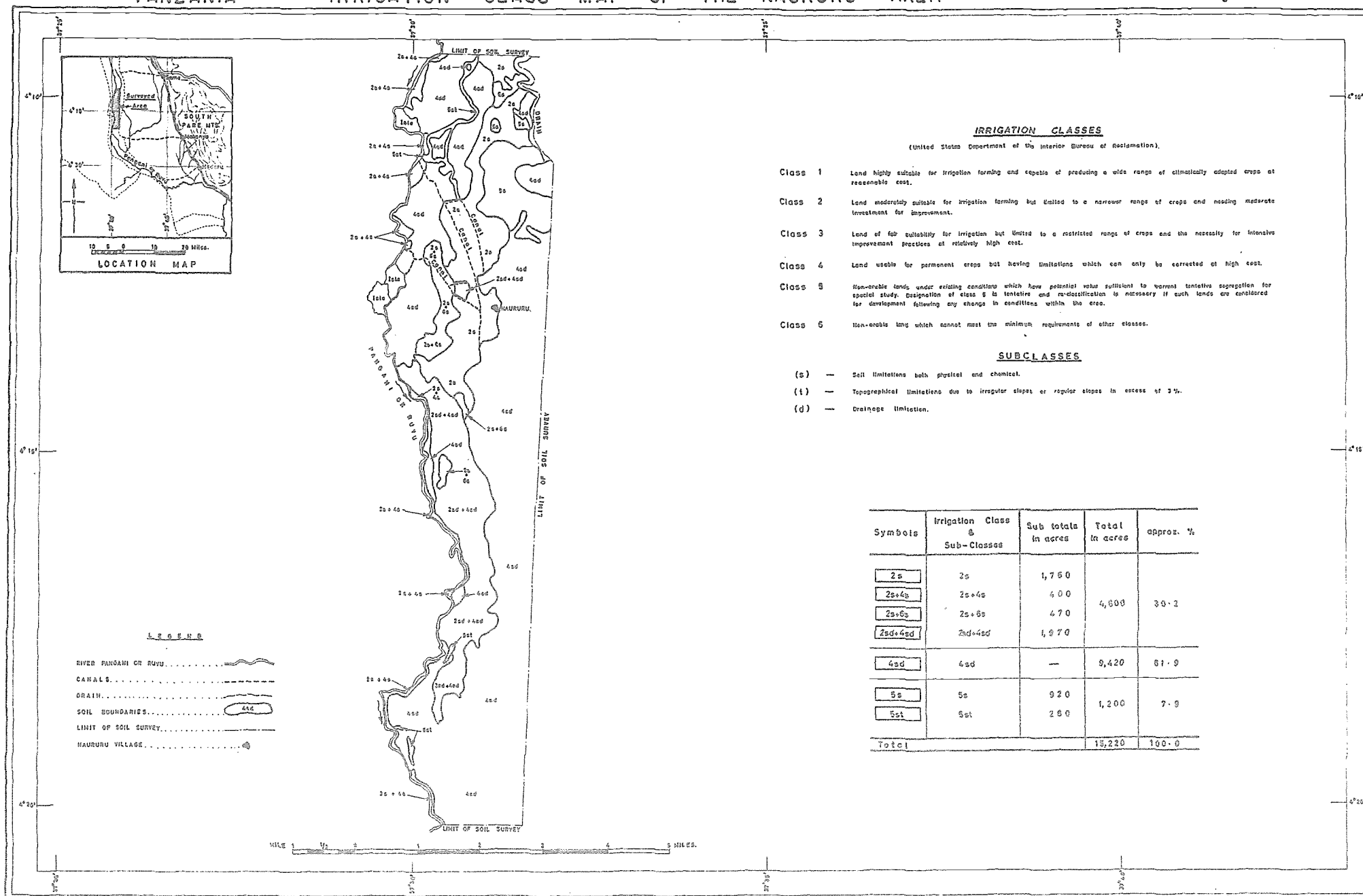


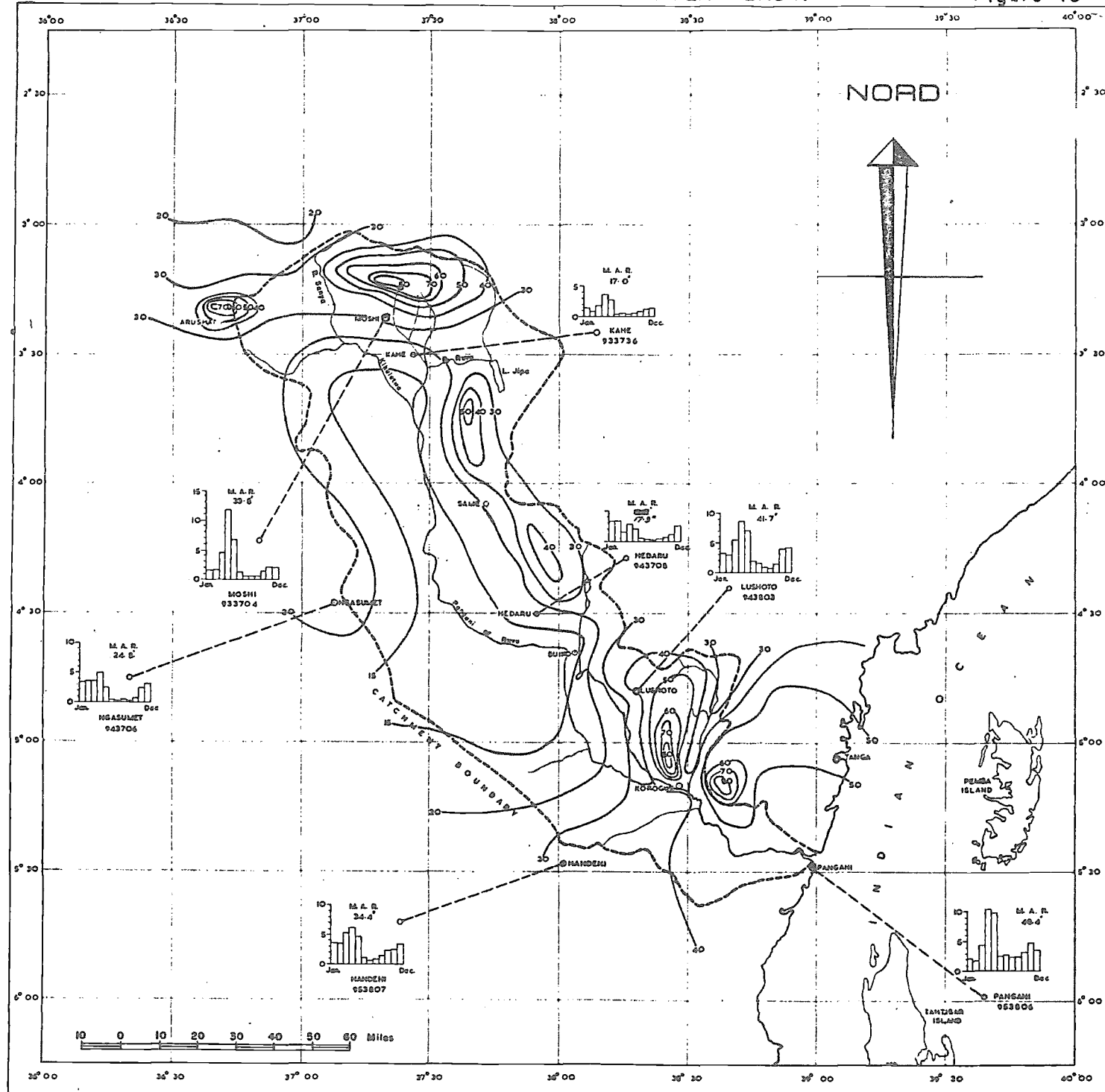
TANZANIA - IRRIGATION CLASS MAP OF MAP THE KAHE AREA

Figure 6





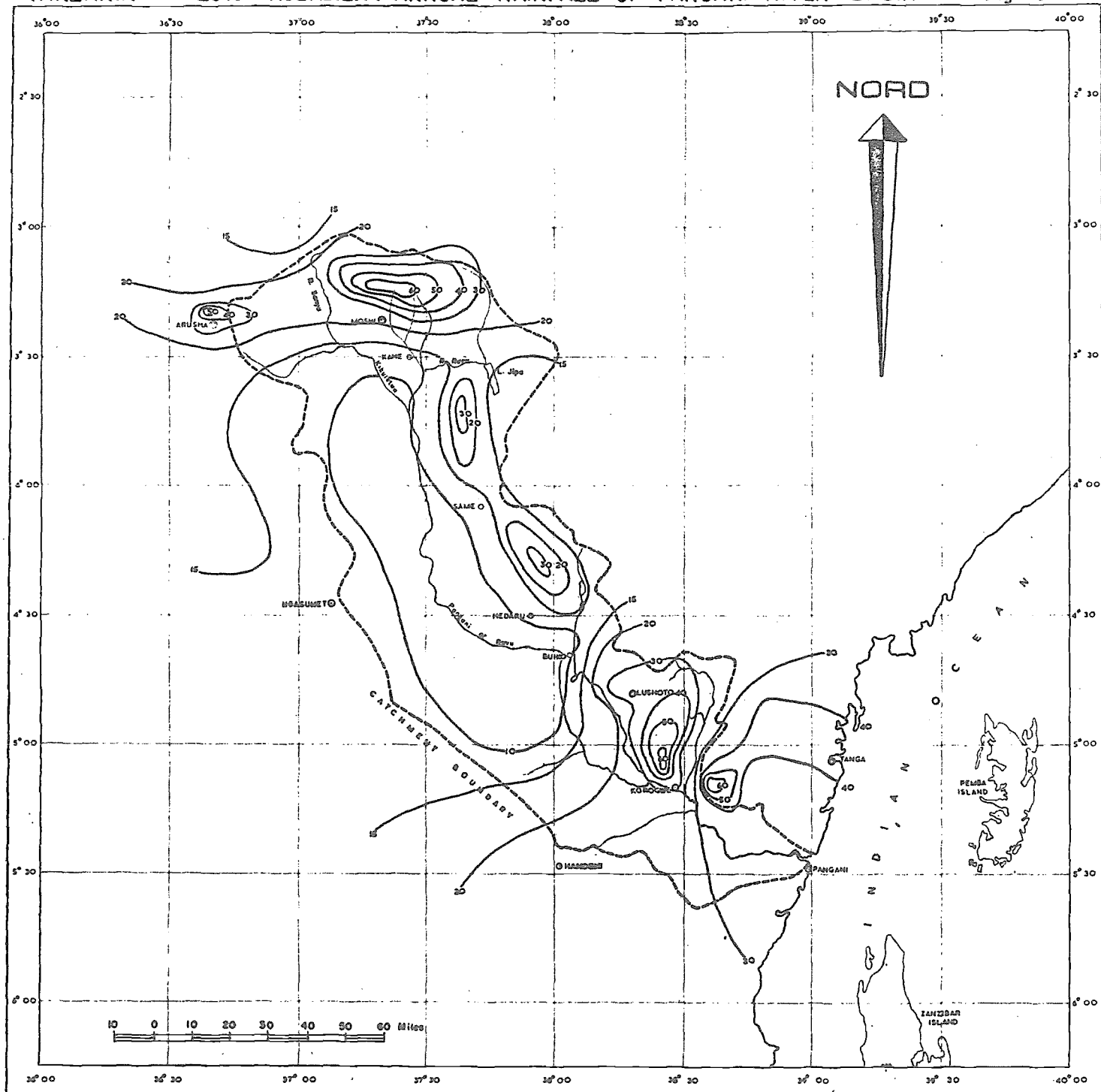


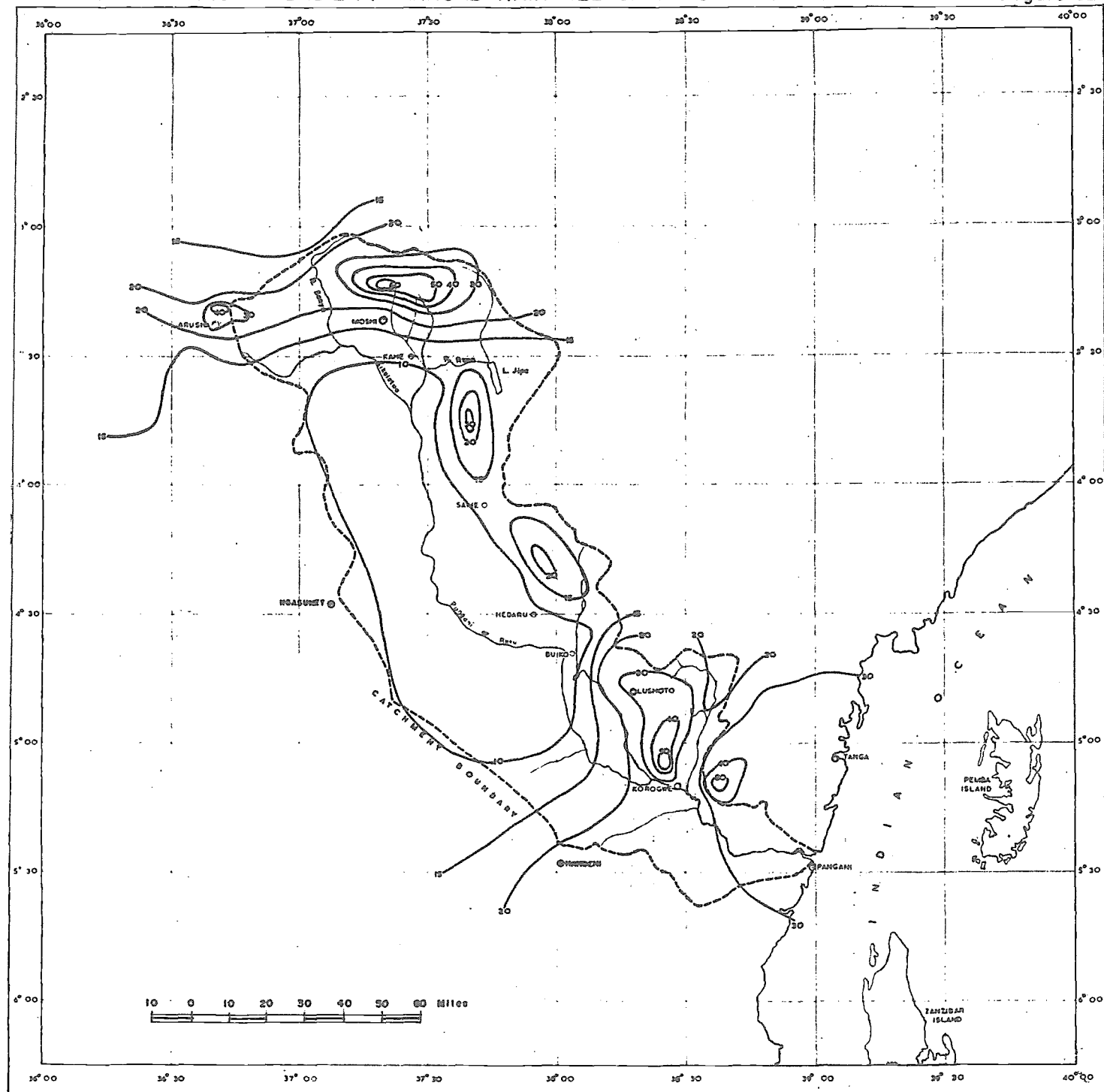


TANZANIA

20% PROBABILITY ANNUAL RAINFALL OF PANGANI RIVER BASIN

Figure II





TANZANIA

NAURURU IRRIGATION SCHEME

