CHAPTER 1 INTRODUCTION

Chapter 1 Introduction

1.1 Background

The Malawi, which is located in South Africa, boarders Mozambique at the east and north, Zambia at the west and Tanzania at the north-east, and is situated between latitudes 9°10' to 17° 7' S and longitudes 32° 41' to 35° 56' E. The total area of Malawi is 94,276 square kilometers and has no sea borders. According to the national census in 1998, total population was about 9,930 thousand and annual average growth rate for the last 21 years was 2.8% (2.0% for the last 11 years). The capital is Lilongwe, which has a population of about 1,350 thousand. The power supply for public demand in Malawi is provided by Electricity Supply Corporation of Malawi (ESCOM). The breakdown of electric power facility, which has a total installed generation capacity of 306,400kW, is described in Chapter 3. The power supply facility comprises of 284,700kW by hydro-power, 21,400kW by thermal gas-turbine and diesel power. The power generated by these power stations is transmitted to consumers through 132kV and 66kV lines, which are trunk transmission lines, and 33kV and 11kV lines, which are trunk distribution lines. The transmission and distribution system is conducted throughout the country, however, the electrification rate of the residential sector is as low as about 4%.

Under these circumstances, the Government of Malawi decided to separate the electrification process, such that extension of trunk transmission and distribution lines for cities and surrounding areas should be done by ESCOM, a privatized company, and rural electrification for rural and remote areas (by extension of distribution lines and utilization of renewable energy), should be entrusted to the Department of Energy, Ministry of Natural Resources and Environmental Affairs. The Government of Malawi then recognized the necessity of formulating a rural electrification master plan considering extension of existing distribution lines and using renewable energy.

Under these circumstances, the Government of Malawi requested the Government of Japan to conduct a study for a long-term rural electrification master plan, in May 2000, taking into account extension of distribution lines and utilization of renewable energy.

In response to this request, the Government of Japan sent a project formulation study team that investigated and studied the sites, and then dispatched a preliminary study team in March 2001. After these studies were completed, the results were analyzed and the scope of work to elaborate the Rural Electrification Master Plan was defined.

1.2 Objectives and Geographical Scope of the Master Plan Study

1.2.1 Objectives

The objectives of the Master Plan Study are:

- to formulate a long-term rural electrification master plan, to be completed by 2020,
- to propose organizational and methodological guidelines together with policy recommendations in order to implement and carry out a rural electrification program, and
- to transfer technology for the rural electrification plan to DOE as a counterpart, which will be the executing body to implement the master plan.

1.2.2 Geographical scope

The master plan study (M/P study) covers the whole country of Malawi but focuses on rural areas.

However, since a master plan for power system and operational development is in place, (that is a development plan for trunk line power systems until 2015 being carried out by Lahmeyer International and Knight Piesold funded by the World Bank), the present study will focus on unelectrified trading centers in rural areas. Since it will be difficult to survey all unelectrified trading centers throughout the country due to time constraints and limited human resources, the master plan is to be carried out based on a socio-economic survey of 54 unelectrified trading centers and 18 electrified trading centers.

1.2.3 Target year

Generally, hydropower plants have a durability of around 50 years and transmission and distribution facilities as well as solar home systems have a durability of around 20 to 25 years.

The study schedule is based on the Scope of Work and the Minutes of Meeting agreed on between JICA preliminary study team and DOE, dated 19 March 2001, with the target year for completion of the master plan study being 2020.

1.2.4 Scope of the M/P study

The M/P study is based on the Scope of Work and the Minutes of Meeting agreed between JICA preliminary study team and DOE, dated 19 March 2001.

The main study items are as follows:

(1) Present situation and future planning for ESCOM distribution lines

(2) Investigation of potential micro-hydro sites

(3) Field investigation

(4) Investigation of the present situation regarding power demand and supply, and study of low cost electrification technologies

(5) Economic and financial study

(6) Identification of appropriate electrification methods for each trading center

(7) Formulation of a rural electrification implementation plan

(8) Study of institutional structure for the execution of rural electrification, and policy recommendations on organizational and methodological guidelines for rural electrification implementation

(9) Preparation of a rural electrification manual

(10) Elaboration of case studies

(11) Formulation of a rural electrification master plan

CHAPTER 2 OUTLINE OF THE MASTER PLAN STUDY

Chapter 2 Outline of the Master Plan Study

2.1 Preparation Work in Japan

Existing reports and other relevant documents were collected and studied as part of preliminary research in Japan. The following objectives guided this research:

(1) Understanding the present socio-economic situation

(2) Analyzing the power demand, supply structure and present situation of the power sector by documentary survey

(3) Preparing the rural social investigation

(4) Studying the present situation of distribution facilities by documentary survey

(5) Developing a preliminary map study for possible potential micro hydropower sites

(6) Preparing a questionnaire for ESCOM, NGO (CHAM) and other related government institutions (including MNREA, DOE)

(7) Preparing and releasing of the inception report

2.2 First Field Survey

The following activities were included in the first field survey:

(1) Explanation and discussion of the inception report, confirmation of activities undertaken by DOE and JICA teams, preparation and confirmation of specifications of equipment required and signing of meeting minutes

(2) Consultation and discussion regarding field surveys and investigation regarding technology transfer for rural electrification through on-the-job training

(3) Identification of roles of related institutions within the Malawi Government in terms of reviewing the present status of energy policy, power policy, decentralization policy, the poverty reduction and strategy paper and the rural electrification bill, together with analysis of these strategies in the long term

(4) Collection of data and information regarding distribution facilities and planning, carried out by an ESCOM site engineer through interviews

33 and 11kV distribution lines have been constructed throughout the country, however, 400/230V lines have not been constructed due to difficulties such as capital contribution, high costs of indoor wiring, etc.

The Ready Board, a tool for dissemination of rural electrification, was implemented for low-income customers, and prepaid meters were introduced targeting high-income customers in order to avoid non-technical losses such as theft and unpaid power charges

(5) Investigation of potential micro hydropower sites

A total of 29 potential sites were investigated; three of them being identified in the northern region (approximate capacity between 5 and 75kW) and nine in the southern region (approximate capacity between 5 and 50kW), and a rural investigation was also conducted

(6) Collection of data and information regarding the existing power demand and supply, and the economic and financial situation of the electricity utility (ESCOM), in order to acquire an understanding of the present situation of the power sector in Malawi

(7) Finalizing and tendering of specifications for the socio-economic survey, evaluation of the proposal with DOE counterpart, and contract negotiation with the first tenderer but without reaching an agreement

The following office equipment was purchased for the first field survey:

(1) Desktop computers (with monitor and general software)	2sets
(2) Black and white laser printer	1set
(3) Inkjet color printer	1set
(4) Black and white copy machine (with auto sheet feeder)	1set
(5) Color image scanner	1set
(6) Crystalline overhead projector	1set
(7) Fax-telephone	1set
(8) Hub for Local Area Network	1set
(9) Mobile phone	3sets

2.3 Second Field Survey

The following activities were carried out during the second field survey:

(1) Contract negotiation with the first tenderer to carry out the socio-economic survey and agreement

(2) Progress monitoring of the socio-economic survey carried out by the local consultant

2.4 First Domestic Activities

Collected data, information and results from the first and second field surveys were reviewed and analyzed. The main topics covered during these first domestic activities are as follows:

(1) Study and analysis of collected data and identification of current problems

(2) Study and analysis of collected data obtained during socio-economic surveys in targeted trading centers

(3) Study and analysis of collected data regarding electrification by distribution line extension

(4) Preparation and establishment of a database for socio-economic survey

(5) Preparation of progress report

2.5 Third Field Survey

The following activities were carried out during the third field survey:

(1) Explanation and discussion of the progress report and confirmation of activities undertaken by DOE and JICA team

(2) Explanation and discussion of the criteria for electrification priority of unelectrified trading centers, and for the selection of the appropriate electrification method for each unelectrified trading center

(3) Collection of data and information for electrification implementation

(4) Investigation of unelectrified trading centers, potential micro-hydro sites and potential distribution extension sites as case study sites

(5) Confirmation of data and information collected during the socio-economic survey

2.6 Second Domestic Activities

Data, information and results from the first, second and third field surveys were reviewed and analyzed. The main topics addressed during these second domestic activities are as follows:

(1) Study and analysis of collected data and identification of current problems

(2) Power demand forecast for electrification of target trading centers based on data and information collected from the socio-economic survey

(3) Formulation of the criteria for electrification priority of unelectrified trading centers, and for the selection of the appropriate electrification method for each unelectrified trading center

(4) Review of the database for rural electrification

(5) Preparation of the first draft of the rural electrification plan

(6) Formulation of administrative reforms for the operation and maintenance of electrification facilities after installation

(7) Preparation of manuals for the implementation of electrification methods

2.7 Fourth Field Survey

The following activities were carried out during the fourth field survey:

(1) Explanation and discussion of the rural electrification plan (first draft)

(2) Explanation and discussion of administrative issues regarding the operation and maintenance of electrification facilities

(3) Discussion of workshop topics including invited countries, number of invited personnel, the agenda, schedule and demarcation

(4) Discussion of the collaboration between the JICA Master Plan Study and UNDP Projects

(5) Field investigation of the sites selected as candidates for case study
(6) Collection of data and information to be used for construction of facilities
(7) Explanation and discussion of the manuals for electrification methods

2.8 Third Domestic Activities

The following activities were carried out during the third domestic activities:

(1) Preparation of the interim report
(2) Preparation of the workshop that will be held during the fifth field survey
(3) Preparation of a case study implementation plan

2.9 Fifth Field Survey

The following activities were carried out during the fifth field survey:

(1) Explanation and discussion of the interim report
(2) Discussion of institutional organization, fund raising for rural electrification facilities after electrification
(3) Holding the workshop for the rural electrification
(4) Implementation of the case-study sites for electrification by grid extension and mini-grid system using micro-hydro power
(5) Collection of additional data and information for electrification cost
(6) Discussion of the collaboration between the JICA Master Plan Study and UNDP Projects
(7) Discussion of the collaboration between the JICA Master Plan Study and WORLD BANK Projects

2.10 Fourth Domestic Activities

The following activities were carried out during the fourth domestic activities:

(1) Preparation of the draft final report
(2) Preparation of workshop proceedings
(3) Preparation of the case study report

2.11 Sixth Field Survey

The following activities were carried out during the sixth field survey:

(1) Explanation and discussion of the draft final report
(2) Explanation and discussion of the case study report
(3) Discussion of the collaboration between the JICA Master Plan Study and UNDP Projects
(4) Discussion of the collaboration between the JICA Master Plan Study and WORLD BANK Projects

2.12 Member of the M/P Study Team

The institution and related main person in Malawi are shown below:

(1) Malawi

- MNREA (Ministry of Natural Resources and Environmental Affairs)
  Mr. George C. Mkondiwa, Principle Secretary
- DOE (Department of Energy Affairs)
  Dr. C. R. Kafumba, Director of Energy affairs
  Mr. Hurry W. Chitenje, Deputy Director of Energy affairs
  Mr. Muhango, Head of Planning Division, DOE
  Mr. G. G. Nyirongo, MAREP Secretariat Manager
  Mr. Diliza W. Nyasulu, MAREP Head of Technical Services
  Mr. Paul M. Mphwiyo, MAREP Head of Economical Services
  Mr. Lunggu, Senior Energy Officer
  Mr. Silema, Energy Officer
  Mr. Sambani, Energy Officer
  Mr. Mayuni, Energy Officer
  Mr. Muheka, Energy Officer
  Ms. Mbano, Energy Officer
  Mr. Phiri, Energy Officer
- JICA Expert
  Mr. Toshiyuki Hayashi, Rural Electrification Adviser, DOE
  Mr. Yasuhiro Kawakami, Rural Electrification Advisor, DOE
- MLG (Ministry of Local Government)
  Mr. Masawani Jere, Senior Local Government Officer
- ESCOM (Electricity Supply Corporation of Malawi LTD.)
  Mr. Douwe van Wyk, Chief Executive Officer
  Dr. Allexon A Chiwaya, Deputy Chief Executive Officer
  Mr. Brian Erasmus, Director of Engineering
  Mr. Dave Malherbe, Director of Commerce
  Mr. Trensio W Chisale, Director of Distribution and Customer Services
  Mr. H Machewere, Deputy Manager Projects
- WB (World Bank)
  Ms. Paivi Koljonen, Senior Energy Economist, Energy Team, African Region
  Ms. Yuriko Sakairi, Senior Energy Economist, Energy Team, African Region
  Ms. Christine E Kimes, Senior Operations Officer, Malawi office

- UNDP (United Nation Development Program)
  Mr. Martin Krause, GEF Regional Coordinator for Southern Africa
  Ms. Etta M'mangiso, Senior Operations Officer
- DANIDA
  Mr. Peter Melchiro Roedder, Project Manager/Team leader

(2) Japan

The Master Plan Study Team consists of the following members:

- M/P Study Team

Takahisa MURATA	Team leader/Rural electrification planning
Masayasu ISHIGURO	Power policy and institutional Issues
Akira YAMAZAKI	Distribution planning
Katsuo ONUKI	Distribution facility
Takashi SUZUKI	Micro-hydro generation planing A
Hiroshi WATABE	Micro-hydro generation planing B
Hiroo YAMAGATA	Energy and power economics
Tomoyuki YAMASHITA	Socio-economic survey/Demand need
Hiroyuki SUKEGAWA	Renewable energy utility/Database development

- Japan International Cooperation Agency (JICA Head Office)

Yoshiki EHARA	Administration
Masami KIDO	Administration

CHAPTER 3 GENERAL SITUATIONS OF MALAWI

Chapter 3 General Situations of Malawi

3.1 Population

A population and housing census has been executed once a decade since 1901 in Malawi (refer to Fig. 3-1-1). According to the latest census result, total population and annual growth rate are 9.93 million and 2.0 percent respectively as of 1998. Population distribution, ratio to the total population, and annual growth rate in each region of the country (Northern, Central and Southern) are summarized in Table 3-1-1. It is presumed that repatriation of Mozambican war refugees in the 1990s (who fled during the 1980s to districts that lie along the border with Mozambique in the Southern Region and others in the Central Region, such as Ntcheu and Dedza Districts) is a reason for the slow annual population growth rate in these districts. The spread of AIDS is also one of the reasons for the slow population growth rate in the whole country.

Only 14 percent of the population live in the urban areas, with 11 percent of the total population being concentrated in the capital city Lilongwe and three other major cities; Zomba, Blantyre, and Mzuzu. Based on the fact that the urban population in Malawi had grown from 850 thousand in 1987 to 1.4 million in 1998 by 4.7 percent per annum (which is more than double national growth rate of 2.0 percent), a substantial percentage of the population is expected to move from rural to urban areas. This will apply particularly to the capital city and three other major cities, with annual growth rates being 6.1% in Lilongwe, 3.6% in Zomba, 3.3% in Blantyre, and 6.2% in Mzuzu respectively.

Population density at regional level reveals that the Northern Region is the smallest with 46 people/km^2, while the Southern Region is the biggest with 146 people/km^2. In the Central Region, it is 114 people/km^2, as shown in Table 3-1-2. At district level, Likoma with 449 people/km^2 and Blantyre with 402 people/km^2 are the most densely populated.

The sex ratio results indicate that about 51 percent of the total population in 1998 were females and 49 percent were males. The age group composition, shown in Table 3-1-3, indicates typical characteristics of “birth many and die young” in a developing country: infants aged less than one and under-five children occupy 4 percent and 16.7 percent respectively, while only 4 percent survive to 65 years and older. Average life expectancies are 45.51 years for males and 46.75 years for females.

3.2 Race, Language and Religion

About 99 percent of the total population in Malawi are Malawians. The others are minorities, such as Mozambicans, Zimbabweans, Zambians, Tanzanians, South Africans, Indians and so on, each contributing less than 0.3 percent of the total population. Malawians are multi-ethnic and consist of five major tribes: Chewa and Lomwe in the Central and Southern Regions, Ngoni in the Central and Northern Regions, and Thumbuka and Nkhonde in the Northern Region.

Regarding languages, around 57 percent of the total population use Chichewa as their primary language at home, as shown in Table 3-2-1. The other languages commonly used for communication are Chinyanja (13 percent), Chiyao (10 percent), and Chitumbuka (9 percent). A reason for the popularity of Chichewa is that more than 90 percent of residents in the Central Region (which occupies 40 percent of national population), use this language. In the Northern Region, Chitumbuka is the most widely used language, while Chinyahja and Chiyao speakers reach 45 percent in the Southern Region. Thus, regional characteristics are significant for language use in Malawi. The official languages are Chichewa and English, which are taught from Primary School.

Religious statistics shown in Table 3-2-2 indicate that Christians form the majority in all regions, totaling about 80 percent of the national population. Muslims represent 12.8 percent of the population, being concentrated in the Southern Region. There are also some traditional religions engaged by a minority of the population.

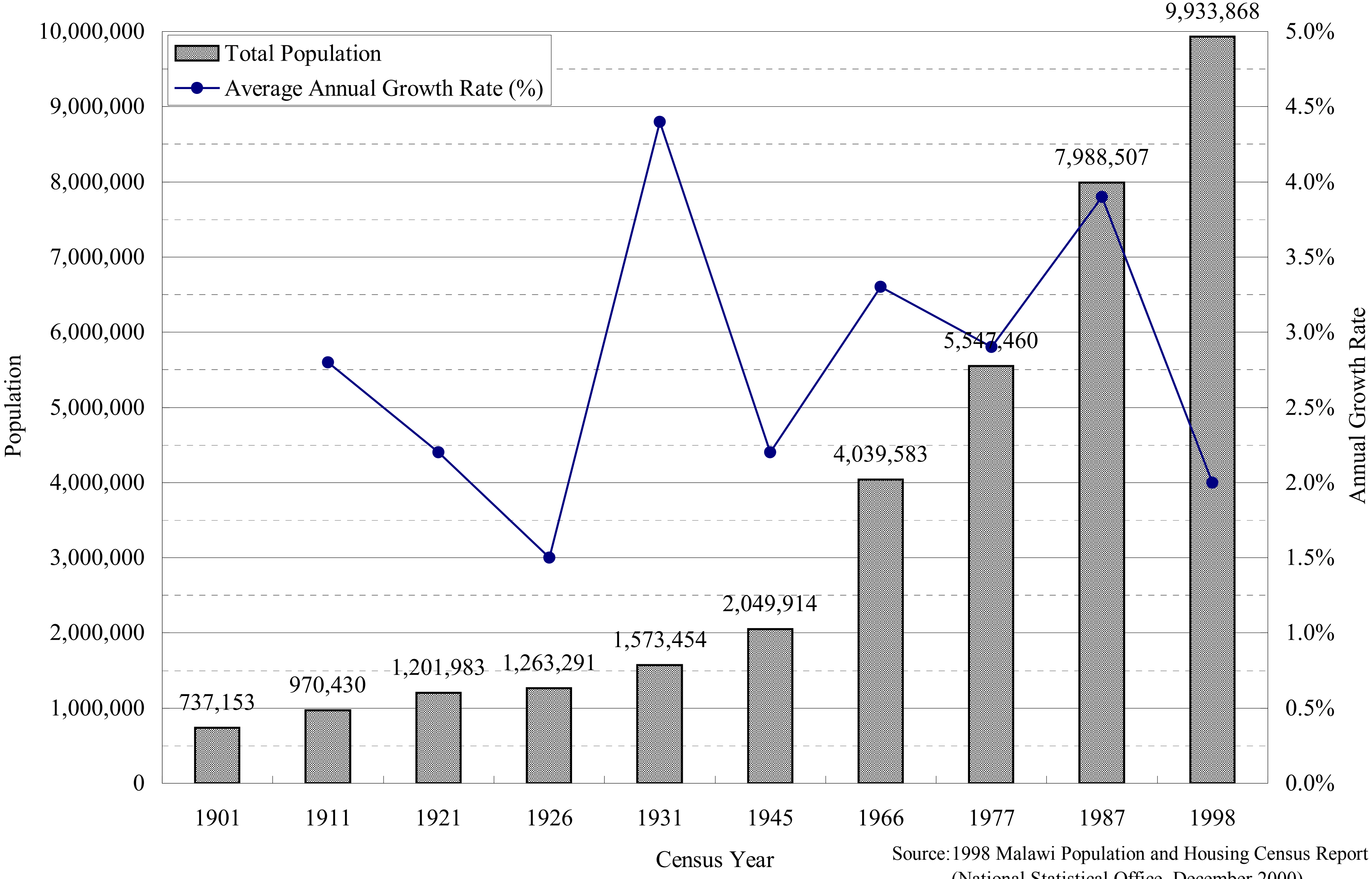
3.3 Fertility and Mortality

Crude Birth Rate (CBR), which is defined as the number of births that occurred in the 12-month period prior to the census per 1,000 people, is about 33.8 and 38.6 in urban and rural areas respectively. The national CBR averages 37.9. At a regional level, the lowest CBR is in the Southern Region (36.1), followed by the Northern Region (37.1), with the highest being in the Central Region (40.1).

Total Fertility Rate (TFR), which is defined as the number of births a woman will have if she survives to the end of her childbearing age, usually 50, is 3.7 and 5.0 in urban and rural areas respectively. The national TFR averages 4.8. At a regional level, the Central Region maintains the highest TFR (5.3) and the Southern Region the lowest (4.5). TFR for the Northern Region is 4.8.

On the other hand, the national Crude Death Rate (CDR), which is defined as the number of deaths that occurred in the 12 month period prior to the census per 1,000 people, is about 21.1. In addition, regional variations of under-five mortality (per 1,000 people) are 17.8, 18.6 and 24.3 in the Northern, the Central and the Southern Region respectively. The Infant Mortality Rate (IMR), the total number of deaths among birth aged under one year old that occurred in the 12 month period prior to the census per 1,000 people, is still high at 121, although it is expected to decline.

Fig. 3-1-1 Population and Annual Growth Rate: 1901 - 1998 Census



Source:1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

Table 3-1-1 Population Distribution and Annual Growth Rate by Region/District

Region	District	1987		1998		Annual Growth Rate
		Population	(Ratio)	Population	(Ratio)	
Malawi		**7,988,507**	**(100.0%)**	**9,933,868**	**(100.0%)**	**2.0%**
Northern		**911,787**	**(11.4%)**	**1,233,560**	**(12.4%)**	**2.7%**
	Chitipa	96,794	(1.2%)	126,799	(1.3%)	2.5%
	karonga	148,014	(1.9%)	194,572	(2.0%)	2.5%
	Nkhata Bay	130,189	(1.6%)	164,761	(1.7%)	2.1%
	Rumphi	94,902	(1.2%)	128,360	(1.3%)	2.7%
	Mzimba	433,696	(5.4%)	610,994	(6.2%)	3.1%
	Likoma	8,192	(0.1%)	8,074	(0.1%)	-0.1%
Central		**3,110,986**	**(38.9%)**	**4,066,340**	**(40.9%)**	**2.4%**
	Kasungu	323,453	(4.0%)	480,659	(4.8%)	3.6%
	Nkhotakota	158,044	(2.0%)	229,460	(2.3%)	3.4%
	Ntchisi	120,860	(1.5%)	167,880	(1.7%)	3.0%
	Dowa	322,432	(4.0%)	411,387	(4.1%)	2.2%
	Salima	189,173	(2.4%)	248,214	(2.5%)	2.5%
	Lilongwe	976,627	(12.2%)	1,346,360	(13.6%)	2.9%
	Mchinji	249,843	(3.1%)	324,941	(3.3%)	2.4%
	Dedza	411,787	(5.2%)	486,682	(4.9%)	1.5%
	Ntcheu	358,767	(4.5%)	370,757	(3.7%)	0.3%
Southern		**3,965,734**	**(49.6%)**	**4,633,968**	**(46.6%)**	**1.4%**
	Mangochi	496,578	(6.2%)	610,239	(6.1%)	1.9%
	Machinga	301,849	(3.8%)	369,614	(3.7%)	1.8%
	Zomba	441,615	(5.5%)	546,661	(5.5%)	1.9%
	Chiradzulu	210,912	(2.6%)	236,050	(2.4%)	1.0%
	Blantyre	589,525	(7.4%)	809,397	(8.1%)	2.9%
	Mwanza	121,513	(1.5%)	138,015	(1.4%)	1.2%
	Thyolo	431,157	(5.4%)	458,976	(4.6%)	0.6%
	Mulanje	419,928	(5.3%)	428,322	(4.3%)	0.2%
	Phalombe	218,134	(2.7%)	231,990	(2.3%)	0.6%
	Chikwawa	316,733	(4.0%)	356,682	(3.6%)	1.1%
	Nsanje	204,374	(2.6%)	194,924	(2.0%)	-0.4%
	Balaka	213,416	(2.7%)	253,098	(2.5%)	1.6%

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

Table 3-1-2 Population Density by Region/District

Region	District	Land Area [Km^2]	(Ratio)	1998 Population	(Ratio)	Density [$Person/Km^2$]
Malawi		**94,276**	**(100.0%)**	**9,933,868**	**(100.0%)**	**105**
Northern		**26,931**	**(28.6%)**	**1,233,560**	**(12.4%)**	**46**
	Chitipa	4,288	(4.55%)	126,799	(1.3%)	30
	karonga	3,355	(3.56%)	194,572	(2.0%)	58
	Nkhata Bay	4,071	(4.32%)	164,761	(1.7%)	40
	Rumphi	4,769	(5.06%)	128,360	(1.3%)	27
	Mzimba	10,430	(11.06%)	610,994	(6.2%)	59
	Likoma	18	(0.02%)	8,074	(0.1%)	449
Central		**35,592**	**(37.8%)**	**4,066,340**	**(40.9%)**	**114**
	Kasungu	7,878	(8.36%)	480,659	(4.8%)	61
	Nkhotakota	4,259	(4.52%)	229,460	(2.3%)	54
	Ntchisi	1,655	(1.76%)	167,880	(1.7%)	101
	Dowa	3,041	(3.23%)	411,387	(4.1%)	135
	Salima	2,196	(2.33%)	248,214	(2.5%)	113
	Lilongwe	6,159	(6.53%)	1,346,360	(13.6%)	219
	Mchinji	3,356	(3.56%)	324,941	(3.3%)	97
	Dedza	3,624	(3.84%)	486,682	(4.9%)	134
	Ntcheu	3,424	(3.63%)	370,757	(3.7%)	108
Southern		**31,753**	**(33.7%)**	**4,633,968**	**(46.6%)**	**146**
	Mangochi	6,273	(6.65%)	610,239	(6.1%)	97
	Machinga	3,771	(4.00%)	369,614	(3.7%)	98
	Zomba	2,580	(2.74%)	546,661	(5.5%)	212
	Chiradzulu	767	(0.81%)	236,050	(2.4%)	308
	Blantyre	2,012	(2.13%)	809,397	(8.1%)	402
	Mwanza	2,295	(2.43%)	138,015	(1.4%)	60
	Thyolo	1,715	(1.82%)	458,976	(4.6%)	268
	Mulanje	2,056	(2.18%)	428,322	(4.3%)	208
	Phalombe	1,394	(1.48%)	231,990	(2.3%)	166
	Chikwawa	4,755	(5.04%)	356,682	(3.6%)	75
	Nsanje	1,942	(2.06%)	194,924	(2.0%)	100
	Balaka	2,193	(2.33%)	253,098	(2.5%)	115

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

Table 3-1-3 Population Distribution by Age Group

Country	Total Population	Age Group (Years Old)					Average Life Expectancy (Years Old)	
		Under 1	1 - 4	5 - 14	15 - 64	65 and Over	Male	Female
Malawi	9,933,868 100.0%	368,325 3.7%	1,292,065 13.0%	2,672,870 26.9%	5,206,150 52.4%	394,458 4.0%	43.51	46.75
Japan	125,570,000 100.0%	5,901,790 4.7%		13,184,850 10.5%	86,392,160 68.8%	20,091,200 16.0%	76.4	82.9

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

Table 3-2-1 Utilizing Language by Population Ratio in Each Region

Region	Language					Total
	Chichewa	Chinyanja	Chiyao	Chitumbuka	Chitonga	
Malawi	57%	13%	10%	9%	-	89%
Northern	5%	-	-	65%	11%	81%
Central	91%	-	3%	3%	-	97%
Southern	42%	26%	19%	-	-	87%

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

Table 3-2-2 Population by Religion in Each Region

Region	Religion				Total
	Christian	Islam	Other	No Religion	
Malawi	7,933,773 79.9%	1,272,429 12.8%	304,961 3.1%	422,705 4.3%	9,933,868 100.0%
Northern	1,187,779 96.3%	17,684 1.4%	18,754 1.5%	9,343 0.8%	1,233,560 100.0%
Central	3,388,408 83.3%	283,964 7.0%	110,609 2.7%	283,359 7.0%	4,066,340 100.0%
Southern	3,357,586 72.5%	970,781 20.9%	175,598 3.8%	130,003 2.8%	4,633,968 100.0%

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

3.4 Education and Literacy

The education system in Malawi consists of three levels of schooling: Primary, Secondary and Tertiary School. Primary School is divided into Junior Form, grades one to four, and Senior Form, grades five to eight. Secondary School encompasses grades nine to twelve. University, Technical School, and Teacher Development Centers are considered to be Tertiary institutions.

Recently, two kinds of Secondary School have been established: traditional schools equipped with dormitories and those upgraded from Community Day Secondary Schools, which have mainly been in charge of correspondence courses, to improve school attendance and literacy rate based on the official VISION 2020 program. The Cluster School System, which groups 10 to 15 Secondary Schools in an area together, has been introduced recently. A Cluster Leading School (Cluster Head School) is selected in each group and is given priority for provision of equipment.

As shown in Table 3-4-1, 30 percent of the 8.3 million persons aged 5 years or older have never attended school, although the enrolment rate has doubles or tripled during the 1990s following a national policy to provide a partial tuition free system for Primary School. In spite of the fact that more than 60 percent of persons aged 5 years or older enroll in Primary School, the percentage of students who go on to higher stages of education decreases sharply: 8.1 percent for Secondary School and 0.3 percent at University level. This situation is a direct result of the education system that certifies only those who have passed the national examination for school graduation. In fact, those who have either never received certification or never attended a school, account for 88 percent of the total population aged 5 years or older. Graduating from school without receiving certification is very common in Malawi. Thus, university graduates with certification are merely 0.2 percent. There are no differentials in the enrolment rate between male and female for primary school. As the education level becomes higher, however, the enrolment rate for females becomes less than half of that for males. At a regional level, the Northern Region experiences higher rates of both enrolment and graduation with certification.

As shown in Table 3-4-2, 4.8 million (or 58 percent) of persons aged 5 years or older are literate in at least one language. The literacy rate was 42 percent in the previous census conducted in 1987, having raised by 16 percent in 10 years. The national literacy rate is better for males than females. At a regional level, the highest literacy rate (at 72 percent) is experienced in the Northern Region, compared to 55 percent and 57 percent in the Central and the Southern Regions respectively. This seems to correlate with relatively high enrolment rates for schools in the Northern Region. A marked variation in literacy rates exists between rural and urban populations, since 80 percent of the urban population aged 5 years or older are literate as opposed to 54 percent in the rural area.

Table 3-4-1 Population Aged 5 Years and Over by Highest Education Attended

		Total (Male & Female)						Male						Female					
		Person 5 years and Over	Never Attended	Attended			Not Certified	Person 5 years and Over	Never Attended	Attended			Not Certified	Person 5 years and Over	Never Attended	Attended			Not Certified
				Primary	Secondary	University				Primary	Secondary	University				Primary	Secondary	University	
Malawi	Urban	1,220,388	149,341	754,946	297,240	18,861	825,106	635,279	58,947	377,932	184,616	13,784	387,408	585,109	90,394	377,014	112,624	5,077	437,698
		100.0%	12.2%	61.9%	24.4%	1.5%	67.6%	100.0%	9.3%	59.5%	29.1%	2.2%	61.0%	100.0%	15.4%	64.4%	19.2%	0.9%	74.8%
	Rural	7,053,090	2,538,690	4,131,409	374,266	8,725	6,448,249	3,408,659	995,406	2,149,558	257,655	6,040	2,998,364	3,644,431	1,543,284	1,981,851	116,611	2,685	3,449,885
		100.0%	36.0%	58.6%	5.3%	0.1%	91.4%	100.0%	29.2%	63.1%	7.6%	0.2%	88.0%	100.0%	42.3%	54.4%	3.2%	0.1%	94.7%
	Total	8,273,478	2,688,031	4,886,355	671,506	27,586	7,273,355	4,043,938	1,054,353	2,527,490	442,271	19,824	3,385,772	4,229,540	1,633,678	2,358,865	229,235	7,762	3,887,583
		100.0%	32.5%	59.1%	8.1%	0.3%	87.9%	100.0%	26.1%	62.5%	10.9%	0.5%	83.7%	100.0%	38.6%	55.8%	5.4%	0.2%	91.9%
Northern	Urban	134,588	10,322	86,639	36,244	1,383	84,100	67,588	4,021	39,905	22,584	1,078	36,946	67,000	6,301	46,734	13,660	305	47,154
		100.0%	7.7%	64.4%	26.9%	1.0%	62.5%	100.0%	5.9%	59.0%	33.4%	1.6%	54.7%	100.0%	9.4%	69.8%	20.4%	0.5%	70.4%
	Rural	889,892	151,833	660,511	76,573	975	742,304	429,926	55,674	320,893	52,565	794	335,463	459,966	96,159	339,618	24,008	181	406,841
		100.0%	17.1%	74.2%	8.6%	0.1%	83.4%	100.0%	12.9%	74.6%	12.2%	0.2%	78.0%	100.0%	20.9%	73.8%	5.2%	0.0%	88.5%
	Total	1,024,480	162,155	747,150	112,817	2,358	826,404	497,514	59,695	360,798	75,149	1,872	372,409	526,966	102,460	386,352	37,668	486	453,995
		100.0%	15.8%	72.9%	11.0%	0.2%	80.7%	100.0%	12.0%	72.5%	15.1%	0.4%	74.9%	100.0%	19.4%	73.3%	7.1%	0.1%	86.2%
Central	Urban	478,359	62,448	301,465	107,603	6,843	335,813	251,237	24,814	154,613	66,798	5,012	161,169	227,122	37,634	146,852	40,805	1,831	174,644
		100.0%	13.1%	63.0%	22.5%	1.4%	70.2%	100.0%	9.9%	61.5%	26.6%	2.0%	64.2%	100.0%	16.6%	64.7%	18.0%	0.8%	76.9%
	Rural	2,879,891	1,056,570	1,686,659	133,320	3,342	2,664,673	1,412,951	432,595	886,361	91,766	2,229	1,263,756	1,466,940	623,975	800,298	41,554	1,113	1,400,917
		100.0%	36.7%	58.6%	4.6%	0.1%	92.5%	100.0%	30.6%	62.7%	6.5%	0.2%	89.4%	100.0%	42.5%	54.6%	2.8%	0.1%	95.5%
	Total	3,358,250	1,119,018	1,988,124	240,923	10,185	3,000,486	1,664,188	457,409	1,040,974	158,564	7,241	1,424,925	1,694,062	661,609	947,150	82,359	2,944	1,575,561
		100.0%	33.3%	59.2%	7.2%	0.3%	89.3%	100.0%	27.5%	62.6%	9.5%	0.4%	85.6%	100.0%	39.1%	55.9%	4.9%	0.2%	93.0%
Southern	Urban	607,441	76,571	366,842	153,393	10,635	405,193	316,454	30,112	183,414	95,234	7,694	189,293	290,987	46,459	183,428	58,159	2,941	215,900
		100.0%	12.6%	60.4%	25.3%	1.8%	66.7%	100.0%	9.5%	58.0%	30.1%	2.4%	59.8%	100.0%	16.0%	63.0%	20.0%	1.0%	74.2%
	Rural	3,283,307	1,330,287	1,784,239	164,373	4,408	3,041,272	1,565,782	507,137	942,304	113,324	3,017	1,399,145	1,717,525	823,150	841,935	51,049	1,391	1,642,127
		100.0%	40.5%	54.3%	5.0%	0.1%	92.6%	100.0%	32.4%	60.2%	7.2%	0.2%	89.4%	100.0%	47.9%	49.0%	3.0%	0.1%	95.6%
	Total	3,890,748	1,406,858	2,151,081	317,766	15,043	3,446,465	1,882,236	537,249	1,125,718	208,558	10,711	1,588,438	2,008,512	869,609	1,025,363	109,208	4,332	1,858,027
		100.0%	36.2%	55.3%	8.2%	0.4%	88.6%	100.0%	28.5%	59.8%	11.1%	0.6%	84.4%	100.0%	43.3%	51.1%	5.4%	0.2%	92.5%

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

Table 3-4-2 Population Aged 5 Years and Over by Literacy Status

		Total (Male & Female)			**Male**			**Female**		
		Literate	Illiterate	Person 5 years and Over	Literate	Illiterate	Person 5 years and Over	Literate	Illiterate	Person 5 years and Over
Malawi	Urban	968,594	251,794	1,220,388	529,342	105,937	635,279	439,252	145,857	585,109
		79.4%	20.6%	100.0%	83.3%	16.7%	100.0%	75.1%	24.9%	100.0%
	Rural	3,796,426	3,256,664	7,053,090	2,078,943	1,329,716	3,408,659	1,717,483	1,926,948	3,644,431
		53.8%	46.2%	100.0%	61.0%	39.0%	100.0%	47.1%	52.9%	100.0%
	Total	4,765,020	3,508,458	8,273,478	2,608,285	1,435,653	4,043,938	2,156,735	2,072,805	4,229,540
		57.6%	42.4%	100.0%	64.5%	35.5%	100.0%	51.0%	49.0%	100.0%
Northern	Urban	112,292	22,296	134,588	57,869	9,719	67,588	54,423	12,577	67,000
		83.4%	16.6%	100.0%	85.6%	14.4%	100.0%	81.2%	18.8%	100.0%
	Rural	622,673	267,219	889,892	318,640	111,286	429,926	304,033	155,933	459,966
		70.0%	30.0%	100.0%	74.1%	25.9%	100.0%	66.1%	33.9%	100.0%
	Total	734,965	289,515	1,024,480	376,509	121,005	497,514	358,456	168,510	526,966
		71.7%	28.3%	100.0%	75.7%	24.3%	100.0%	68.0%	32.0%	100.0%
Central	Urban	369,450	108,909	478,359	205,124	46,113	251,237	164,326	62,796	227,122
		77.2%	22.8%	100.0%	81.6%	18.4%	100.0%	72.4%	27.6%	100.0%
	Rural	1,462,400	1,417,491	2,879,891	815,665	597,286	1,412,951	646,735	820,205	1,466,940
		50.8%	49.2%	100.0%	57.7%	42.3%	100.0%	44.1%	55.9%	100.0%
	Total	1,831,850	1,526,400	3,358,250	1,020,789	643,399	1,664,188	811,061	883,001	1,694,062
		54.5%	45.5%	100.0%	61.3%	38.7%	100.0%	47.9%	52.1%	100.0%
Southern	Urban	486,852	120,589	607,441	266,349	50,105	316,454	220,503	70,484	290,987
		80.1%	19.9%	100.0%	84.2%	15.8%	100.0%	75.8%	24.2%	100.0%
	Rural	1,711,353	1,571,954	3,283,307	944,638	621,144	1,565,782	766,715	950,810	1,717,525
		52.1%	47.9%	100.0%	60.3%	39.7%	100.0%	44.6%	55.4%	100.0%
	Total	2,198,205	1,692,543	3,890,748	1,210,987	671,249	1,882,236	987,218	1,021,294	2,008,512
		56.5%	43.5%	100.0%	64.3%	35.7%	100.0%	49.2%	50.8%	100.0%

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

3.5 Poverty and Living Standards

Of the 9.9 million households in the nation, 6.5 million, equivalent to 66 percent, lived in traditional dwelling units that had thatched roofs with mud walls, or walls made of mud and wattle. About 1.6 million (16 percent) lived in structures that had roofs constructed with iron sheets, tiles, concrete or asbestos and walls made of burnt bricks, concrete or stones. The number of residents in own dwelling totals 8.5 million, which is equivalent to 86 percent. The number of households had increased by 13.6 percent from 1987 to 1998, with an average annual growth rate of 1.27 percent. On average, a household consists of approximately 4.3 persons, as indicated in Table 3-5-1.

Estimated per capita income was US$ 220 in 1999 in Malawi. Compared with the average daily expenditure of MK11.16 per person, the poverty line, which distinguishes poor households from non-poor households, rests at a daily consumption of MK 10.47 per person that is determined by the costs required to acquire recommended daily calories intake (US$1 = MK 25.4 as of April 1998). The poverty headcount estimates in Table 3-5-2 show that 65.3 percent of population and 56.6 percent of households were living in poverty in 1998. Rural areas contain 90 percent of the total population with 91 percent of the total poor living in rural Malawi in 1988. Differentials between urban and rural areas have also been notes: the poverty line is MK11.16/person, MK9.27/person, and MK7.76/person for rural areas in the Northern, the Central and the Southern respectively, settling at MK25.38/person in urban areas. For the poor in rural areas, food consumption exceeds 80 percent of total daily expenditure. In addition, 28.7 percent of the total population being in the ultra poverty, which is 60 percent of the daily consumption of those living on the poverty line.

3.6 Administrative Organization and Local Social Structure

Administrative organization of Malawi consists of three governmental levels: central government, local government and traditional authority. The central government consists of ministries under a president’s administration. These are Finance and Economic Planning (MOF), Health and Population (MOHP), Education, Science and Technology (MOE), Local Government (MLG), Natural Resources and Environmental Affairs (MONREA) and Agriculture and Irrigation (MAI). The president is the head of the administrative organization and appoints cabinet members. The local government is divided into three Regions, Northern, Central and Southern, and these Regions are subdivided into Districts. The whole nation consists of 27 Districts: 6 in the Northern, 9 in the Central and 12 in the Southern Region (Refer to Fig. 3-6-1). Regional executive officials and District Commissioners are appointed in each Region and District as local government administrators, under the jurisdiction of the Ministry of Local Government in the central government.

Table 3-5-1 Number of Households and Average Number of Persons per Household

Region	District	Household Population	Number of Households	Annual Increase Rate	Average Number of Persons per Household
Malawi		**9,883,222**	**2,273,846**	**1.27%**	**4.3**
Northern		**1,227,658**	**243,060**	**1.32%**	**5.1**
	Chitipa	126,097	25,748	1.33%	4.9
	karonga	193,710	39,880	1.36%	4.9
	Nkhata Bay	163,658	33,374	1.29%	4.9
	Rumphi	127,509	25,353	1.32%	5.0
	Mzimba	608,744	117,178	1.31%	5.2
	Likoma	7,940	1,527	-1.00%	5.2
Central		**4,049,971**	**908,942**	**1.32%**	**4.5**
	Kasungu	478,500	96,787	1.34%	4.9
	Nkhotakota	228,685	50,031	1.32%	4.6
	Ntchisi	167,167	35,947	1.35%	4.7
	Dowa	410,065	90,379	1.32%	4.5
	Salima	247,320	58,491	1.31%	4.2
	Lilongwe	1,339,236	307,941	1.35%	4.3
	Mchinji	324,098	70,792	1.31%	4.6
	Dedza	485,326	113,544	1.29%	4.3
	Ntcheu	369,574	85,030	1.15%	4.3
Southern		**4,605,593**	**1,121,844**	**1.17%**	**4.1**
	Mangochi	607,016	151,316	1.31%	4.0
	Machinga	366,993	90,138	-1.40%	4.1
	Zomba	540,352	135,369	1.31%	4.0
	Chiradzulu	234,819	58,529	1.28%	4.0
	Blantyre	802,650	195,792	1.35%	4.1
	Mwanza	137,311	32,177	1.25%	4.3
	Thyolo	457,280	112,136	1.22%	4.1
	Mulanje	426,642	103,973	-1.42%	4.1
	Phalombe	231,385	59,292	1.24%	3.9
	Chikwawa	354,884	79,074	1.25%	4.5
	Nsanje	193,713	43,491	-1.20%	4.5
	Balaka	252,548	60,557	1.28%	4.2

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

Table 3-5-2 Poverty and Ultra-Poverty Lines

Region	Mean Consumption (MK/person/day)	Poverty Line (MK/day)	Food Share of Poverty Line (%)	Poverty Headcount (% of population)	Poverty Headcount (% of Households)	Ultra Poverty Line (MK/day)
Malawi	**11.16**	**10.47**	**-**	**65.3%**	**56.6%**	**6.28**
Northern Rural	-	11.16	79.7%	-	-	6.69
Central Rural	-	9.27	83.7%	-	-	5.56
Southern Rural	-	7.76	84.1%	-	-	4.65
Rural	10.44	-	-	66.5%	57.8%	-
Urban	17.44	25.38	66.8%	54.9%	46.9%	15.23

Source: Profile of Poverty in Malawi, 1998
(National Economic Council, November 2000)

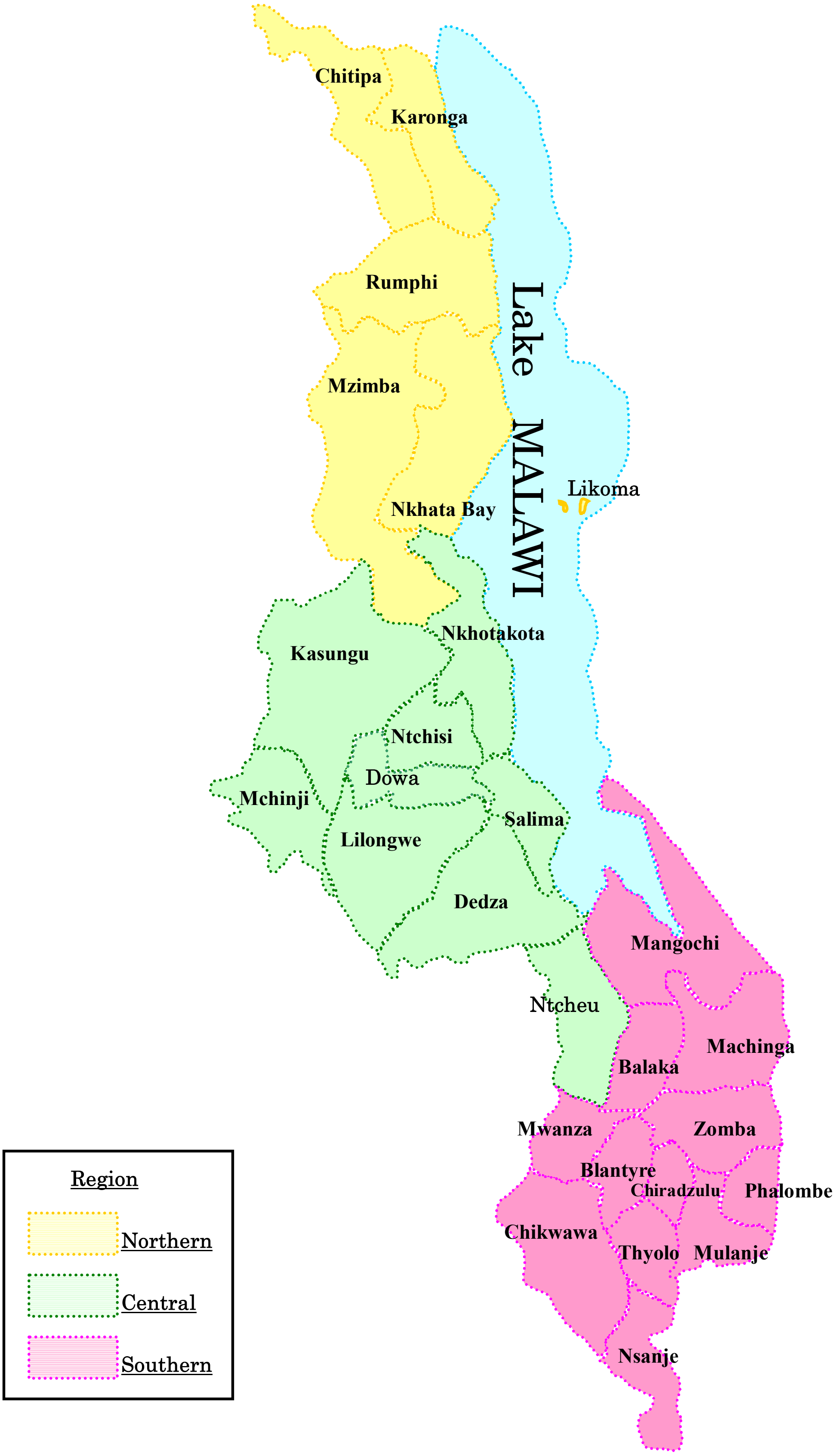


Fig. 3-6-1 Malawi District/Region Map

The nation consists of 345 Traditional Authorities (TA), which are subdivisions of Districts and are governed by traditional chiefs. Although traditional leadership is dependent on family heritage, governmental approval is required at present. Traditional leaders, who are connected with the central government, function as officials working mainly in the areas of tax collection, dispute arbitration, and so on.

Politics, economy and research & development are active in the Capital and three major cities: Lilongwe, Mzuzu, Zomba, and Blantyre. District Centers, where an Assembly Office is located in each District administrated by the Ministry of Local Government, are next to cities in scale. Rural Growth Centers, established with financial support from Germany, aim to prevent population outflow from rural areas, and are generally smaller than District Centers. Centers of daily life with activities for rural residents are Trading Centers (TC), where residents in neighboring villages sell their crops/products for cash, and/or purchase miscellaneous goods at grocery shops. Public facilities, such as schools, hospitals, clinics and so on, also tend to be located in Trading Centers.

3.7 Economic Activity

Malawi is the one of the countries categorized as LLDC (Least among Less Developed Countries) with a personal GNP (Gross National Product) of US$180 in 1996. The landlocked country is densely populated with minimal natural resources. Industrial development is difficult because of the small domestic market, in addition to expensive transportation costs for both materials and products typical for a landlocked country. The economy depends on agriculture. 40 percent of the GDP (Gross Domestic Product) is produced by the agricultural sector, and about 80 percent of validated exports consist of tobacco (63.6%), sugar (7.6%) and tea (6.7%). The crop is dependent on the weather and the GDP is easily influenced by natural calamities such as droughts and floods. The international balance of payments is also influenced by fluctuation of tobacco and tea prices on the international market, thereby critically impacting the country's economy.

Of the 6.8 million persons aged 10 years or older, 4.5 million, equivalent to 66 percent, are economically active, as shown in Table 3-7-1. Of the economically active population, about 3.7 million (83 percent) work in the Agriculture, Animal Husbandry or Forest Sectors, while only around 7,000 (0.2 percent) work in the Administrative and Managerial Sector. 78 percent are self-sufficient farmers and only 13 percent are employers. The proportion of the economically active population living in urban areas is 44 percent, with 69 percent in rural areas. At a regional level, the proportion of economically active populations in the Northern, Central and Southern Regions are 57.4, 67.6 and 66.9 percent respectively. The differential between male and female is significant in urban areas: the proportion of the economically active population is 60 percent for males but only 25 percent for females. In rural areas, this figure reaches about 70 percent for both males and females, with the rate for females being slightly higher than for males.

Table 3-7-1 Population Aged 10 Years and Over by Economic Activity Status

		Working	Unemployment	Economically Active	Not Economically Active	Person 10 years and Over
Malawi	Urban	456,084	25,718	481,802	554,662	1,036,464
		44.0%	2.5%	46.5%	53.5%	100.0%
	Rural	4,002,845	24,643	4,027,488	1,769,156	5,796,644
		69.1%	0.4%	69.5%	30.5%	100.0%
	Total	4,458,929	50,361	4,509,290	2,323,818	6,833,108
		65.3%	0.7%	66.0%	34.0%	100.0%
Northern	Urban	44,407	3,075	47,482	65,548	113,030
		39.3%	2.7%	42.0%	58.0%	100.0%
	Rural	431,808	3,247	435,055	293,124	728,179
		59.3%	0.4%	59.7%	40.3%	100.0%
	Total	476,215	6,322	482,537	358,672	841,209
		56.6%	0.8%	57.4%	42.6%	100.0%
Central	Urban	179,104	9,194	188,298	216,259	404,557
		44.3%	2.3%	46.5%	53.5%	100.0%
	Rural	1,664,769	6,696	1,671,465	676,865	2,348,330
		70.9%	0.3%	71.2%	28.8%	100.0%
	Total	1,843,873	15,890	1,859,763	893,124	2,752,887
		67.0%	0.6%	67.6%	32.4%	100.0%
Southern	Urban	232,573	13,449	246,022	272,855	518,877
		44.8%	2.6%	47.4%	52.6%	100.0%
	Rural	1,906,268	14,700	1,920,968	799,167	2,720,135
		70.1%	0.5%	70.6%	29.4%	100.0%
	Total	2,138,841	28,149	2,166,990	1,072,022	3,239,012
		66.0%	0.9%	66.9%	33.1%	100.0%

Source: 1998 Malawi Population and Housing Census Report
(National Statistical Office, December 2000)

3.8 Current Situation of the Power Sector

3.8.1 Existing facilities and present situation

In Malawi, the Electricity Supply Commission of Malawi (ESCOM) manages the whole power system. The current state of power stations, transmission lines, substations and distribution lines of ESCOM are described in this section.

(1) Power stations

Hydro power stations are the main supply facilities. After the Kapichira hydro power station, with a capacity of 64MW, was added in 2000, the total capacity of power stations in Malawi rose to 306.4MW: 284.7MW for hydro, 15MW of gas turbines, 6.4MW for diesel.

Most of hydro power stations were installed along the Shire River, which is fed by Lake Malawi. The Liwonde Barrage, which is located above the hydro power stations on the Shire River, modulates the water flow through this river. (Fig. 3-8-1)

Two types of thermal power stations were installed, gas turbine and diesel. Thermal generators had been installed in main cities or towns, such as Blantyre, Lilongwe and Mzuzu. They were established to supply electric power for government, water boards, airports, etc. during power outages.

Power plants in Malawi and their capacities are listed in Table 3-8-1.

(2) 132kV and 66kV transmission lines

The transmission system in Malawi is made in two voltages, which are 132kV and 66kV. The total length of 132kV lines is 960km and there are two main lines. One of them is installed to supply the capital city, Lilongwe, from the main hydro power station in the Southern region, and the other is installed along Lake Malawi, running from the Southern region to Chintheche located in the Northern region.

Most of the 66kV transmission lines, with a total length of 820km, branched from 132kV transmission lines except in the Northern region where 66kV lines branched directly from the Wovwe hydro power station, constructed in 1995 to electrify the Northern region. As a result, the Northern system is only connected to the Central system by 33kV-distribution lines and therefore sometimes operates separately. A map of transmission lines is shown in Fig. 3-8-2.

Almost all poles supporting 132kV-transmission lines along Lake Malawi and 66kV lines are made of wood. (Fig.3-8-3) Since a large amount of wooden poles have deteriorated due to termite damage, ESCOM has had to replace some wooden poles as soon as five years after erection. ESCOM is considering the installation of steel towers as a measure to combat this problem, but the source of funds is still unclear.

(3) Transmission substations

As of the end of 1998/99, transformers with a total capacity of 451MVA were in operation in the whole country. Table 3-8-2 indicates capacities of transformers by voltage grade and region, and shows also that the Northern region has the lowest capacity installed for all voltages.

In regards to the condition of facilities, some installations are too old and ESCOM is concerned about repairs in that there are problems. At present, ESCOM is implementing a rehabilitation project close to Blantyre.

(4) Distribution lines

Technical particulars of the distribution system are similar to those mentioned in Section 5.1.

(5) System operation

Two types of Control Center operate the power system in Malawi, these being the National Control Center (NCC) and Area Control Center (ACC).

Operation activities of generators and frequency control are under the jurisdiction of the NCC in Blantyre. Regulations in Malawi permit 2.5% variation in the rated frequency, meaning that the operator should control the frequency between 48.75Hz and 51.25Hz.

One method of frequency control used by ESCOM is to adjust the deviation between two clocks, which show the "Standard Time" and "Frequency Time". The "Standard Time" indicates the time taken from a Global Positioning System (GPS) and the "Frequency Time" indicates the time of a clock that is moved by electric power supplied by ESCOM. The operator assures that the deviation is close to zero in order to control the frequency of the supply.

Three ACC, located in Blantyre at the Southern region, Lilongwe at the Central region and Mzuzu at the Northern region, control the voltages and operate the transmission, substation and distribution facilities.

3.8.2 Past records of electricity supply and consumption

(1) Gross generation of ESCOM

The past record of gross electricity generation in the country is indicated in Table 3-8-3. The total generation was 1,071.9GWh in 1999/00, increasing from 707.08GWh in 1990/91. The average growth rate was 4.7 %. As seen in Table 3-8-3, hydropower constituted the main type of generation and totaled more than 99% of overall production.

(2) Energy sales of ESCOM

The regional energy sales of the country in 1990/91 to 1999/00 are shown in Table 3-8-4. Categorical energy sales are shown in Table 3-8-5 and Fig. 3-8-4.

From these tables and figure the following can be concluded:

(a) The total energy sales were 871.8GWh in 1999/00, increasing from 598.1GWh in 1990/91 at an annual rate of 4.3%.

(b) The Southern region, the main region in the country, consumed more than 60% of the total energy sales. On the other hand, energy sales in the Northern region were relatively very low.

(c) The energy sales for the Domestic sector gradually increased but no major changes can be identified in other categories.

Energy sales by category and region are summarized in Table 3-8-6. Consumption in the Southern region for all categories is the largest in Malawi. This is because Power MV consumers[1], such as tea factories, are concentrated in the Southern region.

(3) Peak demand

Table 3-8-7 shows ESCOM's past record of peak demand, including growth rate and dates. The peak demand increased from 119.4MW in 1990/91 to 196.9MW in 1999/00, the average growth rate during this period being 5.6%.

Most of he annual peak demand has been recorded in the dry season, between July and September, at around 6:30 P.M. The record in 2000 being 204.1MW, accounts for 67% of the total capacity of generators operated by ESCOM.

(4) Number of customers

The number of ESCOM customers from 1990/91 to 1999/00 and the number per category and region in 1998/99 are shown in Table 3-8-8 and Table 3-8-9, respectively.

As with to the energy sales record as shown in Table 3-8-4, the number of customers gradually increased and the regional portion of the total number of customers was largest

1 Consumers supplied by 33kV or 11kV

in the Southern region at around 55%.

Sales per customer category are summarized in Table 3-8-10. The following can be observed from this table.

(a) Industrial demands for each region are similar except for the medium-voltage power demand Power MV in the Southern region.

(b) Domestic demand in the Northern region is around 50% of the demand of other regions.

(5) Load curve

Hourly load data in Malawi has been recorded by the Central Control Center of ESCOM. High load conditions are normally recorded three times a day. The first is from around 6:00 am, the second is at noon and the third is around 18:00 pm. These records coincide with mealtimes to register the energy consumption by electrical cookers. Industrial consumption is included during the second record and the third was record is to determine the peak load including lighting consumption.

With the objective of understanding load patterns in Malawi, typical load curves were identified for a weekday, Saturday and Sunday as shown in Fig. 3-8-5.

Table 3-8-1 Power Plant in Malawi

<table>
<tr><th colspan="2"></th><th>Name</th><th>Capacity (kW)</th><th>Total Capacity (kW)</th><th>Total Capacity (kW)</th><th>Rate</th><th>Commissioning Year</th></tr>
<tr><td rowspan="7">Thermal</td><td>Gas Turbine</td><td>Blantyre</td><td>15,000</td><td>15,000</td><td>15,000</td><td>4.9</td><td>1975</td></tr>
<tr><td rowspan="6">Diesel</td><td rowspan="2">Lilongwe</td><td>3,000</td><td rowspan="2">4,300</td><td rowspan="6">6,400</td><td rowspan="6">2.1</td><td>1972</td></tr>
<tr><td>1,300</td><td>1980</td></tr>
<tr><td rowspan="2">Mzuzu</td><td>1,100</td><td rowspan="2">1,800</td><td>1980</td></tr>
<tr><td>700</td><td>1983</td></tr>
<tr><td rowspan="2">Chitipa</td><td>150</td><td rowspan="2">300</td><td>1988</td></tr>
<tr><td>150</td><td>1988</td></tr>
<tr><td colspan="2" rowspan="21">Hydro</td><td rowspan="6">Tedzani</td><td>10,000</td><td rowspan="6">91,600</td><td rowspan="21">284,700</td><td rowspan="21">93.0</td><td>1973</td></tr>
<tr><td>10,000</td><td>1973</td></tr>
<tr><td>10,000</td><td>1976</td></tr>
<tr><td>10,000</td><td>1977</td></tr>
<tr><td>25,800</td><td>1995</td></tr>
<tr><td>25,800</td><td>1995</td></tr>
<tr><td rowspan="3">Nukula Falls A</td><td>8,000</td><td rowspan="3">24,000</td><td>1966</td></tr>
<tr><td>8,000</td><td>1966</td></tr>
<tr><td>8,000</td><td>1967</td></tr>
<tr><td rowspan="5">Nukula Falls B</td><td>20,000</td><td rowspan="5">100,000</td><td>1980</td></tr>
<tr><td>20,000</td><td>1980</td></tr>
<tr><td>20,000</td><td>1981</td></tr>
<tr><td>20,000</td><td>1986</td></tr>
<tr><td>20,000</td><td>1992</td></tr>
<tr><td rowspan="3">Wovwe</td><td>1,500</td><td rowspan="3">4,500</td><td>1995</td></tr>
<tr><td>1,500</td><td>1995</td></tr>
<tr><td>1,500</td><td>1995</td></tr>
<tr><td rowspan="2">Zomba</td><td>300</td><td rowspan="2">600</td><td>1953</td></tr>
<tr><td>300</td><td>1954</td></tr>
<tr><td rowspan="2">Kapichira</td><td>32,000</td><td rowspan="2">64,000</td><td>2000</td></tr>
<tr><td>32,000</td><td>2000</td></tr>
<tr><td colspan="4">Ground Total</td><td></td><td>306,400</td><td>100</td><td></td></tr>
</table>

(Source: Annual Report 1998/99, ESCOM)

Table 3-8-2 Breakdown of Transmission Substations in 1998/99

<table>
<tr><th>Voltage (Primary/Secondary)</th><th colspan="4">Installed Capacity (kVA)</th></tr>
<tr><th></th><th>Southern</th><th>Central</th><th>Northern</th><th>Total</th></tr>
<tr><td>132kV/66kV</td><td>50,000</td><td>90,000</td><td>15,000</td><td>155,000</td></tr>
<tr><td>132kV/11kV</td><td>50,000</td><td>0</td><td>0</td><td>50,000</td></tr>
<tr><td>66kV/33kV</td><td>110,000</td><td>25,000</td><td>10,000</td><td>145,000</td></tr>
<tr><td>66kV/11kV</td><td>28,500</td><td>67,500</td><td>5,000</td><td>101,000</td></tr>
<tr><td>Total</td><td>238,500</td><td>182,500</td><td>30,000</td><td>451,000</td></tr>
</table>

(Source: Annual Report 1998/99, ESCOM)

Table 3-8-3 Gross Generation in Malawi

Financial Year	Hydro		Thermal (GWh)		Total (GWh)	
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)
1990/91	—	—	—	—	707.1	100
1991/92	—	—	—	—	772.8	100
1992/93	—	—	—	—	784.7	100
1993/94	—	—	—	—	831.9	100
1994/95	856.1	99.5	4.4	0.5	860.5	100
1995/96	857.5	99.7	2.4	0.3	859.9	100
1996/97	890.6	99.8	2.0	0.2	892.6	100
1997/98	976.7	99.8	1.5	0.2	978.2	100
1998/99	1,031.1	99.9	1.3	0.1	1,032.4	100
1999/00	—	—	—	—	1,071.9	100

(Source : ESCOM's Document (1990/91-1993/94, 1999/00)
Annual Report, ESCOM (1994/95-1998/98))

Table 3-8-4 Regional Energy Sales

Financial Year	Southern		Central		Northern		Total	
	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)	(GWh)	(%)
1990/91	—	—	—	—	—	—	598	100.0
1991/92	—	—	—	—	—	—	649	100.0
1992/93	—	—	—	—	—	—	655	100.0
1993/94	483	68.6	193	27.4	28	4.0	704	100.0
1994/95	490	66.9	210	28.7	32	4.4	732	100.0
1995/96	469	64.5	227	31.2	31	4.3	727	100.0
1996/97	468	63.1	237	31.9	37	5.0	742	100.0
1997/98	514	64.0	248	30.9	41	5.1	803	100.0
1998/99	547	64.6	260	30.7	40	4.7	847	100.0
1999/00	—	—	—	—	—	—	872	100.0

(Source : ESCOM's Document (1990/91-1993/94, 1999/00)
Annual Report, ESCOM (1994/95-1998/98))

Table 3-8-5 Category-wise Energy Sales (GWh)

Financial Year	Domestic	Pre-payment	General	Power LV	Power MV	Export	Total
1990/91	—	—	—	—	—	—	598
1991/92	—	—	—	—	—	—	649
1992/93	—	—	—	—	—	—	655
1993/94	144	—	119	154	286	1	704
1994/95	156	—	122	156	297	1	732
1995/96	170	—	121	162	272	2	727
1996/97	197	—	127	167	249	2	742
1997/98	226	—	127	176	271	3	803
1998/99	243	9	130	187	275	3	847
1999/00	—	—	—	—	—	—	872

(Source: ESCOM's Document (1990/91-1993/94, 1999/00)
Annual Report, ESCOM (1994/95-1998/98))

Table 3-8-6 Energy Sales Summaries by Category and Region in 1998/99 (GWh)

Category	Southern	Central	Northern	Total
Domestic	128	103	12	243
Prepayment	8	1	0	9
General	73	46	11	130
Power LV	119	56	12	187
Power MV	216	54	5	275
Export	3	0	0	3
Total	547	260	40	847

(Source: Annual Report 1998/99, ESCOM)

Table 3-8-7 Peak Demand

Financial Year	Peak Load (MW)	Growth Rate (%)	Date
1990/91	119.4	—	04/Jul/1990
1991/92	133.4	11.7	18/Jul/1991
1992/93	138.7	4.0	13/Aug/1992
1993/94	140.2	1.1	26/Aug/1993
1994/95	142.4	3.7	—
1995/96	149.4	2.8	—
1996/97	164.1	9.8	18/Jul/1996
1997/98	179.9	9.6	15/Sep/1997
1998/99	190.2	5.7	—
1999/00	196.9	3.5	14/Jul/1999
2000/01	204.1	4.0	14/Aug/2000

(Source: ESCOM's Document (1990/91-1993/94, 1999/00)
Annual Report, ESCOM (1994/95-1998/98))

*The recorded time in 1994/95, 1995/96 and 1998/99 are unspecified.

Table 3-8-8 Number of Customers

Financial Year	Southern		Central		Northern		Total	
	Number	(%)	Number	(%)	Number	(%)	Number	(%)
1990/91	—		—		—		43,339	100.0
1991/92	—		—		—		45,712	100.0
1992/93	—		—		—		51,000	100.0
1993/94	29,753	56.0	18,745	35.3	4,643	8.7	53,141	100.0
1994/95	31,926	55.7	19,813	34.6	5,531	9.7	57,270	100.0
1995/96	34,099	55.5	21,546	35.0	5,808	9.5	61,453	100.0
1996/97	36,435	55.1	23,204	35.1	6.429	9.8	66,068	100.0
1997/98	39,155	54.4	25,707	35.7	7,128	9.9	71,990	100.0
1998/99	42,066	54.4	27,450	35.5	7,867	10.1	77,383	100.0
1999/00	—		—		—		82,792	100.0

(Source : ESCOM's Document (1990/91-1993/94, 1999/00)
Annual Report, ESCOM (1994/95-1998/98))

Table 3-8-9 Number of Customers by Category and Region in 1998/99

Category	Southern		Central		Northern		Total	
	Number	(%)	Number	(%)	Number	(%)	Number	(%)
Domestic	30,981	53.4	21,166	36.7	5,738	9.9	57,885	100.0
Prepayment	1,279	77.2	145	8.8	232	14.0	1,656	100.0
General	9,291	54.6	5,862	34.5	1,849	10.9	17,002	100.0
Power LV	482	60.9	262	33.1	47	6.0	791	100.0
Power MV	29	64.5	15	33.3	1	2.2	45	100.0
Export	4	100.0	0	0.0	0	0.0	4	100.0
Total	42,066	54.4	27,450	35.5	7,867	10.1	77,383	100.0

(Source : Annual Report 1998/99, ESCOM)

Table 3-8-10 Energy Sales per Customer in 1998/99 (MWh)

Category	Southern	Central	Northern	Average
Domestic	4.1	4.9	2.1	4.2
Prepayment	6.2	4.7	1.8	5.5
General	7.8	7.9	6.0	7.6
Power LV	247.2	213.8	250.3	236.3
Power MV	7,462.2	3,591.9	4,658.0	6,109.8
Export	740.3	—	—	740.3

(Source : Annual Report 1998/99, ESCOM)

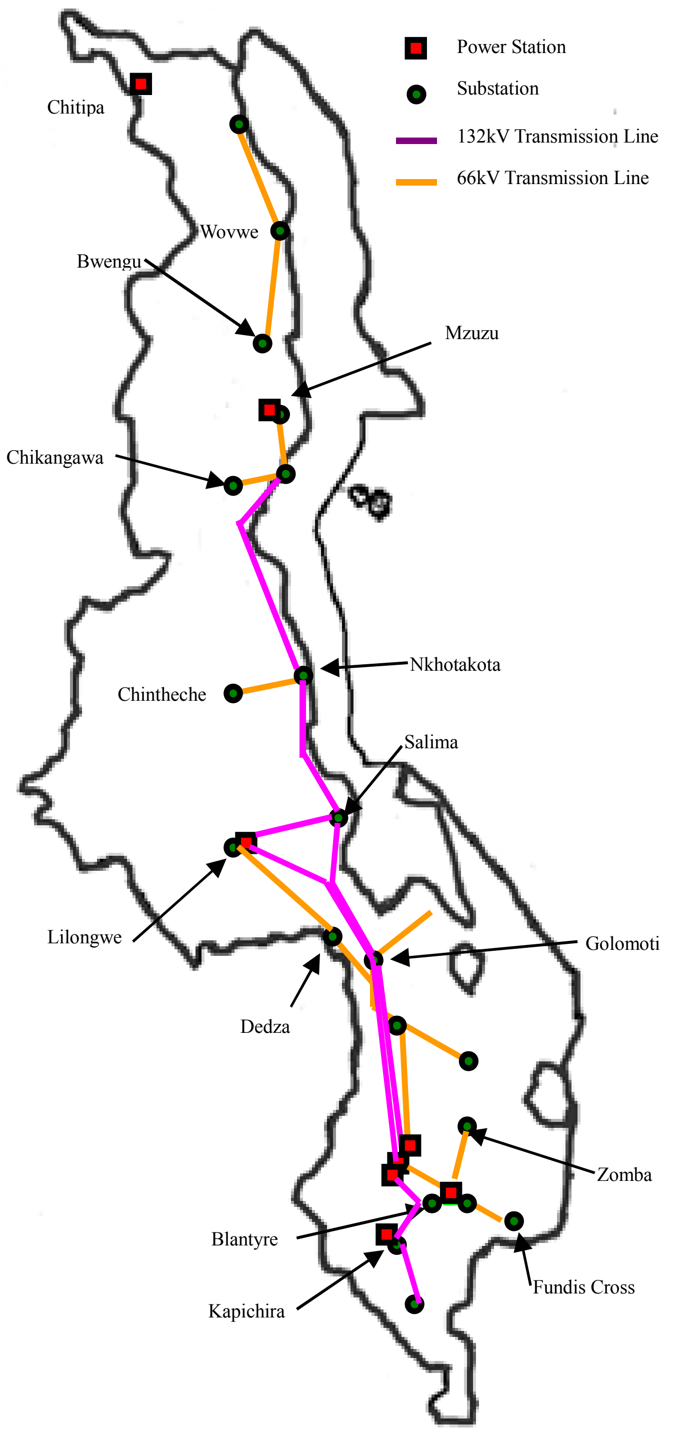


Fig. 3-8-2 Transmission lines in Malawi
(Source: Annual Report 1998/99, ESCOM)

Fig. 3-8-1 Liwonde Barrage

Fig. 3-8-3 66kV Transmission Line

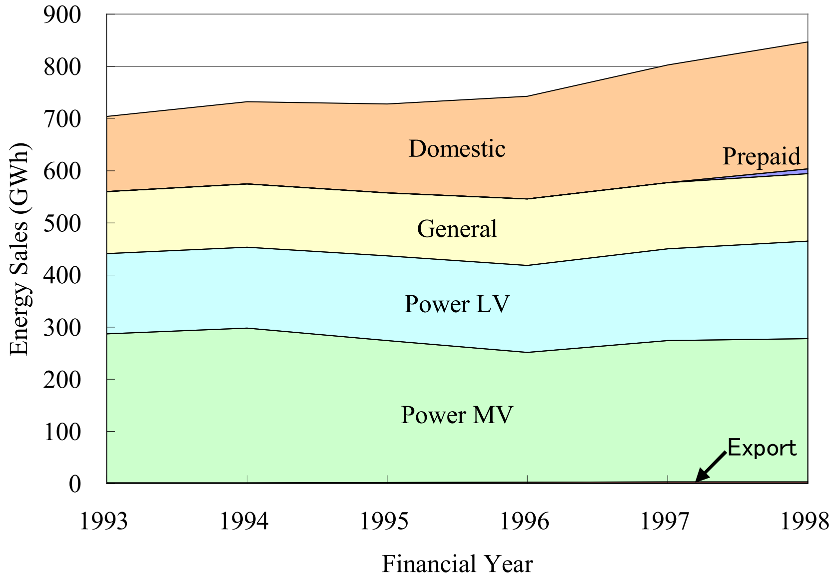


Fig. 3-8-4 Category-wise Energy Sales

(Source: ESCOM's Document (1990/91-1993/94, 1999/00)
Annual Report, ESCOM (1994/95-1998/98))

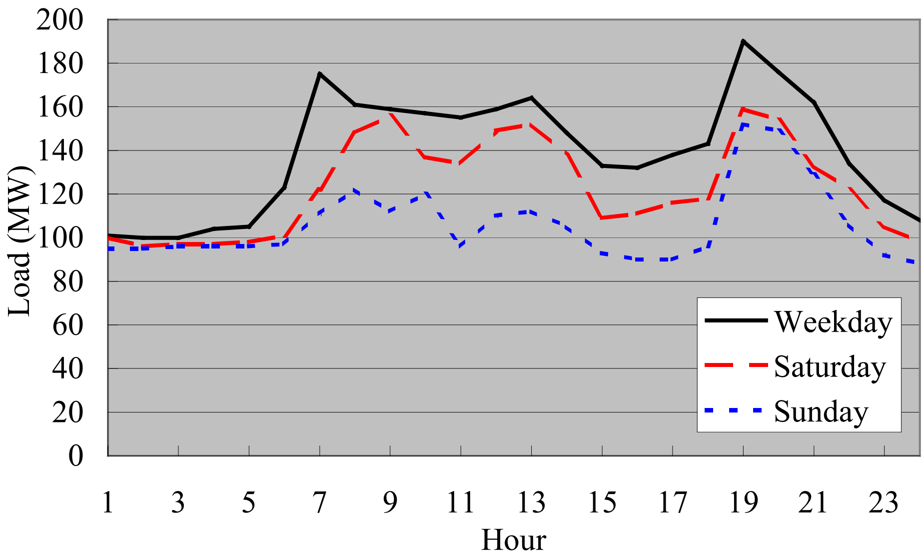


Fig. 3-8-5 Typical Load Curve

(Source: ESCOM)

3.9 Development Plan

3.9.1 Development plan of the power sector

The World Bank has reported in December 1998 the master plan for power system development. This is being followed by ESCOM.

Sections of the World Bank report related to planning are summarized as follows.

(1) Problem of the power sector

According to the World Bank report, the power sector of Malawi experiences the following problems:

(a) Over-reliance on Lake Malawi

Since electricity generation depends on hydropower plants along the Shire River, which is fed by Lake Malawi, the lake level has an influence in power supply.

(b) Blocking of the Shire River by sediments

Sediment caused by storms settles in the Shire River and blocks the water flow. As a result, the potential of hydropower plants decreases.

(c) Island operation

Since the power system in Malawi does not have lines interconnected with other countries, it is not easy to provide reserve capacity efficiently.

(d) Imported oil and gas

In Malawi, oil and gas fuel have to be imported and transport charges are high.

(e) Expensive local coal

There is a small amount of coal but it is not easily accessible because the surface soil is so thick.

To resolve these problems, generation expansion and high-voltage system planning were formulated based on power system analysis and financial analysis, and the results of the demand forecast shown in Chapter4.

(2) Generation expansion and transmission planning

The proposed plan based on minimal cost generation expansion is described in Table 3-9-1. The generation plan has 4 scenario, these are Low, Base, High and DSM in accordance with demand forecast.[2]

The pumping station in Mangochi, located at the starting point of the Shire River, is a remarkable project. This station controls the water flow through the Shire River by pumping up the water from Lake Malawi and directing it down to the Shire River. The World Bank proposed that this project should be implemented as soon as possible, and raised the following points for consideration.

[2] DSM Scenario is not revised by ESCOM in 2000.

(a) Co-operation of many ministries for this project
(b) The necessity of negotiations between three nations (Malawi, Tanzania, Mozambique)
(c) The environmental assessment of Lake Malawi

If the Pumping Station plan were delay or cancelled, the report proposed another scenario as follows.

- The installation of additional gas turbines.
- The reinforcement of interconnection lines to Zambia or Mozambique.

(3) High Voltage Transmission System Planning

Based on the analysis of load flow, dynamic stability and contingency, transmission lines are proposed as shown in Table 3-9-2 and Fig. 3-9-1.

In addition to this plan, ESCOM has another project planned, this being the 66kV transmission line between Rumphi and Mzuzu. After this project has been completed, a high voltage transmission line will connect the Northern and Central regions.

Table 3-9-1 Proposed Plan for Generation Expansion

(a) Low Scenario

Year	Project	Capacity (MW)
2001	Pumping Station in Mangochi	-
2002	Interconnection Line to Tete (Mozambique)	200
2012	Hydro power plant: Kapichira II	64

(b) Base Scenario

Year	Project	Capacity (MW)
2001	Pumping Station in Mangochi	-
2002	Interconnection Line to Tete (Mozambique)	200
2010	Hydro power plant: Kapichira II	64
2012－2015	Gas Turbines in Lilongwe, Mapanga and Mzuzu	3×33

(c) High Scenario

Year	Project	Capacity (MW)
2001	Pumping Station in Mangochi	-
2002	Interconnection Line to Tete (Mozambique)	200
2006	Gas Turbines in Lilongwe	33
2008	Hydro power plant: Kapichira II	64
2010－2011	Gas Turbines in Mapanga and Mzuzu	2×33
2012	Hydro power plant: Lower Fufu	2012
2013-2015	Gas Turbines in Lilongwe, Mapanga and Mzuzu	3×33

(d) DSM Scenario

Year	Project	Capacity (MW)
2001	Pumping Station in Mangochi	-
2002	Interconnection Line to Tete (Mozambique)	200
2010	Hydro power plant: Kapichira II	64
2014-2015	Gas Turbines in Lilongwe and Mapanga	2×33

(Source : Power System Development Study and Operation study 1998, World Bank)

Table 3-9-2 Plan of HV Transmission System

Year	Voltage (kV)	Project	Length (km)	Remarks
2002	132	Nkula B - Tedzani	8	Required
	132	Blantyre West - Chichiri	8	Required
2009	66	Telegraph Hill - Chintheche	78	Recommended
2010	132	Kapichira - Blantyre West	29	Required
2011	66	Lilongwe C - Lilongwe A	10	Required
2013	132	Blantyre - Fundis (Looping into Mapanga)	12	Recommended
2015 and later	132	Lilongwe B - Chinyama - Chikangawa	250	Recommended

(Source : Power System Development Study and Operation study 1998, World Bank)

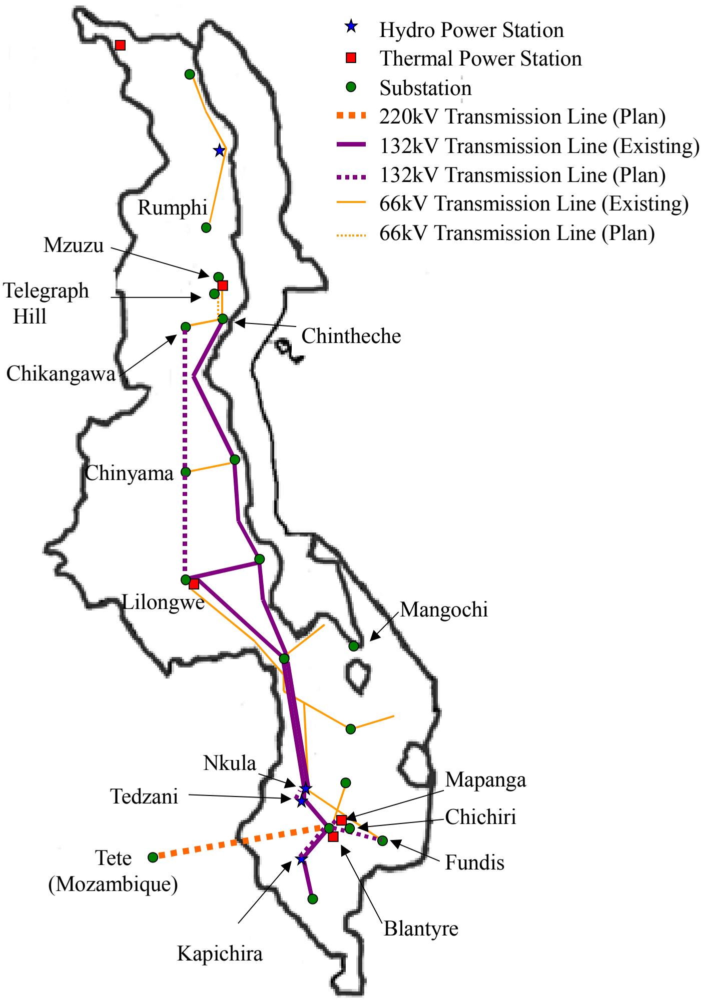


Fig. 3-9-1 Development Plan

CHAPTER 4 DEMAND FORECAST

Chapter 4 Demand Forecast

Demand forecasts for the rural electrification master plan are described in this chapter. Two types of forecasts are summarized as follows.

(1) Forecast of demand in Malawi

Forecast of demand in Malawi is related to grid extension, which is one method for rural electrification. Considering the critical scenario for the demand supply balance in Malawi, the grid extension method is not possible. In Malawi, demand supply balance by ESCOM is representative of the demand balance of the country. The Study Team reviewed this balance for the whole country.

(2) Forecast of potential demand in unelectrified Trading Centers (TCs)

To estimate the necessary power supply and to determine the size/scale/number of power facilities required to fulfill power demand of the long term rural electrification master plan, the demand forecast for electrification target TCs is carried out according to the survey results. Examples of these are power usage records and the rate of demand growth in electrified TCs.

Since the detailed forecast process to identify the potential demand of unelectrified TCs will be explained in Chapter 8 of this report, only forecasted results for the two top-ranking prioritized unelectrified TCs from each district in the country will be presented in this chapter. The target year for the potential demand forecast is in 20 years time, therefore 2021 is the goal for the implementation of this master plan.

4.1 Demand Supply Balance of Malawi

Demand forecast by ESCOM is based on the "Power System Development Study and Operation Study", carried out by the World Bank in 1998. World Bank's forecasts were conducted for Base, High, Low and DSM Scenarios, according to some assumptions and projections as number of new consumers and growth rate of GDP. The forecast model is comprised in three categories and has the items as below.

(a) Domestic

The number of consumers

The average energy sakes of consumers based on connection targets, income and tariff elasticities

(b) General and Small power

The sales based on sectoral income elasticites and general trends

(c) Large power

The consumption of large consumers based on past development and their own projections.

The total generation is the sum of each category including some losses, and the peak demand is calculated from the generation forecast and typical load factors.

As for DSM scenario, about 9% of peak demand and generation gradually decrease up to 2010 by adoption of fluorescent and refitment of water heater with lower capacity.

In 2000, ESCOM has updated Base, High and Low scenarios. Table 4-1-1 shows the result of the forecasts prepared by the World Bank and ESCOM.
Both energy generation and peak demand forecast in 2015 conducted by ESCOM are lager than those reported by the World Bank. The difference can be explained by assumptions made by ESCOM regarding actual data for the year ending 31 March 2000. Some assumptions for ESCOM's forecast are shown in Table 4-1-2 and remarkable differences for Base scenario between World Bank and ESCOM are described as Table 4-1-3.
According to ESCOM, the differences between Base and other scenarios are due to assumptions of GDP and consumer connections; these are depended on economic growth and progress of electrification.
Table 4-1-3 shows that items related to consumption by ESCOM exceed these by World Bank and loss rate is greater than projection in 1998. As a result, total forecasted generation by ESCOM is properly larger than by World Bank.

A comparison between the above demand forecasts and the development plan of power supply described in section 3.9 is shown in Fig. 4-1-1. These Graphs are drawn under the following assumptions.

- Existing generators keep the current generating capacity up to 2020.
- Generators are installed according to World Bank's plan up to 2015. After 2015, new installation projects are not considered.

If all development plans were implemented, the supply capacity would be enough to keep the demand supply balances until the financial year of 2015. Some measures, such as installation of gas turbines and DSM, should be taken into account to assure reserve capacity in 2020.
And ESCOM doesn’t have forecasts including additional demand of this master plan, since demands forecasts were based on World Bank's forecasts. It is necessary that power development plan should be revised.

Table 4-1-1 Demand Forecast in Malawi (Generated)

(a) Low Scenario

Financial Years Ending March	World Bank 1998		ESCOM 2000	
	Energy Generation (GWh)	Peak Demand (MW)	Energy Generation (GWh)	Peak Demand (MW)
2000	1,110	200	1,074	197.89
2005	1,350	245	1,450	267.15
2010	1,620	295	1,815	334.43
2015	2,020	370	2,336	430.36
2020	-	-	3,021	556.67

(b) Base Scenario

Financial Years Ending March	World Bank 1998		ESCOM 2000	
	Energy Generation (GWh)	Peak Demand (MW)	Energy Generation (GWh)	Peak Demand (MW)
2000	1,150	205	1,074	197.89
2005	1,500	270	1,593	293.55
2010	1,910	345	2,137	393.79
2015	2,535	460	2.969	547.14
2020	-	-	4,163	767.10

(c) High Scenario

Financial Years Ending March	World Bank 1998		ESCOM 2000	
	Energy Generation (GWh)	Peak Demand (MW)	Energy Generation (GWh)	Peak Demand (MW)
2000	1,200	215	1,074	197.89
2005	1,770	320	1,714	275.51
2010	2,530	455	2,450	393.94
2015	3,680	670	3,644	585.96
2020	-	-	5,489	882.56

(d) DSM Scenario

Financial Years Ending March	World Bank 1998		ESCOM 2000	
	Energy Generation (GWh)	Peak Demand (MW)	Energy Generation (GWh)	Peak Demand (MW)
2000	1,100	190	-	-
2005	1,400	240	-	-
2010	1,770	310	-	-
2015	2,330	410	-	-
2020	-	-	-	-

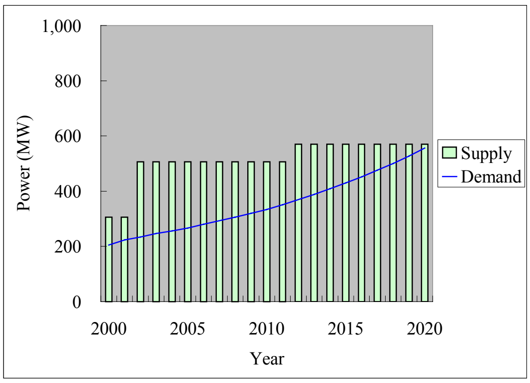
(Source: * Power System Development Study and Operation Study (World Bank 1998)
* ESCOM LOAD FORECAST UPDATE

Table 4-1-2 Assumptions by ESCOM

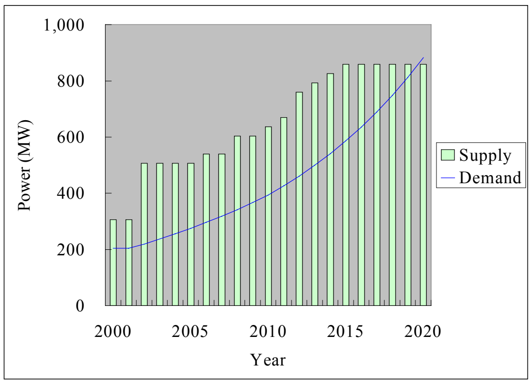
Scenario		Low	Base	High
Number of consumers		Decreasing to 5% p.a.	8.5% p.a.	10% p.a.
TotalGDP	2000	3.0%	5.1%	6.0%
	2001-2004	2.5%	5.0%	5.5%
	After 2004	2.0%	3.5%	5.0%
Losses		Decreasing to 10% by 2010, 10% from 2010		
Load factor		62%		71%

Table 4-1-3 Difference items of World Bank and ESCOM (Base Scenario)

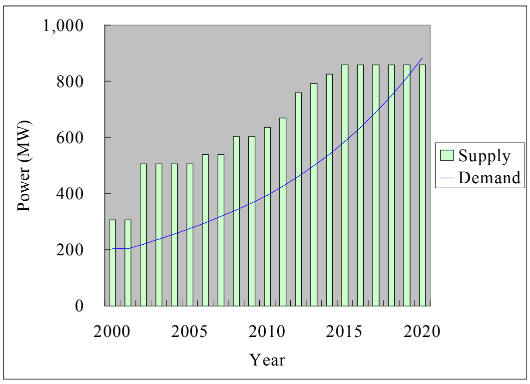
Item	World Bank 1998		ESCOM 2000	
Number of consumers	7.5% p.a.		8.5% p.a.	
GDP Growth Rate	1998-2006	Decreasing from 5.6% to 3.0%	2000	5.1%
			2001-2004	5.0%
	After 2006	3.0%	After 2004	3.5%
Loss	Decreasing to 9% by 2010		Decreasing to 10% by 2010	



(a) Low Scenario



(b) Base Scenario



(c) High Scenario

Fig.4-1-1 Demand Supply Balance of Malawi

(Source: * Power System Development Study and Operation Study (World Bank 1998)
* ESCOM LOAD FORECAST UPDATE)

4.2 Forecast of potential demand in unelectrified TCs

In the rural electrification planning process, the target TCs to be electrified are identified, then the potential demand of the unelectrified TCs is forecasted. This is followed by a comparison of electrification methods that enable the supply of the necessary amount of electricity greater than the forecasted potential demand. These methods are compared to each other in terms of their technical applicability and economic feasibility. Finally, the optimal electrification method for each TC is identified. The results of this process are shown in Figure 4-2-1. Therefore, the forecasted potential demand of an unelectrified TC is essential information for the selection of an appropriate electrification method and for the estimation of the cost of the electrification project. The forecasted results of potential demand are shown in Table 4-2-1 as a basis for selecting the two highest priority TCs for electrification from each district in the country. This table indicates the predicted electric energy consumption (kWh/day) in 2021 for each of the TCs. Electrification methods that meet this consumption will be discussed in the following chapters. The process for forecasting the potential demand in unelectrified TCs is explained in detail in Chapter 8.

Table 4-2-2 shows the forecasted power demand for 249 unelectrified TCs[1]. This table also indicates basic data, such as population, number of households/public facilities/business entities, and market fees for these TCs.

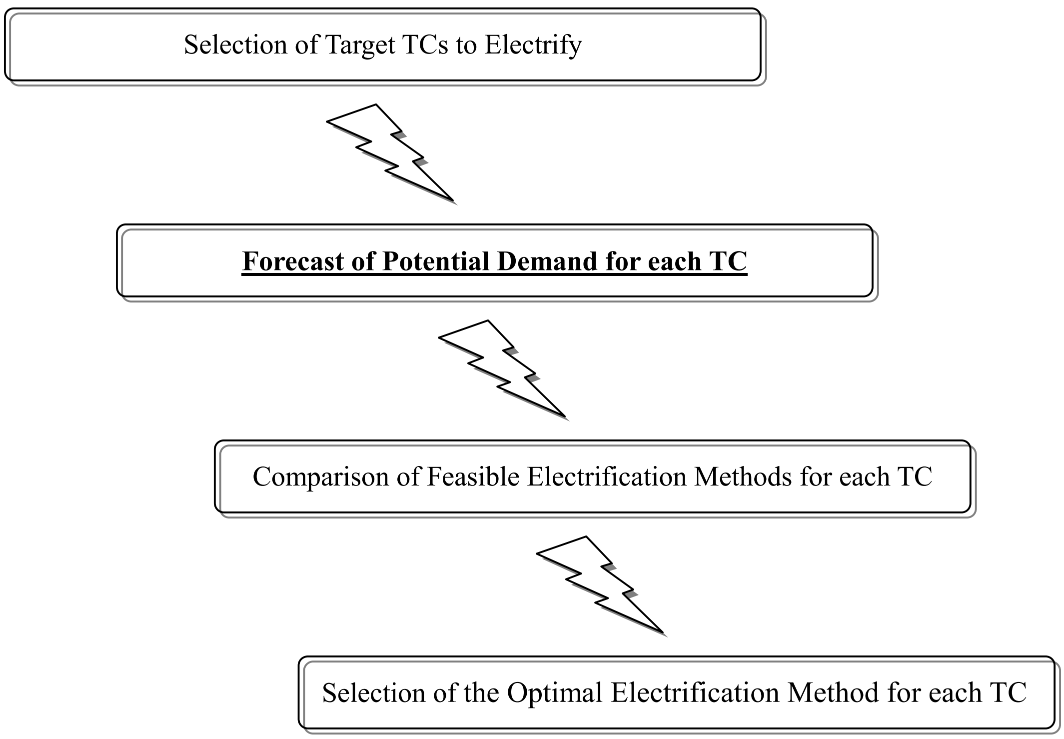


Fig. 4-2-1 Planning Process of Rural Electrification

[1] The basic data was collected from 255 unelectrified TCs as explained in Chapter 8. Among these unelectrified TCs, however, 6 TCs were nominated for REP Phase IV and therefore the potential demand was forecasted for the remaining 249 TCs.

4.3 Power Development in Malawi Related to the Rural Electrification Implementation

ESCOM have to review the total power supply capacity for whole Malawi taking into account the potential power demand of 249 unelectrified trading centers to implement the rural electrification master plan.

Check and review of the "Power System Development Study and Operation Study" carried out by the World Bank in 1998 would be highly recommended.

It is said that the potential capacity for Shire River would be 300-685MW, and other rivers have 445-985 MW potential as the power source.[2] Only 285MW among the potential, however, has been developed up to now. Therefore, the power source potential would be sufficient in Malawi.

In addition to that, the Government of Malawi has an idea to interconnect the SAPP[3] to improve the power system reliability. If this idea would come to true, the pool dispatching operation could be realized, and power supply would also be carried out through this system.

[2] Information from "FINAL DRAFT (Revised) POWER SECTOR REFORM STRATEGY"
[3] South Africa Power Pool

Table 4-2-1 Forecasted Electric Energy Consumption [kWh/day] in year of 2021 for Prioritized TCs (1/2)

Trading Center	District	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Total [kWh/day]
Nthalire	Chitipa	76.4	77.1	76.4	73.5	84.5	209.6	326.3	325.7	317.8	309.8	309.4	307.8	300.1	299.7	300.9	301.4	307.4	349.2	287.1	172.3	151.1	132.2	102.6	86.9	5,285
Lupita	Chitipa	75.9	76.6	75.8	73.0	83.9	208.1	323.9	323.3	315.5	307.5	307.1	305.5	297.9	297.5	298.7	299.2	305.1	346.7	285.0	171.0	150.0	131.2	101.9	86.3	5,247
Kibwe	Karonga	75.9	76.6	75.8	73.0	83.9	208.1	323.9	323.3	315.5	307.6	307.2	305.5	297.9	297.5	298.7	299.2	305.2	346.7	285.0	171.0	150.0	131.2	101.9	86.3	5,247
Pusi	Karonga	70.7	71.3	70.6	67.9	78.1	193.8	301.7	301.1	293.9	286.4	286.0	284.5	277.4	277.1	278.2	278.6	284.2	322.9	265.4	159.3	139.7	122.2	94.9	80.3	4,886
Katowo	Rumphi	58.9	59.4	58.8	56.6	65.1	161.5	251.4	250.9	244.9	238.7	238.4	237.1	231.2	230.9	231.8	232.2	236.8	269.1	221.2	132.7	116.4	101.8	79.1	66.9	4,072
Chitimba	Rumphi	3.9	3.9	3.9	3.7	4.3	10.6	16.5	16.5	16.1	15.7	15.7	15.6	15.2	15.2	15.3	15.3	15.6	17.7	14.6	8.7	7.7	6.7	5.2	4.4	268
Mpamba	Nkhata Bay	22.8	23.0	22.8	21.9	25.2	62.5	97.3	97.1	94.8	92.4	92.3	91.8	89.5	89.4	89.7	89.9	91.7	104.1	85.6	51.4	45.1	39.4	30.6	25.9	1,576
Kavuzi	Nkhata Bay	34.9	35.2	34.8	33.5	38.6	95.7	148.9	148.6	145.1	141.4	141.2	140.5	137.0	136.8	137.3	137.5	140.3	159.4	131.0	78.6	69.0	60.3	46.8	39.7	2,412
Edingeni	Mzimba	5.4	5.5	5.4	5.2	6.0	14.9	23.2	23.1	22.6	22.0	22.0	21.8	21.3	21.3	21.4	21.4	21.8	24.8	20.4	12.2	10.7	9.4	7.3	6.2	375
Euthini	Mzimba	69.4	70.1	69.4	66.8	76.7	190.4	296.4	295.8	288.7	281.4	281.0	279.5	272.6	272.2	273.3	273.7	279.2	317.2	260.7	156.5	137.3	120.1	93.2	78.9	4,800
Likoma	Likoma	40.3	40.7	40.3	38.8	44.6	110.6	172.2	171.9	167.8	163.5	163.3	162.4	158.4	158.2	158.8	159.1	162.2	184.3	151.5	90.9	79.8	69.8	54.2	45.9	2,789
Chizumulu	Likoma	67.6	68.2	67.5	65.0	74.7	185.3	288.4	287.9	281.0	273.9	273.5	272.1	265.3	264.9	266.0	266.4	271.7	308.7	253.8	152.3	133.6	116.9	90.7	76.8	4,672
Chamama	Kasungu	28.2	28.4	28.2	27.1	31.2	77.3	120.3	120.1	117.2	114.2	114.1	113.5	110.6	110.5	110.9	111.1	113.3	128.8	105.8	63.5	55.7	48.7	37.8	32.0	1,949
Chulu	Kasungu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mkaika	Nkhotakota	100.2	101.1	100.1	96.3	110.7	274.7	427.7	426.9	416.6	406.1	405.5	403.4	393.3	392.8	394.4	395.0	402.9	457.8	376.3	225.8	198.1	173.3	134.5	113.9	6,928
Dwambazi	Nkhotakota	69.4	70.1	69.4	66.8	76.7	190.4	296.4	295.8	288.7	281.4	281.0	279.6	272.6	272.2	273.3	273.8	279.2	317.2	260.8	156.5	137.3	120.1	93.2	78.9	4,801
Nthesa	Ntchisi	10.0	10.0	9.9	9.6	11.0	27.3	42.5	42.4	41.4	40.3	40.3	40.1	39.1	39.0	39.2	39.2	40.0	45.5	37.4	22.4	19.7	17.2	13.4	11.3	688
Khuwi	Ntchisi	13.8	13.9	13.8	13.3	15.3	37.8	58.9	58.8	57.4	55.9	55.9	55.6	54.2	54.1	54.3	54.4	55.5	63.0	51.8	31.1	27.3	23.9	18.5	15.7	954
Thambwe	Dowa	28.1	28.4	28.1	27.0	31.1	77.1	120.1	119.8	117.0	114.0	113.8	113.2	110.4	110.3	110.7	110.9	113.1	128.5	105.6	63.4	55.6	48.6	37.8	32.0	1,945
Nambuma	Dowa	83.9	84.7	83.9	80.7	92.8	230.2	358.3	357.7	349.1	340.2	339.8	338.0	329.5	329.1	330.4	331.0	337.6	383.5	315.3	189.2	166.0	145.2	112.7	95.4	5,804
Chikuse	Dowa	20.6	20.7	20.5	19.8	22.7	56.4	87.8	87.6	85.5	83.3	83.2	82.8	80.7	80.6	80.9	81.1	82.7	93.9	77.2	46.3	40.6	35.6	27.6	23.4	1,421
Kandulu	Salima	30.4	30.7	30.4	29.2	33.6	83.4	129.8	129.6	126.5	123.3	123.1	122.5	119.4	119.3	119.8	119.9	122.3	139.0	114.2	68.6	60.1	52.6	40.8	34.6	2,103
Chilambula	Salima	8.5	8.6	8.5	8.2	9.4	23.4	36.4	36.3	35.5	34.6	34.5	34.3	33.5	33.4	33.6	33.6	34.3	39.0	32.0	19.2	16.9	14.7	11.4	9.7	590
Chilobwe	Lilongwe	60.9	61.4	60.8	58.5	67.3	166.9	259.8	259.4	253.1	246.7	246.4	245.1	239.0	238.7	239.6	240.0	244.8	278.1	228.6	137.2	120.3	105.3	81.7	69.2	4,209
Nyanja	Lilongwe	11.8	11.9	11.7	11.3	13.0	32.2	50.2	50.1	48.9	47.6	47.6	47.3	46.1	46.1	46.3	46.3	47.3	53.7	44.1	26.5	23.2	20.3	15.8	13.4	813
Mkanda	Mchinji	54.1	54.6	54.1	52.0	59.8	148.4	231.0	230.5	225.0	219.3	219.0	217.9	212.4	212.1	213.0	213.3	217.6	247.2	203.2	122.0	107.0	93.6	72.6	61.5	3,741
Chiosya	Mchinji	37.8	38.1	37.8	36.3	41.8	103.6	161.3	161.1	157.2	153.2	153.0	152.2	148.4	148.2	148.8	149.0	152.0	172.7	142.0	85.2	74.7	65.4	50.7	43.0	2,614
Kabwazi	Dedza	10.4	10.5	10.4	10.0	11.5	28.7	44.6	44.5	43.5	42.4	42.3	42.1	41.0	41.0	41.1	41.2	42.0	47.7	39.2	23.6	20.7	18.1	14.0	11.9	722
Golomoti	Dedza	22.0	22.2	22.0	21.1	24.3	60.3	93.8	93.7	91.4	89.1	89.0	88.5	86.3	86.2	86.5	86.7	88.4	100.4	82.6	49.5	43.5	38.0	29.5	25.0	1,520

Table 4-2-1 Forecasted Electric Energy Consumption [kWh/day] in year of 2021 for Prioritized TCs (2/2)

Trading Center	District	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	Total [kWh/day]
Kandeu	Ntcheu	22.0	22.2	22.0	21.2	24.4	60.5	94.1	93.9	91.7	89.4	89.2	88.8	86.6	86.4	86.8	86.9	88.7	100.7	82.8	49.7	43.6	38.1	29.6	25.1	1,524
Sharpvalle	Ntcheu	102.7	103.7	102.6	98.8	113.5	281.7	438.5	437.7	427.2	416.4	415.8	413.7	403.3	402.8	404.4	405.1	413.1	469.4	385.8	231.6	203.1	177.7	137.9	116.8	7,103
Makanjira	Mangochi	81.4	82.1	81.3	78.3	90.0	223.2	347.4	346.8	338.5	329.9	329.5	327.7	319.5	319.1	320.4	320.9	327.3	371.9	305.7	183.5	160.9	140.8	109.3	92.5	5,628
Chilipa	Mangochi	6.4	6.4	6.3	6.1	7.0	17.4	27.1	27.1	26.4	25.8	25.7	25.6	25.0	24.9	25.0	25.1	25.6	29.0	23.9	14.3	12.6	11.0	8.5	7.2	439
Chikwewu	Machinga	74.3	75.0	74.2	71.5	82.2	203.8	317.3	316.7	309.1	301.3	300.9	299.3	291.8	291.4	292.6	293.1	298.9	339.6	279.2	167.5	147.0	128.5	99.8	84.5	5,139
Nampeya	Machinga	79.5	80.2	79.4	76.4	87.8	217.9	339.3	338.6	330.5	322.1	321.7	320.0	312.0	311.6	312.9	313.4	319.6	363.1	298.5	179.1	157.1	137.5	106.7	90.4	5,495
Chendausiku	Balaka	49.6	50.1	49.6	47.7	54.9	136.1	211.9	211.5	206.4	201.2	201.0	199.9	194.9	194.6	195.4	195.7	199.6	226.8	186.5	111.9	98.2	85.9	66.7	56.4	3,433
Kwitanda	Balaka	9.6	9.7	9.6	9.3	10.7	26.4	41.2	41.1	40.1	39.1	39.0	38.8	37.9	37.8	38.0	38.0	38.8	44.1	36.2	21.7	19.1	16.7	12.9	11.0	667
Jenale	Zomba	12.7	12.9	12.7	12.3	14.1	34.9	54.4	54.3	53.0	51.6	51.6	51.3	50.0	50.0	50.2	50.2	51.2	58.2	47.9	28.7	25.2	22.0	17.1	14.5	881
Sunuzi	Zomba	23.1	23.3	23.1	22.2	25.5	63.3	98.6	98.4	96.1	93.6	93.5	93.0	90.7	90.6	90.9	91.1	92.9	105.6	86.8	52.1	45.7	40.0	31.0	26.3	1,597
Milepa	Chiradzulu	12.4	12.5	12.4	11.9	13.7	33.9	52.8	52.7	51.4	50.1	50.1	49.8	48.6	48.5	48.7	48.8	49.7	56.5	46.5	27.9	24.5	21.4	16.6	14.1	855
Ndunde	Chiradzulu	10.1	10.2	10.1	9.7	11.1	27.6	43.0	42.9	41.9	40.8	40.8	40.6	39.6	39.5	39.7	39.7	40.5	46.0	37.8	22.7	19.9	17.4	13.5	11.5	697
Chikuli	Blantyre	22.0	22.2	22.0	21.1	24.3	60.3	93.8	93.7	91.4	89.1	89.0	88.5	86.3	86.2	86.5	86.7	88.4	100.5	82.6	49.6	43.5	38.0	29.5	25.0	1,520
Mombo	Blantyre	3.3	3.3	3.3	3.2	3.7	9.1	14.2	14.1	13.8	13.4	13.4	13.4	13.0	13.0	13.1	13.1	13.3	15.2	12.5	7.5	6.6	5.7	4.5	3.8	229
Thambani	Mwanza	46.2	46.6	46.1	44.4	51.0	126.6	197.1	196.7	192.0	187.1	186.9	185.9	181.3	181.0	181.8	182.0	185.7	211.0	173.4	104.1	91.3	79.9	62.0	52.5	3,192
Lisungwi	Mwanza	27.4	27.7	27.4	26.4	30.3	75.2	117.1	116.9	114.1	111.2	111.1	110.5	107.7	107.6	108.0	108.2	110.4	125.4	103.1	61.9	54.3	47.5	36.8	31.2	1,897
Nansadi	Thyolo	50.5	51.0	50.5	48.6	55.8	138.5	215.6	215.2	210.1	204.7	204.5	203.4	198.3	198.1	198.9	199.2	203.1	230.8	189.7	113.9	99.9	87.4	67.8	57.4	3,493
Fifite	Thyolo	31.0	31.3	31.0	29.8	34.3	85.1	132.5	132.2	129.1	125.8	125.6	125.0	121.9	121.7	122.2	122.4	124.8	141.8	116.6	70.0	61.4	53.7	41.7	35.3	2,146
Chinyama	Mulanje	27.1	27.3	27.0	26.0	29.9	74.2	115.6	115.3	112.6	109.7	109.6	109.0	106.3	106.1	106.6	106.7	108.9	123.7	101.7	61.0	53.5	46.8	36.3	30.8	1,872
Nanthombozi	Mulanje	24.7	24.9	24.7	23.8	27.3	67.8	105.5	105.3	102.8	100.2	100.0	99.5	97.0	96.9	97.3	97.4	99.4	112.9	92.8	55.7	48.9	42.7	33.2	28.1	1,709
Chilinga	Phalombe	15.6	15.7	15.6	15.0	17.2	42.8	66.6	66.4	64.8	63.2	63.1	62.8	61.2	61.1	61.4	61.5	62.7	71.3	58.6	35.1	30.8	27.0	20.9	17.7	1,078
Mlomba	Phalombe	27.3	27.6	27.3	26.3	30.2	74.9	116.6	116.4	113.6	110.7	110.6	110.0	107.2	107.1	107.5	107.7	109.9	124.8	102.6	61.6	54.0	47.2	36.7	31.1	1,889
Chapananga	Chikwawa	56.7	57.2	56.6	54.5	62.6	155.3	241.8	241.4	235.6	229.6	229.3	228.1	222.4	222.1	223.0	223.4	227.8	258.9	212.8	127.7	112.0	98.0	76.1	64.4	3,917
Livunzu	Chikwawa	6.5	6.6	6.5	6.3	7.2	17.9	27.9	27.9	27.2	26.5	26.5	26.3	25.7	25.6	25.8	25.8	26.3	29.9	24.6	14.7	12.9	11.3	8.8	7.4	452
Tengani	Nsanje	76.2	76.9	76.1	73.3	84.2	208.9	325.2	324.6	316.8	308.8	308.4	306.8	299.1	298.7	299.9	300.4	306.4	348.1	286.1	171.7	150.6	131.8	102.3	86.6	5,268
Mankhokwe	Nsanje	36.1	36.4	36.0	34.7	39.9	98.9	153.9	153.7	150.0	146.2	146.0	145.2	141.6	141.4	142.0	142.2	145.0	164.8	135.4	81.3	71.3	62.4	48.4	41.0	2,494
Marka	Nsanje	80.4	81.1	80.3	77.3	88.9	220.5	343.2	342.6	334.4	325.9	325.5	323.7	315.7	315.2	316.5	317.0	323.3	367.4	302.0	181.2	159.0	139.1	107.9	91.4	5,560

Table 4-2-2 Basic Data and Forecasted Power Demand for Unelectrified TCs (1/5)

District Number	District Name	TC Number	TC Name	Peak Power Demand (kW)	Population Size	Number of Household	Nos. of Public Facility	Nos. of Business Entities	Annual Market Fee (MKW)	Remarks
1	Chitipa	1	Nthalire	385.22	1,455	291	18	55	75,000	
1	Chitipa	2	Lupita	382.41	1,440	288	17	20	72,000	
1	Chitipa	3	Wenya	373.52	1,611	322	12	6	49,000	
1	Chitipa	4	Kameme	391.45	1,710	342	12	5	45,000	
1	Chitipa	5	Chsenan	208.16	806	161	11	6	35,000	
1	Chitipa	6	Kapoka	263.10	1,110	222	9	5	35,000	
1	Chitipa	7	Chisenga	94.23	286	57	-	-	-	
1	Chitipa	8	Mulembe	34.84	68	14	-	-	-	
2	Karonga	9	Songwe	113.28	390	78	10	20	248,085	
2	Karonga	10	Kibwe	382.42	1,770	354	13	35	144,000	
2	Karonga	11	Pusi	356.15	1,295	259	12	23	140,620	
2	Karonga	12	Iponga	56.29	186	37	16	7	53,915	
2	Karonga	13	Miyombo	113.28	390	78	7	4	30,010	
2	Karonga	14	Mlare	37.97	195	39	9	6	21,680	
2	Karonga	15	Chihepasha	37.97	195	39	2	3	18,048	
2	Karonga	16	Mwenitete	43.42	95	23	13	6	350	
2	Karonga	17	Tilora	37.97	195	39	9	1	350	
2	Karonga	18	Hara	26.26	29	4	9	7		
2	Karonga	19	Lupembe	113.28	390	78	14	6		
3	Rumphi	20	Katowo	296.77	1,075	215	12	52	35,539	
3	Rumphi	21	Chitimba	19.53	95	19	12	40	23,400	
3	Rumphi	22	Lara	113.28	390	78	12	8	5,005	
3	Rumphi	23	Muhuju	203.92	790	156	15	21	3,961	
3	Rumphi	24	Mwasisi	113.28	390	78	10	5	1,203	
3	Rumphi	25	Nchenachena	189.25	700	140	-	-	-	
3	Rumphi	26	Nkhozo	117.14	413	83	8	5	-	
3	Rumphi	27	Ng'onga	50.64	194	31	10	6	-	
3	Rumphi	28	Kamphenda	113.28	390	78	5	4	-	
3	Rumphi	29	Mphompha	113.28	390	78	18	4	-	
4	Nkhata Bay	30	Mpamba	114.86	697	80	28	59	164,808	
4	Nkhata Bay	31	Kavuzi	175.81	697	147	13	12	131,844	
4	Nkhata Bay	32	Khondowe	37.97	195	39	16	11	100,000	
4	Nkhata Bay	33	Sanga	16.20	70	15	22	14	58,845	
4	Nkhata Bay	34	Usisya	322.96	1,220	244	22	22	58,842	
4	Nkhata Bay	35	Nthungwa	152.81	422	122	15	9	50,247	
4	Nkhata Bay	36	Ruarwe	268.38	1,885	250	6	9	17,137	
4	Nkhata Bay	37	Chituka	113.28	390	78	18	23	14,500	
4	Nkhata Bay	38	Maula	37.97	195	39	22	24	14,282	
4	Nkhata Bay	39	Lwazi	37.97	195	39	23	24	12,000	
5	Mzimba	40	Edingeni	27.34	71	5	23	25	372,000	
5	Mzimba	41	Euthini	349.89	1,150	230	22	138	362,496	
5	Mzimba	42	Mpherembe	223.92	780	156	27	65	312,000	
5	Mzimba	43	Jenda	81.48	270	43	14	38	255,500	
5	Mzimba	44	Manyamula	223.92	780	156	19	33	216,000	
5	Mzimba	45	Eswazini	59.81	114	19	16	14	144,000	
5	Mzimba	46	Luwelezi	81.48	209	43	19	20	60,000	
5	Mzimba	47	Emfeni	53.35	224	34	20	15	60,000	
5	Mzimba	48	Engutwini	113.28	390	78	18	11	48,000	

Table 4-2-2 Basic Data and Forecasted Power Demand for Unelectrified TCs (2/5)

District Number	District Name	TC Number	TC Name	Peak Power Demand (kW)	Population Size	Number of Household	Nos. of Public Facility	Nos. of Business Entities	Annual Market Fee (MKW)	Remarks
7	Kasungu	49	Chamama	142.04	225	44	13	181	324,000	
7	Kasungu	50	Mpepa	63.42	80	23	16	18	116,141	
7	Kasungu	51	Matenje	28.07	45	6	19	14	30,000	
7	Kasungu	52	Simlemba	115.79	407	81	16	7	20,000	
7	Kasungu	53	Kamboni	56.96	191	38	11	7	17,000	
7	Kasungu	54	Kapheni	58.77	200	40	16	7	8,000	
8	Nkhotakota	55	Mkaika	504.93	2,000	379	12	61	350,000	
8	Nkhotakota	56	Dwambadzi	349.91	1,000	296	27	73	200,000	
8	Nkhotakota	57	Msenjere	31.68	950	10	7	14	60,000	
8	Nkhotakota	58	Kasitu	31.68	600	10	8	21	40,000	
9	Ntchisi	59	Nthesa	50.15	40	8	8	37	22,800	
9	Ntchisi	60	Khuwi	69.54	295	52	5	54	20,000	
9	Ntchisi	61	Kamsonga	303.23	1,000	200	19	35	11,400	
9	Ntchisi	62	Chinguluwe	127.66	350	72	13	9	9,600	
9	Ntchisi	63	Bumphula	162.87	503	111	6	21	6,300	
9	Ntchisi	64	Malambo	163.01	321	89	14	25	6,000	
9	Ntchisi	65	Ng'ombe	28.97	37	7	5	17	5,400	
9	Ntchisi	66	Kasakula	122.24	321	66	17	18	4,200	
9	Ntchisi	67	Mzandu	67.93	116	28	11	15	3,600	
9	Ntchisi	68	Nthondo	124.05	376	68	21	39	2,400	
9	Ntchisi	69	Kayoyo	89.60	600	52	11	7	2,400	
10	Dowa	70	Thambwe	141.75	500	132	13	63	245,760	
10	Dowa	71	Bowe	205.31	790	158	13	36	88,920	
10	Dowa	72	Chiseflo	183.64	537	134	14	33	72,000	
10	Dowa	73	Bibanzi	17.10	72	16	5	12	72,000	
10	Dowa	74	Msalanyama	47.03	129	27	4	13	56,160	
10	Dowa	75	Kachigamba	157.32	654	127	5	18	52,560	
10	Dowa	76	Chinkhwiri	131.00	550	120	6	18	52,560	
10	Dowa	77	Lipri	125.72	424	92	16	17	50,040	
10	Dowa	78	Kasuntha	264.00	1,037	223	6	20	50,040	
10	Dowa	79	Chankhunga	117.46	600	105	11	28	47,520	
10	Dowa	80	Nalunga	45.22	103	65	9	17	47,520	
10	Dowa	81	Dzoole	104.95	336	69	9	23	28,800	
10	Dowa	82	Kalonga	47.80	250	50	5	12	36,000	
10	Dowa	83	Kalumbu	145.86	450	70	11	76	-	
10	Dowa	84	Mkukula	123.91	2,500	90	9	17	-	
10	Dowa	85	Chakadza	158.09	750	150	3	0	-	
10	Dowa	86	Chimungu	85.86	500	70	0	0	-	
10	Dowa	87	Thonje	85.86	600	70	0	0	-	
10	Dowa	88	Kayembe	114.88	500	80	0	0	-	
10	Dowa	89	Simbi	85.86	450	70	0	0	-	
10	Dowa	90	Bweya	81.34	350	65	0	0	-	
10	Dowa	91	Ntiti	114.88	2,000	80	0	0	-	
11	Salima	92	Kandulu	153.31	615	123	4	36	57,450	
11	Salima	93	Chilambula	42.98	225	45	5	15	57,450	
11	Salima	94	Kambiri Sch.	113.28	390	78	2	5	57,450	
11	Salima	95	Khwidzi	113.28	390	78	4	5	51,450	
11	Salima	96	Thavite	113.28	390	78	7	13	23,200	
11	Salima	97	Makioni	24.46	11	2	5	6	23,200	
11	Salima	98	Michulu	113.28	390	78	3	4	23,200	
11	Salima	99	Chikombe	69.74	200	30	5	17	14,477	
11	Salima	100	Mnema	26.26	12	4	5	5	14,417	
11	Salima	101	Chitala	223.92	780	156	8	10	14,417	
11	Salima	102	Chinguluwe	113.28	390	78	5	2	14,417	
11	Salima	103	Siyasiya	113.28	390	78	8	26	14,417	
11	Salima	104	Matenje	37.97	195	39	2	1	14,417	
11	Salima	105	Chagunda	113.28	390	78	7	4	3,600	
11	Salima	106	Pemba	223.92	780	156	4	9	3,600	
11	Salima	107	Mphinzi	37.97	195	39	6	0	3,600	

Table 4-2-2 Basic Data and Forecasted Power Demand for Unelectrified TCs (3/5)

District Number	District Name	TC Number	TC Name	Peak Power Demand (kW)	Population Size	Number of Household	Nos. of Public Facility	Nos. of Business Entities	Annual Market Fee (MKW)	Remarks
12	Lilongwe	108	Chilobwe	306.77	1,240	248	11	50	432,000	
12	Lilongwe	109	Nyanja	59.22	205	41	8	2	414,000	
12	Lilongwe	110	Kasiya	315.74	1,121	236	17	20	360,000	
12	Lilongwe	111	Chawantha	38.90	77	18	7	4	360,000	
12	Lilongwe	112	Malembo	109.60	243	52	12	6	300,000	
12	Lilongwe	113	Nsaru	437.77	1,615	349	11	44	180,000	
12	Lilongwe	114	Kabudula	36.06	203	37	8	12	72,000	
12	Lilongwe	115	Hiunjiza	198.09	1,500	150	8	9	60,000	
12	Lilongwe	116	Phirilanjuli	91.41	279	54	6	6	48,000	
12	Lilongwe	117	Kachale	96.20	200	15	4	12	48,000	
12	Lilongwe	118	Chimbalanga	114.88	800	80	12	15	48,000	
12	Lilongwe	119	Mtema	169.96	842	141	11	5	30,000	
12	Lilongwe	120	Bisai	112.18	299	77	6	7	28,800	
12	Lilongwe	121	Mbng'ombe	152.94	1,000	100	6	11	24,000	
12	Lilongwe	122	Sinumbe	26.26	22	4	4	5	12,000	
12	Lilongwe	123	Kang'oma	227.12	724	160	9	6	3,000	
12	Lilongwe	124	Chiwamba	102.11	402	88	8	4	1,500	
12	Lilongwe	125	Chadza	224.14	867	201	7	0	1,500	
12	Lilongwe	126	Kalumbu	188.92	698	162	9	6	800	
12	Lilongwe	127	Kalima	45.22	130	25	5	1	750	
13	Mchinji	128	Mkanda	272.69	830	166	17	120	551,000	
13	Mchinji	129	Chiosya	190.49	595	119	15	41	414,000	
13	Mchinji	130	Mikundi	41.61	105	21	22	23	165,000	
13	Mchinji	131	Nkhwazi	27.17	25	5	16	16	50,000	
13	Mchinji	132	Gumba	113.28	390	78	13	11	50,000	
13	Mchinji	133	Kazyozyo	44.32	129	24	16	10	45,000	
13	Mchinji	134	Gumulira	34.39	67	13	4	13	40,000	
13	Mchinji	135	Kabzyala	10.78	46	9	7	10	12,000	
13	Mchinji	136	Kalulu	31.68	50	10	11	14	10,800	
14	Dedza	137	Kabwazi	52.66	186	33	11	37	275,400	
14	Dedza	138	Golomoti	110.78	139	31	17	46	192,000	
14	Dedza	139	Chimoto	113.28	390	78	15	23	143,000	
14	Dedza	140	Chiluzi	191.95	384	77	11	18	130,000	
14	Dedza	141	Mphati	113.28	390	78	8	14	100,000	
14	Dedza	142	Magomelo	343.92	780	156	17	41	78,000	
15	Ntcheu	143	Ntonda	132.31	338	55	19	17	384,000	
15	Ntcheu	144	Kasinje	263.92	780	156	23	53	289,126	
15	Ntcheu	145	Kadzakalowa	300.39	982	219	18	25	250,000	
15	Ntcheu	146	Kandeu	111.11	380	76	20	51	210,000	
15	Ntcheu	147	Sharpvalle	517.75	2,075	415	23	65	180,000	
15	Ntcheu	148	Bilila	203.92	780	156	21	19	110,000	
15	Ntcheu	149	Pengapenga	121.48	202	43	7	21	110,000	
15	Ntcheu	150	Kaloga	283.92	780	156	20	25	58,900	
15	Ntcheu	151	Masasa	3.55	4	1	0	0	-	
16	Mangochi	152	Makanjira	410.20	1,040	208	21	50	360,000	
16	Mangochi	153	Chilipa	32.03	50	10	10	59	240,000	
16	Mangochi	154	Chiponde	243.92	780	156	14	27	130,000	
16	Mangochi	155	Majuni	113.28	390	78	14	7	100,000	
16	Mangochi	156	Mvumba	62.52	212	22	18	14	94,158	
16	Mangochi	157	Katuli	65.36	10	3	14	26	80,000	
16	Mangochi	158	Mkumba	286.71	1,130	226	15	15	38,788	
16	Mangochi	159	Katema	176.12	514	121	12	15	38,630	
16	Mangochi	160	Lungwena	203.92	780	156	13	13	20,000	
16	Mangochi	161	Kwisimba	94.23	285	57	-	-	-	

Table 4-2-2 Basic Data and Forecasted Power Demand for Unelectrified TCs (4/5)

District Number	District Name	TC Number	TC Name	Peak Power Demand (kW)	Population Size	Number of Household	Nos. of Public Facility	Nos. of Business Entities	Annual Market Fee (MKW)	Remarks
17	Machinga	162	Chikwewu	374.60	1,505	301	30	195	249,455	
17	Machinga	163	Nampeya	400.55	1,760	352	14	58	204,000	
17	Machinga	164	Ngokwe	41.61	74	21	26	115	158,705	
17	Machinga	165	Mposa	32.58	54	11	11	18	142,938	
17	Machinga	166	Nayuchi	71.55	158	32	19	37	136,297	
17	Machinga	167	Msosa	74.12	286	57	5	12	116,617	
17	Machinga	168	Ngwepele	133.21	278	56	9	40	114,578	
17	Machinga	169	Mangamba	59.81	94	19	22	33	92,108	
17	Machinga	170	Likhonyowa	113.28	390	78	15	29	81,077	
17	Machinga	171	Malundani	203.92	780	156	21	62	24,066	
17	Machinga	172	Nanyumbu	37.97	195	39	14	6	-	
17	Machinga	173	Molipa	113.28	390	78	11	14	-	
18	Balaka	174	Chendausiku	250.20	1,040	208	5	27	80,000	
18	Balaka	175	Kwitanda	48.60	255	51	5	24	40,000	
18	Balaka	176	Phimbi	37.97	195	39	7	4	18,000	
19	Zomba	177	Jenale	64.22	120	24	7	20	268,800	
19	Zomba	178	Sunuzi	116.43	520	104	3	41	248,600	
19	Zomba	179	Zaone	243.92	780	156	14	39	192,000	
19	Zomba	180	Muwa	67.03	135	27	8	11	192,000	
19	Zomba	181	Mpyupyu	223.92	780	156	11	30	144,000	
19	Zomba	182	Masaula	223.92	780	156	22	26	115,200	
19	Zomba	183	Nachuma	113.28	390	78	6	12	96,000	
19	Zomba	184	Khonjeni	37.97	195	39	6	8	96,000	
19	Zomba	185	Kachulu	203.92	780	156	19	28	94,000	
19	Zomba	186	Sakata	6.04	19	4	12	12	57,600	
19	Zomba	187	Makina	203.92	780	156	0	17	48,000	
19	Zomba	188	Ngwelero	223.92	780	156	18	25	44,800	
19	Zomba	189	Chisunzi	113.28	390	78	11	10	38,000	
19	Zomba	190	Ngondole	203.92	780	156	22	11	24,000	
20	Chiradzulu	191	Kanje	203.92	780	156	3	20	610,833	
20	Chiradzulu	192	Milepa	62.34	110	22	7	40	462,187	
20	Chiradzulu	193	Chimwawa	37.97	195	39	10	10	206,782	
20	Chiradzulu	194	Ndunde	50.78	155	31	2	14	107,151	
21	Blantyre	195	Chikuli	110.80	490	98	6	46	384,000	
21	Blantyre	196	Mombo	16.72	80	16	3	26	174,000	
21	Blantyre	197	Dziwe	37.97	195	39	8	5	80,000	
21	Blantyre	198	Mudi	100.66	321	64	7	3	58,842	
21	Blantyre	199	Mlenje	38.45	88	18	5	5	48,000	
21	Blantyre	200	Domwe	113.28	390	78	2	6	35,000	
21	Blantyre	201	Chigwaja	113.28	390	78	4	8	-	
21	Blantyre	202	Linjidzi	113.28	390	78	6	7	-	
22	Mwanza	203	Chikonde	113.28	390	78	23	45	176,826	
22	Mwanza	204	Thambani	232.69	830	166	14	23	126,000	
22	Mwanza	205	Ligowe	113.28	390	78	14	11	72,077	
22	Mwanza	206	Kam'mwamba	91.09	158	32	9	21	32,606	
22	Mwanza	207	Matope	203.92	780	156	14	9	15,108	
22	Mwanza	208	Magaleta	19.36	93	19	14	2	10,555	
22	Mwanza	209	Kanenekude	52.67	166	33	15	12	-	
22	Mwanza	210	Tulonkhondo	144.59	454	91	13	10	-	
22	Mwanza	211	Kasuza	68.97	22	7	14	16	-	
23	Thyolo	212	Nansadi	254.58	1,175	235	13	18	288,000	
23	Thyolo	213	Fifite	156.43	520	104	5	43	168,000	
23	Thyolo	214	Lalakani	9.88	25	8	3	6	15,000	
23	Thyolo	215	Thomasi	203.92	780	156	12	11	12,000	
23	Thyolo	216	Makapwa	37.97	195	39	7	6	12,000	
23	Thyolo	217	Sandama	341.15	390	78	10	7	12,000	
23	Thyolo	218	Chipho	151.90	403	121	8	7	9,000	

Table 4-2-2 Basic Data and Forecasted Power Demand for Unelectrified TCs (5/5)

District Number	District Name	TC Number	TC Name	Peak Power Demand (kW)	Population Size	Number of Household	Nos. of Public Facility	Nos. of Business Entities	Annual Market Fee (MKW)	Remarks
24	Mulanje	219	Chinyama	136.43	520	104	11	23	360,000	
24	Mulanje	220	Nkando	150.10	483	110	0	43	260,000	
24	Mulanje	221	Nanthombozi	124.54	345	69	3	29	216,000	
24	Mulanje	222	Chambe	262.60	995	199	0	0	208,000	
24	Mulanje	223	Mathambi	155.12	625	125	0	0	130,000	
24	Mulanje	224	Chinakanaka	146.12	575	115	0	0	119,600	
24	Mulanje	225	Msikawanjala	47.64	250	50	0	0	52,000	
24	Mulanje	226	Namphundo	58.64	199	40	0	15	41,600	
24	Mulanje	227	Kambenje	16.15	75	15	0	0	15,600	
24	Mulanje	228	Kamwendo	145.58	430	114	0	9	7,800	
25	Phalombe	229	Chilinga	78.59	62	18	29	52	260,000	
25	Phalombe	230	Mlomba	137.67	415	83	11	40	208,000	
25	Phalombe	231	Phaloni	26.26	20	4	1	9	208,000	
25	Phalombe	232	Chitekesa	113.28	390	78	14	14	156,000	
25	Phalombe	233	Mpasa	37.97	195	39	16	7	41,600	
25	Phalombe	234	Nambazo	113.28	390	78	13	5	10,400	
26	Chikwawa	235	Mitondo	161.61	74	21	13	22	280,000	
26	Chikwawa	236	Linvunzu	32.97	55	11	12	24	200,000	
26	Chikwawa	237	Kakoma	203.92	780	156	9	11	41,000	
26	Chikwawa	238	Tomali	32.36	54	11	13	5	28,458	
26	Chikwawa	239	Ndakwera	99.58	94	19	5	12	28,000	
26	Chikwawa	240	Kanyinda	174.34	286	57	11	24	15,000	
27	Nsanje	241	Tengani	383.98	1,560	312	17	78	576,000	
27	Nsanje	242	Mankhokwe	181.75	660	132	0	2	300,000	
27	Nsanje	243	Mtowe	223.92	9,205	156	15	47	294,288	
27	Nsanje	244	Mbenje	107.35	248	50	12	34	115,200	
27	Nsanje	245	Masenjere	203.92	8,389	156	13	29	15,120	
27	Nsanje	246	Kampata	36.96	3,610	38	5	6	13,824	
27	Nsanje	247	Lulwe	58.90	87	18	6	11	-	
27	Nsanje	248	Chididi	223.92	7,890	156	8	11	-	
27	Nsanje	249	Sankhulani	203.92	3,963	156	3	26	-	

Number of total TCs 249

CHAPTER 5 DISTRIBUTION SYSTEM

Chapter 5 Distribution System

The current situation of the distribution system including house wiring, procedures to make electrification plan by grid extension and results of a case study are described in this chapter.

There are two objectives aimed for the distribution planning in this Master Plan.

(1) To propose a grid extension method for rural electrification, formulated in accordance with the situation in Malawi, providing also the cost estimation and formulating the procedures for the economical evaluation.

(2) To investigate at Pre-F/S level the electrification by grid extension based in a case study. Results of the case study will be used as a background for the elaboration of master plan. Parallel to the realization of the present investigation, to achieve technical transfer to DOE (counterpart).

5.1 Current Situation of Distribution System

Collected data and information concerning the distribution system, together with their analysis, are presented in this section.

ESCOM manages all existing transmission and distribution lines in Malawi according to some Acts and Regulations. Project planning is currently in progress between the ESCOM Head Office and DOE. The following points reflect the current situation of the distribution system based on data collection and site survey results (Appendix 5-1, 5-2).

5.1.1 Voltage classes

The 33kV and 11kV systems are configured as 3 phase-3wire lines, and the 0.4kV/0.23kV system has generally adopted the 3 phase-four wire configuration, but some areas have 5 wires to supply street lamps (Appendix 5-3).

5.1.2 Extended situation of main distribution lines

Three rural electrification programs conducted from the 1980's had supported the extension of distribution lines in Malawi. At present, the total length of distribution lines is about 8,500km as indicated in Table 5-1-1. The total combined length of 33kV and 11kV lines is 4,500km, and 0.4kV/0.23kV lines have an approximate length of 4,000km. The total length of transmission lines is approximately 1,800km. The location of existing and planned lines is described in detail in section 5.3.

In general, if the electrification ratio is higher, the total length of distribution lines is much longer than that of transmission lines. In Malawi, however, distribution lines are not much longer than transmission lines, and it is estimated that the electrification ratio is relatively low.

5.1.3 Operation of distribution lines

The National Control Center (NCC) operates existing main lines and the Area Control Center (ACC) manages the rest. The distribution lines are operated, controlled and maintained by three ACC, located in Blantyre at the Southern region, Lilongwe at the Central region and Mzuzu at the Northern region.

The voltages criterion is ±6% against rated voltages under the regulation. ESCOM has automatic voltage regulators and settings are 34kV or 35kV for systems with a rated voltage of 33kV in order to compensate the voltage drop at the distribution feeder. For 11kV system, typical setting voltage is 11.5kV.

A SCADA as shown in Fig.5-1-1 is installed at the ACC in Blantyre to collect information and control the substations. Operators of the ACC in Lilongwe and Mzuzu however still communicate by phones and radios.

The typical configuration of the distribution system is a radial form as shown in Fig. 5-1-2. When distribution lines have a fault, circuit breakers are opened by Over Current and/or Earth Fault relays in substations and the lines become isolated. After the sections which have fault points are separated by operation of Disconnecting Switches (DSs: Fig. 5-1-3), circuit breakers are closed again. In the case of longer distribution lines, re-closers are rarely installed along those lines as shown in Fig. 5-1-4.

In some areas with a greater concentration of customers requiring high reliability, such as hospitals and airports, the distribution lines are installed to form a loop system. One DS is normally opened for the operation described above. In the event that a fault occurs, the customers are able to receive power from another lines by operating the DSs.

Safety for maintenance works is another reason to install DSs. When maintenance works require inactivating the lines, the maintenance area is effectively separated from the live lines by the operation of DSs. In remote areas of Malawi, the risk of unreliable communication systems force maintenance workers to rely only in the operation of local DSs to interrupt the power.

Substations are generally installed in areas of high demand, and distribution systems are extended from these substations to remote areas. Most of the distribution lines supply the power to towns and rural areas. Therefore, the operation method of main feeders in towns and remote areas are basically the same. This configuration is similar for the system existing in Malawi.

5.1.4 Fault conditions

As shown in Fig. 5-1-5, the number of faults in 1998/99 was 30,124, increasing from 23,201 in 1994/95 with an average growth rate of 6.8%. The majority of faults were caused by lighting strikes. Since the total length of distribution lines was extended from 6,577km to 8,548km (7% of average growth rate) in the same period, it is estimated that faults increased as a result of the installation of distribution facilities.

5.1.5 Maintenance

The maintenance of distribution line is executed for every power lines and ESCOM ACC periodically make maintenance schedule which of their system taking into account the three following items:

(1) Load

Peak load of each feeder

(2) Defects

ESCOM conducts visual inspections to assess the conditions of distribution facilities with the exception of the wooden poles. The wooden poles are checked by sound tests when engineers hit the base of the poles during the dry season. These are useful methods and popular in other countries.

(3) Customer Category

This means that customers require high reliability, such as hospitals and water pumping.

The replacement of damaged facilities and mowing grass are the main items of periodical maintenance. Wooden poles are sometimes damaged from dry grass fires. At the time of the site survey, cutting of grass around wooden poles was observed several times in urban areas. However, these works were not detected in remote areas.

5.1.6 Distribution Facilities

The main distribution facilities in Malawi are summarized below. The majority of facilities must be imported from Southern Africa and Europe. Details of the site survey conducted by the Study Team are presented in Appendixes 5-1 and 5-2.

(1) Conductor

The distribution lines are classified into the following three types:

- Overhead line
- Overhead cable
- Underground cable

The underground cables are mainly used for city lines. Bare aluminum conductors, AAAC (All Aluminum Alloy Conductor) and AAC (All Aluminum Conductors), are usually used for overhead lines. 50mm^2 AAAC called "HAZEL" and 100mm^2 AAAC called "OAK" are typical conductors for 33kV and 11kV distribution systems. AAC "ANT" (50mm^2) and "WASP"(100mm^2) are typical for 0.4kV/0.23kV. ESCOM uses overhead cables for safety and prevention of faults in places with a high density of residences and overgrown trees. As for overhead lines in other countries, installation of ground wires is typical to prevent faults by lightning. In Malawi, ground wires are not installed in distribution lines except for several parts of cities, but they are installed in almost all transmission lines.

(2) Supporting Structure

Few concrete poles are installed in cities, with wooden poles generally being used as supporting structures of overhead feeders. Single wooden poles are usually utilized for the straight section and double poles for the angle and terminal points.

The majority of the wooden poles are installed along roads. This is a common method adopted for easier construction and maintenance.

While the typical span of wooden poles for 33kV and/or 11kV lines in rural areas is from 80m to 100m, it is sometimes about 50m around towns. It is believed that this difference is caused by the proximity of buildings. While more wooden poles are needed in order to avoid conglomerates of houses and retail shops in towns, fewer poles are needed in rural areas because buildings are few and disperse.

In case of 0.4kV/0.23kV lines, their span is usually shorter than 50m. There are also some cases in towns where the span is about 10m because of a high concentration of dwellings.

Regarding installation condition, the wooden poles in some areas were rotten and were therefore replaced (Fig. 5-1-6). The annual reports of ESCOM indicate that the main reason for damage was termite attack and the number of replaced poles increased from 843 in 1998/1999 to 1,620 in 1999/2000. During an interview conducted by the study team, an engineer of northern ACC reported disapproval of the inconsistent and short lifetime of recent wooden poles. Whereas the lifetime of wooden poles are generally around 15 or 20 years in other countries, some poles in Malawi are being replaced between 5 years and 10 years after installation.

Most of the poles are eucalyptus timber. These are supplied by the sole wooden pole maker in Malawi (Appendix 5-4).

However, ESCOM began to import wooden poles a few years ago after considering price and quality. The imported poles are made of pine. Some ESCOM engineers are concerned about the quality of these poles, because verification of quality takes a long time.

(3) Distribution Transformer (Fig.5-2-1)

The capacities of distribution transformers are 25, 50, 75, 100, 150, 200, 315 and 500kVA. Transformers with capacity lower than 200kVA are pole-mounted and the rest are installed on the ground. 50kVA and 100kVA transformers are popular in rural areas (Fig.5-1-7, 5-1-8).

These are installed with T-off connections from 33kV or 11kV feeders, and are provided with lightning arresters and cutout fuses.

The winding connection is as the Star-Delta system. The neutral point of the star side of 0.4kV/0.23kV windings is earthed. An on-load tap changer is normally provided on the delta side of 33kV or 11kV windings. The on-load tap changers have 5 taps and are generally operated in manual mode to regulate the secondary voltage. Technical problems in the operation of transformers have not been reported.

(4) Insulator

The pin and disc type are usually applied for 33kV and 11kV lines. The pin insulators are used for straight sections and glass disc insulators are mainly installed for tee-offs and terminals. The bobbin type is also used for 0.4kV/0.23kV lines.

According to the Annual Report of ESCOM (2000), the number of replaced insulators was about 900, however the number of insulators in Malawi estimated from the total length of lines is more than 200,000. Since the percentage of replaced insulators is less than 0.5%, it is considered that this is not a serious issue.

The glass insulators are sometimes broken by:

- Sudden changes in temperature when the first rain comes after the dry season.
- Children throwing stones.

(5) Switchgear Equipment

The typical 33kV and 11kV feeder bay consists of a circuit breaker, current transformer and arrestor. Circuit breakers are generally of the oil type. Disconnecting Switches along the line are the type of air break switch operated manually.

Since the number of DS is generally related to the electricity demand of the areas where they are installed, the number of installed units is different between towns and rural areas. Although DSs may be installed every several kilometers around towns, they are installed every 10km or more in some rural areas

5.1.7 Safety

Laws of Malawi include a large number of descriptions about safety related to electricity. The following items exemplify this:

(a) Anti-climbing devices for prevention of pole-climbing (Fig.5-1-9)

(b) Warning plate installation at every pole mounted transformer

(c) Protection against over current and earth leakage current

These are general safety methods. The study team has confirmed from site survey that these methods are carried out thoroughly in Malawi.

5.1.8 Results of the study on distribution facilities in remote areas of Malawi

Results of the study about the current situation of distribution systems in Malawi are summarized below.

In general, as the electrification ratio increases, customers require higher supply reliability. Distribution facilities installed in foreign countries in order to improve reliability of the electricity supply, including SCADA, ground wires, reserve lines and loop systems, are not applied in Malawi except in some towns. As a result, distribution systems in rural areas may not withstand faults and accidents without outage, because the system consists of the minimum equipment required for the power supply at normal conditions.

The only differences found in the facilities in towns and rural areas are, with exception of equipment to increase supply reliability, the number of installed DS and the span of wooden poles. Therefore, the situation of these installations should be considered in later studies.

In relation to the operation and maintenance, although there is no difference in the method followed in towns and rural areas, it is expected that the frequency of maintenance in the rural areas is lower than in towns.

With respect to safety issues, some regulations are well established and implemented in the field. However, the majority of consumers do not have enough knowledge about the use of electricity, especially about risks such as electric shocks and earth leakages. Therefore, it is necessary to consider safety issues based on Laws in Malawi, when electrical equipment is studied, especially house wiring.

5.2 Distribution System Planning

In this section, the distribution system planning to formulate the master plan for rural electrification is described. This will include the selection of electrification methods for the candidate trading centers.

5.2.1 Distribution planning manuals (Draft) of DOE

Before the planning method for the distribution system is presented, DOE's draft manuals related to distribution system planning were studied.

DOE has three tentative manuals related to distribution systems as listed in Table 5-1-2. DOE created these manuals with the cooperation of JICA experts. The following items are the key features of these manuals.

(1) Typical facilities and system configuration applied in Malawi, together with voltage classification and regulations under the law in Malawi are shown, however distribution planning procedures are insufficient.

(2) Typical values, such as span length and installed locations of wooden-poles, are specified. Those suit the present situation described in an earlier section.

(3) Although the operation method is based on ESCOM operation, the number of installed facilities is not shown.

5.2.2 Current situation of un-electrified areas in Malawi

Before the proposal of the distribution-planning method, un-electrified areas were studied in a similar way as the study of electrified areas around existing distribution lines.

Site surveys were conducted in the following 19 of the 27[1] districts in Malawi. (Appendixes 5-1

[1] Number of districts will increase to 28.

and 5-2)

(a) Northern region (2districts)
Nkhata Bay, Mzimba
(b) Central region (9 districts)
Kasungu, Nkhotakota, Ntchisi, Dowa, Salima, Lilongwe, Mchinji, Dedza, Ntcheu
(c) Southern region (9 districts)
Mangochi, Machinga, Balaka, Zomba, Chiradzulu, Blantyre, Thyolo, Mulanje

As for the remaining districts, since Likoma district is a small island and is already proposed for electrification under Phase IV, this has been excluded. The remaining 6 districts were investigated for micro hydro implementation, and information was collected from interviews, photographs, etc.

Contents and results of the study conducted about un-electrified are as follows.

(1) Topography outline and road conditions
The areas where TCs are located have in general a flat topography. While steep terrain is seen in national parks and forest reserves, no TCs are indicated on maps in these areas. Some slopes are found at the south in eastern Mangochi and Thyolo district, but as distribution lines are already installed around these areas, it is expected that the slopped terrain is not an obstacle for their construction. However, according to information from the counterpart and micro-hydro site surveys, the area along Lake Malawi in the Northern region has a steep topography, and therefore it is expected that grid extension is difficult there. There are only two un-electrified TCs in this area without access road, from a total of 249 TCs.

(2) Scale of TCs
The size of TCs is varied. While the electrified TCs are generally large, sometimes having a radius of several kilometers, the majority of the un-electrified TCs are small. The diameter is typically less than 1 km and most of the public facilities and retail shops are located in that area.

(3) Issues between TCs
TCs in Malawi are dispersed and the distance between TCs is usually more than 10km, with few retail shops and dispersed households between them. Residents often travel to nearby TCs by walking from several to more than 10 kilometers, being the main reason to visit Maize Mills. There are several Maize Mills in almost every TC and the residents can grind their maize since it is the staple food in Malawi. The other purpose to travel to TCs is to receive medical attention at hospitals. In some interviews conducted in Salima and Mzimba district, patients sometimes walk all day long for this purpose.

(4) Basic data of TCs

The distribution planning requires the location of target TCs as basic information. According to a presentation in a workshop, although maps from countries such as the Republic of Namibia are digitized, only printed maps are available in Malawi. Results of the surveys indicate that the information shown in maps such as locations of old roads and TCs, is reliable, but location of new TCs is not always clear, and in some cases some TCs are not shown at all.

5.2.3 Outline of distribution system planning

Based on the current situation in Malawi and according to objectives of this master plan, the distribution planning method should be proposed taking into account the following items:

- The target of this master plan is the whole country and the scope is very wide. Further to this, the location of TCs, which are the electrification targets, is dispersed.
- Since electrification ratio of about 4% is very low, the number of targets for electrification is large. The number of target TCs considered in this master plan is 249, and it is not expected that this number will reduce because of the population growth.
- As a result of site survey covering the whole country of Malawi, it s concluded that distribution facilities with the same specifications may be applied in general, except for a part in the Northern region which has special topography.

ESCOM has been extending the grid in Malawi in addition to DOE, as indicated before. According to ESCOM, the grid extension can be carried out at a rate of one kilometer in two days, if there is no problem for the procurement of materials. This means that plans conducted by DOE and ESCOM may overlap if this project takes time for plan formulation. Therefore, the proposed method requires the planning by DOE to be conducted quickly after data and information are collected.

This method consist of three stages as follows:

(1) Study of system location

The locations of existing and planning lines are studied. A new project will consider installation from those lines and starting points of new lines. The distribution planning also requires the existence terminal points of lines, which are the TCs. However, the location of many TCs cannot be specified in Malawi due to the limitations indicated earlier. To overcome this issue, it is important the coordination with the socio-economic survey. Distribution lines were also investigated during site surveys as part of this master plan in order to complement the coverage of the socio-economic survey. Information was collected mainly from interviews of residents. As a result, most locations of TCs were covered by the study team with exemption of a few located in the outskirts of cities. The contents of this study are described in Section 5.3.

(2) Design

Study for cost estimation, including voltage class, system configuration and capacity of facilities, are conducted as shown in Section 5.4. In this study, it is important to simplify the specifications applied for the facilities, where possible. This would influence the estimated cost and speed the planning implementation. This is shown in Section 5.5.

(3) Cost estimation

The construction cost is estimated. A main point to take into account is the priority of each TC. The construction cost for candidate TCs is estimated not only by considering the extended length and demand forecast but also the electrification priority. The planning of TCs with second priority must be made after all first-priority TCs are implemented. Further to this, if priority is changed or new TCs are added, the construction cost of concerned TCs has to be revised. This is described in Section 5.5.

The flow of the proposed method is shown below.

It is noted that the following two TCs are excluded for this study. It is assumed that the topography around these TCs is unsuitable for the installation of distribution lines.

<u>Study exclusion TC</u>

- Nkhondowe TC
- Ruarwe TC

（They are in Nkhata-Bay district）

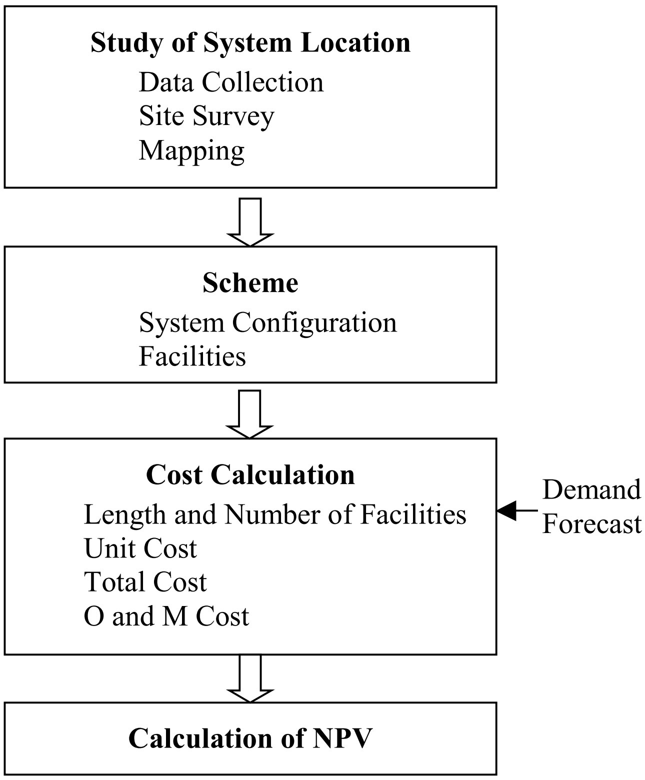
5.3 Study of System Location

In this section, the study of existing and planning system locations is described. Since the objective of the present study is to formulate a master plan for rural electrification, the following distribution lines were excluded from this study:

(a) 400/230V distribution lines,

(b) Lines in cities and towns

(c) Very short lines



Planning Flow

5.3.1 ESCOM data and information

In Malawi, ESCOM manages all transmission and distribution lines. The National Control Center (NCC) operates main existing lines and the Area Control Center (ACC) of ESCOM manages the rest. Project planning is currently in progress with the ESCOM Head Office and DOE. The following information was collected from ESCOM.

(1) ESCOM Head Office and NCC data for existing and planning system

The main existing and planning distribution lines are drawn on 1:1,000,000 maps and rough locations can be identified.

(2) ESCOM ACC data for existing system.

System diagrams of each region were collected; however, these are not drawn on maps. The study team acquired some information from interviews with ESCOM engineers about on-going projects and new lines.

5.3.2 DOE's data and information

DOE has a plan for the rural electrification program Phase Ⅳ. The total length of extended lines is estimated to be approximately 600km. The candidate areas for Phase Ⅳ are presented in Chapter 11.

5.3.3 Site survey

Site surveys for this study are not always required. In this study, the Study Team identified the following to confirm data from ESCOM.

- There are two or more sources of data and information for the same area, and these show some differences.
- The terminal point is not clear. This means that there is no location on the map and the terminal point is not a trading center.

Also it is recommended that the year when the existing lines will be extended be also investigated in the site survey. Since demand forecasts after the electrification of un-electrified TCs were based on the demand trend of electrified TCs, the year when the lines were extended is an important piece of information.

5.3.4 Results

The results of this study are described as follows:

(a) Although data from ESCOM Head Office and ACC show few differences regarding new installation lines, the reliability of ESCOM's data and information is sufficient to formulate the master plan. Therefore, it is recommended that both sets of data and information are collected and compared. If differences are identified, the site survey is preferable.

(b) Data and information for the 11kV lines are inexact for some areas. Many of the 11kV lines are installed around the cities/towns and their lengths are shorter than 33kV lines. These lines are not often used for rural electrification.

(c) The majority of distribution lines are installed along roads for ease of construction and maintenance. Since the location of some roads is not accurately shown on maps, caution is required during site survey investigations.

5.3.5 Mapping

Distribution planning for the formulation of the master plan of rural electrification requires maps showing existing and planning lines. Since maps specifying the location of trading centers are also needed, results of this study are based on the use of 1: 250,000 maps that are available in Malawi. Study results are summarized in Figure 5-3-1 and Appendix 5-1.

It can be confirmed from Figure 5-3-1 that there are long existing and/or planning distribution lines. It can also be noted that there is a large number of areas that do not have distribution lines.

5.4 Preliminary Design

In this section, the design necessary to formulate this master plan is summarized.

5.4.1 Voltage classes of distribution lines

In this study, electrification methods for a number of trading centers are compared on the database, consequently the voltage level for every trading center has not been studied. The classes utilized are listed in Table 5-4-1.

As for extension from existing distribution lines to trading centers, 33kV is applied taking into account the following:

(a) The voltage classes in Malawi are 33kV, 11kV and 0.4kV/0.23kV and the application of same voltage is preferable. Therefore, current voltage classes are applied. The 3-phases 3-wires system is adopted for Maize Mills in the majority of TCs.

(b) At present, the majority are 33kV lines but 11kV lines are installed around cities and towns. Many of the substations have 132kV/33kV and/or 66kV/33kV transformers.

(c) In general, the construction cost of an off-grid system is lower than grid extension when distribution lines are particularly long. Rather than 11kV, 33kV lines are more suitable to prevent voltage drop when the lines are particularly long and/or the trading center has a large demand.

In the case of off-grid systems run by mini-hydro, the majority of generators are installed around the demand area and the problem of voltage drop is unusual. Therefore, 11kV lines whose construction cost is cheaper than 33kV are applied.

The voltage class into trading centers is 0.4kV/0.23kV according to the Law of Malawi. The off-grid systems run by diesel generators also fall into this class.

5.4.2 System Configuration

(a) Radial system

The radial or loop configuration is generally applied for distribution systems. The reliability of loop systems is higher than radial systems. However, there are some issues such as high construction cost and complex protection system. The radial system without reserve lines is adopted for cost reduction, based on results of surveyed distribution systems in remote areas.

(b) Disconnecting Switch (DS)

When faults occur, DSs are operated to separate fault sections. DSs are assumed to be installed every 10km taking into account current situation in Malawi.

(c) Circuit Breaker (CB)

It is assumed that a new organization may manage the extended distribution lines, without concerning the management conducted by ESCOM. Therefore, a circuit breaker and meter will be installed at the connection point of the existing/planned system. This CB is not always necessary, assuming that ESCOM manages the whole new system.

5.4.3 Distribution system facilities

In order to undertake a concrete analysis, specifications were limited to only one type where possible, though DOE's draft manuals and ESCOM had adopted two or more types and capacities for one kind of facility.

The major features of facilities are described below and summarized in Table 5-4-2.

(1) Conductors

- The adopted size of conductors is 100 mm^2 taking into account voltage drop in case of long distances and large demands.
- Although DOE's draft manual applies 1 to 2% of the span length between supporting structures for sag, 5% is adopted based on actual data from ESCOM.

In Malawi, bare conductors are generally applied for 0.4kV/0.23kV. However, bare conductor lines cause frequent faults since they can short when touching obstacles and can be a major cause of illegal connections. The use of bare conductors for overhead LV lines is currently being abolished worldwide. If illegal connections are an issue, consideration of the adoption of overhead cables is recommended.

(2) Supporting Structure

Wooden poles are adopted and span lengths are 100m for 33kV/11kV and 50m for 0.4kV/0.23kV, according to results of site surveys conducted in remote areas in Malawi.

(3) Distribution transformer

- The capacity of 33kV/0.4kV or 11kV/0.4kV is 100kVA. This capacity is being used in many areas of Malawi and can easily supply a trading center with a large demand.
- Maximum loading is 80% of rated capacity based on the DOE manual

- Maximum loading is 80% of rated capacity. In case of TCs requiring more than 80% of rated capacity, additional transformers are installed. This is decided taking into consideration the demand growth in Malawi. If the installation of a new unit is evaluated when the loading is close to 100%, the transformer would be overloaded before the installation takes place.

5.5 Construction Cost

The construction cost is described in this section. This study is conducted by map studies based on past records of ESCOM, because of the large number of un-electrified trading centers in Malawi.

5.5.1 Length and Number of Facilities

(1) Length of 33kV and 11kV lines

The straight distances between candidate trading centers and existing/Planning distribution lines or generators of off-grid systems should be measured on the maps drawn in section 5.3. The measured distances multiplied by coefficient are taken as the length of distribution lines, since the actual lengths are longer than straight distances. The coefficient is derived from the average deference between actual installation length and straight distance from past records. It is recommended that this coefficient is revised in accordance with records from future projects.

In this master plan, the approximate installation lengths of some existing lines were studied based on site survey and data collection and compared with straight distances on maps. As a result, 120% of straight distance was estimated.

The following points are of remarkable importance for this study.

- The extension planning has to be made according to priorities. If all lines were planned to start from existing lines, the estimated cost of grid extension would be huge and very different from the required cost.
- While the priority of TCs was established for every district, the planning of grid extension is not considered for every district. The plan should start from the nearest distribution lines.

(2) Number of 33kV/0.4kV transformers at each trading center

The number of transformers is determined taking into account the demand, maximum loading of transformer and power factor. The demand is based on demand forecast for each trading center and the maximum loading is 80% as shown in section 5.4.3. The power factor varies according to the demand type. Standard power factors are 80% for maize-mill and 90% for the rest. The equations are as follows

$$Number\ of\ Transformer = \frac{Total\ Load\ of\ Trading\ Center(kVA)}{Rated\ Capacity(kVA) * Loading\ 80\%}$$

$$\begin{aligned} & Total\ Load\ of\ Trading\ Center(kVA) \\ & = Load\ of\ Maize\ Mill(kVA) + Load\ of\ other(kVA) \\ & = \left(\frac{Demand\ of\ Maize\ Mill(kW)}{power\ factor\ 90\%}\right) + \left(\frac{Demand\ of\ other(kW)}{power\ factor\ 80\%}\right) \end{aligned}$$

(3) 0.4kV/0.23kV lines

This study takes into account the main target of DOE which is the electrification of public facilities at trading centers. 0.4kV/0.23kV lines are installed from distribution transformers or diesel generators to public facilities.

The number and length of 0.4kV/0.23kV lines are assumed as follows:

- The length of each line between a distribution transformer and customers is 500m.
- Two lines are extended from each distribution transformer.

The number and length of lines at each trading center obtained using the above assumptions are applied when lines are installed from diesel generators.

These values are revised based on records, after completing all installations at each phase. The average values of length per line and number per trading center are then obtained. These values are available for planning of next phase.

(4) Circuit Beaker

A Circuit Breaker is installed at the starting point of new lines.

Construction costs exclude the cost of CB except for the following cases, if ESCOM continues to manage the whole distribution system in Malawi.

- Extension from existing substation
- Difficult protection cases (ex. long lines)

(5) Disconnecting Switch

Disconnecting Switches are installed every 10km according to sections 5.4.2. The value of 10km is revised based on records after completing the installation of each phase.

5.5.2 Unit cost

The unit costs based on the latest records are available for distribution planning, when the specifications are similar to the existing facilities. The foreign and local costs should be separated to consider the difference of exchange rates.

(1) 33kV or 11kV line

The unit cost per km to be used is the average of actual cost of the latest phases.

$$Unit\ Cost\ (US\$\ and\ MK/km) = \frac{Total\ Costruction\ Cost\ of\ 33kV\ or\ 11kV\ lines\ of\ the\ Latest\ Phase\ (US\$\ and\ MK)}{Total\ Length\ of\ 33kV\ or\ 11kV\ lines\ of\ the\ Latest\ Phase\ (km)}$$

(2) Distribution Transformer

The average cost of each transformer of the latest phase is to be applied.

$$Unit\ Cost\ (US\$\ and\ MK) = \frac{Total\ Costruction\ Cost\ of\ Transformer\ of\ the\ Latest\ Phase\ (US\$\ and\ MK)}{Total\ Number\ of\ Transformer\ of\ the\ Latest\ Phase}$$

(3) 0.4kV/0.23kV line

Similar to 33kV or 11kV lines, the unit cost per km to be used is the average of the actual cost of the latest phases.

$$Unit\ Cost\ (US\$\ and\ MK/km) = \frac{Total\ Costruction\ Cost\ of\ 0.4kV/0.23kV\ lines\ of\ the\ Latest\ Phase\ (US\$\ and\ MK)}{Total\ Length\ of\ 0.4kV/0.23kV\ lines\ of\ the\ Latest\ Phase\ (km)}$$

(4) CB and DS

The unit prices of the latest phase are used.

In this plan, the unit costs based on data collected from ESCOM and DOE are applied as shown in Appendix 5-5. Installation costs of lines per km were estimated based on the current situation in rural area of Malawi, including the span of wooden-poles as mentioned above. After the completion of PhaseIV, the above descriptions (1) to (4) will become applicable.

5.5.3 Total Cost

(1) Construction cost

The total cost for each trading center is the sum of costs of 33kV lines, transformer, circuit breaker, disconnecting switches and 0.4kV lines. The equations for every item are as follows:

Total construction cost(US$ and MK)

$= 33kV\ or\ 11kV + Tr + 0.4kV/0.23kV + CB + DS$

$33kV\ or\ 11kV$ (*Total construction cost of* $33kV$ *or* $11kV$ *lines (US$ and MK)*)

$= Unit\ Cost\ (US\$\ or\ MK/km) * Straight\ Distance\ (km) * Coefficient$

$$Tr\ (Total\ construction\ cost\ of\ Distribution\ Transformers\ (US\$\ and\ MK)\ ) = Unit\ Cost\ (US\$\ or\ MK) * Number$$

$$0.4kV / 0.23kV\ (Total\ construction\ cost\ of\ 0.4kV / 0.23kV\ lines\ (US\$\ and\ MK)\ ) = Unit\ Cost\ (US\$\ or\ MK / km) * Length\ (km) * Number$$

$$CB\ (Total\ construction\ cost\ of\ Circuit\ Brea\mathrm{ker}\ (US\$\ and\ MK)\ ) = Unit\ Cost\ (US\$\ or\ MK)$$

$$DS\ (Total\ construction\ cost\ of\ Disconnecting\ Switch\ (US\$\ and\ MK)\ ) = Unit\ Cost\ (US\$\ or\ MK) * Number$$

(2) Engineering Service

The costs of engineering services, which comprise detailed site survey and design, procurement works and site supervision, are preliminary estimated at 8.0% of the above construction cost.

(3) Administration Expenses

Administration expenses of the project owner (DOE) are preliminary estimated at 3.0% of the construction cost.

(4) Land Compensation

The construction of distribution systems is different from generation plants since it is easy to change the location of wooden poles without an important change of costs. Also there are no houses and farmlands in almost all rural areas of Malawi. In this study, land compensation was not included for such reasons.

(5) TAX (VAT)

In this report, Value added tax (VAT) was estimated at 10.0% of the construction cost and Engineering Services. This percentage was VAT rate at the time of this cost estimation. However, the tax increase for 20.0% was informed after draft final report was discussed. The re-estimation of cost according to the VAT rate at the time of project implementation is required.

(6) Estimated results

The total of the above cost V is the project cost of 249 TCs as shown in Table 5-5-1.

5.5.4 Economical evaluation

The cost estimated in above section is compared with the cost of other electrification methods in this master plan by conducting an economical evaluation. The suitable electrification method is selected for each TC based on this evaluation.

“Alternative thermal power method" is applied in this M/P study. For the alternative thermal power method, the cost of the alternative power (= diesel power) is regarded as the Benefit (B), and the cost of each target electrification method is regarded as the Cost (C).

Conditions for the application of this method are indicated in this section. Estimated results of grid extension and diesel power for the 249 TCs are also described.

Detailed of the “Alternative thermal power method" are included in section 6.7.

(1) Initial Investment Cost

The initial installation cost of grid extension is estimated according to the procedures and methods described in the above section 5.4.

(2) Operation and Maintenance Cost

There are three items for the operation and maintenance (O&M) cost:

(a) Fuel cost for ESCOM power plants

(b) O&M cost for ESCOM power plants and transmission lines

(c) O&M cost for installed distribution lines

For the item (a) and (b), the values per kWh indicated in Annual Report of ESCOM(2000) were applied like formulation of master plan study.

As for item (c), O&M cost of distribution system and extension length of ESCOM facilities which are described in the Annual Report of ESCOM (2000) were taken into account. The estimated percentage is about 1.6% of installation cost. However, when the electrification ratio is low the O&M costs are likely to increase and 2% of installation cost is estimated instead.

(3) Results

The results of net present value (NPV) for grid extension and diesel power, and their comparison according to the Benefit/Cost ratio (B/C), are shown in Table 5-5-1.

The table shows that the B/C ratios for all the TCs are above 1.0, with exception of 2 TCs that were not estimated. This means that electrification by grid extension is more economical than diesel power in Malawi.

The future situation of distribution lines is forecasted as shown in Figs. 5-5-1 to 5-5-4, if the grid extension is carried out as planned above.

These figures show that distribution lines are extended in wide areas after Phase XV. Although there are some blank areas in Fig. 5-5-4, most of those areas are part of national parks and forest reserves as shown in Fig. 5-5-5.

5.6 Case Studies on Distribution Systems

The Case Study is a more detailed study after grid extension was selected as the method of electrification for the candidate trading centers (TC). The two objectives of the Case Study are described below.

(1) The formulation of the grid extension method taking into account particular situations of each TC

The formulation process will be based in the following points.

(a) Selection of the tentative route for the 33kV and 11kV distribution lines

(b) Selection of the tentative route to extend distribution lines to public facilities in the TCs

(c) Based on above tentative routes, to study whether electricity supply is possible under the voltage regulation in Malawi or not.

(d) Evaluation of the above results and analysis of the revision of the master plan method

(2) Technical transfer to counterpart

The results of the rural electrification master plan showed that all candidate TCs for Phase V were selected for electrified by grid extension. While the case study is conducted for 4 TCs as presented in this report, DOE counterpart has to conduct the case study for the remaining 48 TCs by itself. Therefore, technical transfer to DOE is addressed for the continued undertaking of the case studies.

5.6.1 Selection of Trading Centers

The trading centers for the case study were selected taking into account following items.

(1) Region

The regional balance was considered, because Malawi is comprised of three regions, Northern, Central and Southern. Since a case study for mini-hydro was conducted including study of lines from generators to the TC in the Northern Region, grid extension was studied for the Central and Southern Regions. Two TCs were selected for grid extension per region.

(2) Prioritization

First priority trading centers of each district were selected.

(3) Distance from existing and Planned lines

The areas where the distance from existing or planned lines is as close as 1km are considered unsuitable, because the study of 33kV or 11kV lines cannot be conducted. And in the case of long distances between distribution lines and trading centers, DOE is not able to acquire any new experience from the implementation of this option. Therefore, a distance of approximately 10 km was considered suitable for this study.

(4) Peak Demand

Trading centers that have a peak demand different from the forecast presented in Chapter 1 were selected. In general, a TC with a large peak demand has many 0.4kV/0.23kV lines, and a TC with a small demand has only a simple system.

As a result, the following trading centers are selected.

(a) Northern Region

Ruarwe TC (Nkhata-bay district)

- Case study for mini-hydro (Refer to Chapter 3)
- Forecasted Peak demand (20 years after electrification) 58kW

(b) Central Region

Mkaika TC (Nkhota-kota district)

- Priority 1st
- Distance from Planning line approximately 10km
- Forecasted Peak demand (20 years after electrification) 505kW

Nthesa TC (Nchisi district)

- Priority 1st
- Distance from existing line approximately 11km
- Forecasted Peak demand (20 years after electrification) 50kW

(c) Southern Region

Chiendausiku TC (Balaka district)

- Priority 1st
- Distance from existing line approximately 13km
- Forecasted Peak demand (20 years after electrification) 255kW

Chikweo TC (Machinga district)

- Priority 1st
- Distance from existing line approximately 18km
- Forecasted Peak demand (20 years after electrification) 375kW

5.6.2 Flow

A Map Study, Site Survey and Study of Voltage Drop were conducted for the 33kV and 11kV lines as shown in the following figure. This is followed by estimation of installation costs for each trading center. The outline of each item is described below.

5.6.3 Map Study

The objective of carrying out a map study is to decide the tentative routes for the 33kV or 11kV lines from the starting point to the candidate TCs. The 1:250,000 maps studied in Section 5.3 of the Technical Background Report are used, and the standard route is drawn on these maps along the roads.

This map study is not carried out for all of the TCs. If the access roads for candidate TC are not specified on the maps, this study cannot be conducted. In these cases, a site survey is conducted after the nearest existing or planned distribution lines are confirmed on the map.

5.6.3 Site Survey

(1) Starting point of 33kV or 11kV lines

To investigate the dividing point or substation or generator which was selected from the map study. If other distribution lines were extended near the TC, the map and route are revised.

(2) Route of 33kV or 11kV lines

This survey is conducted to investigate about the existence of any obstacle for the construction. Large rivers and steep terrain that make the construction of wooden poles are an example. If a difficulty is identified during the survey and the route of distribution lines has to change considerably, the map study is repeated based on these results.

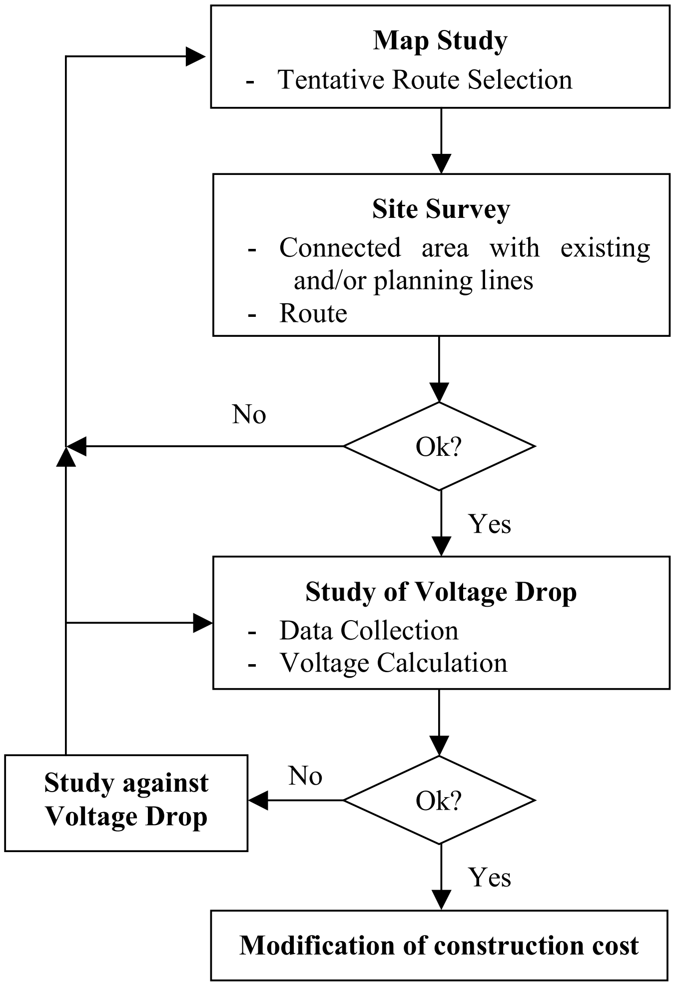


Fig.5-6-1 Flow of Case Study (33kV and 11kV Lines)

(3) Distribution transformer and 0.4kV/0.23kV lines

The tentative locations of distribution transformer and 0.4kV/0.23kV lines are studied. The procedure is the following.

(a) To draw an outline map of the candidate trading center.

(b) To select the suitable area sites where pole-mounted transformer will be installed.

(c) To draw the most suitable route between the distribution transformer and the public facilities on the outline map. Route distances are estimated.

5.6.4 Study of Voltage Drop

The voltage drop after installation of lines is assumed based on demand forecast, distance of distribution lines and current voltage condition. The current voltage conditions are collected from ESCOM.

If any problems occur with respect to the voltage of 33kV lines, discussion with ESCOM will be necessary regarding issues related to voltage compensation as follows.

(a) Re-evaluation of route (ex. new feeder from substation)

(b) Installation of facilities to compensate for voltage drop (ex. static capacitors, step voltage regulators)

As for 0.4kV/0.23kV lines, the following measures are considered.

(a) Change of the pole-mounted transformer location

(b) Change from single phase to 3 phases

5.6.5 Cost estimation and economical/financial evaluation

DOE installs distribution lines to public facilities in the TCs considered for Phase V. The installation cost of electrification for public facilities in each TC is estimated in this section, The installation cost of grid extension to satisfy the total demand of each TC is estimated based on tentative route to the public facilities considered in this case study, since the distribution lines to private sectors, such as households, retail shops and Maize Mills, will be extend by the management organization. Economical and financial evaluations are carried out for the total demand of each TC. The equipment to be extended includes the pole-mounted transformer and 0.4kV/0.23kV lines.

5.6.6 Result

The following key factors are outlined from the results

When the grid extension is planned, it is very important to determine the length of extension lines. Especially attention should be paid for the length of 33kV lines because of the strong impact on the total cost of grid extension.

The following table shows a comparison of the length of 33kV lines considered in the master plan and case study. As a result, it is found that these are similar except for Chikweo TC.

TC	Length (km)		
	Master Plan	Case Study	Diffrence
Chiendausiku	12	13	+1
Chikweo	18	10	-8
Mkaika	10	10	0
Nthesa	10	11	+1

The reason why extension lengths for Chikweo TC are different in both studies is the selection of the starting point. As described in the Technical Background Report, the construction in Malawi is carried out at a rate of two days per km. This is why the location of existing lines selected at the time of the master plan could differ from that selected by the case study. In such a case, the installed cost has to be revised during the case study. Thus the length of lines of master plan should be compared on the assumption that the 33kV lines were selected under different conditions.

In the case of Chikweo TC, the extension length of 33kV lines was 20km if lines were installed from the point determined by the master plan, thus this assumption results in a similar length for both master plan and case study.

Therefore, the proposed method for grid extension is suitable to formulate the master plan in Malawi.

5.7 House Wiring

The electrification ratio in Malawi is estimated as 4%. One of the reasons why the ratio is low is because the majority of the households cannot afford payment of house wiring. In this section, the house wiring for poor households in Malawi and southern Africa countries are described.

5.7.1 Current house wiring in Malawi

In Malawi, either the Prepaid Meter (Fig.5-7-1) or Ready Board (Fig. 5-7-2) is installed for some customers instead of conventional meter. The majority of ESCOM customers are using conventional meters.

According to ESCOM, the Prepaid Meter is one of the meters for high-income customers. A customer pays the tariff before using electricity and gets a receipt at the ESCOM office. The customer enters a code (written on the receipt) into the Prepaid Meter to be able to use the equivalent amount of electricity.

The Ready Board is a house wiring system for low-income customers promoted by ESCOM. The main components are conductors, sockets, breakers, earth leakage circuit breaker and a small lamp. These customers have some electric appliances such as cooking heaters (Fig.5-7-3), fans (Fig. 5-7-4), radios and lighting.

The Prepaid Meter is fixed on the wall of a house in the same way as a conventional meter, while the Ready Board is installed inside the house on the wall of a living room or dining room. In some cases consumers cut accidentally the cables of the Ready Board. Several electrical appliances are sometimes plugged to a single socket of the Ready Board, because it has only three sockets.

5.7.2 Key features of house wiring for poor households in Malawi

ESCOM reported that the main problem in electrifying the poverty stricken households is the house wiring. Major item requirements related to low cost and safe electrification are indicated below

a. Ready Board

The purchase price was MK6,000 including wiring cost and deposit of tariff. ESCOM sold 150 sets of this Ready Board in peri-urban area of Mbayani Township in Blantyre but promotion has ceased at present.

The installation cost of the Ready Board is MK15,000 which is higher than the promotion price. The cost comprises MK4,000 for components of the Ready Board and MK11,000 for construction. The construction cost includes safety features such as a bracket and conductor.

b. Bracket (Figs. 5-7-5, 5-7-6)

Walls of houses in poverty-stricken areas are made of mud and can therefore easily be damaged, necessitating use of a bracket. A conductor is installed through the bracket to the Ready Board installed inside the house.

c. Conductor

In peri-urban areas, houses are so close together such that drop wires to the houses can easily touch the roofs. If a bare drop wire was used, the cost would be lower but occurrences of fire will increase. Therefore, the use of insulated drop wire which is already undertaken by ESCOM should be encouraged.

5.7.3 House wiring for the poverty stricken households in Southern Africa

Based on workshops and some investigations, the government and/or power companies in Southern Africa implement the house wiring in poverty stricken households in the same manner as in Malawi.

(1) The Republic of South Africa

The Republic of South Africa's public electric power corporation (ESKOM) carried out the development of a low cost house wiring system containing the Ready Board in 1999. This development was based on the following social factors:

- Under The Reconstruction and Development Program (RDP) of the Republic of South Africa, infrastructure development had followed the abolition of racial discrimination, and the necessity of electricity supply and development of house wiring for low-income consumers was addressed.
- A prepaid meter has been requested as an option for consumers who experience unemployment since their monthly income is unpredictable.
- ESKOM considered the use of Prepaid Meters in the sites to be electrified as a means of overcoming problems such as inadequate mailing address listings and the difficulty of recovering bill mailing costs.

The system developed consists of both the Ready Board alone (prefabricated wiring) and the Prepaid Meter System (a combination of Ready Board and Prepaid Meter).

With regards to the equipment configuration, although there is no great difference by comparison with the Ready Board and Prepaid Meter System used in Malawi, ESKOM does not collect connection fees from small consumers whereas ESCOM does. Cooperation from The Development Bank of Southern Africa and a regional autonomous organization helps to promote the project in order to implement the Ready Board in non-electrified areas, thereby allowing ESKOM to install systems in around 300,000 houses every year.

(2) Republic of Botswana

In the Republic of Botswana, the house-wiring system called “Ready Box House Wiring System” is applied as a low-cost house wiring. The main components are breakers, a lamp and three sockets. The installation of this system including a 60W lamp is approximately US$ 27.00.

(3) Republic of Namibia

The Ready Board and Pre-payment metering are also applied in the Republic of Namibia. Components of the Ready Board are the same as in Malawi.

5.7.4 Low-cost house wiring in Malawi

A safe supply of electricity should be considered for the low-cost interior wiring in Malawi.

(1) Breaker and Earth Leakage Breaker

Breakers and earth leakage breakers (ELB) are important for the safe use of electricity in wires and sockets. Since a breaker cuts out the power supply when there is an over-current caused by a short and/or ground fault, etc., electric shock on people and fire are prevented. An ELB is installed in order to prevent an electric shock on the consumer caused by an earth leakage. Laws of Malawi – Electricity (Wiring) Regulations – require the protection against over-current and earth leakage for safety reasons.

If these components were not applied, the installation cost could decrease. However, consumers could not access electricity safely. Therefore, it is not recommended the utilization of panel boards that do not provide protection of consumers.

There is also the approach using a breaker and a fuse to protect against over current, being the installation cost of a fuse generally lower than a breaker. However, it is reported in other countries that customers often use a wire instead of a fuse after an over-current blows the fuse. In this case, since protection is lost, the use of a fuse tends to be eliminated internationally.

(2) Wiring

For safety reasons and as a protection measure against illegal connection, the service line is to be connected to the house wire in a high location. And use of bare wire tends to decrease in other countries. As a result of site surveys, the study team considered the walls of houses too weak and the roofs too burnable in poverty areas. The walls should be reinforced and overhead cables should be adopted; however the methods that ESCOM is using are practical.

The wire through the bracket is installed onto the wall to connect to the Ready Board inside the house. Electrical appliances can be plugged in because the Ready Board has a lamp and sockets (Fig. 5-7-7). Although the wiring embedded in the wall is better from a safety perspective, the increase of installation cost and weakness of the walls make this impractical.

Also some wires for electrical appliances are connected to one socket, because Ready Board has only three sockets. About this point, it is considered that education of customers is needed, for example, to remove wires when appliances are not used and to move the conventional board when the number of used appliances increase.

The following is outlined about the low-cost wiring in Malawi.

(a) Ready Board promoted by ESCOM in Malawi is composed of minimal components for the safe use of electricity. The Ready Board is based on regulations in Malawi.

(b) Ready Board is composed of standard general-purpose components. A similar board is widely used in Southern Africa.

(c) A board which has components similar to Ready Board is recommended for low-cost wiring in Malawi.

(d) However, there are some points which should be improved, such as wiring from the outside of the Ready Board and the connection of sockets and electrical appliances. It is considered that education of customers is needed.

Table 5-1-1 Total Lengths of Transmission and Distribution Lines

Line		Length
Transmission Line	Total	1,780km
	132kV	960km
	66kV	820km
Distribution Line	Total	8,548km
	33kV	2,052km
	11kV	2,414km
	400/230V	4,082km

(Source：Annual Report 1998/99, ESCOM)

Table 5-1-2 Acts and Manuals

Law of Malawi	(1) Electricity Council. Act No.19 of 1998 (Electricity) (2) Electricity (Supply) Regulations 1999 (3) Electricity (Wiring) Regulations 2000
DOE	(1) Planning Manual of Distribution System in Rural Area of Malawi (2) Supervising Manual of Distribution System Construction for Rural Electrification (3) Design Manual of Distribution System in Rural Area of Malawi
ESCOM	No manual (Construction and design are based on some drawings)

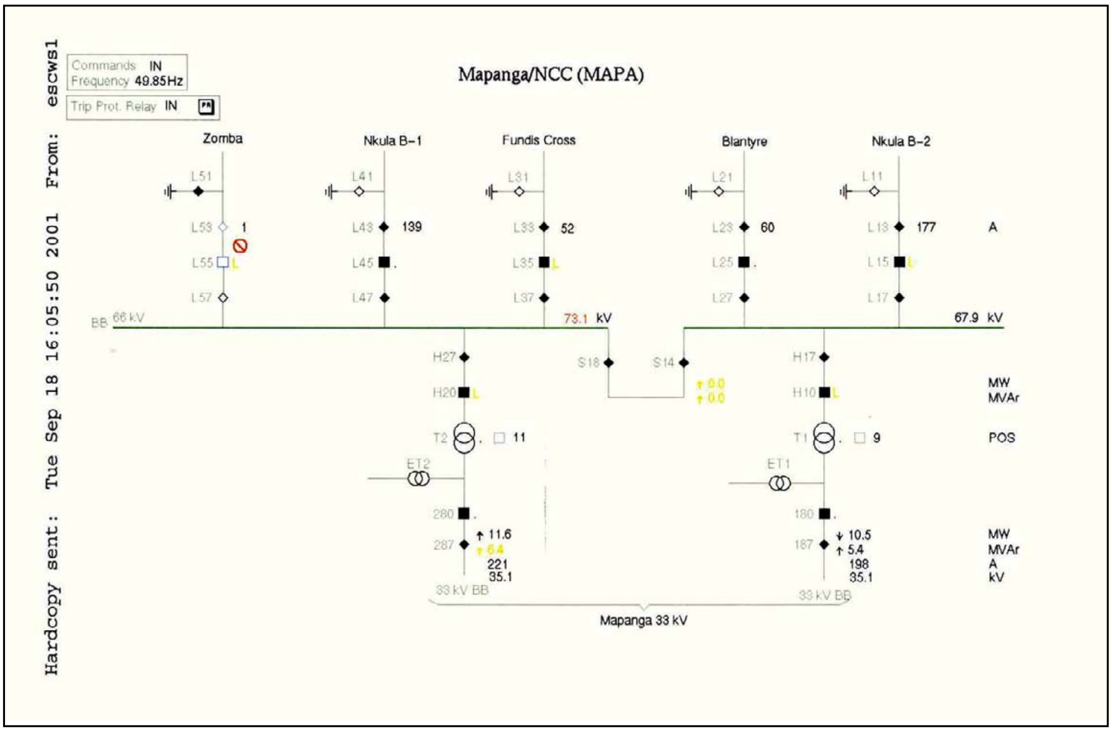


Fig. 5-1-1 SCADA system of NCC (Sample)

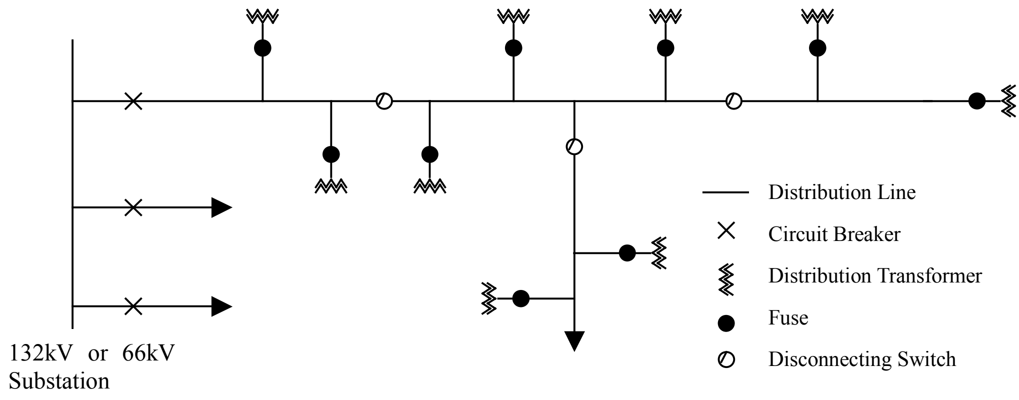


Fig.5-1-2 Typical configuration of Distribution System

Fig. 5-1-3 Disconnecting Switch

Fig. 5-1-4 Recloser

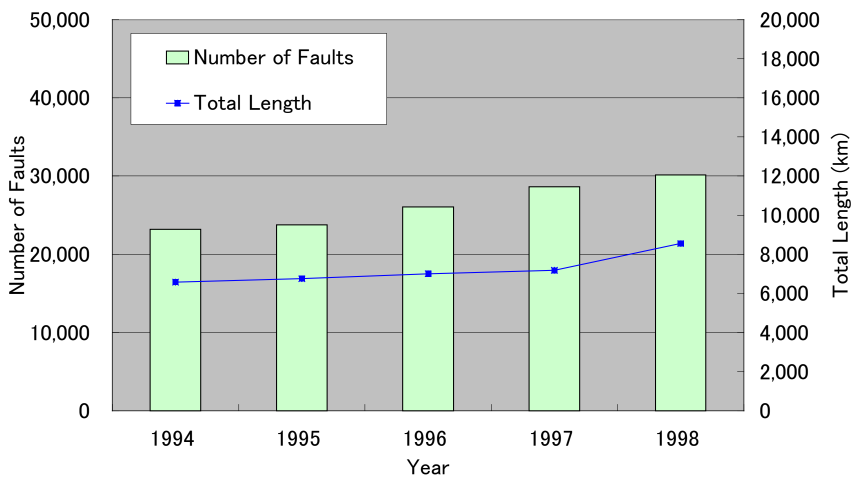


Fig. 5-1-5 Number of Faults

Fig. 5-1-6 Reconstructed pole

Fig. 5-1-7 Transfomer (50kVA)

Fig. 5-1-8 Transformer (100kVA)

Fig. 5-1-9 Safety Guard

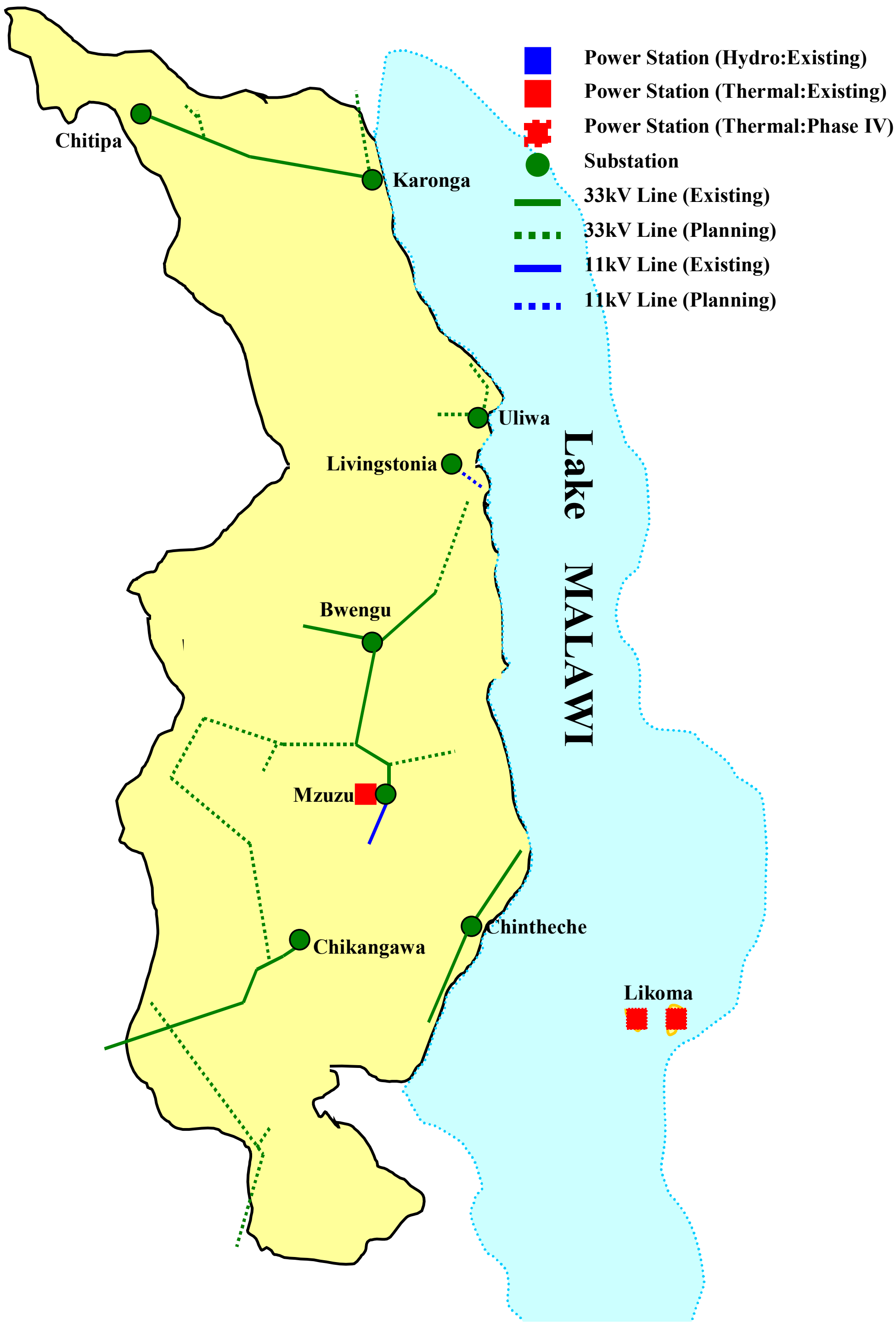


Fig.5-3-1 (a) Existing and Planning Distribution Lines
(Northern Region)

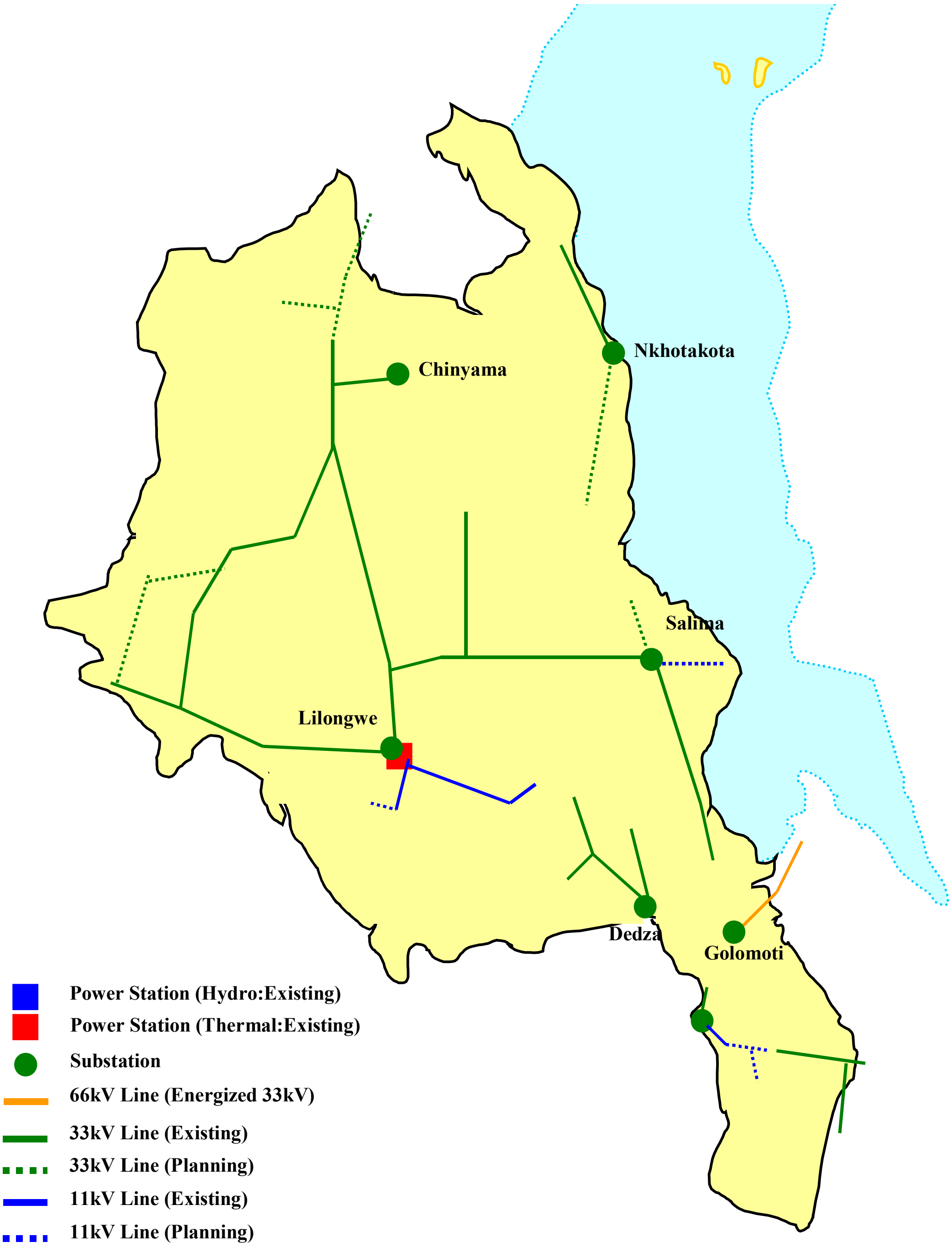


Fig.5-3-1 (b) Existing and Planning Distribution Lines
(Central Region)

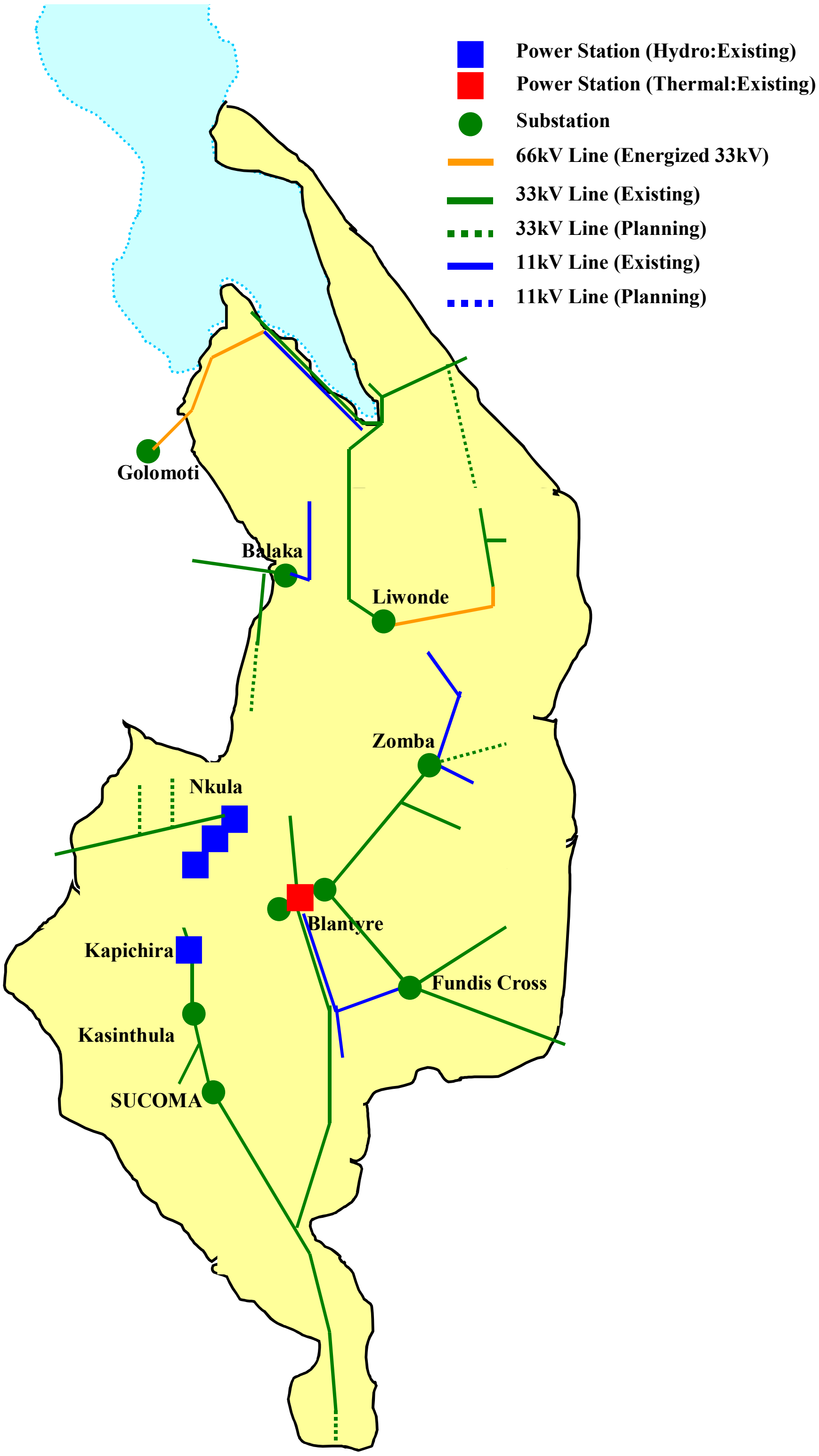


Fig.5-3-1 (c) Existing and Planning Distribution Lines
(Southern Region)

Table 5-4-1 Voltage Classes

Voltage	Description
33 kV (3 phases 3 wires)	From existing or planning distribution system to trading center (distribution transformers)
11 kV (3 phases 3 wires)	From mini-hydro plant to trading center (distribution transformers)
0.4 kV/0.23 kV (3 phases 4 wires)	From distribution transformers and diesel generators to consumers

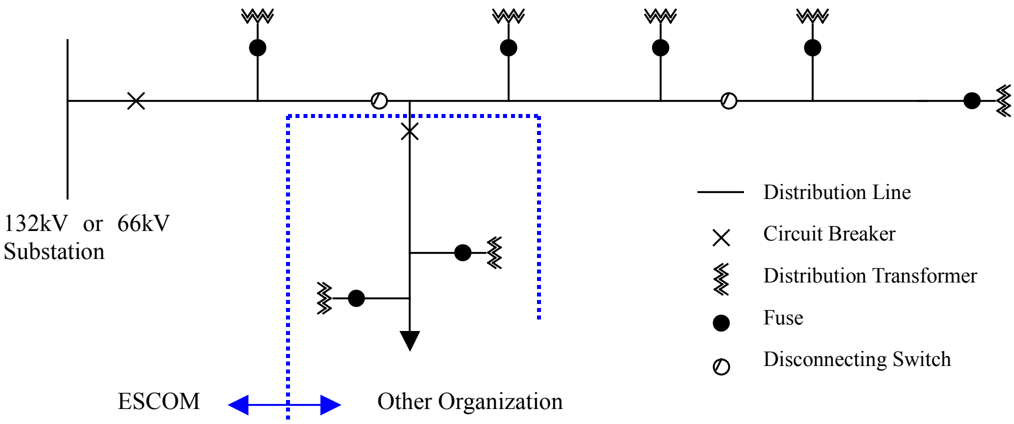


Fig. 5-4-1 System Configuration

Table 5-4-2 Facilities

Facilities	Item		Description
Conductor	Voltage	33kV	AAAC 100 mm^2
		11kV	AAAC 100 mm^2
		0.4kV/0.23kV	AAC 100 mm^2
	Sag		5% of line distance
Supporting Structure	Poles		Wooden
	Span Length	33kV	100m
		11kV	100m
		0.4kV	50m
Distribution Transformer	Type		3 Phases
	Capacity		100 kVA
	Maximum Loading		80% of rated capacity

Table 5-5-1 Calculation of Cost and Benefit

Region	District Name	Phase	TC Name	2020 TC Peak Demand except for Maize Mill	2020 Demand of Maize Mill	2020 Peak Demand (kW)	2020 Demand (MWh/ year)	Installtion Grand Total (1,000 US$)	B/C	Cost: Grid Extension NPV (1,000 US$)	Benefit: NPV Benefit (1,000 US$)
Northern	Chitipa	5	Nthalire	265	120	385	1,929	1,023.4	2.03	996.5	2,027.4
	Chitipa	5	Lupita	262	120	382	1,915	155.8	12.05	167.3	2,016.1
	Chitipa	6	Wenya	294	80	374	1,871	214.2	8.87	222.7	1,974.6
	Chitipa	6	Kameme	311	80	391	1,960	468.3	4.41	466.4	2,058.2
	Chitipa	7	Chsenan	148	60	208	1,042	192.6	6.25	194.1	1,212.2
	Chitipa	7	Kapoka	203	60	263	1,318	121.9	11.36	129.2	1,467.6
	Chitipa	8	Chisenga	54	40	94	472	356.8	2.00	345.5	691.1
	Chitipa	8	Mwenemulembe	15	20	35	174	158.7	2.73	153.4	417.9
	Karonga	5	Songwe	73	40	113	567	88.1	8.69	89.6	779.2
	Karonga	5	Kibwe	322	60	382	1,915	155.8	12.05	167.3	2,016.2
	Karonga	6	Pusi	236	120	356	1,784	155.8	11.40	166.1	1,893.3
	Karonga	6	Iponga	36	20	56	282	71.1	7.29	70.7	515.6
	Karonga	7	Miyombo	73	40	113	567	88.1	8.69	89.6	779.2
	Karonga	7	Mlare	38	0	38	190	249.3	1.79	240.1	430.4
	Karonga	8	Chihepasha	38	0	38	190	176.3	2.53	170.3	430.4
	Karonga	8	Mwenitete	23	20	43	217	71.1	6.54	70.1	458.2
	Karonga	9	Tilora	38	0	38	190	234.7	1.90	226.1	430.4
	Karonga	9	Hara	6	20	26	132	71.1	5.45	69.2	377.7
	Karonga	10	Lupembe	73	40	113	567	117.3	6.63	117.5	779.2
	Rumphi	5	Katowo	197	100	297	1,486	527.4	3.13	518.3	1,620.1
	Rumphi	5	Chitimba	20	0	20	98	234.7	1.53	225.2	344.8
	Rumphi	6	Lara	73	40	113	567	88.1	8.69	89.6	779.2
	Rumphi	6	Muhuju	144	60	204	1,021	119.6	9.63	124.1	1,195.2
	Rumphi	7	Mwasisi	73	40	113	567	131.9	5.93	131.5	779.2
	Rumphi	7	Nchenachena	129	60	189	948	105.0	10.27	109.5	1,124.7
	Rumphi	8	Nkhozo	77	40	117	587	88.1	8.85	89.8	794.7
	Rumphi	8	Ng'onga	31	20	51	254	71.1	7.00	70.4	493.0
	Rumphi	9	Kamphenda	73	40	113	567	117.3	6.63	117.5	779.2
	Rumphi	9	Mphompha	73	40	113	567	251.6	3.17	245.9	779.2
	Nkhata Bay	5	Mpamba	75	40	115	575	237.0	3.39	232.1	785.5
	Nkhata Bay	5	Kavuzi	136	40	176	880	224.8	4.77	223.3	1,065.0
	Nkhata Bay	6	Khondowe	38	0	38	190	-	-	-	582.5
	Nkhata Bay	6	Sanga	16	0	16	81	100.3	3.43	96.7	331.5
	Nkhata Bay	7	Usisya	243	80	323	1,617	407.6	4.30	405.1	1,742.7
	Nkhata Bay	7	Nthungwa	113	40	153	765	373.7	2.64	364.5	961.1
	Nkhata Bay	8	Ruarwe	228	40	268	1,344	-	-	-	2,563.4
	Nkhata Bay	8	Chituka	73	40	113	567	161.1	4.89	159.4	779.2
	Nkhata Bay	9	Maula	38	0	38	190	71.1	6.17	69.8	430.4
	Nkhata Bay	9	Lwazi	38	0	38	190	114.9	3.86	111.7	430.4
	Mzimba	5	Edingeni	7	20	27	137	71.1	5.51	69.3	382.0
	Mzimba	5	Euthini	210	140	350	1,752	155.8	11.23	165.8	1,862.3
	Mzimba	6	Mpherembe	144	80	224	1,121	121.9	10.11	127.3	1,287.1
	Mzimba	6	Jenda	41	40	81	408	88.1	7.20	88.1	634.2
	Mzimba	7	Manyamula	144	80	224	1,121	361.5	3.61	356.2	1,287.1
	Mzimba	7	Eswazini	20	40	60	299	71.1	7.47	70.9	529.7
	Mzimba	8	Luwelezi	41	40	81	408	117.3	5.47	116.0	634.2
	Mzimba	8	Emfeni	33	20	53	267	100.3	5.12	98.5	503.8
	Mzimba	9	Engutwini	73	40	113	567	175.7	4.50	173.3	779.2
	Kasungu	5	Chamama	42	100	142	711	344.6	2.71	336.1	912.0
	Kasungu	5	Mpepa	23	40	63	318	190.9	2.97	185.5	550.1
Central	Kasungu	6	Matenje	8	20	28	141	176.3	2.27	169.8	384.9
	Kasungu	6	Simlemba	76	40	116	580	371.4	2.19	360.5	789.2
	Kasungu	7	Kamboni	37	20	57	285	249.3	2.15	241.0	518.3
	Kasungu	7	Kapheni	39	20	59	294	71.1	7.42	70.8	525.5
	Nkhotakota	5	Mkaika	345	160	505	2,529	277.2	8.91	289.3	2,577.5
	Nkhotakota	5	Dwambadzi	270	80	350	1,752	378.4	4.92	378.5	1,862.4
	Nkhotakota	6	Msenjere	12	20	32	159	71.1	5.83	69.5	405.3
	Nkhotakota	6	Kasitu	12	20	32	159	158.7	2.65	153.2	405.3
	Ntchisi	5	Nthesa	10	40	50	251	158.7	3.19	154.1	491.0
	Ntchisi	5	Khuwi	50	20	70	348	161.1	3.65	157.3	574.6
	Ntchisi	6	Kamsonga	183	120	303	1,519	226.4	7.15	231.0	1,651.9
	Ntchisi	6	Chinguluwe	68	60	128	639	88.1	9.33	90.3	842.7
	Ntchisi	7	Bumphula	103	60	163	816	210.2	4.83	208.7	1,007.3
	Ntchisi	7	Malambo	83	80	163	816	210.2	4.83	208.7	1,007.8
	Ntchisi	8	Ng'ombe	9	20	29	145	71.1	5.60	69.4	388.5
	Ntchisi	8	Kasakula	62	60	122	612	131.9	6.22	131.9	821.0
	Ntchisi	9	Mzandu	28	40	68	340	207.8	2.81	201.9	568.1
	Ntchisi	9	Nthondo	64	60	124	621	146.5	5.68	145.9	828.2

Region	District	Phase	TC	2020 TC Peak Demand except for Maize Mill	2020 Demand of Maize Mill	2020 Peak Demand (kW)	2020 Demand (MWh/ year)	Installtion Grand Total (1,000 US$)	B/C	Cost	Benefit
	Name		Name							Grid Extension NPV (1,000 US$)	NPV Benefit (1,000 US$)
Central	Ntchisi	10	Kayoyo	50	40	90	449	193.3	3.53	189.0	666.7
	Dowa	5	Thambwe	122	20	142	710	134.2	6.74	135.1	910.9
	Dowa	5	Bowe	145	60	205	1,028	297.8	4.08	294.4	1,200.8
	Dowa	6	Chiseflo	124	60	184	920	359.2	3.13	352.1	1,102.2
	Dowa	6	Bibanzi	17	0	17	86	158.7	2.20	152.5	335.1
	Dowa	7	Msalanyama	27	20	47	236	114.9	4.22	112.1	472.6
	Dowa	7	Kachigamba	117	40	157	788	119.6	8.03	121.9	979.1
	Dowa	8	Chinkhwiri	111	20	131	656	251.6	3.49	246.8	862.0
	Dowa	8	Lipri	86	40	126	630	161.1	5.22	160.0	834.9
	Dowa	9	Kasuntha	204	60	264	1,322	241.7	6.04	243.7	1,471.2
	Dowa	9	Chankhunga	97	20	117	588	146.5	5.47	145.6	795.9
	Dowa	10	Nalunga	25	20	45	226	176.3	2.73	170.7	465.4
	Dowa	10	Dzoole	65	40	105	526	193.3	3.90	189.7	740.0
	Dowa	11	Kalonga	48	0	48	239	71.1	6.77	70.3	475.7
	Dowa	11	Kalumbu	66	80	146	730	178.0	5.24	177.1	927.3
	Dowa	12	Mkukula	84	40	124	621	102.7	7.95	104.1	827.7
	Dowa	12	Chakadza	138	20	158	792	119.6	8.06	121.9	982.2
	Dowa	13	Chimungu	66	20	86	430	175.7	3.79	172.0	651.7
	Dowa	13	Thonje	66	20	86	430	131.9	5.01	130.1	651.7
	Dowa	14	Kayembe	75	40	115	575	251.6	3.19	246.0	785.6
	Dowa	14	Simbi	66	20	86	430	146.5	4.52	144.1	651.7
	Dowa	15	Bweya	61	20	81	407	131.9	4.88	129.9	633.6
	Dowa	15	Ntiti	75	40	115	575	88.1	8.76	89.7	785.6
	Salima	5	Kandulu	113	40	153	768	119.6	7.91	121.7	963.1
	Salima	5	Chilambula	43	0	43	215	85.7	5.43	84.0	456.4
	Salima	6	Kambiri Sch.	73	40	113	567	88.1	8.69	89.6	779.2
	Salima	6	Khwidzi	73	40	113	567	88.1	8.69	89.6	779.2
	Salima	7	Thavite	73	40	113	567	266.2	3.00	259.9	779.2
	Salima	7	Makioni	4	20	24	122	158.7	2.42	152.9	370.5
	Salima	8	Michulu	73	40	113	567	356.8	2.25	346.4	779.2
	Salima	8	Chikombe	30	40	70	349	88.1	6.57	87.5	575.4
	Salima	9	Mnema	6	20	26	132	176.3	2.22	169.8	377.7
	Salima	9	Chitala	144	80	224	1,121	180.3	7.03	183.1	1,287.1
	Salima	10	Chinguluwe	73	40	113	567	88.1	8.69	89.6	779.2
	Salima	10	Siyasiya	73	40	113	567	88.1	8.69	89.6	779.2
	Salima	11	Matenje	38	0	38	190	114.9	3.86	111.7	430.4
	Salima	11	Chagunda	73	40	113	567	88.1	8.69	89.6	779.2
	Salima	12	Pemba	144	80	224	1,121	165.7	7.61	169.2	1,287.1
	Salima	12	Mphinzi	38	0	38	190	234.7	1.90	226.1	430.4
	Lilongwe	5	Chilobwe	227	80	307	1,536	483.6	3.49	476.9	1,666.1
	Lilongwe	5	Nyanja	39	20	59	297	71.1	7.44	70.8	527.4
	Lilongwe	6	Kasiya	216	100	316	1,581	138.9	11.54	147.9	1,707.9
	Lilongwe	6	Chawantha	19	20	39	195	205.5	2.19	198.3	434.2
	Lilongwe	7	Malembo	50	60	110	549	146.5	5.22	145.2	758.6
	Lilongwe	7	Nsaru	318	120	438	2,192	350.9	6.36	356.4	2,267.3
	Lilongwe	8	Kabudula	36	0	36	181	190.9	2.30	184.2	422.8
	Lilongwe	8	Hiunjiza	138	60	198	992	508.1	2.36	495.1	1,166.0
	Lilongwe	9	Phirilanjuli	51	40	91	458	280.8	2.49	272.8	679.8
	Lilongwe	9	Kachale	16	80	96	482	175.7	4.05	172.5	699.0
	Lilongwe	10	Chimbalanga	75	40	115	575	280.8	2.87	273.9	785.6
	Lilongwe	10	Mtema	130	40	170	851	239.4	4.37	236.9	1,035.7
	Lilongwe	11	Bisai	72	40	112	562	207.8	3.80	204.0	774.8
	Lilongwe	11	Mbng'ombe	93	60	153	766	312.4	3.14	305.9	961.6
	Lilongwe	12	Sinumbe	6	20	26	132	176.3	2.22	169.8	377.7
	Lilongwe	12	Kang'oma	147	80	227	1,137	209.5	6.16	211.2	1,299.9
	Lilongwe	13	Chiwamba	82	20	102	511	88.1	8.18	89.1	728.6
	Lilongwe	13	Chadza	184	40	224	1,122	256.3	5.04	255.7	1,288.0
	Lilongwe	14	Kalumbu	149	40	189	946	163.4	6.80	165.3	1,123.4
	Lilongwe	14	Kalima	25	20	45	226	100.3	4.75	98.1	465.4
	Mchinji	5	Mkanda	153	120	273	1,366	121.9	11.66	129.7	1,511.9
	Mchinji	5	Chiosya	110	80	190	954	297.8	3.87	293.7	1,135.6
	Mchinji	6	Mikundi	22	20	42	208	190.9	2.44	184.4	450.9
	Mchinji	6	Nkhwazi	7	20	27	136	85.7	4.58	83.2	381.3
	Mchinji	7	Gumba	73	40	113	567	222.4	3.57	218.0	779.2
	Mchinji	7	Kazyozyo	24	20	44	222	190.9	2.50	184.6	461.8
	Mchinji	8	Gumulira	14	20	34	172	234.7	1.84	225.9	416.1
	Mchinji	8	Kabzyala	11	0	11	54	129.5	2.49	124.3	309.8
	Mchinji	9	Kalulu	12	20	32	159	129.5	3.23	125.3	405.3
	Dedza	5	Kabwazi	33	20	53	264	234.7	2.21	226.8	501.1
	Dedza	5	Golomoti	31	80	111	555	88.1	8.59	89.5	769.2

										Cost	Benefit
Region	District Name	Phase	TC Name	2020 TC Peak Demand except for Maize Mill	2020 Demand of Maize Mill	2020 Peak Demand (kW)	2020 Demand (MWh/ year)	Installtion Grand Total (1,000 US$)	B/C	Grid Extension NPV (1,000 US$)	NPV Benefit (1,000 US$)
Central	Dedza	6	Chimoto	73	40	113	567	88.1	8.69	89.6	779.2
	Dedza	6	Chiluzi	72	120	192	961	119.6	9.24	123.6	1,141.4
	Dedza	7	Mphati	73	40	113	567	207.8	3.82	204.1	779.2
	Dedza	7	Magomelo	144	200	344	1,722	214.2	8.31	221.3	1,838.4
	Ntcheu	5	Ntonda	52	80	132	663	207.8	4.23	205.0	867.2
	Ntcheu	5	Kasinje	144	120	264	1,322	314.7	4.69	313.5	1,470.9
	Ntcheu	6	Kadzakalowa	200	100	300	1,504	138.9	11.14	147.2	1,640.5
	Ntcheu	6	Kandeu	71	40	111	556	193.3	4.05	190.0	770.5
	Ntcheu	7	Sharpvalle	378	140	518	2,593	309.4	8.22	320.7	2,634.7
	Ntcheu	7	Bilila	144	60	204	1,021	312.4	3.88	308.3	1,195.2
	Ntcheu	8	Pengapenga	41	80	121	608	146.5	5.61	145.8	817.9
	Ntcheu	8	Kaloga	144	140	284	1,422	244.0	6.33	246.9	1,562.7
	Ntcheu	9	Masasa	4	0	4	18	249.3	1.15	238.4	275.0
	Mangochi	5	Makanjira	190	220	410	2,054	1,265.3	1.75	1,228.9	2,145.1
	Mangochi	5	Chilipa	12	20	32	160	339.9	1.25	326.3	406.7
	Mangochi	6	Chiponde	144	100	244	1,221	121.9	10.75	128.3	1,379.0
	Mangochi	6	Majuni	73	40	113	567	88.1	8.69	89.6	779.2
Southern	Mangochi	7	Mvumba	23	40	63	313	71.1	7.70	71.0	546.4
	Mangochi	7	Katuli	5	60	65	327	327.6	1.76	316.2	557.8
	Mangochi	8	Mkumba	207	80	287	1,436	197.2	7.78	202.3	1,573.9
	Mangochi	8	Katema	116	60	176	882	297.8	3.64	293.0	1,066.2
	Mangochi	9	Lungwena	144	60	204	1,021	210.2	5.67	210.7	1,195.2
	Mangochi	9	Kwisimba	54	40	94	472	222.4	3.18	217.1	691.1
	Machinga	5	Chikwewu	275	100	375	1,876	348.6	5.64	351.2	1,978.9
	Machinga	5	Nampeya	321	80	401	2,006	363.1	5.73	366.4	2,100.5
	Machinga	6	Ngokwe	22	20	42	208	263.9	1.77	254.2	450.9
	Machinga	6	Mposa	13	20	33	163	263.9	1.61	253.7	408.9
	Machinga	7	Nayuchi	32	40	72	358	400.6	1.52	386.3	588.5
	Machinga	7	Msosa	54	20	74	371	175.7	3.49	171.4	598.8
	Machinga	8	Ngwepele	53	80	133	667	295.4	3.02	288.7	870.8
	Machinga	8	Mangamba	20	40	60	299	205.5	2.66	199.3	529.7
	Machinga	9	Likhonyowa	73	40	113	567	88.1	8.69	89.6	779.2
	Machinga	9	Malundani	144	60	204	1,021	210.2	5.67	210.7	1,195.2
	Machinga	10	Nanyumbu	38	0	38	190	71.1	6.17	69.8	430.4
	Machinga	10	Molipa	73	40	113	567	88.1	8.69	89.6	779.2
	Balaka	5	Chendausiku	190	60	250	1,253	241.7	5.80	243.1	1,410.0
	Balaka	5	Kwitanda	49	0	49	243	100.3	4.88	98.2	478.9
	Balaka	6	Phimbi	38	0	38	190	354.5	1.26	340.6	430.4
	Zomba	5	Jenale	24	40	64	322	234.7	2.43	227.4	553.3
	Zomba	5	Sunuzi	96	20	116	583	131.9	6.02	131.6	791.8
	Zomba	6	Zaone	144	100	244	1,221	121.9	10.75	128.3	1,379.0
	Zomba	6	Muwa	27	40	67	336	146.5	3.94	143.2	564.5
	Zomba	7	Mpyupyu	144	80	224	1,121	121.9	10.11	127.3	1,287.1
	Zomba	7	Masaula	144	80	224	1,121	227.1	5.65	227.8	1,287.1
	Zomba	8	Nachuma	73	40	113	567	131.9	5.93	131.5	779.2
	Zomba	8	Khonjeni	38	0	38	190	129.5	3.43	125.6	430.4
	Zomba	9	Kachulu	144	60	204	1,021	105.0	10.85	110.2	1,195.2
	Zomba	9	Sakata	6	0	6	30	114.9	2.59	110.1	284.9
	Zomba	10	Makina	144	60	204	1,021	134.2	8.66	138.1	1,195.2
	Zomba	10	Ngwelero	144	80	224	1,121	136.5	9.11	141.3	1,287.1
	Zomba	11	Chisunzi	73	40	113	567	102.7	7.52	103.6	779.2
	Zomba	11	Ngondole	144	60	204	1,021	148.8	7.86	152.0	1,195.2
	Chiradzulu	5	Kanje	144	60	204	1,021	105.0	10.85	110.2	1,195.2
	Chiradzulu	5	Milepa	22	40	62	312	234.7	2.40	227.3	545.8
	Chiradzulu	6	Chimwawa	38	0	38	190	71.1	6.17	69.8	430.4
	Chiradzulu	6	Ndunde	31	20	51	254	71.1	7.01	70.4	493.6
	Blantyre	5	Chikuli	91	20	111	555	175.7	4.44	173.2	769.3
	Blantyre	5	Mombo	17	0	17	84	158.7	2.19	152.5	333.6
	Blantyre	6	Dziwe	38	0	38	190	85.7	5.14	83.8	430.4
	Blantyre	6	Mudi	61	40	101	504	146.5	4.99	144.8	722.8
	Blantyre	7	Mlenje	18	20	38	193	85.7	5.16	83.8	432.4
	Blantyre	7	Domwe	73	40	113	567	102.7	7.52	103.6	779.2
	Blantyre	8	Chigwaja	73	40	113	567	102.7	7.52	103.6	779.2
	Blantyre	8	Linjidzi	73	40	113	567	146.5	5.36	145.4	779.2
	Mwanza	5	Chikonde	73	40	113	567	88.1	8.69	89.6	779.2
	Mwanza	5	Thambani	153	80	233	1,165	300.1	4.46	298.0	1,328.1
	Mwanza	6	Ligowe	73	40	113	567	102.7	7.52	103.6	779.2
	Mwanza	6	Kam'mwamba	31	60	91	456	222.4	3.13	217.0	678.6
	Mwanza	7	Matope	144	60	204	1,021	268.6	4.49	266.5	1,195.2
	Mwanza	7	Magaleta	19	0	19	97	100.3	3.55	96.8	344.1

Region	District Name	Phase	TC Name	2020 TC Peak Demand except for Maize Mill	2020 Demand of Maize Mill	2020 Peak Demand (kW)	2020 Demand (MWh/ year)	Installtion Grand Total (1,000 US$)	B/C	Cost: Grid Extension NPV (1,000 US$)	Benefit: NPV Benefit (1,000 US$)
Southern	Mwanza	8	Kanenekude	33	20	53	264	234.7	2.21	226.8	501.1
	Mwanza	8	Tulonkhondo	85	60	145	724	283.2	3.32	277.6	922.3
	Mwanza	9	Kasuza	9	60	69	345	88.1	6.54	87.5	572.3
	Thyolo	5	Nansadi	215	40	255	1,275	136.5	10.00	142.8	1,427.6
	Thyolo	5	Fifite	96	60	156	783	105.0	9.04	107.9	975.6
	Thyolo	6	Lalakani	10	0	10	49	205.5	1.53	196.9	300.3
	Thyolo	6	Thomasi	144	60	204	1,021	283.2	4.26	280.4	1,195.2
	Thyolo	7	Makapwa	38	0	38	190	114.9	3.86	111.7	430.4
	Thyolo	7	Sandama	221	120	341	1,708	153.5	11.20	163.1	1,827.3
	Thyolo	8	Chipho	112	40	152	761	163.4	5.86	163.5	957.5
	Mulanje	5	Chinyama	96	40	136	683	356.8	2.54	347.6	883.7
	Mulanje	5	Nkando	102	40	142	711	148.8	6.12	149.0	911.8
	Mulanje	6	Nanthombozi	65	60	125	624	131.9	6.29	132.0	830.2
	Mulanje	6	Chambe	183	80	263	1,315	136.5	10.24	143.1	1,465.6
	Mulanje	7	Mathambi	115	40	155	777	163.4	5.93	163.6	970.3
	Mulanje	7	Chinakanaka	106	40	146	732	119.6	7.65	121.3	928.4
	Mulanje	8	Msikawanjala	48	0	48	239	85.7	5.64	84.2	475.1
	Mulanje	8	Namphundo	39	20	59	294	85.7	6.19	84.8	525.0
	Mulanje	9	Kambenje	16	0	16	81	85.7	4.01	82.7	331.3
	Mulanje	9	Kamwendo	106	40	146	729	105.0	8.63	107.4	926.2
	Phalombe	5	Chilinga	19	60	79	394	207.8	3.05	202.4	616.7
	Phalombe	5	Mlomba	78	60	138	689	224.8	4.01	221.4	888.7
	Phalombe	6	Phaloni	6	20	26	132	114.9	3.40	111.1	377.7
	Phalombe	6	Chitekesa	73	40	113	567	117.3	6.63	117.5	779.2
	Phalombe	7	Mpasa	38	0	38	190	158.7	2.80	153.5	430.4
	Phalombe	7	Nambazo	73	40	113	567	222.4	3.57	218.0	779.2
	Chikwawa	5	Mitondo	22	140	162	809	148.8	6.68	150.0	1,002.2
	Chikwawa	5	Linvunzu	13	20	33	165	190.9	2.23	184.0	410.4
	Chikwawa	6	Kakoma	144	60	204	1,021	297.8	4.06	294.4	1,195.2
	Chikwawa	6	Tomali	12	20	32	162	71.1	5.87	69.5	408.0
	Chikwawa	7	Ndakwera	20	80	100	499	146.5	4.92	144.8	712.6
	Chikwawa	7	Kanyinda	54	120	174	873	119.6	8.63	122.7	1,059.1
	Nsanje	5	Tengani	284	100	384	1,923	155.8	12.08	167.4	2,022.4
	Nsanje	5	Mankhokwe	122	60	182	910	105.0	10.03	109.1	1,094.6
	Nsanje	6	Mtowe	144	80	224	1,121	180.3	7.03	183.1	1,287.1
	Nsanje	6	Mbenje	47	60	107	538	146.5	5.16	145.1	749.5
	Nsanje	7	Masenjere	144	60	204	1,021	224.8	5.32	224.6	1,195.2
	Nsanje	7	Kampata	37	0	37	185	129.5	3.40	125.6	426.4
	Nsanje	8	Lulwe	19	40	59	295	190.9	2.84	185.3	526.1
	Nsanje	8	Chididi	144	80	224	1,121	165.7	7.61	169.2	1,287.1
	Nsanje	9	Sankhulani	144	60	204	1,021	192.6	6.16	193.9	1,195.2

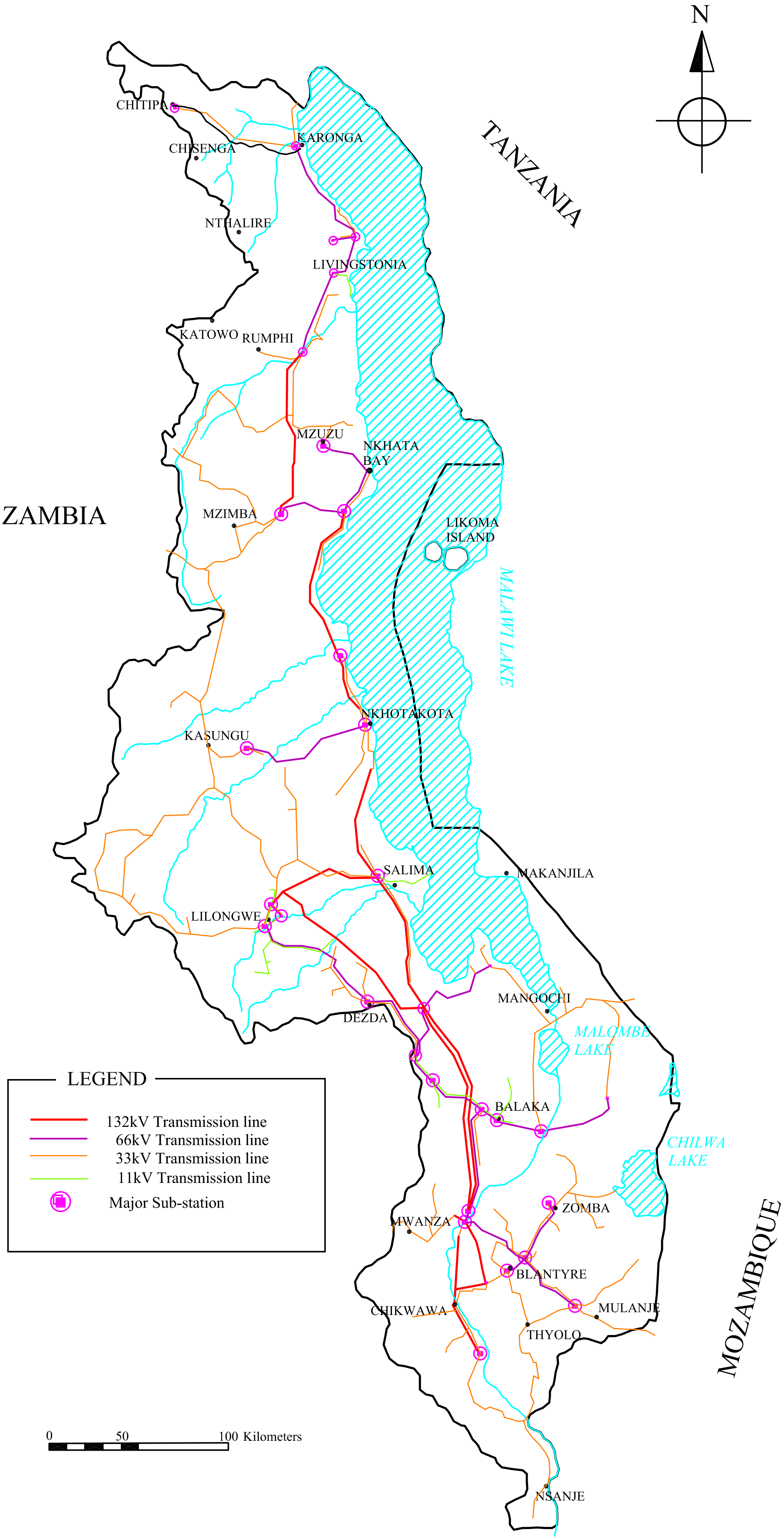


Fig.5-5-1Extended situation of distribution lines after Phase Ⅳ

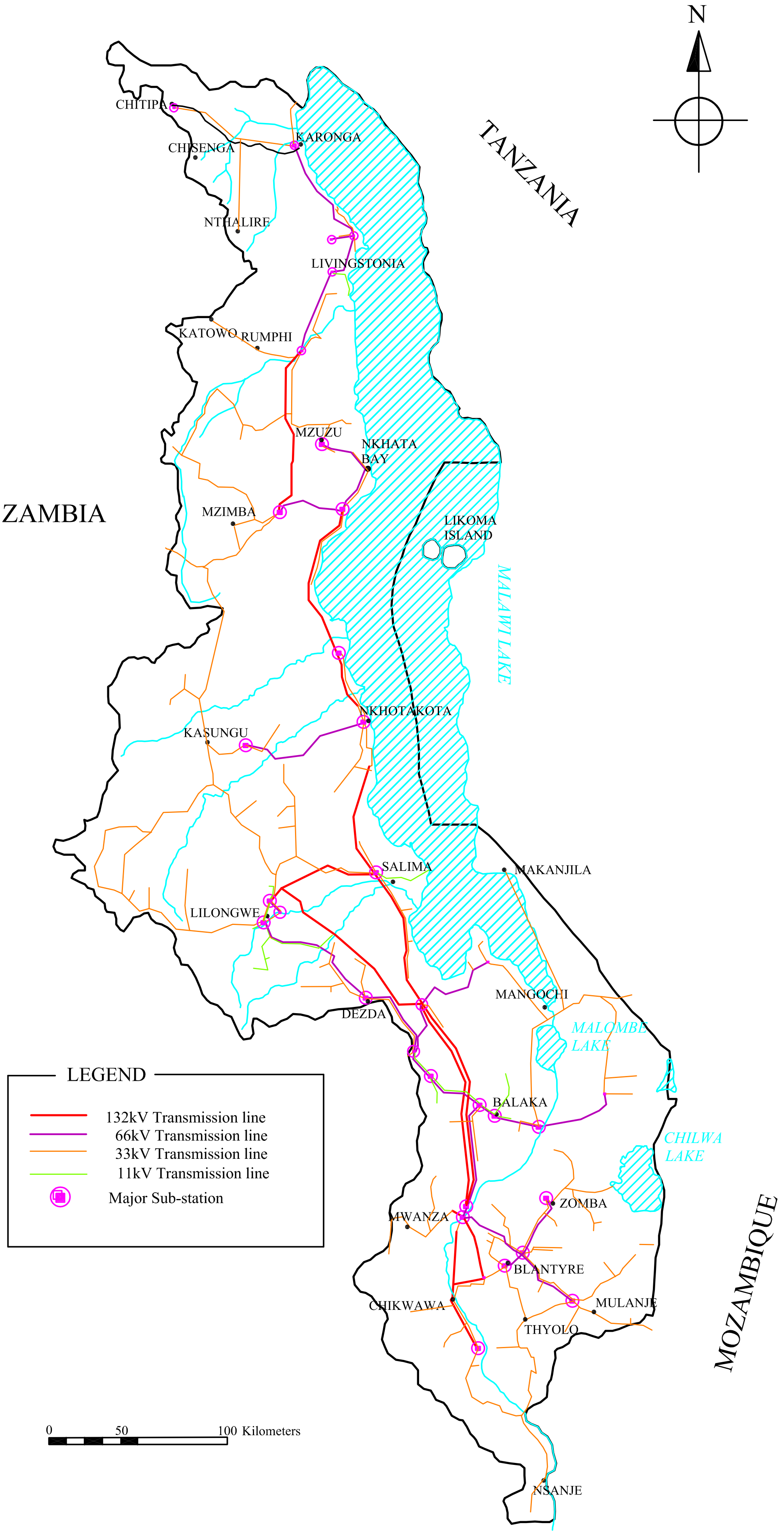


Fig.5-5-2 Expected distribution lines after Phase V

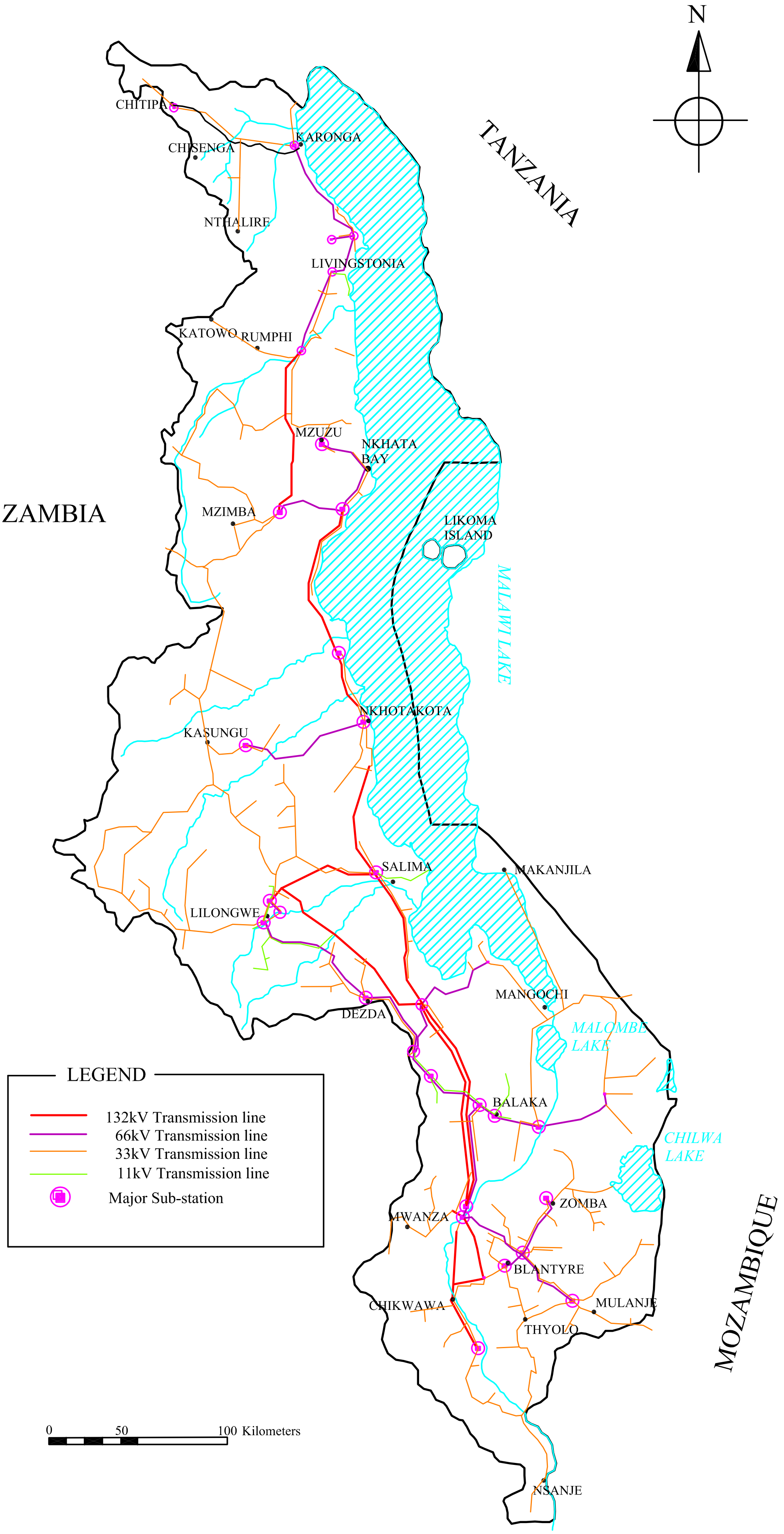


Fig.5-5-3 Expected distribution lines after Phase VI

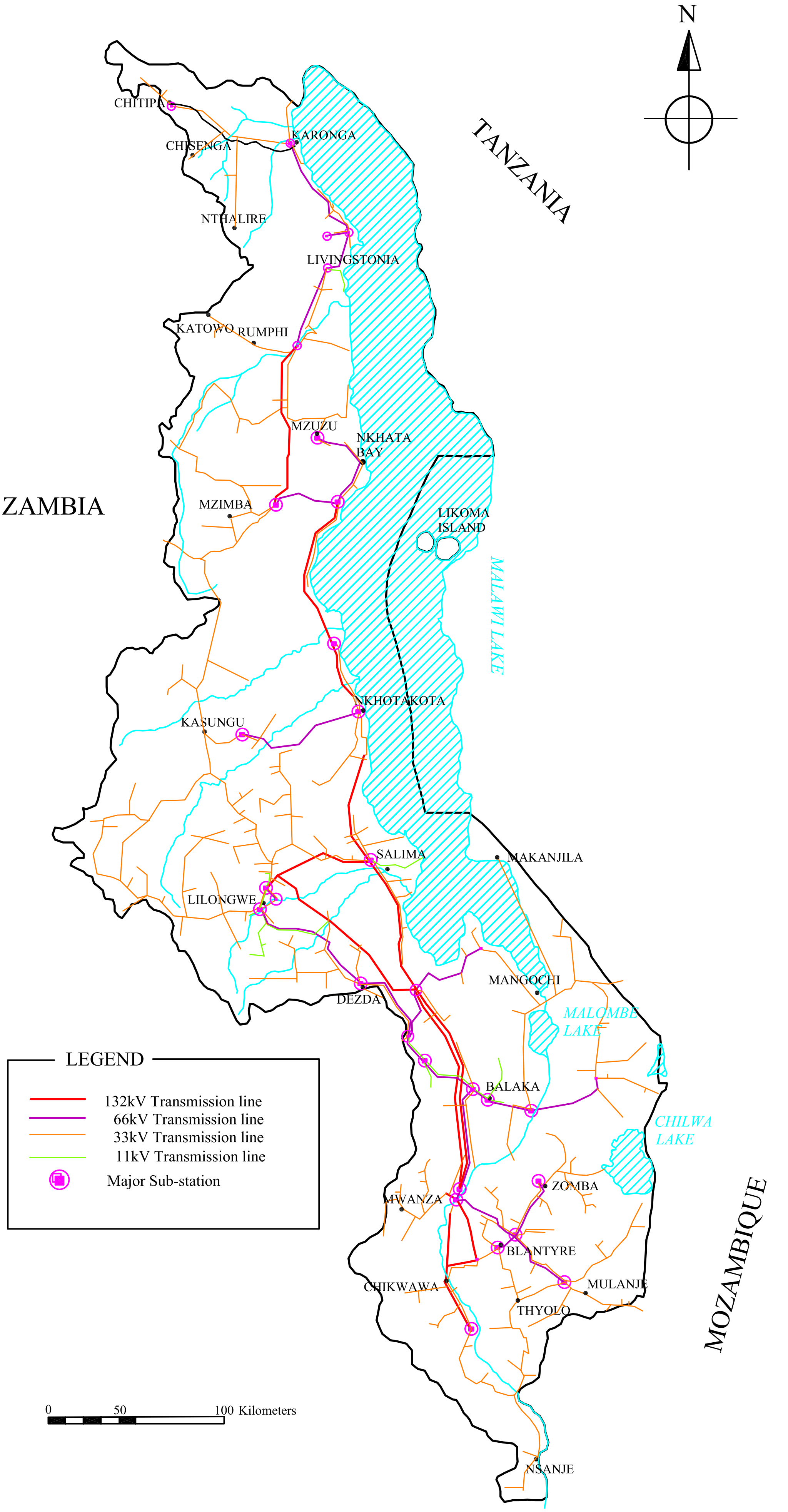


Fig.5-5-4 Expected distribution lines after Phase X V (1)

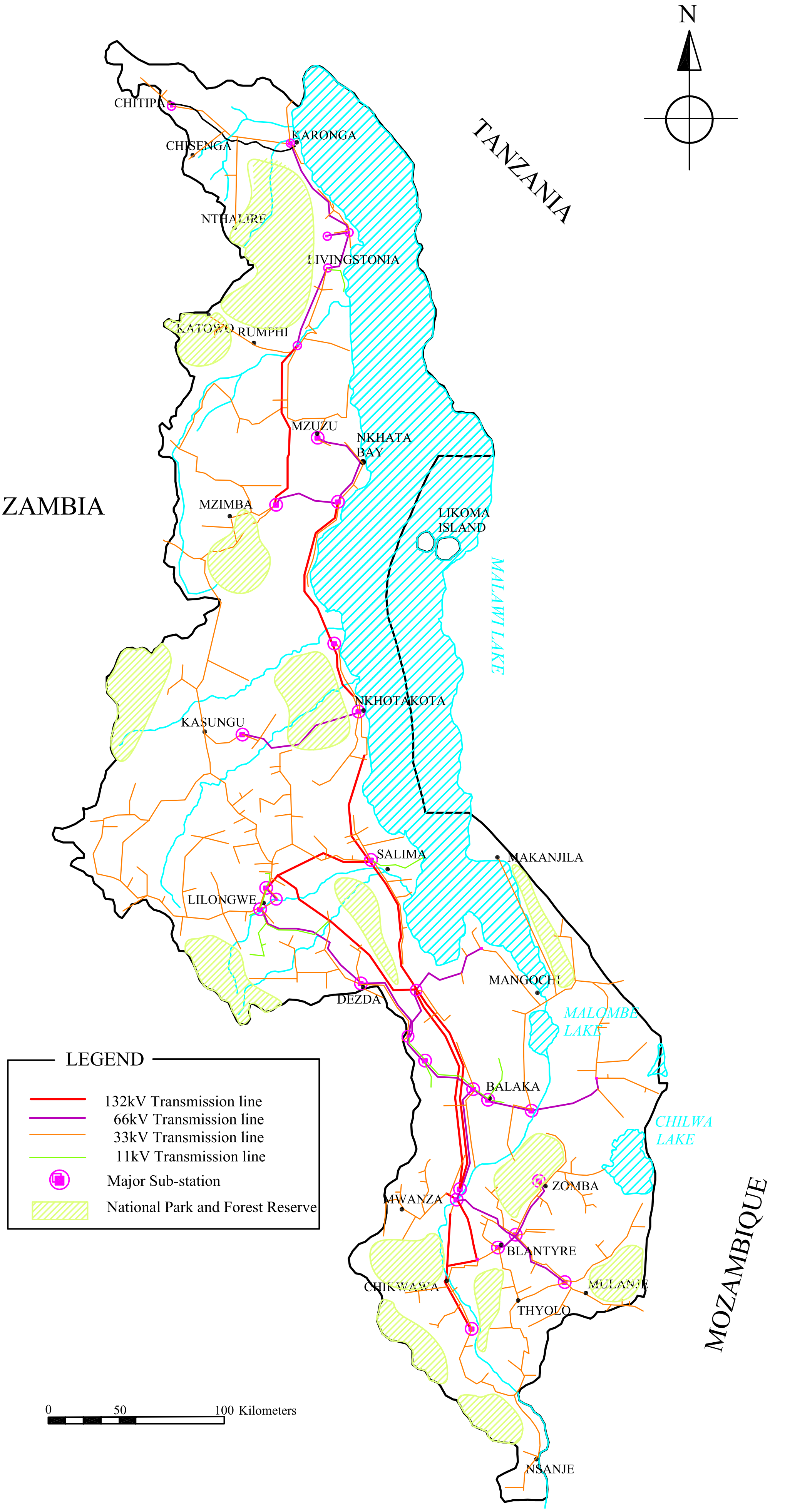


Fig.5-5-5 Expected distribution lines after Phase X V (2)

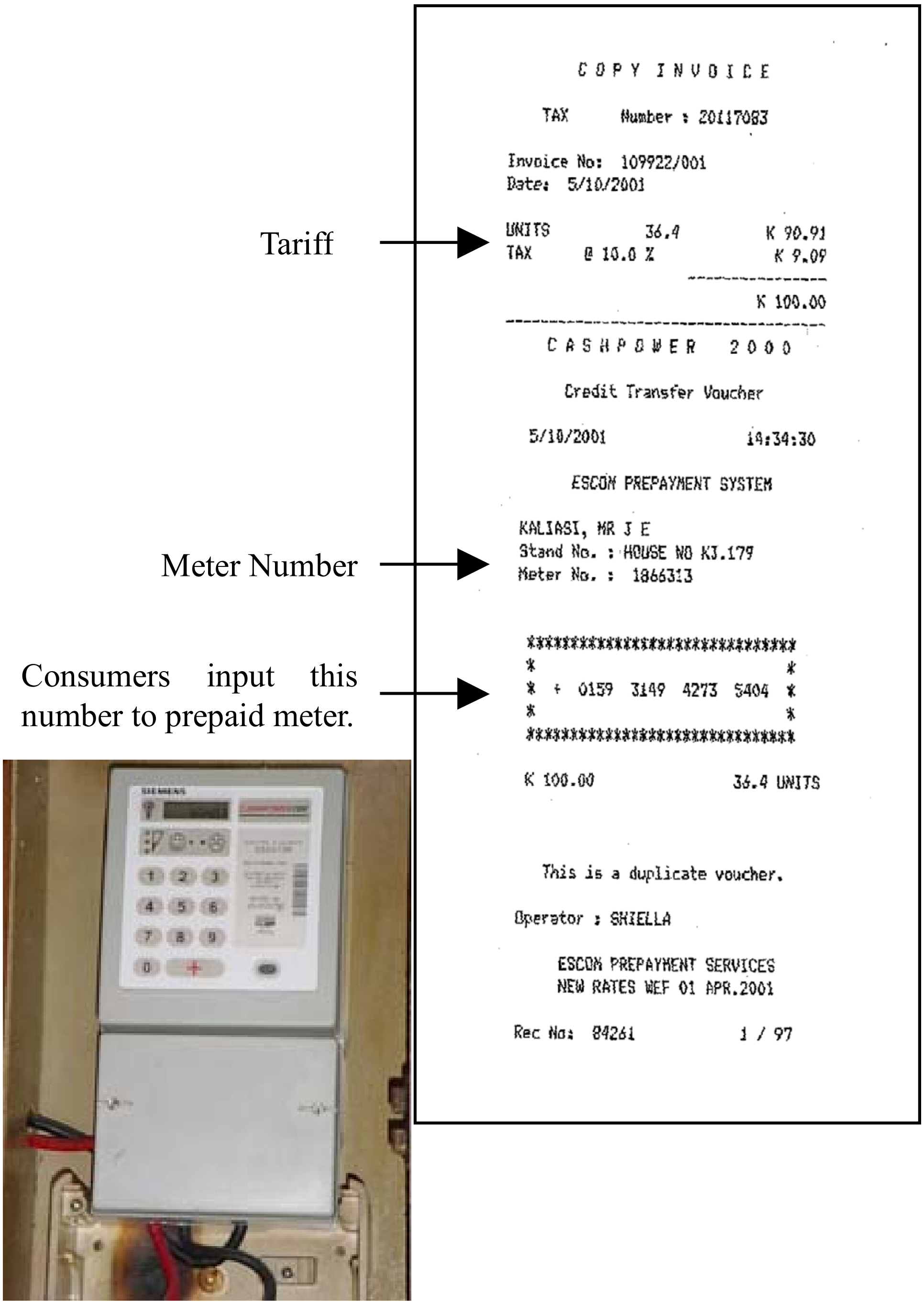


Fig.5-7-1 Prepaid Meter and Sample Receipt

Fig.5-7-2 Ready Board

Fig.5-7-3 Cooker

Fig.5-7-4 Electrical Fan

Fig.5-7-5 Bracket (outside)

Fig.5-7-6 Bracket (inside)

Fig.5-7-7 Ready Board and Wiring

CHAPTER 6 MICRO-HYDROPOWER GENERATION PLANNING

Chapter 6 Micro-Hydropower Generation Planning

6.1 Purpose

The main purposes of the micro-hydropower generation planning in this study are shown as follows:

- The JICA study team conducts potential survey to find the micro-hydropower potential sites near non-electrified T/Cs. Results of the survey are incorporated into a rural electrification database in order to utilize isolated micro-hydropower (micro-hydropower + mini grid) as a power supply for rural electrification.

- The JICA study team works out efficient estimate methods for preliminary cost estimates of micro-hydropower development. Those are regarded as a part of rural electrification criteria and are used in economic comparison for identification of suitable electrification method for each non-electrified T/Cs.

- The JICA study team conducts Pre-Feasibility Study (Pre-F/S) in the case study of micro-hydropower development. The technical aspects of the micro-hydropower development procedures for rural electrification are specified throughout the implementation of the Pre-F/S.

The target scale of micro-hydropower in this Master Plan is assumed to be about 200kW at the maximum, since it is off-grid micro-hydropower development for rural electrification.

6.2 Data Collection

Data collection and analysis of the following items, which are required for the micro-hydropower potential survey, was conducted during the field survey stages.

6.2.1 Topography and geology

The topographic maps with the scale of 1/1,000,000 (a total of one sheet), 1/250,000 (a total of ten sheets) and 1/50,000 (a total of 158 sheets), which are published by the survey department, are generally marketed available in Malawi. The JICA study team acquired these topographic maps in during the first field survey stage.

Mostly 1/250,000, and 1/50,000 topographic maps were used in the potential survey. Although these topographic maps were made in the 1970s, information concerning location of T/Cs, roads, rivers, forest reservation areas, etc., which are required for the potential survey, are relatively correct, so their use is satisfactory for the potential survey.

On the other hand, a geological map, published by the geological department, is commercially available in Malawi. The JICA study team acquired this map, which covers the entire country, in order to understand the general geological conditions in Malawi. Generally speaking, it is very unusual for micro-hydropower development to be influenced by geological conditions at the sites, since the civil structures are very small scale and not accompanied by installation of underground structures, such as tunnels.

6.2.2 Rainfall and river discharge

Malawi belongs to the tropical savanna climate, and the average annual rainfall is between about 700mm to 2,000mm. The rainfall is comparatively much in Malawi, in contrast to the rest of the African countries. The rainfall distribution in Malawi is shown in Fig. 6-2-1. According to this figure, in the area adjacent to the Malawi lakeshore located in the east side of the Nyika Highland and Viphya Mountains (with as high an altitude as 2,000m), the average annual rainfall is over 1,200mm. On the other hand, in the area adjacent to the national boundary of Zambia on the western side, the rainfall is less than 1,000mm. This distribution of rainfall is considered to be due to the influence of the trade wind from southeast. The trade wind collects moisture from the Malawi Lake (the third largest in Africa) as it passes over it. As the trade wind goes up along the mountain slope of Nyika and Vipya, the moisture is released as rainfall there. Then, relieved of its moisture, the dry trade wind climbs over the mountains and blows to down the Zambian side.

Malawi has both a wet and a dry season, and approximately 80% or more of the annual average rainfall is concentrated on the wet season between December and April. Thus the river discharge in the driest month (October) generally decreases to about 5% compared to the discharge in the rainiest month (February), and there are many rivers drying up.

In the potential survey, data and information about rainfall and river discharge are taken from the "National Water Resource Master Plan" (the UNDP M/P), which was prepared by UNDP in 1986. In the UNDP M/P, the whole of Malawi is classified into 17 areas, and discharge data (from observation periods of over ten years) at hydrological stations in the each area are arranged systematically. Since it is necessary in the potential survey to comprehensively and efficiently estimate the river discharge at a large number of potential sites under the same conditions, the UNDP M/P is a very valuable to be used for this purpose.

6.2.3 Land and river use

The following items, concerning land and river use, should be preliminary ascertained along as part of the potential survey.

- Whether or not a potential site exists within a national park or a forest reservation area.
- Present state of the land use at the planned structure sites
- Existing river water rights such as irrigation, drinking water and so on in the potential sites

The first item is verified by the use of 1/50,000 topographic maps, where the classification of national parks and forest reservation areas was indicated. The other items are confirmed by the site survey.

6.3 Review of Existing Hydropower Development Plans

The JICA study team reviewed future power sources development master plan prepared by ESCOM in order to coordinate those with our micro-hydropower development plan for rural electrification. Also results of previous study for hydropower projects were reviewed. Then results of the review are considered in the selection of micro-hydropower potential sites.

6.3.1 Review of future power sources development master plan by ESCOM

According to results of hearing investigation from ESCOM, they implements power source development plans, based on the power sources development master plan, proposed by the "Power System Development and Operation Study", which was prepared by the WB in 1998.

In the WB study, power demand in Malawi was forecasted to be 370, 460 and 670 MW for the Low, Base, and High cases, respectively, by 2015. Moreover, about 100 hydropower potential sites were examined by map study in the WB study to identify some promising sites for interconnection to the grid.

Power Sources Development Master Plan Proposed by WB study

Generation		Scenarios for demand		
		Low	Base	High
64MW	Hydro-Kapichira 1	2000	2000	2000
200MW	Interconnection to Mozambique	2002	2002	2002
64MW	Hydro-Kapichira 2	2012	2010	2008
33MW	Gas Turbine in Lilongwe		2012	2006
33MW	Gas Turbine in Mapanga		2014	2010
33MW	Gas Turbine in Mzuzu		2015	2011
90MW	Hydro-Lower Fufu			2012
33MW	Gas Turbine in Lilongwe			2013
33MW	Gas Turbine in Mapanga			2014
33MW	Gas Turbine in Mzuzu			2015

Based on results of the demand forecast and the map study for hydropower potential, the power sources development master plan by the year of 2015 was proposed by the WB, as shown in the above table. Among the power sources listed in the above table, the Kapichira 1 hydropower project in the Shire River system was completed and began operation in October 2000 by ESCOM. The other power sources listed in the above table have a large power output of 33 MW or more and are planed to be connected to the national grid. Gas Turbine projects are to be installed in cities. Also the hydropower projects are to be installed in electrified areas, already connected to the grid. Consequently it is confirmed that there are no power sources development projects implemented by ESCOM in the non-electrified areas.

Two hydropower projects in the Shire River with the installed capacity of 150 MW or more were identified as promising projects in the WB study, in addition to the hydropower projects listed in the above table. The WB study did indicated, however, that it is preferable to develop these hydropower projects after the year of 2015 by when the plant factor of gas turbines to be installed will rise with the increase of power demand. So it can be said that there is currently no active hydropower development in Malawi carried out by ESCOM.

6.3.2 Review of previous study for hydropower projects

In addition to the above hydropower potential study carried out by the WB study, the UNDP carried out potential study for small-scale hydropower development in their UNDP-M/P. Consequently, 12 potential sites in the northern area of Malawi were identified and listed up in the "National Energy Plan" prepared by the Malawi government in 1987.

A German consultant conducted feasibility study for two of the twelve potential sites in 1990, these being Wowve and Lufila project. After the F/S, it was concluded that the Wowve hydropower project with installed capacity of 4.5MW was a promising project. So the Wowve hydropower project was developed with financial support from Germany and has been under operation by ESCOM since 1995.

On the other hand, any studies have not yet been conducted for the other ten sites. Our preliminary review for the other ten sites indicated that most of them were not suitable potential sites as micro-hydropower development for rural electrification due to the fact that surrounding areas of the identified potential sites are already electrified or there are no demand sites around the identified potential sites.

The JICA study team, anyway, referred to information and data, obtained from those study results, as much as possible in the identification of micro-hydropower potential sites.

6.4 Micro-hydropower Potential Survey

The purposes of the potential survey for micro-hydropower development are as follows.

- To confirm the existence of off-grid micro-hydropower potential around non-electrified Trading Centers (T/Cs)
- To verify site conditions such as hydrology, topography and environment around the non-electrified T/Cs, along with the site survey for the potential sites

6.4.1 Basic concept for micro-hydropower potential survey

Considering that micro-hydropower development is utilized as isolated power supply for rural electrification, the micro-hydropower potential survey are carried out according to the following basic concepts:

(1) For selection of target non-electrified T/Cs

① The T/Cs are far from existing transmission/distribution lines

② The T/Cs have no plans for extension of transmission/distribution line in the near future (this implies that the T/Cs, listed in the Phase Ⅳ Electrification Plan, are excepted in this study)

(2) For selection of micro-hydropower potential sites

③ Potential sites are always near the target non-electrified T/Cs

④ There are rivers close to the T/Cs, expected to flow throughout the year

⑤ Access roads to the potential sites from the T/Cs are available at present time

Consequently, even most promising sites or areas, identified from the viewpoint of hydropower potential, will be excluded from this study, unless the site conditions of them meet the above concept requirements.

In this study, the JICA study team carried out the potential survey mainly in the northern and southern part of Malawi, where some hydropower potential are expected due to much rainfall. As for the central part of Malawi, on the other hand, it is assumed that electrification by the grid extension has a cost advantage there, since not only the grid comparatively extends to rural areas but also there is little rainfall in the central part.

6.4.2 Map study for selection of micro-hydropower potential sites

(1) Selection of survey area

Prior to site selection for micro-hydropower potential sites, the survey area was first selected based on the following conditions:

- Area in which large and middle scale non-electrified T/Cs are located
- Areas far from the existing grid
- Areas with similar hydrological and topographic site conditions

As a result, the northern, the central and southern part was divided into seven, one and five areas respectively as shown in Fig. 6-4-1. A map study is carried out in these each divided area in order to select micro-hydropower potential sites near non-electrified T/Cs.

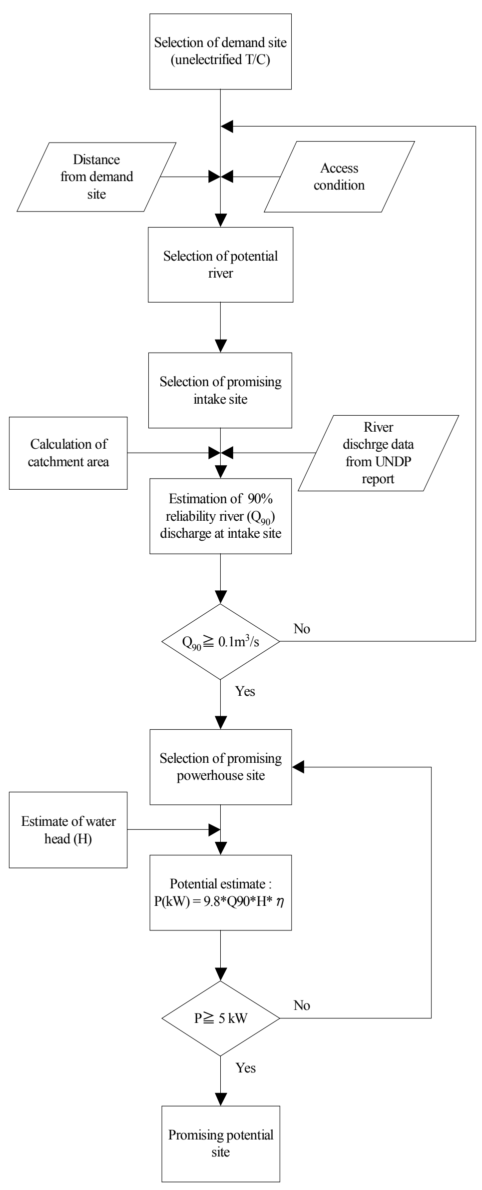
(2) Selection of target non-electrified T/Cs

According to the above basic concepts, target non-electrified T/Cs were selected using 1/50,000 topographic maps for each area divided above. Among the non-electrified T/Cs to satisfy the basic concepts, those with comparatively large scale and long distance from the existing grid were preliminary selected as the target demand sites, based on discussions with the counterpart of DOE.

Concerning all non-electrified T/Cs selected as targets in the socio-economic survey carried out in this study, on the other hand, map study was carried out in spite of the satisfaction of the above basic concepts.

(3) Selection of micro-hydropower potential sites

According to the right flowchart, the map study was carried out using 1/50,000 topographic maps, and the micro-hydropower potential sites were selected for each target non-electrified T/Cs.



Flowchart for Map Study

It should be noted that even very promising micro-hydropower potential sites distant from the demand site, they tend to have less cost advantage. That is the reason why the a micro-hydropower development, for example, 10km away from the demand site, will necessitate the construction of the an 11kV distribution line in addition to the generation facilities, thus having less minimal cost advantage. Thus, the micro-hydropower potential sites should be as close to the demand sites as possible.

With regard to plant discharge, 90% reliable river discharge (Q_{90}: river flow is not less than Q_{90} for 329 days among a year) at the proposed intake site was applied as the plant discharge, generally being adopted in micro-hydropower development projects for rural electrification. The Q_{90} at each potential site was estimated by means that discharge record at the streamflow gauging station near the potential site was converted to discharge at the potential site in proportion to catchment area. The discharge record at the streamflow gauging station was quoted in the UNDP-M/P report.

The JICA Study Team judged in this map study that there was little potential in any sites where the estimated Q_{90} was below $0.01m^3/s$ or the estimated capacity was below 5kW. Therefore such sites were excluded from targets for site survey.

It is recommended that the site survey should be implemented in September or October, because river flow is the lowest at this time of year in Malawi and it is very suitable and effective for checking the micro-hydropower potential.

As a result of the map study, a total number of 35 potential sites, consisting of 20 sites in the northern part, 1 site in the central part and 14 sites in the southern part, were selected as shown in Fig. 6-4-1.

6.4.3 Survey items at site survey

Site survey was carried out during the field survey stages for a total number of 35 potential sites, identified by the above map study. The main items confirmed by the site survey are as follows:

（Survey items at the site survey）

- Distance to potential sites from target T/Cs
- Access conditions to the potential sites
- Information about the target T/Cs (number of public facilities, etc by hearing from residents.)
- Natural and social environment around the potential sites
- River flow at the potential sites and in/around the survey area
- Existence of facilities, such as drinking water facilities, irrigation channel, and etc., in the potential river
- Expected gross head for power generation
- Location for of structure sites (intake, headrace channel, penstock and powerhouse)
- River water rights and land use conditions at the structure sites
- Location of the nearest gauging stations, observation systems, organizations and accuracy of measured hydrological data

In the site survey, it is also another main purpose to comprehensively check the site conditions in each divided survey area in order to understand outline of topographic and hydrological conditions in Malawi. Therefore detailed surveys to ascertain the river discharge and the gross head at each potential site were not carried out, since time allocated for the site survey was not enough to do them.

In addition, it is recommended that survey record sheet, as shown in Table 6-4-1, where the above survey items are presented in advance, should be used in the site survey so that the survey are carried out thoroughly and objectively.

6.4.4 Field survey in the northern area

The JICA Study Team together with DOE surveyed the twenty micro-hydropower potential sites in the northern part of Malawi, which were selected from the map study, as shown in Fig. 6-4-1. The results of the field survey are summarized in Table 6-4-2(1) ～(4), showing eight promising micro-hydro potential sites in the northern area. The site survey results of each site are summarized as follows.

【Chitipa area】（Table 6-4-2(1)）

1. Mpawamu site

The Mpawamu site aims to electrify the Chiwanga T/C (distance from existing distribution lines : approximately 46 km), which is located in the northernmost tip of Malawi and on the nearest border of Tanzania and Zambia. The proposed generation plan is to utilize the Mpawamu River, which is about 2 km away from the Chiwanga T/C. In the field survey, the water flow could not be quantified because the river was reduced to a series of puddles. Additionally, some local villagers informed that the rivers surrounding the Chiwanga T/C, including the Mpawamu River, dry up every year. As a result of this survey, the Mpawamu site was deemed to lack the micro-hydropower potential for electrification of the Chiwanga T/C.

2. Hanga site

The Hanga site aims to electrify the Kameme T/C (distance from existing distribution lines : approximately 26 km) by utilizing the Hanga River, which is about 1 km away from it. In the field survey, a minimal water flow was confirmed, and some local villagers also informed that the Hanga River dried up often in the past. Since there are no other rivers to obtain water flow surrounding the Kameme T/C, the Hanga site was deemed to lack the micro-hydropower potential for electrification of the Kameme T/C.

3. Kaseya site

The Kaseya site aims to electrify the Ifumbo T/C (distance from existing distribution : approximately 15 km), which is situated 15 km to the north of Chitipa. Since the Kaseya River, which is close to the Ifumbo T/C, has a catchment area of more than 550 km^2, a certain water flow was expected. However, a discharge of less than 0.01 m^3/s

was confirmed in the field survey and some local villagers also informed that the Kaseya River dries up every year. Therefore, the Kaseya site was deemed to lack micro-hydropower potential.

4. Kapoka site

The Kapoka site aims to electrify the Chipwera T/C (distance from existing distribution lines : approximately 20 km) by utilizing the Kapoka River, which is about 2 km away from the Chipwera T/C. In the field survey, a discharge of 0.03 m^3/s was confirmed in the Kapoka River. In addition, a gross head was estimated to be between 10 and 15 m. Since the installed capacity is approximately 2 kW according to the above conditions, the Kapoka site was deemed to have a minimal micro-hydropower potential.

On the other hand, a new access road to the Chipwera T/C was found in this survey. It was verified that this road leads to the Misuku T/C, whose electrification has already been decided by extension of distribution lines. Consequently, in order to electrify the Chipwera T/C, the extension route of distribution lines to Misuku T/C should be carried out along this road.

Other information (Chitipa area)

- Since the mean annual rainfall of the Kaseya basin is more than 1,000 mm and has plentiful of forest reserves, it is expected that some tributaries flowing out of them are recognized as having not only a certain water flow but also a gross head due to their location in the mountains. The actual water flow of these tributaries was confirmed during this site survey. Thus these tributaries are considered to have some micro-hydropower potential.
- Therefore, micro-hydropower generation is regarded as one of the appropriate electrification methods in the case that there are some villages surrounding these tributaries.

【Chisenga area】（Table. 6-4-2(1), (2)）

5. Chisenga site （General plan：Fig. 6-4-2）

The Chisenga site aims to electrify the Chisenga T/C (distance from distribution lines : approximately 35 km) by utilizing the Chisenga River. In the field survey, a discharge of 0.1 m^3/s was confirmed for the Chisenga River. The Chisenga River has drinking water facilities to supply the Chisenga T/C, and some local villagers informed that the river has not dried up since these facilities were installed in the 1980s. In order to avoid any damage to the water drinking facilities, a field survey was carried out in the upstream of them. The slope of the river around the proposed site is comparatively gentle, and it was confirmed that there is a gross head between 15 and 20 m, estimated by a simplified level surveying of the waterway. As a result of this survey, installed capacity is assumed to be about 15 kW. Further to this, the access road from the proposed site to the demand site is about 5 km in length.

- Name of T/C : Chisenga T/C
- Name of River : Chisenga River
- Catchment area : 4 km^2
- Discharge during site survey : 0.1 m^3/s
- Estimated gross head : 15～20 m
- Estimated installed capacity : 15 kW

6. Kakasu site （General plan：Fig. 6-4-3）

The Kakasu site aims to electrify the Mulembe T/C (distance from existing distribution lines : approximately 35 km) by utilizing the Kakasu River. A discharge of less than 0.1 m^3/s was confirmed for the Kakasu River during the site survey, however some local villagers informed that the river does not dry up throughout the year. The reason why the Kakasu River does not dry up despite a small catchment area of 8 km^2 is thought to be because the Kakasu basin is supplied with water from the Jembya forest reserve. Additionally, the slope of the river near the proposed site is comparatively steep, and a gross head is estimated to be between 10 and 30 m.

Therefore, the Kakasu site was deemed to have a promising micro-hydropower potential. As a result of this survey, installed capacity was estimated to be about 15 kW. The access road from the demand site to the proposed site is about 10 km in length.

- Name of T/C : Mulembe T/C
- Name of River : Kakasu River
- Catchment area : 8 km^2
- Discharge during site survey : Less than 0.1 m^3/s
- Estimated gross head : 10～30 m
- Estimated installed capacity : 15 kW

7. Jembya site

The Wenya T/C is about 85 km away from existing distribution lines, and is a comparatively large-scale T/C in the Chitipa district. The Jembya site aims to electrify the Wenya T/C by utilizing the Jembya River. In the site survey, a discharge of 0.05

m^3/s was confirmed for the Jembya River, and some local villagers also reported that the river around the proposed intake site dries up once every few years. Therefore, the Jembya site was deemed to have a minimal micro-hydropower potential.

8. Lufiliya site

The Lufiliya site also aims to electrify the Wenya T/C. A certain water flow was expected in the Lufiliya River, because the proposed intake site on it has a catchment area of 108 km^2 including a part of the Musisi forest reserve. In the site survey, however, a discharge of less than 0.05 m^3/s was confirmed for this river, and some local villagers informed that the Lufiliya River around the proposed intake site dries up once every few years.

Therefore, the Jembya River was deemed to lack micro-hydropower potential.

Other information (Chisenga area)

- In this site survey, the Kakasu River was investigated as the only micro-hydropower potential to electrify the Mulembe T/C. The investigation of the conditions of the Chisenga River led to the assumption that the Malawa River, which is close by, is also a promising micro-hydropower potential site. Because the Malawa River is closer to the Mulembe T/C than the Kakasu River, it is considered as a promising alternative for the Kakasu site.
- Some local villagers informed that the Sekwa River has drinking water facilities supplying the Wenya T/C. A discharge of 0.05 m^3/s was confirmed in the field survey close to the bridge at the M9 road. However, a greater flow of water flow is expected in the upstream, where the drinking water facilities are installed. Therefore, the Sekwa River is considered as an alternative micro-hydropower potential site to electrify the Wenya T/C.

【Nthalire area】 （Table. 6-4-2(2), (3)）

9. Miwanga site

The Miwanga site aims to electrify the Kopakopa T/C, which is situated 35 km to the northeast of Nthalire. Although the proposed intake site on the Miwanga River has a catchment area of 61 km^2, including a part of the Musisi forest reserve, a minimal discharge of 0.02 m^3/s was confirmed in the site survey.

A gross head is estimated to be a maximum of 20 m by utilizing the fall surrounding the site. The maximum installed capacity is estimated to be approximately 3 kW according to the above conditions. Therefore, the Miwanga River was deemed to have a minimal micro-hydropower potential.

10. Kalopa site

The Kalopa site aims to electrify the Mahowe T/C, which is situated 30 km to the northeast of Nthalire. In spite of the existence of the Mahowe forest reserve upstream, the Kalopa River around the Mahowe T/C had dried up completely during the site survey. Therefore, the Kalopa River was deemed to lack the micro-hydropower potential to electrify the Mahowe T/C.

11. North Rukuru site

It is clear that the area in and around the Nthalire T/C is completely isolated from the existing distribution lines, as shown in Fig. 6-4-1. The Nthalire T/C has many public facilities, which are shown in Table 6-4-2(3), and is a very large-scale T/C in the Chitipa district. Since the Nthalire T/C is more than 100 km away from the existing distribution lines, there is a high expectation of electrification by identification of power resources. Because the North Rukuru River is one of the greatest rivers in Malawi, it is expected to obtain a plentiful water flow from it. The North Rukuru site aims to electrify the Nthalire T/C by utilizing the North Rukuru Main River.

Because the North Rukuru River around the Nthalire T/C is comparatively flat, it was difficult to obtain a gross head for generation. The proposed generation plan, however, has a potential feature to utilize enough and stable water flow throughout the year. The site survey confirmed that the proposed intake site has a catchment area of 330 km^2 and a discharge of approximately 1 m^3/s. Although the expected gross head was estimated to be from 5 to 10 m from map study results, it was verified the difficulty to obtain a gross head for generation due to the flat topography. Therefore, the surveyed North Rukuru site was deemed to lack micro-hydropower potential.

12. Choyoti site （General plan：Fig. 6-4-4）

The Choyoti site also aims to electrify the Nthalire T/C. Although the Choyoti River is a tributary of the North Rukuru River and has a small catchment area of 14 km^2, a discharge of 0.2 m^3/s was confirmed in the site survey. The whole Choyoti basin is situated in the Nyika National Park that has a dense forest. In addition, there are drinking water facilities for the Nthalire T/C on the Choyoti River, and it has never dried up. Thus, it is deemed that the discharge for generation should definitely be obtained in the dry season. As the slope of the river near the proposed site is very steep due to the existence of many small falls, a gross head for generation is assumed to be from 30 to 40 m.

Therefore, the Choyoti River is a promising potential site as alternative plan for the North Rukuru River. As a result of this survey, an installed capacity is presumed to be approximately 60 kW. An access road from the demand site to the proposed power station is of approximately 15 km in length, and it is necessary to establish a new bridge across the North Rukuru River. In addition, it became clear that it is also necessary to establish small seventeen bridges and to renovate an access road.

Further to the above, it is important to make arrangements regarding environmental issues since the proposed site is located within the Nyika National Park.

- Name of T/C : Nthalire T/C
- Name of River : Choyoti River
- Catchment area : 14 km^2
- Discharge during site survey : 0.2 m^3/s
- Estimated gross head : 30～40 m
- Estimated installed capacity : 60 kW

【Katumbi area】 （Table 6-4-2(3)）

13. Hewe site （General plan：Fig. 6-4-5）

The Katowo T/C is 45 km away from Bolero that has extended the existing distribution lines. Since the Katowo T/C has many public facilities, as indicated in Table 6-4-2(3), and is a large-scale T/C around the area, it is expected to be electrified quickly. The Hewe site aims to electrify the Katowo T/C by utilizing the Hewe River. Although the Hewe River had dried up around Katowo T/C, a discharge of 0.2 m^3/s was confirmed in the upstream. The whole Hewe basin is situated in the Nyika National Park which has a plentiful forest. In addition, as there are drinking water facilities for the Katowo T/C in the Hewe River, it is deemed that water flow for generation should definitely be obtained in the dry season.

In order to avoid any damage to the water drinking facilities, a field survey was carried out in the downstream of the intake to assess local conditions. Since the river near the proposed site is as steep as 1/10, it was confirmed that an estimated gross head for generation is from 25 to 30 m, found from a simplified level surveying of the waterway. As a result of this survey, the installed capacity was estimated to be approximately 45 kW. An access road from the demand site to the proposed power station is approximately 15 km in length, it is necessary to establish a small bridge across the Hewe River.

- Name of T/C : Katowo T/C
- Name of River : Hewe River
- Catchment area : 37 km^2
- Discharge during site survey : 0.2 m^3/s
- Estimated effective head : 25～30 m
- Estimated installed capacity : 45 kW

Other information (Katumbi area)

- In the site survey, some local villagers informed that the Chisimuka River, around the Katumbi area, does not dry up throughout the year.
- A discharge of 0.1 m^3/s was confirmed in the downstream of the Chisimuka River. Additionally, since a gross head, in the upstream of it is estimated to be from 15 to 30 m according to a 1:50,000 topographic map, this river is a promising development site to electrify the Katowo T/C, as an alternative to the Hewe River.

【Chilumba area】 （Table 6-4-2(3)）

14. Remero site

The Remero site aims to electrify the Mulale T/C, which is situated 15 km from existing distribution lines, by utilizing the Remero River. The Remero River around the Mulale T/C had completely dried up, and some local villagers also informed that the river around the proposed intake site dries up every year during the dry season. Therefore, the Remero site was deemed to lack the micro-hydropower potential to electrify the Mulale T/C.

15. Chitimba site

The Chitimba site aims to electrify the Chitimba T/C, which is situated 20 km from existing distribution lines. Although a discharge of 0.05 m^3/s was confirmed in the Chitimba River during the site survey, it was verified that it is very difficult to obtain a gross head for generation due to the flat topography of the river. 10 km upstream from there, it is possible to obtain a gross head, but this is irrelevant because of the distance to the demand site and access problems.
From the above results, the Chitimba site was deemed to lack the micro-hydro potential to electrify the Chitimba T/C.

Other information (Chilumba area)

- There are many rivers around the Chilumba area, which originate in the Nyika highland situated in the northern mountains of Malawi, flowing along the eastern slope of the mountains and finally flowing into the Malawi Lake. Since a number of non-electrified villages are scattered around these rivers, it is considered that the micro-hydropower development is one of the appropriate electrification methods for these villages. In this survey, flow of these rivers was confirmed at the M1 crossing while moving northwards.

- Water flow could be verified only for the Chitimba River and few others during the dry season, because the majority of rivers surrounding this part had dried up. In the Wovwe hydropower station (installed capacity of 4.5MW) operated by ESCOM, situated in the middle of the Wovwe River (one of the above rivers), the intake site on it within the Nyika highland was found having an abundant water flow even in the dry season. However, the lower reaches of the river had dried up completely. It is presumed that this was caused by evaporation or irrigation in the plain around the Malawi Lake.
- Therefore it is presumed that the other rivers that had dried up downstream, have a reasonable water flow in the mountains and thus their gross head could be easily obtained. According to the above results it is thought that there are micro-hydropower potential sites in the mountains. Since the target T/Cs in this survey are located along the M1 road, it is evident that the potential sites become far from the demand sites. However, by considering that distribution lines had been already prepared in the Chilumba part, the electrification by micro-hydropower generation, identification of power resources might be pointless.

【Rumphi area】 （Table 6-4-2(4)）

16. Nchenachena site （General plan：Fig. 6-4-6）

The Nchenachena site aims to electrify the Nchenachena T/C, which is situated 23 km from existing distribution lines by utilizing the Nchenachena River. The proposed intake site on the Nchenachena River was found to have a discharge of 0.2 m^3/s despite its small catchment area of 18 km^2. The whole Nchenachena basin is situated in the Nyika National Park where there is a plentiful forest. In addition, there are drinking water facilities for the Nchenachena T/C and some local villagers informed that it had never dried up. Thus, it is deemed that a discharge for generation should definitely be obtained in the dry season. The slope of the river near the proposed site, which is located at the foot of the Nyika highland, was very steep due to the existence of many small falls, and a gross head for generation was assumed to be from 10 to 30 m. As a result of this survey, the installed capacity was presumed to be approximately 30 kW. Although the access route from the demand site to the proposed site is approximately 2 km in length, at present there are only footpaths.

- Name of T/C : Nchenachena T/C
- Name of River : Nchenachena River
- Catchment area : 18 km^2
- Discharge during site survey : 0.2 m^3/s
- Estimated gross head : 10～30 m
- Estimated installed capacity : 30 kW

17. Luwatizi site

A tributary of the Luwatizi River aims to electrify the Mphomapha T/C, which is situated 18 km from existing distribution lines and located at the ridge of EL 1,585 m. In the survey, the tributary of the Luwatizi River around the Mphomapha T/C had dried up, and some local villagers also informed that the river around the proposed intake site dries up every year during the dry season. Therefore the tributary of the Luwatizi site was deemed to lack the micro-hydropower potential to electrify the Mphomapha T/C.

【Nkhatabay area】 （Table 6-4-2(4)）

18. Murwerzi site （General plan：Fig. 6-4-7）

The Khondowe T/C, which is situated 52 km to the north of Nkhatabay and is along the west shore of the Malawi Lake, is a small-scale T/C. As an access road has not been prepared at present, it is only possible to access the site by foot. In this site survey, a motorboat was hired at Nkhatabay, so that Khondowe T/C was reached in three hours by moving northwards on the Malawi Lake. The Murwerzi site aims to electrify the Khondowe T/C by utilizing the Murwerzi River, which flows close by. Although a discharge of 0.05 m^3/s for the Murwerzi River was confirmed during the site survey, it has not dried up since drinking water facilities for the Khondowe T/C were installed.

The slope of the river near the proposed site is very steep, and a gross head for generation is assumed to be from 10 to 15 m with a shorter waterway. As a result of this survey, installed capacity was presumed to be approximately 5 kW. An access track from the demand site to the proposed power station is approximately 1 km in length.

- Name of T/C : Khondowe T/C
- Name of River : Murwerzi River
- Catchment area : 7 km^2
- Discharge during site survey : 0.05 m^3/s

- Estimated gross head : 10～15 m
- Estimated installed capacity : 5 kW

19. Lizunkhuni site (General plan : Fig. 6-4-7)

The Ruarwe T/C, which is situated 7 km to the south of Khondowe T/C, is also situated along the west shore of Malawi Lake. As it is difficult to access the Ruarwe T/C by car, a boat provides access twice a week (Nkhatabay～Chilumba). The Lizunkhuni site aims to electrify the Ruarwe T/C by utilizing the Lizunkhuni River that flows close by. A discharge of 0.15 m^3/s was confirmed in the site survey. Although it is presumed that the mean annual rainfall of the Lizunkuni basin is less than 1,000 mm, it has a catchment area of 80 km^2 including a plentiful forest reserve. In addition, since there are drinking water facilities for the Ruarwe T/C and the Lizunkhuni River has never dried up, it is deemed that water flow for generation should definitely be available in the dry season. Also, because the slope of the river near the proposed site is as steep as 1/10 due to the existence of many small falls, it was found that an estimated gross head is between 50 and 60 m, with a shorter waterway (500m), relying on a simplified level surveying of the waterway.

As a result of this survey, installed capacity was presumed to be approximately 50 kW. An access track from the demand site to the proposed power station is approximately 1 km in length.

- Name of T/C : Ruarwe T/C
- Name of River : Lizunkhnui River
- Catchment area : 80 km^2
- Discharge during site survey : 0.15 m^3/s
- Estimated gross head : 50～60 m
- Estimated installed capacity : 50 kW

20. Sasasa site (General plan : Fig. 6-4-8)

The Sasasa site aims to electrify the Usisya T/C, which is situated 50 km from the existing distribution lines, by utilizing the Sasasa River. In the site survey, a discharge of 0.1 m^3/s was confirmed for the Sasasa River. As there are drinking water facilities for the Usisya T/C in the Sasasa River and the river has not dried up since they were installed, it is deemed that water flow for generation should definitely be obtained in the dry season. Additionally, it is easy to obtain a gross head because there is a fall of about 20 m height 2 km away from the T/C.

As a result of this survey, the installed capacity was presumed to be about 20 kW. An access road from the demand site to the proposed power station is about 3 km in length.

- Name of T/C : Usisya T/C
- Name of River : Sasasa River
- Catchment area : 85 km^2
- Discharge during site survey : 0.1 m^3/s
- Estimated gross head : 20～30 m
- Estimated installed capacity : 20 kW

<u>Other information (Nkhatabay area)</u>

- Our Study Team identified a new road under construction leading to the Chikwina T/C, about 20 km away from Usisya T/C. Also, the Chikwina T/C had decided to electrify by extension of distribution lines according to the Phase Ⅳ program.
- In case that the distribution lines are extended to Usisya T/C along the existing access road, this extension should be for about 50 km along this road, situation that points out the possibility of electrification by an isolated micro-hydropower development. However, since the distance from Chikwina T/C, under plans of electrification, to Usisya T/C is only about 20 km, further extension of distribution lines once the new road is completed is also considered as a rural electrification method.

6.4.5 Site survey in the central part

The JICA Study Team together with DOE surveyed a micro-hydropower potential site in the central part of Malawi, which was selected from the map study, as shown in Fig. 6-4-1. The results of the site survey are summarized in Table 6-4-2(5). Results of this survey are as follows.

【Nkhotakota area】 （Table 6-4-2(5)）

<u>21. Dwambadzi site</u>

The Dwambadzi site aims to electrify the Dwambadzi T/C, which has been given the second place of priority in the Nkhotakota District, by utilizing the Dwambadzi River close by. According to the information from the socio-economic survey, this T/C is situated 38 km away from existing distribution lines, but it was confirmed in the site survey that the distribution lines had been extended to 17 km from the T/C.

Although a plentiful water flow was confirmed in the site survey during the rainy season, it was difficult to obtain a gross head for generation due to the flat topography of the river around the T/C. It is possible to obtain a gross head 5 km upstream from there, but this is irrelevant because of the distance to the demand site and access problems. Therefore, the Dwanbadzi site was deemed to lack the micro-hydropower potential to electrify the Dwanbadzi T/C.

6.4.6 Site survey in the southern part

The JICA Study Team together with DOE surveyed fourteen micro-hydropower potential sites in the southern part of Malawi, which were selected from the map study, as shown in Fig. 6-4-1. The results of the site surveys are summarized in Tables 6-4-2(5)～(7), showing that there are three promising micro-hydro potential sites in the southern part. The site survey results of each site are summarized as follows.

【Makanjila area】 （Table 6-4-2(5)）

22. Mafi site

The Mafi site aims to electrify the Namalaka T/C, which is situated 25 km from existing distribution lines, by utilizing the Mafi River. In the site survey, a minimal water flow was confirmed, and some local villagers also informed that the Mafi River dries up every year. However, since the Mafi basin within the Namizimu forest reserve has a comparatively large catchment area of 93 km^2, it is expected that water flow may be found in the upstream within the mountains, approximately 4 km from the site surveyed. This can be caused by evaporation or irrigation in the plains around the Malawi Lake. It is assumed that this represents a similar situation to the Chilumba area at the northern part. Therefore, it will be necessary to survey the upstream of the Mafi River in order to determine whether there is any micro-hydropower potential or not.

23.Ngapani site （General plan：Fig. 6-4-9）

The Ngapani site aims to electrify the Kwisimba T/C, which is situated 38 km from the existing distribution lines, by utilizing the Ngapani River around the T/C. Since the Ngapani basin, including the Namizimu forest reserve, has a catchment area of 48 km^2, a discharge of 0.05 m^3/s was confirmed in the site survey. However, as the slope of the river is very gentle, a long waterway will be required to obtain a gross head. As a result of this survey, the installed capacity was presumed to be approximately 5 kW.

There is a distance of approximately 2 km from the demand site to the power station.

- Name of T/C ：Kwisimba T/C
- Name of River ：Ngapani River
- Catchment area ：48 km^2

- Discharge during site survey : 0.05 m^3/s
- Estimated gross head : 5～15 m
- Estimated installed capacity : 5 kW

【Western area of Mangochi】 （Table 6-4-2(5)）

24. Mtemankhokwe site （General plan：Fig. 6-4-10）

The mean annual rainfall around the western part of Mangochi, which is one of the areas with low rainfall in Malawi, is 700 mm. At first it was thought that there were hardly any micro-hydro potential sites in this part. However, following the receipt of information from local people, a field survey was conducted at the Mtemankhokme River, which does not dry up throughout the year.

The Mtemankhokwe site aims to electrify the Katema T/C, which is situated 23 km from the existing distribution lines. Although a discharge of less than 0.1m^3/s was confirmed for the Mtemankhokwe River in the site survey, it was found an estimated head of 20 to 30 m, with reference to a fall of approximately 20 m, by using a simplified level surveying of the waterway. As a result of this survey, installed capacity was presumed to be approximately 25 kW. On the other hand, although an access road from the demand site to the proposed site is approximately 4 km in length, it is enough to establish a new road of approximately 300 m.

- Name of T/C : Katema T/C
- Name of River : Mtemankhokwe River
- Catchment area : 24 km^2
- Discharge during site survey : Less than 0.1 m^3/s
- Estimated gross head : 20～30 m
- Estimated installed capacity : 25 kW

25. Ntobwa site

The Ntobwa site aims to electrify the Chiripa T/C, which is situated 25 km from the existing distribution lines. A minimal water flow was confirmed in the site survey. Additionally, it is difficult to utilize it as a hydropower generation, because some local villagers informed that other rivers surrounding the Chiripa T/C dry up every year.
Therefore, the Ntobwa site surveyed was regarded as having no micro-hydropower potential to electrify the Chiripa T/C.

【Mwanza area】 （Table 6-4-2(6)）

26.Tsupe site

The Tsupe site aims to electrify Thambani T/C, which is situated 23 km from the existing distribution lines, by utilizing the Tsupe River close by. Although a discharge of 0.03 m^3/s was confirmed in the Tsupe River, some local villagers informed that it has never dried up. Further to this, as the slope of the river is very gentle, a gross head may be approximately 10 m at the highest. Since the installed capacity would be approximately 2 kW as determined in this survey, the Tsupe River was regarded as having a minimal micro-hydropower potential.

27.Ngona site

The Ngona site aims to electrify the Changoima T/C, which is situated 42 km from the existing distribution lines, by utilizing the Ngona River close by. Although a proposed intake site on the Ngona River has a catchment area of 140 km^2, and a discharge of 0.03 m^3/s was identified in the site survey, some villagers informed that the Ngona River around the proposed intake site dries up once every few years. Additionally, as the slope of the river is very gentle, it is difficult to obtain a gross head for generation. Therefore, the Ngona site was deemed to have a minimal micro-hydropower potential.

28. Branch of Mwanza site

A branch of the Mwanza site aims to electrify the Chapananga T/C, which is situated 55 km from the existing distribution lines. Since there was no water flow identified around the proposed site, and reed-growth was observed, the branch of Mwanza site was regarded as lacking micro-hydropower potential.

Other information (Mwanza area)

- The Mwanza River, which flows from north to south, was found to have a discharge of 0.5 m^3/s around Mwanza City. Although a generation plan was not proposed on the Mwanza River because of the lack of demand sites, the river, including its tributary, was regarded as having some promising micro-hydropower potential.
- The Mkulumazi and Linsugi Rivers, which flow from the northern area of Mwanza, each one have a discharge of 3 m^3/s as found at the M2 crossing. It was deemed from this that upstream of both rivers might there be some promising micro-hydropower potential sites. However, a site survey was not carried out around there due to the existence of extension plans of distribution

lines to the Neno T/C.

【Thyolo area】 （Table 6-4-2(6), (7)）

29. Livunzu site

A site survey was conducted to assess the electrification of Livunzu T/C since results of socio-economic surveys indicated that this T/C, situated 22 km from existing distribution lines, has drinking water facilities.

There is an office of the Water Department that takes care of drinking water facilities around the T/C. According to information received from the Water Department, the water supply project, which aimed to connect four rivers (Maperarera, Limphangwi, Livunzu, Mbazi River) around the T/C, was commenced by foreign donors in 1990, but was left unfinished when they withdrew in 1998. These rives do not dry up throughout the year, but it was confirmed from the investigation report of the water supply project that their discharges decrease to less than 0.01 m^3/s in the dry season.

Therefore, the Livunzu River surveyed was regarded as having a minimal micro-hydropower potential to electrify the Livunzu T/C.

30. Nswadzi site （General plan：Fig. 6-4-11）

The Nswadzi site aims to electrify the Sandama T/C, which are situated 20 km from the existing distribution lines, by utilizing the Nswadzi River. The Nswadzi River is a tributary of Thuchila River that flows into the Ruo River on the border with Mozambique, and has a large catchment area of 380 km^2. In the site survey, a discharge of 1 m^3/s was confirmed in the Nswadzi River. It is thought that these conditions may be affected by a large number of tea plantations accounting for 80 percent of the entire catchment area. The proposed generation plan needs a long waterway to obtain a gross head, which is estimated to be from 5 to 15 m. Therefore, the Nswadzi site is considered to have a promising micro-hydropower potential. As a result of this survey, the installed capacity was presumed to be about 75 kW.

An access road from the demand site to the proposed power station is about 3 km in length.

- Name of T/C ：Sandama T/C
- Name of River ：Nswadzi River
- Catchment area ：380 km^2
- Discharge during site survey ：1 m^3/s
- Estimated gross head ：5～15 m
- Estimated installed capacity ：75 kW

In the third field survey, when our team visited the site to conduct the simplified level surveying of the waterway, it was confirmed that 11 kV distribution lines were extended up to 6 km from the center of the T/C. Consequently, it was considered that electrification by extension of distribution lines has an advantage over micro-hydropower electrification.

31. Nsandi site

A site survey was conducted to assess the electrification of the Nsandi T/C, since results of socio-economic surveys that indicated this T/C is situated 20 km from existing distribution lines. The Nsandi River has a fall of about 15 m, situated 3 km away from the center of the Nsandi T/C. In the case of utilizing the waters from its upstream, it was presumed that a gross head of 20 m could be obtained. Because some local villagers informed that the river water decreases in the dry season, it is necessary to confirm the river flow again in the dry season. However, the end of 33 kV distribution lines was confirmed at 2.5 km from the center of the T/C. Consequently, it was considered that electrification by extension of distribution lines has an advantage over micro-hydropower electrification.

【Mulanje area】 （Table 6-4-2(7)）

32. Namadzi site

A site survey was conducted to assess the electrification of the Milepa T/C, since results of socio-economic survey indicated that this T/C is situated 31 km from the existing distribution lines. However, it was confirmed in the site survey that the distribution lines had been extended to 18 km from the T/C.

The Namadzi River, which flows 1 km away from the Milepa T/C, has a tobacco estate in the upstream and a large catchment area of 260 km^2. Some local villagers informed that the river dried up once in the past. However, since the topography around T/C is flat and the slope of the river is very gentle, it is difficult to obtain a gross head for generation. Consequently, the Namadzi site was deemed to have a minimal micro-hydropower potential.

33. Khuluzulu site

A site survey was conducted to assess the electrification of the Chiringa T/C, since results of socio-economic surveys indicated that this T/C is situated 20 km from existing distribution lines and has drinking water facilities.

The drinking water facilities utilize the waters from the upstream of the Khuluzulu

River, which is situated between 5 and 6 km from the center of the Chiringa T/C, however the river around the T/C is a small stream 50 cm wide. It was also confirmed that ESCOM was extending the distribution lines to Migowi, which is situated 14 km away from the Chiringa T/C. In addition, since the Chiringa T/C is a large-scale, it is estimated that there is a great demand. It is assumed from the above that electrification by extension of distribution lines has an advantage over micro-hydropower electrification.

34. Muloza site

Mt. Mulanje (approx. EL. 3,000 m) situated in the eastern part of the Mulanje district, is the highest mountain in Malawi. The mean annual rainfall around this area is about 2,000 mm, one of the heaviest rainfalls in Malawi. There are large tea plantations to the south of the mountain that rely on the plentiful rain. One of these tea plantations has in operation a micro hydropower station since it was installed in the 1950s. At present this is the only micro-hydropower station working in Malawi.

The Muloza site aims to electrify the Mlelemba T/C, which is situated 21 km from the existing distribution lines, by utilizing the Muloza River. In the site survey, a discharge of 0.05 m^3/s was confirmed for this river, and some local villagers informed that the river flow is very similar each year. Therefore, there was no water flow that it was expected.

Because the river is comparatively rapid due to the existence of many falls, it is presumed that a reasonable gross head for generation can be found. It is difficult, however, to construct the intake facilities because of the topographical conditions, such as the river width being 100 m and stony. This leads to increase of construction cost, because the installed capacity is estimated to be about 7 kW according to the discharge of 0.05 m^3/s even if a gross head of about 20 m is obtained. Additionally, since the balance of the estimated installed capacity and construction cost will be bad, economical efficiency may be got worse too far. On the other hand, a suitable intake site was identified in this survey, but the slope almost disappears downstream. Since the gross head that can be obtained is about 5 m, according to the surveyed conditions, the installed capacity is presumed to be about 2 kW. Consequently, the Maloza site has a very limited micro-hydropower potential to electrify the Mlelemba T/C.

35.Nasinga site

The Nasinga site aims to electrify the Nkhulambe T/C, which is situated 15 km from the existing distribution lines, by utilizing the Nasinga River. In the site survey, a discharge of 0.02 m^3/s was confirmed for this river. Although this site survey covered only the measurement of discharge, the installed capacity is expected to be about 2 kW by the use of a 15 m height identified on the 1:50,000 topographic map. As a result, the Nasinga River surveyed has a very limited micro-hydro potential to electrify the Nkhulambe T/C

<u>Other information (Mulanje area)</u>

- Since the mean annual rainfall around this part is about 2,000 mm, one of the heaviest rainfalls in Malawi, it was expected that there is a certein water flow. However, rivers almost dried up at the road crossings.

6.4.7 Additional Micro-hydropower Potential Survey

The total number of non-electrified target T/Cs considered in this M/P is 249. These were identified through the socio-economic survey. A Map Study was carried out in order to estimate the micro-hydropower potential near these T/Cs, taking the following into consideration.

- T/Cs located less than 20km from the existing grid were selected for the Map Study (it is clear that grid extension is the most cost-effective method for T/Cs located within 20km from the existing grid).

- Results obtained from the site investigation would be regarded as essential information for a more accurate Map Study.

The Map Study results are summarized in Table 6-4-3. According to these results, a total of eleven sites were identified as potential sites. The reasons for some T/Cs not being identified as potential sites are also described briefly.

6.4.8 Promising micro-hydropower potential sites confirmed in the site survey

As results of the potential survey, the following 11 sites were confirmed as promising potential sites. They are considered as one of the available electrification method for target non-electrified T/Cs, and economic comparison with different electrification methods will be conducted in order to select the most suitable electrification method for the target non-electrified T/Cs.

Promising potential sites identified in the potential survey

District	T/C	Distance from the grid	Potential site	Potential (P, Q, H)		
Chitipa	Chisenga	35km	Chisenga	15kW	$0.10m^3/s$	15-20m
Chitipa	Mulembe	35km	Kakasu	15kW	$0.10m^3/s$	10-30m
Chitipa	Nthalire	102km	Choyoti	60kW	$0.20m^3/s$	30-40m
Rumphi	Katowo	45km	Hewe	45kW	$0.20m^3/s$	25-30m
Rumphi	Nchenachena	23km	Nchenachena	30kW	$0.20m^3/s$	10-30m
Nkhatabay	Khondowe	-*	Murwerzi	5kW	$0.05m^3/s$	10-15m
Nkhatabay	Ruarwe	-*	Lizunkhuni	50kW	$0.15m^3/s$	50-60m
Nkhatabay	Usisya	50km	Sasasa	20kW	$0.10m^3/s$	20-30m
Mangochi	Kwisimba	38km	Ngapani	5kW	$0.05m^3/s$	5-15m
Mangochi	Katema	23km	Mtemankhokwe	25kW	$0.1m^3/s$	20-30m
Thyolo	Sandama	6km	Nswadzi	75kW	$1.0m^3/s$	10-15m

*) It is difficult to estimate the distance from the existing grid, since there are no access roads to the T/Cs at present.

6.4.9 Incorporation of results of the potential survey into the rural electrification database

In order to systematically record information and data concerning micro-hydropower potential obtained through a series of the potential survey, the information and data was incorporated into the rural electrification database for each of the non-electrified T/Cs listed in that database.

With regard to micro-hydropower potential in Malawi, the following information was acquired from a series of the site survey carried out:

- Rivers, whose catchment area includes forest reservations area with rainfall of approximately 1,000 mm, can be expected to have some micro-hydropower potential in the mountainous areas, even if the catchment area is very small.

- Water supply facilities* have been installed on many of such rivers. Consequently it is very meaningful for evaluation of their micro-hydropower potential to verify whether or not such facilities are installed in the rivers.
  * The Malawi government installed these facilities for the purpose of water supply to nearby T/Cs in the 1980s – 1990s.

- On the other hand, the even river discharge, which flows out from the mountain areas with the above conditions, becomes very low or disappears in those downstream plain areas in many cases due to high levels of solar irradiation. Therefore, the general expectation that the river flow increases towards the downstream areas along with the increase of catchment area is not always the case in Malawi

It is recommended that the above points would be taken into consideration enough in the potential survey conducted hereafter by counterpart DOE officials. Especially it is noted that every effort should be made during the site survey to collect information concerning water supply facilities installed in the target non-electrified T/Cs, since this information is very meaningful for the preliminary assessment of micro-hydropower potential.

6.5 Impact of Micro-hydropower Development on Social and Natural Environment

Generally speaking, micro-hydropower development causes no serious impact on the natural and social environment, since the development scale is very small and the alteration area by such development is extremely limited.

The following shows the potential impact on the natural and social environment, which is assumed in micro-hydropower development in Malawi.

- With regard to the impact on the social environment, land compensation for installation of power generation facilities is generally recognized as the typical impact. Actually in some of the potential sites, it was confirmed by the site survey carried out that candidates of installation sites for civil facilities were located in maize or other vegetation fields. From the view of counterpart officials who collaborated with the study team during the site survey, it will not cause serious problem for the micro-hydropower development, if an adequate compensation fee is paid to the landowner (local residents).

- With regard to impact on the natural environment, it is recognized as the typical impact that the development in forest reservation areas and National Parks may influence the protected wildlife in those areas. In fact the majority of the 35 potential sites selected by the map study are located in forest reservations, with some sites located in the Nyika National Park, the most famous National Park in Malawi.
  In general, developments in such areas are subject to certain regulations in many cases. In Malawi there are some examples of hydropower development projects located in such control areas such as the Wowve hydropower development

project (installed capacity of 4.5MW, under operation since 1995). According to information from ESCOM staff that operates the Wowve power station, the project was developed smoothly without any problems, although almost all power generation facilities were located in the Nyika National Park. Moreover from the perspective of DOE counterpart officials, it causes no serious problem for the development if adequate countermeasures against negative environmental impacts are taken on the basis of the environmental survey.

An environmental assessment would be conducted in the Map Study within the micro-hydropower potential survey to verify the existence of any environmental impact such as that effected by project development in a national park, for example. It is understood that even if the environmental assessment is conducted to this extent, it would not interfere with the main purpose of the micro-hydropower potential survey. A detailed environmental survey will be implemented in the case study for each of the target T/Cs, where micro-hydropower development is selected as the optimum electrification method.

6.6 Preliminary Cost Estimate for Micro-hydropower Potential Sites

6.6.1 General

In this M/P study the most suitable electrification method for each non-electrified T/C will be selected through economic comparison among the electrification methods available for each T/C. To achieve this, project cost for the micro-hydropower potential sites identified in the potential survey needs to be estimated preliminary (at M/P study level).

The JICA study team developed an efficient method for estimating the preliminary cost of the micro-hydropower project, based on information and data obtained from 1:50,000 topographic maps and from results of the site survey already undertaken. Then based on this method, preliminary cost estimates were carried out for the 11 promising potential sites identified in the above potential survey.

6.6.2 Cost data collection

(1) Civil works

A majority of the civil facilities for micro-hydropower projects are generally constructed with masonry structures, and a number of such examples can be seen in micro-hydropower development projects in throughout Southeast Asia.

The success or failure of micro-hydropower development depends on the specification of facilities and equipment to be installed. It is very important for the sustainable operation of micro-hydropower plants to define these specifications, so that they can be repaired with non-specified technology readily in the event of minor failures occurring in the facilities and equipment. This is particularly important for micro-hydropower plant operation, since village residents operate and maintain civil facilities on a daily basis. From the viewpoint of this, it is very meaningful that civil facilities are constructed with such specifications as masonry structures, since these are very familiar to the village residents.

A number of small masonry bridges could be seen along the roads in Malawi during the site survey. This technology can be readily applied to micro-hydropower development. Thus, specifications with masonry structures will be applied for the civil facilities on micro-hydropower development in this study.

Cost data and information were collected from a number of contractors in Malawi in order to identify adequate unit prices for cost estimates of civil works. Also previous examples of cost estimates on similar hydropower projects in Malawi were considered as a reference.

(2) Hydroelectrical and hydromechanical works

It will be necessary to import the turbine, generator and steel penstock for the hydroelectrical and hydromechanical works, since these are not manufactured in Malawi. The cross flow turbine, which is generally recognized as the typical type of turbine in micro-hydropower development, was judged to be a suitable type for the identified potential sites, referring to the turbine application diagram shown in Fig. 6-6-1. At present, the cross flow turbines and generators can be imported into Malawi from South Africa, Japan and Europe. In order to decide the most suitable specifications of the cross flow turbines and generators for the micro-hydropower projects in Malawi, the cost and reliability of them were compared with each other. The results are as follows:

- Units made in South Africa are the cheapest one, however the operation reliability of these units cannot be evaluated, since there is only a small number of these units in operation.

- European units are cheaper than Japanese units, and there is no difference with respect to operation reliability from Japanese ones.
- European units can be imported from an agency in Tanzania. Consequently convenient after-sales service provided by technical staff of the agency can be expected.

Taking the above results into consideration, it was decided that the cost estimates for hydroelectrical works would be based on the application of European units.

With regard to cost estimate for hydromechanical works, some examples of cost estimate on similar hydropower projects in Malawi are referred in order to set the adequate unit price for steel penstock and gate.

6.6.3 Procedures for preliminary cost estimate at Master Plan level

The cost estimate of each potential site is conducted at Master Plan level according to the following procedures, utilizing 1:50,000 topographic maps. The following procedure assumes that the site survey has not been carried out for each potential site at this point of time.

Ⅰ. Construction Cost

The construction cost is estimated by the unit price estimate method.

1.1 Preparatory Works

The construction cost of preparatory works includes both access roads and bridges (large and small). The length of the access road and number of bridges are roughly estimated by using 1:50,000 topographical maps. The unit prices for each structure is determined reasonably, based on information obtained from a number of local contractors in Malawi and reference on unit prices adopted in past similar hydropower projects. Site installation costs are estimated at 10% of the above cost.

1.2 Civil Works

Taking into consideration the characteristics of civil facilities for micro-hydropower projects, civil facilities can be classified as follows:

1) Weir, intake, headtank and powerhouse →depend on plant discharge
2) Headrace and tailrace →depend on plant discharge and length

3) Penstock and spillway → depend on plant discharge and length

Work items are grouped into excavation (soil, rock) and stone masonry works. Work expenses of these group items are estimated using calculation formulas presented in the following sections. Unit prices are derived from information supplied by a number of local contractors in Malawi and reference on unit prices adopted in past similar hydropower projects. Site installation costs are estimated at 15% of the total cost of each civil facility.

(1) Weir, intake, headtank and powerhouse

In order to estimate the total volume of stone masonry works for the weir, intake, headtank and powerhouse facilities, previous examples of cost estimates in other micro-hydropower projects were investigated to find the relationship between plant discharge (Q) and volume of stone masonry works (M_a). As a result of this investigation, it was found that there is a close correlation between Q and M_a. Then the following formula was derived from this correlation. The total volume of stone masonry works for the weir, intake, headtank and powerhouse is estimated in this study by using the following formula:

$$M_a = 530.18 \times Q$$

Where M_a : Total volume of stone masonry works (m^3)

Q : Plant discharge (m^3/s)

In estimating the total volume of soil and rock excavation works, a number of cost estimates on past micro-hydropower projects were investigated in order to determine the relationship between the volume of the stone masonry works and the excavation works. The results showed that the total volume of the excavation works is between 1.0 and 5.0 times the total volume of the stone masonry works. It is considered that the difference from 1.0 to 5.0 times is because of the differences in the topographic conditions of each site. This result can be interpreted as follows: the ratio becomes small (or large) due to a decrease (or increase) of the excavation volume if the topography in the potential site is flat (or steep). Further to this, the volume ratio between soil and rock excavation is also dependent on the topography of the site.

Because it is difficult to accurately determine the topography of each site by using 1:50,000 topographic maps, a preliminary approach assumes that the total volume of excavation works is twice the total volume of stone masonry works. Similarly, another preliminary approach assumes that the volume ratios of soil and rock excavation to the total excavation volume are 0.3 and 0.7, respectively. According to these assumptions, the total excavation volumes of weir, intake, headtank and powerhouse are estimated from the following formulas:

$Ex(c) = M_a \times A \times B_s$

$Ex(r) = M_a \times A \times B_r$

Where $Ex(c)$: Total volume of soil excavation works (m^3)

$Ex(r)$: Total volume of rock excavation works (m^3)

M_a : Total volume of stone masonry works (m^3)

A : Volume ratio of excavation to stone masonry works, which depends on the topography of each site

B_s , B_r : Volume ratios of soil and rock excavation works to stone masonry works, which depend on the topography of each site

(2) Headrace and tailrace

The uniform flow calculations, which vary from $0.05m^3/s$ to $0.5m^3/s$ of plant discharge, were carried out in order to obtain the cross section area of the headrace and tailrace channels, required to run off each plant discharge. Based on these calculation results, a formula relating the plant discharge (Q) and the lining area of headrace and tailrace channel is derived as follows.

$S = 0.5178 \times Q + 0.2052$

Where S : Lining section area of headrace and tailrace channel (m^2)

Q : Plant discharge (m^3/s)

The total volume of stone masonry works for the headrace and tailrace are estimated from the following formula. The total length of these structures is estimated by using 1:50,000 topographic maps.

$M_b = S \times L$

Where, M_b : Total volume of stone masonry works (m^3)

S : Lining area of headrace and tailrace channel (m^2)

L : Total length of waterway (m)

In estimating the total volume of soil and rock excavation works, a number of cost estimates on past micro-hydropower projects were investigated in order to determine a relationship between the volume of the stone masonry works and the excavation works. The results of this investigation indicated that the total volume of the excavation works is between 4.0 and 10.0 times the total volume of the stone masonry works. It is considered that the difference from 4.0 to 10.0 times is dependent on the topography of each potential site. This can be interpreted as follows: the ratio becomes small (or large) due to the decrease (or increase) of the excavation volume, if the site topographic condition is flat (or steep). Further to this, the volume ratio between soil and rock excavation is also dependent on the topography of the site.

Because it is difficult to accurately determine the topography of each potential site by using 1:50,000 topographic maps, a preliminary approach assumes that the total volume of excavation works is 5.0 times the total volume of stone masonry works. Similarly, another preliminary approach assumes that the volume ratios of soil and rock excavation to the total excavation volume are 0.3 and 0.7, respectively. According to these assumptions, the total excavation volumes of headrace and tailrace are estimated from the following formulas:

$Ex(c) = M_b \times A \times B_s$

$Ex(r) = M_b \times A \times B_r$

Where, $Ex(c)$: Total volume of soil excavation works (m^3)

$Ex(r)$: Total volume of rock excavation works (m^3)

M_b : Total volume of stone masonry works (m^3),

A : Volume ratio of excavation works to stone masonry works, which depends on the topography of each site

B_s , B_r : Volume ratios of soil and rock excavation works to stone masonry works, which depend on the topography of each site

(3) Penstock and spillway

In order to estimate total volume of stone masonry works for the penstock and spillway, previous examples of cost estimates in other micro-hydropower projects were investigated to find the relationship between plant discharge (Q) and volume of stone masonry works (M_a). As a result of this investigation, it was found that there is a close correlation between Q and M_a. Then the following formula is derived from this correlation. The total volume of stone masonry works for the penstock and spillway are estimated in this study by using the following formula:

$Mc = 0.14 \times Q$

Where, Mc : Total volume of stone masonry works (m^3)

Q : Plant discharge (m^3/s)

In estimating the total volume of soil and rock excavation works, a number of cost estimates on past micro-hydropower projects were investigated in order to determine the relationship between the volume of the stone masonry works and the excavation works. The results showed that the total volume of the excavation works is approximately 0.3 times the total volume of the stone masonry works, with no remarkable differences. It is considered that the penstock and spillway are generally installed on gentle slopes so that the installation of them are not strongly dependent on the topography of the potential site as compared with other civil facilities.

The total excavation volume for the penstock and spillway is estimated from the following formulas, preliminary assuming that the volume ratios of soil and rock excavation to the total excavation volume are 0.3 and 0.7, respectively.

$Ex(c) = Mc \times 0.30 \times B_s$

$Ex(r) = Mc \times 0.30 \times B_r$

Where, Ex(c) : Total volume of soil excavation works (m^3)

Ex(r) : Total volume of rock excavation works (m^3)

M_c : Total volume of stone masonry works (m^3)

B_s , B_r : Volume ratios of soil and rock excavation works to stone masonry works, which depend on the topography of each site

1.3 Hydromechanical Works

In order to estimate the cost of hydromechanical works, they are classified into two cost categories, which are 1) gate and screen, 2) penstock. The weight of these structures is estimated using formulas given below. Their unit prices are determined by reference of unit prices adopted in past similar hydropower projects. Site installation costs are estimated at 10% of the total cost estimated for each cost category.

(1) Gate and screen

In order to estimate the total weight of gates and screens, a number of cost estimates on past micro-hydropower projects were investigated to find a relationship between the plant discharge (Q) and the total weight (Ws). As a result of this investigation, it was found that there is a high correlation between Q and Ws. Then the following formula is derived from this correlation, and is used to estimate the total weight of gates and screens in this study.

$W_S = 18.18 \times Q$

Where, W_S : Total weight of gate and screen (t)

Q : Plant discharge (m^3/s)

(2) Penstock

The weight of penstocks can be calculated from the following formulas.

$W_P = 7.85 \times \pi \times D_P \times t \times 10^{-3} \times 1.15 \times L$

$t = 0.0362 \times H \times D_P + 2$

Where W_P : Weight of penstock (t)

D_P : Average diameter of penstock (m)

$D_p = (2*Q/\pi)^{1/2}$, Q : Plant discharge (m^3/s)

t : Thickness of penstock (mm)

L : Length of penstock (m)

H : Gross head (m)

1.4 Hydroelectrical Works

The cost of hydroelectrical works, which comprises turbines, generators and other relevant equipment, is estimated from the following formula, which was derived from the cost data obtained from the agency dealing with European equipment in Tanzania.

$T_C = 671.98 \times P_P + 108{,}410$

Where T_C : Cost of hydroelectrical works (US$)

P_P : Plant output (kW)

1.5 Distribution line works

The cost of distribution line works for micro-hydropower development is estimated by a similar procedure described in Chapter 3.

II .Engineering Services

The cost of engineering services, which comprise detailed design, procurement works and site supervision, is preliminary estimated at 8.0% of the above construction cost (=Σsection 1.1 to 1.5).

Ⅲ. Administration Expenses

Administration expenses of the project owner (DOE) are preliminary estimated at 3.0% of the construction cost(=Σsection 1.1 to 1.5).

Ⅳ.Land Compensation

Land compensation costs are preliminary estimated at 3.0% of the construction cost(=Σsection 1.1 to 1.5).

Ⅴ.Tax (VAT)

Value added tax (VAT) is estimated at 10.0% of the construction cost and Engineering Services in this report. However, the tax increase for 20.0% was informed at discussion concerning the draft final report with C/P, which was carried out in January 2003. So re-estimation of the project cost should be carried out according to the VAT rate at the time of the project implementation.

The total of the above cost items I to Ⅴ is the project cost of the micro-hydropower development.

6.6.4 Review of cost estimates according to results of the site survey

Project features including plant discharge, gross head and length of headrace channel & access road, estimated by the map study, will be reviewed according to results of the site survey carried out.

Also results of the site survey will be used in order to review cost estimates carried out in the above procedures for improvement of their accuracy. The review, based on site topographic conditions obtained from the site survey, is carried out as follows.

(1) Preparatory works

Confirmed site information including length of access roads and number of bridges necessary for access to the potential site are used in order to review the cost estimate.

(2) Civil works

In order to review the cost estimates for civil works, the site topographic conditions confirmed during the site survey are used as follows:

- Volume ratio (A) of excavation works to stone masonry works
  → If the installation site was found to be on a steep slope, the ratio is increased
- Volume ratios ($B_s : B_r$) of soil and rock excavation works
  → If the installation site was found to be on rock foundation, the value of B_r is increased

(3) Land compensation

If compensation expenses are estimated to be more expensive than the preliminary estimated figure using 3.0% ratio due to the site conditions, which will be obtained from the site survey, the ratio (3.0%) should be increased.

6.6.5 Result of cost estimates for the promising potential sites

Project cost for the promising potential sites, listed in section 6.4.8, are estimated according to the above-mentioned procedures. A summary of these results is included below. The breakdown of results are presented in Appendix-1.

Cost estimate result of the promising potential sites

District	T/C	Site	Output (kW)	Amount (US$)
Chitipa	Chisenga	Chisenga	15	433,610
Chitipa	Mulembe	Kakasu	15	487,140
Chitipa	Nthalire	Choyoti	60	896,580
Rumphi	Katowo	Hewe	45	641,090
Rumphi	Nchenachena	Nchenachena	30	476,890
Nkhatabay	Khondowe	Murwezi	5	299,890
Nkhatabay	Ruarwe	Lizunkhuni	50	631,460
Nkhatabay	Usisya	Sasasa	20	493,150
Mangochi	Kwisimba	Ngapani	5	473,450
Mangochi	Katema	Mtemankhokwe	25	392,200
Thyolo	Sandama	Nswadzi	75	1,213,930

6.7 Project Evaluation for Micro-hydropower Development

In this M/P study, grid extension, micro-hydropower, solar power and diesel power are taken into consideration as the electrification methods for non-electrified T/Cs. The appropriate method for each non-electrified T/C will be selected by economic comparison between the electrification methods available in each T/Cs.

Prior to the economic comparison, evaluation of the micro-hydro potential sites identified is carried out in order to assess their economical viability. This section describes the specific procedures utilized in the evaluation process.

6.7.1 Economical evaluation methods

Comparing the economic effects in the event “a target project is realized” and the situation where “it is not realized”, is a concept generally applied in determining the economic viability of power development projects.

If this concept is applied to rural electrification projects considered under this M/P study, then it is necessary to compare the cost of each target electrification method, such as grid extension, micro-hydropower and solar power, with the cost of an alternative electrification method (= diesel power), which would be implemented in the situation where they are not realized. Generally, this method is called the “alternative thermal power method", and is widely applied on economical evaluation of hydropower projects. This method is applied in this M/P study, and the diesel power is taken into consideration as an alternative method of power supply to grid extension, micro-hydropower and solar power.

For the alternative thermal power method, the cost of the alternative power (= diesel power) is regarded as the Benefit (B), and the cost of each target electrification method is regarded as the Cost (C). Both costs (B and C) are projected for 20-years of the project life period according to the Discounted Cash Flow Method, and then converted to present values respectively. Since the present values of B and C include O&M and fuel costs required for the project life, then the economic viability can be assessed by evaluating both the initial investment and running cost for the 20-years.

6.7.2 Procedure of economical evaluation

The procedure of economical evaluation according to the Discounted Cash Flow Method is as follows:

①Calculation of cost of diesel power (B), including annual O&M and fuel costs.

②Calculation of cost of micro-hydropower (C), including annual O&M costs.

③Calculation of present value of B and C, which are projected for 20-years of the project life period.

④Economical evaluation by assessing the B/C value (ratio of benefit to cost) for each micro-hydropower potential site

Details of each step in the above procedure are indicated as follows:

6.7.3 Calculation of diesel power cost (Benefit)

(1) Initial Investment Cost

Assuming that the diesel power satisfies in full the power demand of the target T/Cs, the initial installation cost, including transportation cost, is estimated according to the following formula. This formula was derived from the actual cost data for the rural electrification project on Likoma Island of Malawi.

$$T_{D2} = (402.34 \times P_P + 56{,}749) + C_{DL}$$

Where, T_{D2} : Installation cost of diesel generator (US$)

P_P : Estimated power demand in the target T/Cs (kW)

C_{DL} : Installation cost of distribution line (US$)

The installation cost of the distribution line (C_{DL}) is estimated according to the procedures and methods described in Chapter 5.

(2) O&M Cost

O&M costs of the diesel power plant are calculated as the total of "plant operation costs" and "fuel costs", as shown below:

- Plant operation costs

  Based on examples of diesel power plants for rural electrification in Southeast Asia, it is assumed that the plant is operated by a plant manager, an electrical engineer, a civil engineer, a mechanical engineer, distribution engineer and two fuel transportation staff. In addition to this, material and equipment costs for the plant operation are estimated at 2.0% of the initial investment cost. Unit labor costs are estimated at 10US$/day for a plant manager, 8US$/day for an engineer and 5US$/day for a fuel transportation staff.

- Fuel costs

  In order to calculate the annual amount of fuel consumed at the plant, the fuel consumption rate is calculated by the following formula that takes into account the capacity of the generator.

$$F_{D2} = 0.1476 \times P_P$$

Where, F_{D2} : diesel fuel consumption rate for unit of l/hr

P_P : installed capacity (kW)

The annual fuel cost is estimated by multiplying the unit price of fuel by the annual fuel consumption, which is derived from the above fuel consumption rate and the annual electricity demand estimated for the target T/Cs. The unit price of diesel fuel should be determined with consideration of the transportation costs for each site. Except for potential sites where land transportation is difficult, however, the unit price in this study level is taken as the market price excluding the transportation cost, because of the following reasons:

- The potential surveys are carried out by map studies at M/P study level. Therefore it is difficult to rely on map studies to determine the fuel transportation route and its road condition for each site.

- The cost of diesel power is treated as the benefit (B) in the B/C evaluation regardless of such the electrification method as micro-hydropower, grid extension or solar power. This then influences the absolute value of the B/C ratio, but does not change the relative relation of the B/C ratios between different electrification methods.

6.7.4 Calculation of cost of micro-hydropower (Cost)

(1) Initial Investment Cost

The initial installation cost of micro-hydropower is estimated according to the procedures and methods described in the above section 6.6.

For the case where micro-hydropower cannot satisfy fully the power demand estimated for the target T/Cs because of its limited potential, it is assumed that the shortage of micro-hydropower potential is supplemented with diesel power. The cost of the diesel power is also estimated according to the procedure described in the above section 6.7.3. Consequently the total initial investment cost is the sum of the installation cost for micro-hydropower and diesel power.

(2) Operation and Maintenance Cost

Based on a number of examples of operation at micro-hydropower plants for rural electrification in Southeast Asia, it is assumed that the plant is operated by a plant manager, an electrical engineer, a civil engineer, a mechanical engineer, and distribution engineer. Also it is assumed that the diesel power plant to supplement the shortage in micro-hydropower is operated by the same staff and additional fuel transportation staff.

The costs of material and equipment required for the operation are estimated at 2.0% of the initial investment cost. Unit labors cost are estimated at 10US$/day for a plant manager, 8US$/day for an engineer and 5US$/day for a fuel transportation staff. Also cost for diesel fuel of supplemental diesel power can be estimated in the same manner described in previous section 6.7.3.

6.7.5 Calculation of the present value of Benefit and Cost projected up to 2020

The Benefit (cost of diesel power) and Cost (cost of micro-hydropower) are projected for 20-years of the project life period by applying the Discounted Cash Flow Method, taking into account a discount rate of 10%. The Benefit and Cost are then converted to the present value respectively. When calculating the present value of diesel power, it was assumed that the generator was replaced every ten years, as dictated by the operation life of generators.

6.7.6 Economical evaluation by assessing B/C ratios for each micro-hydropower potential site

Based on the present value of Benefit and Cost, as indicated above, the benefit-cost ratio (B/C) is calculated for each micro-hydropower potential site. Calculation results for each potential site are shown in Appendix-2 and summarized in the table below. As shown in this table, all the potential sites will be supplemented with diesel power, since their micro-hydropower capacities are less than the power demand estimated for the target T/Cs.

District	T/C	Power demand	Micro-hydropower	Diesel power	B/C
Chitipa	Chisenga	100kW	15kW	85kW	0.73
Chitipa	Mulembe	40kW	15kW	25kW	0.54
Chitipa	Nthalire	390kW	60kW	330kW	0.88
Rumphi	Katowo	300kW	45kW	255kW	0.90
Rumphi	Nchenachena	190kW	30kW	160kW	0.87
Nkhatabay	Khondowe	100kW	5kW	95kW	0.86
Nkhatabay	Ruarwe	60kW	50kW	10kW	1.01

Nkhatabay	Usisya	140kW	20kW	120kW	0.76
Mangochi	Kwisimba	100kW	5kW	95kW	0.65
Mangochi	Katema	180kW	25kW	155kW	0.89
Thyolo	Sandama	350kW	75kW	275kW	0.79

In the above table it can be seen that only one site, Ruarwe T/C, can be electrified with micro-hydropower more economically than diesel power only. This is highlighted by the B/C value greater than 1.0.

With respect to the other T/Cs, it can be said that electrification with diesel power only is more economical than micro-hydropower (with supplement of diesel power), as the B/C values are less than 1.0. This means that since a large initial investment cost in micro-hydropower development cannot be compensated by a large O&M costs in diesel power operation, spent through the operation life of the project, the micro-hydropower becomes less cost-effective than diesel power only. This is the reason why approximately 80% of the power demand estimated in most of the T/Cs, except Ruarwe T/C, must be supplemented with diesel power generation. This in turn results in a marked increase of O&M costs for the operation of diesel power in conjunction with micro-hydropower.

6.8 Implementation of a Case Study for Micro-hydropower Development

6.8.1 Objective

The objectives of the case study for micro-hydropower development are as follows:

- To clarify the procedures and methods concerning both the technical and institutional aspects for implementing micro-hydropower development for rural electrification.
- To justify the technical and economical validity of the micro-hydropower project throughout the case study at a Pre-F/S level and to propose a suitable institutional system for the operation of the project.
- To carry out technology transfer to the counterpart throughout the case study so that they can implement the micro-hydropower development themselves.
- To take results of the case study into the final rural electrification M/P and to enhance the validity of the M/P.

6.8.2 Selection of a potential target site for the case study

The Lizunkhuni site, which can supply electricity to the Ruarwe T/C in Nkathabay District, was selected as the target site for this case study after discussions with the DOE counterpart. The following issues were taken into consideration:

- Of the potential sites identified in this study, Lizunkhuni is the only site that shows a B/C value greater than 1.0.
- It was justified through economical comparison that micro-hydropower was the most suitable electrification method for the Ruarwe T/C.

6.8.3 Outline of the Lizunkhuni site (refer to Fig. 6-4-7)

The Ruarwe T/C is situated along the west shore of Malawi Lake. As it is difficult to access the Ruarwe T/C by car, just a ferry transport provides access twice a week (Nkhatabay～Chilumba). The Lizunkhuni site aims to electrify the Ruarwe T/C by utilizing the Lizunkhuni River that flows close by. A discharge of 0.15 m^3/s was confirmed in the site survey. Mean annual rainfall in the Lizunkuni River basin is estimated to be more than 1,500 mm and, the River has a catchment area of 80 km^2 including a plentiful forest reserve. In addition, since there are drinking water facilities for the Ruarwe T/C and the River has not dried up in the past according to information obtained from hearing investigation to the local residents, it is deemed that river flow for the power generation should definitely be available in the dry season.

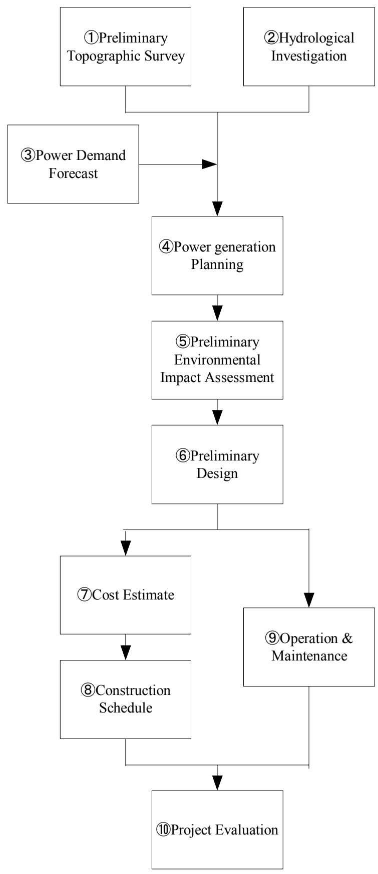
Also, because the slope of the river near the proposed site is as steep as 1/10 due to the existence of many small falls, it was found that an estimated gross head is between 50 and 60m with a shorter waterway of about 500m, relying on the simplified level surveying carried out during the site survey.

As a result of the site survey, installed capacity was presumed to be about 50 kW. An access road from the demand site to the proposed power station is approximately 1 km in length.

- Name of T/C : Ruarwe T/C
- Name of River : Lizunkhuni River
- Catchment area : 80 km^2
- Discharge during site survey : 0.15 m^3/s (on October 2001)
- Estimated gross head : 50～60 m
- Estimated installed capacity : 50 kW

6.8.4 Implementation plan for the case study

The case study will be carried out during the fifth field survey stage in October 2002, according to the following flowchart. Results of the case study will be obtained at Pre-F/S level. The contents of each study item, which are indicated in the flowchart, are described as follows:



Flowchart of Case Study for Micro-hydropower Development

① Preliminary Topographic Survey

In order to obtain the basic information for preliminary design and estimation of work quantification for civil facilities, the following preliminary topographic survey was carried out.

- Topographic survey
  Section : Installation site of intake facilities
- River cross-section survey
  Section : Weir site and river flow measurement point
- Longitudinal survey
  Section : Along the water way from intake to powerhouse site
- Cross-section survey
  Section : Headrace channel route

② Hydrological Investigation

In order to obtain the basic information required for power generation planning and the preliminary design, the following hydrological investigation was carried out.

- Data collection
- River flow measurement
  River flow measurement was carried out during the case study in October. To measure actual river discharge in October is very useful and effective information for the power generation planning, since this is when river flows are the lowest in Malawi.
- Estimate of low flow
  Based on results of the discharge measurements and other relevant data collected, the

annual low flow duration at the weir site was estimated. This data was used for basic information necessary for the power generation planning.

- Estimate of the highest river and lake water level in the past

  In order to prevent any installed facilities from being washed away and flooded during the operation, they will be installed at a suitable location and level. This will be decided through a series of detailed studies in order to understand the highest river and lake water level in previous years.

  The following were carried out during the case study in order to achieve the above.

  - Collection of information about the river and lake water level in the past by interviewing the local residents
  - Estimate of river water level during flood by utilizing the uniform flow calculation.

③ Power Demand Forecast

Future power demand in the target T/C was already forecasted according to the procedures and methods described in the rural electrification manual. However, the power demand forecast was reviewed, based on information and data concerning the socio-economic conditions in the target T/C acquired from the socio-economic survey, which was be carried out during the case study.

④ Power Generation Planning

Based on the results of the power demand forecast, the hydrological investigation and topographic survey, project features including suitable installed capacity, installation sites and waterway routes were studied and decided.

⑤ Preliminary Environmental Impact Assessment (EIA)

In order to preliminary assess the environmental impact with the project development, site survey was carried out in order to collect the following information from local residents:

- Situation of the compensation for land and assets in the installation site
- Local regulations associated with the forest reservation in and around the project area
- Conditions of the water usage, fishery, etc., in the Lizunkhuni River
- Ecological conditions, in particular rare species in and around the project area

⑥ Preliminary Design

Based on the above study results, preliminary design was implemented at Pre-F/S level to decide the main specification of the power facilities and equipment. Drawings for the main facilities such as the weir, intake, headrace channel, headtank, penstock and powerhouse, were prepared according to the design specifications.

⑦ Cost Estimate

The project cost was generally estimated according to the procedures and methods described in the above section 6.6. However, with regard to the cost estimate of the preparatory and civil works, the work quantities for each cost category were reviewed with the drawings prepared above in order to enhance the accuracy of the project cost estimation.

⑧ Construction Method and Schedule

The construction implementation schedule was prepared from the results of the above studies. With regard to the preparatory and civil works, assuming that the works will be carried out by local contractors in Malawi, the technical level of the local contractors was taken into account in preparation of the construction schedule. In addition to this, rainfall conditions in Malawi was also taken into consideration for preparation of the work plan for weir installation so that the installation is carried out during the dry season, and cost of the river diversion works, required for the weir installation, is reduced as much as possible.

⑨ Operation & Maintenance

With regard to the operation and maintenance of the project from technical and administrative perspectives respectively, an alternative of O&M system was proposed in consideration of examples for O&M systems in rural electrification project with micro-hydropower in Southeast Asian countries.

⑩ Project Evaluation

Financial evaluation was carried out for the project evaluation. Benefit of the project is evaluated in power tariff revenue. Firstly the power tariff of the project was found so that the project can secure 8% of internal rate of return, which was applied in project evaluation of this M/P described in Chapter 9 of the Technical Background Report. Then as for necessity of some subsidy to the project in order to set the power tariff at current tariff level, a suggestion was made.

6.8.5 Summary of results of the case study

Procedures for and results of the case study are presented in detail in the case study report. A brief summary is provided below.

(1) Optimization of installed capacity for micro-hydropower

Taking into consideration the electricity demand estimated for the Ruarwe T/C, three alternatives for the installed capacity of micro-hydropower are proposed as indicated below. An economic comparison was carried out to determine the best option from these three alternatives. Installation of supplementary diesel power was also considered for each of the alternatives in two phases, at 10 and 20 years later after the electrification.

Phase	**Power** Demand Target	Case A (90% river flow ratio)			Case B (80% river flow ratio)			Case C (70% river flow ratio)		
		Hydro Power	Diesel Power	Total Capacity	Hydro Power	Diesel Power	Total Capacity	Hydro Power	Diesel Power	Total Capacity
1	230	140 (100)	130	230	200 (135)	95	230	200 (150)	80	230
2	270	-	170	270	-	135	270	-	120	270
B/C		**1.37**			**1.45**			**1.38**		

※ Figures for “Hydro Power” in brackets stand for the average power output in the dry season. The installed capacity of supplemental diesel power is decided based on this amount so that the total installed capacity of micro-hydro and diesel power can satisfy the power demand.

An economic comparison was carried out by using the B/C method, which is described in detail in section 6.7. The benefit (B) is evaluated including all the electrification costs in case of using diesel power only. Case B indicated in the above table with an installed capacity of 200kW for micro-hydropower was selected as the optimum plan, since it has the maximum B/C value.

Preliminary design and cost estimate of the micro-hydropower facility was carried out for the above optimum plan. Main features, structural drawings and project cost of the micro-hydropower are presented in Appendix-3.

(2) Operation and Maintenance

As for operation and maintenance system of the electrification project, an alternative are proposed in Appendix-3 in consideration of examples of O&M systems in rural electrification project with micro-hydropower in Southeast Asian countries. In the alternative, the O&M team consists of a manager, two accounting officers and four operators. Each operator has specialized knowledge for the operation and maintenance of the civil, electrical, mechanical and distribution facilities to be installed.

As a result to the socio-economic survey carried out in the case study, it was found that there are existing cooperatives that operate and maintain the drinking water facilities installed in Ruarwe T/C, and these facilities have been operated relatively well. It therefore believed that villagers in Ruarwe T/C may have the necessary knowledge to operate a cooperative for the rural electrification project, and that members of the O&M team for this project could be chosen from local villagers in Ruarwe T/C. Members would be selected at the beginning of the next detailed design stage of the project and would then be actively involved in the design and construction works. Additionally they should receive from DOE, ESCOM and relevant organizations enough technical and administrational training to operate and maintain the project. In order to accomplish this, an administrative structure would need to be established to support such training.

(3) Financial evaluation

Based on the study result so far, the team has conducted a financial evaluation in a similar manner that ESCOM carried out for the electrification of Likoma Island. The necessary tariff levels required to achieve an internal rate of return of 8% has been calculated for the evaluation. The IRR level of 8% has been chosen since this is the equivalent of the level used at Likoma Island by ESCOM, and also because it is a level often quoted by other donors such as the World Bank.

As a result, this project requires a tariff level of 3.35 times the current level even with consideration of cost reduction effect on the initial construction cost by voluntary participation of villagers. Especially in Ruarwe T/C, it has been revealed that the residents' income level is lower than the national average (see Chapter 1). Therefore, it is unlikely that the current residents of this T/C will be able to afford a tariff level that is over three times the national level. Therefore, it will require some form of subsidy.

(4) Project evaluation

As indicated above, the project cannot be justified financially because of the requirement of a high electricity tariff, and consequently it is not considered a viable project from a business perspective. Additionally, ESCOM would not extend the grid to Ruarwe T/C, because of the low level of income amongst the villagers and the lack of an access road.

Consequently it should be recognized that the only viable method for the electrification of Ruarwe T/C is to install a mini-grid using micro-hydropower as proposed in this study. Some form of subsidy would be required for the project implementation in order to reduce the high electricity tariff to the current tariff level. According to trial calculations, 80% and 65% of the investment and O&M costs respectively would need to be subsidized in order to achieve the current tariff level in this project.

6.9 Case Study Result Consideration

6.9.1 Application of 90% of river flow to the plant discharge in the potential survey stage

As described in section 6.4 concerning the procedure of the micro-hydropower potential survey, 90% river flow was applied as the plant discharge in order to estimate the micro-hydropower potential in each site. The application of 90% river flow as the plant discharge is generally recognized as appropriate in rural electrification projects if the estimated power demand is similar to the installed capacity determined by using the 90% river flow.

On the other hand, 90% river flow applied as plant discharge cannot always be justified if the power demand estimated is much larger than the site's micro-hydropower potential. This means that surplus river flow in the wet season should be utilized for micro-hydropower generation in order to reduce the fuel consumption for supplemental diesel power operation. It is evident then that the optimum plant discharge for each potential site should be determined through economic comparison between alternatives. In fact the optimum plant discharge selected throughout the case study in Ruarwe T/C was not 90% but 80% river flow.

In the potential study stage, however, there are no disadvantages in applying the 90% river flow as plant discharge for the following reasons:

- 80% river flow was found to be the optimum plant discharge in Ruarwe site throughout the case study. However, optimum plant discharge is greatly influenced by the site conditions such as river flow duration, water head and power demand. Thus application of 80% river flow as plant discharge cannot always be justified for other sites.

- The case study results and trial calculations of the plant discharge optimization for other potential sites revealed that the difference of the B/C value calculated by applying the 90% river flow and the optimized flow to the plant discharge is 0.05 at most, which is negligible.

- The B/C values for micro-hydropower and distribution line extension calculated for eleven unelectrified T/Cs are tabulated below, showing the relative differences for both alternatives. As shown in the table below, it is quite clear that the above difference of 0.05 for the B/C values between the application of 90% river flow and optimized flow as the plant discharge would not influence the selection of the optimum electrification method, since the differences of the B/C values for the micro-hydro and D/L extension are more than 0.36 at least.

Comparison of B/C values

T/C	Micro-hydro (with Diesel)※	D/L Extension	Difference
Nthalire	0.88	2.07	-1.19
Chisenga	0.73	2.00	-1.27
Mulembe	0.54	0.90	-0.36
Katowo	0.90	3.19	-2.29
Nchenachena	0.87	10.32	-9.45
Khondowe	0.85	2.07	-1.22
Ruarwe	1.01	1.49	-0.48
Usisya	0.76	2.51	-1.75
Kwisimba	0.65	1.41	-0.76
Katema	0.89	3.66	-2.77
Sandama	0.79	4.56	-3.77

※ B/C value calculated throughout the potential survey based on application of 90% river flow as plant discharge of micro-hydropower

- The main purpose of the potential study stage (=M/P study level) is to determine the optimum electrification method by economic comparisons of available electrification alternatives. As described above, the application of 90% river flow to the plant discharge would not influence this result. Therefore the optimization of the plant discharge would be carried out not in the potential study stage but in the case study stage.

6.9.2 Preliminary cost estimate at Master Plan level

The procedure for the preliminary cost estimate of micro-hydropower at Master Plan level was proposed in section 6.6.3. Cost estimate results found by using the proposed procedure and from the case study are compared below:

		Cost estimate results
- by the proposed procedure（M/P study level）	:	1,183,000 (USD)
- by the case study（Pre-F/S level）	:	1,026,000 (USD)

The difference between both cost estimate results - about 15% - is due to the study level.

Even so, it is quite clear that the cost estimate of micro-hydropower is greatly dependent on the site hydrological and topographical conditions. Thus in order to improve the accuracy of the cost estimate, site conditions should be thoroughly investigated and understood through site surveys.

6.9.3 Cost reduction effect in civil works by village volunteers

As indicated in section 6.7.6, rural electrification projects with mini-grid using micro-hydropower cannot be justified economically in Malawi since the B/C values for the majority of the potential sites are less than 1.0. In rural electrification projects in Southeast Asian countries, on the other hand, there are some examples where investment cost in civil works was reduced by the voluntary participation of villagers. It was confirmed in the workshop held in Ruarwe T/C during the case study that voluntary participation of villagers in the construction works is available. In fact, the villagers' voluntary participation in the construction works for the installation of drinking water facilities in Ruarwe T/C was introduced as an example in the workshop. Therefore it can be assumed that villagers' voluntary participation in this electrification project is quite possible, and that the consequential cost reduction on overall project costs can be expected to a certain extent.

In the case study, B/C values calculated for two cases were compared in order to clarify the economic effect of the voluntary participation of villagers in the construction works. One case is "without the villagers participation in the construction works", and the other is "with the villagers participation in 50% of the excavation works". The comparison showed an improvement of about 0.2 point in the B/C value. It should be noted that the improvement effect in this project is of maximum importance, since the excavation volume in this project is estimated to be substantially larger than for other potential sites due to the topographic site conditions. Therefore a similar level of improvement could not be expected for other potential sites. As shown in the above table of comparison of B/C value between micro-hydro and D/L extension, additionally, it is quite clear that an improvement effect of about 0.2 point in the B/C values shown in the table above would not influence the selection of the optimum electrification method.

Consequently, even with cost reduction by voluntary participation of villagers in the construction works of the micro-hydropower project being taken into account for the economic comparison for selection of the optimum electrification method, the micro-hydropower could not be presumed to be superior to the D/L extension, from an economic perspective.

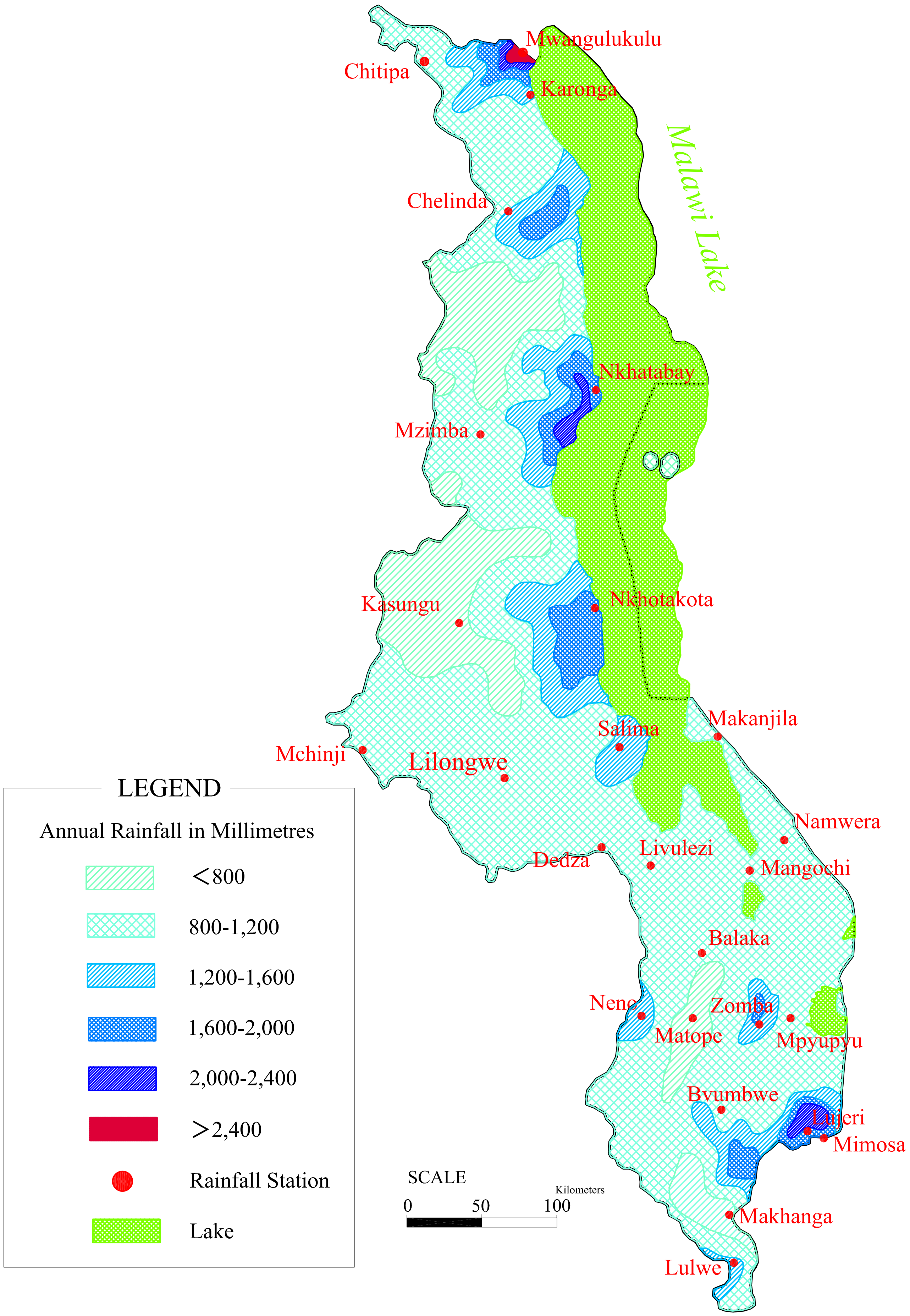


Fig. 6-2-1 Mean Annual Rainfall Map

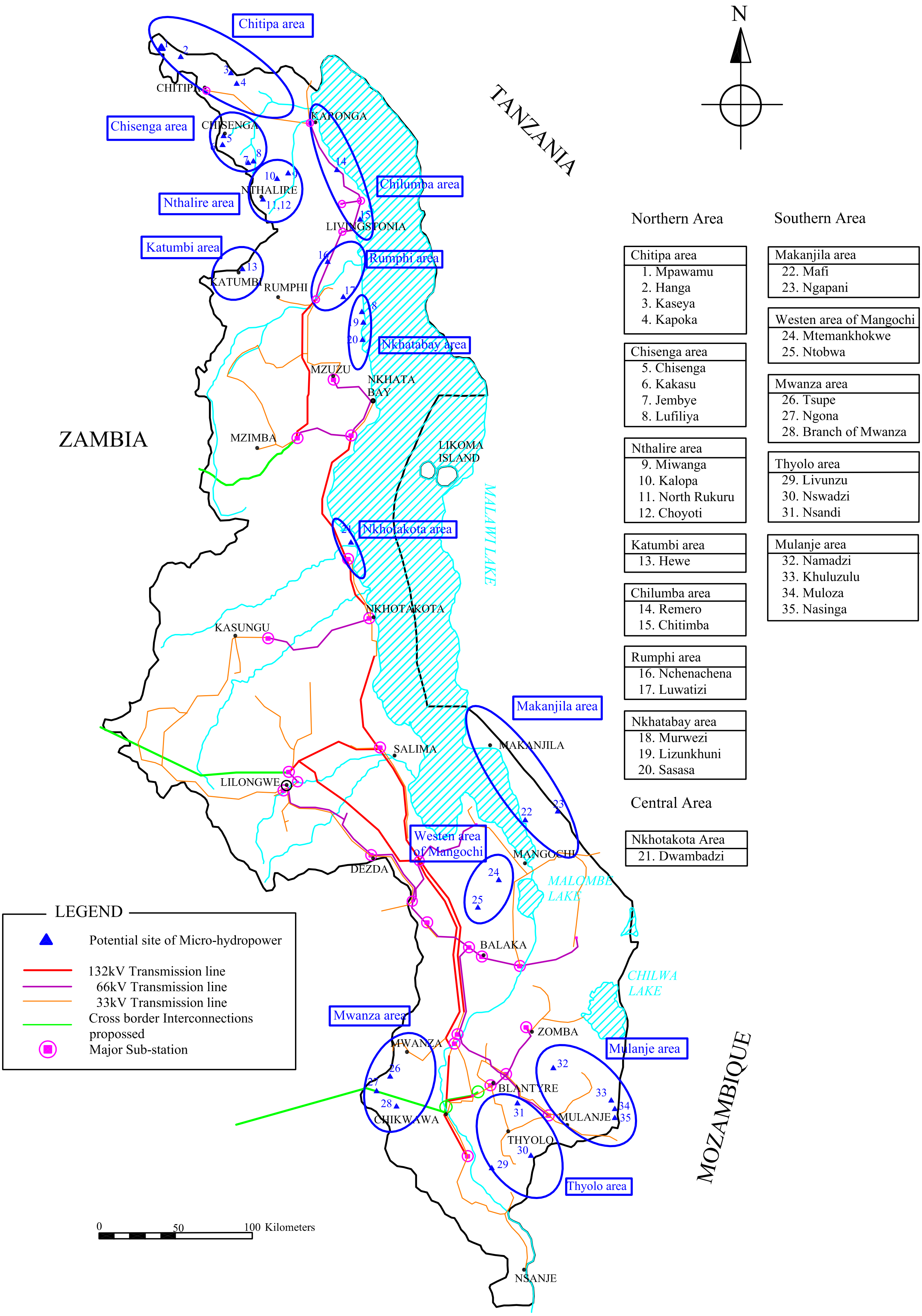


Fig. 6-4-1 Location of the micro-hydropower potential sites

Teble 6-4-1 Micro-Hydropower Potentail Site Investigation Record

(1/2)

Results of Preliminary Study on Topographic Maps			
General			
Name of demand site		Name of potential site	
Distance from existing grid to demand site	(km)	Distance from potential to demand site	(km)
Streamflow Gauging Station (SGS) to estimate river discharge at the site			
Name of SGS		Catchment area	(km^2)
Annual average dis.	(m^3/s)	90% reliable dis.	(m^3/s)
Main features of the potential site			
Catchment area	(km^2)	Length of water way	(m)
90% dis. at the site	(m^3/s)	Head from the maps	(m)
Installed capacity	(kW)	Annual energy	(kWh)

Results of Site Investigation			
Date / Time		Observer	
Location by GPS at demand site	S	Elevation: m	
	E		
Access conditions	from to	km	hour
	Passability by car in wet season : yes, no	Road conditions:	great good bad
	Note:		
Name of demand site		Kind of demand site	T/C G/C Village
Number of public buildings in the demand site	・Health center :	・Post office :	
	・Primary school :	・Traditional court :	
	・Secondary school :	・Mission :	
	・Police post :	・Others :	
Name of river		Conditions	Waterfall Rapid Reservoir
Dry up or not ?	・Not dry up ・Dry up	every year, times per 10-year	
Water right in river by residents	Irrigation, Drinking, Washing,	Bathing, Fishery, Others	
Environmental conditions	National Park, Forest Reservation, Game Reservation, Others		
River width	(m) at	Ave. flow velocity	(m/s)
Ave. depth of river	(m)	Present Discharge	(m^3/s)
Notes :			

Facilities			
【Intake and Settling basin】			
Elevation :	m by	Elevation :	m by
Riverbed condition :		Riverbed condition :	
Area of settling basin :		Area of settling basin :	
Land conditions :		Land conditions :	
Access conditions :		Access conditions :	
Note :	existing facilities such as irrigation, drinking and so on		
【Headrace】			
Type :		Type :	
Topographic conditions throughout the route:		Topographic conditions throughout the route:	
Land conditions:		Land conditions:	
Access conditions :		Access conditions :	
Notes :	existing facilities such as irrigation, drinking and so on		
【Head tank】			
Elevation :	m by	Elevation :	m by
Land conditions :		Land conditions :	
Access conditions :		Access conditions :	
Notes :			
【Penstock】			
Slope of bank :	Steep Gentle	Slope of bank :	Steep Gentle
Topographic conditions throughout the route:		Topographic conditions throughout the route:	
Land conditions :		Land conditions :	
Notes :			
【Spillway】			
Slope of bank :	Steep Gentle	Slope of bank :	Steep Gentle
Topographic conditions throughout the route:		Topographic conditions throughout the route:	
Land conditions :		Land conditions :	
Notes :			
【Power Station】			
Elevation :	m by	Elevation :	m by
Land conditions :		Land conditions :	
Flood marks :		Flood marks :	
Access conditions :		Access conditions :	
Notes :			
Prospective head	m by		
Prospective capacity	kW = 9.8 * Prospective head : * Present dis.: * 0.75		
Notes :			

Table.6-4-2 (1) Result of Site Survey for Micro-hydropower Potential in Northern Area of Malawi

	Site survey area	Chitipa area				Chisenga area
	Name of potential site	1. Mpawamu	2. Hanga	3. Kaseya	4. Kapoka	5. Chisenga
Demand side	Name of demand site	Chiwanga T/C	Kameme T/C	Ifumbo T/C	Chipwera T/C	Chisenga T/C
	Name of district	Chitipa	Chitipa	Chitipa	Chitipa	Chitipa
	Distance from existing grid	46km	26km	15km	20km	35km
	Number of public buildings in the demand site (by hearing from residents)	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 0 ・Post office : 1 ・Traditional court : 1 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 1 ・Post office : 1 ・Traditional court : 0 ・Mission : 0	・Health center : n/a ・Primary school : n/a ・Secondary school : n/a ・Police post : n/a ・Post office : n/a ・Traditional court : n/a ・Mission : n/a	・Health center : 1 ・Primary school : 1 ・Secondary school : 2 ・Police post : 1 ・Post office : 1 ・Traditional court : 0 ・Mission : 0
	Access conditions	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car
Supply side	Name of potential river	Mpawamu	Hanga	Kaseya	Kapoka	Chisenga
	Catchment area at promising intake site	$61km^2$	$150km^2$	$550km^2$	$84km^2$	$4km^2$
	Present river discharge estimated at site survey	$0m^3/s$	$0m^3/s$	very few	$0.03m^3/s$	$0.1m^3/s$
	Dry up or not throughout the year[1)] (by hearing from residents)	dry up (every year)	dry up (some year)	dry up (every year)	not dry up	not dry up
	Gross head estimated at site survey	n/a[2)]	n/a	n/a	10～15m	15～20m
	Potential estimated	-	-	-	2kW	15kW
	Distance from demand site	n/a	n/a	n/a	2km	5km
	Environmental conditions at the potential site	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : ○ ・Game reservation : -
	Existing river use by residents	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : n/a ・Drinking : n/a ・Washing : n/a ・Bathing : n/a ・Fishery : n/a ・Others : n/a	・Irrigation : n/a ・Drinking : n/a ・Washing : n/a ・Bathing : n/a ・Fishery : n/a ・Others : n/a	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -
	Present land use conditions	Vegetation filed	Vegetation filed	Vegetation field	Field & Forest	Forest
	Remarks					Drinking water facilities in Chisenga River

1) It is judged that there are no hydropower potential at the site, once river dries up throughout the year
2) "n/a" means that the item was not investigated in the site survey.

Table.6-4-2 (2) Result of Site Survey for Micro-hydropower Potential in Northern Area of Malawi

	Site survey area	Chisenga area			Nthalire area	
	Name of potential site	6. Kakasu	7. Jembya	8. Lufiliya	9. Miwanga	10. Kalopa
Demand side	Name of demand site	Mulembe T/C	Wenya T/C	Wenya T/C	Kopakopa T/C	Mahowe T/C
	Name of district	Chitipa	Chitipa	Chitipa	Chitipa	Chitipa
	Distance from existing grid	35km	85km	87km	83km	75km
	Number of public buildings in the demand site (by hearing from residents)	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 0	・Health center : 0 ・Primary school : 1 ・Secondary school : 1 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 0
	Access conditions	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car
Supply side	Name of potential river	Kakasu	Jembya	Lufiliya	Miwanga	Kalopa
	Catchment area at promising intake site	8km^2	82km^2	108km^2	61km^2	35km^2
	Present river discharge estimated at site survey	0.1m^3/s	0.05m^3/s	0.05m^3/s	0.02m^3/s	0m^3/s
	Dry up or not throughout the year[1)] (by hearing from residents)	not dry up	dry up (some year)	dry up (some year)	not dry up	dry up (every year)
	Gross head estimated at site survey	10～30m	n/a	n/a	10～20m	n/a
	Potential estimated	15kW	-	-	3kW	-
	Distance from demand site	10km	n/a	n/a	5km	n/a
	Environmental conditions at the potential site	・National park : - ・Forest reservation : 〇 ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : − ・Game reservation : -
	Existing river use by residents	・Irrigation : 〇 ・Drinking : 〇 ・Washing : 〇 ・Bathing : 〇 ・Fishery : - ・Others : -	・Irrigation : 〇 ・Drinking : 〇 ・Washing : 〇 ・Bathing : 〇 ・Fishery : - ・Others : -	・Irrigation : 〇 ・Drinking : 〇 ・Washing : 〇 ・Bathing : 〇 ・Fishery : - ・Others : -	・Irrigation : 〇 ・Drinking : 〇 ・Washing : 〇 ・Bathing : 〇 ・Fishery : - ・Others : -	・Irrigation : − ・Drinking : − ・Washing : − ・Bathing : − ・Fishery : - ・Others : -
	Present land use conditions	Forest & Vegetation filed	Vegetation filed	Vegetation filed	Vegetation filed	Vegetation filed
	Remarks					

1) It is judged that there are no hydropower potential at the site, once river dries up throughout the year
2) "n/a" means that the item was not investigated in the site survey.

Table.6-4-2 (3) Result of Site Survey for Micro-hydropower Potential in Northern Area of Malawi

	Site survey area	Nthalire area		Katumbi area	Chilumba area	
	Name of potential site	11. North Rukuru	12. Choyoti	13. Hewe	14. Remero	15. Chitimba
Demand side	Name of demand site	Nthalire T/C	Nthalire T/C	Katowo T/C	Mulale T/C	Chitimba T/C
	Name of district	Chitipa	Chitipa	Rumphi	Karonga	Karonga
	Distance from existing grid	102km	102km	45km	15km	20km
	Number of public buildings in the demand site (by hearing from residents)	・Health center : 1 ・Primary school : 3 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 1	・Health center : 1 ・Primary school : 3 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 1	・Health center : 1 ・Primary school : 2 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 1	・Health center : 1 ・Primary school : 1 ・Secondary school : 2 ・Police post : 0 ・Post office : 1 ・Traditional court : 0 ・Mission : 0	・Health center : 1 ・Primary school : n/a ・Secondary school : n/a ・Police post : n/a ・Post office : n/a ・Traditional court : n/a ・Mission : n/a
	Access conditions	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car
Supply side	Name of potential river	North Rukuru	Choyoti	Hewe	Remero	Chitimba
	Catchment area at promising intake site	330km^2	14km^2	37km^2	100km^2	33km^2
	Present river discharge estimated at site survey	1m^3/s	0.2m^3/s	0.2m^3/s	0m^3/s	0.05m^3/s
	Dry up or not throughout the year[1] (by hearing from residents)	not dry up	not dry up	not dry up	dry up (every year)	n/a
	Gross head estimated at site survey	n/a	30～40m	25～30m	n/a	n/a
	Potential estimated	-	60kW	45kW	-	-
	Distance from demand site	15km	15km	15km	n/a	1km
	Environmental conditions at the potential site	・National park : ○ ・Forest reservation : - ・Game reservation : -	・National park : ○ ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : ○ ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -
	Existing river use by residents	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : ○ ・Others : -	・Irrigation : − ・Drinking : ○ ・Washing : − ・Bathing : − ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : n/a ・Drinking : n/a ・Washing : n/a ・Bathing : n/a ・Fishery : n/a ・Others : n/a	・Irrigation : n/a ・Drinking : n/a ・Washing : n/a ・Bathing : n/a ・Fishery : n/a ・Others : n/a
	Present land use conditions	Forest & Vegetation filed	Forest	Forest	Field & Forest	Field & Vegetation
	Remarks	Nyika national park	Nyika national park			

1) It is judged that there are no hydropower potential at the site, once river dries up throughout the year
2) "n/a" means that the item was not investigated in the site survey.

Table.6-4-2 (4) Result of Site Survey for Micro-hydropower Potential in Northern Area of Malawi

	Site survey area	Rumphi area		Nkhatabay area		
	Name of potential site	16. Nchenachena	17. Luwatizi	18. Murwerzi	19. Lizunkhuni	20. Sasasa
Demand side	Name of demand site	Nchenachena T/C	Mphomapha T/C	Khondowe T/C	Ruarwe T/C	Usisya T/C
	Name of district	Rumphi	Rumphi	Nkhatabay	Nkhatabay	Nkhatabay
	Distance from existing grid	23km	18km	-	-	50km
	Number of public buildings in the demand site (by hearing from residents)	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 0 ・Post office : 1 ・Traditional court : 1 ・Mission : 1	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 0 ・Post office : 1 ・Traditional court : 0 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 0 ・Post office : 1 ・Traditional court : 1 ・Mission : 0	・Health center : 1 ・Primary school : 2 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 2 ・Mission : 0
	Access conditions	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・No access road by car ・Boat from Nhkata Bay	・No access road by car ・Boat from Nhkata Bay	・Non-paved road ・Passable by 4WD car
Supply side	Name of potential river	Nchenachena	Luwatizi	Murwerzi	Lizunkhuni	Sasasa
	Catchment area at promising intake site	18km^2	13km^2	7km^2	80km^2	85km^2
	Present river discharge estimated at site survey	0.2m^3/s	0m^3/s	0.05m^3/s	0.15m^3/s	0.1m^3/s
	Dry up or not throughout the year[1)] (by hearing from residents)	not dry up	dry up (every year)	not dry up	not dry up	not dry up
	Gross head estimated at site survey	10～30m	n/a	10～15m	50～60m	20～30m
	Potential estimated	30kW	-	5kW	50kW	20kW
	Distance from demand site	2km	n/a	1km	1km	3km
	Environmental conditions at the potential site	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : ○ ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -
	Existing river use by residents	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : − ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : - ・Drinking : ○ ・Washing : - ・Bathing : - ・Fishery : - ・Others : -	・Irrigation : - ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -
	Present land use conditions	Vegetation filed	Vegetation filed	Vegetation filed	Forest	Field & vegetation
	Remarks	Drinking water facilities in Nchenachena River		Drinking water facilities in Murwerzi River	Drinking water facilities in Lizunkhuni River	Drinking water facilities in Sasasa River

1) It is judged that there are no hydropower potential at the site, once river dries up throughout the year
2) "n/a" means that the item was not investigated in the site survey.

Table.6-4-2 (5) Result of Site Survey for Micro-hydropower Potential in Central and Southern Area of Malawi

	Site survey area	Nkhotakota area	Makanjila area		Western area of Mangochi	
	Name of potential site	21. Dwambadzi	22. Mafi	23. Ngapani	24. Mtemankhokwe	25. Ntobwa
Demand side	Name of demand site	Dwambadzi T/C	Namalaka T/C	Kwisimba T/C	Katema T/C	Chiripa T/C
	Name of district	Nkhotakota	Mangochi	Mangochi	Mangochi	Mangochi
	Distance from existing grid	17km	25km	38km	23km	25km
	Number of public buildings in the demand site (by hearing from residents)	・Health center : 1 ・Primary school : 2 ・Secondary school : 1 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 1	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 0 ・Mission : 1	・Health center : 0 ・Primary school : 1 ・Secondary school : 0 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 0 ・Post office : 1 ・Traditional court : 0 ・Mission : 1	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 0 ・Post office : 1 ・Traditional court : 1 ・Mission : 1
	Access conditions	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car
Supply side	Name of potential river	Dwambadzi	Mafi	Ngapani	Mtemankhokwe	Ntobwa
	Catchment area at promising intake site	140km^2	93km^2	48km^2	24km^2	18km^2
	Present river discharge estimated at site survey	not confirmation in the dry season	very few	0.05m^3/s	0.1m^3/s	very few
	Dry up or not throughout the year[1)] (by hearing from residents)	not dry up	dry up (some year)	not dry up	not dry up	not dry up
	Gross head estimated at site survey	n/a[2)]	n/a	5～15m	20～30m	n/a
	Potential estimated	-	-	5kW	25kW	-
	Distance from demand site	3km	4km	2km	4km	1km
	Environmental conditions at the potential site	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -
	Existing river use by residents	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : - ・Drinking : ○ ・Washing : - ・Bathing : - ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -
	Present land use conditions	Field	Field	Field	Vegetation field	Vegetation field
	Remarks					

1) It is judged that there are no hydropower potential at the site, once river dries up throughout the year
2) "n/a" means that the item was not investigated in the site survey.

Table.6-4-2 (6) Result of Site Survey for Micro-hydropower Potential in Southern Area of Malawi

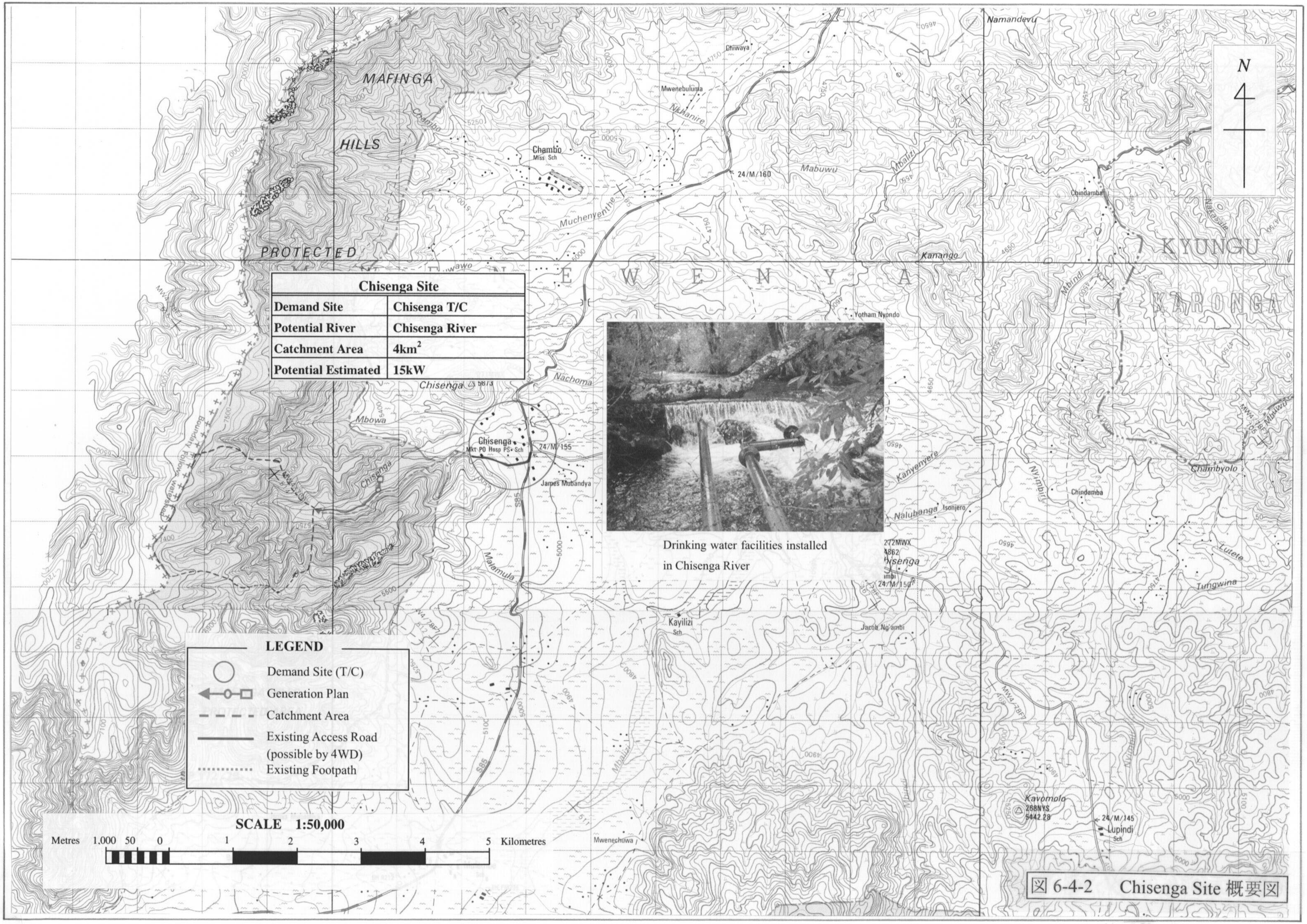
	Site survey area	Mwanza area			Thyolo area	
	Name of potential site	26. Tsupe	27. Ngona	28. Branch of Mwanza	29. Livunzu	30. Nswadzi
Demand side	Name of demand site	Thambani T/C	Changoima T/C	Chapananga T/C	Livunzu T/C	Sandama T/C
	Name of district	Mwanza	Chikwawa	Chikwawa	Chikwawa	Thyolo
	Distance from existing grid	23km	42km	55km	22km	6km
	Number of public buildings in the demand site (by hearing from residents)	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 0 ・Post office : 0 ・Traditional court : 0 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 1 ・Post office : 0 ・Traditional court : 1 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 0	・Health center : 1 ・Primary school : 1 ・Secondary school : 0 ・Police post : 1 ・Post office : 1 ・Traditional court : 0 ・Mission : 0
	Access conditions	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car
Supply side	Name of potential river	Tsupe	Ngona	Branch of Mwanza	Livunzu	Nswadzi
	Catchment area at promising intake site	24km^2	140km^2	12km^2	60km^2	380km^2
	Present river discharge estimated at site survey	0.03m^3/s	0.03m^3/s	0.m^3/s	not confirmation in the dry season	1m^3/s
	Dry up or not throughout the year[1)] (by hearing from residents)	not dry up	dry up (some year)	dry up (every year)	not dry up	not dry up
	Gross head estimated at site survey	5～10m	n/a	n/a	n/a	10～15m
	Potential estimated	2kW	-	-	-	75kW
	Distance from demand site	5km	5km	2km	1km	3km
	Environmental conditions at the potential site	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -
	Existing river use by residents	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : − ・Drinking : − ・Washing : − ・Bathing : − ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -
	Present land use conditions	Vegetation field	Vegetation filed	Vegetation filed	Vegetation filed	Vegetation filed
	Remarks					

1) It is judged that there are no hydropower potential at the site, once river dries up throughout the year
2) "n/a" means that the item was not investigated in the site survey.

Table.6-4-2 (7) Result of Site Survey for Micro-hydropower Potential in Southern Area of Malawi

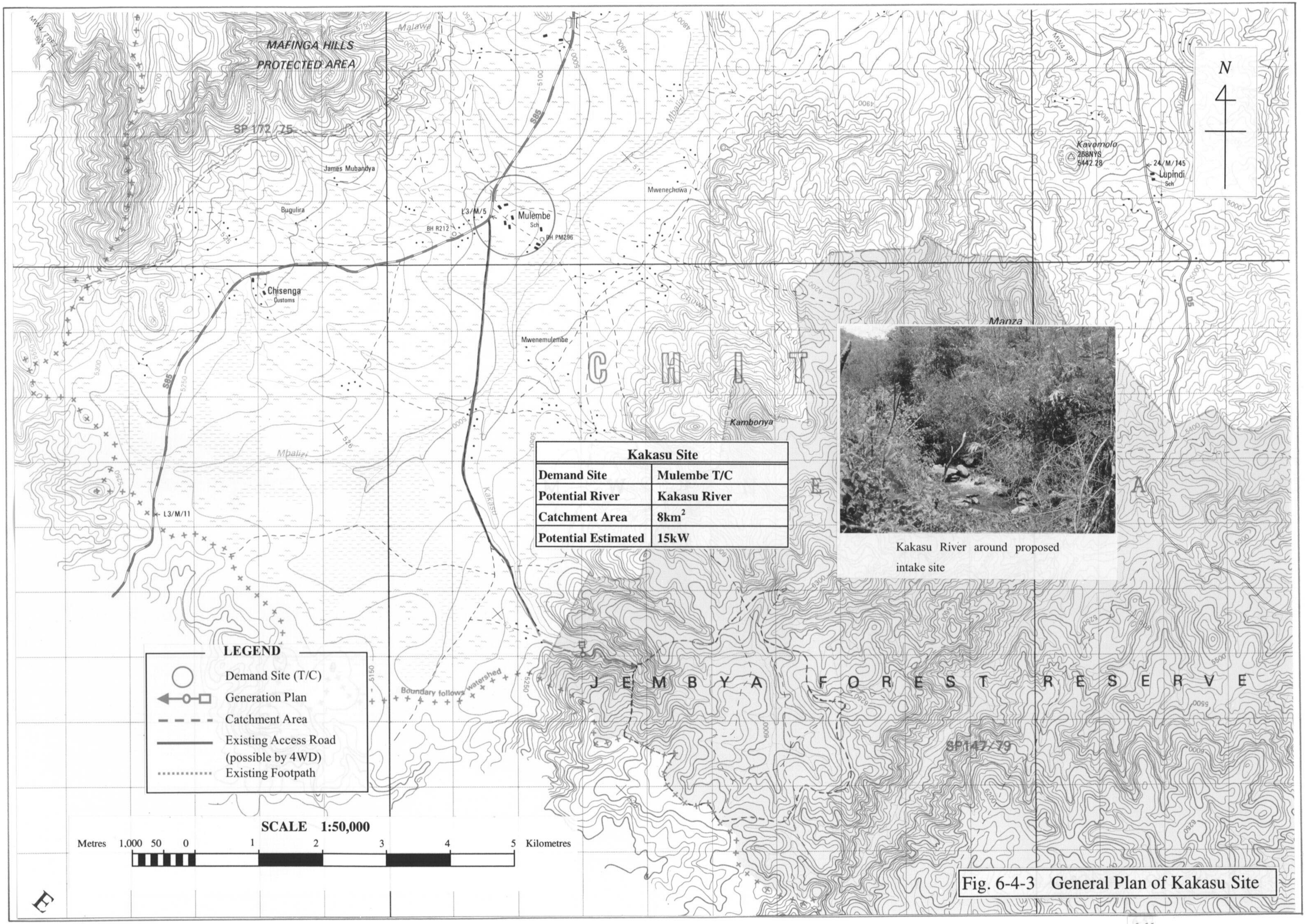
	Site survey area	Thyolo area	Mulanje area			
	Name of potential site	31. Nsandi	32. Namadzi	33. Khuluzulu	34. Muloza	35. Nasinga
Demand side	Name of demand site	Nsandi T/C	Milepa T/C	Chiringa T/C	Mlelemba T/C	Nkhulambe T/C
	Name of district	Thyolo	Chirazulu	Phalonbe	Nulanje	Phalombe
	Distance from existing grid	2.5km	18km	14km	21km	15km
	Number of public buildings in the demand site (by hearing from residents)	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 0 ・Mission : 1	・Health center : 2 ・Primary school : 0 ・Secondary school : 0 ・Police post : 1 ・Post office : 1 ・Traditional court : 0 ・Mission : 1	・Health center : 2 ・Primary school : 1 ・Secondary school : 1 ・Police post : 1 ・Post office : 1 ・Traditional court : 1 ・Mission : 1	・Health center : 1 ・Primary school : 1 ・Secondary school : 1 ・Police post : 1 ・Post office : 0 ・Traditional court : 0 ・Mission : 1	・Health center : n/a ・Primary school : n/a ・Secondary school : n/a ・Police post : n/a ・Post office : n/a ・Traditional court : n/a ・Mission : n/a
	Access conditions	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car	・Non-paved road ・Passable by 4WD car
Supply side	Name of potential river	Nsandi	Namadzi	Khuluzulu	Muloza	Nasinga
	Catchment area at promising intake site	50km^2	266km^2	380km^2	42km^2	13km^2
	Present river discharge estimated at site survey	not confirmation in the dry season	not confirmation in the dry season	not confirmation in the dry season	0.05m^3/s	0.02m^3/s
	Dry up or not throughout the year[1)] (by hearing from residents)	not dry up	dry up (some year)	not dry up	not dry up	n/a
	Gross head estimated at site survey	15～20m	0～5m	n/a	5m	n/a
	Potential estimated	-	-	-	2kW	-
	Distance from demand site	3km	1km	n/a	1km	n/a
	Environmental conditions at the potential site	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -	・National park : - ・Forest reservation : - ・Game reservation : -
	Existing river use by residents	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : ○ ・Drinking : ○ ・Washing : ○ ・Bathing : ○ ・Fishery : - ・Others : -	・Irrigation : n/a ・Drinking : n/a ・Washing : n/a ・Bathing : n/a ・Fishery : n/a ・Others : n/a
	Present land use conditions	Vegetation filed	Vegetation filed	Vegetation filed	Vegetation filed	Vegetation filed
	Remarks					

1) It is judged that there are no hydropower potential at the site, once river dries up throughout the year
2) "n/a" means that the item was not investigated in the site survey.



Chisenga Site	
Demand Site	Chisenga T/C
Potential River	Chisenga River
Catchment Area	4km^2
Potential Estimated	15kW

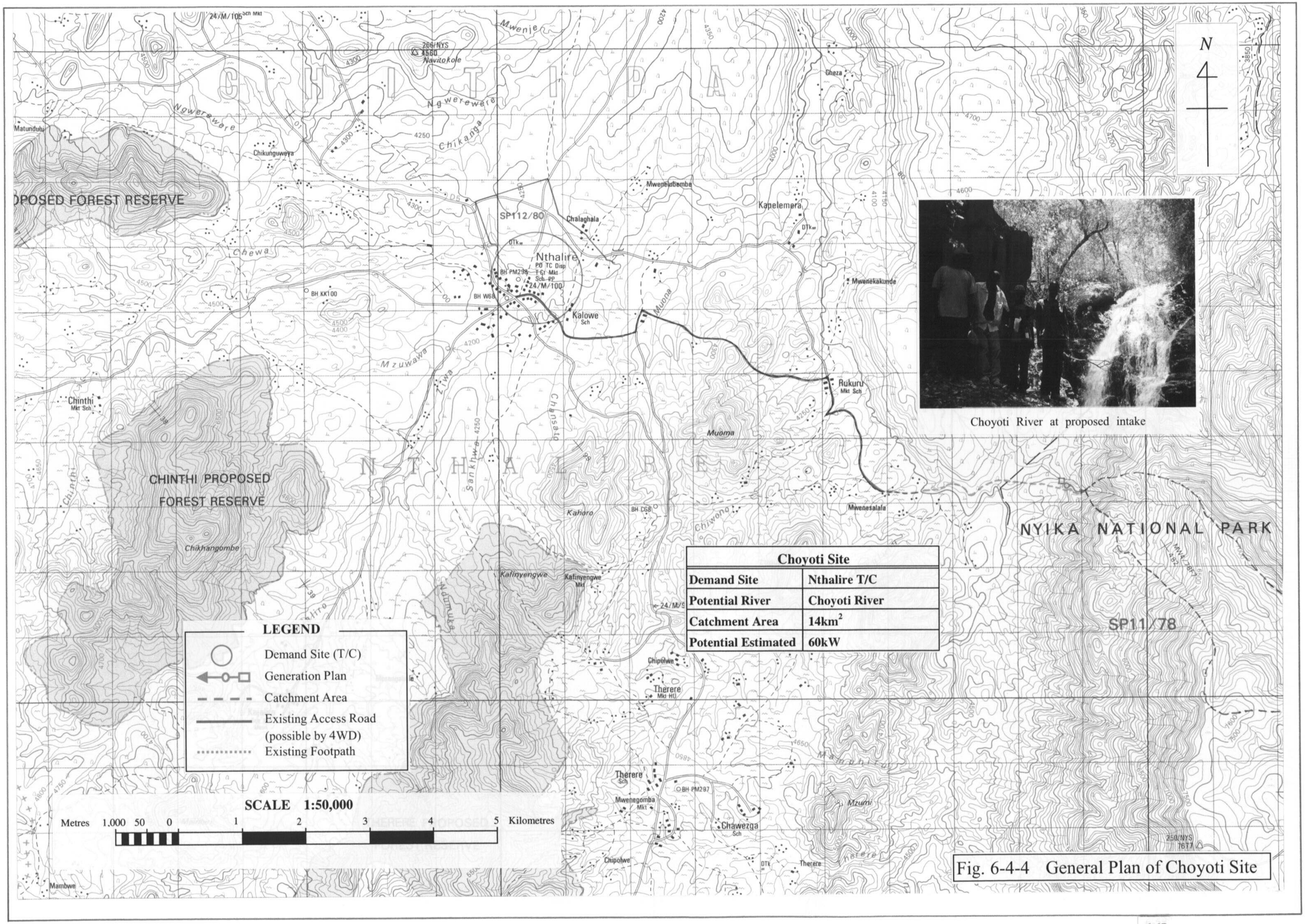
図 6-4-2 Chisenga Site 概要図



Kakasu Site	
Demand Site	Mulembe T/C
Potential River	Kakasu River
Catchment Area	8km^2
Potential Estimated	15kW

Kakasu River around proposed intake site

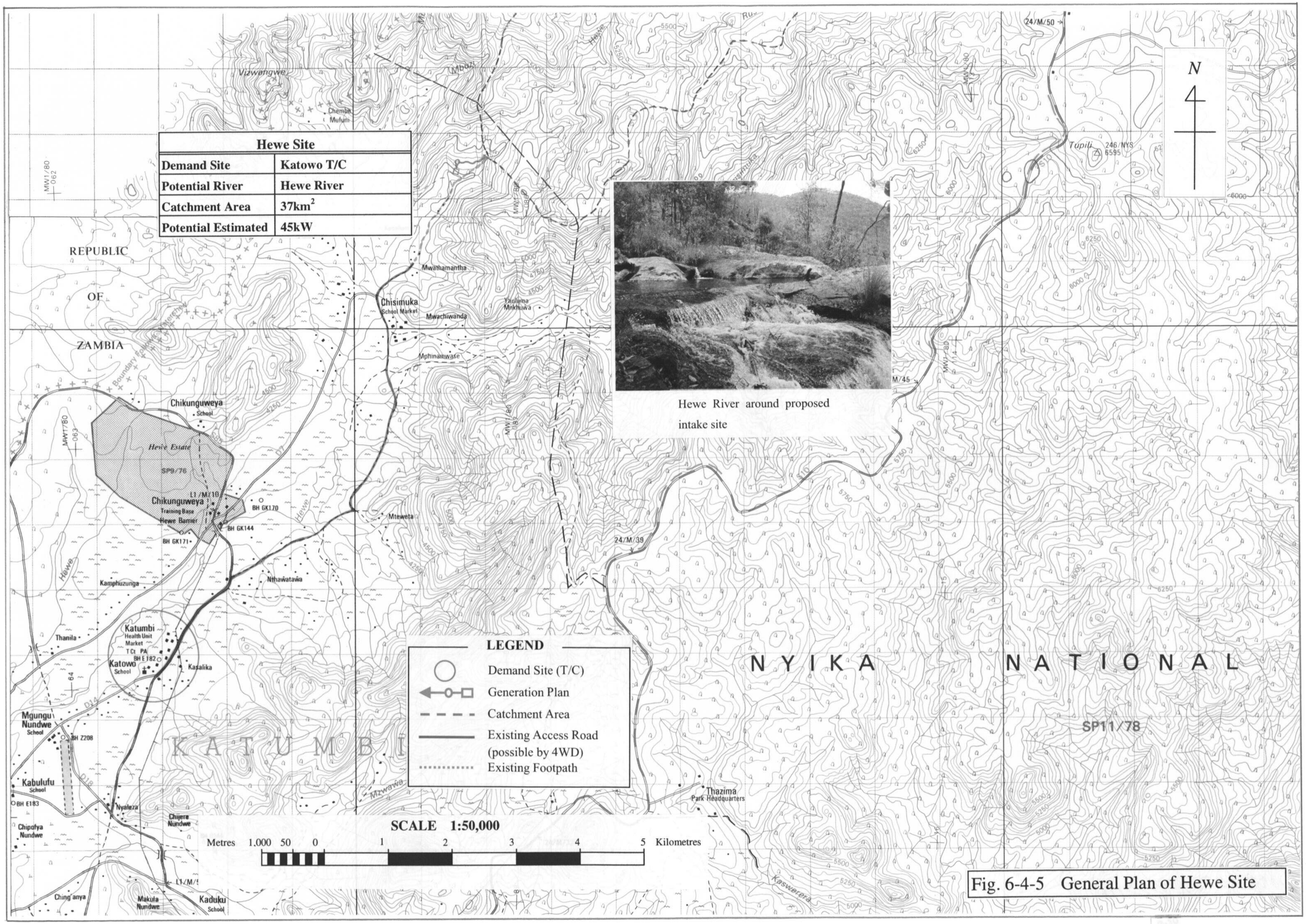
Fig. 6-4-3 General Plan of Kakasu Site



Choyoti River at proposed intake

Choyoti Site	
Demand Site	**Nthalire T/C**
Potential River	**Choyoti River**
Catchment Area	**14km^2**
Potential Estimated	**60kW**

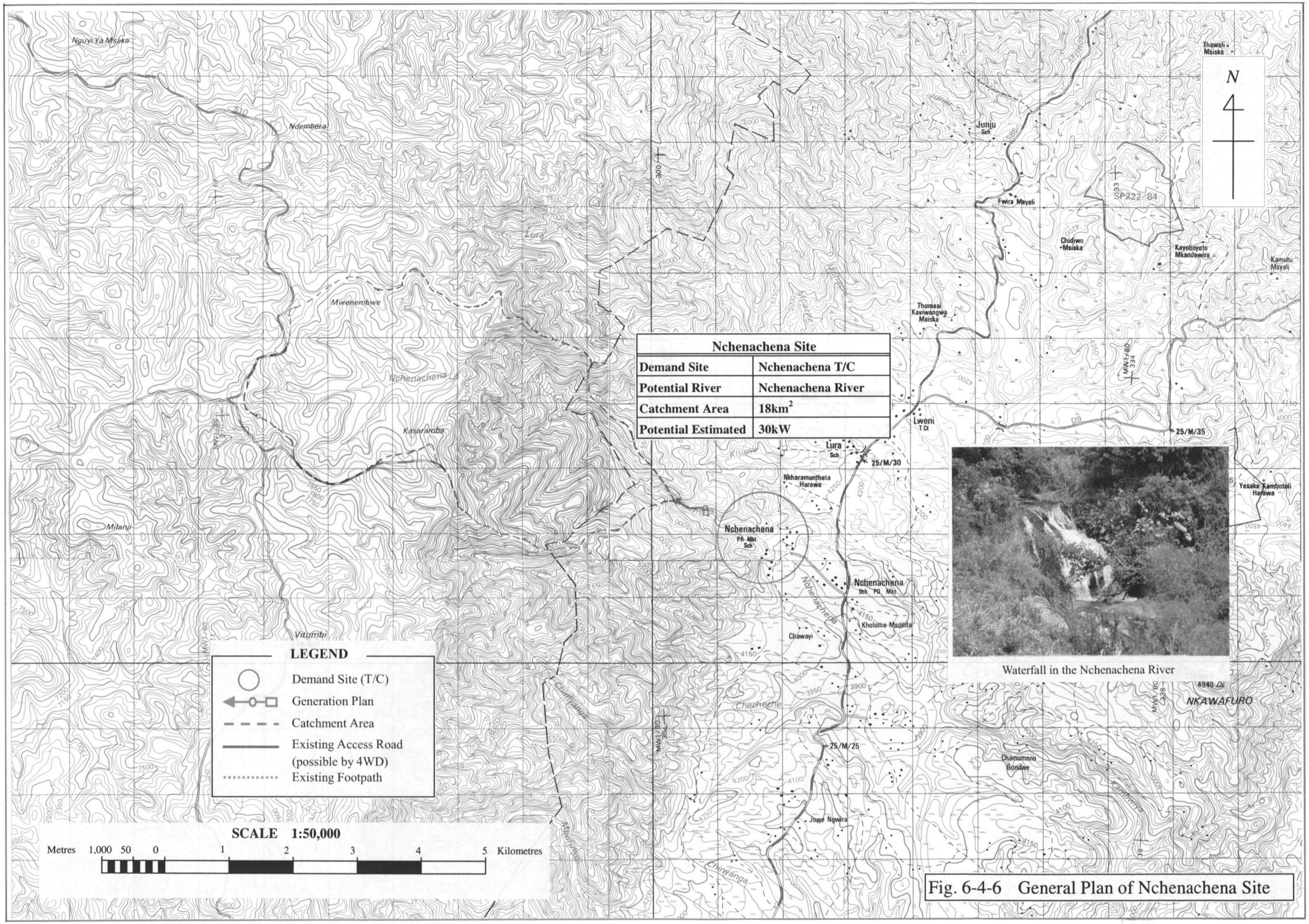
Fig. 6-4-4 General Plan of Choyoti Site



Hewe Site	
Demand Site	Katowo T/C
Potential River	Hewe River
Catchment Area	37km^2
Potential Estimated	45kW

Hewe River around proposed intake site

Fig. 6-4-5 General Plan of Hewe Site



Nchenachena Site	
Demand Site	Nchenachena T/C
Potential River	Nchenachena River
Catchment Area	18km^2
Potential Estimated	30kW

Waterfall in the Nchenachena River

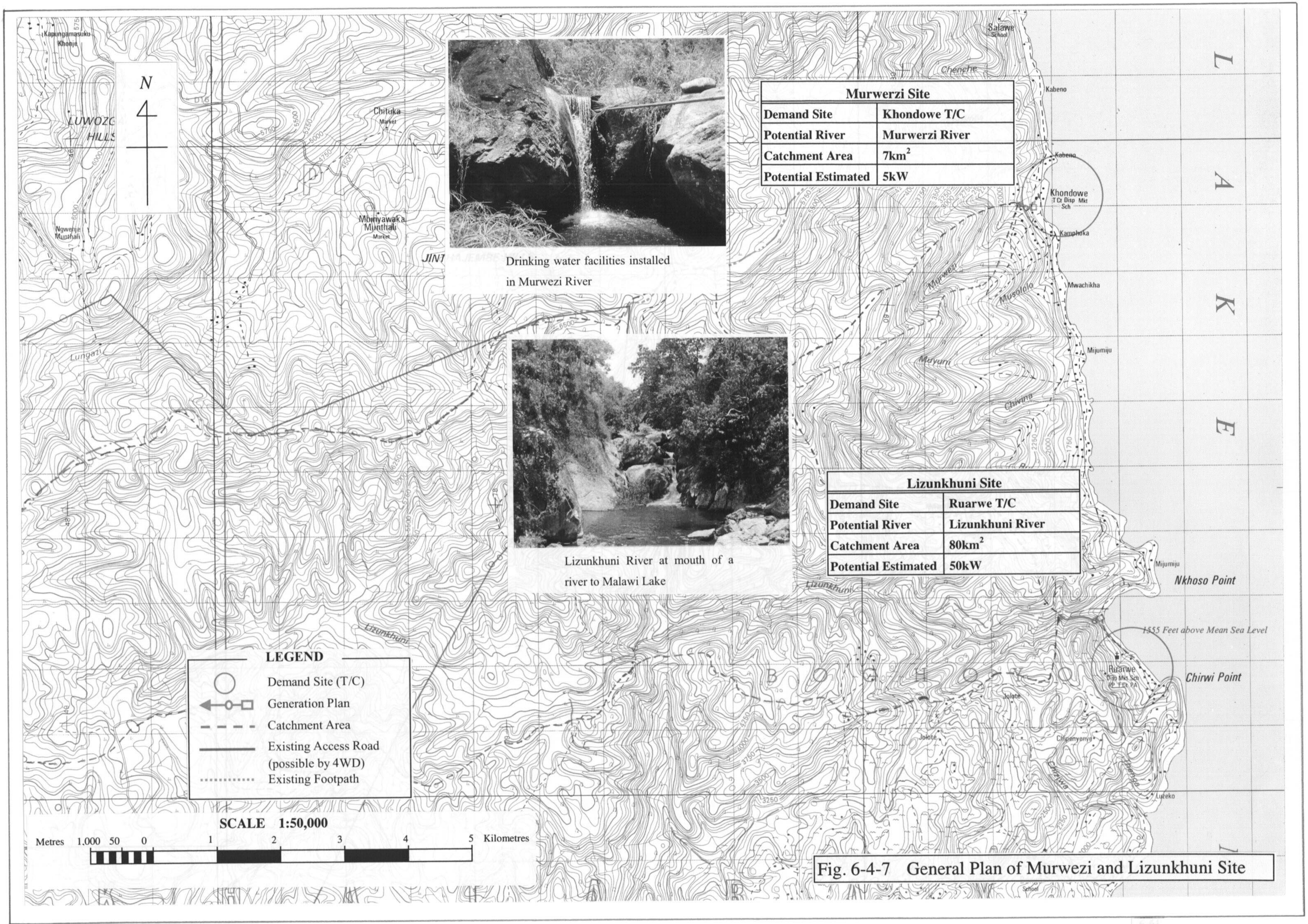
LEGEND

- Demand Site (T/C)
- Generation Plan
- Catchment Area
- Existing Access Road (possible by 4WD)
- Existing Footpath

SCALE 1:50,000

Metres 1,000 50 0 1 2 3 4 5 Kilometres

Fig. 6-4-6 General Plan of Nchenachena Site



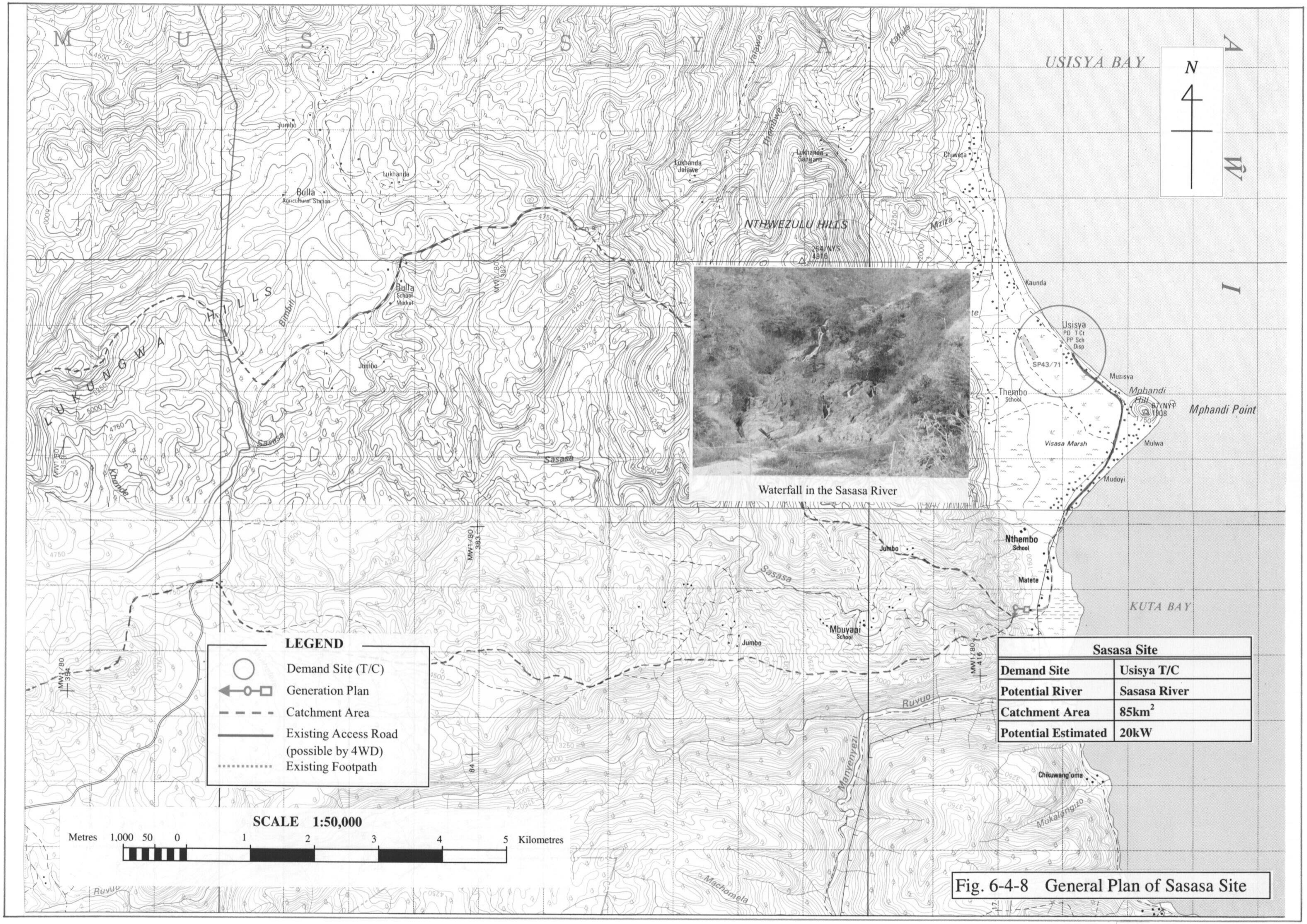
Drinking water facilities installed in Murwezi River

Lizunkhuni River at mouth of a river to Malawi Lake

Murwerzi Site	
Demand Site	Khondowe T/C
Potential River	Murwerzi River
Catchment Area	7km^2
Potential Estimated	5kW

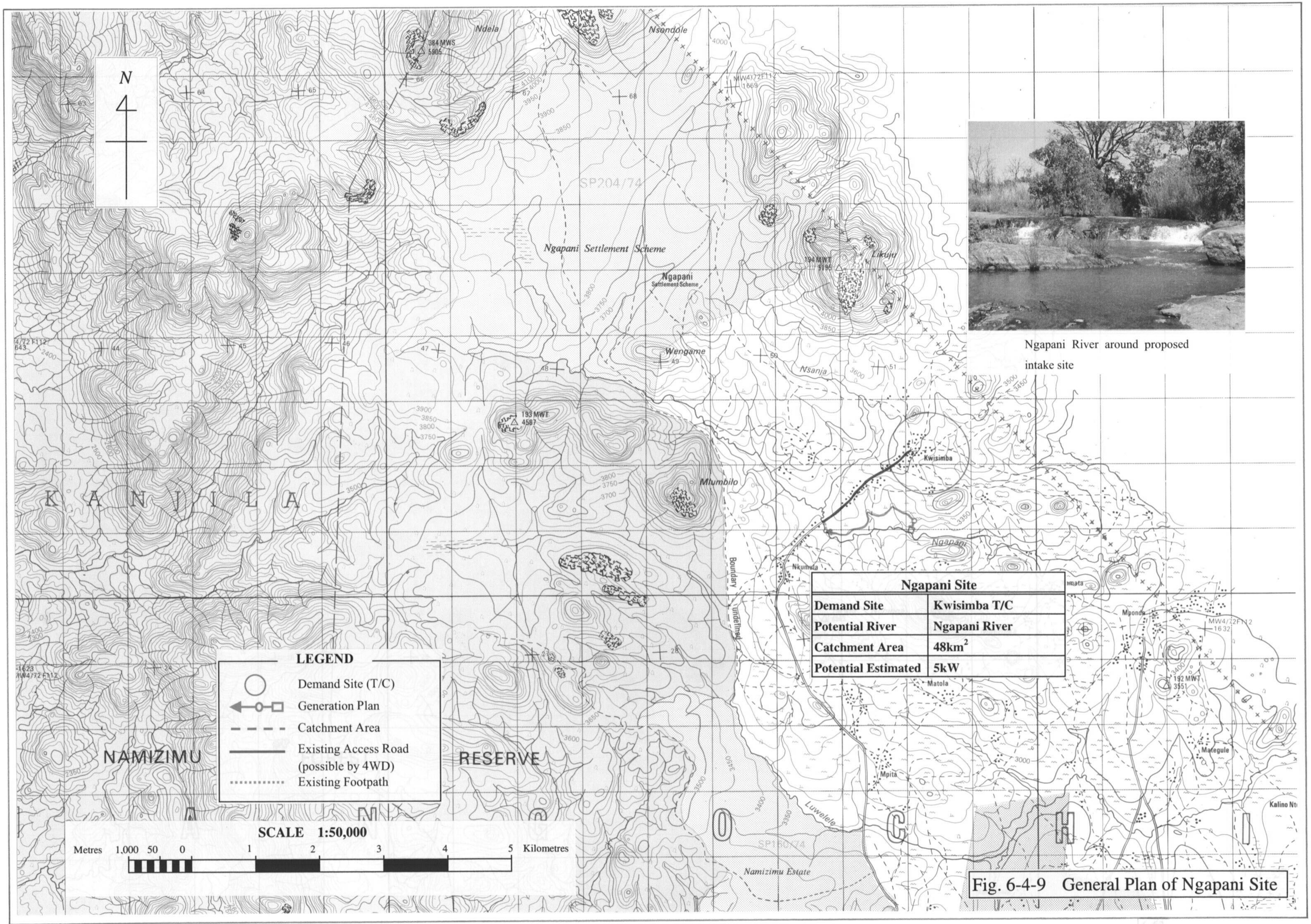
Lizunkhuni Site	
Demand Site	Ruarwe T/C
Potential River	Lizunkhuni River
Catchment Area	80km^2
Potential Estimated	50kW

Fig. 6-4-7 General Plan of Murwezi and Lizunkhuni Site



Sasasa Site	
Demand Site	Usisya T/C
Potential River	Sasasa River
Catchment Area	85km^2
Potential Estimated	20kW

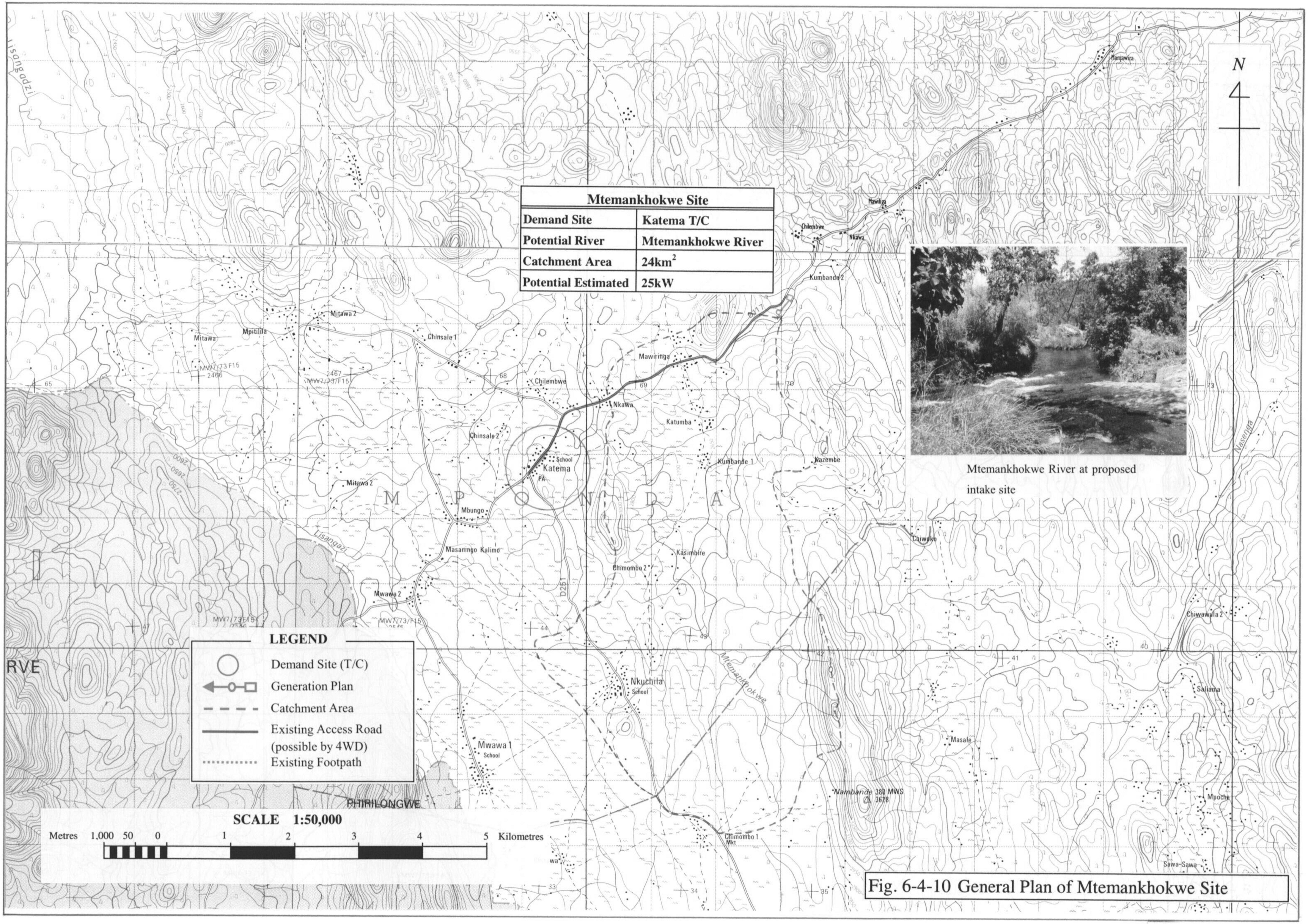
Fig. 6-4-8 General Plan of Sasasa Site



Ngapani River around proposed intake site

Ngapani Site	
Demand Site	**Kwisimba T/C**
Potential River	**Ngapani River**
Catchment Area	**48km^2**
Potential Estimated	**5kW**

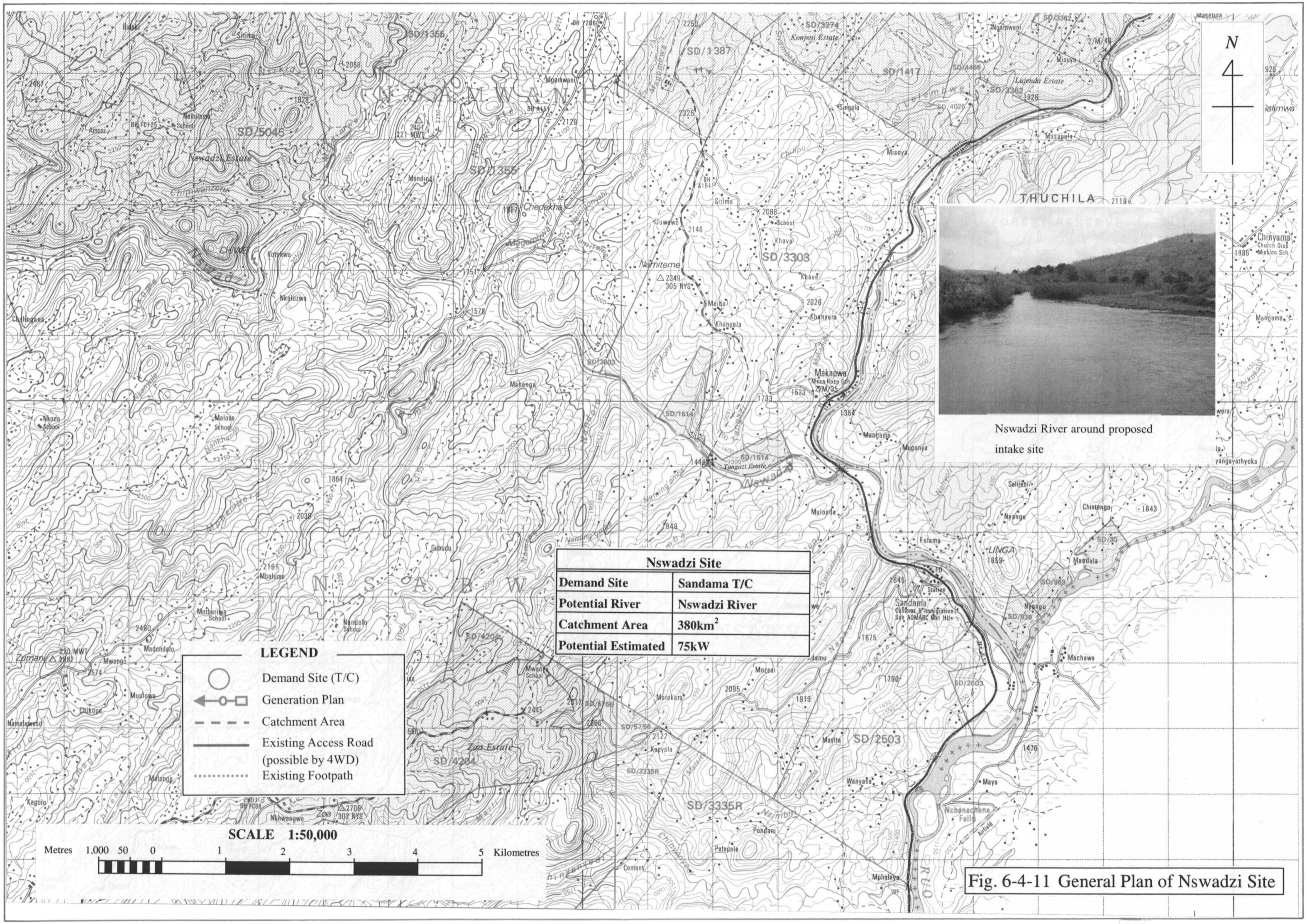
Fig. 6-4-9 General Plan of Ngapani Site



Mtemankhokwe Site	
Demand Site	Katema T/C
Potential River	Mtemankhokwe River
Catchment Area	24km^2
Potential Estimated	25kW

Mtemankhokwe River at proposed intake site

Fig. 6-4-10 General Plan of Mtemankhokwe Site



Nswadzi Site	
Demand Site	Sandama T/C
Potential River	Nswadzi River
Catchment Area	380km^2
Potential Estimated	75kW

Nswadzi River around proposed intake site

Fig. 6-4-11 General Plan of Nswadzi Site

Table 6-4-3 Result of Micro-hydropower Potential Survey for unelectrified TCs listed up in Socio-economic Survey and located more than 20km far from existing grid

District Name	TC Name	Distance from the Existing grid (km)	Potential Estimated (kW)	Evaluation	Remarks
Chitipa	Nthalire	100.0	60	○	Site survey carried out in this study
Chitipa	Wenya	85.0	—	c	Site survey carried out in this study
Chitipa	Kameme	26.0	—	b	Site survey carried out in this study
Chitipa	Chisenga	35.0	15	○	Site survey carried out in this study
Chitipa	Mulembe	35.0	15	○	Site survey carried out in this study
Rumphi	Katowo	45.0	45	○	Site survey carried out in this study
Rumphi	Chitimba	20.0	—	a	Site survey carried out in this study
Rumphi	Nchenachena	23.0	30	○	Site survey carried out in this study
Nkhata Bay	Khondowe	—*	5	○	Site survey carried out in this study
Nkhata Bay	Usisya	50.0	20	○	Site survey carried out in this study
Nkhata Bay	Nthungwa	20.0	—	c	
Nkhata Bay	Ruarwe	—*	50	○	Site survey carried out in this study
Kasungu	Simlemba	21.0	—	a	
Salima	Michulu	20.0	—	a	
Lilongwe	Hiunjiza	29.0	—	b	
Mangochi	Chilipa	25.0	—	a	Site survey carried out in this study
Mangochi	Katema	23.0	25	○	Site survey carried out in this study
Mangochi	Kwisimba	38.0	5	○	Site survey carried out in this study
Machinga	Nayuchi	23.0	—	b	
Balaka	Phimbi	21.0	—	b	
Chiradzulu	Milepa	31.0	—	b	Site survey carried out in this study
Mwanza	Thambani	23.0	—	c	Site survey carried out in this study
Thyolo	Sandama	20.0	75	○	Site survey carried out in this study
Phalombe	Chiringa	20.0	—	c	Site survey carried out in this study
Chikwawa	Chapananga	55.0	—	a	Site survey carried out in this study
Chikwawa	Linvunzu	22.0	—	c	Site survey carried out in this study

*) It is difficult to estimate the distance from the existing grid, since there are no access rords to the TCs at present

Evaluation
○; There is a micro-hydropower potential
a ; There is no river near the targeted TC, which is expected to have continuous flow through all seasons
b ; There is no water head obtained in the river due to the flat topography
c ; There is less than 5 kW potential in the river

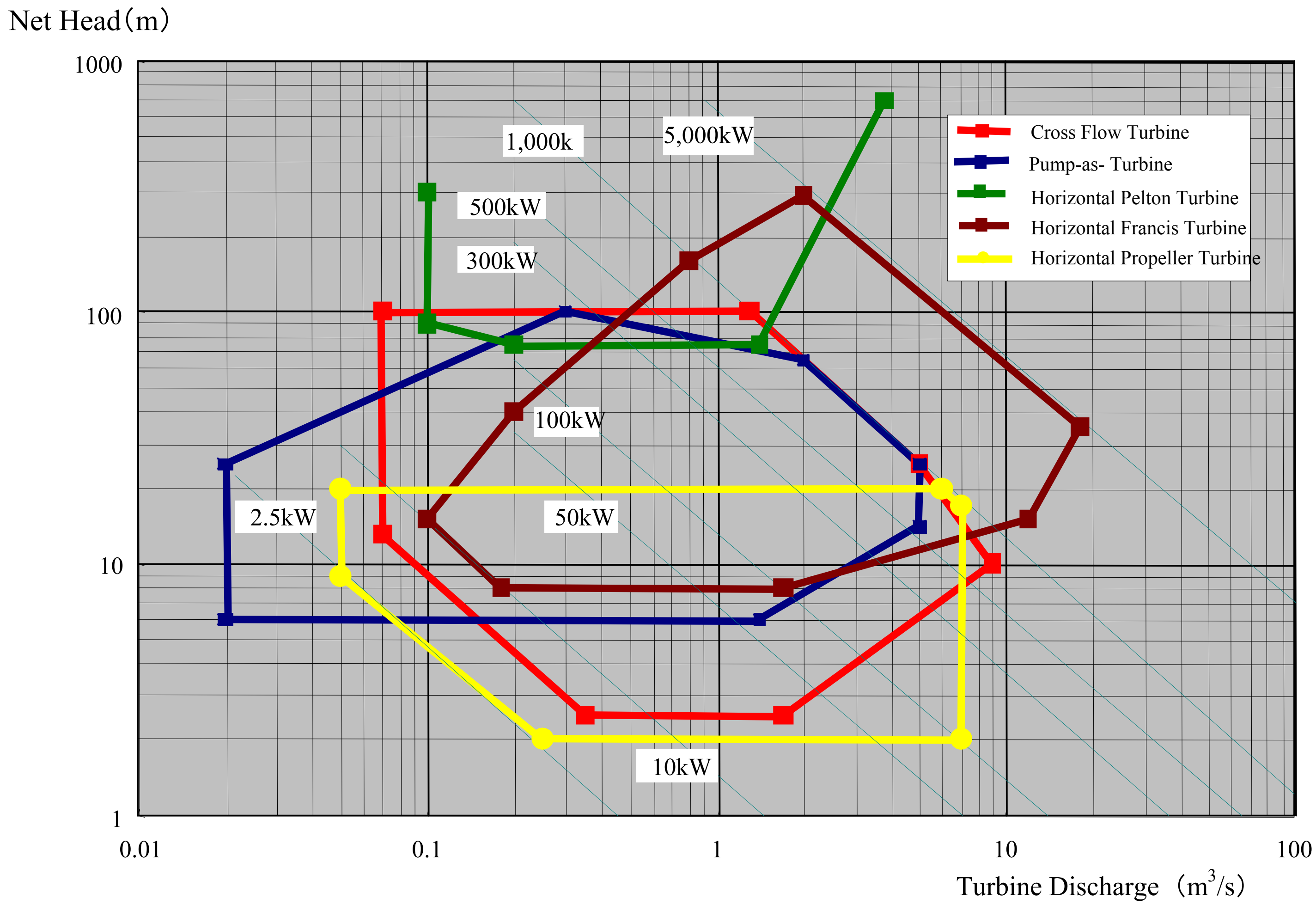


Fig. 6-6-1 SMALL-SIZE HYDRO TURBINE APPLICATION CHART