(3) Promotion of the further development of the Urban Service Centres and Rural Service Centres.

(4) Construction of a transport network to assist the settlement of rural inhabitants and regional development efforts (to assist production activities and to create functional linkage between villages).

(5) Provision of site selection guidelines for infrastructure services taking the limited resources into consideration.

(6) Provision of site selection guidelines for other governmental development projects and private investment projects.

(7) Promotion of the rational use of land to meet the conditions set by the requirements for the protection and management of natural resources as well as for environmental conservation and the daily needs of inhabitants.

In order to achieve the above objectives, a comprehensive development policy has been adopted to make concrete progress in such areas as agriculture, industry, tourism service, employment, population distribution, urban functions, land use and transport, electricity supply, domestic water supply, medical care, educational facilities, postal service and telephone service, etc. Of these services to be provided for rural inhabitants, improvement of the domestic water supply has been very slow as shown by the low service ratio of 17%, indicating a need for further development efforts.

2-3-3 Groundwater Development Projects

The Statement of Development Policies (1987-1996) sets the target water service ratio in rural areas in 1996 at 74%.

The National Development Five Year Plan (1992-1996) envisages an increase of the service population in rural areas from the 1991 level of 4,893,000 to 5,860,000 in 1996, necessitating the development of new water supply sources to cater for an additional 967,000 people. The requirements of this figure will supposedly be met in the following manner.

Boreholes	250,000
Shallow Wells	78,000
Gravity Piped Water Supply	639,000

1,000 new boreholes will be required to provide water for 250,000 people.

As the budgetary constraints in Malawi make it difficult for the government to implement government-led projects to provide domestic water to rural inhabitants, all projects are, in fact, funded by donor countries or international organizations with coordinated efforts to avoid the overlapping of project areas.

The gravity piped water supply system has been introduced in 56 areas since 1968 with the assistance of the US, Denmark, Canada, Japan, UNICEF, CSC (Christian Services Committee) and AfDB, etc. Surveys are currently in progress in an additional 15 areas in view of introducing this type of water supply.

As shown in Table 2-3-1, 18 projects can be listed as national groundwater development projects. It has been decided to construct a total of 521 boreholes in the five years from 1992 to 1996 under integrated groundwater development projects in the following areas.

① Kalembo	200	(KfW)
② Salima/Nkhotakota	131	(EEC)
③ Namwera/Mangochi	190	(KfW)

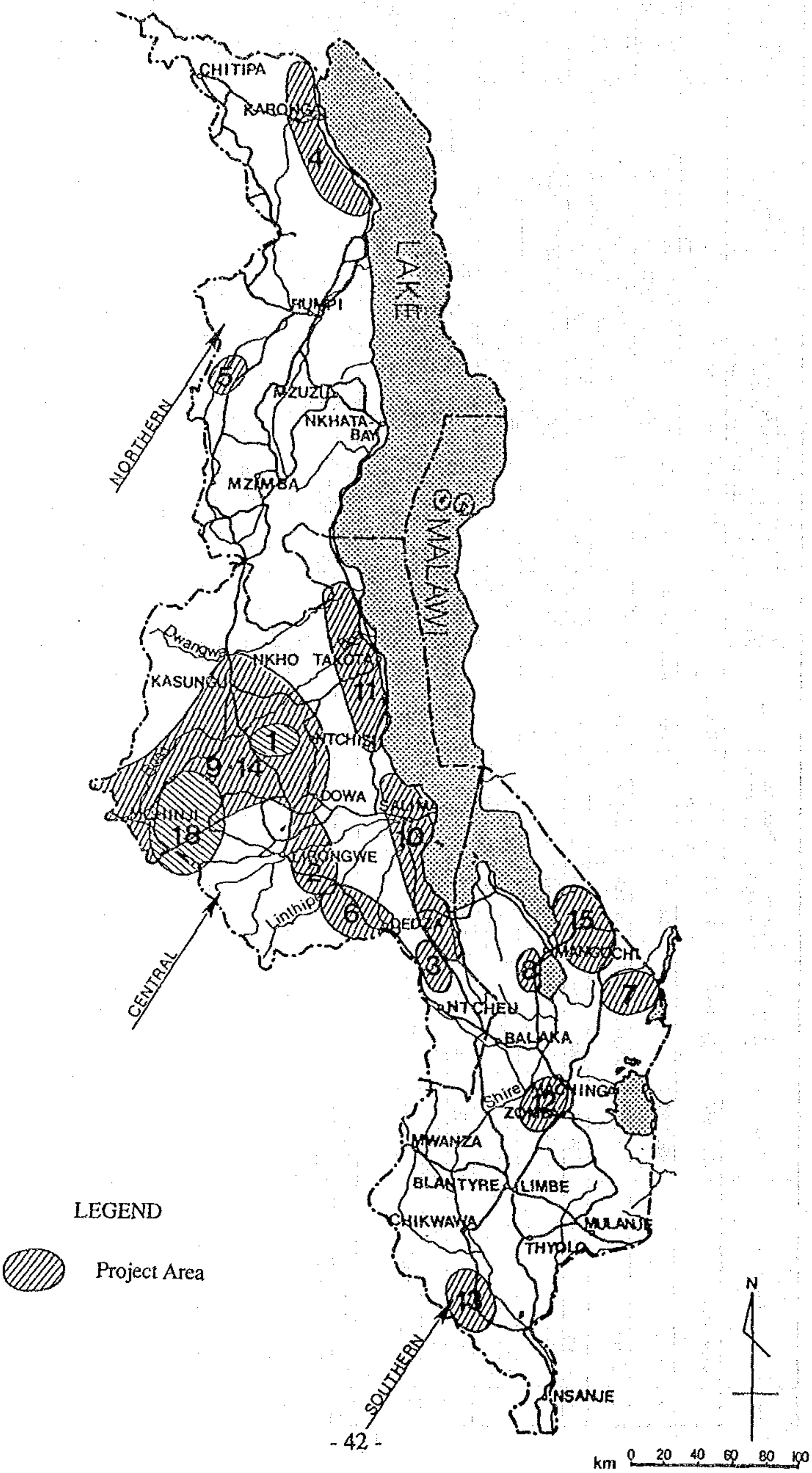
The construction of a further 150 boreholes is also scheduled under smaller projects. No concrete plan exists to construct the remaining 329 boreholes and Japanese grant aid in this regard is much hoped for.

Table 2-3-1 National Groundwater Development Projects of Department of Water

No.[1]	Project Area	Period	Source of Funds	Amount of Funds (K)	Executing Organization	Contractor	Target Population	Progress: Borehole New	Progress: Borehole Rehab.	Progress: Shallow Well New	Progress: Shallow Well Rehab.	Type of Pump	Remarks
1	Dowa West	1982-1986	IFA (loan)	530,000	Ministry of Agriculture	Dept. of Water, PC[2]	70,000	115	29	136	54	MALDEV	
2	Lilongwe NE	1984-1990	IDA (loan)	1,066,000	- do -	Dept. of Water	91,000	442	70	185	150	MALDEV/INDIAN MARK II /AFRIDEV	
3	Livulezi	1981-1982	DANIDA/UNICEF (grant)	358,000	Dept. of Water	- do -	43,000	134	5	60	0	MALDEV/AFRIDEV/NIRA /INDIAN MARK II	
4	Karonga	1986-1991	DANIDA (grant)	565,000	- do -	PC	75,000	300	0	0	0	AFRIDEV	
5	Emcisweni	1986-1989	UNICEF (grant)	286,000	- do -	Dept. of Water, PC	22,500	40	0	20	0	MALDEV/INDIAN MARK II	
6	Dedza Hills	1987-1988	IDA (loan)	650,000	Ministry of Agriculture	PC	71,000	120	47	120	100	AFRIDEV	
7	N. Kawinga	1989-1990	Japan (grant)	¥989 mil.	Dept. of Water	- do -	41,000	164	0	0	0	VERGNET	
⑧	Kalembo	(1992-1994)	KfW (grant)	4,000,000	- do -	- do -	56,500	0/200	0/26	0	0	APFIDEV	
9	*Kasungu/Mchinji/Dowa East*	1987-1990	*IFAD (loan)*	820,000	*Ministry of* Agriculture	- do -	62,000	0	248	0	-	AFRIDEV	Rehabilitation took place at 95 sites in Mchinji District
10	Salima-Bwanje	1987-1990	EEC (loan)	1,600,000	- do -	- do -	48,250	97	96	0	-	AFRIDEV	
⑪	Salima-Nkhotakota	1991-(1992) in progress	EEC (loan)	2,500,000	- do -	- do -	50,50	53/131	25/71	0	0	AFRIDEV	
12	Zomba West	being requested	-	-	-	-	-	-	-	-	-	-	
13	Nsanje	- do -	UNICEF	-	-	-	-	-	-	-	-	-	
⑭	Dowa/Kasungu/Mchinji	1991-(Mar, 1992) in progress	IFAD (loan)	900,000	Ministry of Agriculture	Dept. of Water	15,250	0/61	0	0	0	AFRIDEV	New borehole construction work in progress at 4 sites out of 5 requested in Mchinji District
⑮	Namuwera/Mangochi	1989-(1992) in progress	KfW (grant)	2,260,000	- do -	PC	47,500	130/190	0	0	0	AFRIDEV	
⑯	Northern & Central Regions	1991-(1992) work will commence soon	IDA (loan)	US$ 4.4 mil.	- do -	- do -	262,500	0	0/1,050	0	0	AFRIDEV	*Planned rehabilitation* at 27 sites in Mchinji District. No concrete sites given
17	Southern Region	(1992-1994) being requested	UNCDF/UNDP (grant)	US$ 5.2 mil.	Dept. of Water	- do -	250,000	0	0/1,000	0	0	AFRIDEV	
18	Mchinji	- do -	Japan (grant)	-	- do -	-	-	-	-	-	-	AFRIDEV proposed	

Notes: 1) Nos. in circles are currently in progress or work in planned to commence shortly.
2) PC: private company

Fig. 2-3-1 Locations of National Groundwater Development Projects



2-4 Details of the Malawi Request

2-4-1 Background of the Request

Since independence in 1964, the Government of Malawi has continuously regarded the promotion of agriculture as an important policy objective. At present, agriculture absorbs some 86% of the working population and its share in the GDP (130 million US dollars in 1990) is as high as 33%.

One important prerequisite for the development of agriculture is a secured supply of clean domestic water, which is one of the most basic needs of human life, especially in rural areas.

The Government of Malawi has, therefore, introduced such targets as (i) the provision of a sufficient amount of domestic water (27*l*/person/day), (ii) a reduction of the water transportation time by means of reducing the transportation radius to less than 500m and (iii) a reduction of the waterborne disease occurrence rate through a stable supply of clean water in line with the objectives of the UN International Drinking Water Supply and Sanitation Decade (1981-1990). The two main pillars of the actual work are the construction of boreholes and the construction of gravity piped water supply facilities which are being implemented nationwide.

The financial difficulties faced by the Government of Malawi, however, have forced delays in national development projects. It appears extremely difficult for the Government of Malawi to implement groundwater development without outside help and the Government of Malawi has accordingly requested international organizations as well as donor countries to provide the necessary cooperation. One such request was made to the Government of Japan in 1987 to assist the Project for North Kawinga Groundwater Development and the subsequent grant aid provided by the Government of Japan was highly evaluated by the Government of Malawi. Under this background, the Government of Malawi has made a further request to the Government of Japan for the provision of grant aid for the Groundwater Development Project in Mchinji District where the water supply situation is particularly poor.

2-4-2 Contents of the Request

(1) Objectives

1) Provision of a stable supply of clean domestic water for local inhabitants to facilitate their settlement and to prevent the spread of waterborne diseases.

2) Improvement of the water service ratio and sanitation standard in villages by the construction of boreholes using deep groundwater.

3) Liberation of villagers from non-productive water transportation work to utilize the extra time thus created for agricultural production work (in consideration of WID issues).

4) Improvement of the standard of living of local inhabitants and assistance of agricultural promotion measures.

(2) Implementation Body

The Department of Water will act as the implementation body for the proposed Project.

(3) Proposed Project Area

The proposed Project Area covers the entire Mchinji District, except areas served by the gravity water supply system in the west and estate farming areas in the north. The proposed Project Area is divided into three zones. The highest priority is given to Zone 1 because of the population density and the current water service ratio, followed by Zone 2 and Zone 3 in that order (see Map of the Project Area).

(4) Population in Proposed Project Area

It is estimated that the population in the proposed Project Area will increase to 203,130 by 1996 which is the final target yet of the current Statement of Development Policies.

The estimated population in each zone in 1996 is as follows.

Zone 1	108,480
Zone 2	56,890
Zone 3	37,760

(5) Requested Contents

1) Construction of 300 boreholes in the Project Area using two drilling rigs, one of which was provided by the Government of Japan in 1989 under its grant aid.

2) Provision of one set of drilling machines, equipment, spare parts and materials required for the construction of the boreholes. It is preferable to use

the Afridev Handpump in the Project, because the Government of Malawi has a policy to standardize on this type of pump for the smooth implementation of VLOM.

3) Provision of on-the-job training (drilling and other techniques) to the Malawian counterpart staff during the construction period.

4) Provision of technical training in Japan in regard to drilling techniques and hydrogeology.

(6) Project Standard Figures

1) The target design water supply rate is 27*l*/person/day.

2) The target service population/borehole is 250.

3) The target water transportation distance is less than 500m.

CHAPTER 3

OUTLINE OF THE PROJECT AREA

CHAPTER 3 OUTLINE OF THE PROJECT AREA

3-1 Location and Population

Malawi stretches in the north-south direction and is administratively divided into three regions, i.e. Northern, Central and Southern, which in turn are divided into five, nine and ten districts respectively (total 24 districts).

Mchinji District, the Project Area, is located in the Central Region to the west of Lilongwe, the capital of Malawi. Mchinji District borders Zambia in the west and Mozambique in the south. Its capital, Mchinji Boma, is some 100km from Lilongwe and the urban centres are connected by a paved Main Road (M4).

From an administrative point of view, Mchinji District consists of Mchinji Boma, three Traditional Authority (T.A.) and three Sub-Traditional Authority (S.T.A.). The Project Area covers 1,730km^2 which is half of the Mchinji District's total area and the requested Zones 1-3 are located across both T.A. and S.T.A. boundaries (see Fig. 3-1-1).

Mchinji District has a total area of 3,356km^2 and, according to the 1987 census, a population of 248,161, of which 138,585 live in the Project Area (excluding those living on farming estates). The populations of each zone, T.A. and S.T.A. are shown in Table 3-1-1. Table 3-1-1 also gives the estimated populations in 1996, which is the target year for the Five Year Plan, based on the population growth rates of each T.A. and S.T.A. in the past (1977-1987).

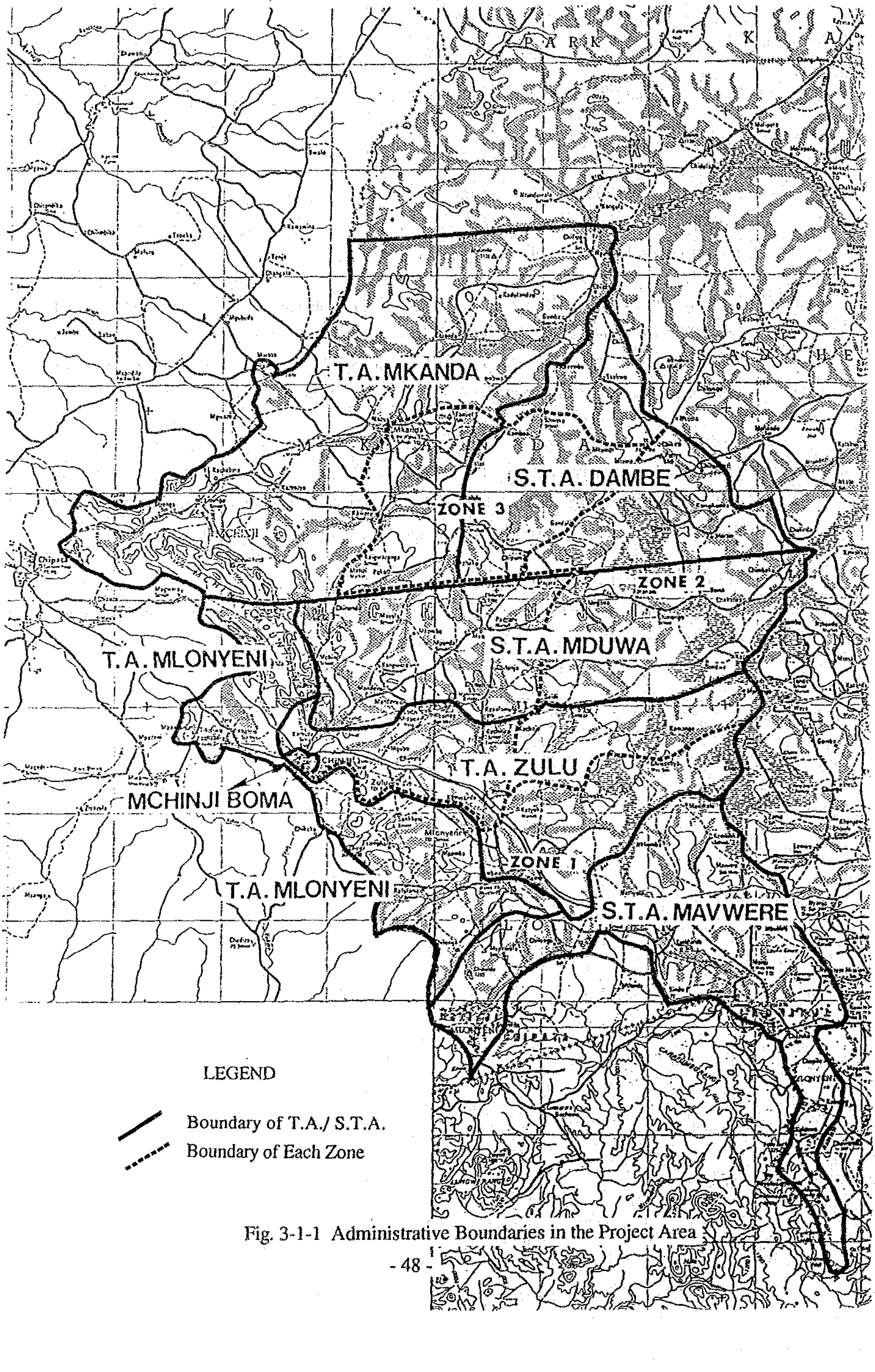


Fig. 3-1-1 Administrative Boundaries in the Project Area

Table 3-1-1 Population in Project Area

Administrative Area	Population Growth Rate (%) 1977-87	Population	Zone 1	Zone 2	Zone 3	Total
			849.5km²	560.2km²	320.4km²	1,730.1km²
T.A. Mlonyeni	3.69	1987	13,500			13,500
		1996(est.)	18,700 (77)			18,700 (77)
S.T.A. Mavwere	3.72	1987	48,568			48,568
		1996(est.)	67,470 (198)			67,470 (198)
T.A. Zulu	4.03	1987	15,632	10,963		26,595
		1996(est.)	22,31 (80)	15,640 (90)		37,950 (170)
S.T.A. Mduwa	4.95	1987		13,067		13,067
		1996(est.)		20,180 (151)		20,180 (151)
T.A. Mkanda	4.62	1987			14,514	14,514
		1996(est.)			21,790 (93)	21,790 (93)
S.T.A. Dambe	5.78	1987		12,709	9,632	22,341
		1996(est.)		21,070 (88)	15,970 (35)	37,040 (123)
Total		1987	77,700	36,739	24,146	138,585
		1996(est.)	108,480 (355)	56,890 (329)	37,760 (128)	203,130 (812)

Source: National Statistical Office (rearranged by Department of Water)
Note: Figures in brackets denote number of villages.

3-2 Natural Conditions

3-2-1 Climate and Hydrology

The Project Area has a tropical savanna climate. In general, the dry season is between April and October while the rainy season is between November and March.

The mean annual rainfall in Mchinji District is some 990mm. The actual rainfall, however, varies from 1,060mm in Mchinji Boma to 870mm in Mkanda. Past rainfall data for Mkanda show a large fluctuation in the annual rainfall, ranging from 1,188mm in the wet year of 1986 to 403mm in the dry year of 1987. As only some 10% of the annual rainfall falls in the dry season, the difference between the dry and rainy seasons is very distinctive.

The mean annual temperature is 19.0°C. The temperature drops to the lowest level of 15.1-15.3°C in the dry June and July and increases to 21.0-21.8°C towards the end of the dry season and the beginning of the rainy season, i.e. October-November.

The mean annual humidity is 70%. The humidity during the dry season is 51-72% and increases 78-85% in the rainy season (based on data at the Lilongwe Meteorological Station). The mean annual evaporation at the Lilongwe Station in the last 29 years is 1,864mm while the mean annual evapotranspiration is 1,589.5mm. These figures substantially exceed the annual rainfall, a typical characteristic of the dry area.

In general, the Project Area belongs to the Bua River basin which flows into Lake Malawi. In addition to the Bua River itself, such tributaries as the Rusa, Namitete and Liwelezi also run through the Project Area. The annual surface runoff of these rivers is 77-201mm, i.e. some 10-20% of the annual rainfall. Lowland swamp areas called Dambo, where no water channels can be seen, are widely observed in the Project Area. These Dambo areas are flooded during the rainy season but dry up with the arrival of the dry season.

The meteorological stations and hydrometric stations in the Project Area are shown in Fig. 3-2-1 and the main observation data of these stations are compiled in Fig. 3-2-2, Table 3-2-1, Table 3-2-2 and Table 3-2-3.

Fig. 3-2-1 Locations of Meteorological Stations and Hydrometric Stations

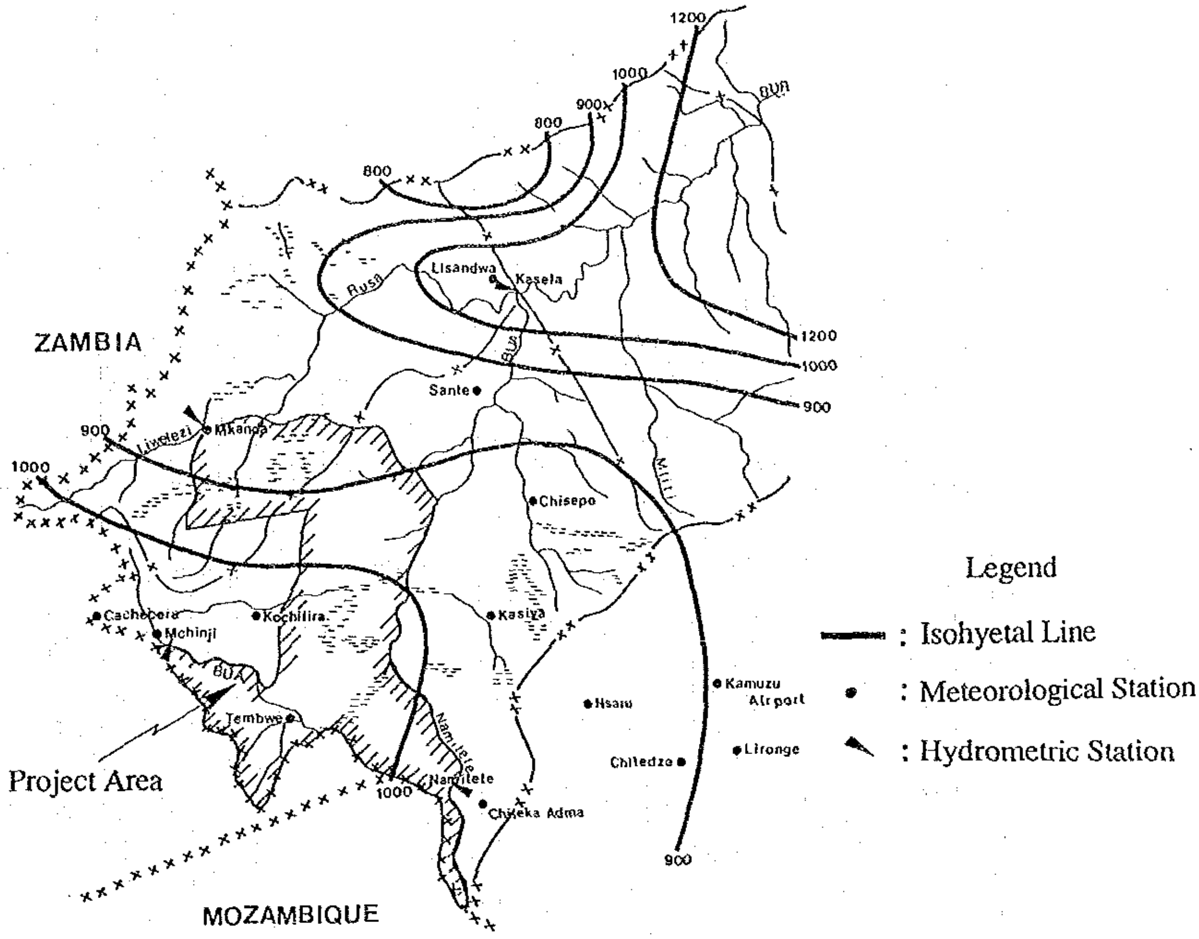


Fig. 3-2-2 Mean Monthly Rainfall and Temperatures in Mchinji District

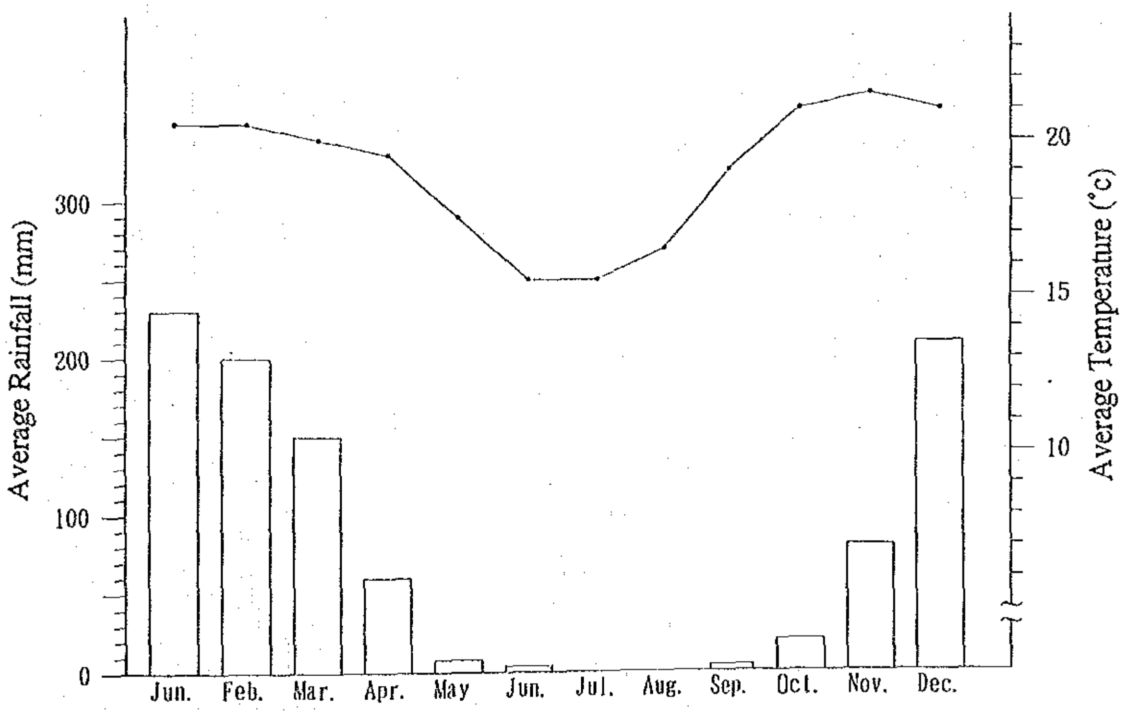


Table 3-2-1 Mean Annual and Monthly Rainfall in Mchinji District

Meteorological Station		Mean Monthly Rainfall (mm)												Mean Annual Rainfall (mm)	Total Years of Observation
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
Mchinji District	Mchinji Boma	241.7	218.7	179.9	68.9	8.9	2.4	0.2	1.8	1.6	19.0	93.1	219.8	1,056.0	58
	Chileka Admarc	229.2	194.0	125.8	54.9	5.2	3.5	1.5	0	1.5	10.8	76.0	197.6	900.0	27
	Kochilera	250.9	228.2	143.9	61.4	5.1	2.7	0.2	0.4	0.5	12.5	95.7	213.4	1,014.9	21
	Tembwe	244.7	194.3	139.3	72.5	9.2	2.1	0.2	0	9.1	22.5	79.4	221.4	994.7	13
	Kachebere	215.9	215.8	171.4	68.7	9.2	3.5	0.8	0.2	0.1	28.6	87.8	227.8	1,029.8	14
	Mkanda	212.5	165.2	156.3	28.9	5.1	0.2	0.7	0.2	1.3	18.2	81.5	204.2	874.3	8
	Average	232.5	202.7	152.8	59.2	7.1	2.4	0.6	0.4	2.4	18.6	85.6	214.0	978.3	
Lilongwe		215.3	202.9	133.8	41.9	8.8	1.0	1.0	1.0	3.3	6.0	66.2	166.3	847.5	29
Average Rainy Days at Lilongwe		20	18	14	7	2	1	0	0	1	1	7	16	87	29

Source: National Meteorological Centre

Table 3-2-2 Mean Monthly and Annual Temperatures in Mchinji District

Meteorological Station		Mean Monthly Temperature (°C)												Mean Annual Temp. (°C)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mchinji District	Mchinji Boma	20.2	20.1	19.9	19.1	17.4	15.1	14.9	16.3	18.9	20.8	21.6	20.7	18.8
	Kochilera	21.2	21.1	21.0	21.0	18.4	16.2	16.0	17.4	20.0	21.9	22.8	21.8	19.8
	Tembwe	21.6	21.4	21.3	20.5	18.8	16.6	16.4	17.7	20.4	22.3	23.2	22.1	20.2
	Kachebere	18.0	17.9	17.8	16.9	15.2	12.8	12.5	13.9	16.6	18.4	19.2	18.5	16.5
	Mkanda	20.9	20.8	20.6	19.8	18.1	15.9	15.7	17.0	19.7	21.6	22.4	21.4	19.5
	Average	20.4	20.3	20.1	19.3	17.6	15.3	15.1	16.5	19.1	21.0	21.8	20.9	19.0
Lilongwe		21.0	20.9	20.7	19.7	17.6	15.6	15.2	17.0	19.9	22.7	23.0	21.7	19.6

Source: National Meteorological Centre

Table 3-2-3 Mean Monthly Discharge of Bua River Basin

Hydrometric Station	River	Catchment Area (km²)	Mean Monthly Discharge (m³/sec)													Runoff mm/yr	Observation Years
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Av.		
Namitete	Namitete	147	1.78	4.43	2.74	1.12	0.471	0.295	0.191	0.111	0.058	0.018	0.189	0.629	0.94	201	1956-1980
Mchinji	Bua	126	0.920	2.06	2.05	1.12	0.479	0.376	0.318	0.213	0.136	0.080	0.094	0.487	0.68	171	1960-1980
Kaseta	Rusa	2,580	7.23	21.40	30.10	18.70	6.27	1.76	0.674	0.305	0.137	0.037	0.004	1.55	6.32	77	1964-1980
Mkanda	Liwelezi	278	1.29	2.36	3.33	1.93	0.940	0.736	0.667	0.564	0.426	0.315	0.213	0.947	1.14	129	1976-1980

Source: Department of Water

3-2-2 Topography

Malawi stretches in the north-south direction and the geologically famous Great Rift Valley runs along this main axis of the country, creating rich topographical features dotted with mountains, rivers, valleys and plains. The depression in the Great Rift Valley has created Lake Malawi, the third largest lake in Africa (30-75km wide in the east-west direction and 550km in the north-south direction with an elevation of 475m), along the eastern international boundary of the Northern and Central Regions. In the Southern Region, the Shire River which originates from Lake Malawi flows towards the south to join the Zambezi River in Mozambique.

Malawi's rich topography can be classified as follows (see Fig. 2-1-1 Map of Physiographic Zones).

(1) Rift Valley Plains

These are areas with few undulations along the shoreline of Lake Malawi and in the Shire Valley where the elevation is below 600m. Relatively Cenozoic sediments are widely observed.

(2) Rift Valley Escarpments

These are steep slopes forming the border areas between the plateau areas and rift valley plains. Outcrops of the bedrock due to erosion are observed with much evidence of dissection in progress.

(3) Plateau Areas

These areas are distributed on both sides of the Great Rift Valley and have an elevation between 900m and 1,300m. The plateau areas show many undulations and Cenozoic sediments are observed at valley and riverbed sites. Most of the surface water runs off to the grassy swamps called Dambo.

(4) Highland Areas

Highland areas are mountainous areas with an elevation ranging from 2,000m to 3,000m and rise sharply from the plateau areas. They are formed by such intrusive rocks as granite and syenite and show a high degree of dissection.

The Project Area is located on a plateau called the Lilongwe Plain and is generally flat with gentle undulations. The elevation is between 1,100m and 1,200m. Some steep slopes are observed along the border areas with Zambia and Mozambique. The highest point in the Project Area is Nachora Hills in Zone 1 with an elevation of 1,380m and located to the south of Mchinji Boma. There is a minor mountain range with an elevation of around 1,300m along the Mozambique border at the southern tip of Zone 1. The Mchinji Ridge with an elevation of 1,600-1,700m is located to the north of Mchinji Boma and the dam supplying Mchinji Boma with water for the gravity piped system is located here.

The river basin in the Project Area is fairly well developed and consists of the Bua, which originates from the Mchinji Ridge, and the Rusa, Namitete and Liwelezi, all of which are tributaries of the Bua.

While the Bua River, which enjoys the richest runoff of all, does not dry up in the dry season, parts of the Rusa and Liwelezi do dry up, causing standing water here and there. The Namitete, which originates from the Dzalanyama Ridge in the south, almost totally dries up in the dry season.

3-2-3 Geology

Malawi largely belongs to the Mozambique orogenic zone of the Pre-Cambrian to the Lower Paleozoic. The prominent rocks are metamorphic rocks, mainly gneiss, gabbro which intrudes into metamorphic rocks and plutonic rocks, including granite. In addition, sedimentary rocks of the Karro system of the Upper Paleozoic, igneous rocks of the Mesozoic and sedimentary rocks of the Cretaceous onwards are distributed in parts of Malawi albeit on a minor scale compared to the dominant bedrock formations of the Mozambique orogenic zone.

An important feature of Malawi's geological structure is the formation of the rift valley which traverses Malawi and was formed by faulting which began in the Tertiary period of the Cenozoic. The areas surrounding the rift valley were continuously crushed in the Quaternary period and thereafter, producing numerous fracture zones and tension cracks.

The Project Area is located on a plateau to the west of the rift valley and outcrops of bedrock are observed in the highlands, such as Mchinji Ridge. The plateau is generally covered by unconsolidated sediments. The geological composition of the Project Area is as follows.

(1) Basement Complex

The main components are biotite gneiss and quartz-feldspathic gneiss of the Precambrian to the Lower Paleozoic with the intrusion of quartzite and other rocks. These rocks are hard with few pores and are distributed throughout the

Project Area. Foliation shows the strike running in the north-south or northwest-southeast direction and the dip is almost vertical is most places.

(2) Plutonic Rocks

These rocks are as old as the bedrock and are mainly granite and metagabbro. Granite is distributed from the western part of the Project Area to the Mchinji Ridge. In comparison, metagabbro is mainly observed in the eastern part of the Project Area. Areas where plutonic rocks are distributed show a high resistance to general weathering and tend to create such special topographical features as monadnocks due to segregated erosion.

(3) Sediments

The main components are residual sediments which were originally weathered rocks subject to soil forming processes. The following four types can be observed.

1) Red Sandy Clay Soil

This is found in the northeastern and eastern parts of the Project Area, contains iron and is accompanied by a thin laterite layer.

2) Sandy Soil

This is found at the feet of steep hills in the western and southern parts of the Project Area, is colluvial originating from granite and is rich in quartz.

3) Laterite Soil

This is a typical soil in the tropics and is widely distributed in the Project Area. It is covered by colluvial in the western part.

4) Muddy Soil

This is found in the upper layers of lowland swamps, such as Dambo and water channels. It mainly consists of fine sand, silt and fine clay.

(4) Geological Structure

The geological structure of the gneiss has a strike running in the north-south or northwest-southeast direction and shows a syncline along the Mchinji Ridge. Although it has been confirmed that a fault strikes across the direction of the axis of the syncline, it is unclear how far the fault strikes because of the thick sedimentary cover of the plateau in question.

The Project Area's geological formation and soil distribution are shown in Fig. 3-2-3 Geological Structural Map and Fig. 3-2-4 Geological Section.

Fig. 3-2-3 Geological Structural Map

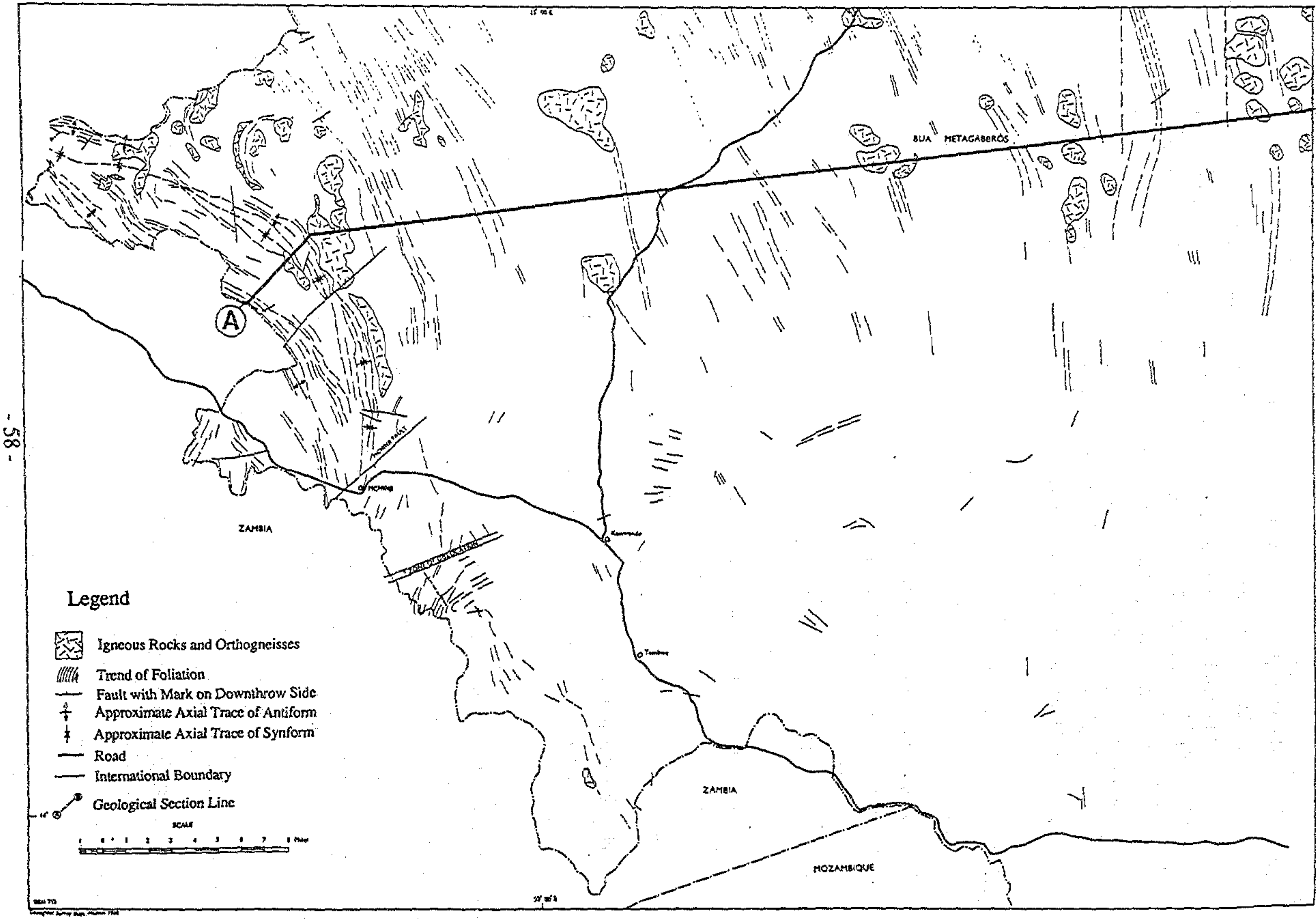


Fig. 3-2-4 Geological Section

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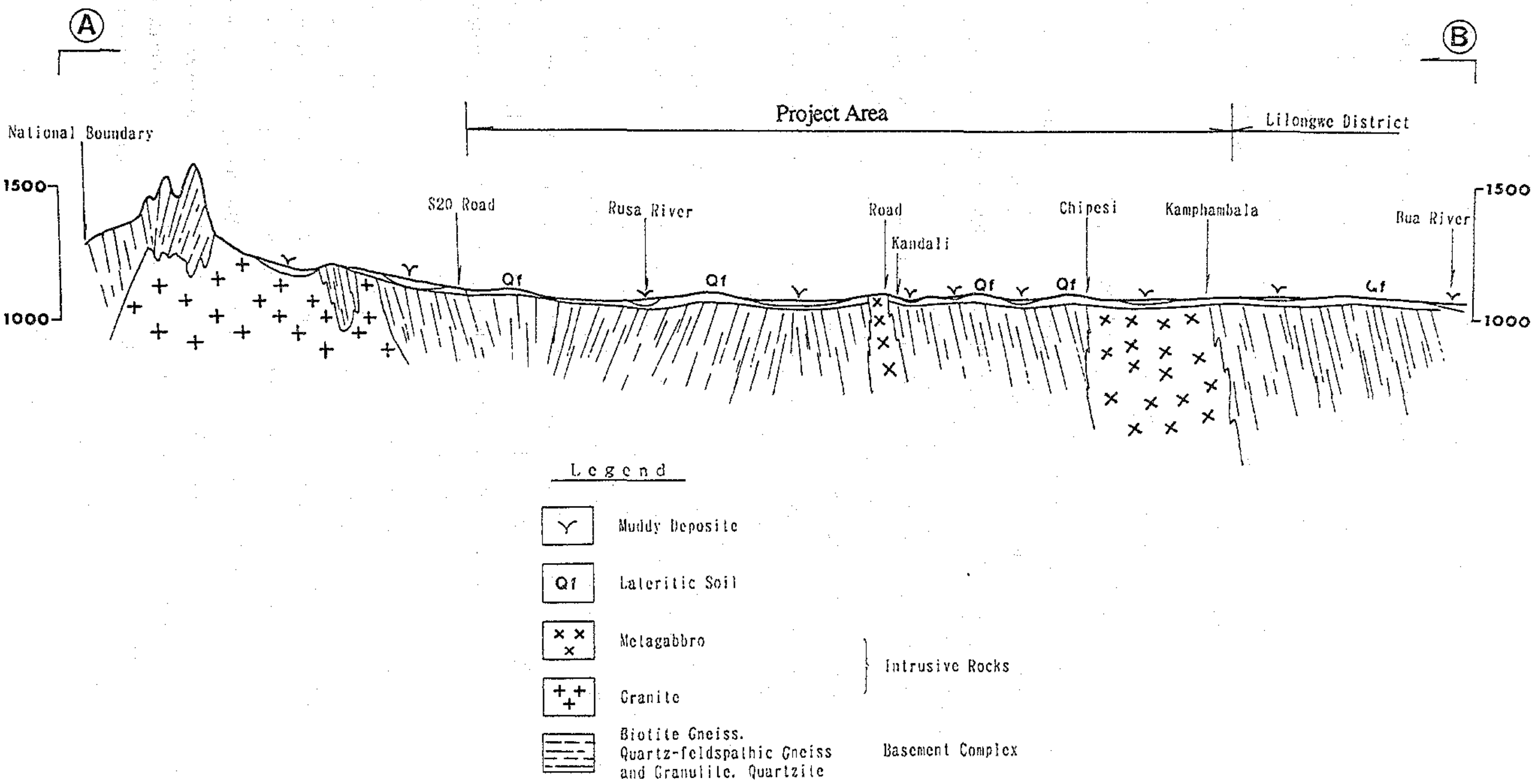


3-3 Hydrogeological Conditions

3-3-1 Outline of Hydrogeological Conditions

The Project Area can be divided into the following two areas based on the hydrogeological conditions.

(1) Generally flat plateau covering most of the Project Area with many lowland swamps, such as Dambo.

(2) Foot areas of the Mchinji Ridge and hills in the southern and southeastern parts of Mchinji District, mainly composed of intrusive rocks.

Muddy soils (mainly silt and clay) with a low permeability are distributed in the surface layer of many parts of the plateau. Below this layer, however, laterite and weathered gneiss (weathered down to gravel size with well developed cracks) are found, forming good aquifers. The mountainous areas are steep and allow the easy runoff of rainwater. The predominance of hard rocks also makes it difficult for surface water and rainwater to permeate the ground. The distribution of unconsolidated sediments, mainly sandy soils, highly weathered rocks and weathered rocks with well developed fissures, is observed in foot areas, forming aquifers. Few aquifers have developed in places where unweathered rocks are distributed near the ground surface.

In any area, aquifers are mainly formed by weathered rocks with well developed cracks. Two types of aquifers can be distinguished in the plains based on the degree of weathering as shown in Fig. 3-3-1. Type 1 aquifers are also observed in foot areas. These aquifers are composed of weathered rocks with well developed cracks and also contain hard rocks. Type 2 aquifers are composed of clay and gravels originating from highly weathered rocks. The groundwater level in these aquifers is easily affected by seasonal conditions while the distribution of the aquifers is largely determined by the shape of the bedrock and groundwater level.

In addition to the weathered rock formations, fracture zones in the bedrock which are distributed along tectonic lines, such as faults, provide a good prospect of aquifers. Judging from the topographical features of the Project Area, however, extensive investigation will be required to track down such fracture zones. Existing documents indicate the existence of a tectonic line along the Bua River which runs in the north-south direction along the eastern edge of the Project Area. Groundwater recharged from the ground surface is believed to run from the southwest to the northeast in the Project Area with a similar hydraulic gradient to those rivers originating from the Mchinji Ridge (see Fig. 3-3-2).

In general, the annual water balance can be estimated using the following equation.

Precipitation $\times$ Catchment Area

$= $ Evapotranspiration + Surface Runoff + Groundwater Recharge

As existing data on evapotranspiration appears excessive, a trial estimate was made using data on Dowa West where the hydrogeological conditions appear similar to those of the Project Area.

Groundwater Recharge = Catchment Area $\times$ Average Groundwater Recharge

= 1,730km^2 x 16mm/year

(average groundwater recharge at Dowa West; actual value varies from 4 to 36mm/year)

$\fallingdotseq 2.77 \times 10^7 m^3$/year

A minimum groundwater recharge of 6.92 x $10^6 m^3$/year can be expected in the Project Area on the basis of the adoption of the lowest groundwater recharge value of 4mm/year for Dowa West.

Fig. 3-3-1 Typical Profile of Weathered Basement Aquifer

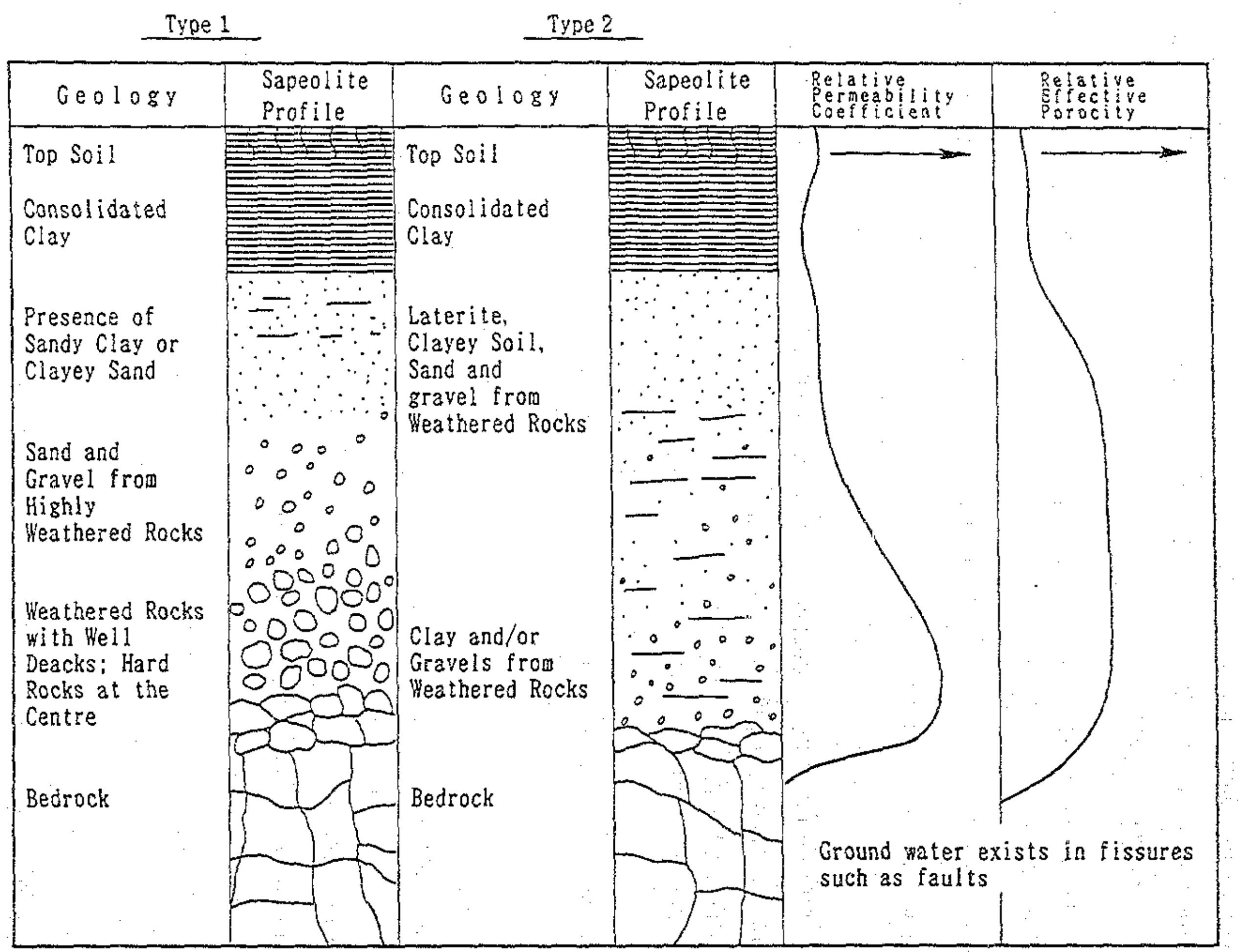
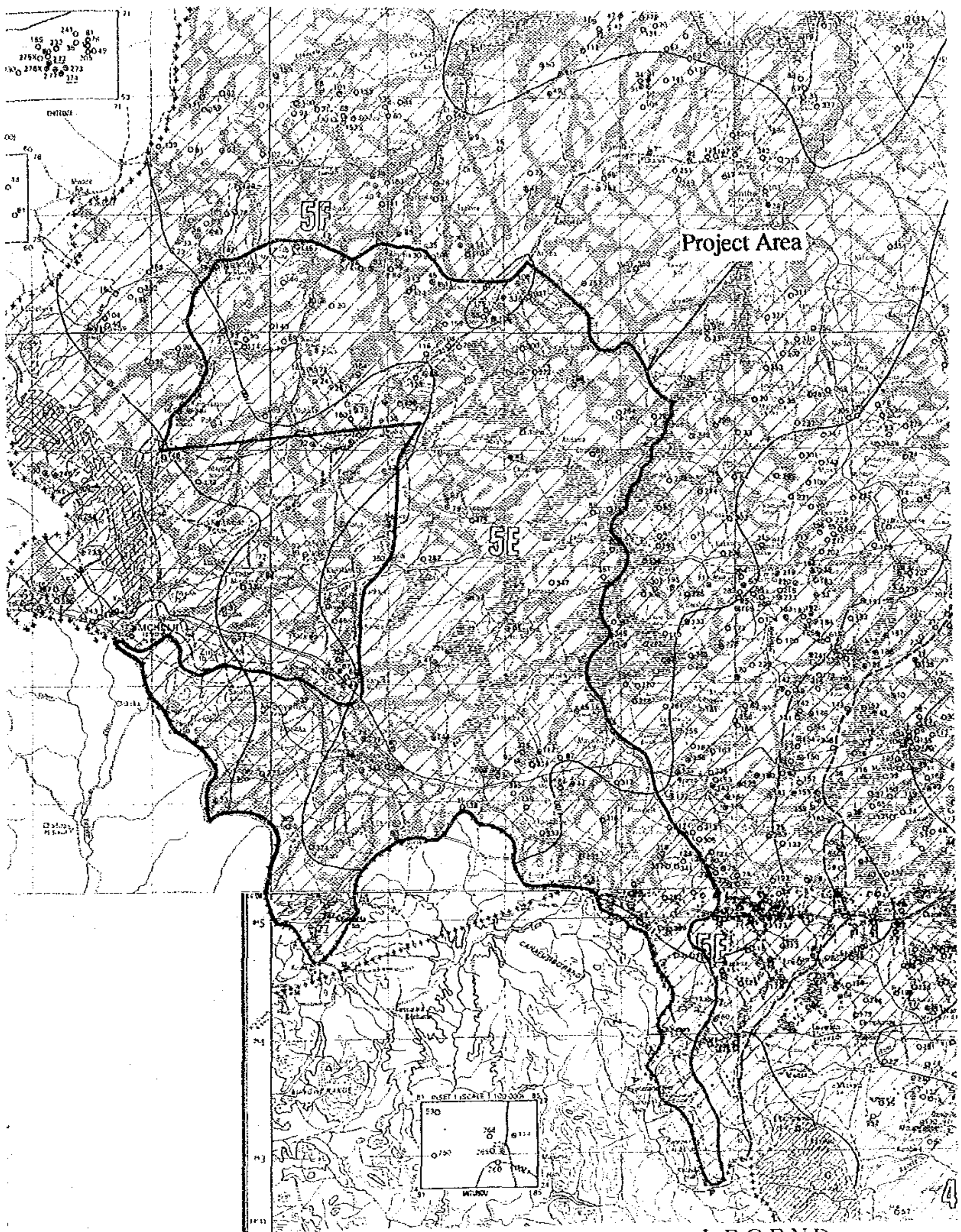


Fig. 3-3-2 Hydrogeological Map



LEGEND

Fractured Basement

Weathered Basement

1150 Contour Line of Groundwater Level

3-3-2 Existence of Groundwater (Electric Prospecting Results)

Electric prospecting was conducted in the Project Area and the hydrogeological conditions of the Project Area were examined using the prospecting results and existing borehole data. As the Project Area has rather uniform topographical and geological conditions except in foot areas, the prospecting points were selected to cover as wide an area as possible taking the distribution of existing boreholes and the road conditions into consideration. The distribution of the prospecting points are listed in Table 3-3-1 and indicated in Fig. 3-3-3.

Table 3-3-1 Distribution of Electric Prospecting Points

T.A./S.T.A.	Zone 1	Zone 2	Zone 3	Total
T.A. Mlonyeni	9			9
S.T.A. Mavwere	9			9
T.A. Zulu	4	4		8
S.T.A. Mduwa		5		5
T.A. Mkanda			4	4
S.T.A. Dambe		5	2	7
Total	22	14	6	42

(1) Prospecting Method and Equipment Used

The target prospecting depth using mainly the Wenner method and vertical prospecting using the Schlumberger method in parts was set at 100m. The following measures were employed to improve the prospecting accuracy when a stable reading of a low resistivity layer was unavailable due to a small potential difference.

1) Use of multiple electrodes (particularly current electrodes).

2) Sprinkling of water near electrodes to reduce the earth resistance.

3) Use of a high voltage booster to increase the impressed current.

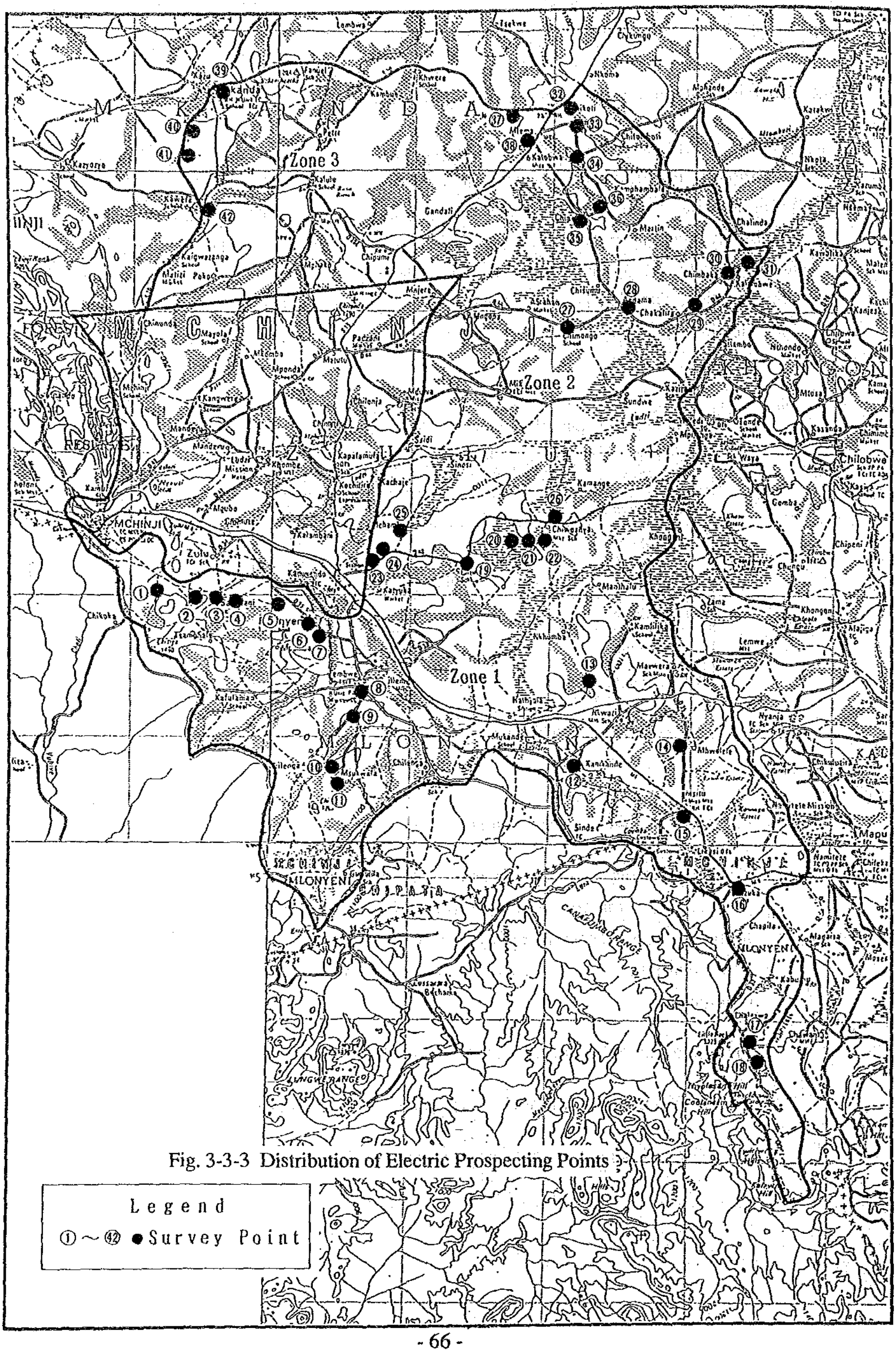


Fig. 3-3-3 Distribution of Electric Prospecting Points

Table 3-3-2 Prospecting Equipment Specifications

Model	Specifications		
McOHM (made in Japan)	Voltage Output	:	400V p-p (constant current)
	Current Output	:	1, 2, 5, 20, 50, 100, 200mA (constant current)
	Operating Voltage	:	DC12V
	Input Impedance	:	1MΩ
	Potential Difference Measurement	:	±0.6V, ±6V
	Resolution	:	20μV
	Stacking Number	:	1, 4, 16, 64
	Data Memory	:	File Registration Max. 128
			Data Point Max. 2,000
	Interface	:	RS-232C

(2) Prospecting Results

The prospecting data for each site are given in the form of ρ–a curves in the Appendix while the analysis results are compiled in the geological sections by electric prospecting in Fig. 3-3-4. Based on the resistivity readings, the geological formation of the Project Area can be divided into 3-5 layers. Assuming that the surface is the 1st layer and is followed by the 2nd, 3rd and so on in accordance with the depth, the 3rd layer constitutes a main aquifer. As stated earlier, aquifers are classified as Type 1 or Type 2 depending on the geological features. An aquifer with a resistivity of 50Ω-m or more is classified as Type 1 while an aquifer with a resistivity of less than 50Ω-m is classified as Type 2. In addition, there are three geological formation Types (A, B and C) based on the resistivity of the bedrock obtained by the electric prospecting as shown in Table 3-3-3.

Table 3-3-3 Types of Geological Formation Based on Resistivity

Formation Type	Resistivity (Ω-m)			
	1st Layer	2nd Layer	3rd Layer	4th Layer
A	50 - 2,000	40 - 1,000	100 - 420	800<
B	100 - 2,000	30 - 300	10 - 190	60 - 700
C	200 - 2,000	15 - 160	30 - 330	2 - 50

* The 3rd Layer constitutes a main aquifer.

Fig. 3-3-4 (1) Geological Section by Electric Prospecting Unit : Ω-m

Zone 1 T. A. Mlonyeni

* Schlumberger's Electrode Array

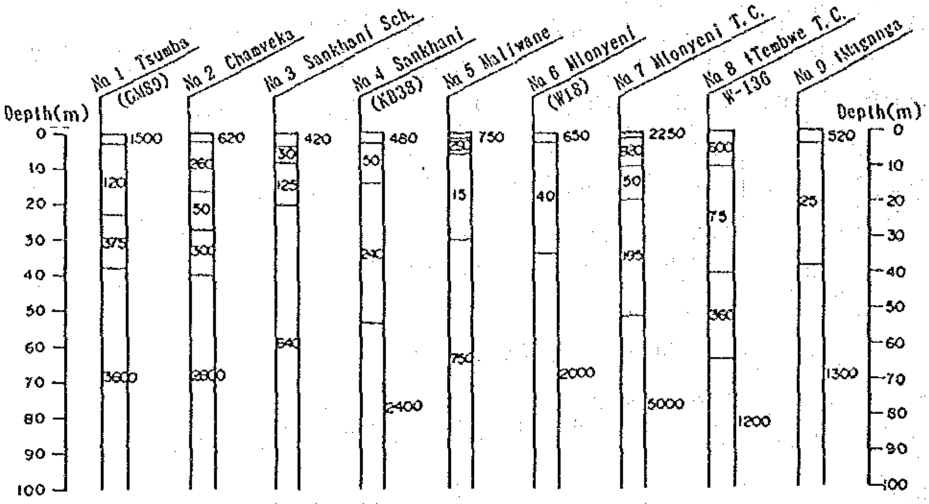


Fig. 3-3-4 (2) Geological Section by Electric Prospecting Unit : Ω-m

Zone 1 S. T. A. Mavwere

* Schlumberger's Electrode Array

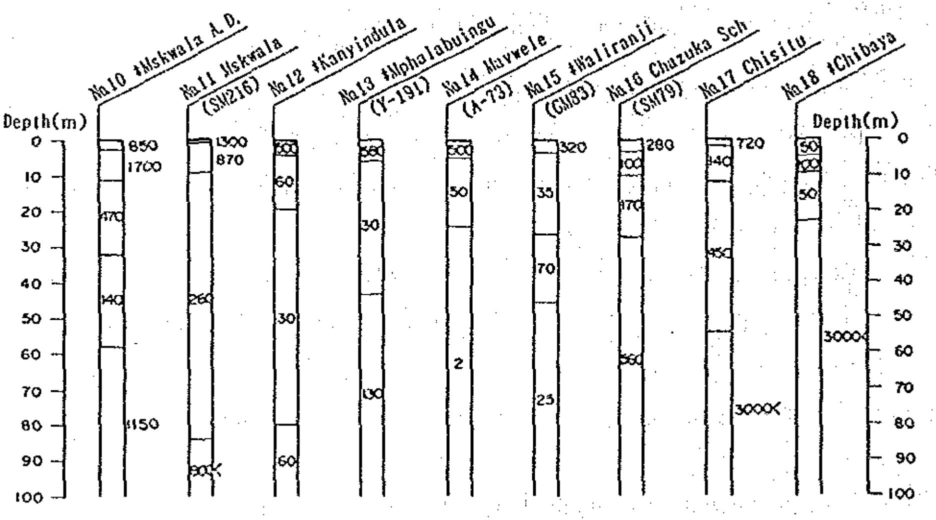


Fig. 3-3-4 (3) Geological Section by Electric Prospecting Unit : Ω-m

Zone 1 T. A. Zulu | Zone 2 T. A. Zulu

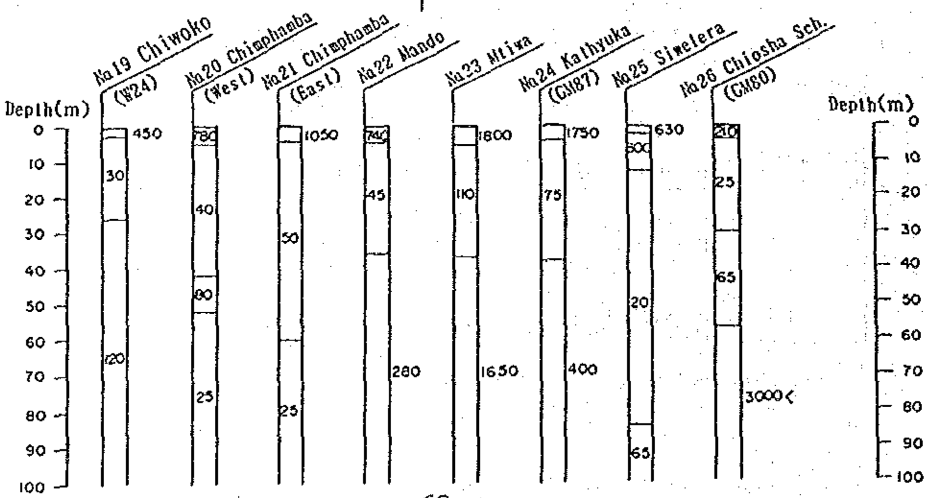


Fig. 3-3-4 (4) Geological Section by Electric Prospecting Unit : Ω-m

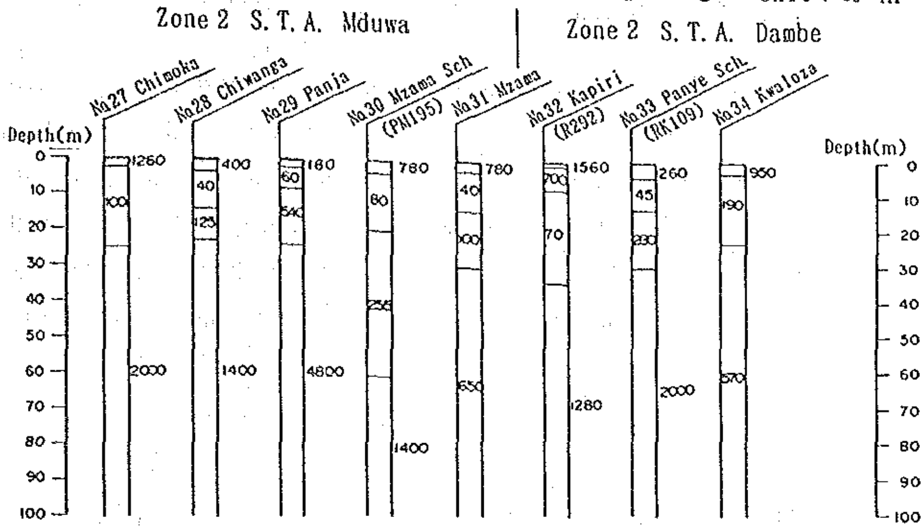
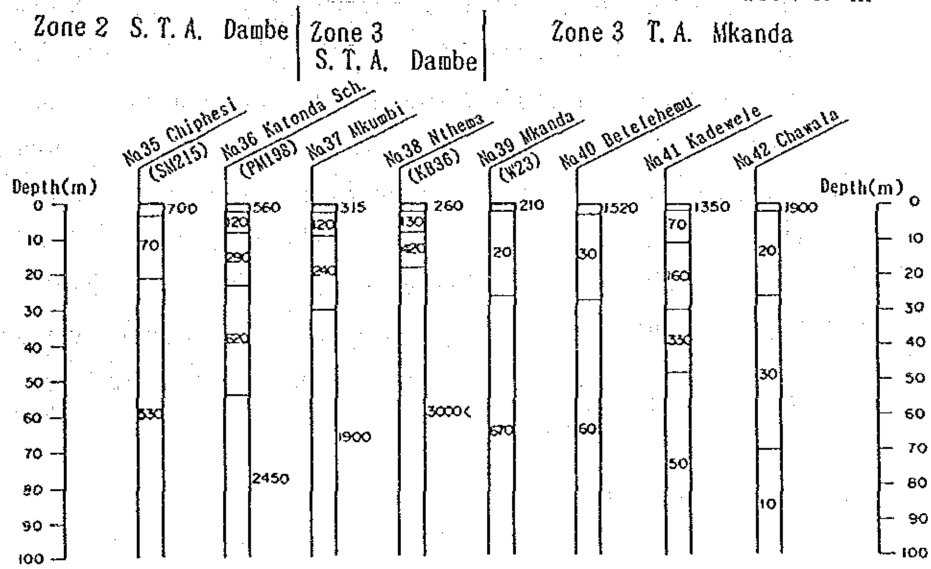


Fig. 3-3-4 (5) Geological Section by Electric Prospecting Unit : Ω-m



1) Type A Formation

Half of the prospecting sites are represented by this type. An aquifer under the Type A formation is likely to be composed of weathered rocks, suggesting the existence of good quality groundwater. The 4th layer is bedrock with few cracks and, therefore, has low permeability. The groundwater quantity is determined by the depth of the 4th layer and the resistivity and thickness of the 3rd layer. Groundwater can be obtained from the 4th layer only if a fracture zone is involved.

2) Type B Formation

The 3rd and 4th layers of this type are composed of highly weathered/ weathered rocks and weathered/low weathered rocks respectively. Both layers are aquifers. This type differs from the Type A formation mainly in that the resistivity of the 4th layer is lower than that of the Type A formation. The Type B formation can be further divided into two sub-formations depending on the resistivity of the 3rd layer. Here, the Type B formation where the resistivity is upto 50Ω-m is classified as B1 and the Type B formation where the resistivity is more than 50Ω-m is classified as B2. B1 is assumed to be a geological formation where weathered rocks have reached the stage of becoming clay and sand, suggesting a lower permeability and inferior water quality. B2 promises a rich groundwater quantity unless the depth of the 4th layer is extremely shallow.

3) Type C Formation

This type is characterized by a lower resistivity of the deepest layer than the layers above it. Judging from the geological structure, the deepest layer is bedrock. Its low resistivity is caused by either the existence of a fault fracture zone or the groundwater having a high electrolyte (salt) content. The existing borehole A-73 (Zone 1 in S.T.A. Mavwere) is an example of the latter and is out of use due to the high salt content. The electric prospecting results in the nearby area showed typical readings for a Type C formation. The resistivity in the area declines to as low as 2Ω-m and the electric conductivity of the groundwater is estimated to be 5,000μS/cm. Given such data, it is appropriate to consider the possible exclusion of those sites where a Type C formation was found by the electric prospecting from the candidate sites for new boreholes. In making such a decision, however, the relative depth of each layer, water quality and quantity of groundwater and the resistivity readings must be carefully checked.

Table 3-3-4 Electric Prospecting Results

Zone	T.A./S.T.A.	Formation Type		
		A	B	C
1	T.A. Mlonyeni	7	2	0
	S.T.A. Mavwere	4	3	2
	T.A. Zulu	0	2	2
	Sub-Total	11	7	4
2	T.A. Zulu	2	2	0
	S.T.A. Mduwa	4	1	0
	S.T.A. Dambe	2	3	0
	Sub-Total	8	6	0
3	T.A. Mkanda		2	2
	S.T.A. Dambe	2		
	Sub-Total	2	2	2
Total		21	15	6

Type A is concentrated in the northeastern and southern parts of the Project Area while Type B is observed throughout the Project Area. Type C is observed in the central part and shows a NE-SW axis. Type B1 shows a similar trend to Type C. The overall distribution of these types indicates their parallel existence with the direction of the fold axis of the Mchinji Ridge and the Dzalanyama Ridge at the southern end, indicating the possible existence of a tectonic line in this direction.

Each formation based on the resistivity value and the corresponding geological features (soils or rocks) is shown in Table 3-3-5.

Table 3-3-5 Correspondence Between Resistivity and Geological Features

		Resistivity (Ω-m)	Corresponding Geological Features
1st Layer		50 - 2,250	dry surface soil, clayey soil, silt, sandy soil and laterite
2nd Layer		25 - 290	wet clay, sand, silt and highly weathered rock
3rd Layer		15 - 540	highly weathered rock - weathered rock (rich varieties from clay to fresh rock)
4th Layer	A	800<	hard bedrock with few cracks
	B	60 - 75	highly weathered rock - weathered rock, B1 of 300Ω-m or below may indicate a fracture zone.
	C	<50	highly weathered rock - weathered rock; presence of a fracture zone or groundwater with high electrolyte content

(3) Evaluation of Aquifers

The resistivity of an aquifer is closely related to the resistivity of groundwater and is calculated using the following equation.

$$\rho a = F \times \rho w$$

where, ρa : resistivity of formation

ρw : resistivity of groundwater

F : formation factor (related to pore ratio of formation and generally between 1 and 8 for an aquifer

A small F value represents silt or clayey soil with poor permeability while a large F value represents bedrock with few cracks and poor permeability.

Since the groundwater resistivity at most of the existing boreholes is 30-100Ω-m, insertion of this value in the above equation results in an aquifer resistivity value (ρa) of 30-800Ω-m.

$$\rho a = F \times (30\text{-}100) = 30\text{-}800\Omega\text{-m} \ (:F = 1 - 8)$$

It is, therefore, essential for any formation to have a resistivity value of between 30 and 800 to be considered a possible aquifer.

The electric prospecting results and drilling data on the existing boreholes are compiled in Table 3-3-6. Using the data on groundwater resistivity (converted from the electric conductivity value), it is concluded that the aquifer resistivity (ρw) is 30-670Ω-m (F= 1 - 9.3).

Although the value of F at one site is as high as 9.3, the resistivity of the aquifer at this site is 280Ω-m, suggesting that the value of F is acceptable. At sites where the value of F approaches 1, the resistivity of both the aquifer and groundwater is low, implying that the possible yield at these sites with a Type A or Type B formation is low unless the depth of the bedrock is sufficiently deep. In the case of the Type C formation, poor water quality may be the cause of such low resistivity.

(4) Summary of Electric Prospecting Results

The electric prospecting results for the Project Area can be summarized as follows.

1) The aquifer resistivity is 30-670Ω-m.

2) At sites showing the resistivity characteristics of a Type A or Type B formation, the possible yield tends to be low unless the depth of the bedrock is 25m or more if the aquifer resistivity is 100Ω-m or less.

3) At sites showing the resistivity characteristics of a Type C formation, the aquifer resistivity must be carefully examined. If the measured resistivity is 30Ω-m or less, there is a likelihood that the quality of the groundwater in the deep layers is poor. The omission of such sites from the prospective borehole sites is, therefore, deemed appropriate.

4) The average depth of the bedrock in (the 4th layer) each formation is given below.

Type A	44.0m
Type B	30.0m
Type C	50.0m

The borehole developed cracks of the Type B formation suggest that yield may increase in accordance with a deeper drilling depth. The evaluation results for each electric prospecting site are given in Table 3-3-7.

5) Characteristics of Each Zone

a) Zone 1

Prospecting was conducted as 22 sites in 18 villages and the average depth to the bottom of an aquifer was found to be 42m. Type A formations are concentrated in the western part of T.A. Mlonyeni and the southeastern part of S.T.A. Mavwere and the distribution of hard bedrock with few cracks is also observed at several sites. The eastern half has more Type B and C formations and the depth to the bottom of an aquifer in the Type B formation is 30-40m which is slightly shallower than in the case of other types.

b) Zone 2

Prospecting was conducted at 14 sites in 13 villages and the average depth to the bottom of an aquifer was found to be 37m. Only Type A and B formations are observed in Zone 2. There is one Type B2 site in the southwestern part which shows a low resistivity value at the aquifer bottom as in the case of the Type C formation. The depth to the aquifer bottom is more than 40m in the southern part and less than 30m in the northern part. It is of some concern, therefore, that yield at sites showing the Type A formation in the northern part could be low.

c) Zone 3

Prospecting was conducted at six sites in six villages. Because of the existence of estates, the sites were located in the northeastern part near Zone 2 and around the road in the west which divides the Project Area into north and south. The average depth to the bottom of an aquifer was found to be 36.5m. The Type A formation is observed in the northeastern part where the depth to the aquifer bottom is less than 30m. In the western part, the resistivity of the bedrock tends to decrease from north to south (i.e. changes from Type B1 to Type B2 and further to Type C) and the depth to the aquifer bottom increases in the south. Consequently, the depth to the aquifer bottom is sufficient in the south but there it is likely that groundwater with a high salt content exists in deep areas, necessitating a careful decision on borehole depth by a thorough check of the water quality during drilling.

Table 3-3-6 Electric Prospecting Results and Data on Existing Boreholes

Zone	TA/STA	Borehole No.	Drilling Depth (m)	Yield (l/min)	Electric Conductivity (μs/cm)	Aquifer		Geological Features	Remarks
						Resistivity (Ω-m)	Depth (m)		
1	T.A. Mlonyeni	GM 89	35.0	90.0	-	375	38		out of order
		KB 38	-	-	-	240	54		under construction
		W 18	36.0	72.0	-	40	34	highly weathered rocks	predominance of clay
		W 136	33.0	24.0	-	75	40	- do -	sandy
	S.T.A. Mavwere	SM 216	45.0	27.0	213	260	82		
		Y 191	45.0	30.0	-	30	43	weathered rocks	
		A 73	48.2	54.7	-	50/2	24	highly weathered rocks	sand and graves, partially clay, not in use due to high salt content
		GM 83	36.4	124.0	-	35/70	27/46		
		SM 79	45.0	85.5	270	170/560	27	weathered rocks	
	T.A. Zulu	W 24	30.5	54.0	165	30/120	26	laterite	
2	T.A. Zulu	GM 87	35.0	60.0	-	75	38	weathered rocks	
		GM 80	35.7	60.0	-	25/65	30/50		
	S.T.A. Mduwa	PM 195	58.8	54.0	331	255	61		
	S.T.A. Dambe	R 292	61.0	12.6	191	70/1,275	34	weathered rocks	
		RK 109	45.0	48.7	335	280/2,000	30		
		SM 215	45.0	108.0	-	70/530	21	weathered rocks	
		PM 198	45.0	33.0	274	290/620	23/54		
3	T.A. Mkanda	W 23	30.0	18.2	467	20/670	26	highly weathered rocks	gravels
		GK 228	29.6	78.0	560	20-30	26		
	S.T.A. Dambe	KB 36	-	-	-	420/3,000<	18		under construction

Table 3-3-7 (1) Evaluation of Groundwater Development Sites

No.	Zone	T.A./S.T.A.	Village	Aquifer		Type	Evaluation	Remarks
				Resistivity (Ω-m)	Depth (m)			
1	1	Mlonyeni	Tsumba	375	38	1-A	o	GM 89: yield 90 l/min
2			Chamveka	300	40	1-A	o	
3			Sankhani Sch.	125	20	1-B	Δ	low yield due to shallow depth
4			Sankhani	240	54	1-A	o	KB-38: under construction
5			Maliwani	15	30	2-B	Δ	low resistivity
6			Mlonyeni	40	34	2-A	o	W 18: yield 72 l/min
7			Mlonyeni T.C.	195	52	1-A	o	
8			Tembwe T.C.	360	64	1-A	o	W 136: yield 24 l/min, insufficient depth (33m)
9			Maganga	25	38	2-A	Δ	relatively low resistivity
10		Mavwere	Mskwala A.D.	140	58	1-A	o	
11			Mskwala	260	82	1-A	o	SM 216: yield 27 l/min, insufficient depth
12			Kanyindula	30	80	2-B	Δ	low resistivity of bedrock, caution for possible poor water quality
13			Mphalabungu	30	43	2-B	o	Y 191: yield 24 l/min
14			Mavwere	50	24	2-C	x	A 73: yield 54.7 l/min, not used due to poor water quality
15			Waliranji	70	46	1-C	o	GM 83: yield 124 l/min

Evaluation Symbols:
o - presence of promising aquifer
Δ - concern regarding low yield and/or poor water quality
x - unsuitable for borehole construction

Table 3-3-7 (2) Evaluation of Groundwater Development Sites

No.	Zone	T.A./S.T.A.	Village	Aquifer		Type	Evaluation	Remarks
				Resistivity (Ω-m)	Depth (m)			
16	1	Mavwere	Chazuka Sch.	170	27	1-B	o	SM 79: yield 85.5 l/min
17			Chisitu	450	54	1-A	Δ	presence of weathered rock layer at shallow depth
18			Chibaya	50	23	2-A	x	bedrock at too shallow a depth
19		Zulu	Chiwako	30	26	2-B	o	W 24: yield 54 l/min
20			Chimphamba (West)	80	52	1-C	o	
21			Chimphamba (East)	50	60	2-C	o	
22			Mando	45	36	2-B	o	
23	2	Zulu	Mtiwa	110	37	1-A	o	
24			Kathyuka	75	38	1-B	o	GM 87: yield 60 l/min
25			Siwelera	20	84	2-B	Δ	low resistivity
26			Chiosha Sch.	65	57	1-A	o	GM 80: yield 60 l/min
27			Chimoko	100	25	1-A	Δ	bedrock at too shallow a depth
28			Chiwanga	125	22	1-A	x	bedrock at too shallow a depth
29			Panja	540	24	1-A	x	bedrock at too shallow a depth, high resistivity
30			Mzama Sch.	255	61	1-A	o	PM 195: yield 54 l/min

Evaluation Symbols:
o - presence of promising aquifer
Δ - concern regarding low yield and/or poor water quality
x - unsuitable for borehole construction

Table 3-3-7 (3) Evaluation of Groundwater Development Sites

No.	Zone	T.A./S.T.A.	Village	Aquifer		Type	Evaluation	Remarks
				Resistivity (Ω-m)	Depth (m)			
31	2	Mduwa	Mzama	100	30	1-B	o	
32		Dambe	Kapiri	70	34	1-A	o	R 292: yield 12 l/min
33			Panye Sch.	280	30	1-A	o	RK 109: yield 48.7 l/min
34			Kwaloza	190	23	1-B	o	
35			Chiphesi	70	21	1-B	o	SM 215: yield 96 l/min
36			Katonda Sch.	290	23	1-B	o	PM 198: yield 33 l/min
37	3	Dambe	Mkumbi	240	30	1-A	o	
38			Nthema	420	18	1-A	x	KB 36: under construction, 100m distant from existing borehole
39		Mkanda	Mkanda	20	26	2-B	Δ	W 23: yield 18.2 l/min, low resistivity
40			Betelehemu	30	27	2-B	Δ	low resistivity of both aquifer and bedrock
41			Kadeweke	330	48	1-C	o	
42			Chawala	30	70	2-C	Δ	caution for water quality due to low resistivity of bedrock

Evaluation Symbols:
- o - presence of promising aquifer
- Δ - concern regarding low yield and/or poor water quality
- x - unsuitable for borehole construction

3-3-3 Existing Borehole and Groundwater Situation

The existing boreholes in the Project Area serve as a stable supply source of domestic water. Those people with no access to borehole facilities individually or communally use either dug wells, using the advantages of a shallow groundwater depth and few undulations, or Dambo for domestic water supply.

In the case of Dambo, the ground is dug 1-2m to obtain seepage water. However,such simple digging sites often dry up in the dry season, necessitating further digging at the same sites or at different sites. Digging remains can be seen scattered around all villages.

Most dug wells have a depth of 5-6m (maximum: some 11m) and the water depth is approximately 1-2 feet. These dug wells are unsatisfactory sources of drinking water as they provide only a limited quantity of water and can be easily contaminated. They are also liable to collapse since the water is obtained through a soft sedimentary layer composed of clay and/or sand, making the water depth generally shallow. In many places, colloidal organic substances and clay granules are mixed with the groundwater, resulting in poor water quality.

In regard to both Dambo and dug wells, as the water is obtained through unconsolidated sediments with a low permeability coefficient, the walls are liable to collapse and the water yield is inadequate. They are also affected by groundwater level fluctuations and, therefore, do not constitute stable domestic water sources. Moreover, the water quality is questionable as these facilities can be easily contaminated from the surface in addition to the existence of collodial substances in the water.

In comparison, the existing boreholes use crack (fissure) water deposited in mainly weathered rocks deep in the ground. There is a total of 133 boreholes in the Project Area, of which 95 are accessible by local inhabitants. The locations of these boreholes are shown in Fig. 3-3-5 and data on them is given in the Appendix.

Hydrogeological data obtained from these boreholes are summarized in Table 3-3-8.

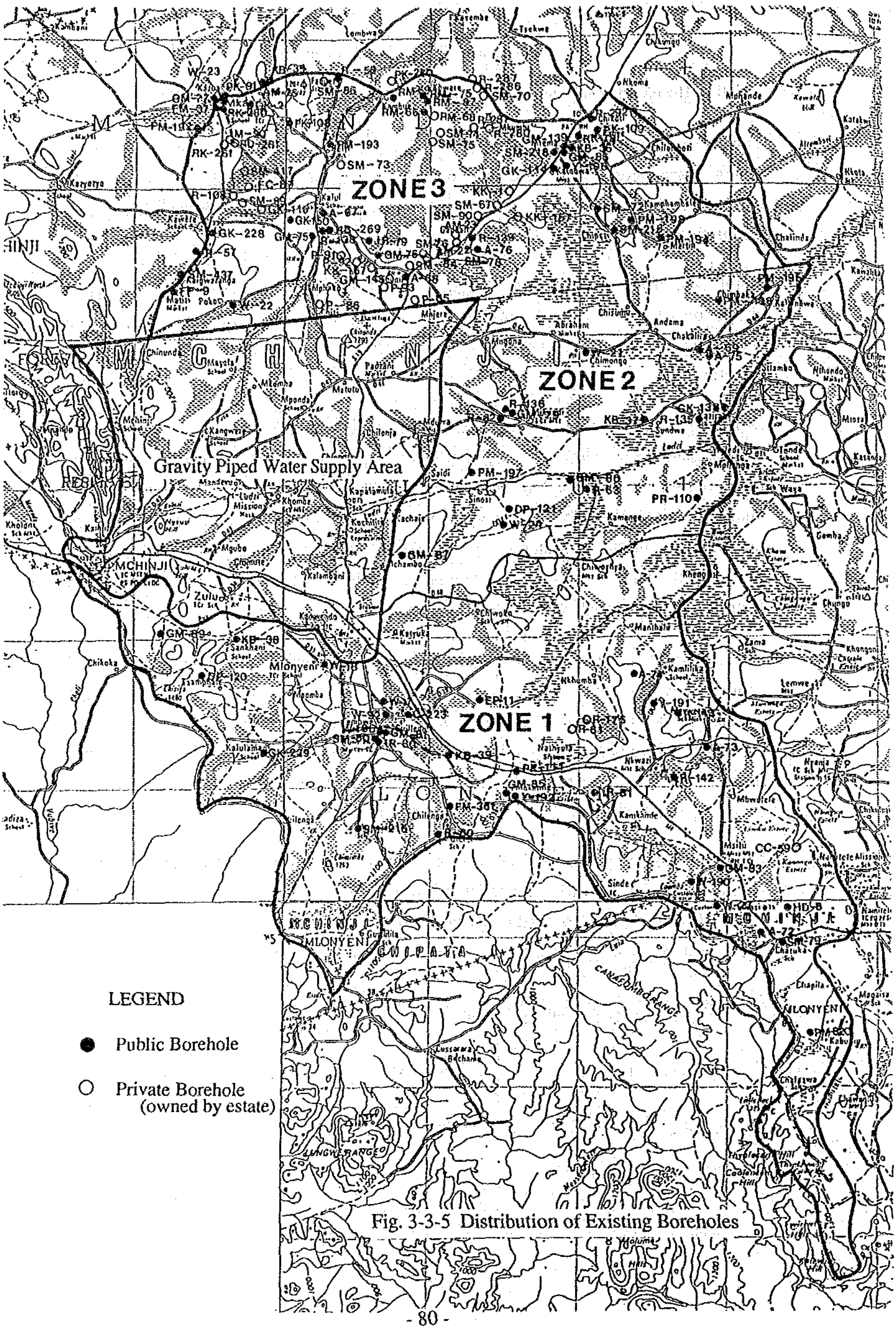


Fig. 3-3-5 Distribution of Existing Boreholes

Table 3-3-8 Data on Existing Boreholes

Zone	Year of Construction	Drilling Depth (m)	GL-(m)	Yield (l/min)	Hydraulic Constant	Geological Features (Aquifer)
1	1951-1991; mainly 1960-1970; two currently under construction	30-60 Average: 41	3-15	12-187 Average: 65	Transmissivity Coefficient: $T=8.9x10^{-6}$ - $1.5x10^{-5}m^2/sec$ Storativity: $S=2.5x10^{-1}$	Weathered gneiss is the most dominant; highly weathered layers of laterite, clay and gravels, presence of fracture zones in parts
2	1959-1991; more than half in 1970's; two currently under construction	24-90 Average: 45	3-13	18-330 Average: 79	Transmissivity Coefficient: $T=3.2x10^{-6}$ - $1.1x10^{-5}m^2/sec$	Predominantly weathered gneiss; highly weathered layers of laterite, clay and gravels in parts
3	1959-1991; mainly 1970's and 1980's; one currently under construction	28-90 Average: 53 Average depth of boreholes at estates: 56.8m Average depth of public boreholes: 47.6m	3-18	11-300 Average: 100 (Motor Pump: 190) (Handpump: 62)	Transmissivity Coefficient: $T=4.8x10^{-6}$ m^2/sec	Mainly weathered gneiss; weathered layers of laterite, clay and gravels and weathered quartzite
Summary		Drilling depth generally corresponds to thickness of weathered rock layer due to use of percussion-type rigs. Weathered rock layer in Zone 3 is relatively thicker than others	Mainly less than 10m corresponding to general depth of shallow wells	Yield of over 10 l/min can be expected for existing boreholes. Boreholes producing some 50 l/min form largest group	TC of an aquifer generally shows a value of some $1x10^{-5}m^2/sec$. No firm data on the storativity are available but $2.5x10^{-1}$ appears reasonable.	Aquifers mainly consist of weathered gneiss. Aquifers are mainly observed 25-40m deep in Zone 1 and 30-45m deep in Zones 2 and 3.

3-3-4 Water Quality

The water quality test was conducted on 45 samples of domestic water collected from boreholes, dug wells, Dambo, river, gravity piped system and dam in and around the Project Area. The backgrounds of these 45 samples are given in Table 3-3-9.

Table 3-3-9 Sources of Water Samples Subject to Water Quality Test

Source	Number of Samples					Remarks
	Zone 1	Zone 2	Zone 3	Surrounding Areas	Total	
Boreholes	7 (2)	8 (4)	3 (2)	2 (2)	20 (10)	Ten samples tested by Water Quality Laboratory
Dug Wells	12	5	3		20	Depth: less than 10m; mainly 5~6m deep; often dry up in dry season
Dambo	2				2	Depth: 1~1.5m; dry up in dry season, forcing relocation or further digging
River	1				1	Used for washing and bathing
Gravity Piped System				1 (1)	1 (1)	One sample tested by Water Quality Laboratory
Dam	1				1	
Total	24 (2)	13 (4)	6 (2)	3 (3)	45 (11)	

Note: Figures in brackets are the number of samples tested by the Water Quality Laboratory.

The water test results are shown in Appendix 5 A-7. Based on these results, the water quality characteristics of the existing boreholes, dug wells and Dambo are summarized in Table 3-3-10.

Based on the test results shown in Table 3-3-10, it can be concluded that shallow water sources, such as dug wells and Dambo, are unsuitable as drinking water sources as they are liable to contamination.

While the water quality of the boreholes is generally good, Fe was detected in some samples. As shown by the test results for dug wells and Dambo, Fe is not present in a large amount in natural groundwater. Therefore, it is believed appropriate to argue that the Fe has dissolved from the casings and/or rising main. This problem can be solved by replacing the pipes with non-corrosive pipes using PVC or other similar materials.

Ammonia, coliform and other bacteria were detected at all the dug wells and at some boreholes. Contamination has presumably occurred due to the lack of drainage facilities and also due to the use of the areas around the shallow wells and boreholes as watering places for livestock. This problem can be solved by the introduction of proper drainage facilities and by educating villagers on the need for public hygiene.

Table 3-3-10 Water Quality Characteristics by Water Source

Analysis Item	Existing Boreholes	Dug Wells and Dambo
EC	Mainly 150-500μS/cm with rich electrolytes	Generally low at 50-200μS/cm showing the characteristics of surface water or shallow water
PH	Neutral - weak alkaline	Weak acid - weak alkaline
Turbidity	Transparent without the presence of organic substances	White - brown with the presence of organic substances and clay granules
Ammonia	Detected in six samples	Detected in most samples
Coliform / Other Bacteria	Not detected in most samples; minor presence in some samples	Strong presence detected in most samples
Fe	Three samples exceeded Malawi proposed limit	Negligible
So^{-4}	All samples are within Malawi proposed limit	Same as left

3-4 Social Environment

3-4-1 Infrastructure

Mchinji Boma, the capital of Mchinji District, is not only the socioeconomic centre of western Malawi but also plays an important role in the transportation network with neighbouring Zambia. From Lilongwe, Malawi's capital, the paved Main Road 4 (M4) and railway lines extend to Mchinji Boma where an airport and local offices of the central government are also located. The M4 runs across Zone 1 of the Project Area in the east-west direction and a well developed road network is observed along the M4. Most villages are located along secondary and feeder roads of the network and have various social facilities (Fig. 3-4-1).

There are 61 primary schools in Mchinji District which cover the entire district. In comparison, there are only four secondary schools and three correspondence college in the district, all of which are located in large villages along the M4.

Mchinji Boma has a general hospital and an additional nine clinics and maternity clinics are located in the district.

The district has four public markets.

Telephone stations are located in Mchinji Boma, Kamendo, Tembwe and Nkhwaji, all of which are along the M4, and in Kapiri in the north. These telephone stations also act as post offices. In addition, five villages have their own post offices.

Electricity supply is currently limited to large villages along the M4 but future extension to Zone 3 areas in the north is planned.

3-4-2 Roads

Roads in the Project Area are classified as main roads, secondary roads, district roads and other roads. The conditions of these roads are outlined below.

(1) Main Roads (National Roads)

The M4 is classified as a main road. It is asphalt paved throughout and has a road width of 8m. Bridges over rivers are concrete and are as wide as other parts of the road, allowing the easy passage of large vehicles.

(2) Secondary Roads

The M4 and two important villages in the north, i.e. Mkanda and Kapiri, are connected by a secondary road which has a width of 5.5m and uses laterite subgrade. Gutters of 1m in width and 0.8m in depth are provided on both sides of the road. Bridges over Dambo and small rivers are concrete with a width of some 3.5m and are strong enough to support heavy vehicles.

(3) District and Other Roads

Villages in the Project Area are connected by district and other roads in addition to the above trunk roads. As well as the roads shown in Fig. 3-4-1, villages are also connected by other roads which are passable by vehicles. In general, the width of such roads is 3.0-3.5m. The road conditions are not as good as those of trunk roads because of the lack of paving. Nevertheless, the wide distribution of laterite makes a firm road bed, allowing vehicle passage during the rainy season. In places where the road surface is composed of sandy soil or where the road gradient is steep, however, passage is difficult in the rainy season even for four-wheel drive vehicles.

The bridges for district roads show a similar structure to those for secondary roads. Some bridges are constructed of wood and it is impossible for heavy vehicles to use some of the deteriorated wooden bridges. Heavy vehicle access to most villages necessitates an alternative route avoiding Dambo.

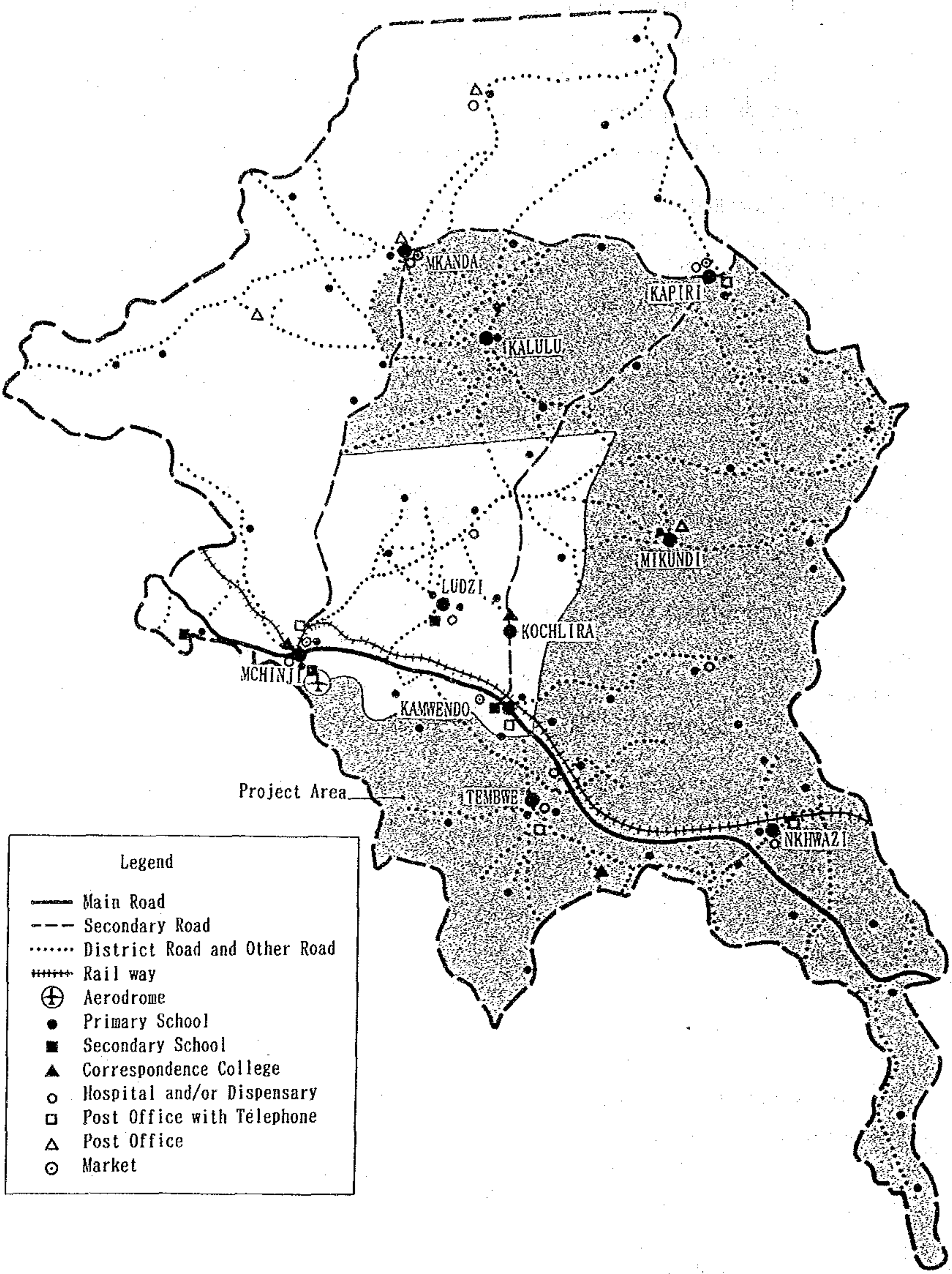


Fig. 3-4-1 Locations of Public Main Social Facilities and Road Network

3-4-3 Social Conditions

Villages in the Project Area are distributed throughout the entire area because of the generally flat topography which provides fertile farming land, except for Dambo. The population density is relatively low in the north (Zones 2 and 3) where there are many large estates while it tends to be high in the south (Zone 1) along the M4.

A total of 812 villages have been identified in the Project Area based on the 1977 census results and the relationship between the population level (estimated in 1996) and the number of villages is shown in Table 3-4-1 and Fig. 3-4-2. Small villages with a population of less than 200 account for 68% and only 6% of all villages have a population of 500 or more.

Table 3-4-1 Population Level and Number of Villages

Population Level	< 100	100-199	200-299	300-399	400-499	500-599	600-699	700 <	Total
No. of Villages	349	200	110	66	35	19	11	22	812
Ratio (%)	43	25	14	9	4	2	1	3	
	68		26			6			

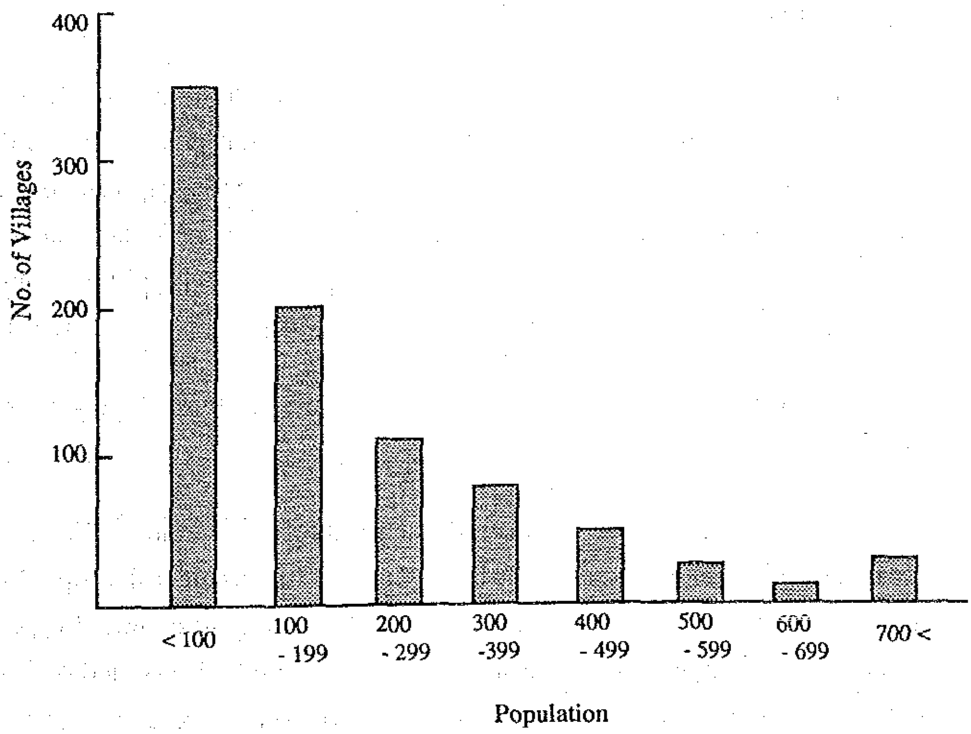


Fig. 3-4-2 Population Level and Number of Villages

The social structure of a village is shown in Fig. 3-4-3. While legal issues are dealt with by the chief of the T.A./S.T.A., which is a hereditary post, and/or the district commissioner, both development and administrative issues are discussed and decided on by the District Development Committee (DDC) which is composed of representatives of government ministries and agencies and chiefs of the T.A./S.T.A.

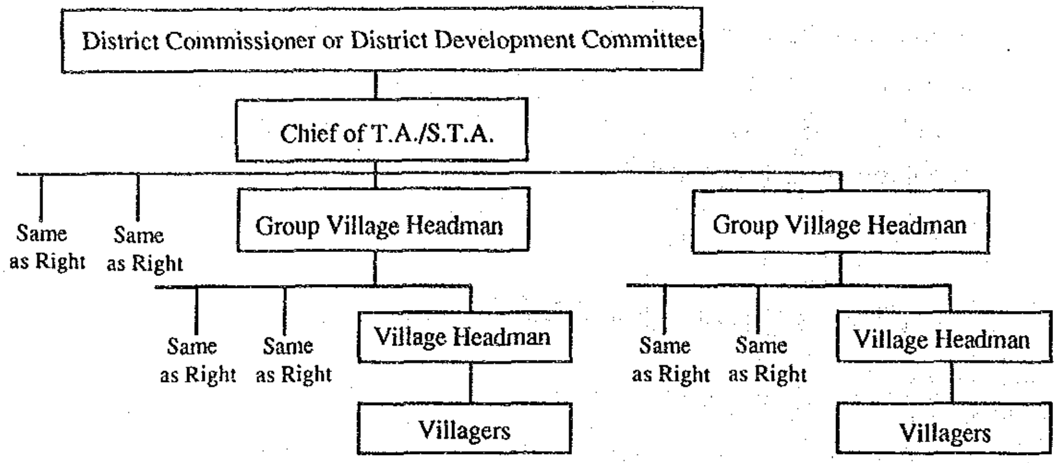


Fig. 3-4-3 Social Structure of a Village

3-4-4 Economic Conditions

Mchinji District, where the Project Area is located, has a total area of 3,346km^2 (of which 2,225km^2 is cultivable) and is one of the most fertile areas in Malawi. Its proximity to Lilongwe, Malawi's capital and a large consumption area, makes agricultural development in the area extremely important. Consolidation of the infrastructure, including an improved domestic water supply, will without doubt result in increased agricultural output and other favourable results.

Most of the Project Area's inhabitants (Zones 1, 2 and 3) are engaged in agriculture which is outlined below.

As Table 3-4-2 shows, the main agricultural products in Mchinji District include tobacco, maize, groundnuts and cassava. Tobacco is an important cash crop while maize and cassava are cultivated for self-consumption. A major export commodity, tobacco is mainly cultivated by estates which mostly produce flue-cured tobacco and barley. Small-scale independent farmers mainly produce fire- cured or sun/air-cured tobacco.

Table 3-4-3 shows the livestock resources of Mchinji District which include cattle, goats, sheep, pigs and chickens. Cattle are the most important and are mainly raised by small-scale independent farmers in a traditional manner. Goats and pigs are also important sources of protein and tend to be raised by commercial breeders for market sale.

Table 3-4-2 Outputs of Main Agricultural Products of Small-scale Independent Farmers in Mchinji District

(Unit: tons)

	1987/88	1988/89	1989/90
Maize	54,577	77,249	74,691
Tobacco	343(12,805)	692(13,500)	1,200(17,362)
Groundnuts	11,128	7,000	2,880
Pulses	185	128	127
Soybeans	4.8	6.6	209
Cassava	3,091	2,200	3,671
Sweet Potatoes	2,878	2,760	1,197
Potatoes	–	–	98

Source: Kasungu ADD and Tobacco Control Commission
Note: Figures in brackets are outputs of estates.

Table 3-4-3 Livestock Resources in Mchinji District

(Unit: head)

	Cattle	Goats	Sheep	Pigs	Donkeys	Chickens
1988	23,411	25,793	294	27,982	14	25,489
1989	25,339	24,238	414	21,742	17	47,328
1990	28,227	23,961	398	22,614	22	49,682

Source: Mchinji RDP

3-4-5 Water Supply Situation

(1) Existing Water Supply Facilities

The existing water supply facilities in Mchinji District consist of a piped service in Mchinji Boma, a gravity piped system at the eastern foot of the Mchinji Ridge and boreholes in the remaining areas.

1) Piped Service in Mchinji Boma

The piped service in Mchinji Boma is similar to the facilities provided for other urban centres and the Design and Construction Section and the Maintenance Section, both of the Department of Water, are responsible for its construction and maintenance respectively.

The water supply source is a valley located 11km from Mchinji Boma at the southern foot of the Mchinji Ridge.

The service network has been expanded over the years to meet increased demand and its present configuration is outlined below.

• Intake Pipes	: 4 inches	
• Distribution Pipes	: 6 inches (2 inches at terminals)	
• Water Taps	: 245 for individual use 6 for public use	
• Storage Tanks	: high places	20,000 gallons
	low places	14,000 gallons
• Purification Method	: chlorination	
• Daily Consumption	: 320m^3	

As this service is understood to be available to not only residents of Mchinji Boma but also those of nearby villages, the exact service population is unknown.

2) Gravity Piped Water Supply System

A small-scale intake weir is provided in the valley at the eastern foot of the Mchinji Ridge and water is supplied from there to the eastern area of the Mchinji Ridge. This service area is omitted from the Project Area and the system is managed by the Rural Piped Water Supply Section of the Department of Water. The system is outlined below.

Distribution Pipe : 19-90mm (total length: 136km)

Water Taps : 215
Storage Tanks : approx. 150m^3, 4 sites
Purification Method : unpurified
Daily Consumption : 37,000 persons × 36l/day
(originally 20,000 persons × 36l/day)
Year of Completion : 1976

At present, the water supply volume in places far from the storage tanks is very poor, prompting a plan to branch out the piped service for Mchinji Boma described in 1) above. Because of the limited availability of water at the source, however, no concrete plan to extend the piped supply to replace the gravity supply system has yet been finalized.

3) Boreholes in Project Area

Those areas which are not served by either 1) or 2) above have boreholes (average depth: 45-50m) as the form of water supply. The distribution of boreholes in the Project Area is shown in Table 3-4-4 and Fig. 3-3-5. In addition, technical data on the boreholes are given in the Appendix.

Table 3-4-4 Distribution of Existing Boreholes

	Zone 1	Zone 2	Zone 3	Total
T.A. Mlonyeni	9	–	–	9
S.T.A. Mavwere	19 (3)	–	–	19 (3)
T.A. Zulu	9	2	–	11
S.T.A. Mduwa	–	12	–	12
T.A. Mkanda	–	–	18 (9)	18 (9)
S.T.A. Dambe	–	15 (2)	11 (24)	26 (26)
Total	37 (3)	29 (2)	29 (33)	95 (38)

Note: Figures are for public boreholes.
Those in brackets are separate boreholes located on estates.

The total number of boreholes in the Project Area is 133, of which 95 are for public use. As the service population per borehole is believed to be 250, the service ratio vis-a-vis the Project Area population of 138,585 (1987) is only

17%. The boreholes are most densely located in Zone 3 in the north and are sparse in Zone 1 in the south except along the M4.

The construction of these boreholes commenced as early as 1951 and most were constructed in the period between 1971 to 1980.

before 1960	11
1961-1970	26
1971-1980	63
1981-	22
under construction	5
year of construction unknown	6

According to records from the time of construction, the early handpumps used for these boreholes came from various sources, including Malawi, Britain and South Africa. Most pumps have now been replaced by Afridev handpumps because of the implementation of a rehabilitation project with the assistance of the IFAD. However, it appears that many of these handpumps have problems with the pump head and/or other parts as the Afridev handpumps in use are an old model which has subsequently been improved. Two pumps are currently out of order, preventing the use of the respective boreholes.

(2) Foreign Assistance for Groundwater Development

Groundwater development projects assisted by foreign organizations in the Project Area are mainly rehabilitation projects for the existing boreholes. Three such completed and planned projects are described below.

1) Kasungu/Mchinji/Dowa East Project

[Rehabilitation of 248 boreholes (1987-1990) by IFAD]

This project was completed in 1990 and 95 boreholes in Mchinji District, covering many of the Project Area's boreholes, were rehabilitated.

2) Dowa/Kasungu/Mchinji Project

[Construction of 61 new boreholes (1991-1993) by IFAD]

This project is currently in progress and the construction of boreholes is being conducted at five sites in the Project Area, i.e. T.A. Mlonyeni (Zone 1), T.A. Zulu (Zone 1), S.T.A. Mduwa (Zone 2), S.T.A. Dambe (Zone 2) and T.A. Mkanda (Zone 3).

3) Northern and Central Regions Project

[Rehabilitation of 1,050 boreholes (1991-1992) by IDA]

This project will commence soon and 27 boreholes in Mchinji District will be subject to rehabilitation. Selection of the subject boreholes is currently in progress by the Department of Water.

What these projects achieved or will achieve is the maintenance of the present low service ratio and, therefore, there are strong hopes for Japanese grant aid in Malawi.

(3) Realities of Domestic Water Supply

The water service ratio in the Project Area vis-a-vis boreholes is 17% and the remaining 83% of the population who do not benefit from a public facility water supply depend on dug wells, Dambo or river for domestic water. The quality of water obtained from the latter sources is poor, as described in 3-3-3, and is unsuitable for drinking. Moreover, the supply from these sources (other than boreholes) tends to dry up in the dry season, forcing the women to travel further for water.

A questionnaire survey was conducted on housewives in 30 villages to obtain a realistic picture of domestic water supply. Table 3-4-5 gives the survey results. The table also includes the results of a questionnaire survey conducted in North Kawinga as an example of an area where a water supply system using boreholes is firmly established.

1) Water Transportation Time

In the case of inhabitants using boreholes as the domestic water supply source, the average water transportation time is 1.3 hours. In the case of those using dug wells or Dambo, the corresponding time increases by some 30% to 1.5-1.7 hours in the rainy season when the groundwater level is comparatively high. In the dry season (for 2-4 months), the time is considerably longer as people must search for water over a wide area. The water transportation time in North Kawinga was as long as 6 hours/day before the completion of the boreholes due to the relative lack of such water sources as rivers and Dambo coupled with difficulties in drawing water from dug wells.

Table 3-4-5 Results of Questionnaire Survey on Local Housewives

Domestic Water (l/person/day) Consumption Rate – Total

Area	Type of Water Source	Av.	1-5	6-10	11-15	16-20	21-25	26-30	31+
Project Area in Mchinji District	Dambos (2 cases)	Av.=15		1		1			
Project Area in Mchinji District	Dug Wells (21 cases)	Av.=21		4	5	3	2	4	3
Project Area in Mchinji District	Boreholes (7 cases)	Av.=41 (Av.=29 for wives of farming households only)			2				5
North Kawinga	Boreholes (7 cases)	Av.=34				1	1		5
North Kawinga	Dug wells or Dambo (prior to borehole completion (7 cases)	Av.=16		1	3	3			

Domestic Water (l/person/day) Consumption Rate – Drinking/Cooking

Area	Type of Water Source	Av.	1-5	6-10	11-15	16-20	21-25	26-30	31+
Project Area in Mchinji District	Dambos (2 cases)	Av.=7	1	1					
Project Area in Mchinji District	Dug Wells (21 cases)	Av.=10	7	8	2	3			1
Project Area in Mchinji District	Boreholes (7 cases)	Av.=24 (Av.=15)	2			2	1		2
North Kawinga	Boreholes (7 cases)	Av.=18		1	3	1	1	1	
North Kawinga	Dug wells or Dambo (prior to borehole completion (7 cases)	Av.=9		5	2				

Degree of Satisfaction

Area	Type of Water Source	Q'ty: Ratio of Satisfied	Q'ty: Satisfied	Q'ty: Not Satisfied	Quality: Ratio of Satisfied	Quality: Satisfied	Quality: Not Satisfied
Project Area in Mchinji District	Dambos (2 cases)	0%		2	0%		2
Project Area in Mchinji District	Dug Wells (21 cases)	50%	11	10	40%	9	12
Project Area in Mchinji District	Boreholes (7 cases)	100%	7		70%	5	2
North Kawinga	Boreholes (7 cases)	100%	7		100%	7	
North Kawinga	Dug wells or Dambo (prior to borehole completion (7 cases)	60%	4	3	0%		7

Frequent Waterborne Diseases

Area	Type of Water Source	Surveyed Cases	Diarrhea	Dysentry	Cholera	Helminthiases	None
Project Area in Mchinji District	Dambos (2 cases)	Surveyed Cases: 3 (one of which occurred when Dambo was used to substitute a borehole following pump failure)	3	1			
Project Area in Mchinji District	Dug Wells (21 cases)	(Surveyed Cases: 14)	11	1	1	3	3
Project Area in Mchinji District	Boreholes (7 cases)	(Surveyed Cases: 5)	1				
North Kawinga	Boreholes (7 cases)	Not Surveyed					
North Kawinga	Dug wells or Dambo (prior to borehole completion (7 cases)	Not Surveyed					

Water Transportation Work (hours/day)

Area	Type of Water Source	Av.	-1	1.1-2.0	2.1-3.0	3.1+
Project Area in Mchinji District	Dambos (2 cases)	Av.=1.5	1	1		
Project Area in Mchinji District	Dug Wells (21 cases)	Av.=1.7	9	7	3	2
Project Area in Mchinji District	Boreholes (7 cases)	Av.=1.3	3	2	2	
North Kawinga	Boreholes (7 cases)	Av.=1.2	4	3	2	
North Kawinga	Dug wells or Dambo (prior to borehole completion (7 cases)	Av.=5.9	1			6

Remarks

Area	Type of Water Source	Remarks
Project Area in Mchinji District	Dambos (2 cases)	• Due to the availability of Dambo near villages, the water transportation time is similar to that using boreholes. Water tends to dry up towards the end of the dry season, necessitating a switch to another source or the digging of a new well. • The domestic water consumption rate is less than half of that using boreholes due to shallow water depth and slow recovery of the groundwater level.
Project Area in Mchinji District	Dug Wells (21 cases)	• Water is a muddy white or brown and some samples have bad odour. 40% of the users complained about the quality. There is a high occurrence of waterborne diseases, such as diarrhea. Education on sanitary requirements is needed together with a clean water supply from boreholes or other sources.
Project Area in Mchinji District	Boreholes (7 cases)	• Data on the consumption rate and transportation time are similar to those for North Kawinga. • Some inhabitants are not satisfied with the water quality due to the inclusion of Fe, in turn caused by old casings and/or rising main.
North Kawinga	Boreholes (7 cases)	◎(Compared to Conditions Prior to Completion of Boreholes) • Water consumption rate has almost doubled • No further complaints on water quality • Water transportation time reduced to approximately one-fifth
North Kawinga	Dug wells or Dambo (prior to borehole completion (7 cases)	

2) Domestic Consumption Rate

The domestic water daily consumption rate of inhabitants using borehole water is approximately 30*l*/person which is slightly higher than the target 27*l*/person set by the Government of Malawi. The daily consumption rate of those relying on other sources is 15-21*l*/person, half or two-thirds of those using borehole water. The main reason for this low consumption rate is the shallow depth of water sources of around 10cm and the long time required for the groundwater level to recover after being drawn.

3) Water Quality

In reply to the question regarding the frequent occurrence of waterborne diseases, one in five of those using borehole water complained of diarrhea. In comparison, of the 17 respondents, 14 (more than 80%) mentioned diarrhea, dysentery, cholera and helminthiases, indicating the use of bacteria infested water. Nevertheless, the fact that only 60% of the respondents complained about poor water quality implies a poor perception on the part of these inhabitants in regard to their use of poor quality water for domestic use.

Complaints were also expressed about the poor water quality of some boreholes, presumably because of the dissolution of Fe in the water from old casings and/or rising main.

4) Current Domestic Water Problems

The above survey results show that the construction of water supply facilities using clean water from boreholes has been largely delayed in Mchinji District due to the fact that domestic water is easily available from Dambo or dug wells during the rainy season. The problems faced by those using water sources other than boreholes are an insufficient volume and poor water quality. While inhabitants who have long used dug wells or Dambo are little aware of the poor quality of the domestic water they use, they will be educated on the importance of using clean water through access to such facilities as boreholes with handpumps in the coming years.

3-4-6 Waterborne Diseases

Waterborne diseases recorded in Malawi and Mchinji District from 1986 to 1990 are compiled in Table 3-4-6.

According to the data given in Table 3-4-6, the number of patients in Mchinji District vis-a-vis the population (248,161) is relatively low (1987). In reality, however, some 80% of the people using unhygienic water from Dambo or dug wells suffer from waterborne diseases as shown by the questionnaire results described in 3-4-5. It appears reasonable to assumed that the number of registered patients is much lower than the actual number of sufferers as few live within travelling distance of a hospital or clinic.

It is, therefore, necessary to provide health education as well as a supply of clean drinking water to improve the situation.

Table 3-4-6 Occurrence of Waterborne Diseases in Malawi and Mchinji District

Disease	Area	1986		1987		1988		1989		1990	
		Sufferers	Dead	Sufferers	Dead	Sufferers	Dead	Sufferers	Dead	Sufferers	Dead
Typhoid, Paratyphoid	Nationwide	988	100	855	81	936	79	1,284	116	1,293	127
	Mchinji District	4	1	1	0	19	1	11	1	12	2
Bacillary, Amoebic Dysentery	Nationwide	677	20	967	12	1,281	54	1,371	72	1,479	97
	Mchinji District	29	1	36	0	43	2	55	5	24	0
Enteritis, Diarrhoea	Nationwide	12,636	879	9,760	601	16,473	905	13,139	923	19,502	1,239
	Mchinji District	245	12	328	16	255	13	321	16	317	25
Schistosomiases	Nationwide	886	7	958	7	978	9	903	12	1,009	8
	Mchinji District	32	0	27	0	24	0	54	0	35	1
Ancylostomiases	Nationwide	1,212	12	1,040	26	1,782	9	1,230	14	1,599	1
	Mchinji District	36	0	72	0	70	0	62	0	47	0
Other Helminthiases	Nationwide	354	2	445	5	822	4	544	1	935	8
	Mchinji District	6	0	4	0	16	0	25	0	21	0
Malaria	Nationwide	41,851	1,604	44,916	1,529	53,572	2,241	50,990	2,276	57,748	2,586
	Mchinji District	1,373	38	1,681	50	1,844	37	1,987	40	1,695	93
Infectious Hepatitis	Nationwide	537	39	472	33	489	52	643	55	401	59
	Mchinji District	5	0	5	0	5	0	5	0	0	0

Source: Ministry of Health

3-5 Water Supply Administration

The only administration relating to water supply in the Project Area is Namitete Maintenance Office of the Department of Water which is located on the border between Mchinji District and Lilongwe District along the M4 and which is mainly responsible for the repair of handpumps.

The area of responsibility of this Office covers the entire Mchinji District and part of Lilongwe District and the current organization of the Office is shown in Fig. 3-5-1.

The procedure for the repair of handpumps is explained below.

(1) Posting of a repair request card explaining the state of pump failure from the person responsible for borehole maintenance (village inhabitant) to the Headquarters of the Department of Water.

(2) After examination of the request card, the Department of Water issues a repair order to the relevant Maintenance Office via the Regional Office.

(3) The Maintenance Office dispatches an operator to conduct the necessary repair free of charge.

Table 3-5-1 shows the budget appropriation for Namitete Maintenance Office for the last four years. The Office is allocated a 5 ton crane-mounted truck. The vehicle and equipment cost accounts for some 80% of the total budget due to the deterioration of vehicles.

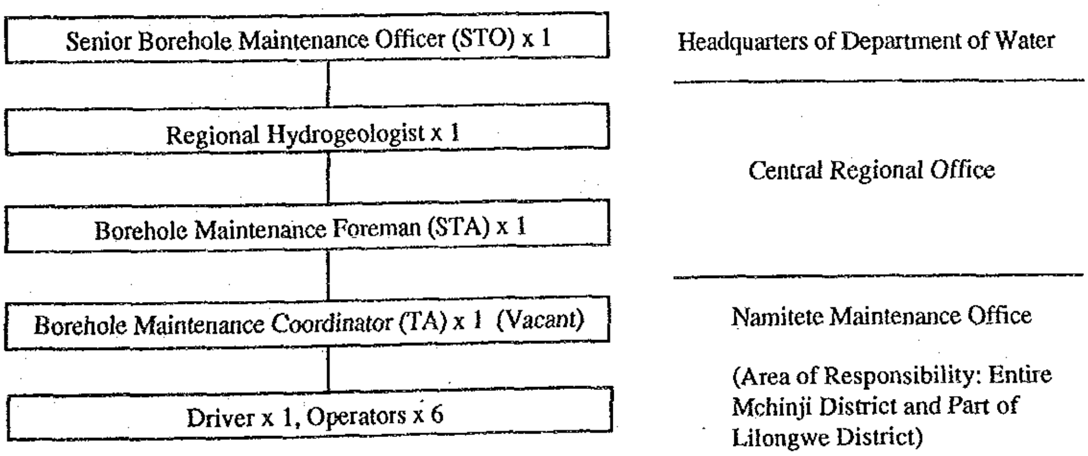


Fig. 3-5-1 Current Maintenance Structure of Boreholes in Mchinji District

Table 3-5-1 Budget Appropriation for Namitete Maintenance Office

	1987/88	1988/89	1989/90	1990/91
Personnel Cost	6,000	6,000	6,960	6,960
Fuel Cost	2,900	3,300	3,600	3,960
Vehicle & Equipment Cost	85,300	97,650	101,500	103,880
Travelling Expenses & Others	12,450	15,230	18,900	25,200
Total	106,650	122,180	130,960	140,000

CHAPTER 4

CONTENTS OF THE PROJECT

CHAPTER 4 CONTENTS OF THE PROJECT

4-1 Objectives of the Project

One of the most important objectives of the Statement of Development Policies (1987-1996) issued by the Government of Malawi is the development of a domestic water supply in rural areas with a view to providing rural inhabitants with an adequate supply of domestic water, reducing the time required for water transportation and reducing the occurrence of waterborne diseases. The concrete targets suggested are an increase of the water service ratio and service population in rural areas to 74% and 5,860,000 respectively by 1996, necessitating the development of new water sources to meet the demand of 967,000 people in the five year period. Financial hardship in Malawi, has caused a general delay in the implementation of projects envisaged by the Statement of Development Policies and it appears very difficult for the Government of Malawi to conduct the planned groundwater development without assistance from overseas.

As part of the overall attempt to rectify the domestic water supply shortage in rural areas, the Government of Malawi has prepared a development plan to construct 300 boreholes in Mchinji District where the domestic water supply shortage is critical. The objectives of the present Project are to materialize the borehole construction work and to procure the necessary machines, equipment and materials for this work as well as technical cooperation as part of the work, all of which are essential for the success of the development plan, by securing grant aid from the Government of Japan.

4-2 Examination of Requested Project Contents

4-2-1 Examination of Project Viability and Necessity

(1) The construction of 1,000 boreholes in the next five years is required to achieve the target water service ratio of 74% introduced in the Statement of Development Policies. The Government of Malawi has already commenced a national drive to achieve this target by enlisting the assistance of international organizations and donor countries and assistance to construct 671 boreholes has so far been pledged. The plan to construct 300 boreholes in Mchinji District is part of this national drive and, if realized, the Japanese grant aid will play an important role in the implementation of Malawi's national plan.

(2) Mchinji District has fertile land and is an important area for agricultural development in Malawi from a national point of view due to the government emphasis on agricultural development and its proximity to Lilongwe, the capital of Malawi and a large food consumption area. In the light of such importance, Mchinji District has been selected as the model district for comprehensive rural development and the Mchinji District Physical Development Plan has been jointly prepared by the Office of the President, UNDP and UNCHS. The Plan addresses the necessity of developing diverse fields of the socioeconomic infrastructure, including agriculture, industry, tourism service, employment, population distribution, urban functions, land use and transportation, electricity supply, domestic water supply, medical and educational facilities, postal service and telephone service, etc. The water supply service, which is one of the most basic requirements, is particularly poor in rural areas with a service ratio as low as 17%. The water service ratio in the Project Area will improve to approximately 50% with the implementation of the Project, indicating not only the very favourable effect of this groundwater development project on Mchinji District but also the urgency of its implementation.

4-2-2 Examination of Implementation and Management Capability

The Ministry of Works will have overall responsibility for the implementation of the Project while the construction work will be supervised by the Groundwater Section, Water Resources Branch of the Department of Water. Following completion, the boreholes will be operated and maintained under the VLOM system.

The Department of Water experienced Japanese grant aid with the North Kawinga Groundwater Development Project and, therefore, has a working knowledge of the mechanism of Japanese grant aid system. Accordingly, it has the appropriate organization and staff to implement the Project. As Table 2-2-2 shows, the assignment to the Project of 58 staff members of the Department of Water's total 551 staff members is currently envisaged. These mainly consist of the entire technical staff of the Headquarters and technical staff of the Central Regional Office under whose jurisdiction Mchinji District is placed. In addition, the Southern Regional Office and Northern Regional Office will assign one driller each for the purpose of enabling these drillers to undergo on-the-job training on the drilling rigs previously provided and to be newly provided by Japan.

In the case of a foreign-assisted project, the budget for project implementation (including the cost of on-the-job training) generally is included in the development budget consisting of grant or loan amount for the project from overseas, and a contribution by the Government of Malawi which is usually equivalent to some 3% of the construction cost (excluding the material and equipment cost). The past development budgets of the Groundwater Section given in Table 2-2-1 show annual fluctuations due to the predominance of foreign grants and loans. In other words, the budget of the Groundwater Section depends on how much international organizations and/or foreign governments are intending to provide in a specific fiscal year. Taking the successfully completed North Kawinga Project as an example, however, a total of K91,879 has been appropriated from the Government of Malawi in the last four years as the Malawi portion of the development budget. Given this, it is reasonable to believe that proper budgetary arrangements will be made on the Malawi side during the Project implementation period.

The VLOM system under which the boreholes will be maintained following their completion aims at self-reliant maintenance at a village level with the assistance of an operator of the local Maintenance Office of the Groundwater Section who is responsible for providing technical services for 100 boreholes.

The VLOM system has already been adopted for the maintenance of boreholes constructed under integrated groundwater development projects implemented in Lilongwe NE, Livulezi and Karonga and has proven successful. Preparations to introduce the VLOM system in North Kawinga are also underway with actual commencement planned in fiscal 1992.

The maintenance cost for the boreholes is totally provided from the current budget of the central government and, therefore, villagers are not required to make any contribution. The annual maintenance cost for the 300 boreholes will be as follows.

Personnel Cost (3 operators)	K100/month × 12 × 3	=	K3,600
Vehicle, Fuel & Equip. Costs	K500/borehole × 300	=	K150,000
Travel Allowance	K20/day x 10 days/month × 12 × 3	=	K7,200
	Total	=	K160,800

Table 3-5-1 shows the budget of the Namitete Maintenance Office which controls boreholes in Mchinji District and part of Lilongwe District. The amount for fiscal 1990 was K140,000. As this Office controls some 300 boreholes, its maintenance cost is similar to that planned under the Project, implying that the planned budgetary appropriation can be achieved with little difficulty.

4-2-3 Examination of Similar Projects

In addition to the foreign-assisted groundwater development projects discussed earlier, the construction of five new boreholes is currently underway in Mchinji District with the assistance of the IFAD and with completion scheduled in March, 1992. These five boreholes are included in the 95 existing boreholes in the present report which is far below the required number of boreholes (813 based on a service population of 250/ borehole vis-a-vis the estimated population of 203,130 in 1996) in the Project Area.

As far as the future of Mchinji District is concerned, an IDA project aiming at the rehabilitation of 27 existing boreholes is the only project with a firm commitment.

The above two are small scale projects to Mchinji District when compared to the present Project which aims at drastically improving the District's service ratio as well as the living conditions of its inhabitants. There will, therefore, be no overlapping between the Project and these two international projects.

4-2-4 Examination of Project Components

(1) Direct Beneficiaries

The current water service ratio in the Project Area is some 17%. With the construction of 300 new boreholes, however, the ratio for the estimated population of 203,130 in 1996 will improve to almost 50% (the service populations of both the existing and new boreholes will be approximately 100,000), approaching the national target of 74% in rural areas in 1996.

(2) Target Supply Rate

The questionnaire survey conducted in the Project Area revealed a current domestic water supply rate of some 30*l*/person/day for those living near boreholes. In the case of the previous Kawinga Project, the supply rate for villagers living far from boreholes was 12-20*l*/person/day. A target rate of 27*l*/person/day is deemed an appropriate average figure.

The water balance calculation for the Project Area indicates that the groundwater discharge is at least $6.9 \times 10^6 m^3$/year (see 3-3). The estimated pump discharge from 395 boreholes is $0.97 \times 10^6 m^3$/year based on the target supply rate of 27*l*/person/day and a service population of 250/borehole.

As the estimated groundwater discharge far exceeds the estimated pump discharge, an increased water demand in the future due to an improved service ratio, increased service population and improved supply rate will be well catered for.

(3) Service Population/Borehole

Assuming a service population of 250 persons/borehole and a service rate of 27*l*/person/day, the required pump discharge/borehole will be $6.75m^3$/day. As the general pumping operation hours in rural areas of Malawi are eight hours (five hours in the morning, one hour in the early afternoon and two hours in the evening), a pump capable of discharging 15*l*/min will provide $7.2m^3$/day. Consequently, the standard service population of 250 persons/borehole set by the Government of Malawi is deemed appropriate.

In the case of villages with a population of more than 250 inhabitants, boreholes are constantly used from dawn to sunset, suggesting that boreholes can be used for as many as 14 hours/day. The resulting maximum daily pump discharge is $12.6m^3$ which is sufficient to meet the domestic water requirement of a village with more than 400 inhabitants.

(4) Target Number of Boreholes to be Constructed

The Project Area will have an estimated population of 203,130 in 1996 and the required number of boreholes to serve a population of this size based on a service population of 250/borehole is 813. Excluding 95 existing boreholes, therefore, the number of boreholes to be constructed is 718. There are 812 villages in the Project Area, of which 549 (68%) are small villages with a population of less than 200. Although it is desirable to provide at least one borehole for each village, a project to meet this requirement would be too large to be practical under the present conditions and given the very low water service ratio. As a result, it appears appropriate that the number of boreholes to be constructed under the Project will be based on the overall population size.

Given the above limitation currently imposed on the Project scope, the subject villages will in principle be those with a population of more than 200. As far as villages with a much larger population are concerned, one borehole will be allocated for each some 400 inhabitants based on the examination results in (3) above. The resulting number of boreholes required in the Project Area is approximately 300.

(5) Borehole Construction Priority

The Project Area is divided into three zones and priority is given to Zone 1, followed by Zone 2 and then Zone 3 in view of the current water service ratio and population density.

Table 4-2-1 Water Service Ratio and Population Density in Project Area (1987)

Zone	Population	No.of Existing Boreholes	Water Service Ratio No.of Existing Boreholes × 250 ÷ Population (%)	Population Density (persons/km^2)
1	77,700	37	11.9	91.4
2	36,739	29	19.7	65.6
3	24,146	29	30.0	75.4
Average	138,585	95	17.1	80.1

(6) Hydrogeological Conditions and Average Drilling Depth of Planned Boreholes

The Project Area has annual rainfall of approximately 1,000mm. The weathered bedrock layer which is expected to act as an aquifer is distributed throughout the area, providing a good prospect for groundwater development. Compared to North Kawinga, the Project Area tends to have a thicker weathered bedrock layer. However, as this layer is found to have many undulations, it is important to conduct electric prospecting to examine the geological structure in detail prior to the final decision on the borehole sites so that sites with favourable conditions for groundwater development can be selected.

Based on the field survey (i.e. electric prospecting) results, topographical and geological features and data on existing boreholes in the Project Area, the maximum and average drilling depths for the new boreholes have been provisionally set at 75m and 50m respectively.

(7) Required Number of Groundwater Development Teams

1) Using the requested rotary/air-hammer type drilling rig, the drilling of 1-2 boreholes/week (transportation of rig, drilling to a depth of 50m and casing installation) appears possible based on concrete examples in North Kawinga and other areas. Consequently, the average drilling distance is set at 12m/day.

2) A failure rate of 20% is adopted for the Project Area in view of the following considerations.

   a) The success rate for drilling boreholes in North Kawinga was some 75%.

   b) The success rate for the Project Area can improve on the above 75% for North Kawinga because of the presence of a more favourable aquifer.

   c) The fact that groundwater from some boreholes cannot be used as domestic water because of its poor quality must be taken into consideration.

3) In principle, the construction work should be conducted in the dry season (8 months from April to November). Given the good road conditions in the Project Area which will allow the work to be continued along trunk roads during the rainy season, the actual construction period (including overhaul work) is set at 12 months from mid-March to mid-March (11 months for drilling work).

4) Based on the above conditions, the required total construction period is calculated below assuming the employment of two teams.

   Total Drilling Length : 50m × 300 × 1.2 = 18,000m

   Required Working Days: 18,000m ÷ 10.5m/day ÷ 2 ≒ 860 days
   ≒ 29 months

   In addition to the above, time for preparation and machines and equipment maintenance must also be taken into consideration.

5) It is judged from the aforegoing examination results that the use of two groundwater development teams will be required to complete the construction of some 300 new boreholes in three years. This project implementation period also appears reasonable in view of the need for the transfer of technology.

(8) Target Year

As the Project will be implemented pursuant to the Statement of Development Policies (1987-1996), the completion of the Project by fiscal 1996 is aimed at. Assuming that the Project commences in fiscal 1992, the actual work period will extend over four fiscal years due to the lead time required for the procurement of machines, equipment and materials. The Project will, therefore, be completed by the target year of fiscal 1996.

(9) Machines and Equipment and Materials

Various machines and equipment, including a drilling rig, will be required for the construction of the boreholes. The drilling rigs currently owned by the Department of Water are generally old and shows signs of deterioration except for the two rigs provided by Japan for the North Kawinga Project. As the work efficiency of the rigs is extremely poor, the work schedule cannot be prepared based on their design performance. The two rigs provided by Japan are currently in the possession of the Southern Regional Office and Central Regional Office.

The Japanese rig of the Southern Regional Office is playing an important role in an UNHCR project (dealing with refugees from Mozambique) and an urgent disaster prevention project in Phalombe, etc. and its use will continue to be demanded for the foreseeable future. Therefore, the Japanese provision of a new rig to join the existing rig of the Central Regional Office will be necessary for the successful implementation of groundwater development (borehole construction) in Mchinji District.

Transfer of the newly provided rig to the Northern Regional Office is planned to improve its work efficiency. Given the prospect of improved government work efficiency from the national perspective, the provision of one new drilling rig set under the Project appears appropriate from the viewpoint of the objectives of Japanese grant aid cooperation system.

(10) Pump

The Afridev handpump will be adopted for the Project to promote the use of the VLOM system which the Government of Malawi is trying to introduce nationwide.

4-2-5 Examination of Requested Facilities, Machines, Equipment and Materials

(1) Requested Facilities

The facilities requested by the Government of Malawi for the Project are water supply facilities consisting of boreholes and ancillary structures. As clean surface water which does not require purification and which is enjoyed through the gravity piped water supply system in neighbouring areas is unavailable in the Project Area, boreholes using deep groundwater are deemed to be the most appropriate water supply facilities in terms of both the construction cost and maintenance.

1) Boreholes

With regard to the actual borehole dimensions, the depth should be determined in line with the geological conditions of the site as described in 4-2-4. 100mm is deemed to be an appropriate diameter for the completed boreholes which is the minimum figure given the bottom structure of the pump (the outside diameter of the rising main of the Afridev handpump is some 82mm) and borehole maintenance (cleaning of the boreholes).

2) Ancillary Facilities

Ancillary facilities for the boreholes include an apron, drainage channel and washing slab, etc. The construction of these facilities pose few problems if the standard specifications in Malawi are adopted in their planning. Consideration must be given to the structural aspect, i.e. use of reinforcing bars or others, as the existing boreholes often show ① a loose concrete slab holding the pump and ② a number of concrete cracks.

Animal dung is often mixed with standing water in places where the drainage conditions are poor, eventually resulting in contamination of the groundwater. It will, therefore, be necessary to provide an appropriate drainage facilities for some of the new boreholes.

(2) Requested Machines, Equipment and Materials

The machines, equipment and materials originally requested by Malawi are one set of drilling rig with other machines and equipment, one set of tools and spare parts for the drilling rig with other machines and equipment provided for the North Kawinga Project, borehole construction materials (such as castings, screens, etc.) for 300 boreholes and pumps.

As already explained in 4-2-4, use of the two drilling rigs provided by Japan for the North Kawinga Project for the present Project will hamper the implementation of other projects, including the UNHCR project to assist refugees from Mozambique. Since the provision of a new drilling rig (accompanied by technical cooperation) will greatly contribute to strengthening the work capability of the Government of Malawi, the provision of a new drilling rig appears essential.

Although the Malawi request does not give a concrete list (and quantities) of machines, equipment and materials, it appears appropriate to refer to the North Kawinga Project to determine the required items and quantities of the machines, equipment and materials for the Project in view of ① the similarity of the geological conditions of the Project Area to those of North Kawinga and ② the successful outcome of the North Kawinga Project with the planned items and quantities. The feasibility of using locally manufactured PVC pipe casings and a low cost muddy water agent as a substitute for bentonite is discussed in 5-4-5.

4-2-6 Examination of Necessity to Provide Technical Cooperation

The Malawi request for technical cooperation is twofold, i.e. ① the training of drillers for the drilling rig priviously provided and to be newly provided by Japan and ② the training of hydrogeologists. In association with the North Kawinga Project, two drillers (one each from the Southern Regional Office and Central Regional Office) underwent technical training. These drillers have since been engaged in borehole construction planned by the Government of Malawi. There is a strong desire for further training as the various problems experienced by them in terms of drilling technology and the repair/maintenance of rigs, etc. are partially attributed to their lack of adequate expertise. Moreover, the number of well trained drillers must be increased for the efficient operation of the three rotary rigs which will be owned by the Government of Malawi with the implementation of the Project.

The Department of Water, which is responsible for groundwater development, employs senior engineers who have studied hydrogeology. While these engineers (hydrogeologists) have certain project administration experience and knowledge of hydrogeology, they strongly hoped for training in Japan to get Japanese knowledge, technics and experience in the field of groundwater development.

4-2-7 Basic Concept for Implementing the Project by Japanese Grant Aid

As the aforegoing examination confirms the positive effects, feasibility and viability of the Project and the responsible body for project implementation, etc. and as these meet the criteria of Japanese grant aid system, the provision of Japanese grant aid for the Project is deemed appropriate. The Project components are outlined in the following sections for preparation of the basic design assuming the provision of Japanese grant aid for the Project.