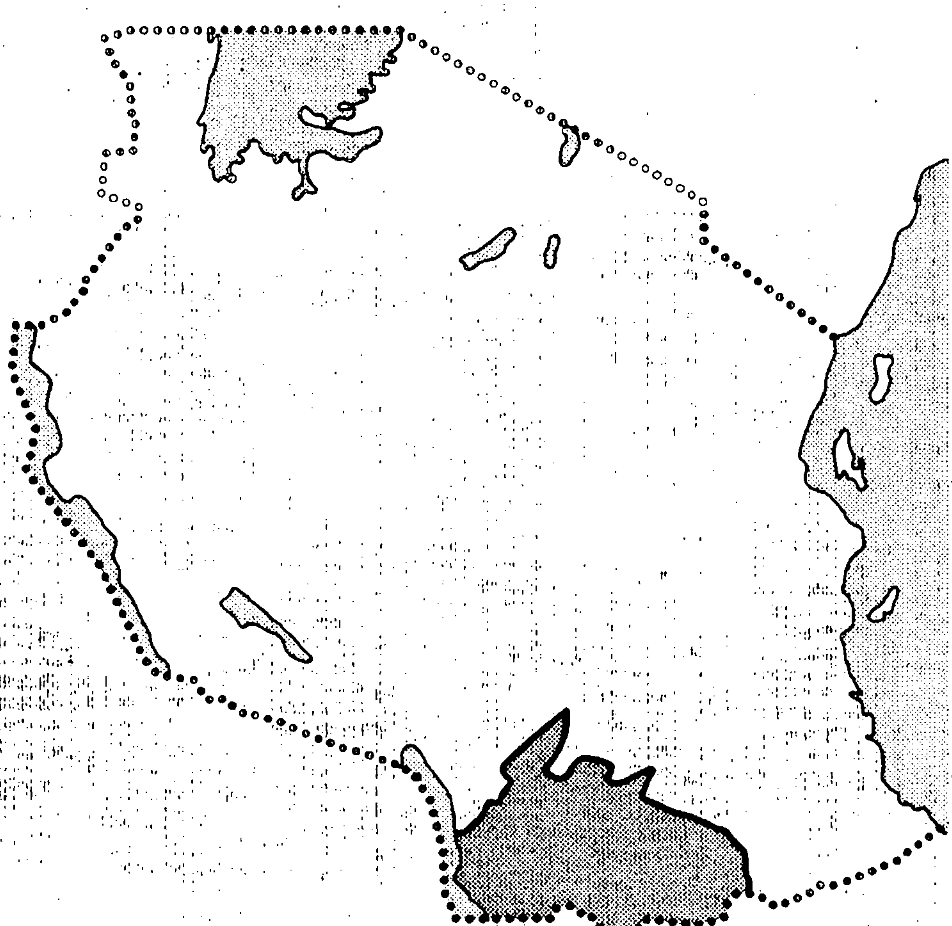
UNITED REPUBLIC OF TANZANIA

DANISH INTERNATIONAL DEVELOPMENT AGENCY • DANIDA

RUVUMA WATER MASTER PLAN

SUMMARY
VOLUME 3



CARL BRO • COWICONSULT • KAMPSAX - KRÜGER •

UNITED REPUBLIC OF TANZANIA

DANISH INTERNATIONAL DEVELOPMENT AGENCY • DANIDA

RUVUMA WATER MASTER PLAN

SUMMARY
VOLUME 3

CARL BRO • COWICONSULT • KAMPSAX - KRÜGER • CCKK 1982

GUIDE TO RUVUMA WATER MASTER PLAN

VILLAGE WATER SUPPLIES	DEVELOPMENT FRAMEWORK	POPULATION	3/2, 4A/2/4, 12/3
		LIVESTOCK	3/2, 4A/2/3/5, 12/2
		AGRICULTURE	3/2, 4A/3/5, 11/3, 12/2
		INDUSTRY	3/2
	VILLAGES AND EXISTING WATER SUPPLY	INVENTORY	5A/1, 12/4
		DEVELOPMENT	4A/4
		TRADITIONAL W.S.	4A/6, 12/5
		IMPROVED W.S.	4A/6
	WATER USE AND DESIGN CRITERIA	HUMAN CONSUMPTION	3/5, 5A/4, 12/8
		LIVESTOCK DEMAND	3/5, 5A/4, 12/9
		TECHNICAL ASPECTS	3/5, 5A/4
	WATER SUPPLY PLANNING CRITERIA	TECHNOLOGY OPTIONS	5A/5, 12/7
		WATER QUALITY	3/5, 4A/6, 4B/7, 5A/3, 12/5/10/11
		SOURCE SELECTION	3/6, 4B/7, 12/5
		PRIORITY CRITERIA	3/5, 5A/2, 12/12
		COST CRITERIA	5A/2/6, 12/12
	PROPOSED SUPPLIES	REHABILITATION	4B/8
		SINGLE VILLAGE SCHEMES	4B/8
		GROUP VILLAGE SCHEMES	4B/8
		SCHEME LAY-OUT AND DETAILS	5B, 5C, 5D
	COST	ECONOMIC COST	3/6, 4B/9/10, 5B, 5C, 5D
		FINANCIAL COST	3/6, 4B/9/10
	IMPLEMENTATION	STRATEGIES	3/6, 4B/10
		PROGRAMME	3/6, 4B/10
		ORGANISATION	3/6, 4B/11, 12/6
		PARTICIPATION	3/6, 4B/10/11, 12/6
WATER RESOURCES	HYDROLOGY	RAINFALL	3/3, 7/3
		EVAPORATION	3/3, 7/4
		RUNOFF	3/3, 7/5/6
		MODELLING	3/3, 7/7
		BALANCES	3/3, 7/7/8
	HYDROGEOLOGY	GEOLOGY	3/4 9/5
		GROUNDWATER DOMAINS	3/4 9/7
		GEOPHYSICS	3/4 9/8
		CHEMISTRY	3/4 9/9
		GROUNDWATER DEVELOPMENT	3/4 9/12
		DRILLING	3/4 9/11
WATER-RELATED PROJECTS	WATER RELATED PROJECTS	IRRIGATION	11/4, 12/9
		HYDROPOWER	11/4

NOTES

THE CHAPTERS REFERRED TO ARE THOSE WHERE THE MAIN DESCRIPTIONS APPEAR.

THE REFERENCE CODE 5A/6 MEANS, VOLUME 5A, CHAPTER 6.

CONTENTS VOLUME 3, SUMMARY

CONTENTS VOLUME 3, SUMMARY

CONTENTS VOLUME 3, SUMMARY

1. INTRODUCTION

1.1 General

Improvements in the rural water supply situation in Tanzania have in recent years grown into a major policy matter for the central Government. Policy decisions regarding provision of piped water supplies giving ease of access to domestic points and providing clean, potable and dependable water have been taken. The objective of serving every villager is still quite distant although remarkable progress is being made. On a national basis approximately 40% of the rural villages are presently served while the regions under study are lagging behind this figure with an average percentage supplied of 22%. These figures, however, do not take account of the schemes not operating nor of the proportion of population served.

The benefits of an improved water supply are i.a. shorter walking distances, higher reliability and health improvements. The improved water supply, when combined with education in better hygienic practices, and the improved health facilities should be able to contribute to the general well-being of the rural population.

This volume purports to summarise some of the main topics of the Water Master Plan. One of these is the development context outlining the planning framework while the hydrology and hydrogeology studies are concerned with establishing the extent of the resources, surface water as well as groundwater. The present water use in the villages is studied and appropriate design criteria derived after which the main plan has been prepared. Finally, the potential for development within other water-using sectors, like irrigation and hydropower, has been evaluated.

2. DEVELOPMENT CONTEXT

2.1 Regional character

Ruvuma Region has a predominantly agricultural based economy, with almost the entire population depending on agriculture for their livelihood although just over 5 per cent of the total area is cultivated.

The climatological and topographical variations in the region result in considerable variations of life-style and densities.

In the west of the region the higher land form and lake influence leads to mean annual rainfalls of 1,300 mm. The highest densities and most productive agriculture is found in this area.

To the east of the region the land becomes more undulating and climatically dryer with rainfalls reducing to around 1,000 mm mean annual values.

The administrative and settlement pattern of the region is diagrammatically shown in Figure 2.1.

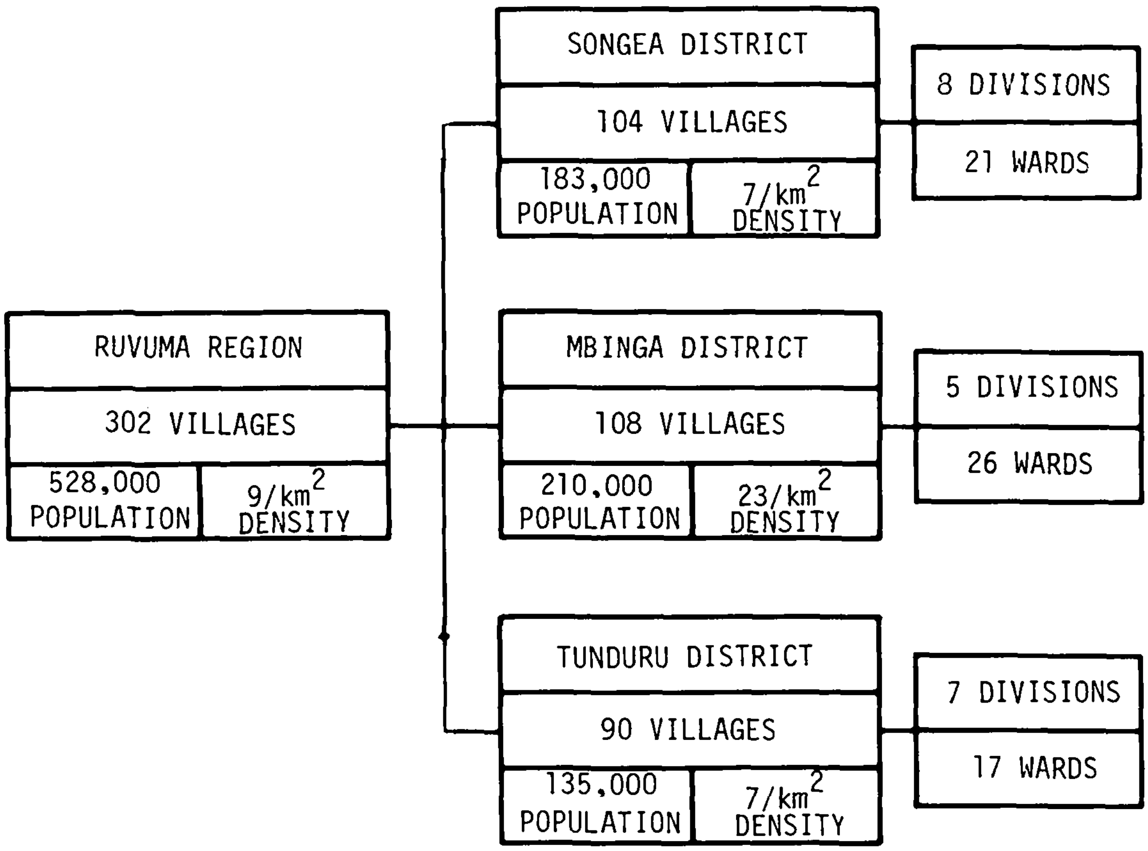


Figure 2.1 - Ruvuma Region administrative and settlement characteristics.

2.2 Development strategies

2.2.1 General

The rural development strategy is centered on the principle of cooperative or "ujamaa" farming in collective village settlements where associated social welfare benefits can be economically established.

Villagisation has been accomplished by some 99 per cent of the villages in Ruvuma Region.

Village development is in the hands of a committee who are administered by a chairman, manager and secretary. After establishing village needs and priorities in the development context, the village committee communicates these for further consideration through the ward, division, district and regional administrative hierachy as appropriate.

In both the agricultural and industrial sectors, development policy is based on self-reliance with emphasis on small-scale farming and village industries.

Major constraints to present development in the rural areas of the region are communications, marketing facilities, skilled manpower and foreign reserves.

Ruvuma region is particularly remote in relation to the rest of the country although the new road from Makambako to Songea is expected to significantly improve this situation.

The area covered by the region, 61,000 km^2, also results in many remote areas with poor communication with the regional headquarters, and thus the rest of the country. Tunduru District has in fact better communications with Mtwara than Songea.

2.2.2 Agriculture

Farming is dominated by the small-scale cooperative system.

Maize is the most important food crop in the region. The most important cash crops are coffee, cashew nuts and oil seed. Coffee is grown in small-scale in the northern parts of Mbinga District together with some wheat. In the eastern parts of the region cashew nuts and oil seed are particularly suited to the soil conditions.

Information gathered from the village inventory on the agricultural status in the region is illustrated in Figure 2.2.

Shortage of land is generally not a constraint in the region. Response from the village inventory indicated that 85 per cent of villages had no problem. The major shortage of land was recorded in Mbinga District, 35 per cent.

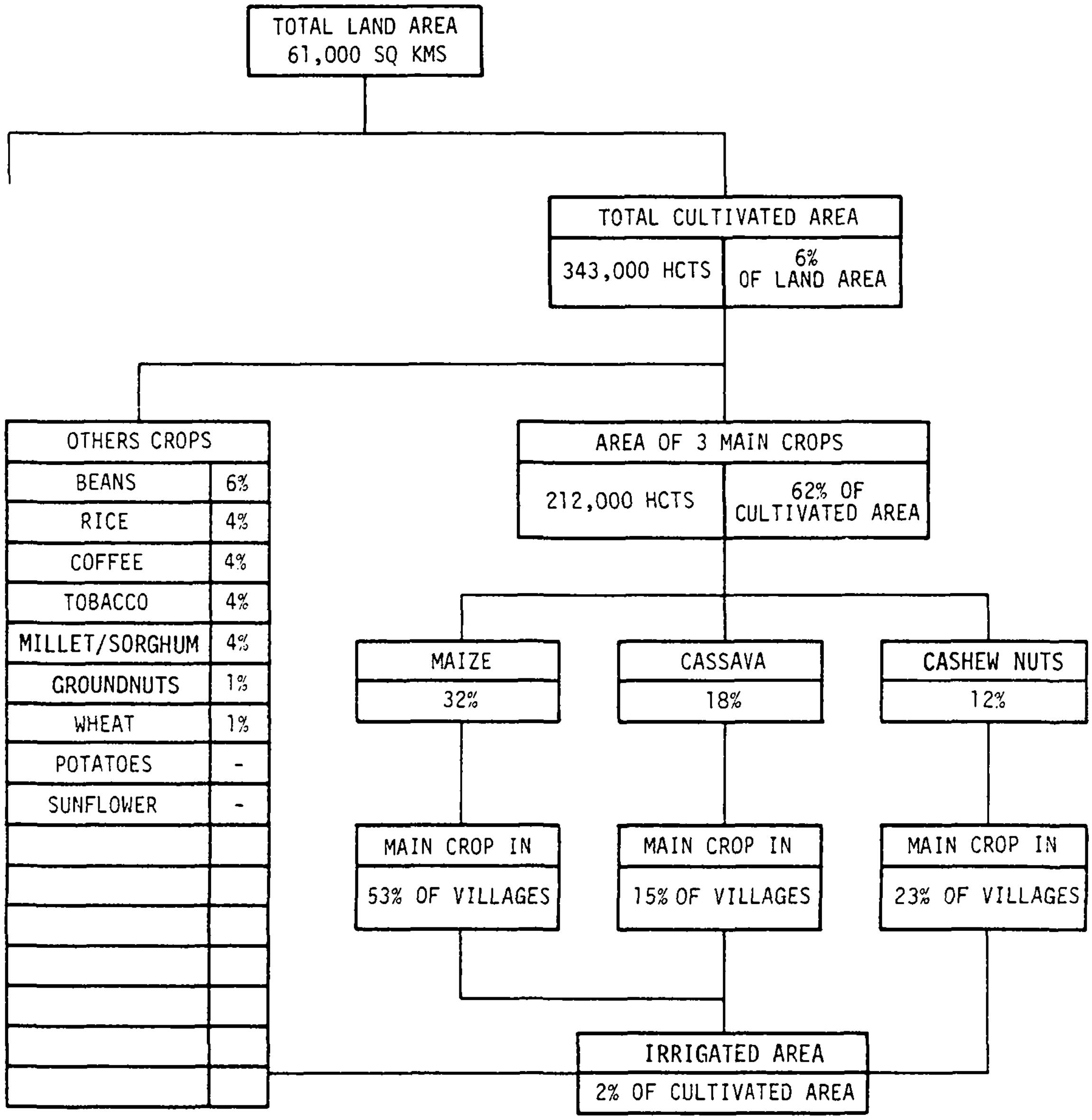


Figure 2.2 - Agricultural production - Ruvuma Region.

There is a high potential for development in Ruvuma Region, particularly in the Wet Highland Zone of the region, which has a per capita income already well above the national average and rising. The new road to Makambako is also expected to make a significant effect on the marketing potential of this part of the region.

2.2.3 Livestock

Livestock does not play a significant role in the farming community of the region.

Goats play a more important role than cattle due to the high incidence of tsetse fly in the region. Donkeys are kept in relatively few parts of the region.

Information abstracted from the village inventory on livestock is illustrated in Figure 2.3 along with other sources of information.

	VILLAGE INVENTORY	MINISTRY OF LIVESTOCK DEVELOPMENT
CATTLE	39,000	44,000
SHEEP & GOATS	93,000	80,000
PIGS	43,000	12,000
DONKEYS	850	-

Figure 2.3 - Livestock figures - Ruvuma Region.

The Socio-Economic Group indicated that their village level studies pointed to an underestimate of the cattle population in the village inventory of 1.5 to 2.5 times. However, since there is reasonable correlation with the official figures we have assumed a population of around 50,000 head or 0.1 units per capita approximately.

The development trend is to improve the quality of stock and quality and quantity of milk. Several state ranches occur in all three districts.

2.2.4 Fishing

The fishing industry proves an important income to dwellers on the Lake Nyasa Shore. Most of the marketing is done locally because of communication problems and delays.

2.2.5 Industry

Industrial development is an essential part of the strategy for self-reliance. In 1973 guidelines were issued which emphasised the importance of the development of small-scale industries by village communities.

In the short term, priority is being given to industries providing basic needs of the Tanzanian people, agricultural, constructional, transport-related, foreign exchange earning and technologically orientated manufacturing.

Most of the present medium-scale industries are based, or planned, in Songea town with the exception of a cashew nut factory planned for Tunduru. There are plans for development of small-scale industries in each region and development of a new estate has started in Songea. Planned production will include printing, soap making, weaving, tailoring, carpentry and joinery.

The development of rural industries is unlikely to take place generally for some time. The concentration of effort is more likely to be placed on the specific projects listed above.

The village inventory showed that in 93 per cent of the villages in the region no industry occurred.

2.3 Population growth and village development

2.3.1 Population growth

The population projected for the water master planning of the region is based on the results of the 1967 and 1978 census information. These census growth figures were applied generally at divisional level with local adjustments being made to take into account special circumstances and migrating tribes. The growth rates applied and the resultant 2006 populations, which is a 20 year planning horizon based on the mid-point of the projected 1982 to 1991 implementation period, are illustrated in Figure 2.4.

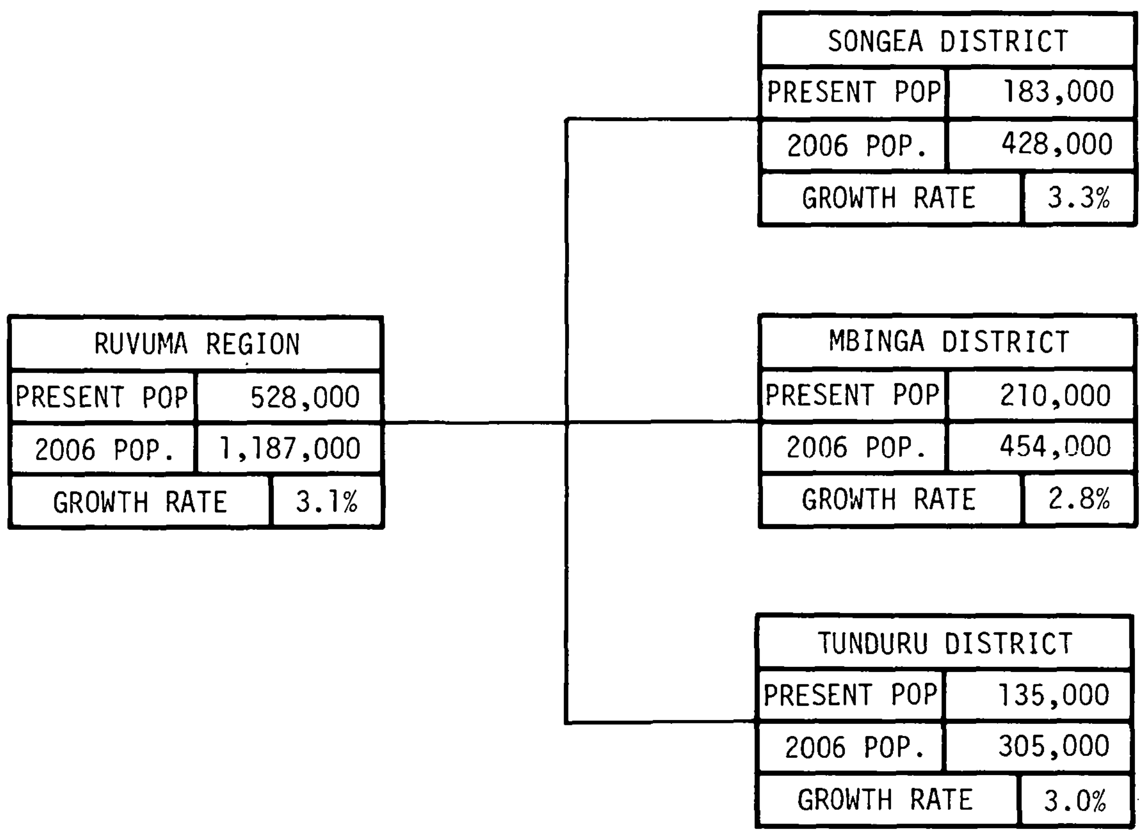


Figure 2.4 - Projected population growths - Ruvuma Region.

2.3.2 Village character

Villages tend to be located along feeder roads which in turn are often following the routes of ridges in many parts of the region. Consequently, this has in many cases proven to be an unsuitable location for an economic water supply system.

Again in consequence of their location along feeder roads, villages have a tendency to be of elongated character, which is not an economic shape for a water supply distribution system.

Of the villages located in the region 99 per cent were found to be officially registered. Those villages not registered were given a reference number outside the normal registration numbering system.

The village boundaries were located to the extent possible in order to show the character of the village, its potential for development and its locational reference to the rest of the surrounding area. In many cases, however, village information on boundaries was not available or was in conflict with the enumeration maps. We have attempted to compromise to the best of our ability all available information on village boundaries and consider these to give a fair representation of the nature of the villages in the region. The boundaries shown, however, should not be used to delineate legal village limits.

The location of villages throughout the region and the demarkation of village boundaries together with administrative boundaries are shown in Drawings R-1 to R-4.

Although the majority of villagers are living in the main habitated area of the village, this character changes in different parts of the region. It was generally found that cattle owners lived more on the outskirts of the village than those who cultivated the land. Therefore, the nature of village habitation tends to follow the pattern of rural livelihood practiced.

Even in villages when the majority of villagers lived inside the main habitated area, villages were found to be quite spread out with densities of this habitated area ranging from 1,000 to under 200 persons per square kilometre. Densities of under 500 per square kilometre were found to be very costly in terms of a piped distribution network, and where such villages occur, consideration of in-filling in the future rather than further spreading of the village is necessary. It is considered that in most parts of the region an area of land of 1 hectare per family is an adequate provision for immediate proximity of private farming. The majority of fields for cooperative farming would then be situated outside the main habitated area limits. Such an arrangement would result in village population densities of between 500 and 700 per square kilometre and economic piped distribution networks.

The nature of villages as presently found in the region are illustrated in Figure 2.5 together with the possible situation at the end of the planning period, 2006.

RUVUMA REGION

VILLAGE SIZE		AVERAGE	
	PRESENT	1750	
	2006	3930	
MAIN POPULATED AREA	>80% HOUSEHOLDS	<40% HOUSEHOLDS	
	79%	9%	

SONGEA DISTRICT

VILLAGE SIZE		AVERAGE	
	PRESENT	1760	
	2006	4120	
MAIN POPULATED AREA	>80% HOUSEHOLDS	<40% HOUSEHOLDS	
	87%	1%	

MBINGA DISTRICT

VILLAGE SIZE		AVERAGE	
	PRESENT	1940	
	2006	42000	
MAIN POPULATED AREA	>80% HOUSEHOLDS	<40% HOUSEHOLDS	
	56%	25%	

TUNDURU DISTRICT

VILLAGE SIZE		AVERAGE	
	PRESENT	1500	
	2006	3390	
MAIN POPULATED AREA	>80% HOUSEHOLDS	<40% HOUSEHOLDS	
	98%	0%	

Figure 2.5 - Village characteristics - Ruvuma Region.

With the projected growth rates villages in some areas can be seen to be of a size where sub-division is likely to take place before 2006. Separate reference has been made to such villages in the Water Master Plan.

2.3.3 Village facilities

The development of health and education facilities in the villages were found to be well established.

Most villages had a substantial number of tradesmen but significantly in the construction trades, associated with the formation of the villages, such as carpenters and masons and not to the same degree in water technology orientated trades of mechanical engineering and plumbing. The development of appropriate trades at village level for construction work is seen as a positive indication of potential of similar development of water technology trades if large-scale implementation programme of a similar nature to the villagisation exercise is initiated.

The service facilities in the villages were found to be minimal. No electricity services were available and less than 1 per cent had petrol or garage facilities.

The character of village facilities is illustrated in Figure 2.6.

SONGEA DISTRICT		
SCHOOL	100%	
HEALTH FACILITY	61%	
CARPENTERS	MASONS	BLACKSMITHS
95%	95%	91%
MECHANICS	PLUMBERS	
30%	30%	
NO SERVICE	87%	
BUS SERVICE	11%	

RUVUMA REGION		
SCHOOL	100%	
HEALTH FACILITY	57%	
CARPENTERS	MASONS	BLACKSMITHS
94%	93%	93%
MECHANICS	PLUMBERS	
28%	21%	
NO SERVICE	92%	
BUS SERVICE	6%	

MBINGA DISTRICT		
SCHOOL	100%	
HEALTH FACILITY	44%	
CARPENTERS	MASONS	BLACKSMITHS
100%	98%	94%
MECHANICS	PLUMBERS	
39%	19%	
NO SERVICE	95%	
BUS SERVICE	3%	

TUNDURU DISTRICT		
SCHOOL	100%	
HEALTH FACILITY	61%	
CARPENTERS	MASONS	BLACKSMITHS
87%	83%	93%
MECHANICS	PLUMBERS	
12%	11%	
NO SERVICE	94%	
BUS SERVICE	4%	

Figure 2.6 - Village facilities - Ruvuma Region.

The character of village facilities throughout the region can be seen to be effectively self-contained as regards basic social facilities and semi-skilled manpower but severely lacking in service facilities and communications.

2.4 Existing water supply structure

2.4.1 Improved water supplies

In Ruvuma Region, 21 per cent of villages, 63 in number have an improved water supply. These are fairly evenly spread throughout the region.

The majority of supplies are from surface water sources, 94 per cent, with the majority being pumped schemes.

Although a considerable amount of rehabilitation needs to be done most schemes are operating, 77 per cent. A more significant problem is the proportion of villagers within villages served by improved supplies who do not use the scheme due to domestic points being too distant or because of dissatisfaction with the scheme. In 50 per cent of villages less than 60 per cent of the population use the improved supply. Almost 80 per cent of this number gives the reason of distance for their non-use.

Taking into account these schemes presently not operating and the proportion of villages not using improved supplies in these villages served, it is calculated that only 11 per cent of the population of the region are presently using an improved water supply. This compares unfavourably with the total population of the villages served which represents 24 per cent of the regional total.

2.4.2 Design and construction

The designed capacity of schemes was found to be adequate and in many cases over-generous. However, schemes were often found to operate badly due to poor construction techniques which appear to be caused mainly by lack of qualified staff and poor supervision. The major design problem encountered was the inadequate layout of distribution network and number of domestic points for the village layout.

The selection of sources and design of intakes indicated in many cases inadequate hydrological investigation, survey and quality testing.

2.4.3 Operation and maintenance

50 per cent of schemes which breakdown are repaired in under 2 weeks. A significant proportion, 40%, take longer than 1 month and some take over 6 months.

The major reasons given for these delays in repair were transport and lack of spare parts.

On site scheme maintenance is very poor. This was particularly obvious in cases of schemes where pumping systems were installed. But also simple maintenance operations such as cleaning of intakes, repairs to leaking tanks or taps were frequently recorded as being ignored. The general impression in the villages is of a lack of interest and sense of responsibility in the upkeep of existing improved supplies.

2.4.4 Traditional sources

In 269 villages of the region, i.e. 89%, traditional water sources are still considered to be an important element of the water supply situation.

Nearly half the sources are springs in all districts but particularly in Tunduru dug holes are common. Rivers and streams account for about 25% of the region's traditional supplies and are particularly common in Mbinga District.

Water collection at traditional sources is a social outlet with large numbers gathered for bathing, washing, livestock watering as well as water collection. Consequently, considerable pollution of sources takes place.

The accessibility of traditional sources is not an extreme problem in most of the region, with almost 45% being less than 400 m distance from their nearest source and 80% being under 1 km. Only in the drier eastern areas does this latter figure reduce to under 70%.

A bigger problem than distance with regard to accessibility is the altitude difference between source and village. Because of the topographical nature of much of the region and location of villages along ridges, the water sources are often at the bottom of steep valleys falling away from the village. Almost 90% of villages come into this category with 30% of these having elevation differences of more than 50 metres.

Reliability of sources is again not generally problematic, 82% of sources were perennial. In Tunduru, however, 35% of sources are seasonal.

The chemical quality of water available throughout the region is good with the exception of turbidity, iron and pH. Bacteriological quality cannot be judged with confidence on the basis of a single sample for each source but statistically the results showed around 30% indicating some bacteriological pollution. Protection of sources was almost non-existent. Only in areas where epidemics had been experienced did the people seem to have any appreciation of the need to protect their water source from pollution.

3. HYDROLOGY AND SURFACE WATER RESOURCES

3.1 General

The hydrological studies undertaken as part of the present Water Master Plan for Iringa, Ruvuma and Mbeya Regions have had as their primary objective to assess the availability of surface water resources for human utilisation, with particular emphasis on rural water supply. A secondary objective has been to study the hydrology of the regions in a more general context in order to determine their overall water balance. As an important part of this activity detailed modelling studies of the hydrological processes from rainfall to runoff have been carried out for three selected representative catchments (index areas) in the regions.

Although this volume purports to present a summary of the Water Master Plan for one region only, the surface water resource related descriptions are common to the three regions as these aspects are best described on an interregional basis using physical divisions rather than administrative boundaries.

The hydrological study has involved extensive field work, including a comprehensive field measurement programme in 1980, and inspection of a large number of hydro-meteorological gauging stations. A computerised data base including runoff and rainfall data for all stations in the regions has been established and updated, based partly on existing data stored in Dar es Salaam and Nairobi, partly on data collected during the study period. In total, rainfall records from 289 stations with a total record length of 3,700 station years and runoff records from 74 stations with a total record length of 1,047 station years have been included in the study.

The project area, generally known as the Southern Tanzanian Highlands, is characterised by the mountains of southern Mbeya and Iringa, the relatively flat, high plains of northern Mbeya and Iringa and the undulating hills covering most of Ruvuma Region. This topography has a profound impact on the hydrology of the regions by giving rise to high rainfall, and hence high runoff and abundant surface water availability in the mountainous areas, while contributing to lower the rainfall and runoff in the flatter northern and eastern parts of the project area. Thus the general pattern of mean annual rainfall and runoff shows a remarkable dependence upon the topographical features.

The reason for this impact of topography upon the rainfall regime is the combined effect of local convergence and orographic lifting of air masses, primarily during the northeast monsoon period from December through February, but also during subsequent inter-monsoon period from March through May. The south-east monsoon from June through September brings little moisture to the project area, in which rains usually start in November during the passage of the inter-tropical convergence zone from north to south.

The surface runoff in the regions occurs within five major drainage basins. The Indian Ocean drainage basin covers Iringa, Ruvuma and more than half of Mbeya, while the remaining part of Mbeya drains to the internal Lake Rukwa drainage basin. Drainage to the Indian Ocean takes place through the Rufiji River tributaries, the Great Ruaha, the Luwegu and the Ruhudji/Kilombero Rivers as well as the Ruvuma River and the Lake Nyasa drainage system.

3.2 Rainfall

Rainfall conditions in the regions have been studied with the objective of verifying and refining existing regional rainfall maps, while at the same time providing data for the hydrological studies, particularly for the low flow assessment for water supply and the detailed hydrological studies of the three index areas.

The rainfall study has involved inspection of a large number of rain gauges and establishment of additional daily rain gauges and self-recording pluviographs in index areas selected for morethorough studies. Rainfall data have been collected, checked and stored in the data base so as to form the basis for statistical analyses and preparation of iso-hyetal maps for mean and minimum annual rainfall.

In general, a reasonably dense network of rain gauges exists in the populated areas, while the sparsely populated northern and eastern parts of the project area are inadequately covered. A total of 289 stations with 3,700 station years of data is now contained in a data base established by the Consultants in line with MAJI computer processing standards, and the average degree of data availability (ratio of total period of valid observations to total period of station operation) is 82%. Although there is a scope for improvement of the operation and maintenance of many rainfall stations the reliability of rainfall data is generally quite good.

The rainfall studies confirm the general pattern outlined above, as can be seen from the isohyetal maps in Figures 3.1 and 3.2. Mean annual rainfall varies from less then 500 mm in northern Iringa, to more than 2,600 mm in southern Mbeya. Individual annual rainfall amounts vary from less than 250 mm to more than 3,100 mm. The seasonal rainfall variation is basically unimodal, rains occuring in the period from November through May, while the period June to October is generally dry. Rainfall amounts may vary considerably from year to year. Hence frequency analyses of annual rainfall amounts at various locations show that rainfall in wet years may be 50-60% higher than in dry years and the 10-year minimum annual rainfall as shown in the isohyetal map in Figure 3.2 is about 30-50% lower than the corresponding mean annual rainfall.

Detailed studies of local rainfall patterns indicate a generally very high spatial variability, hence confirming the convectional nature of rainfall in the Southern Highlands. Heavy localised rainstorms occur, which in the wet areas may produce up to several hundred millimetres of rain in a day.

Analysis of trends for selected reliable long term stations confirm the general view that no significant change in the rainfall regime of the Southern Highlands has taken place over the past 50 years. A similar conclusion has been reached with respect to runoff conditions, and this implies that general hydrological conclusions may be drawn on the basis of the historical records available for the present study.

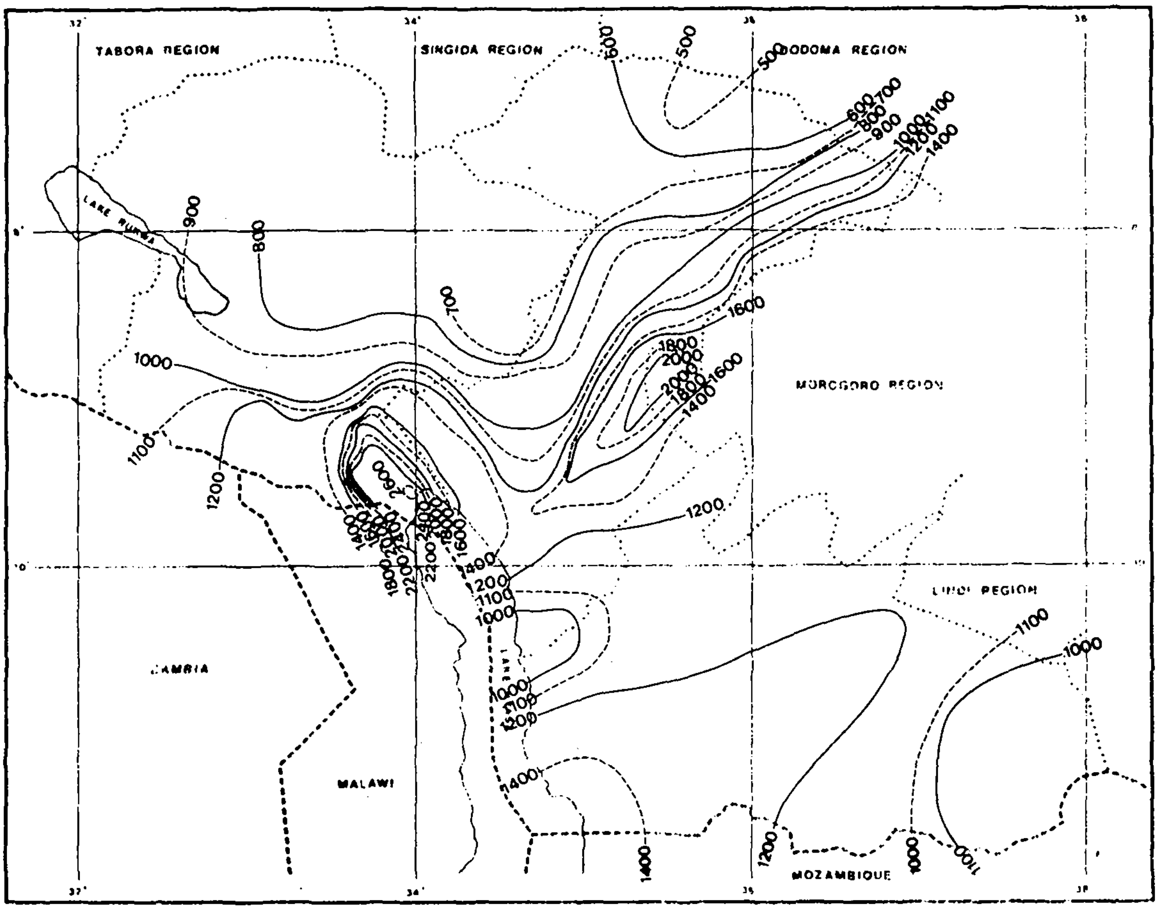


Figure 3.1 - Mean annual rainfall.

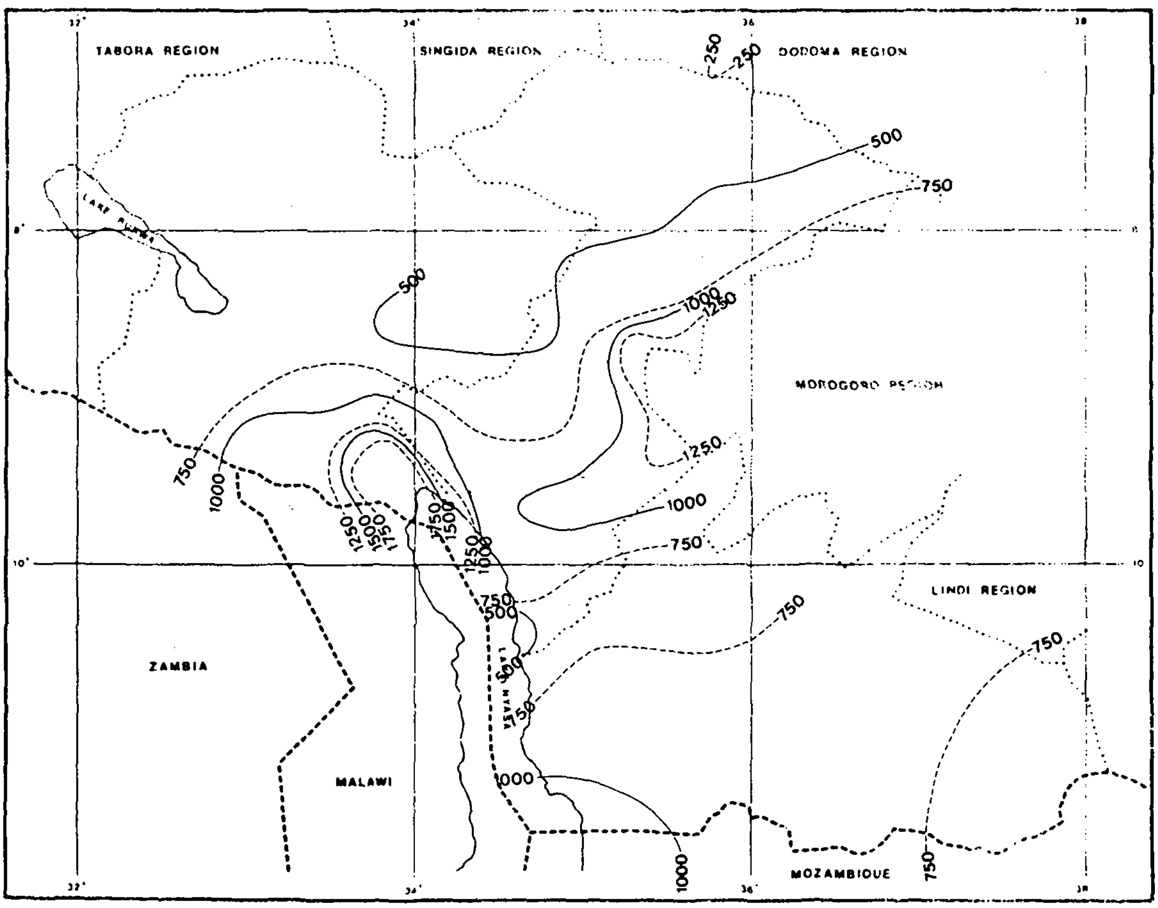


Figure 3.2 - 10-year minimum annual rainfall.

3.3 Evaporation

Studies of evapotranspiration, defined as the combined process of evaporation from free water surfaces, and transpiration from crops and natural vegetation have been essential for the detailed hydrological index area studies, as well as for the determination of overall water balances. A primary objective of these investigations has been to determine the spatial and seasonal variability of the potential evapotranspiration, which represents the maximum possible rate of water loss to the atmosphere. However, because of the lack of adequate water in the soil for the plants during the dry season the actual evapotranspiration is always less than the potential rate, and consequently, from a water balance point of view, studies of actual evapotranspiration have been equally important.

All available pan evaporation data have been collected and analysed, and some of the available climatological data have been collected and used for indirect determination of potential evapotranspiration using the Penman formula. A comprehensive comparison study between all available direct (evaporation pans) and indirect (Penman) estimates of potential evapotranspiration has been undertaken.

The areal coverage of climatological and pan evaporation stations is inadequate for detailed evapotranspiration mapping, particularly in northern Mbeya and Iringa and eastern Ruvuma. In addition the quality of data from these stations are generally rather poor, primarily because of station operation and maintenance problems. The results of the present evapotranspiration study are consequently subject to considerable uncertainty.

Having arrived at an average pan coefficient of 0.7 for converting pan evaporation measurements to potential evapotranspiration an isoline map of annual potential evapotranspiration has been prepared (cf. Figure 3.3). Evaporation rates from free water surfaces are approximately 20% higher than the potential evapotranspiration rates indicated in this map. Whereas potential evapotranspiration, as opposed to rainfall, varies only little from year to year, the spatial variability is considerable, ranging from more than 2,200 mm per year in the dry and warm northern Iringa, to less than 850 mm per year in the cool and wet highlands of southern

Mbeya and Iringa. Potential evapotranspiration generally increases during the dry season, reaching a maximum in October just before the rainy season sets in. Compared to the variation in rainfall the seasonal variation of potential evapotranspiration is rather small.

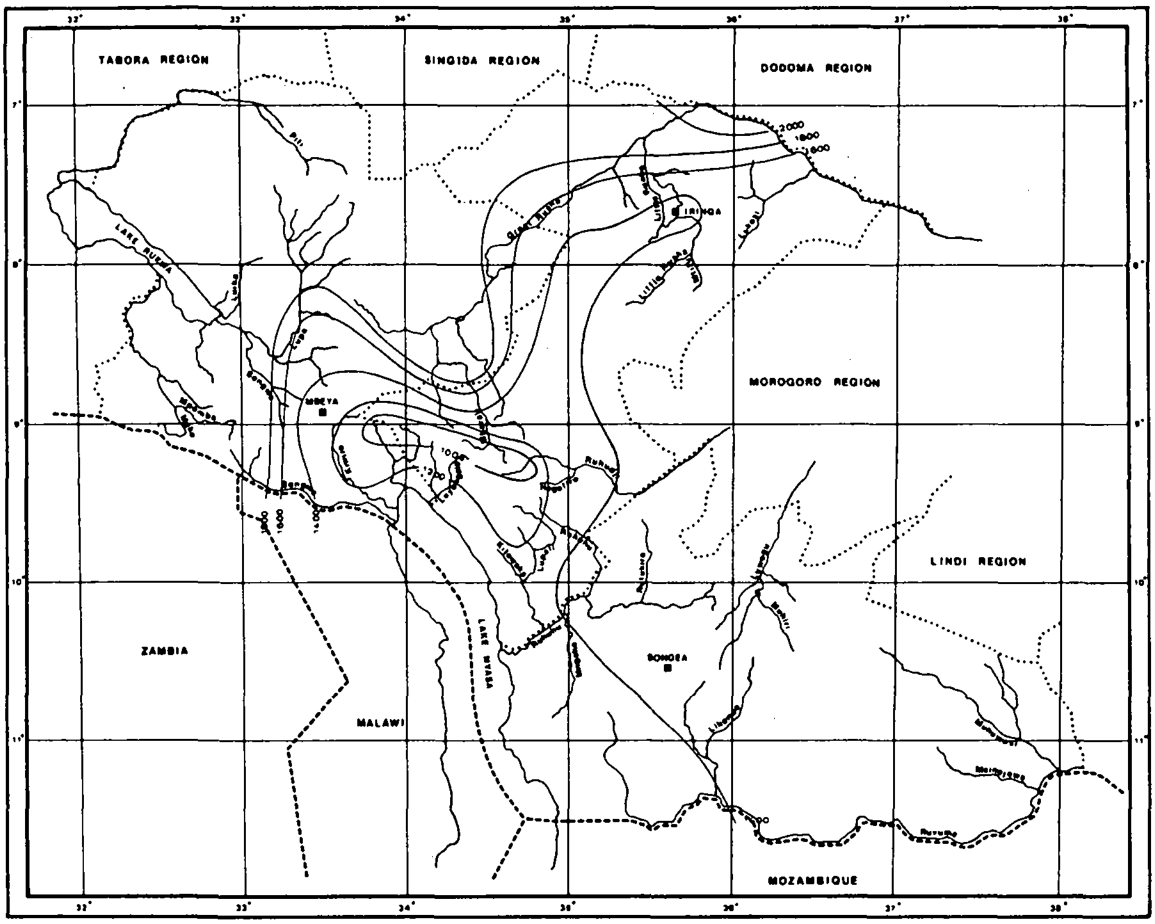


Figure 3.3 - Annual potential evapotranspiration.

Actual evapotranspiration has been estimated from mathematical modelling studies of the index areas, and also as the difference between rainfall and runoff from general water balance considerations. The ratio of actual potential evapotranspiration varies in the range 0.40-0.65, increasing from dry to wet areas.

3.4 Runoff

The main objective of the runoff studies has been to make an inventory of surface water resources for village water supply planning. For this purpose low flow conditions have been of primary interest, in the generalisation of regional runoff characteristics, as well as in the assessment of minimum yields for specific surface water supply schemes. In addition, as part of the general hydrological study, runoff conditions have been investigated in great detail, by compiling and analysing all available water level and streamflow data, and conducting detailed rainfall runoff studies in the three index areas.

In order to verify and improve the existing data material almost all the streamflow gauging stations in the regions have been inspected. A comprehensive programme of streamflow measurements has been undertaken during the dry season of 1980, particularly for the purpose of improving the rating curves (water level - streamflow relationships) in the critical low flow regime. This programme has been implemented by MAJI's hydro-teams, under the Consultants' planning and supervision. A large number of spot measurements of streamflow have been carried out in connection with the general village inventory to support the low flow evaluation.

In general, a reasonably dense network of streamflow gauging stations covers the project area, particularly after the completion of the Norwegian financed Hydrometeorological Survey of Western Tanzania. However, in certain areas, such as eastern Ruvuma and the Lake Nyasa drainage area, station coverage is still inadequate. The reliability of water level and streamflow data is generally acceptable, but satisfactory operation and maintenance is still a problem for many stations. Only little information is available on sediment transport, and the data available cover only the streamflow recession period when sediment loads are low.

The surface runoff pattern corresponds rather closely to the general unimodal rainfall pattern. Streams start rising in November-December, experience maximum flow in March-April, and have their recession period from May to October-November. In the warm and dry northern parts of Iringa and Mbeya, with average annual rainfall below 500-800 mm, streams run dry every year, and the southwestern highlands, where average annual rainfall is in the range 1,200-1,600 mm, streams are perennial, and mean annual runoff exceeds 10 $l/s/km^2$. Between these extremes, in areas like eastern Ruvuma, western Mbeya and Mufindi receiving 800-1,200 mm of rainfall annually streams are perennial or intermittent (only occasionally dry) and mean annual runoff is in the range 2-10 $l/s/km^2$.

As an important result of the present study isoline maps of mean annual runoff and 10-year minimum instant runoff have been prepared (cf. Figures 3.4 and 3.5). While based primarily on the analysis of available streamflow data, information from the spot gauging programme, interviews with the local population, hydrogeological considerations and consideration of rainfall and evapotranspiration regimes have been entered into the preparation of these maps.

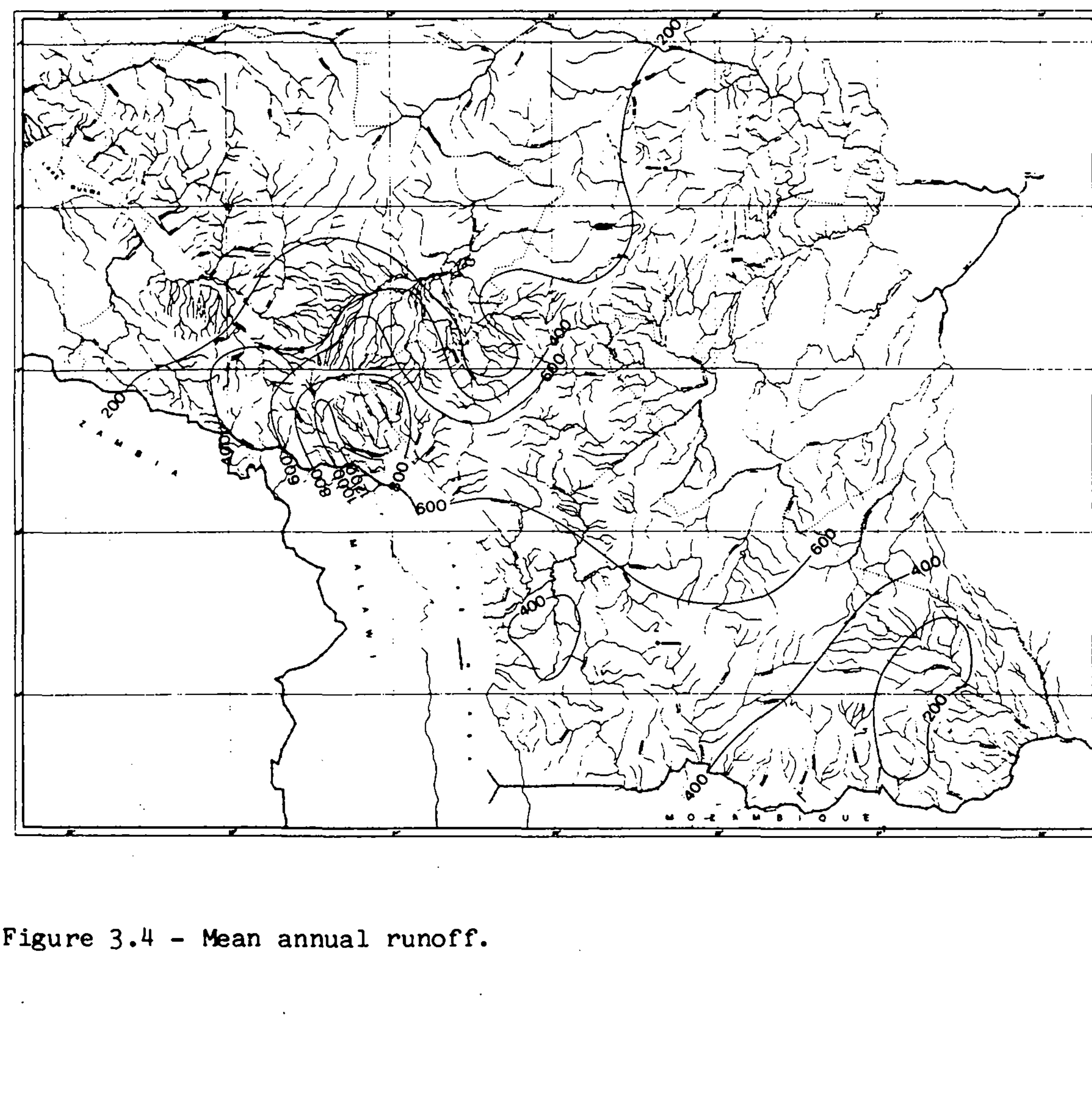


Figure 3.4 - Mean annual runoff.

3.5 Index area studies

The primary objective of the detailed hydrological studies in selected representative catchments has been to investigate water balances in different hydrological regions. Another objective of these studies has been to provide the necessary hydrological background and instrumentation for continued representative studies in the regions.

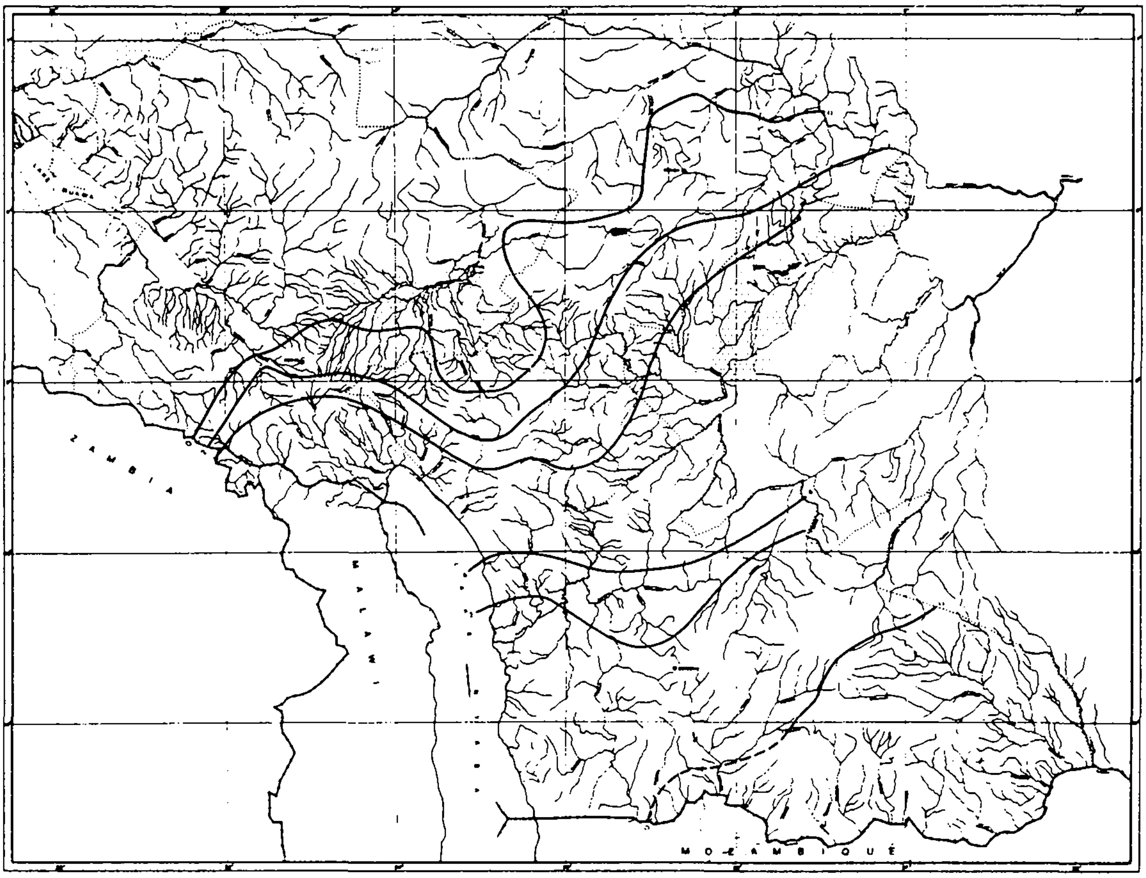


Figure 3.5 - 10-year minimum runoff.

10-year minimum runoff. (1 = Dry, 2 = 80% of streams has a 10-year minimum runoff in the interval 0-2 $l/s/km^2$, 3 = 80% of streams has a 10-year minimum flow in the interval 2-4 $l/s/km^2$, 4 = 80% of streams has a 10-year minimum flow above 4 $l/s/km^2$).

In order to meet these objectives within the scope of the hydrological studies three index areas have been selected the Kiwira River in Mbeya Region, the Little Ruaha River in Iringa Region and the Mngaka River in Ruvuma Region.

Mathematical modelling studies have been carried out using the so-called NAM-model, a hydrological computer simulation model, originally developed at the Technical University of Denmark. The model describes the land phase of the hydrological cycle by accounting, on a daily basis, for the water content in surface water, soil and groundwater storage, thus computing daily values of actual evapotranspiration, infiltration, recharge to the groundwater storage and the various runoff components: overland flow, interflow and baseflow. The required input to the model is daily rainfall and mean monthly potential evapotranspiration.

The results of the modelling studies have been very encouraging. Close agreement between observed and simulated runoff for the three catchments has been obtained, and on this basis it has been possible to extend the rather short streamflow record for Mngaka River using longer records of rainfall. The model predictions of soil moisture levels correspond closely with agricultural experience in the three catchments, soil moisture being fully depleted in the dry Lake Ruaha catchment, while being depleted only partly in the wetter Mngaka and Kiwira catchments.

Probably the most important and encouraging result from the modelling studies has been that model parameters vary little between the catchments, implying that the NAM-model with a standard set of parameters can be applied to obtain at least approximate prediction of runoff from rainfall in the major part of the project area.

With the above evidence of the ability of the NAM model to account for the hydrological processes, the model computation of non-measurable quantities such as actual evapotranspiration, groundwater recharge baseflow etc. have been utilised to support the determination of overall water balances.

3.6 Water balances

The results of the rainfall, evaporation, runoff and index area studies described above has been summarised in the form of maps showing average annual values of characteristic water balance quantities, such as actual evapotranspiration, average runoff coefficient, ratio of actual to potential evapotranspiration and water surplus/deficits defined as the difference between rainfall and potential evapotranspiration.

Gross figures in mm per year for rainfall, actual evapotranspiration and runoff an a regional basis are also presented (cf. Table 3.1)

It is emphasised that the water balance representations have been included for illustative purposes only, and that hydrological information for operational use must be found in the more detailed sections of the report and the associated data volume.

Finally, an investigation of existing water right issues have been made, indicating that during low flow periods surface water resources are quite heavily appropriated in the populated agricultural areas for southern Mbeya and Iringa, and to some extent also in the area around Iringa Town.

Catchment No.	Area Km^2	Mean annual runoff $\bar{Q}$ (mm)	10-year minimum runoff l/sec/Km^2	mm/year	Mean annual rainfall $\bar{P}$ (mm)	Mean annual potential evapotranspiration $\bar{E}_p$ (mm)	$\bar{E}_a$ $\bar{P}-\bar{Q}$ (mm)	$\bar{P}-\bar{E}_p$ (mm)	$\bar{E}_a/\bar{E}_p$	$\bar{Q}/\bar{P}$
1.1	10,900	<200	0	0	700	1,600	>500	-900	>0.31	<0.29
1.2	7,500	<200	0	0	650	1,600	>450	-950	>0.28	<0.31
1.3	5,200	200	1	32	700	1,700	500	-1,000	0.29	0.29
1.4	9,900	250	1	32	800	1,600	550	-800	0.34	0.31
1.5	2,200	500	1	32	1,050	1,300	550	-250	0.42	0.48
1.6	7,100	400	1	32	950	1,400	550	-450	0.39	0.42
1.7	2,600	350	2	63	1,100	1,500	750	-400	0.50	0.32
1.8	1,600	500	3	95	1,500	1,400	1,000	100	0.71	0.33
1.9	1,450	400	3	95	1,300	1,400	900	-100	0.64	0.31
1.10	4,700	600	4	126	1,500	1,400	900	100	0.64	0.40
1.11	5,800	800	8	252	1,900	1,200	1,100	700	0.92	0.42
1.12	4,000	600	4	126	1,400	1,200	800	200	0.67	0.43
1.13	2,150	600	4	126	1,400	1,200	800	200	0.67	0.43
1.14	5,500	450	2	63	1,100	1,300	650	-200	0.50	0.41
1.15	8,300	600	4	126	1,250	1,500	650	-250	0.43	0.48
1.16	6,750	600	2	63	1,200	1,500	600	-300	0.40	0.50
1.17	4,250	500	1	32	1,200	1,500	700	-300	0.47	0.42
1.18	1,350	300	0	0	1,000	1,500	700	-500	0.46	0.30
1.19	2,000	450	1	32	1,300	1,300	850	0	0.65	0.35
1.20	7,600	400	1	32	1,300	1,300	900	0	0.69	0.31
1.21	6,600	500	1	32	1,300	1,400	800	-100	0.57	0.38
1.22	9,600	250	0	0	950	1,500	700	-550	0.46	0.26
1.23	6,850	400	0	0	1,150	1,400	750	-250	0.54	0.35
1.24	4,400	200	0	0	950	1,500	750	-550	0.50	0.21
1.25	5,800	<200	0	0	650	1,900	>450	-1,250	>0.24	<0.31
3.1	5,300	<200	0	0	850	1,900	>650	-1,050	>0.34	<0.24
3.2	6,600	<200	0	0	800	1,900	>600	-1,100	>0.32	<0.25
3.3	2,200	<200	0	0	900	1,900	>700	-1,000	>0.37	<0.22
3.4	2,800	<200	0	0	900	1,900	>700	-1,000	>0.37	<0.22
3.5	6,500	<200	0	0	900	1,600	>700	-700	>0.44	<0.22
3.6	2,000	<200	0	0	900	1,800	>700	-900	>0.39	<0.22
3.7	5,700	<200	0	0	1,050	1,900	>850	-850	>0.45	<0.19
3.8	4,000	200	0	0	1,000	1,700	800	-700	0.47	0.20

Table 3.1 - Water balance elements.

3.7 Recommendations

As part of the present Water Master Plan study hydrological investigations have provided an inventory of available surface water resources. This inventory has been based primarily on existing hydrological data, supplemented by discharge measurements in 1980, and has resulted in regional runoff maps, as well as specific low flow estimates at a number of locations in the regions. Rural water supply schemes can in many cases be designed and implemented safely on the basis of this information, particularly in areas where surface water resources are perennial, and planned water supply schemes require little water. However, in other cases it will be necessary to make additional hydrological measurements and investigations in order to ensure that potential surface water sources do indeed satisfy design requirements, both with respect to quantity and quality.

It is strongly recommended, therefore, that supplementary (temporary) hydrological gauging stations be established soon at locations where such additional hydrological investigation may be required.

With respect to the network of permanent hydrological gauging stations it is concluded that coverage is adequate in almost all parts of the regions, and that new stations should be established primarily as part of a general network improvement programme. The rain gauge network, however, needs strengthening in the poorly covered northern and south-eastern parts of the project area, while the network of pan evaporation stations requires a thorough general improvement. An effective programme of sediment sampling needs to be initiated.

For all types of hydro-meteorological gauging stations, and not least for the climatological stations in the regions, more frequent station inspections are required in order to properly support and encourage the observers, and thus ensure regular and reliable reporting of data to the central agencies. Poor infrastructure and inadequate transport possibilities represent a major constraint in this respect.

Upon receipt of data reports from the various hydro-meteorological stations expedient control, processing, storage and publication of data are primary responsibilities of the central agencies, such as MAJI and the Department of Meteorology (DOM). These tasks are currently not being performed to the required standard, with the result that data are published with long delays, and not always properly checked. A major constraint in this respect is the lack of computer facilities at MAJI Ubungo. MAJI has a number of well-trained and experienced hydrologists, who, given adequate computer facilities, could maintain an up-to-date high quality data base to support the investigations required for water resources management, whether for water supply, irrigation or other purposes. The Water Master Plan Coordination Unit, located at MAJI Ubungo, has as one of its important responsibilities the task to organise a large volume of information in a data bank, which also requires computer facilities. For these reasons alone acquisition of a medium-size computer system to be installed at MAJI Ubungo is strongly recommended.

However, MAJI´s needs and capabilities in computer analysis go beyond data base management. MAJI has experienced staff, competent at hydrological data analysis by the use of computers, including mathematical modelling of hydrological processes. As part of the present study MAJI hydrologists have been trained in the use of the Danish hydrological catchment model, the so-called NAM-model, which has proven to be a useful tool for hydrological investigations in the three regions concerned, and probably also for many other parts of Tanzania. Consequently, it is strongly recommended that the NAM-model, together with other hydrological software, be installed and tested at a computer installation at MAJI Ubungo, hence enabling MAJI hydrologists to put their knowledge to practical and beneficial use for the solution of future water resource problems.

Finally, it is recommeded that the water right system be critically reviewed, and that rights not properly utilised be withdrawn.

In addition to the general recommendations given in this chapter, sections are included at the end of each chapter, which contain more specific recommendation, and eleborate on the above, particularly with respect to gauging network and procedures.

4. HYDROGEOLOGY AND GROUNDWATER RESOURCES

4.1 Geology and structure

4.1.1 Geology

The rocks found in the regions can be divided by their geological age into three main groups:-

- Pre-Cambrian rocks
- Karroo sediments
- Neogene deposits.

The pre-Cambrian rocks are collectively referred to as the Basement Complex, and they occupy 68% of the study area. They are, therefore, the most important geologic unit. 97% of the Basement Complex rocks are psammitic metamorphic rocks or acidic plutonic rocks covering a large range of gneisses, granites and migmatites, which when weathered usually form good aquifers. The remaining basement rocks are pelitic basic and ultra-basic plutonic rocks, and basic and intermediate extrusives, all of which have poor water bearing qualities in their weathered form.

The continental deposits of the Karroo System occur predominantly in Ruvuma Region, where they occupy the Ruhuhu Trough and large parts of Tunduru District (the Tunduru Basin). They cover 21% of the study regions (61% of Ruvuma Region). The Karroo sediments were laid down on mainly pre-Cambrian crystalline rocks, which have been exposed to weathering in pre-Karroo times. The thickness of the Karroo Beds are believed to be up to 3000 metres in the Ruhuhu Trough and Tunduru Basin. Karroo rocks probably occur at depth in the Rukwa Trough and below the Lake Beds of the Usangu Flats. Lithologically the Karroo rocks are mudstones, siltstones, sandstones, conglomerates, varved clays, carbonaceous shales and coals.

The Neogene sedimentary deposits of hydrogeological importance within the study area are alluvial and colluvial deposits and Lake Beds.

Alluvium and colluvium deposits occur in connection with escarpments where rivers dispose of their sediment load as they flow across the topographically level terrain below the scarp. Due to the large proportion of eroded plateaus of little topographical relief, the alluvial deposits have a limited areal extent. Only in the northern part of the Ruaha Valley and in Kyela District have larger alluvial plains been observed.

Lake Beds are found in the Rukwa Trough and across the Usangu Flats. Lithologically they are fine sands, silts and clays. Their thickness is estimated to be up to 200 metres at the most.

The occurrence of the Neogene extrusive rocks of the Rungwe Volcanic Province is limited to mainly Rungwe District in Mbeya Region. The rocks are usually divided into the Older and Younger Extrusives. The Older Extrusives are lavas in the trachyte to phonolitic range and basalts. The Younger Extrusives are lavas in the trachyte to phonolitic range associated with widespread pumice and ash.

4.1.2 Structure

The structural setting of the study area is dominated by the pre-Cambrian orogenic episodes and subsequent rift faulting, which has taken place since the late pre-Cambrian. These mountain building episodes have been separated by periods of erosion, uplift and sedimentation. The faults that can be observed in the pre-Cambrian rocks are mainly parallel to the trends of the fold belts. Movements along these faults have taken place during several periods since the Bukoban, in the late-Cretaceous, Tertiary and Quarternary. The present linear topographic expression of the faults was established during the Pleistocene. The tectonic valleys, the Eastern and Western Rift Valleys are the result of these late movements. They are shown in Figure 4.1.

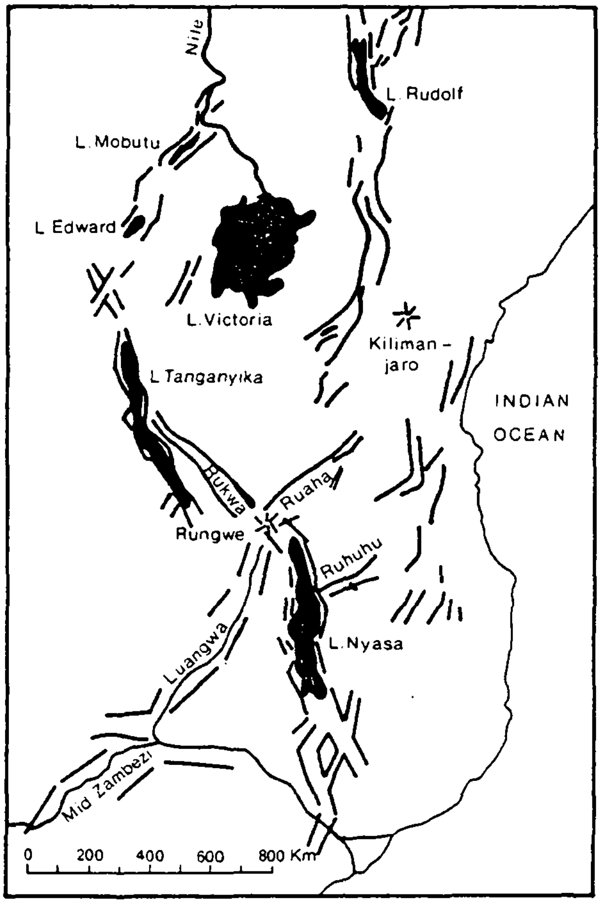


Figure 4.1 - The East African Rift Valleys. The Luangwa - Mid Zambesi rifts are older features now largely filled in with Karroo sediments.

4.2 Geomorphology

Iringa, Ruvuma and Mbeya Regions are characterised by high plateaus. They are a result of erosion which has taken place during the past 150 million years, since the late Jurassic. These plateaus are known as erosion surfaces established during different geological periods. They are:-

- The Gondwana and post-Gondwana Surfaces. They form the crests of the present water sheds at 2000-3000 m.a.s.l. They are preserved mainly as plateau remnants, dissected by later erosion cycles.

- The African Surface, a very smooth and mechanically stable land surface covering the major part of the study regions.

- The post-African Surface, a more undulating and mechanically unstable surface, less developed than the African Surface.

- The Coastal Plain and Congo Surfaces with limited areal extent within the regions. They are found as narrow belts along rivers and lake shores.

The aggradational surfaces, established by deposition of material during the Neogene, are areally limited, but of local hydrogeological importance. They are mainly:-

- The Rukwa Trough
- The Usangu Flats
- The Rungwe Volcanics.

A geomorphological classification provides a link between the geology and the hydrogeology of the Basement Complex. It is used as a framework in describing the hydrogeology of the study area, especially the Basement Complex.

4.3 Groundwater occurrences

4.3.1 The Basement Complex

Once a land surface has become mechanically stable, deep chemical weathering takes place by circulating groundwater. This process establishes a weathered zone or saprolite zone above the parent rock. As time is the most important factor in producing the in-situ weathered profile the profile is thicker and more developed on older rather than younger pediplains.

The aquifer across the pediplains is predominantly the lower part of the saprolite.

This single aquifer system is illustrated in Figure 4.2.

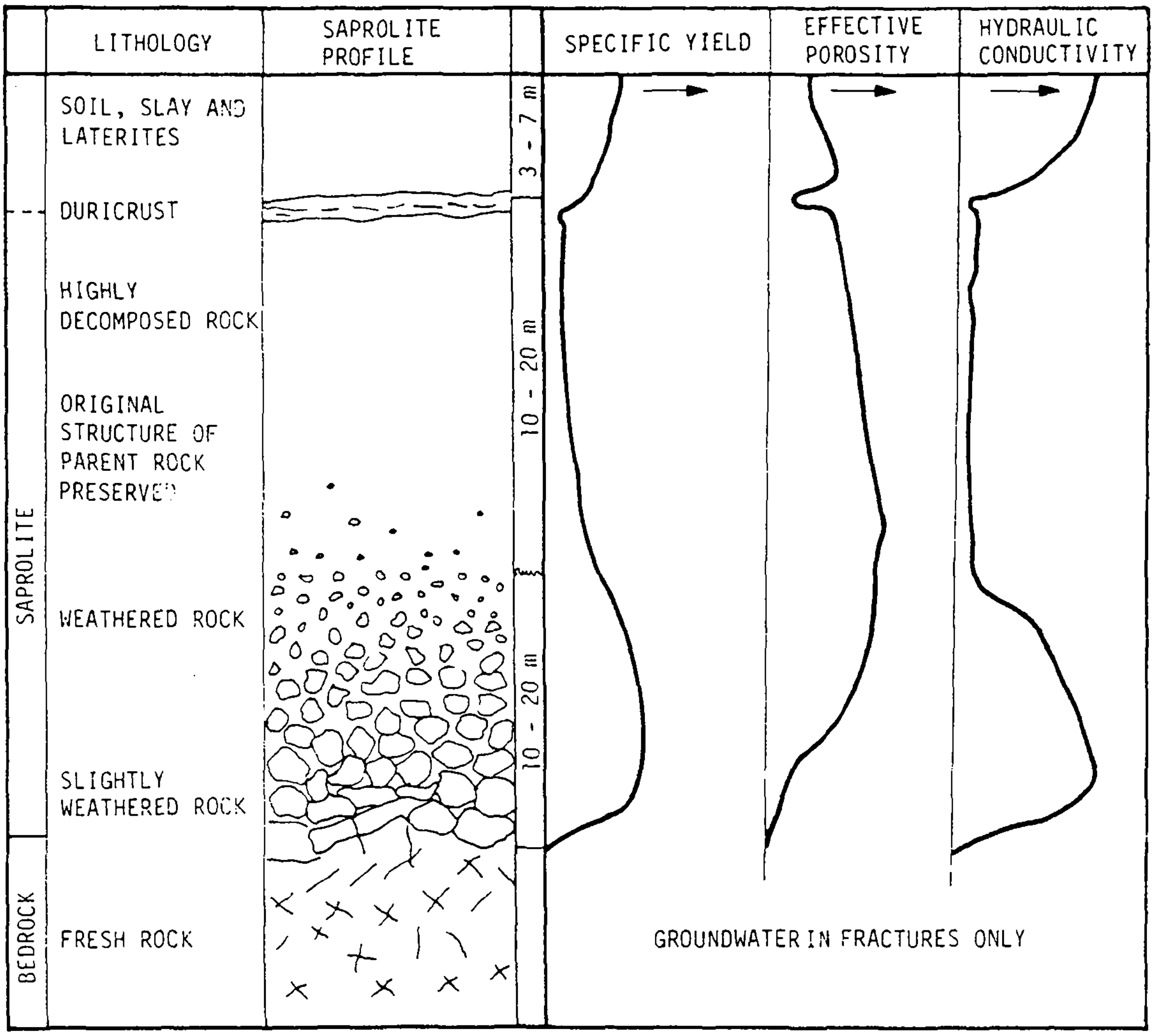


Figure 4.2 - A typically saprolite profile and its hydraulic properties as found on an old pediplain.

Generally, therefore, across the Basement Complex the groundwater occurrences can be classified according to the geomorphological history of a given area.

The mature African Surface posesses the best potential for aquifer development. Groundwater is generally occurring everywhere. Aquifers will be artesian with rest water levels 2-8m below ground level.

As the topography becomes more rolling (post-Gondwana and post-African Surfaces) perennial groundwater is found along the lower reaches of hills and in valleys. Rest water levels are shallow in the low-lying, deep in the more elevated areas.

Across the highly dissected plateaus of the Gondwana Surface, groundwater is restricted to valleys. Groundwater levels may be deep. In the scarp areas and in areas where rejuvenation of erosion has resulted in a thin saprolite cover or a complete removal, fracture and fissure zones must be struck by drilling to locate a reliable groundwater source.

The yields of wells across the Basement Complex follow a log-normal distribution. Average yields from successful boreholes are 3-7 m^3/hr. An estimated 75% of boreholes striking water would have yields sufficient for hand pumps and an estimated 55% would have yields sufficient for motor-driven pumps.

In Figure 4.3 the frequency distributions of the saprolite thickness and the specific capacities together with the boreholde yields as a function of drilling depth are shown. The data applied are from boreholes drilled in the Basement Complex in Tanzania.

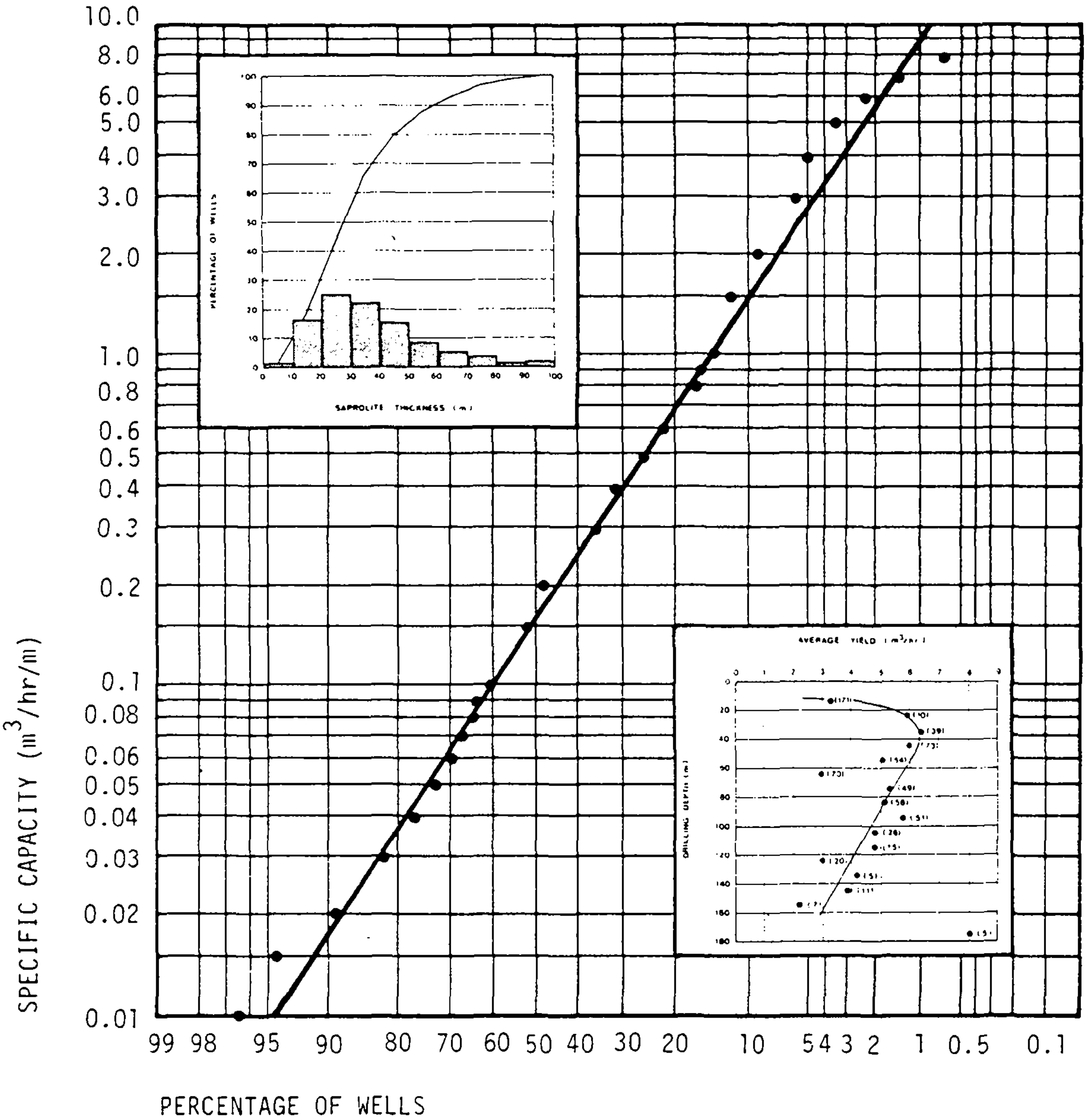


Figure 4.3 - Specific capacity frequency distribution (143 boreholes), saprolite thickness frequency distribution (236 boreholes) and average yields (508 boreholes). Data from boreholes drilled in the Basement Complex in Tanzania.

4.3.2 The Karroo Basins

Information on the hydrogeology of the Karroo is based mainly on the Consultants' drilling results. The aquifers are found to be predominantly confined. Groundwater levels reflect the topography, they are deep (up to 25 m below ground) in upland areas and shallow (2-4 m below ground) in depressions. Perennial groundwater generally occurs everywhere.

The yields of wells drilled in the Karroo rocks may, according to the results of drilling, be expected to be higher than in the Basement Complex rocks.

4.3.3 Neogene deposits

Lake Beds

Drilling in the Rukwa Trough and across the Usangu Flats has shown that perennial groundwater may be expected to exist in these deposits. The specific capacities of wells are considerably higher than in general across the Basement Complex, and more than 90% of wells having water will have yields sufficient for hand pump implementation. However, water levels are expected to be deep, about 10 m in the Rukwa Trough and up to 25 metres below ground level across the Usangu Flats.

Alluvial deposits

Drilling in these has shown that they are the most prospective groundwater sources within the regions. Yields are generally high, up to 10 m^3/hr allowing for 10 m drawdown. Water levels are shallow, less that 4 m below ground and wells can be sited in or around villages.

The Rungwe volcanics

In these rocks drilling for groundwater is not recommended, as topography is very rugged and groundwater quality unpredictable. Springs offer much better prospects.

4.3.4 Springs

Springs have been found to constitute the major mode of groundwater drainage over:-

- The Gondwana and post-Gondwana Surfaces
- The African Surface
- The Karroo Basins
- The Rungwe Volcanics.

The yield of springs are generally 0.5-1 l/s, but yields over 100 l/s have been recorded. Where found, they are reliable groundwater sources which should be considered the prime target of groundwater implementation.

4.4 Groundwater chemistry

4.4.1 The Basement Complex

Although local variations occur, the groundwater quality within the Basement Complex generally meets the requirements of the standards set for drinking water. Iron, manganese and fluoride contents will mostly lie within accepted limits. Exceptions are areas influenced by Neogene tectonics. Boreholes drilled in such areas may contain juvenile water, often with a high content of chloride and sometimes flouride.

These areas are found following the fault-lines defining the Rift Valleys and associated fault-lines.

4.4.2 The Karroo Basins

In these sedimentary continental deposits groundwater is chiefly potable. All samples analysed have indicated water qualities suitable for human consumptions.

4.4.3 Neogene deposits

Lake Beds

The groundwater quality in the Lake Bed sediments has been found to be highly variable. Potable groundwater has been found, but groundwater has also been observed to be locally influenced by juvenile water originating from fracture zones below the Lake Beds. Across the Usangu Flats this is demonstrated by high fluoride contents in places. In the Rukwa Trough this has resulted in high salinities locally.

Alluvial deposits

In these deposits the groundwater quality is generally acceptable, but the iron content may locally be high, and juvenile water has been found near Neogene faults.

The Rungwe Volcanics

In these rocks the groundwater quality is unpredictable. Numerous Neogene faults are responsible for a large content of dissolved solids and in places gases in the groundwater. This seems not to have affected the quality of spring water, which is generally good, except for the juvenile hot springs.

4.4.4 Springs

Except for the juvenile springs, spring water is reported to have more than acceptable quality and is probably the best drinking water found in the regions, regardless the geologic environment.

The groundwater types recognised in the regions are shown in Figure 4.4 as Piper-diagrams. Groundwater situated in the strong acids part of the Piper-diagram is not suited for village water supply, groundwater situated in the weak acids part is.

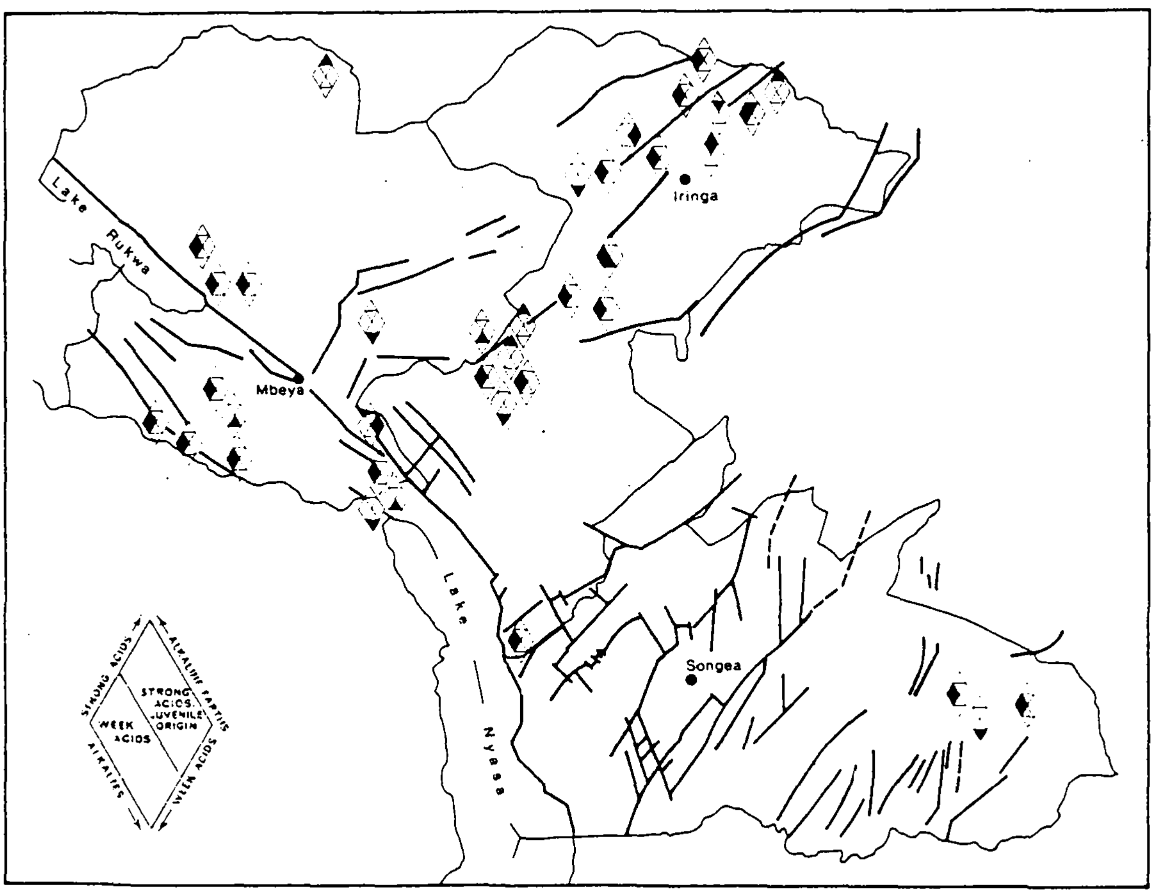


Figure 4.4 - Groundwater types in the regions represented by Piper-diagrams.

4.5 Geophysical investigations

Geoelectric and seismic surveys have been found useful in determining the saprolite thickness across the Basement Complex. After empirical corrections, the results of these investigations have been found to be in accordance with borehole strata logs, and they confirm the geomorphological features found across the Basement Complex.

Geophysical surveys have also proven useful in defining the boundaries of the Karroo Basins in Ruvuma Region.

Down-the-hole logging is an effective tool in determining lithological contacts in rapidly changing layers such as the Karroo sediments. Logging is less suited to define the contact between weathered and fresh rock, as their composition of basic minerals is the same, and the contact is seldom distinct.

4.6 Drilling programme

Drilling was carried out using two rigs, 1 MAJI Schramm T64 Rig (Rig 45) and 1 MAJI CME Auger Rig (Rig 53). A total of 70 holes were drilled in the regions, 20 of which were deep holes drilled by Rig 45 and 50 were shallow holes drilled by Rig 53.

4.6.1 Results of drilling

Drilling in the Basement Complex, which was comparatively well known beforehand, gave no essential new knowledge, but confirmed the interpretation of the hydrogeologic conditions based on the existing data.

Drilling in the Karroo, Lake Beds and alluvial deposits, however, have given useful results in drawing the preliminary conclusions outlined in Section 4.3 above.

4.6.2 Recommendation for future drilling

Methods of drilling

The Schramm T64 Rig has been found to be too heavy in relation to the road conditions in Tanzania. For rotary drilling in hard rocks lighter rigs should be preferred. Percussion rigs may, although they have slower penetration rate, prove to be more efficient rigs to operate, because they are less heavy and require less sophisticated maintenance.

Auger drilling has proved successful in unconsolidated deposits and, equipped with cleaning and jetting equipment, would be an efficient method of drilling, although the drilling depths is limited to about 30 metres.

Hand drilling is recommended in alluvial deposits. The yields of aquifers here are usually high enough to provide the base for groundwater abstraction from hand drilled tube wells. In many places hand dug ring wells can be successfully used.

Siting wells

Across the well pedimented plateaus of the Basement Complex geomorphological interpretation should be used to site wells. Geophysical surveys may be useful but are not considered necessary, because the weathering and consequently the groundwater conditions are revealed by the geomorphological characteristics in these areas.

In the Karroo Basins, groundwater conditions are largely given by the topography. Therefore, geomorphological interpretations would be sufficient to site wells. Along the edges of Basins, however, geoelectric soundings can be advantageously used to determine the depth to the pre-Karroo land surface, and consequently determine the main type of strata to be expected.

Across Lake Beds and alluvial deposits, the surface is so level and groundwater conditions so uniform, that no investigations are required before drilling, exept for field reconnaissance.

Implementation of wells

Because of the advantages of hand pumps in relation to motor driven pumps wells should be equipped with hand pumps, whether deep or shallow. Many of these wells will be suitable for motor driven pumps, should this prove beneficial in the future.

Shallow well drilling programme

Wells utilising shallow groundwater resources can be successfully drilled in several areas. They are:-

- Alluvial plains in the Ruaha Valley and in Kyela District at the northern end of Lake Nyasa.
- Alluvial fans along escarpments, notably in the Rukwa Trough and bordering the Usanga Flats. Local fans are found elsewhere in association with major faults.
- The colluvial deposits along escarpments.
- The Karroo sediments of the Congo Surface in the Ruhuhu Trough.
- Local alluvial tracts in river valleys across Basement Complex plateaus.
- Alluvial deposits in valleys dissecting the Gondwana plateaus.

These wells should be auger wells, hand drilled tube wells to 20 m or dug ring wells to 10 m. An estimated 90% or more of wells striking water will have sufficient yields for hand pump implementation.

Wells equipped with hand pumps and utilising medium deep or deep groundwater resources can be successfully drilled in parts of the remaining area. These are:-

- The topographically level areas on the African and post-African Surfaces, where the saprolite cover is preserved. Drilling depths would on an average be 50 m and 40 m, respectively.

- The Karroo Basins. Drilling depths cannot be estimated accurately, but would probably be in the range 50-100 m.

- The Usangu Flats and Rukwa Trough. Drilling depths would on an average be 40 m.

Across the Basement Complex an estimated 75% of wells striking water will have sufficient yields for hand pump implementation. This figure would be somewhat higher for the Karroo. Across the lake beds of the Usangu Flats and the Rukwa Trough the estimate is 90% or more.

I scarp areas, areas with rejuvenated erosion and topographically irregular terrains, general guidelines cannot be given. The saprolite aquifer is not present and the presence of reliable groundwater will depend on fracture and fissure zones, some of which conduct poor quality groundwater.

14.7 Future hydrogeologic data collection

It is recommended, that selected springs and boreholes are monitored regularly in the future to establish a base for evalutating hydrogeologic conditions on a regional basis. Boreholes drilled by the Consultants covering the main hydrogeological domains have been selected. Also a number of springs have been proposed as a part of the monitoring programme.

5. WATER USE AND DESIGN CRITERIA

5.1 General

5.1.1 Study methodology

The primary objectives of the water supply aspects of the Water Master Plan were as follows:-

- to visit each village in the region and gather information related to the selection of a water supply system for that village
- to amalgamate this information into a comprehensive plan for water supply development in the region.

Thus, village level studies were used to develop the regional plan which in turn provides a basis for determining the procedure for implementation.

The benefits of this methodology is that a follow up to the study can be more readily commenced. The fact that detailed information has been gathered for each village, and this has been used to relate its position in an implementation programme, means that much of the normal preliminary investigation work of scheme development has already been covered.

However, it should be cautioned that the proposals at village level have, of necessity, been prepared in a water master planning format. As such therefore, they should not be considered as fixed designs. At the time that a particular village is being studied for implementation, more detailed consideration of the water demand, source quality and capacity should be incorporated as is normal practice in the detailed design stages.

5.1.2 Village inventory

The village inventory, jointly developed between the Socio-Economic Group and the Consultants, forms the data base for most of the study.

Information was gathered on ten separate categories ranging from registration, social structure, agriculture and industries to water supply.

Over 150 questions were contained in each inventory, although all were not applicable to every village. To manipulate and analyse this vast store of information all village inventories were computerised. The original format of answers received in each village can therefore be readily reproduced from computer tape to assist engineers involved in detailed design at a later stage.

Further information gathered during the village visits with respect to village location, character, levels, together with the proposed water supply, has been transferred onto a village sketch which is produced with an associated summary page of village information in Volumes 5B to 5D.

The information contained in these volumes,on the sketch and summary sheet, is intended to provide the Water Master Plan user with sufficient data to identify the character of each village and its water supply and implementation proposals. The full details of the village inventory therefore should only need to be referred at the time of detailed design work.

5.1.3 Household surveys

In order to complement the village inventory level information more "in depth" studies were carried out at selected villages within selected zones by the Socio-Economic Group.

These studies were used, within a water supply context, to establish base criteria such as per capita demand, storage requirements, service level, peak factor and need for livestock watering.

The Socio-Economic Group studies are separately contained in Volume 12 of this Water Master Plan. The findings of the studies have also been incorporated where appropriate in the water supply context of the Plan to present a comprehensive development of the proposals put forward.

5.2 Priority criteria

5.2.1 General

Priority criteria can be separately considered in two applications

- in connection with selection of scheme for a particular village,
- in connection with implementation of schemes.

These two aspects are presented in the sub-sections below.

5.2.2 Selection of scheme type

The selection of a water supply scheme for a particular village involves many aspects. The technical aspects include

- scheme type
- source reliability
- source quality
- development cost.

All of these aspects were important in determining the most suitable water source for a particular village. Due to changing circumstances of water availability in different parts of the region it was not possible to pre-determine a priority order or category limits, which would be applicable in all cases, however, the principles below were followed:-

- Scheme type should be preferably such that no, or only very simple, mechanical operation was necessary. Shallow well or gravity supplies thus having preference.
- Source reliability should be sufficient to serve the projected demand within a 10 year minimum return period in the case of surface water sources, or with a minimum 80 per cent reliability in the case of groundwater sources. If this, in some cases, proved to be impossible but otherwise the source is the best available in the area, the source has been referred for more detailed capacity investigation.
- Source quality should be acceptable in relation to accepted health limits to be used without or with the most simple forms of treatment.

- The cost of development of the scheme should be within acceptable limits for the location of the village or the area in question. This was obviously a variable factor throughout the region but a preliminary maximum figure of 300 T/Shs. per capita of design population was aimed for. If the proposal was above this cost, it was only accepted after careful consideration of other alternative methods of supply.

Applying the above parameters, scheme type selection proved to be relatively straight-forward for each village. The village opinion had significant influence since it was seen that many improved schemes had been previously constructed with little usage by villagers due to dissatisfaction with the water quality. This not because of an unacceptable quality according to health standards, but because of a different character to that to which they had been accustomed.

Close liaison was also made with the regional MAJI office to check whether proposals had already been formulated for villages, and if this was the case, these were carefully studied and taken into account. Finally, when proposals for a particular village had been finalised these were passed to the MAJI office to receive comments if any as to their suitability.

The procedure for village scheme selection can therefore be summarised as shown in Figure 5.1.

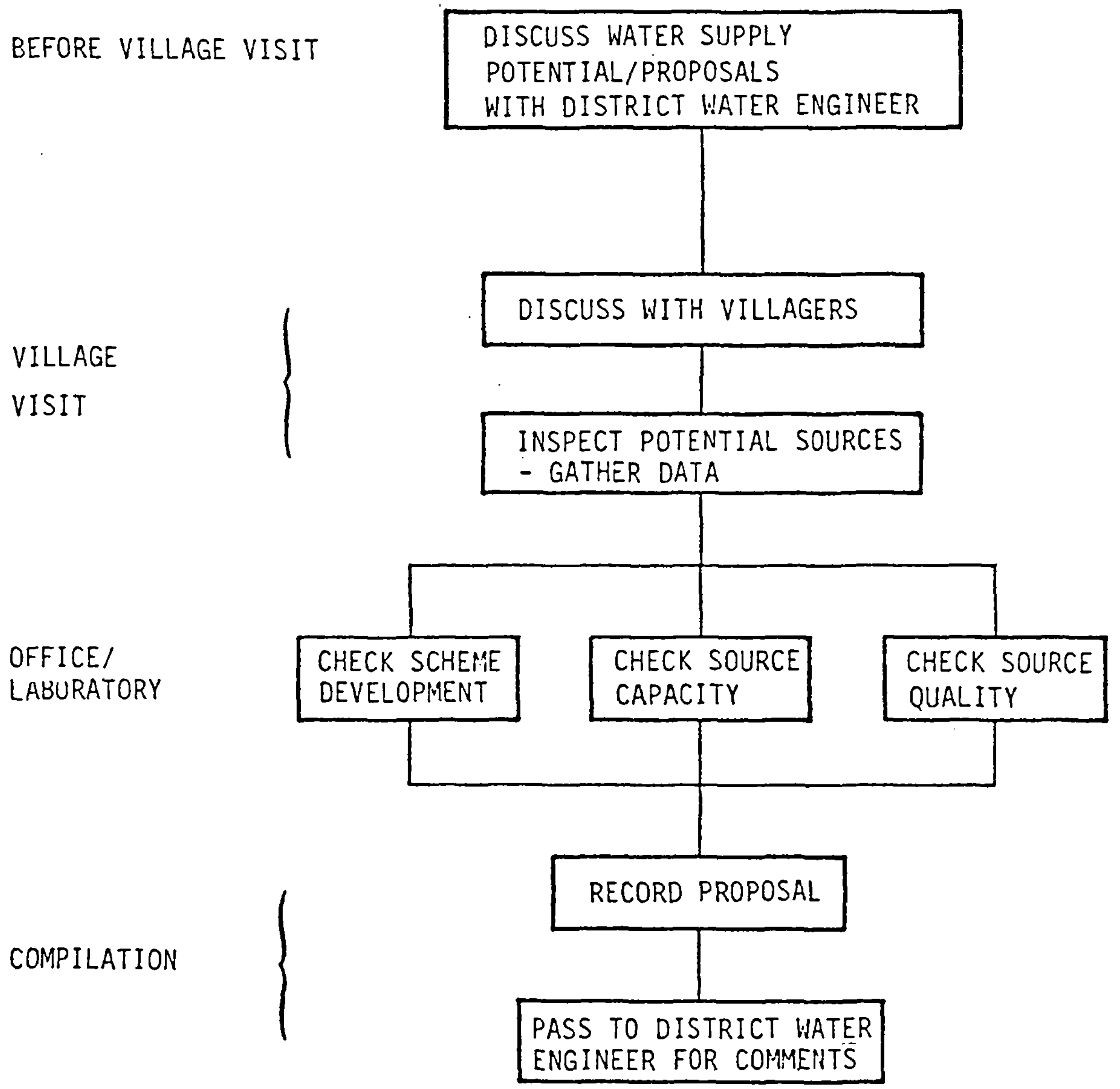


Figure 5.1 - Procedure for village scheme selection.

5.2.3 Implementation

The considerations taken into account in assessing an individual village's priority with regard to implementation are five-fold.

- Need
- Development potential
- Technology of proposed scheme
- Cost
- Village attitude.

It is concluded that "need" should be the main criteria for judging the priority rating of a particular village.

Development potential, if judged in general context, it is considered can in many cases be contrary to the objectives of the "need" criteria. If development criteria, however, is considered in relation to the provision of a water supply system, then obviously in these areas of highest need will the the greatest development potential be realised from the introduction of a water supply.

The technology of a proposed water supply scheme and its cost are considered to be two important criteria in deciding whether or not, or when, a water scheme should be constructed. However, these two factors reflect the village water supply solution rather than the existing water supply situation in the village. It is felt that it is important to keep these differentiations clear. Priority criteria in assessing a village's position with respect to obtaining a water supply scheme should be judged on the situation existing in the village. If the solution of serving a particular village results in schemes which, due to the type of technology required or due to the cost involved, would make this an inappropriate scheme to implement, it is considered that the scheme should not be constructed at the present time. However, it is also believed that this should not affect the village position with respect to its priority rating. Therefore, depending on that rating an effort should be made to adopt an acceptable solution for that village such that implementation can be completed as planned.

Village attitude is also proposed to be handled in a similar way. From the village visits and the Socio-Economic Group studies it has become abundantly clear that villages should not have a new water supply scheme implemented until full agreement of the scheme and of participation in its development is received from the village concerned. This agreement, however, although a pre-requisite of construction of a new water supply, is not a reflection of the existing water supply situation and thus priority rating of construction and should be considered separate from that rating.

In applying the level of need criteria to a particular village, three aspects were considered and results obtained thereon from information gathered in the village.

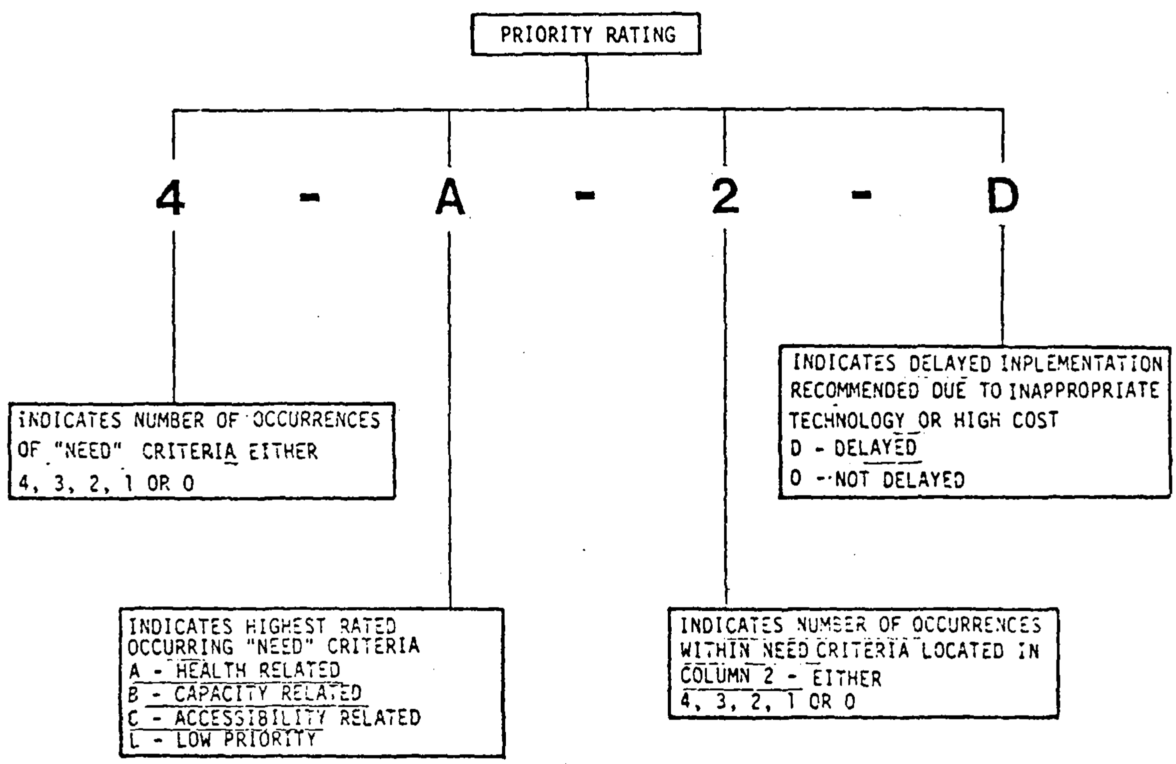
- Health with respect to water supply
- Water supply capacity
- Water supply accessibility.

Where villages had a situation prevailing such that they did not satisfy pre-determined criteria within any of these categories, they were considered to have a "high priority" of implementation. Conversely, villages which did satisfy all criteria were judged to have a "low priority" of implementation.

To enable a construction programme of implementation to be drawn up, further subdivision within these categories were made in order by

- Number of occurrences of problems in all categories.
- Number of occurrences within categories of health, capacity and then accessibility separately in that order.

A priority rating has therefore been drawn up which is illustrated in Figure 5.2.



Examples: 4-A-2-D indicates
- 4 total occurrences of need criteria
- highest rated need is in health category
- 2 occurrences of need in health category
- scheme implementation should be delayed due to technology or cost

2-B-2 indicates
- 2 total occurrences of need criteria
- highest rated need is in capacity category
- 2 occurrences (i.e. total) of need are in capacity category
- no delayed implementation recommended

0-L-0 indicates
- no occurrences of need criteria
- therefore low priority
- no delayed implementation

Figure 5.2 - Water Master Plan priority criteria rating system

When all other aspects are equal after priority rating has been applied, villages have been listed with those having the lowest per capita cost first.

Finally, it is stressed that while priority ratings have been applied to all villages in the region as part of the Water Master Plan it would be wrong to consider this as placing a village in a fixed position with regard to its potential of receiving an improved water supply. Rather the resultant priority system should be used as a starting point in considering relative merits of implementation, and due notice should be taken of altered circumstance, which may change a particular village's rating.

5.3 Water quality criteria

5.3.1 General

In parallel with the collection of the village inventory data it was possible to take water samples and consequent analyses for each village in the region. Although a vast amount of information was thus gathered, the fact that only one sample was possible at each source imposes limitations on the reliability with which these results should be used to judge on individual sources. Statistically of course, it is possible to see with some confidence the pattern of water source quality available throughout the region, and this facility has been utilised to the fullest.

5.3.2 Water sampling and testing

It was attempted to take at each village a sample of at least one traditional source to give an impression of quality of the present supply situation, a sample of an existing water supply, if appropriate, and a sample of the proposed source.

Testing was carried out for bacteriological, physical and a range of chemical characteristics. For bacteriological analysis portable filter membrane equipment was used with incubation being carried out in the Landrovers used for the field trips. Evaluation of pH value and conductivity was intended to be carried out in the field using portable electrode meters but field conditions proved difficult for this to operate successfully. All other testing was carried out in Regional laboratories set up for the project and by means of portable digital titration type equipment.

5.3.3 Analyses and presentation

The water quality analyses were computerised in conjunction with the other village inventory information. Statistical results were then studied in each of the separate categories of source type tested, namely:-

- existing schemes
- traditional sources
- proposed sources.

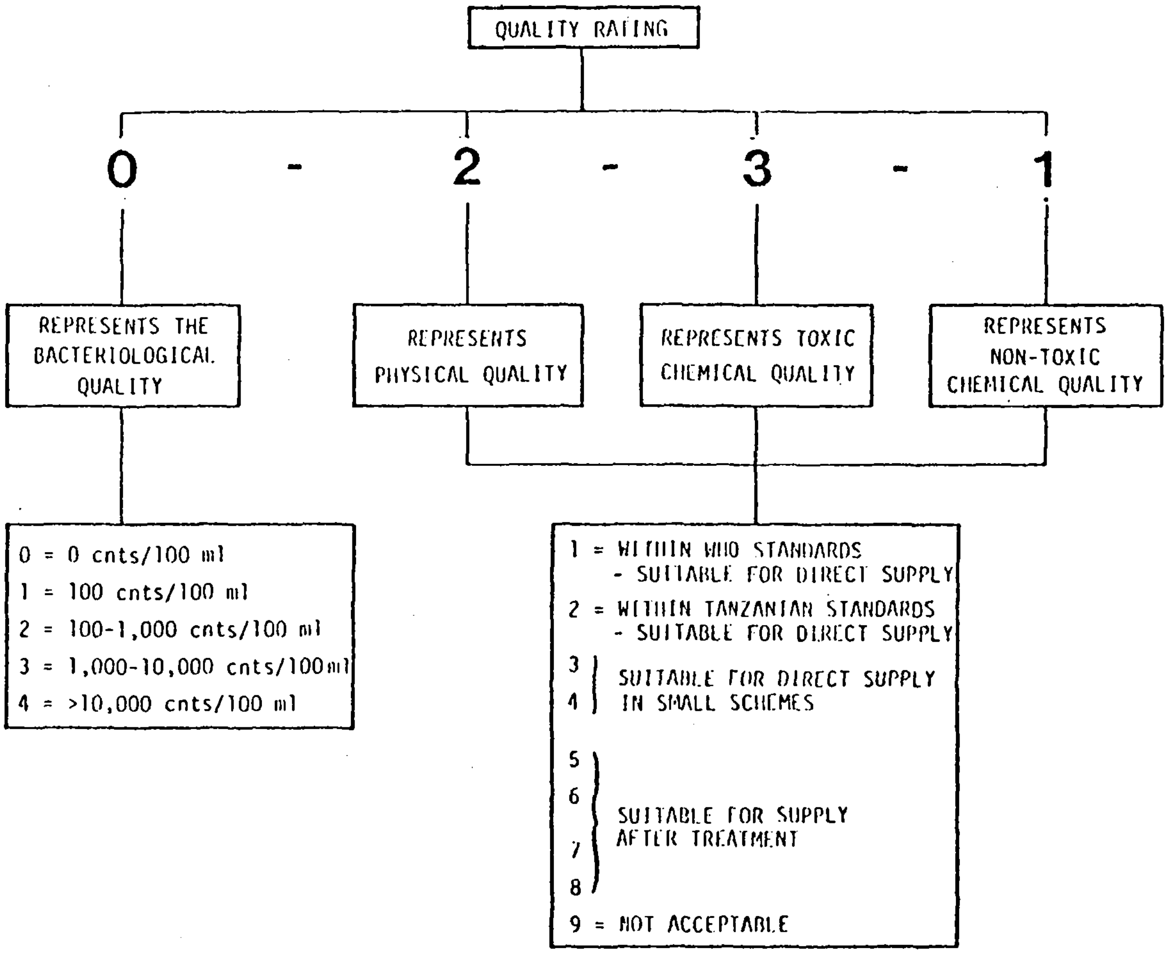
Further analyses of the water quality results were also possible in relation to other appropriate sections of the village inventory such as villagers' attitude to the source or health-related aspects.

In order to present the proposed source quality in an easily recognised format, a four-digit rating system was devised as illustrated in Figure 5.3.

The bacteriological quality is not directly applicable to interpretation of the suitability of the source representing as it does a sample at one point in time. However, as a guideline of necessity of further investigation the following categorisation has been adopted:-

- Code 0 - Suitable for direct supply if pollution risk is low, i.e.
  - closed society, no main through roads, railways
  - upland source, no habitation and minimal grazing in the catchment area
  - small scheme, less than 10,000 design population
- Code 1 - As code 0. Protection must be considered or treatment applied if pollution risk as above is unacceptable.
- Code 2 - Treatment probably necessary unless pollution risk as above is low and identification of pollution possible and protection feasible.

- Code 3 - As code 2 except that treatment should only be omitted if source of pollution is very clearly identifiable and protection can be considered completely effective.
- Code 4 - Source unlikely to be suitable for development as domestic water supply.



Examples: 0-2-3-1 indicates
- bacteriological quality 0 cnts/100 ml
- physical quality within Tanzanian standards
- toxic chemical quality suitable for direct supply in small schemes
- non-toxic chemical quality within WHO standards

Note: 4-9-9-9 indicates a sample not available.
Cnts. refers to E.Coli.

Figure 5.3 - Water Master Plan quality rating.

5.3.4 Evaluation and application

In selecting sources for a village water supply only those which gave indication of high quality and with little possibility of pollution were considered, if at all available. It was considered not feasible from an economic or technical viewpoint to introduce treatment systems to small-scale village water supplies in remote parts of the region.

The water quality analysis of proposed sources showed with little exception that the chemical quality of these was satisfactory within this framework. The only significant exception was that in some areas iron and manganese were found in proportions too high to be acceptable.

Turbidity proved to be a more common problem and was also reflected in the villagers' attitude to the source becoming "dirty" in the wet season.

Water sources, which gave results within WHO or Tanzanian quality standards, were selected whenever possible. Slight relaxation of some standards are recommended for small water supplies, where these do not have health implications and the risk due to a small-scale supply in a closed society, is minimal. Where these limits were exceeded or large-scale supplies were involved, treatment has been proposed. The delineation between a small and large-scale supply for this purpose has been taken as 10,000 design population.

Where treatment has been recommended, only simple non-mechanical, non-chemical, systems have been proposed. These are

- infiltration - in case of small supplies with turbidity problems
- aeration - in case of iron, manganese problems
- slow sand filtration - in case of large supplies with turbidity problems and/or bacteriological pollution risk
- horizontal roughing filters - in case of large supplies with turbidity levels higher than those suitable for slow sand filters
- combinations of the above as appropriate

Careful consideration of the suitability of the proposed treatment will need to be made in all villages at detailed design stage. This would include further sampling and testing of the site suitability, particularly in the case of infiltration. It is our firm opinion that such methods of treatment are the only ones suitable for the improvement of water source quality in the rural parts of the region. Any more sophisticated system, depending on chemicals or mechanical plant would run a high risk of not operating within a short period of time. It is more realistic to install a treatment system which will, with some certainty, make an acceptable improvement of water quality than a system which will produce a high quality water but has only a low probability of operating at all.

The problem of water quality becomes even more significant in respect to bacteriological pollution. Throughout most of the region the potential for development of groundwater supplies by acceptable technology i.e. hand-pumps from shallow wells is limited. In this connection, however, the possibility of development of basement aquifers under artesian pressure using hand-pumps must be borne in mind - see Chapter 7, Volume 4B and Volume 10. Therefore, the majority of schemes selected have been from surface water sources, where development by gravity has been possible. While these sources were selected whenever possible, in the upland stretches of the catchments, where the risk of bacteriological pollution is slight, WHO or Tanzanian quality standards cannot be guaranteed at all times even from such sources.

The possibility of chlorinating these supplies to ensure safe drinking water has been ruled out since, although the necessary equipment is easily installed and not costly, the supply of chemicals and control of operation is judged to be completely inappropriate to the present rural village supply situation.

These opinions are further supported by the fact that Socio-Economic Group studies indicate that pollution takes place in the water collection chain between source and consumption. Study of the relevant information also indicate that at present a significant proportion of water-related diseases in the rural areas of the region are caused by water-washed rather than by water-based transmission.

The control of disease with respect to bacteriological quality is therefore seen to be not only a case of providing a high quality source, but also involving the introduction of a health education and hygiene development programme.

Selecting sources, which have an acceptably low risk of bacteriological pollution, improved as necessary by protection measures, and combining education programmes, is seen as an important advance in a step by step improvement of the village water supply situation. As the benefits of an improved water supply become more apparent, villagers become more aware of health implications and when budgetary and logistical circumstances permit, a logical further development would be the introduction of treatment systems to these water supplies. The outline selection of sources has been made, bearing this principle in mind and, it is recommended that during detailed design stages, whenever practical, and within acceptable cost limits, additional hydraulic head is provided for the later introduction of a simple treatment system.

In schemes above 10,000 design population more careful study of the bacteriological pollution risk has been made. Where, after due consideration this has been deemed to be unacceptable, slow sand filtration is proposed as being the most appropriate means of control of bacteriological quality in larger schemes in the present situation in the rural areas. The size of the scheme justifies the cost involved and there is no dependence on chemical supplies or problem with mechanical maintenance. Problems previously encountered with this type of system in Tanzania is felt to be due to wrong design and/or insufficient training in operation procedures rather than being due to inherent faults in the system.

5.4 Design criteria

5.4.1 General

The parameters considered were

- planning period
- water demand
- peak factor
- storage
- level of service

The current values of these parameters, as presently applied within the Ministry of Water and Energy, were used as a basis for evaluation of levels to be applied in the Water Master Plan. The details gathered at village level and the "in-depth" studies carried out be the Socio-Economic Group were used to supplement these basic data and compile recommendations. The applied values are illustrated in Figure 5.4.

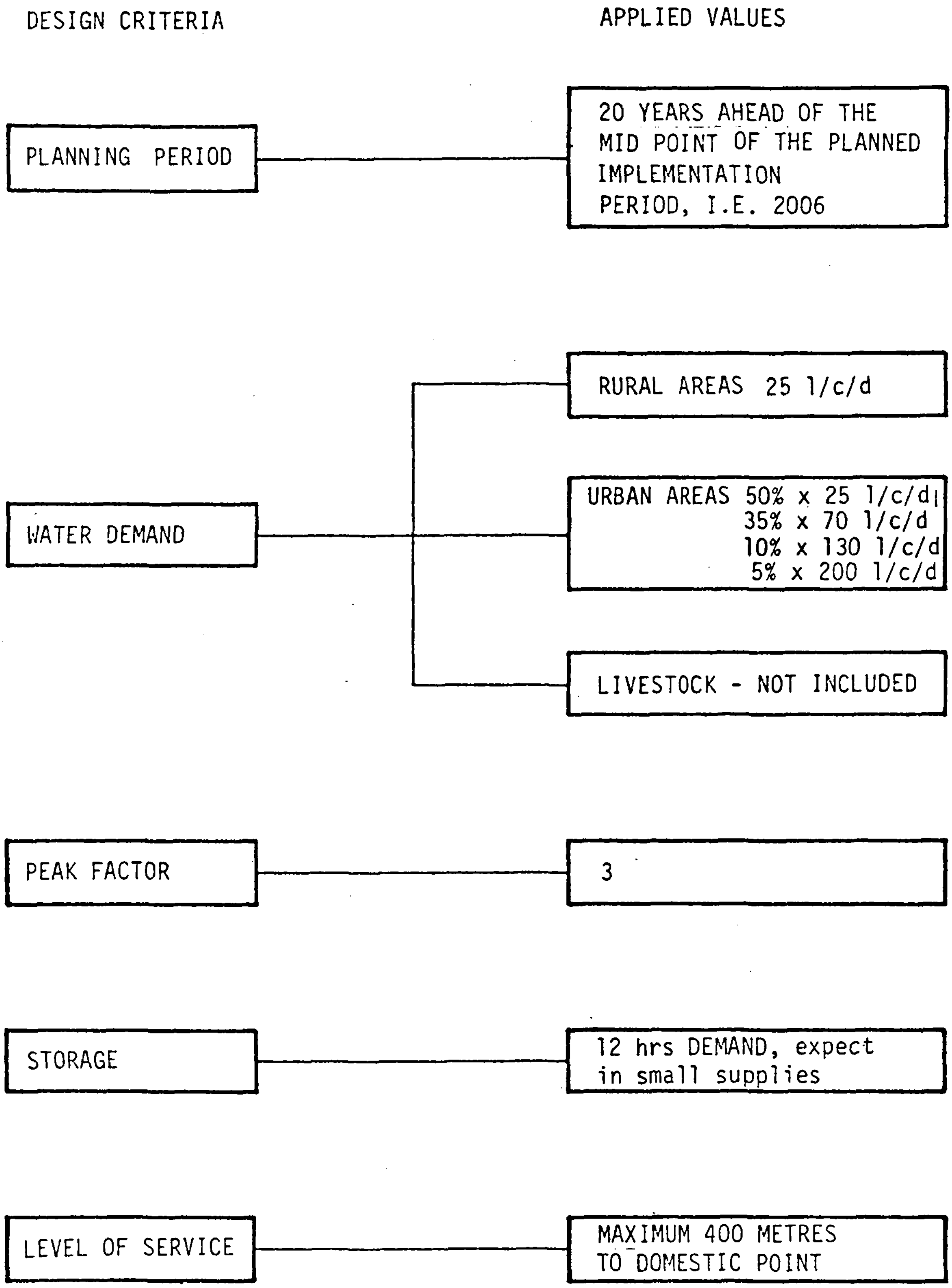


Figure 5.4 - Water master plan applied design criteria.

5.4.2 Planning period

The 20 year planning period presently used by the Ministry of Water and Energy has been adopted.

In certain cases where this has resulted in an excessive growth the potential for phasing of the scheme construction for the 10 year demand has been commented upon.

The applied year for projection of water demand is 2006, being 20 years ahead of the mid point of the planned implementation period, 1982 to 1991. The use of the same year for the calculation of the projected demand for all villages avoids in the water master planning format, rigid formulation of implementation order, yet achieves the representative presentation of the total figures. When the implementation period of each village is finally selected the actual demand calculation for that case can then be calculated.

5.4.3 Water demand

Detailed studies at village level by the Socio-Economic Group reported that the average present water consumption in the rural areas for all domestic purposes varies between 11 and 18 l/c/d.

If the demand for institutions, schools and health centres, are added to these figures, and an estimated growth in demand is allowed to account for the observed positive influences on water demand, which are likely to apply in the future, such as education and per capita income, a resultant planning demand figure of 25 l/c/d is calculated as being appropriate.

The demand for livestock watering was not considered as being either economic or necessary to include in the domestic water supply. Such a demand would add approximately 20 per cent to the present calculated demands. This would reduce considerably the viability of development of many of the sources selected. These sources have been chosen to achieve a high quality water supply delivered by means requiring the simplest operational techniques. To satisfy these requirements, which are not necessary for the purposes of livestock watering, inevitably involves higher costs in many cases than would otherwise be the case. Socio-Economic Group studies showed that the demand for livestock watering as expressed by villagers, was inconsistent with the observed use of facilities provided. In most of the region, natural watering facilities are available for livestock with little or no associated inconvenience.

It is therefore recommended that the present policy of including livestock watering demand in all village supplies should not be applied. Where provision of water for livestock is necessitated through unavailability of natural sources at all times of the year, consideration should be given to development of lower cost and quality sources than those necessitated for the domestic supply. We consider it would be appropriate for such livestock supplies, and also associated demands such as dipping, to be the subject of a village community project, using local technology such as bamboo pipes, rather than being provided within the framework of a regional programme.

Industrial demand was not found to be significant in the villages. Only cottage industries were found to be operating apart from major industrial developments near urban centres or in special allocated projects. Water supplies for such industrial developments are separately considered and it is proposed that the water demand for the present cottage type industries within the villages can be accommodated within the per capita demands already calculated.

In all cases an estimate of water supply source capacity has been made such that if, during detailed design phase, an additional demand is envisaged for a particular village then the potential development from the source in question can be investigated.

5.4.4 Peak factor

Study of the daily consumption pattern by the Socio-Economic Group showed that a peak factor of 3 was appropriate for application to the present rural village water supply schemes.

The trend of peak factor reducing, as level of service increased, was evident from these studies and therefore the economy of introduction of this peak factor rather than the present Ministry of Water and Energy figure of 4 is strongly recommended in association with the Water Master Plan implementation.

5.4.5 Storage

It is concluded that storage of the equivalent of 12 hours demand should be included in all villages except in small schemes where the length of gravity main is less than 2 km. The possibility of serving larger schemes on the basis of a constant free-flowing principle is considered un-economic and not desirable from drainage and health aspects in addition to the problem of imparting the impression that the water supply is an unlimited and free asset.

5.4.6 Level of service

Village level studies did not indicate a threshold point in respect of distance to water collection point. Consumption could be seen to be increasing with reducing distance, but at no point did a significant change occur.

Sensitivity studies on the cost of providing a different level of service, on the other hand, showed that the 400 m distance was significant. Below this point the curve rose steeply, resulting in an additional 30 to 40 per cent to scheme costs if a 200 m criterion was introduced. Above this point the curve flattens and even a 1,000 m service level results in savings of only 10 per cent. These results of course are themselves sensitive to altered village density levels, but have been calculated for the average situation observed in the region.

It is therefore proposed that the 400 metre criterion be adopted as a base planning figure in the Water Master Plan; <u>however, due note has to be taken of the present water supply situation when implementation is being prepared for each particular village.</u>

6. FUTURE WATER SUPPLY

6.1 General

Ruvuma Region has a low density of population with much of the western part being covered by soils of medium to high fertility. Consequently, the agricultural development potential of the region is high.

The villagisation programme is well established with the development of the social facilities of education and health almost universal. Infrastructure services, however, are at a very low state of development.

The region suffers considerably at present from being so remote. The new Makambako to Songea road will improve this situation but the extent of the region generally and the long stances in Tunduru in particular will still result in transport and communications proving a major constraint to further development.

In the water supply sector the effective proportion of population presently supplied is much less than commonly expected.

The number of villages served is 21% of the region, representing 24% of the population, but due to problems with many schemes and a low proportion of villagers using schemes in these villages which have supplies, the effective population served is only around 11%.

The availability of traditional sources in the region is not generally problematic. Reliability is quite high although obviously to a lesser degree towards the eastern dry parts of the region. Accessibility follows a similar pattern but over the region only 20% have greater than 1 km to their nearest water source. The quality of traditional source water is poor, and the proximity of these sources to the village results in communal use for many purposes other than domestic water collection. Consequently, pollution is rife and protection measures neither seem to be practised nor appreciated.

The demand for water for domestic purposes is minor compared to the resources available but the problem lies rather in selection of suitable quality sources which are developable by acceptable technology within economic costs. The supply of water for purposes other than domestic consumption is not considered appropriate to the present need and economic constraints. The calculation of livestock figures is uncertain but based on the available information, this could be from 10 to 40% of the domestic population demand.

Water for social institutions is included in the allowance of domestic demand but industrial development in the villages is not anticipated to justify additional supply for this purpose. Large and medium scale industrial developments in the region are separately catered for in respect to water supply, and it is proposed that small scale industries be similarly considered when such developments are projected.

A summary of the future water demands of the region as an average is given in Figure 6.1. The figure given for the water resource is corresponding to the 10-year minimum runoff. This could be taken as representing the unregulated resource. If regulation by means of impounded reservoirs is taken into account much larger amounts of water could be made available. The comparison between the figures can be taken as indications only as the exact geographic distribution of resources and demands is an overriding factor.

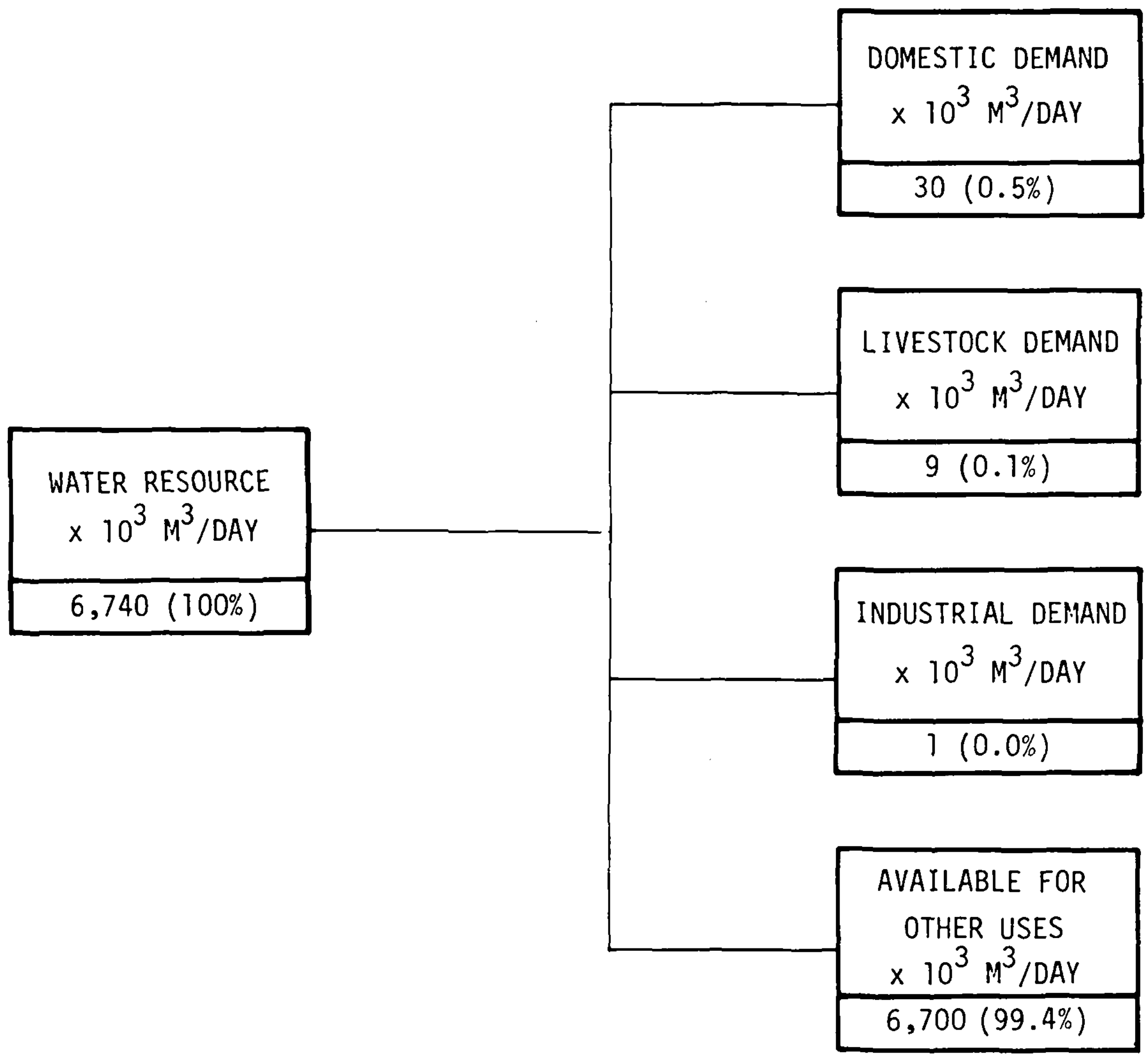


Figure 6.1 - Comparison of future water demands and resources. Demand/resource percentage given in paranthesis.

It appears from the figure that the future demand is only a small fraction of the available average resource. If, for instance, the natural conditions allowed the surplus water to be used for irrigation an area of the size of order of 70,000 ha could be intensively irrigated.

6.2 Source selection

The present improved water supply schemes in the region are predominantly abstracted from surface water sources, 95%. This situation is also reflected in traditional source types, although to a lesser degree, around 62% are from surface sources.

This pattern of present sources has influenced the selection of sources for the Water Master Plan proposals. While groundwater provides a high quality and generally reliable source of water supply, the means of abstraction should be appropriate to the technologies suitable for village level supplies. The lack of major shallow groundwater resources in the region has therefore resulted in only a small proportion of groundwater sources being proposed. The resultant proposals are 97% from surface water sources.

The definition of groundwater sources as given in Volume 9, Chapter 12, para. 12.2 is based on drilling method as follows:-

- Shallow groundwater resources - those that can be developed by drilling with hand tools or by power augering.

- Deep groundwater resources - those that can be developed by drilling with percussion rigs or rotary rigs.

The potential of "medium-deep" borehole supplies, however, should be studied for possible incorporation as an alternative supply, particularly in areas where the selection of surface water sources are unattractive for reasons of scheme technology, cost or source quality. "Medium-deep" groundwater is the name applied to groundwater occurring in the basement complex at around 50 m depth but under artesian pressure such that abstraction by hand pumps is possible.

An important consideration in the selection of water sources has been village opinion. Villagers, although displaying little appreciation of pollution protection of sources, are very aware of physical and chemical quality of the water. They are accustomed in the region to drinking soft surface water of high acidity. Consequently, they consider in many cases the harder groundwater sources unpalatable, often referring to them as saline when tests show otherwise. It has therefore been considered important to select sources which villagers are going to approve of when developed.

6.3 Layout of future water supply systems

The selection of the Water Master Plan schemes has been principally concerned with proposing those types which will ensure simple operation and maintenance. Thus, gravity supplies have been selected whenever possible.

The existing schemes have proven to require considerable rehabilitation with only 15% of those being retained without some additional work being carried out on them. In order to further introduce acceptable scheme technologies, improve quality or make more economic schemes, existing scheme structures have in many cases been incorporated into new supplies. This has occurred in over 30% of cases.

Because of the topographic nature of the region , and the location of villages, in many cases it was found necessary to introduce group village supplies to maintain gravity systems. Where this proved unpractical or uneconomic non-fossil fuel pumped systems have been proposed if possible. Of these alternative pumping systems we propose that only hydrams are sufficiently proven to be immediately introduced.

The proposed water supply schemes are diagrammatically illustrated in Figure 6.2. The scheme types involved in these proposals are also illustrated in Figure 6.3.

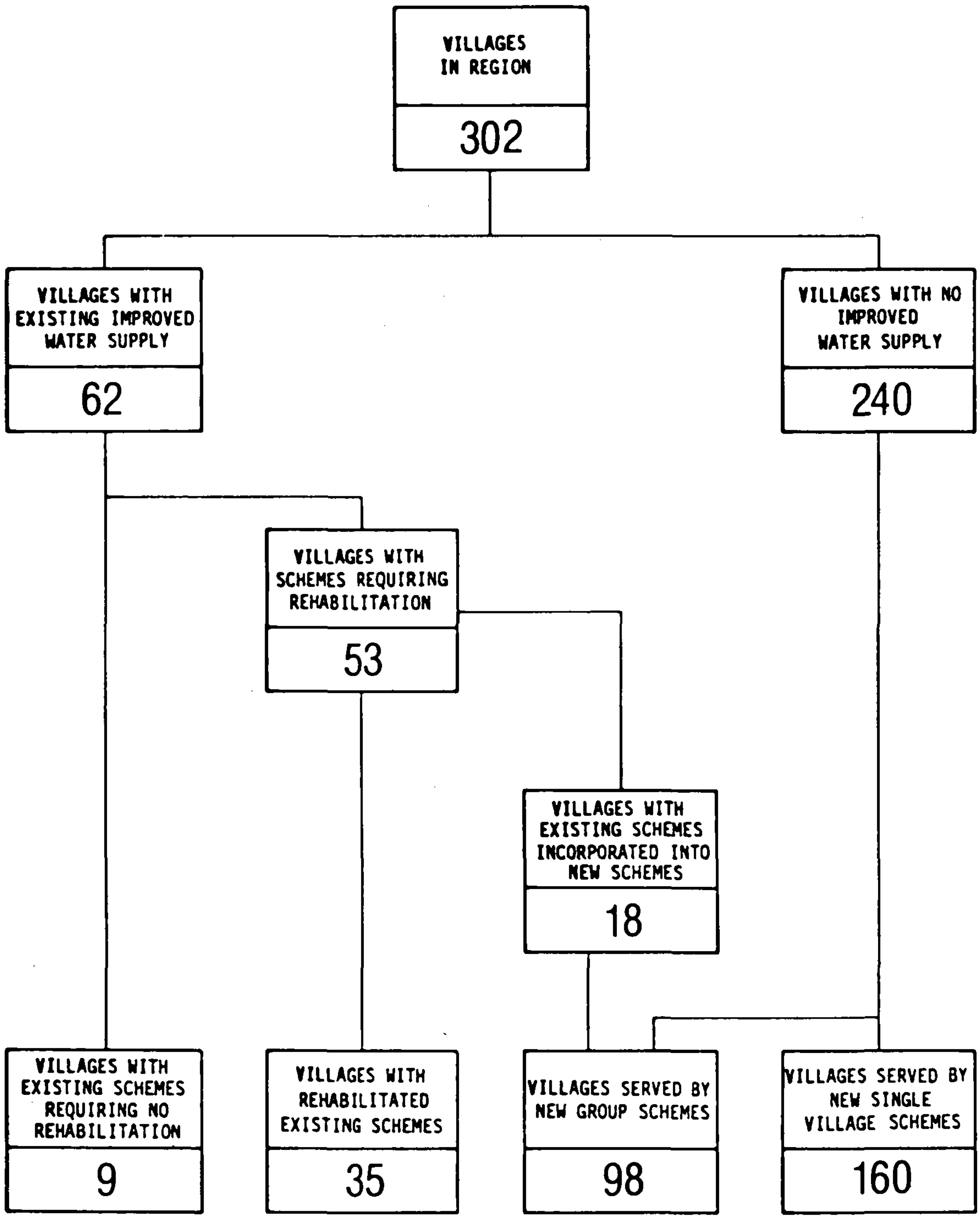


Figure 6.2 - Water Master Plan village water supply proposals.

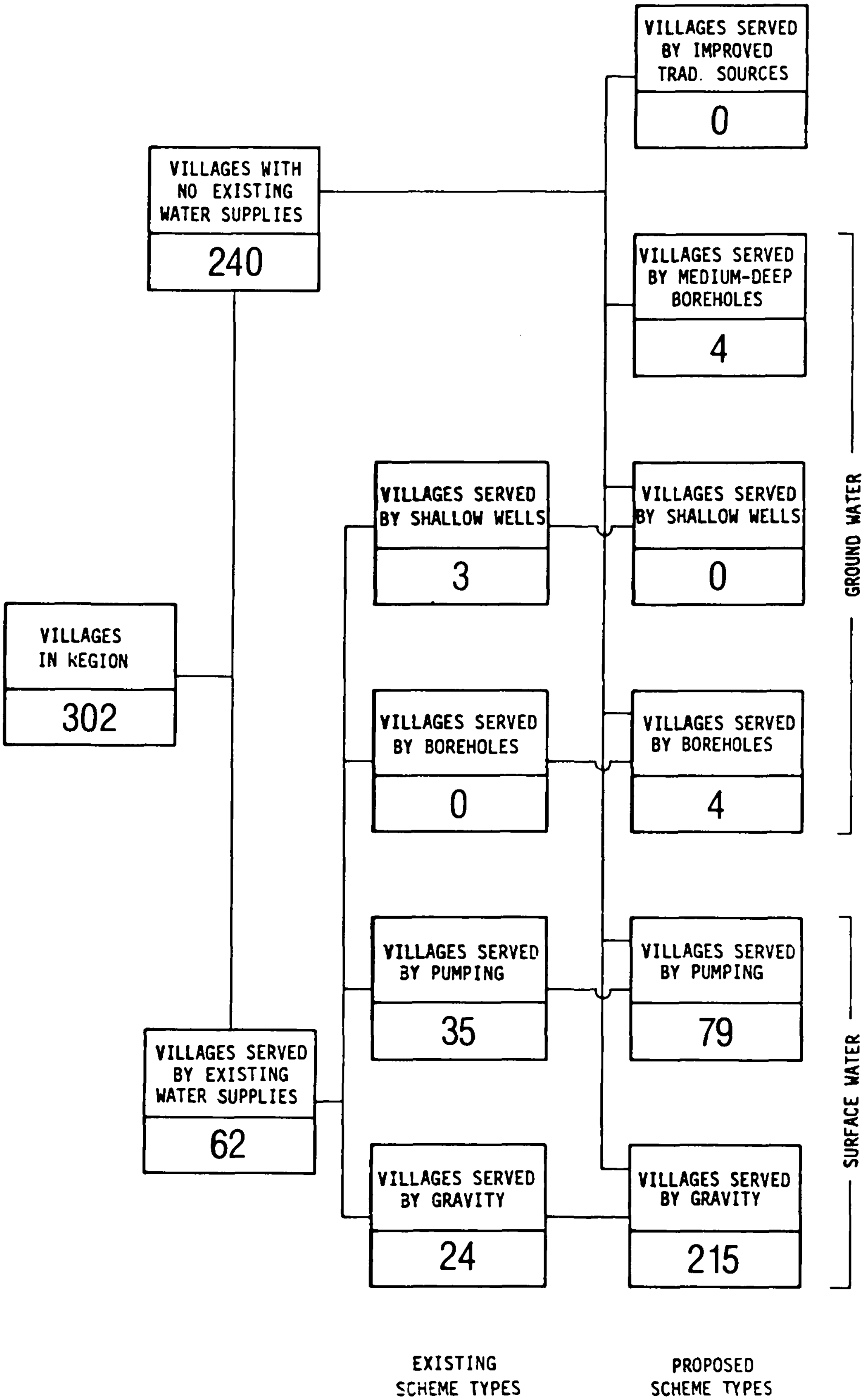


Figure 6.3 - Water Master Plan proposals - village water supply scheme types.

The quality of water source has been chosen such that whenever possible no treatment is required in accordance with the principles previously put forward. Protection of sources should be introduced in all cases, the degree and nature of the protection being in accordance with the type and location of the source.

Where treatment has proven necessary because of the source quality or size of scheme, only three basic simple types have been proposed. These are infiltration for cases where turbidity is a problem in small supplies, and aeration where iron is a problem. In larger supplies slow sand filtration has been put forward as the most appropriate means of safeguarding bacteriological quality and reducing turbidity. Horizontal roughing filters are proposed in association with slow sand filters if the turbidity level necessitates.

A summary of the water supply treatment proposals is given in Figure 6.4.

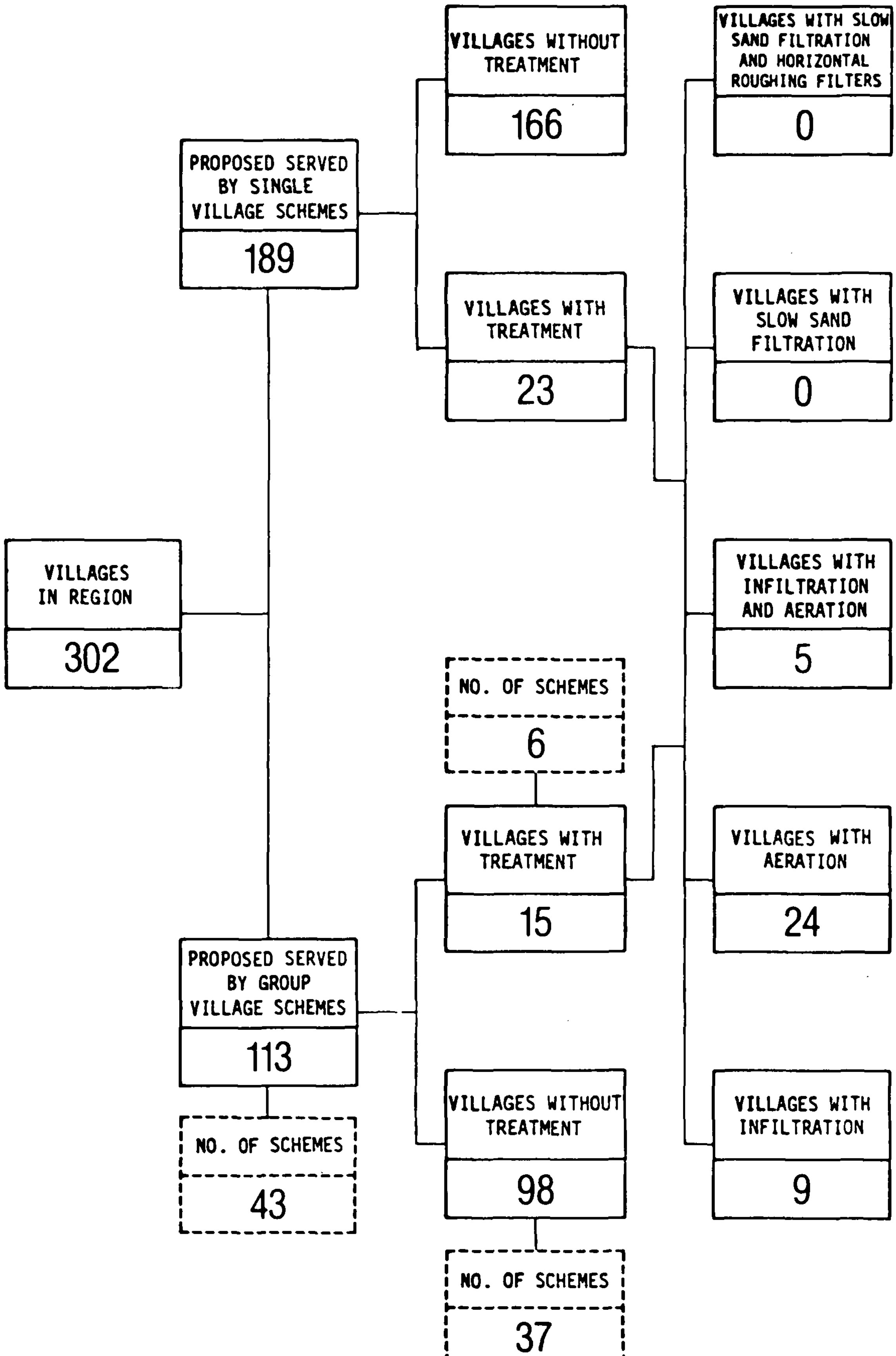


Figure 6.4 - Water Master Plan proposals - village water supply treatment.

6.4 Cost estimates

The cost estimates of the water supply scheme proposals have been based on the use of local materials, wherever available, construction by MAJI staff and using design criteria established as part of the Water Master Plan.

The resultant cost levels and per capita equivalents are given in Figure 5.1. Costs are given in million Tanzanian Shillings and based on constant July 1981 levels, and per capita costs are based on the design population.

Sensitivity studies carried out on various aspects of constructional or design alternatives showed that the most significant effect on cost level could be obtained by using imported pipe material for construction. Savings of 30 to 35% on total scheme cost could be obtained if imported pipe materials are used, and although such a policy is contrary to the principles of assisting local industrial development we consider the scale of saving to be too great to be ignored.

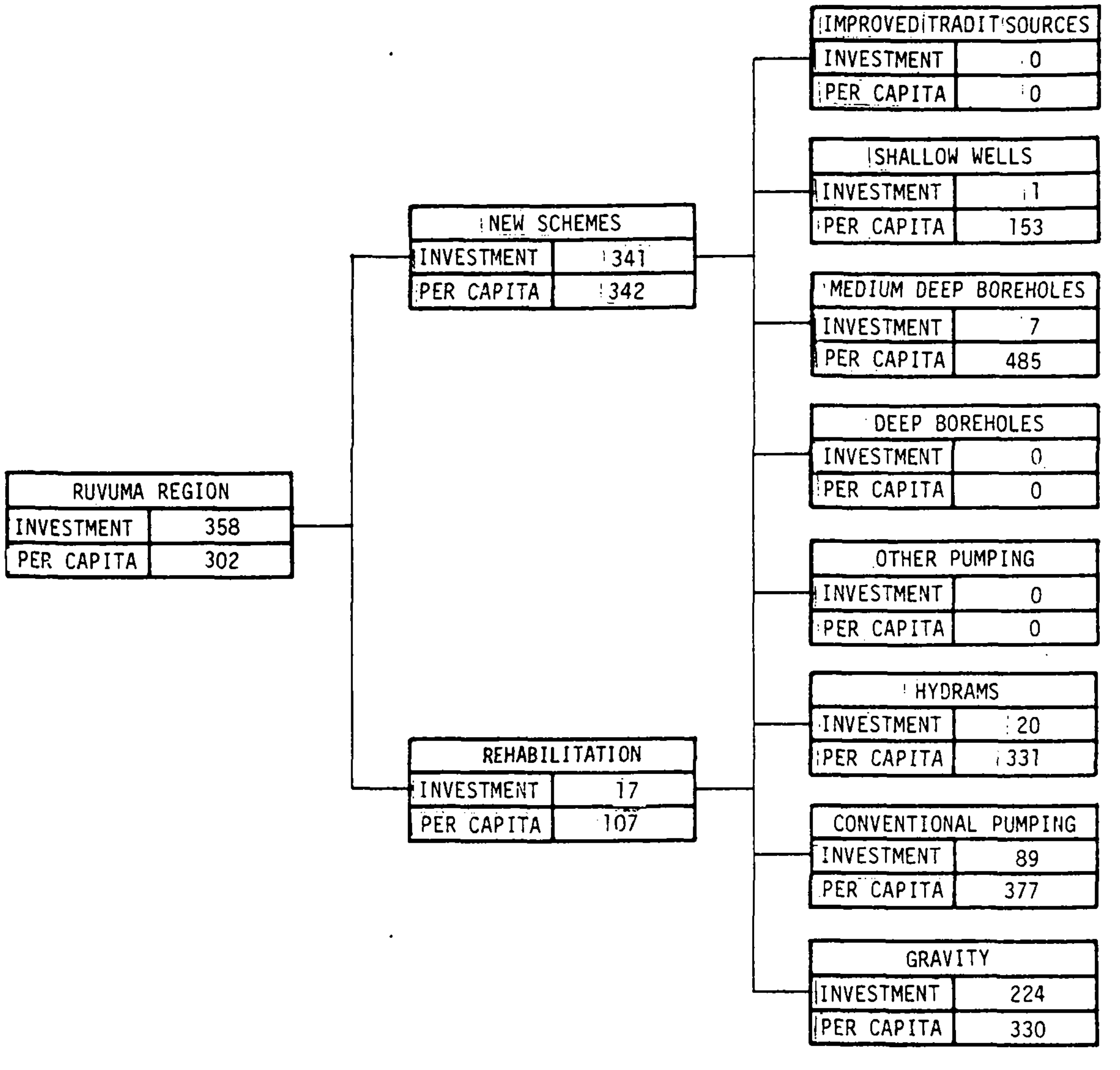


Figure 6.5 - Water Master Plan proposals - cost estimates

6.5 Implementation

6.5.1 Strategy

The implementation of the village water supply proposals is recommended to be carried out by MAJI construction teams assisted by village community participation.

Two factors lead us to believe that this procedure is essential. Firstly, the manpower requirements for the construction programme is so immense that only by mobilising village labour can it be contemplated within the time span envisaged. Secondly, the remote nature but organised structure of the villages together with experience of the existing improved supply situation indicate that a high level of village involvement is necessary for successful operation and maintenance of schemes constructed.

The implementation programme has been subdivided into three categories of operation, namely district level, regional level, rehabilitation and groundwater.

The division between schemes implemented by regional teams and district teams has been taken as T.Shs. 3,000,000.

6.5.2 Construction procedure and programme

The construction sequence has been planned to complete implementation of all water supplies by 1991 in line with the Tanzanian Government policy.

However, flexibility of adjustment of this programme has been catered for by providing an implementation planning chart based on the established priority of villages. This chart can be used to establish some alternative implementation programmes which may be necessitated by budgeting or other constraints.

Within the framework of the implementation plan proposed the policy has been to establish a steady build up of momentum of construction to ensure a thorough training and preparation of the construction units and associated administrative structure involved.

A similar "tailing-off" of construction work is built in to the end of the construction programme to avoid a sudden cut-off of the constructional involvment in the region. The "tail-off" in construction work has been matched as far as possible with the increasing need for operation and maintenance staff.

6.5.3 Operation and maintenance

The operation and maintenance principles proposed involve a significant move from MAJI responsibility to villagers responsibility.

This is considered necessary to avoid problems already caused by remoteness of many villages and associated communications problems and also to establish a much greater sense of responsibility within the villages for the proper operation and maintenance of their water schemes.

The MAJI organisation will still remain an important unit in the rural water supply field, however. Its function will be to coordinate the smooth functioning of the vastly increased number of schemes within the region by operating a monitoring system, back-up maintenance facilities and training.

6.5.4 Recurrent costs

The recurrent costs of the implementation programme are an important consideration.

Due to difficulties in ascertaining the scale of participatory savings in operation and maintenance the present MAJI system costs are given. Estimates of potential savings of the participatory situation are 20 to 30 per cent of those given below.

On completion of the programme in 1992 the equivalent MAJI system cost is estimated to be T.Shs. 19.1 million per year. This represents a cost of T.Shs. 25.90 per capita per annum at this point in time. When the full design population is achieved the equivalent cost will be T.Shs. 16.40 per capita per annum.

Various considerations of realising this revenue have been considered. The most favourable would appear to be a combination of government funds to operate the MAJI element, "in-kind" payment by villagers, such as free labour participation in maintenance activities or contribution of some cash crop proportion to a communal fund for operative expenses and the remainder of cash costs being met from communal village funds or a local levy.

6.6 Organisation and management

The present organisation and staff quite naturally have limited experience of the scope and nature of the future tasks to be carried out in connection with the proposed implementation and therefore some adjustments and improvements of that organisation as well as staff training must be undertaken.

It is proposed that efforts with respect to organisational improvements be primarily directed towards the region which is regarded as the power centre of rural water administration. Consequential changes within the national water administration and district water engineers administration should then be made as appropriate.

A detailed implementation plan should be set up, developed and carried out initially as a pilot project within one region. The objective of this proposal is to obtain sufficient experience with respect to suggested planning procedures, training activities, interactions between various organisational functions, cooperation between Tanzanian staff, donor agency and external staff resources, and thus facilitate the efficient handling of corresponding tasks in other regions.

To ensure sufficient capacity for organisational and procedural changes external assistance will be needed.

To secure a balanced process, plans for rehabilitation of existing schemes and construction of new ones should always be determined in view of organisational capacity, including capacity for operation and maintenance, at any time.

7. WATER RELATED PROJECTS

7.1 General

The Water Master Planning excercise has had as one of its primary objectives to investigate the availability of water for village water supply and to propose suitable systems for implementation of the particular supplies. Though the water necessary to sustain human life must have the first priority other uses of water must be considered as well in order to exploit this resource for the benefit of productive uses. The two water-related activities having a major potential in the regions are irrigation and hydropower. The demands on the water resource from these two activities differ widely in scope. While irrigation actually consumes water through an increase in evapotranspiration over the irrigated fields, hydropower generation is usually connected to impounding dams and will cause an increased equalization of river flows over the year. By regulating flows a reservoir will enhance the possibilities for activites relating to run-of-the-river downstream of the hydropower site. As for the irrigation, substantial amounts of water are withdrawn from the river system and depriving the downstream user of part of the river flow.

To arrive at an illustration of the scale of the water demands in relation to resources it can be mentioned that the gross surface water resource expressed as the mean annual runoff over the three regions is approx. 59,000 mill. m^3 while the water demand for domestic use is approx. 46 mill. m^3/year or 0.8% of the surface water resource. Those figures are of course indicative at the size of order only since the geographical distribution of demands and the distribution of the runoff in time and space greatly influence this ratio. Locally water shortages may occur though demands may be small.

As regards irrigation demands another picture emerges. If for instance the 10-year minimum runoff over the entire area was used for irrigation at a rate of 1 m^3/s per 860 ha field, then approx. 190,000 ha could be irrigated.

If reservoirs could be created to equalize river flows over the year then a mean flow would be 1,870 m^3/s corresponding to approx. 1.6 mill. ha of irrigated land.

This, of course, is a purely theoretical figure which is reduced by the use of water for other purposes, the actual distribution of land and water resources and a large number of other physical as well as human factors.

The study of appropriation of water rights has shown that in certain areas (i.e. around Iringa Town and in parts of Southern Iringa and Mbeya) appropriation is close to the 10-year minimum runoff meaning that the unregulated resource is fully utilized. However, the detailed lists of water rights have also shown a large number of uses which are probably not in existence anymore. A revision of the water rights issue is strongly recommended before more final deductions about availability of water are made. This is particularly important in the irrigation context as very large amounts of water are needed in comparison with other uses.

In general, the regions have a great potential for creation of equalizing reservoirs which would thus greatly improve the possibilities for the exploitation of increasingly larger proportions of the runoff.

7.2 Irrigation

7.2.1 Agricultural conditions

The great majority of Tanzania's population of some 18 million people live on the land as peasant producers. Approximately 50% of the Gross National Product stems from agriculture, and half of this is produced by peasant producers, mostly at subsistence level, and mostly on holdings under 5 ha in size. The great majority of peasant producers are fully dependent upon rainfed agriculture.

Some 75% of Tanzania's export is derived from agriculture, the main cash crops being cotton, coffee, tea, sisal, cashew nuts and cloves from Zanzibar.

In recognition of the critical importance of the agricultural sector the Government of Tanzania is giving high priority to agricultural development. Key elements of the Government's strategy for development are:-

- Better use of land resources
- Irrigation development so as to reduce dependence on rainfed agricultural production
- Encouragement of mechanised village communal farms
- Better provision and distribution of farm inputs
- Reduction of past harvest losses
- Strengthening of credit facilities for small farmers.

During the recent Food Strategey Workshop in Arusha (November 1981) Government emphasis on food production was reiterated and stressed.

While all the above mentioned points are to a large degree interrelated and must go together, it is perhaps in the field of irrigation and in the tapping of the regions' vast and under utilised water resources that the greater potential for a rapid development of agricultural production lies, both in food crops and in some cash crops such as tea, coffee and cocoa, etc.

The three regions under review are at very different stages with respect to irrigation development and planning. Whereas in Ruvuma Region only small scale village irrigation is practised, large schemes are implemented or under study in Iringa Region. A Regional Integrated Development Programme (RIDEP) has been prepared for Iringa Region, and RIDEP teams are currently working in both Iringa and Mbeya, while no such planning has started in Ruvuma Region. This gives a widely differing possibility of evaluation of the irrigation potentials and constraints from region to region.

In most areas the natural rainfall will normally be sufficient to sustain one crop, and in areas with abundant rainfall such as Kyela and Rungwe Districts and the Mporoto Mountains, year-round cultivation is possible without irrigation. However, crop failure or semi-failure is a regularly recurring event as the amount of rain varies considerably from year to year, and consequently supplementary water in the form of irrigation, particularly towards the end of the dry season, holds promise of considerable increase in agricultural output. Not only does irrigation water sustain crops which otherwise could not be grown, it also contributes to increasing crop yields in general by ensuring optimal water availability. Furthermore, the uncertainty or risk of insufficient rain is a serious factor in making peasant producers reluctant to invest cash in agricultural input, and it is felt that supplementary irrigation would create a more secure base and thus encourage investment in fertilizers, insecticides, implements, etc., which contribute to increasing the agricultural output.

Apart from the 3,200 ha Mbarara scheme in Iringa Region, large scale irrigation is not presently practised in the three regions under review. However, there is a great number of individual micro-schemes of traditional rather primitive irrigation, not least in Iringa Region, where vegetables, particularly tomatoes and onions, are grown under irrigation, as well as some dry season maize.

Consistent and reliable estimates on the extent of existing irrigation in the regions are hard to find. According to a recent FAO/UNDP survey report on the National Village Irrigation Development Programme present and potential traditional small scale peasant irrigation can be summarised as follows:

Region	Area under Irrigation (ha)	Area under Cultivation (ha)	Available potential arable land (ha)
Iringa	828	309,300	464,200
Ruvuma	14,580	138,000	452,000
Mbeya	12,000	191,600	884,000

Table 7.1 - Present and potential small scale peasant irrigation

The figure from Iringa Region in this table was supplied by the region to the Irrigation Division of KILIMO. It is believed to be inaccurate, and does not tally with information later compiled by RIDEP - Iringa.

7.2.2 Irrigation potentials in Iringa Region

Iringa Region is basically highland areas ranging from an altitude of 700 m in the Ruaha valley to about 2100 m in the higher areas. The area is generally well watered, having a unimodal rain pattern with genereally sufficient rainfall for one good crop a year. There is a great number of perennial streams and a good potential for an agricutural production during the dry season under irrigation, not least in the form of mini or village irrigation schemes.

Iringa is a region with a vast diversity and large agricultural as well as livestock potential. Generally there is a great potential for most temperate agricultural crops and for tropical crops as diverse as rice in the lower river basin areas, to tea and pyrethrum in the hills, and timber for wood pulp in the Sao Hill area.

Several large scale scheme potentials have been identified by various institutions and Consultants. These schemes comprise:-

- Madibira rice project, 5,000 ha National Agricultural and Food Corporation (NAFCO) rice scheme, 3,000 ha small scale farming. Impounded reservoir
- Kimande scheme, 6,000 ha rice scheme, impounded reservoir and flood control needed
- Mtera reservoir scheme, approx. 6,000 ha of area emerging when reservoir levels are low
- Pawaga-Kimande, 10,000 ha under investigation by Regional Integrated Development Planning (RIDEP) team
- Mbuyuni project, 2-3,000 ha under investigation by North Korean team
- Manda project, 3,000 ha jointly for Ruvuma and Iringa Regions
- Isagawafule, 5,000 ha water drawn from Ruhuhu river system.

All in all approx. 37,000 ha irrigable farm land has been identified as suitable for large scale operations. As regards small to medium scale projects following list applies:-

	Present existing	Potential
Iringa District	1,790 ha	6,530 ha
Mufindi District	283 -	3,123 -
Njombe District	181 -	1,315 -
Makete District	not available	1,204 -
Rudewa District	115	235 -
		12,407 ha

Table 7.2 - Small to medium scale irrigation potential

Concerning mini irrigation schemes in the villages a considerable potential appears to exist but exploitation of this potential is very much tied in with traditional agricultural practices and the possibilities for introducing changes.

7.2.3 Irrigation potentials in Ruvuma Region

Ruvuma Region suffers from poor communication and from being virtually cut off from the rest of the country for part of the year. This creates problems both for export of any surplus, and for bringing in farm inputs such as fertilizers, other chemicals, spares and other supplies.

In general, the region has good rainfall and high agricultural potential. It is hilly and undulating country with numerous streams and rivers, many of which are perennial.

Mbinga and Songea Districts are well populated in the higher areas, while in the lower areas vast resources remain untapped. These districts have fertile lands with a good production of agricultural products with maize being the mainstay of the economy in Songea District, while Mbinga District produces increasing crops of mild coffee for export. The main cash crop in Tunduru District is cashew nuts, with a scope of cotton production. These cash crops can carry the high transport costs induced by the poor infrastructure in the region.

According to figures obtained from Irrigation Division of KILIMO there is a total of 14,580 ha being irrigated in the region. These are all traditional small scale irrigation schemes. Due to the topography there is not a big scope for large scale irrigation projects. It would appear that there is water available in most of the villages for mini-irrigation schemes of from 2 ha to 50 ha or even more.

7.2.4 Irrigation potentials in Mbeya Region

Mbeya Region presents a variety of agricultural zones, many of which have a very high either actual or potential agricultural production. It also has some of the most densely populated districts in the country, as well as areas where the density is very small.

The region is rich in water resources, but it is also a region where this water resource is threatened by mismanagement of the watersheds. This affects not only Mbeya Region, but may in the long run adversely affect the entire Rufiji River Basin.

A zoning of the Usangu flats has been considered by the Mbeya RIDEP team. An irrigable cultivation zone of some 70,000 ha has been defined.

It is reported that up to 20,000 ha is presently being cultivated and irrigated by peasant producers. In addition the large scale irrigation project at Mbarara covers 3,200 ha with planned expansion for a 2,700 ha large scale irrigation development, and another 2,000 ha is considered suitable for small scale irrigation from the Chimala and Great Ruaha rivers. In addition there are plans for 1,000 ha of small farming in the Kapunga area, based on water from the Chimala river.

The Kyela District presents a special problem which is related to irrigation but rather has to do with the prevention of flooding.

Only one crop per year is produced, although the climate and water availability would make two crops possible. For the crop that is produced the problem is to avoid excessive flooding rather than getting water on to the rice fields. Floods make the communication difficult, and often spoil the crops.

Two main proposals for flood relief have been brought forward. One is to build levees along the river banks while the other is to establish diversion canals. A very large increase in production would be possible if such measures were introduced. In Mbozi District the existence of some eight irrigation schemes of 150 ha to 200 ha per scheme is reported.

In the Lake Rukwa area a potential for an 8,000 ha irrigation rice scheme has been pointed out by the Agricultural Office in Mbeya. As for Mbeya and Chunya Districts numerous micro schemes are in existence and there is seemingly a scope for improving efficiencies.

7.2.5 Recommendations on irrigation

The present review of irrigation conditions and possibilities in Iringa, Ruvuma and Mbeya Regions has indicated a large number of strategic elements of a successful irrigation development in the area. Detailed and comprehensive recommendations for such a development will undoubtedly result from the Regional Integrated Development Programmes. However, based on the present review, particularly the identified constraints to agricultural development the following specific recommendations are stressed:-

- Poor infrastructure is probably the single most important constraint to agricultural development in the regions. Access roads, and transport possibilities in particular, need to be improved in order for peasants to be able to get their products to the market.
- Higher mountain areas should be protected against devastating erosion by tree planting on the steepest slopes, and a soil and water conservation programme in the lower areas. It would be necessary to continue this with a programme of planting trees for fire-wood in the villages, so as to have an alternate source of fuel for cooking.

- Agricultural extension services need improvement. Personnel should be found for this task who would also be skilled in the installation, operation and maintenance of irrigation works. It is necessary that the extension officer has the confidence of the people he is to serve, and that he has sufficient time to get to grips with the problems in the field. Special courses for training extension officers should be considered.
- Irrigation development in Usangu and Kyela should be examined in more detail.
- A more detailed study of the potential for small and mini village irrigation schemes should be undertaken.
- Soil fertility and suitability for irrigation should be investigated, initially by preparation of detailed soil maps for the three regions (i.e. ongoing soil mapping by Uyole Agricultural Centre), secondly by more detailed soil investigations in promising areas.
- Credit facilities should be extended to the small peasant producer, possibly by the creation of small credit unions with memberships of say up to 20 farmers. It should then be a rule that all members were responsible for any single defaulter's debt. It was indicated to the Consultant that if small peasant credit societies of this nature were set up, then the National Bank of Commerce might be willing to consider an enhanced rate of interest on their deposits in order to encourage this kind of business.
- Mechanised cultivation practices should be carefully controlled. If the Irrigation Division of KILIMO goes ahead with creation of a mobile irrigation construction unit, it would be well to join it with a soil conservation unit and to insist that no irrigation construction work be undertaken without appropriate soil conservation measures.
- The incidence of bilharzia and malaria must be reduced by controlling the vectors, i.e. the bilharzia-bearing snail Bionphilaria opp., and the malaria-bearing Anopheles mosquitos. Extensive work has been done by Tropical Pesticide Research Institute and by Tanganyika Planting Company (TPC), Ltd. on snail and mosquito control on the 8,000 ha irrigated sugar estate near Moshi. The results have been very good,

and their methods would be worth studying with a view to extending particularly the snail control to other parts of the country. In Kyela and Usangu, with water that is not alkaline, the introduction of the biological control as successfully practiced by TPC in some of their non-alkaline drains may hold some promise.

7.3 Hydropower

7.3.1 Power supply situation

The Tanzanian policy seeks to diversify the economy by developing the industrial sector, thus reducing the reliance on agricultural exports for the generation of foreign exchange. The current trend is towards basic industries like cement, pulp and paper and textiles, although several other types of industries are planned as well.

The industrial developments will require large amounts of energy and the power generation is thus crucial to the national development plan.

Present policies on domestic use includes plans to bring electricity to a larger part of the urban population and to emphasise rural electrification as a means towards the cementation of the village structure.

On a national basis the maximum demand (1979) was 140×10^6 Watt (140 MW) while approximately 800×10^9 Watt x hrs (800 GWh) was generated. This corresponds to less than 50 kilowatt x hrs (50 kWh) per capita. However, less than 5% of the population has access to electricity.

The Iringa, Ruvuma and Mbeya Regions are presently served by isolated systems. These comprise diesel driven generating units in the main population centres and some minor hydroelectric installations.

The power demand has in some places reached or surpassed the capacity limits of the generating units, and installation of additional units is planned in Mbeya and Njombe.

In parallel with these plans construction of extensions of the national grid is undertaken. Of particular interest is the extension from Kidatu to Mbeya via Iringa and Mufindi.

The power supply from the diesel-powered generating units is in many cases unreliable. Frequent power breaks occur and this combined with inadequate capacity render the conditions in for instance Mbeya quite unsatisfactory for the consumer. Load-shedding is taking place. The distribution from the isolated units is at 11 kilo Volt (kV) lines while only when long distances are involved 33 kV lines have been constructed.

Table 7.3 lists the larger power installations in the three regions, their type and available capacity.

Name/location	Type	Available capacity kW	Owner
Iringa Region			
Tosamaganga	hydro	1,220	TANESCO
Iringa Urban	diesel	700	TANESCO
Wemba/Njombe *	hydro	100	Benedict.Fathers
Bulongwa	hydro	180	Bulongwa Hospital
Ruvuma Region			
Songea Urban	diesel	530	TANESCO
Songea	hydro	45	Magareza Project
Peramiho	hydro	30	Benedict. Fathers
Peramiho	hydro	3	Benedict. Fathers
Hanga **	hydro	-	St. Marus
Mbeya Region			
Mbalizi	hydro	270	TANESCO
Mbeya Urban	diesel	2,080	TANESCO
Tukuyu	diesel	1,050	TANESCO
Isoko/Tukuyu	hydro	10	Moravian Mission
Isoko/Tukuyu	hydro	7	Moravian Mission
Rungwe	hydro	21	Moravian Mission
Tunduma	diesel	225	TANESCO
Utengule	hydro	-	Swiss Plantation
Mbarali	hydro	160	State farm

Table 7.3 - Existing power installations * under procurement
** under installation

7.3.2 Hydropower development

The generation of hydropower exploits the difference in hydraulic head between two points of a river. By construction of impounding dams at appropriate locations the head difference and thus the potential of a power plant can be increased.

The initial cost of a hydropower project is generally higher than that of a comparable thermal plant. The initial cost of the hydropower project includes the cost of the dam, diversion works, conduits, the generating plant itself, access roads, etc. Often a hydro-electric project is located at a relatively inaccessible location which adds to the initial cost because of the expense of hauling materials and equipment and because of long transmission lines to carry the energy to the market. In addition to the cost of transmission facilities there is loss of energy during transmission.

Thermal plants are usually located near their load centres, eliminating the need for long transmission lines. The site requirements for a thermal plant include the availability of an adequate supply of fuel and plenty of water for cooling the condensers.

The cost of operating a thermal plant is much higher than for a hydroelectric plant, mainly because of fuel costs. A thermal plant is also more difficult to operate and maintain, and the cost of maintenance and repairs is substantial.

Once found technically and economically feasible, the hydropower production costs are known more or less for the useful life of the project. The price of thermal power is conversely very dependent on fluctuating fuel prices, which in the Tanzanian context means a constant increase in the foreign currency bill.

Hydropower developments mean utilisation of a renewable source of energy, while conventional thermal power developments will exhaust the available resource. As the river flows vary considerably throughout the year and can be regulated only through establishment of reservoirs, an electricity supply based on hydropower only may not be feasible, or say possible. However, even a combination of the two sources of electric energy could mean a substantial reduction of oil imports.

7.3.3 Hydropower potential assessment

The hydropower potentials of Iringa, Ruvuma and Mbeya Regions have been assessed on an outline basis. Potentials, where development is deemed uneconomical, are not included. The feasibility of the schemes included in the total hydropower potential of the regions still remain to be established, and through a detailed feasibility study some of the identified sites may prove not economic.

This is valid for the medium to large scale potentials while the small scale development can only be assessed in more general terms.

It is important to note that the identified potentials are based on preliminary findings and should be taken as indicative only. As several areas in the three regions are not covered by topographic maps the potentials identified are far from being exhaustive.

7.3.4 Hydropower potential in Iringa Region

The hydropower potential of the Iringa Region is found mainly in the mountainous areas around Njombe, draining both westwards to Lake Nyasa and eastwards to the Kilombero Valley. Also, along the escarpment further east on the Iringa/Morogoro border line well-defined potential sites for hydropower developments are found. Both areas receive above average rainfall, and the scarps and plateaus represent desirable conditions for hydropower developments with respect to head and storage potentials. The streams in these areas are perennial. As, to a great extent, topographic maps exist for these areas, it has been possible to identify a number of specific sites and to estimate their potential. Some potential for hydropower is also found in the Great Ruaha River Basin, but except for a few potential developments on the Little Ruaha river and the known potential in connection with the Mtera Reservoir very little can be done owing to lack of topographic information.

The schemes identified represent the following energy potential:-

- Firm power capacity 675 MW
- Firm energy capability 5,785 GWh/year
- Installed capacity 975 MW
  (at 0.7 load factor)

The feasibility of the schemes will have to be established through further studies.

According to information obtained from TANESCO aid agencies from various countries are presently conducting studies on specific small hydro-electric projects in the region, or may start doing so in the near future.

In the Iringa Region Denmark is presently sponsoring the study of the Ruhudji River Falls in Njombe, while the Federal Republic of Germany is sponsoring a study on the Hagafiro River east of Njombe.

7.3.5 Hydropower potential in Ruvuma Region

The only river basin of any significance to the hydropower potential in the Ruvuma region is the Ruhuhu River. This basin is partly located in the Iringa region and potential hydropower developments on the upper Ruhuhu fall within this region.

The lower reaches of the Ruhuhu River form the border line between the Iringa and Ruvuma regions. As this part of the basin geographically is closer to the central parts of the Ruvuma region, developments here are listed under this region.

In addition, conditions for hydropower developments are present on the scarps along Lake Nyasa, but the catchments are mainly small. The rest of the region has undulating terrain and streams that tend to dry up between rainy seasons. It is therefore not likely that one will find feasible developments here. Using the 1:50,00 maps with 20 m contour lines no developments on the Ruvuma River with tributaries appear to be feasible. Exceptions are on the upper reaches of the Lumeme River along the Mbamba Bay-Mbinga road.

The schemes identified represent the following total energy potential:-

- Firm power capcity 290 MW
- Firm energy capability 2,495 GWh
- Installed capacity 410 MW
  (at 0.7 load factor)

The feasibility of the schemes will have to be established through further studies.

As for Iringa Region information obtained from TANESCO indicate that aid agencies from various countries are presently conducting studies on specific small-scale hydro-electric projects in the region or may start doing so in the near future. The list of schemes may therefore be revised once the results from these studies become available. However, these schemes are not likely to have any impact on the regions' total hydropower potential.

In the Ruvuma region, Sweden is presently sponsoring studies in the Songea and Tunduru areas, while the Federal Republic of Germany is sponsoring a study on the Luaita River near Mbinga.

7.3.6 Hydropower potential in Mbeya Region

The hydropower potential in the Mbeya region is found in the mountainous areas south and south-east of Mbeya town. These areas receive above average rainfall and along the scarps surrounding the northern end of Lake Nyasa, the topography is in favour of hydropower developments. For the larger part of the Mbeya region or approximately all areas north of 8° 30' degrees South the annual rainfall is less than 1000 mm which, combined with a very pronounced dry season results in few perennial streams. As topographic maps with contour lines are non-existent for these areas potential reservoirs cannot be identified. The feasibility of hydropower developments here therefore is very uncertain, hence the schemes covered by the Western Tanzania Project, Report No. 2 on the Mtembwa, Songwe (to Lake Rukwa), Lupa, Lukwate, Wuku and Yeye Rivers are disregarded for the purpose of this study. It is recommended, however, that these basins be looked into later, when maps and further hydrological information becomes available.

The Songwe River, draining areas on both sides of the Tanzania - Malawi border to Lake Nyasa, has large reservoir possibilities in the Bupigu area half way between Tunduma and the lake. Although hydrological conditions here are favourable to hydropower developments, lack of mapping precludes evaluations of the feasibility. Potential sites are therefore not included in this study, but should be kept in mind for future studies.

The schemes identified represent the following total power and energy potential:-

• Firm power capacity	185 MW
• Firm energy capability	1,630 GWh
• Installed capacity (at 0.7 load factor)	265 MW

The feasibility of the schemes will as mentioned earlier have to be established through further studies.

There is at present no other known hydropower studies being conducted in the Mbeya region. However, according to information obtained from TANESCO a more detailed study of a possible development on the Kiwira River may soon go ahead sponsored by the Korean Aid Agency.

7.4 Conclusions and recommendations on hydropower

The hydropower potentials identified through this outline study are summarised in Table 7.4.

To arrive at an idea about the scale of the hydropower potential identified it could be mentioned that the total 1979 maximum demand was about 140 MW. Projections of this demand in conjunction with grid extensions to cover most demand centres in Tanzania could take this figure to, say 700 MW in the year 2005. The hydropower potential (if found feasible) in Iringa region alone could cater for this demand. It is thus clear that extremely large potentials are present, and if just one of the larger identified potential locations is deemed feasible power demand in a foreseeable future can be satisfied from hydro-electricity.

There is additional hydropower potentials in the regions that could be developed through small-scale projects. However, the potential energy of these schemes is without any significance to the regions' total hydropower potential and also the identification of such schemes requires extensive field work. However, considering the prices of fuel, the foreign currency shortage and the difficulties involved in maintaining thermal plants it is expected that small-scale hydropower plants will play an increasingly important role in the power supply for the rural areas. Also on an international scale more and more effort is directed towards development of appropriate hydraulic machinery for use in mini-hydropower plants.

River/Name	Sites	Firm Capacity MW	Firm Energy GWh	Installed Capacity MW
Iringa				
Ruhudji	4	202	1,720	276
Mpanga	1	65	550	90
Ruaha	1	62	530	90
Ruhuhu				
Upper Ruhuhu	3	86	740	122
Nkiwe	4	195	1,670	275
Others	8	66	575	120
Total	21	676	5,785	973
Ruvuma				
Ruhuhu				
Lower Ruhuhu	3	280	2,425	400
Others	3	8	70	11
Total	6	288	2,495	411
Mbeya				
Rumakali	2	150	1,335	215
Kiwira	2	30	260	42
Others	4	4.5	40	6.5
Total	8	185	1,635	265

Table 7.4 - Hydropower potential summary. Iringa, Ruvuma and Mbeya Regions.

The Tanzanian policy - to industrialise in order to increase exports and hence generate foreign currency will undoubtedly mean a steady increase in the demand for electric energy. Import of oil for thermal electricity generation at the same time means a great pressure on the economy because of the increasing prices. Hence, the development of indigenous resources, of which hydropower is plentiful, must be expected to play an important role in the future Tanzanian economy.

With the planned transmission line extension from Kidatu at the eastern corner of the Iringa Region right through this region to Mbeya partly under construction already, transmission distances from potential schemes in this area are cut to within 150 km. This would make further studies of potential hydropower developments rather meaningful. One important benefit, among other things, would then be the combination of local supply and "export" of surplus capacity, i.e. development of locally too large schemes may be justified resulting in benefit from the economies of scale.

The Iringa and Mbeya Regions both have potential sites for hydropower developments that deserve closer study as they may easily play an important role in the future economy of Tanzania with respect to rural as well as national developments. The feasibility of the potential sites described in this study will have to be established in more detail through further hydrological, geological and other studies. The rough cost estimates given should be used in ranking the schemes for further investigations only. It seems appropriate to concentrate on the less remote schemes with respect to the planned transmission line and high head schemes before low head schemes.

8. MAIN RECOMMENDATIONS

8.1 General

Below, the main recommendations of the Water Master Plan are summarised. Emphasis has been placed on recommendations of a general and broad nature, whereas the more detailed and specific recommendations are dealt with in the various volumes.

8.2 Hydrology

- Strengthening of rainfall data network, collection, storage and analysis should take place through more frequent inspections, computerised storage and processing and regular publication.

- Systematic analysis of rainfall intensity records should be initiated.

- Climatic station operation should be improved and extension of network can take place when satisfactory operation has been obtained.

- Further detailed hydrological investigations are necessary at intake locations where water demands and estimated minimum flows are of the same order of size.

- Adequate computer facilities should be provided at MAJI to remove bottlenecks in data processing and provide annual publications.

- Water-rights should be reviewed critically and rights not properly utilised should be withdrawn.

- An effective programme of sediment transport measurements and analyses should be initiated.

- The simple rainfall-runoff model (NAM) should be installed at a MAJI computer and utilised in future water resources investigations.

8.3 Hydrogeology

- Regional geological mapping should be initiated for the northern parts of Iringa and Mbeya Regions and the Tunduru Karroo Basin in Ruvuma Region.

- Across the Basement Complex geomorphological interpretation will be basic to location of wells. Geophysical surveys can supplement knowledge but are not essential.

- In Karroo formations well-siting can be done on geomorphological interpretations only.

- Across lake beds and alluvial deposits simple field reconnaissance will be sufficient for siting of wells.

- Only hand pumps shall be applied in wells.

- Shallow wells constitute a tecnology option in alluvial plains and in alluvium and collovium along escarpments.

- Medium-deep wells with hand pumps constitute a technology option at topographically level areas on African and post-African surfaces, Karroo Basins, Usangu Flats and Rukwa Trough.

- The heavy Schramm T64 Rig is not recommended for drilling under Tanzania conditions. Rotary drilling with light rigs or simple percussion drilling are more suitable.

- Hand-drilling can be successfully done in alluvial deposits.

- A number of springs and boreholes should be monitored for future reference.

8.4 Water Quality

- Water quality survey and monitoring operations should be strengthened by establishing water quality measurement services in the respective regions.

- These services should be capable by standardized and intercalibrated methods to carry out measurements needed according to the proposed programmes for overall water quality with desired accuracy.

- Systematic survey and monitoring programmes should be prepared for existing, traditional and proposed sources.

- More emphasis should be given to field surveys to ensure adequate quality of various characteristics of water sources without delay.

- To ensure the field surveys the establishment of mobile units might be considered.

- Systematic water quality records should be established in the regions.

- Frequent reporting systems should be prepared.

- Cooperation and coordination with other supporting activities should be considered.

8.5 Water Engineering

8.5.1 General principles

- Water should only be served to the concentrated habitated area of the village. From a water supply point of view it is suggested that village development is restricted to a maximum allowance of 1 hectare of immediate land per family to avoid excessive cost of distribution systems.

- Water supply schemes shall be selected so as to provide simple and reliable technical solutions, where local inputs are pre-dominant and foreign inputs are at a minimum.

- Low cost schemes shall be identified, and design factors which influence cost shall be carefully evaluated and realistic.

- Further investigations of schemes requiring rehabilitation are required to accurately determine the extent of work necessary.

- Implementation programmes shall be carried out within the existing institutional framework and on a decentralised basis as far as possible.

- Villages should be directly responsible for operation and maintenance of their own water supplies.

- Village boundary maps produced as part of the Water Master Plan should be used as a basis for an official Village Boundary Map for each District/Region.

- The village inventory data have been prepared in a computerised format with the objective of future updating and usage being simplified.

8.5.2 Scheme priority

- "Need" should be the main criteria for judging the priority rating of a village. After need rating villages should be listed in accordance with the principle of lowest per capita cost first.

- Schemes of unacceptable technology level or of exceptionally high cost should not be constructed but effort should be made to identify a scheme which is acceptable.

- No scheme should be commenced with respect to design or construction until full agreement with the village government is obtained regarding outline of the scheme and commitments entailed.

8.5.3 Source selection and design

- Source selection shall be done in such a way as to keep pollution risks low and to minimise the need for expensive and complicated equipment.

- More hydrological/hydrogeological investigation is required to properly assess the reliability of proposed sources.

- Water sources conforming to WHO or Tanzanian temporary standards should be selected wherever possible. Where not possible, slight relaxations for small water supplies where those do not have health implications or the "risk" is minimal, are recommended.

- Only three simple forms of treatment are proposed; infiltration for turbidity problems in small supplies; aeration where iron is a problem; slow sand filtration with or without roughing filters as appropriate for bacteriological treatment and turbidity control on larger schemes.

- Intakes should be better designed regarding foundations, erosion, screening, measuring devices, scouring.

- A Regional or Inter-Regional Design Unit should prepare standard drawings, design procedures and planning charts to improve design practices.

- Of manufactured pipe systems, PVC and PEH pipes have the most suitable application to Tanzanian rural water supply development.

- Durability, jointing and health problems in connection with bamboo pipes need to be solved before inclusion in large scale implementation can be considered.

- An overall per capita consumption of 25 litres per day should be adopted as a planning figure but detailed analysis of the demand of each village needs to be considered at design stage.

- Inclusion of livestock watering is neither economic nor necessary in the domestic water supply system of most villages. Where necessitated through unavailability of natural sources at some times of the year, consideration should be given to the development of lower cost and quality sources, possibly as a community project.

- A service level of 400 metres walking distance should be provided as a planning figure. However, where traditional sources are at a distance of less than this figure, careful consideration of the possible usage of the scheme must be made.

- Of non-conventional pump types, only hydrams are considered sufficiently proven to be presently introduced. Waterwheels, wind power and solar power should be further studied for potential incorporation.

- Due to cost and technical limitations diesel or petrol powered pumping systems should not be incorporated.

- In the limited areas where shallow well development is possible in the three regions, problems with respect to suitable hand pumps and villager acceptance need to be solved.

8.5.4 Scheme construction

- The use of imported pipe materials are recommended due to significant cost savings.

- Construction is proposed to be carried out by MAJI assisted by village participation.

- Construction is to be carried out by Regional or District Teams depending on size of scheme. Rehabilitation and groundwater schemes are to form separate construction categories.

- Detailed specification for construction of works is required and should be enforced by adequate supervision.

- Trench invert preparation and pipe jointing should receive special attention.

- Manpower for construction should be substantially drawn from the villages.

- Construction supervising teams should be formed to oversee three construction teams to economise on skilled labour.

- A rehabilitation programme could form an appropriate means of commencing an early improvement of implementation procedures.

8.5.5 Operation and Maintenance

- Operation and maintenance are proposed to be significantly moved from being MAJI responsibility to being village responsibility.

- Scheme attendants are selected from the village and trained during scheme construction.

- A supply of basic materials should be provided at the completion of each project for initial operation and maintenance purposes.

- The District Water Engineers Office is responsible for providing assistance to villagers on a paid basis when requested and also for monitoring and control of scheme.

- The Regional Water Engineers Office is responsible for coordination and training.

- Cost of operation and maintenance should be borne by a combination of government funds to run MAJI element, in-kind payment by villagers for operational expenses and the remainder cash costs by communal village fund or local levy.

- Continued operation of water supplies will also depend on the availability of some measure of foreign currency for operation and maintenance costs.

- A comprehensive workshop should be established at Regional level and a small workshop at District level.

8.5.6 Organisation and management

- Organisational capabilities of national, regional and district water administrations should be strengthened.

- A detailed organisation plan for all relevant activities covering a period of 2-3 years should be developed.

- The plan should initially be developed and implemented - totally or partly - as a pilot project, preferably within one region in view of the limited resources to secure proper experience to be obtained with respect to organisational inter-actions and suggested procedures before similar activities in other regions are undertaken.

- Improved procedures for planning, budgetting, control and coordination should be established.

- Involvement of all organisational levels in the shaping and priority rating of short term goals should be regarded as essential.

- External resources should be inserted to provide the necessary capacity for change with respect to organisational and procedural matters.

- The regional water administrations should be regarded as the most appropriate points to concentrate initial restructuring activities.

- The systematic handling and follow-up on all aspects of village participation is regarded vital to the long term success of water schemes.

- Training should be instigated as a tool to secure proper understanding and satisfactory performance.

- Operation and maintenance functions should be given a higher esteem in accordance with their importance to the long term utilisation of - investments and efforts.

8.6 Water-related projects

8.6.1 Irrigation

- Access roads, and transport possibilities in particular, need to be improved in order for peasants to be able to get their products to the market.

- Higher mountain areas should be protected against devastating erosion by tree planting on the steepest slopes, and a soil and water conservation programme in the lower areas.

- Agricultural extension services need improvement. Personnel should be found for this task who would also be skilled in the installation, operation and maintenance of irrigation works.

- A more detailed study of the potential for small and mini village irrigation schemes should be undertaken.

- Soil fertility and suitability for irrigation should be investigated, initially by preparation of detailed soil maps for the three regions (i.e. ongoing soil mapping by Uyole Agricultural Centre), secondly by more detailed soil investigations in promising areas.

- Credit facilities should be extended to the small peasant producer, possibly be the creation of small credit unions with memberships of say up to 20 farmers.

- Mechanised cultivation practices should be carefully controlled. If a mobile irrigation construction unit is created it should be joined with a soil conservation unit.

- The incidence of bilharzia and malaria must be reduced by controlling the vectors, i.e. the bilharzia-bearing snail Bionphilaria opp., and the malaria-bearing Anopheles mosquitos. Introduction of biological control as done by Tanganyika Planting Company may hold some promise.

8.6.2 Hydropower

- The promising results of the reconnaissance study should be followed up by a closer study of selected potential sites.

- Selection of sites for further studies should be based on proximity to the National Power Grid and schemes with high head possibilities should have priority in the selection over those with low head.

- Unmapped areas, or rather areas where no topographic details are known, should be mapped.

8.7 Recommendations from the socio-economic studies

8.7.1 Design criteria

- Human water consumption of 25 l/cap/day at the end of the 20-year design period should be adopted.

- A peak factor of 3 should be adopted.

- No fixed distance criteria should be adhered to, except for budget planning purposes where 400 m may be used. The actual locations of domestic points should be guided by the principle that the walking distance between a house and a domestic point in general should be less than the distance between a house and the nearest alternative traditional source. Village participation is extremely important in the actual location of domestic points.

- Livestock watering facilities should only be constructed free of charge where livestock watering directly or indirectly conflicts with human use of water and/or agricultural land use. In all other cases cattle owners or cattle project developers should pay the full cost of the facilities.

- Small scale irrigation projects aimed at promoting peasant production and with a high village participation content in planning, implementation and operation and maintenance is generally preferable to large scale irrigation projects.

8.7.2 Complementary programmes

- Sanitary improvements consisting of upgrading existing latrines using an appropriate level of technology within easy economic access of the villagers should be promoted (provisional recommendation).

- Health education is of prime importance to the success of a water and sanitation programme. It should be part and parcel of each water and sanitation project (provisional recommendation).

8.7.3 Organisation at village level

- To facilitate communication between villages and the government bureaucracy an Extension Unit should be established and attached to the Community Development Department within the Prime Minister's office. Its main functions should include (i) assistance to villages during selection, planning, implementation, operation and maintenance of schemes, (ii) to serve as a link between village and government bureaucracy within the water sector, (iii) to assist in health education and sanitation efforts.

- The Extension Unit should at all stages of the project cycle assist villagers in cooperating with MAJI and other governmental agencies.

- Each village in which water improvements are to be introduced should establish a Village Water Committee (VWC) consisting of the village chairman, two other members of the village government plus three women elected by the village assembly. Its main functions include (i) to participate in location of domestic points, (ii) to help organise self-help labour during construction, (iii) to select candidates for training as scheme attendant, (iv) to supervise scheme attendant's work, (v) to ascertain proper hygiene around domestic points, (vi) to act as a channel of information from villagers to project personnel and vice versa.

- In group schemes a Project Committee should be formed consisting of the UWC-chairman and a female member from each village within the project. This is part of a forum where information of relevance for the project as a whole can be discussed between the committee, the government bureaucracy including project personnel and the party machinery.

8.7.4 Village participation

- Villagers should own their own water scheme.

- Villagers - mainly through VWC - should participate in the planning of the scheme by (i) approving the proposed water source and (ii) locating domestic points, laundry and cattle watering facilities (if any).

- Villagers should participate in the implementation of schemes by (i) organising self-help labour, (ii) digging trenches, (iii) assisting in laying pipes, (iv) assisting in constructing domestic points and drainage.

8.7.5 Operation and maintenance

- Villagers should be legally responsible for all O&M activities.

- Villagers should be responsible for operation and maintenance of schemes by (i) selecting, supervising and "paying" scheme attendants, (ii) by paying part of operating and maintenance cost. Village share of O&M cost should be determined by scheme technology and the economic base of the village. As a general rule no village can be expected to cover all O&M costs.

- Actual operation and maintenance work should be shared between MAJI and the village according to scheme technology. The exact sharing of work has to be further discussed.

- Villagers should only be financially responsible for that part of the scheme which they are also maintaining themselves.