BASIC DESIGN STUDY REPORT

ON

THE RURAL WATER SUPPLY PROJECT (Phase-II)

IN

THE REPUBLIC OF ZIMBABWE

May 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

BASIC DESIGN STUDY REPORT

ON

THE RURAL WATER SUPPLY PROJECT (Phase-II)

IN

THE REPUBLIC OF ZIMBABWE

May 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Republic of Zimbabwe, the Government of Japan has decided to conduct a basic design study on the Rural Water Supply Project (Phase II) and entrusted the study to the Japan Internation Cooperation Agency (JICA). JICA sent to Zimbabwe a study team headed by Mr. Shin-ichi Teramura, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs from January 31 to March 10, 1988.

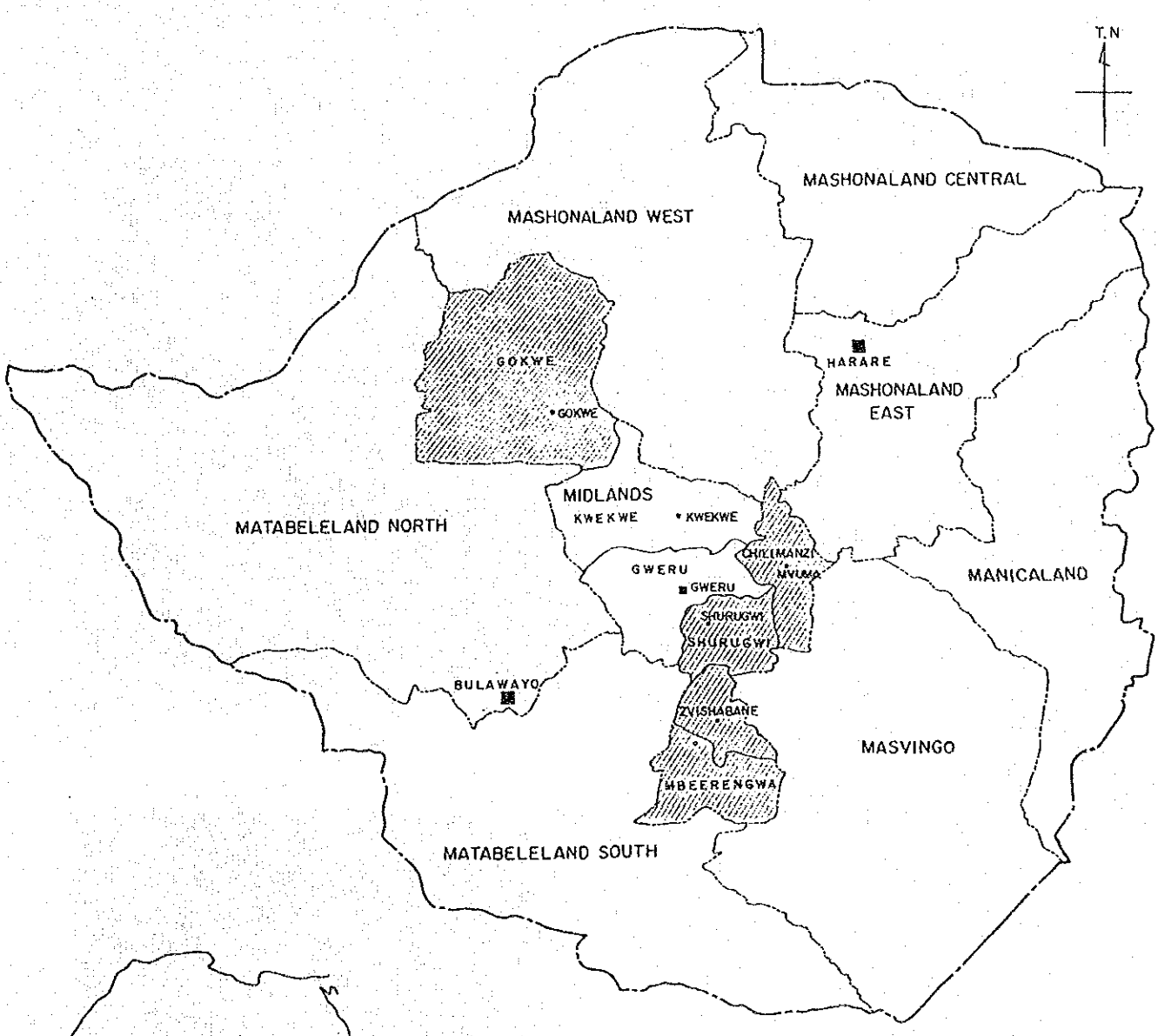
The team had discussions on the Project with the officials concerned of the Government of Zimbabwe and conducted a field survey in the Project area. After the team returned to Japan, further studies were made, a draft report was prepared and, for the explanation and discussion of it, a mission headed by Mr. Satoshi Nagata, Kyushu Regional Agricultural Administration Office, Ministry of Agriculture, Forestry & Fisheries, was sent to Zimbabwe from April 23 to May 4, 1988. As a result, the present report has been prepared.

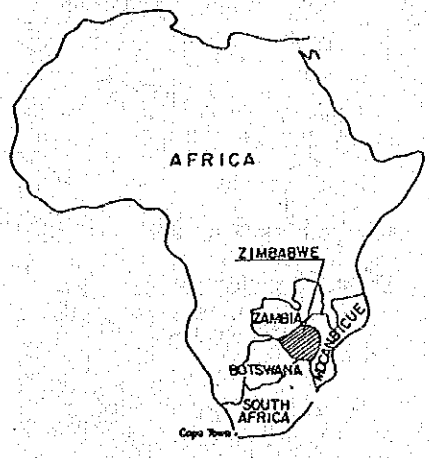
I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

May, 1988

Kensuke Yanagiya
President
Japan International Cooperation Agency





KEY MAP

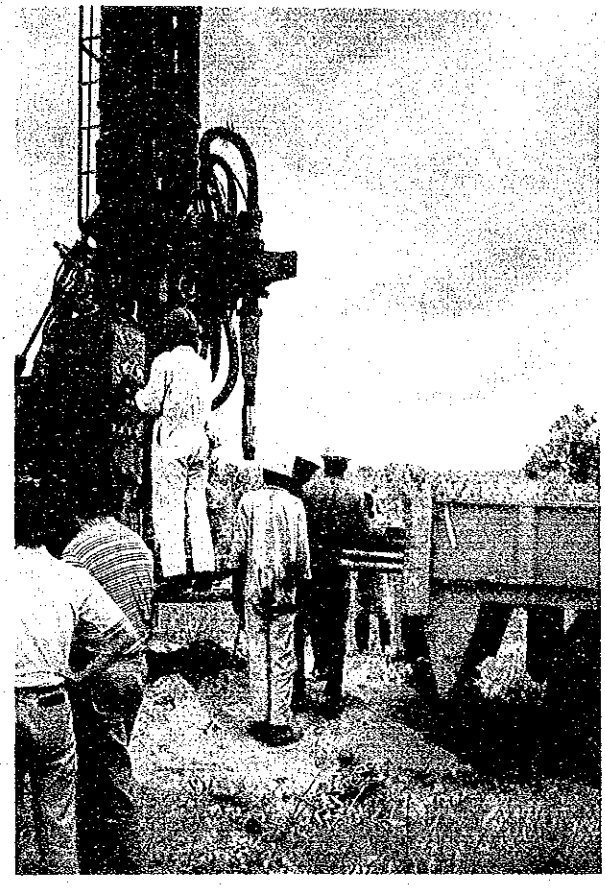
OBJECTIVE DISTRICT

SCALE

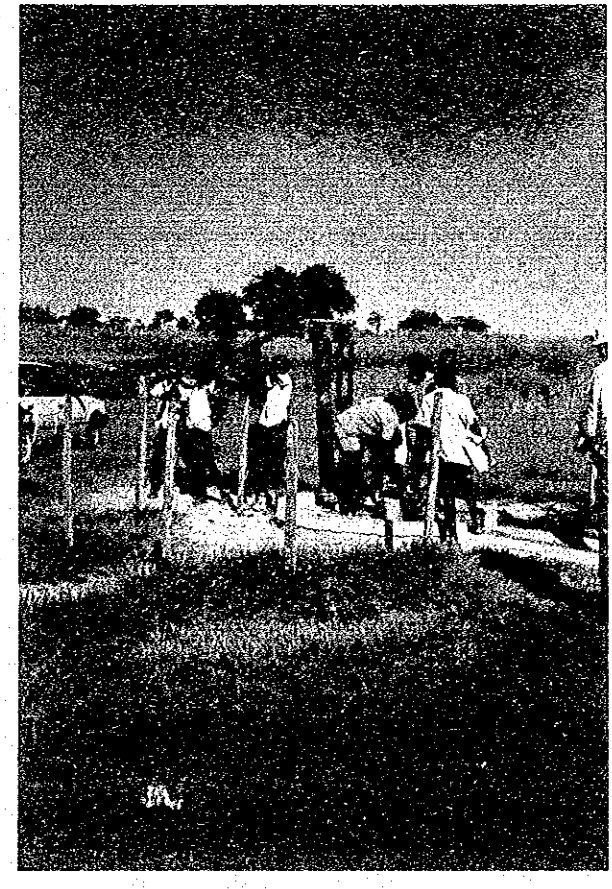
0 80 160 km

PROJECT LOCATION MAP

RURAL WATER SUPPLY PROJECT (PHASE-II)



Drilling Rig supplied under
Phase-1 Project.
(In Mashonaland Province)



Borehole constructed by
Phase-1 Project.
(In Shurugwi C.L.)

GEP Survey
(Proposed Site)

GEP Survey
(Existing Borehole Site)

Basic Design Report (Phase 2)
on the Rural Water Supply Project
in the Republic of Zimbabwe

CONTENTS

PREFACE
LOCATION MAP
PHOTOGRAPH
CONTENTS
LIST OF TABLES
LIST OF FIGURES

Page

SUMMARY i

CHAPTER 1 INTRODUCTION 1

CHAPTER 2 BACKGROUND OF THE PROJECT 4

2-1. General Conditions in Zimbabwe 4
2-2. Governmental Organization 5
2-3. Summary of National Development Plan 5
2-4. Project Area 6
2-5. Water Supply Situation in the Project Area 7
2-5-1. Master Plan 7
2-5-2. Water Supply Situation in the Project Area 7
2-6. Present Progress of the Rural Water Supply Scheme in the Project Area 9
2-7. Present Conditions of Equipment Supplied under the Phase 1 Project 10
2-8. Present Conditions of International Cooperation in the Rural Water Supply Programme 12

Page

CHAPTER 3 OUTLINE OF THE PROJECT AREA 13

3-1. Topography and Geology 13
3-2. Hydrogeology 15
3-2-1. Outline of Hydrogeology in Zimbabwe 15
3-2-2. Hydrogeology in the Project Area 20
3-3. Geoelectrical Prospecting (GEP) 23
3-4. Data on Existing Boreholes 33
3-5. Water Quality Tests of Existing Boreholes 40
3-6. Synthetic Analysis of Hydrogeology 44
3-6-1 Hydrogeological Maps 44
3-6-2. Description of Each Type of Hydrogeology 44
3-6-3. Location of Existing Deep Boreholes 49
3-6-4. Hydrogeological Subareas in Gokwe 50
3-6-5. Analysis of Existing Data 51
3-6-6. Attentions to be paid in Groundwater Development 52

CHAPTER 4 OUTLINE OF THE PROJECT 55

4-1. Objectives of the Project 55
4-2. Outline of the Project 56
4-2-1. General 56
4-2-2. Executing Agency 56
4-2-3. Outline of the Project 57
4-2-4. Summary of Construction Equipment and Materials.. 60

CHAPTER 5 BASIC DESIGN 62

5-1. Design Policy 62
5-2. Examination of Design Criteria 63
5-2-1. Project Area (Gokwe) 63
5-2-2. Water Demand and Population 65

Page

5-2-3. Yield and Rest Level of Boreholes 68
5-2-4. Examination on Factors of Proposed Boreholes..... 69
5-2-5. Site Selection 70
5-3. Design of Facilities 71
5-3-1. Design of Boreholes 71
5-3-2. Design of Head Works 71
5-4. Basic Plan of Equipment and Materials 76
5-4-1. Selection of Major Equipment and Materials 76
5-4-2. List of Major Equipment and Materials 82
5-4-3. Procurement of Equipment and Materials 87
5-5. Comparison of Major Equipment Included in the Phase 1 and the Phase 2 Projects 88

CHAPTER 6 PROJECT IMPLEMENTATION PROGRAMME 90

6-1. Main Body of Project Implementation 90
6-1-1. Main Body of Project Implementation 90
6-1-2. Consultant 91
6-1-3. Contractor (Supplier) 91
6-2. Responsibilities of the Governments of Zimbabwe and Japan 92
6-3. Construction Plan 93
6-3-1. Construction Plan Policy 93
6-3-2. Construction Schedule Plan 96
6-4. Personnel Plan 101
6-4-1. Zimbabwean Personnel Plan 101
6-4-2. Plan for Dispatch of Japanese Engineers 102
6-5. Implementation Schedule 105
6-6. Rough Estimation of Project Cost 107

CHAPTER 7 OPERATION AND MAINTENANCE PLAN 108

7-1. Operation and Maintenance System 108
7-2. Maintenance Cost 108

Page

CHAPTER 8 PROJECT EVALUATION 110

CHAPTER 9 CONCLUSION AND RECOMMENDATIONS 112

9-1. Conclusion. 112
9-2. Recommendations 113

LIST OF TABLES

		Page
Table 2-4-1.	List of Project Areas	6
2-5-1.	Population by District, Midlands Province	8
2-5-2.	Water Supply Situation in the Project Area	9
2-5-3.	Required Point Water Sources by 1990/2005	9
2-6-1.	Borehole Drilling Programme of Provincial Office (1988)	10
3-2-1.	Hydrogeological Units in Zimbabwe	16
3-2-2.	Geological Units for Middle Zambezi Basin	21
3-2-3.	Hydrogeological Units in Gokwe Area	22
3-3-1.	List of GEP Survey Sites	27
3-3-2.	Data on Boreholes on which Survey was Performed by GEP, in Gokwe Area	28
3-4-1.	Summary of Existing Boreholes Data in Gokwe	38
3-4-2.	Summary of Existing Borehole Data in Gokwe	39
3-5-1.	List of Test Samples	41
3-5-2.	Results of Water Quality Tests in Gokwe	42
3-5-3.	Test Results Comparison between Guidelines of Zimbabwe and WHO	43
4-2-1.	Boreholes to be Constructed under the Project ..	56
5-2-1.	List of Proposed Boreholes in Gokwe Area	66
5-4-1.	Types and Numbers of Vehicles Required	79
5-5-1.	Comparison of Major Equipment in Phase 1 and Phase 2	89
6-3-1.	Construction Quantities in Gokwe	94
6-3-2.	Construction Schedule by each Item	101
6-4-1.	Zimbabwean Personnel Required for Project Implementation	103
7-2-1.	Maintenance Costs by DDF, Midlands Province for 1987/1988	108
7-2-2.	Borehole Maintenance Cost by District (1987/88)	109

LIST OF FIGURES

		Page
Fig. 2-2-1.	Governmental Organizations	5
3-3-1.	Location Map for GEP Survey	26
3-3-2.	$\int$-a Curves of GEP	29
3-4-1.	Location Map of Existing Deep Boreholes in Gokwe ..	36
3-4-2.	Borehole Depth and Rest Level of Deep Boreholes in Gokwe	37
3-6-1.	Hydrogeological Map of Gokwe	42
3-6-2.	Hydrogeological Profiles	43
3-6-3.	Hydrogeological Profiles	44
4-2-1.	Organization Chart of MEWRD	58
4-2-2.	Organization Chart of Provincial Water Engineer's Office, Midlands	59
5-3-1.	Design of Shallow Boreholes under 100 m Depth	72
5-3-2.	Design of Deep Boreholes over 100 m Depth	73
5-3-3.	Plan and Profile of Head Works	74
6-5-1.	Implementation Schedule for the Project	106

SUMMARY

The Republic of Zimbabwe is situated in Southern Africa. Being surrounded by neighbouring countries, this country is landlocked. It has an area of 391,000 km^2, and a population of 8,600,000 in 1985. The country is located in the tropical zone; nonetheless, the temperature is moderate and comfortable due to its high land elevation. The annual average temperature and precipitation at Harare, the capital, are 25.3°C and 800 mm, respectively. However, for eight months of the year, the country receives no rainfall, and the climate can, therefore, considered as semi-arid.

About 70 percent of the population depends upon agricultural income. There are three types of agricultural management; the large-scale commercial farming, peasant farming practiced in the Communal Lands and small-scale commercial farming conducted in the resettlement areas. Most farmers are engaged in the second type agriculture for home consumption.

In the country the Government of Zimbabwe had been working on "the National Master Plan for Rural Water Supply and Sanitation" since 1982, and the Master Plan was completed in 1986. This Project aims to contribute to the above-mentioned national policy. Japanese grant aid cooperation in this field was extended in 1983 to the Government of Zimbabwe (Phase 1 project completed in March 1985), and the grant aid extended this time is for Phase 2.

The Project Area is composed of the following Communal Lands;

List of Communal Lands in the Project Area

Communal Land	Population (1985)	Area (km)	District
Gokwe	254,109	14,380	Gokwe
Chilimanzi	44,432	1,040	Mvuma
Shurugwi	43,797	830	Shurugwi
Runde/Mazvihwa	61,361	1,550	Zvishavance
Mberengwa	165,322	3,750	Mberengwa
Total	569,021	21,550	

More than 60 percent of the population has no adequate water supply facilities. The aims and objectives of the National Master Plan are to supply water to those people in the rural areas. The water supply situation in the Project Area is as shown below;

Water Supply Situation in the Project Area

Communal Lands	Population (1985) (Persons)	Persons Served by Piped Water (No.: Persons)	Persons Served by Point Source (No.: Persons)
Gokwe	254,109	18: 17,800	628: 125,600
Chilimanzi	44,432	6: 5,200	86: 17,200
Shurugwci	43,797	2: 4,600	55: 11,000
Runde/Mazvihwa	61,361	-: -	48: 9,600
Mberengwa	165,322	2: 3,200	143: 28,600
Total	569,021	28: 30,800	960: 192,000

The Project aims to improve the above-mentioned poor water supply situation by constructing boreholes. The Project Area is composed of the five Communal Lands shown in the above table, and four of them, with the exception of Gokwe, were situated in the area of the Phase 1 Project. Gokwe area is being newly added to the Project, and is the major beneficiary of the Project.

Geologically Gokwe is mainly composed of sedimentary rocks, and its geology is quite different from that of the Phase-1 area where Granites and Gneisses of Precambrian systems prevail. From the hydrogeological point of view, Gokwe area can be divided into the following three subareas.

It is sometimes required to construct boreholes 200 up to 400 m deep for groundwater use in Gokwe area.

Hydrogeological Subarea in Gokwe

1. Southwest; This area consists of Kalahari Sands to Upper Sandstone and forms a highland 1,000-1,200 m in elevation. The groundwater development of shallow aquifers within a depth of 100 m is possible although deep boreholes with a depth of 100 - 200 m shall be constructed in case a big yield is required for water supply to a large population. However,the rest level of deep boreholes is usually deeper than 60 m, and it is difficult to pump up water by man power without an engine pump.

2. Central; This is composed of areas other than the southwest and northeast regions. Upper Sandstone and partially Basalt or Mudstone are predominant in this area. The development of deep boreholes to date is limited here. Deep boreholes are only six out of 70 existing boreholes, and the low success rate of drilling in Sandstone and

Mudstone area shall be pointed out.

3. Northeast; This area is mainly composed of Mudstone and deep drilling to a depth over 100 m has been done due to the fact that there are few effective aquifers in Mudstone. Besides, there are 21 (40%) deep boreholes out of the 54 existing boreholes in Upper Sandstone area. It can be said that success rate of existing boreholes, that is, 90% in Sandstone and at a little less than 70% in Mudstone, will go down in the future due to the decrease in suitable sites for development.

The executing agency of the Project is the Ministry of Energy and Water Resources and Development (MEWRD) of the Government of Zimbabwe. In the Project 120 boreholes will be constructed as shown below, and the equipment and materials necessary for constructing these boreholes will be supplied under Japanese grant aid.

Borehole Numbers for the Phase 2 Project

Communal Land	Population (1985)	Proposed B/H
Gokwe	254,109	40
Chilimanzi	44,432	11
Shurugwi	43,797	11
Runde/Mazaihwa	61,361	16
Mberengwa	165,322	42
Total	569,021	120

MEWRD shall be responsible for the following Project implementation;

(1) Gokwe Area

- MEWRD shall select 40 borehole sites in consultation with the Ministry of Local Government, Rural and Urban Development (MLGRUD) and construct the borehole facilities at these sites by using equipment and materials provided under the grant aid of the Government of Japan. For this purpose, MEWRD shall secure the necessary personnel, equipment and materials other than those provided by the Government of Japan.

- MEWRD shall execute siting and construction as the main body of the Project execution, with the cooperation of Japanese engineers to be dispatched to Zimbabwe for on-the-job training at the beginning stage of the Project. MEWRD shall continue the remaining works with its own resources safter Japanese engineers return to Japan.

(2) Other Areas

- Using the rigs in its possession, MEWRD shall construct 80 boreholes . However, permanent casings and hand pumps for the above 80 boreholes will be provided under the grant aid of the Government of Japan.

The following equipment and materials will be supplied under Japanese grant aid.

(1) Drilling rig
(2) High pressure aircompressor
(3) Supporting vehicles

(4) Geophysical prospecting equipment
(5) Borehole testing equipment
(6) Permanent casing pipes
(7) Water analysis kit
(8) Hand pump
(9) Radio system
(10) Engine welder
(11) Concrete mixer
(12) Mud water agents
(13) Mobile workshop
(14) Spare parts

The Project implementation cost to be borne by the Zimbabwean side is roughly estimated at Z$1,064,000.

The Project implementation period is scheduled as follows: It will take 11.5 months from the signing of the Exchange of Notes (E/N) by both Governments to the Contract for consulting services, the procurement of equipment and materials and their transportation to Zimbabwe; 21.0 months for the completion of the construction with the cooperation of Japanese engineers; and 38.3 months to the completion of the Project by MEWRD.

The boreholes constructed under the Project shall be maintained by the Zimbabwean side. The organization for their maintenance has been established and is operated by the District Development Fund (DDF) of the MLGRUD. The annual maintenance cost per borehole was Z$189 in 1987/88 as informed by DDF, Midlands, and outlined in Table 7-2-1.

It is pointed out that a direct benefit of the Project is safe drinking water supply to 47,000 people in total. Furthermore, many more people will be benefited by further borehole construction, after completion of the Project, which will be carried out by MEWRD

using the equipment to be supplied under the Project. Equipment supplied under the Phase 1 Project are presently engaged in a rural water supply project in Manicaland Province and are benefiting an increasing population day by day.

The operation of the equipment to be supplied in the Phase 2 Project are essentially similar to that of equipment having been supplied under the Phase 1 Project. And in Zimbabwe, there are no problems regarding the operation of equipment and it can be pointed out that the finance for local personnel and materials will be managed by the Government.

From the above facts, it is concluded that the grant aid cooperation for the Project is justifiable from both the technical and financial points of view.

CHAPTER 1. INTRODUCTION

The water supply situation in the Republic of Zimbabwe is much poorer in the Communal Lands than in big cities. The former have a low percentage of pipe-supplied safe water, whereas the latter enjoy safe drinking water supply. Many inhabitants of the Communal Lands are using unsafe water from rainfalls, rivers, lakes or ponds.

To improve the above situation in rural areas, the Government of Zimbabwe has carried out the "National Master Plan for Rural Water Supply and Sanitation" (hereinafter referred to as "the Master Plan") since 1982 based upon "The International Drinking Water Supply and Sanitation Decade" launched by the United Nations on 10 November, 1980. The Master Plan was completed in 1986 except for final approval by the Government.

The Master Plan Report shows necessary additional water points for the Project Area by 1990, the short-term target year, as follows:

District	Exist. Water Points (W/P)	Needed W/P by 1990
Gokwe	628	870
Mvuma	86	770
Shurugwi	55	180
Zvishavane	48	150
Mberengwa	143	280
Total	960	2,250

The Government of Zimbabwe requested a feasibility study on "the Rural Water Supply Project" to the Government of Japan in 1982, and as a result of the study, the Government of Japan extended grant aid amounting to 800 million Japanese Yen to the Government of

Zimbabwe for the Rural Water Supply Project (the Phase 1 Project).

Following the Phase 1 Project which was completed in March, 1985, the Government of Zimbabwe made a request for grant aid to the Government of Japan so as to accelerate the Rural Water Supply Project, and after the examination of the request, the Government of Japan decided to conduct a basic design study for the Phase 2 Project.

In response to the above decision, the Japan International Cooperation Agency (hereinafter referred to as "JICA") sent to Zimbabwe a study team headed by Mr. Shin-ichi Teramura, Grant Aid Division, Ministry of Foreign Affairs (hereinafter referred to as "MOFA") from 31 January, 1988 to 10 March, 1988.

The study team made a series of discussions with the officials concerned of the Ministry of Energy and Water Resources and Development (hereinafter referred to as "MEWRD"), the executing agency of the Government of Zimbabwe, and conducted a field survey in the Project Area.

The results of the discussions between MEWRD and the study team are summarized in the Minutes of Discussion signed on 9 February, 1988 by the representatives of both parties.

The member list of the study team, its field survey itinerary , a list of related officials contacted by the team, a copy of the Minutes of Discussion, and the list of reference documents are herein attached as appendices.

Based upon the said survey, the study team has carried out, since their return to Japan, an examination of the effectiveness of the Project, design of the water supply facilities, selection of the equipment and materials necessary for implementation of the

Project, a rough estimate of the Project cost, planning for operation and maintenance of the facilities and so forth.

This report describes the most effective plan for the Project implementation.

CHAPTER 2. BACKGROUND OF THE PROJECT

2-1. General Conditions in Zimbabwe

The Republic of Zimbabwe is situated in southern Africa at 20 degrees south latitude and 30 degrees east longitude, and has a total land area of 391,000 km^2. The population was estimated at 8,600,000 in 1985. Being surrounded by four neighboring countries, Zimbabwe is landlocked. Most of the land lies on a plateau higher than 500 m above sea level. The major cities like Harare, the capital, Bulawayo, and Mutare, etc., lie on the central high plateau. The country is located in the tropical zone. Nonetheless, the temperature is moderate due to the high elevation. The annual average temperature at Harare is 25.3°C and the annual average precipitation is about 800 mm. However, for eight months of the year, the country receives no rainfall and the climate can, therefore, considered as semi-arid.

The country gained independence in 1980. It has a comparatively good economic infrastructure compared with other African countries, taking into consideration the progress of neighboring countries. Zimbabwe is cooperating with developed countries.

About 70 percent of the country's population is dependent on agricultural income. Three types of agricultural management have been developed ; the large scale commercial farming, peasant farming practiced in the Communal Lands, and small scale commercial farming conducted in the resettlement areas. Most farmers are engaged in the second type of agriculture for home consumption.

The population of the country was 7.55 million according to the 1982 census and estimated at 8.60 million in 1985 with an increasing rate of 3.7%.

2-2. Governmental Organization

The Governmental organizations are given in Fig. 2-2-1. The Project Area, which is composed of several Communal Lands, is governed by the District Councils.

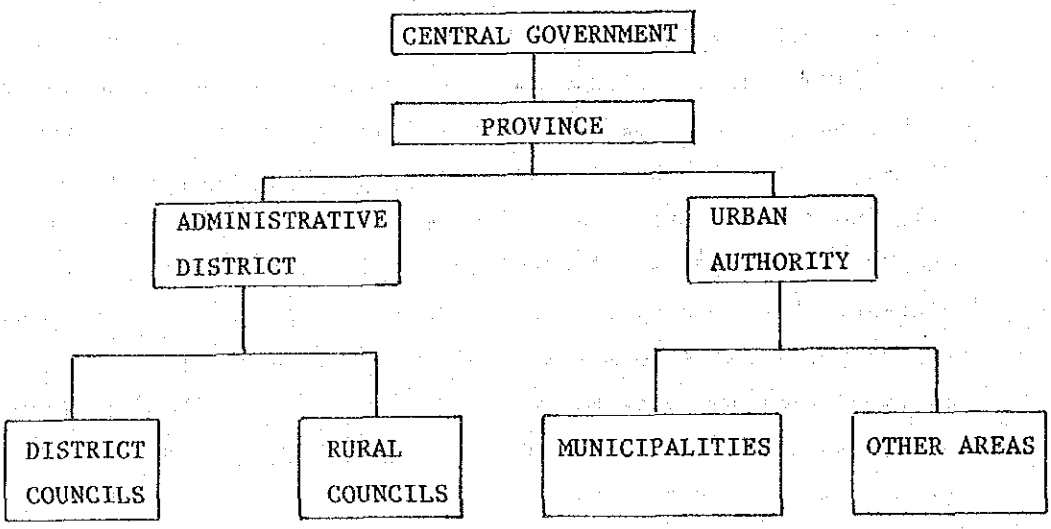


Fig. 2-2-1. Governmental Organizations

2-3. Summary of National Development Plan

In the present "First Five-Year National Development Plan (1986-1990)" Zimbabwe has elaborated six major development objectives which are summarized below:

a) Transformation and control of the economy as well as economic expansion;
b) Land reform and efficient utilization of land;
c) Raising the standards of living of the entire population and, in particular, the peasant population;
d) Enlargement of employment opportunities and manpower development;
e) Development of science and technology; and

f) Maintenance of a correct balance between the environment and development.

The major sectors of the Zimbabwean economy are manufacturing and agriculture, and the Gross Domestic Product (GDP) for 1985 was Z$8.099 million or Z$1,080 per capita. The manufacturing and agriculture accounted for 29% and 13% of GDP in 1985, respectively. However, the increase rate of per capita income in 1980 to 1985 at constant prices in 1980 was 17.0 %.(Source: Central Statistic Office)

2-4. Project Area

The Phase 2 Project covers the following areas. Gokwe has been added to the areas of Phase 1. The main target of the Project under grant aid of the Japanese Government is placed on Gokwe area, and the development of the other areas will be undertaken by the Zimbabwean side.

Table 2-4-1. List of Project Areas

Communal Land	Population (1985)	Area (km^2)	District
Gokwe	254,109	14,380	Gokwe
Chilimanzi	44,432	1,040	Mvuma
Shurugwi	43,797	830	Shurugwi
Runde/Mazvihwa	61,361	1,550	Zvishavane
Mberengwa	165,322	3,750	Mberengwa
Total	569,021	21,550	

2-5. Water Supply Situation in the Project Area

2-5-1. Master Plan

"The International Drinking Water Supply and Sanitation Decade" was inaugurated by the General Assembly of the United Nations Organization on 10 November, 1980. In Zimbabwe, the Government decided to prepare its Master Plan for the above decade in 1982 and started the Master Plan Study in 1983 with the assistance of the Norwegian Agency for International Development (NORAD). The Master Plan was completed in 1986.

The major policy shown in the Master Plan for the Rural Water Supply is summarized as follows:

(1) The Water Supply Programme is divided into three phases; short-term (1985-1990), medium-term (1985-1995) and long-term (1985-2005) phases.

(2) Piped water supply will be planned for the most important locations such as growth points and district service centres.

(3) Point-water sources such as boreholes or protected shallow wells will be planned for the normal rural area.

2-5-2. Water Supply Situation in the Project Area

(1) Population

The population in Midlands Province for 1982 was 1.08 million. Of this population 761,000 live in the District Council Areas, and most of them stay in the Communal Lands.

The population by District Council is given in Tab. 2-5-1.

Table 2-5-1. Population by District, Midlands Province

District Council	Population	Increase Rate (%)
*Chezia Gokwe	218,969	4.75
Chikomba	97,223	1.80
Manyame	46,805	3.85
Mashambazhon	108,387	4.10
*Mberengwa	150,777	2.65
*Shurugwi	41,717	1.45
*Mvuma	42,144	1.50
*Zvishavane	55,216	3.10
Total	761,238	2.90

Note: * shows the Project Area

(2) Water Supply Situation

As shown in Table 2-5-2, 30,800 people or 5.4% of the total of 569,000 people, are served with piped water. 192,000 people (33.7%) use water from adequate water supply facilities, and the remaining people (over 60%) are eagerly waiting for adequate water supply facilities to be developed.

The required new water source points, which are summarized in the Master Plan Report, are given in Table 2-5-3. This table shows that a total of 2,250 water sources must be developed in the short-term by 1990. Considering the ratio (1:2) of boreholes to shallow wells, it is estimated that about 1,500 new boreholes shall be constructed.

Table 2-5-2. Water Supply Situation in the Project Area

Communal Lands	Population (1985) (Persons)	Persons Served by Piped Water (No.: Persons)	Persons Served by Point Source (No.: Persons)
Gokwe	254,109	18: 17,800	628: 125,600
Chilimanzi	44,432	6: 5,200	86: 17,200
Shurugnci	43,797	2: 4,600	55: 11,000
Runde/Mazvihwa	61,361	-: -	48: 9,600
Mberengwa	165,322	2: 3,200	143: 28,600
Total	569,021	28: 30,800	960: 192,000

Table 2-5-3. Required Point-Water Sources by 1990/2005

District	Existing Sources	Required Sources (1990)	Required Sources (2005)
Gokwe	628	870	1,720
Nvuma	86	770	1,300
Shurugwi	55	180	310
Zvishavane	48	150	290
Mberengwa	143	280	480
Total	960	2,250	4,100

2-6. Present Progress of the Rural Water Supply Scheme in the Project Area

The MEWRD Provincial Office in Gweru, which is responsible for projects in the Project Area, has its own implementation programme for the rural water supply scheme financed by other related authorities so as to improve the water supply. The programme of the Provincial Office for 1988 is given in Table 2-6-1.

Eight percussion type rigs are being operated for the programme.

Table 2-6-1. Borehole Drilling Programme of Provincial Office (1988)

(1)	Drought Relief Project	27 Sites
(2)	Ministry of Local Government	54 Sites
(3)	Ministry of Land	9 Sites
(4)	Resettlement Areas by Min. of Land	36 Sites
	Total	126 Sites

2-7. Present Condition of Equipment supplied under the Phase 1 Project

(1) Inspection Results at Drilling Site

Guided by the Drilling Superintendent of MEWRD, the study team inspected a drilling site near Mt. Darwin in Mashonaland Central Province on 9 February, 1988.

The drilling rig supplied under the Phase 1 Project showed about 12,000 km of travel distance and about 1,000 hours of operation based on the estimation by MEWRD. The other rig was working in Kariba area and under similar conditions to the above rig.

The travel distances of the supporting vehicles were as shown below;

* Cargo Truck: 111,000 km
* Light Vehicle: 160,000 km

These distances suggest the imminent end of the vehicles' working lives, because they have been usually running on poor gravel

roads.

After the Phase 1 Project, rigs supplied under the Phase 1 Project were deployed to the NORAD Project in Manicaland Province and drilled 230 boreholes (totally 12,000 m deep) as of October, 1987. The rigs were still working well, drilling ten to fifteen boreholes per month on an average. The drilling rigs has satisfied MEWRD with the exception of their hydraulic system. They have been maintained by twice monthly oil-changes and monthly scheduled inspection during the year under the supervision of the Drilling Superintendent.

As for the compressor, MEWRD was satisfied by its performance. However, its trailer facility has been upgraded to take account of the poor road conditions.

(2) Inspection Results at the Provincial Office

There were one cargo truck and two light vehicles (one pick-up type and one station wagon type) at the Provincial Office.

The operation distances of the cargo truck, pick-up and station wagon were 68,000 km, 164,000 km, and 110,000 km, respectively, and all of them seemed to have been well worn by overoperation.

(3) Maintenance Condition of Boreholes

The study team inspected three boreholes constructed in Shurugwi C.L., and found that all of them had been maintained well and were serving many villagers. For one site of the three, the users had constructed washing/trough facilities.

This fact shows that users have been greatly interested in borehole maintenance.

(4) Performed Result in the Project Area

The drilling rig was operated for construction of a deep borehole with a depth of 230 m in Gokwe town. However, for operation reasons, the rigs are now limitedly operated to drill to a depth of 150 m.

After the Gokwe project, the rig was returned to the NORAD Project, and is presently working well.

Except for the above-mentioned drilling work, no drilling by the rigs supplied under the Phase 1 Project had been done in the Project Area although there were records of 18 drilling sites with a total depth of 1,105 m in southern parts of Gweru city in Midlands Province.

2-8. Present Conditions of International Cooperation in the Rural Water Supply Programme

Various international and loan agreements for the Rural Water Scheme have been executed after the independence of Zimbabwe. The internationally aided drilling projects presently being executed are;

- NORAD Project in Manicaland and Mashonaland Provinces,
- EEC Project in Matabeleland Province,
- Dutch Aid Projects in the countrywide, and
- German Aid Project in Masvingo Province.

No international cooperation has been extended to the Project Area since the completion of the Phase 1 Project by the Government of Japan. However, the Government of Holland is interested in the rehabilitation programme of shallow wells and is presently in contact with the officials of the Government of Zimbabwe.

CHAPTER 3. OUTLINE OF THE PROJECT AREA

The Project covers Gokwe area and Phase 1 Project areas. However, the field survey of this study was conducted in Gokwe area which has been newly added to this Project. The survey results attained in Gokwe area are described below;

3-1. Topography and Geology

Topographically Midlands Province consists of flat heights with peaks composed of intrusive rocks in some places. The inhabitants of the Communal Lands are engaged in agriculture and/or stock raising, and live on the heights.

The vegetation varies from steppes to forestry lands in the Project Area. There is little forestland in the Communal Lands located in the south and southwest parts of the Province, but Gokwe area, which is located in the northeast part of the Province, is covered by trees except for mudstone area. Reflecting the amount of rainfall, the vegetation varies from savanna to steppes as the land goes towards the south.

Geologically the area is divided into Gokwe area located in the northwest part and Chilimanzi to Mberengwa areas located in the west to southwest part. That is to say, the northwest part is composed of sedimentary rocks of the Triassic to Jurrassic periods, partially interposed with basalt and/or rhyolite, and of Quaternary deposits mainly composed of Kalahari sand, covering the Triassic and Jurassic rocks. On the other hand, the west to southwest part is composed of Precambrian basement rocks, mainly Granites and/or Gneisses and partially Schists.

The geological conditions of the Project Area are summarized as follows:

i) Gokwe Area

The main parts of Gokwe are composed of Karoo sandstone, Cretaceous sandstone/grit or Karoo mudstone, Kalahari sands and alluvial deposits other than the small body of the Sijarira group. The sandstones in the Lower Karro Group sometimes have artesian aquifer and are important for groundwater development.

ii) Chilimanzi Area

The area is divided into two subareas, a younger granite subarea in the northern part and an older gneiss subarea in the southern part.

iii) Shurugwi Area

The area is composed of younger granites and older gneisses. The Great Dike, which extends through Zimbabwe from north to south, is located in the west part of the area, and linear structures parallel to the Great Dike are distributed near the Dike.

iv) Runde/Mazvihwa Area

There is a S-shape metavolcanic peak in the area, which extends from south to north. Around the peak zones are younger granites and older gneisses.

v) Mberengwa Area

The area is characterized by the striped structures of various rocks in the WSW to ESE directions. Also there are older gneisses associated by tonalites in the northwest part and the Great Dike on the west edge of the area.

3-2. Hydrogeology

3-2-1. Outline of Hydrogeology in Zimbabwe

The hydrogeological conditions in Zimbabwe are described in the Master Plan Report and summarized into ten units as shown in Table 3-2-1.

The summary of hydrogeology in Zimbabwe is described below.

(1) Archaean Granite and Gneissose Rocks

These rocks are composed of granites and gneisses, and are widely distributed in Zimbabwe. Aquifers of these rocks, however, depend on the thickness of weathered zones, and are only locally distributed.

(2) The Greenstone Belt

(a) Bulawayan Rocks

Bulawayan rocks consist of metalavas and have deep weathered zones. The aquifer is well developed and has a average yield in a range of 100-200 m^3/day from boreholes.

Table 3-2-1. Hydrogeological Units in Zimbabwe

Hydrogeological Unit	Lithology	Groundwater Development Potential
1. Archaean Granite and Gneissose Rocks	Granites, Gneisses	Mod. - Low
2. Greenstone Belt		
2-a) Bulawayan Unit	Metavolcanics	High
2-b) Shamvanian Unit	Acidic Lavas	Low
3. Argillites of the Piriwiri, Lomagundi, Tengwe River and Sijarira Formations	Phyllites	Low
4. Lomagundi and Tengwe River Group Calcareous Facies		
4-a) Lomagundi Calcareous Facies	Dolomites	High
4-b) Tengwe River Calcareous Facies	Limestones	Mod.
5. Umkondo Group	Schists Phyllites	Low
6. Karoo Sequence		
6-a) Batoka Basalt	Basalts	Mod.
6-b) Forest Sandstone	Fine Sandstones	High
6-c) Escarpment Grit	Coarse Sandstones	High
6-d) Madumabisa Mudstone	Mudstones	Low
6-e) Upper and Lower Wankie Sandstone	Sandstones	High
7. Cretaceous Formation	Conglomerate, Mudstone	Low
8. Kalahari Sands	Sands	High
9. Alluvial Deposits	Alluvium	High
10. Mashonaland Dolerite	Dolerite	Mod.

(b) Shamvanian Rocks

Shamvanian rocks are characterized by a felsitic rock assemblage including acid lavas, phyllites and greywache. The aquifer is poorly developed compared with Bulawayan and has an average yield in a range of 10-25 m^3/day.

(3) Argillites of the Piriwiri, Lomagundi, Tengwe River and Sijarira Formations

Argillites are composed of quartzite, slate, shale and/or siltstone, and their aquifer is normally poor.

(4) Calcareous Rocks of the Lomagundi and Tengwe River Groups

The rocks mainly consist of dolomite. The shallow aquifer is not recommended for groundwater development, but the deep aquifer is very good and has a yield of 500-2,000 m^3/day from boreholes when it encounters karst networks.

(5) Umkondo Group

This group mainly consists of schists, and the normal yield from a borehole ranges between 10-50 m^3/day.

(6) Karoo Sequence

(a) Batoka Basalt

Basalt has a local aquifer which has a yield from 20-100 m^3/day up to 250 m^3/day locally.

(b) Forest Sandstone

This fine sandstone's yield is controlled by primary porosity and permeability, and the sandstone sometimes forms a regional aquifer with a yield of 30-300 m^3/day from boreholes.

(c) Escarpment Grit

This grit consists of coarse sandstone and has a thickness of about 30-40 m in Gokwe. Borehole yields of 100-300 m^3/day are available.

(d) Madumabisa Mudstone

This mudstone has been very poorly developed. Sometimes there are such problems as brackish water and/or a fluoride hazard, and the water is not suitable for human consumption in many cases.

(e) The Upper and Lower Wankie Sandstone

This sandstone's yield is controlled by primary porosity and permeability. It forms regional confined aquifers having a yield of 100-500 m^3/day from 100-150 m deep boreholes.

(7) Cretaceous Formation

This formation is composed of conglomerate, sandstone and mudstone. The aquifer is generally poor, and has a yield of 10-50 m^3/day from 70-100 m deep boreholes.

(8) Kalahari Sands

Kalahari sands consist of fine to medium sands. The aquifer of this sand is generally good, and has a yield of 100-1,000 m^3/day (occasionally) from 70-100 m deep boreholes.

(9) Alluvial Deposits

These deposits consist of unconsolidated sequences. Yields from these deposits are extremely variable from low to very high according to their contents of clean sand and gravel.

(10) Mashonaland Dolerite

This is dolerite intruded with granites and gneisses of Unit 1 and has a yield range of 50-250 m^3/day from 30-50 m deep boreholes.

3-2-2. Hydrogeology in the Project Area

The geological stratigraphy for Gokwe area is shown in Table 3-2-2 and summarized in Table 3-2-3 from a hydrogeological point of view for the Project. That is to say, the hydrogeology of Gokwe area is summarized for the following 6 units. Gokwe area, however, is covered by Kalahari sands, Upper sandstone and Upper mudstone, except for the Sijarira formation located in the northeast part of Gokwe.

i)	Kalahari Sands:	Kalahari Sands, Sedimentary rocks above Batoka Basalt.
ii)	Basalt:	Batoka Basalt
iii)	Upper Sandstone:	Sandstones of Upper Karoo Group, mainly Forest Sandstone.
iv)	Upper Mudstone:	Madumabisa Mudstone
v)	Lower Sandstone:	Sandstones of Lower Karoo Group
vi)	Lower Mudstone:	Mudstones of Sijarira formation
vii)	Basement Complex:	Granites, Gneisses

Table 3-2-2. GEOLOGICAL UNITS FOR MIDDLE ZAMBEZI BASIN

Time	Geology		Thickness (m)
QUATERNARY - CRETACEOUS	Kalahari Sand Sandstone etc		
LOWER JURASSIC	Batoka Basalt		50 - 80
TRIASSIC	Forest Sandstone	UPPER Karoo GROUP (UPPER Sandstone)	610
	Pebbly Arkose		140
	Fine Red Marly Sandstone		70
	Ripple Marked Flags		0 -
	Escarpment Grit		1,200
PERMIAN - CARBONIFEROUS	Madumabisa Mudstone (Upper Mudstone)		500
	Upper Wankie Sandstone	LOWER Karoo GROUP	30
	Black Shale and No.1 Seam		25
	Wankie Main Coal Seam		70
	Lower Wankie Sandstone		60
	Glacial Beds		100
PRECAMBRIAN	Sijarira GROUP		
PRECAMBRIAN	Granite, Gneiss, Schist, etc.		Basement

Table 3-2-3. Hydrogeological Units in Gokwe Area
(Summarized for this Report)

Age	Formation/Rocks	Hydrogeological Conditions
Quaternary - Cretaceous	Kalahari Formation (Kalahari Sand, Sandstone)	Forming good aquifers, located on high land, Deep boreholes and rest level.
Lower Jurassic	Batoka Basalt	Aquifers locally located in weathered zone or boundary zone of sandstone. Generally deep rest level due to high location.
Triassic	Upper Sandstones (Forest sandstone etc.	Equivalent to Upper Karoo, and can be summarized as Upper Sandstone. Promising aquifer is deep, but generally deep rest level
Permian	Upper Mudstone (Madumabisa Mudstone)	Generally poor, and lower water quality.
Permian - Carboniferous	Lower Sandstone	Regional aquifer, distributed below the mudstone, required deep boreholes.
Precambrian	Lower Mudstone (Sijarira Group; Sandstone/mudstone)	Sedimentary rocks of sandy - silty rocks, almost same condition as Upper Mudstone in view of hydrogeology.
Precambrian	Basement Complex (Granites/Gneisses)	Forming an aquifer within weathered zone or fissured zone, locally.

3-3. Geoelectrical Prospecting (GEP)

(1) General

The survey of twenty-four (24) GEP sites in total was carried out by the study team in Gokwe area. The sites were selected as follows, and shown in Table 3-3-1 and Fig. 3-3-1.

- Existing Borehole Site (E-No. is given)

  A total of eleven (11) sites were surveyed in order to gain information on the relationship between GEP and borehole results.

- Proposed Borehole Site (P-No. is given)

  A total of thirteen (13) sites were surveyed for further study for the Project implementation.

The Wenner method is applied for GEP with a prospecting depth of 100 m. An Mc-OHM instrument produced by OYO Corporation in Japan was used.

(2) GEP Results

GEP results are shown in Fig. 3-3-2 and the Data of existing boreholes for which GEP was performed are shown in Table 3-3-2.

Fig. 3-3-2 shows ρ -a curves of existing borehole sites together with proposed sites by geological conditions. The following points can be recognized based on the existing borehole data, hydrogeological conditions and GEP results.

i) Kalahari Sands

The existing borehole site E-5 has a yield of 36 l/min (0.6 l/sec) and its range of apparent resistivity is 20-60 ohm-metre. On the other hand, the existing site E-14, which is located 100 m higher than E-5, has a yield of 9 l/min (0.15 l/sec) and its range of apparent resistivity is 1,000-10,000 ohm-metre. From this point of view, the target zones of Kalahari sand for groundwater development should have a resistivity less than 100 ohm-metre.

ii) Basalt

The existing borehole E-4 has a yield of 100 l/min (1.7 l/sec) and apparent resistivity of about 130 ohm-metre. It can be considered that basalt having resistivity of about 100 ohm-metre forms a good aquifer.

iii) Upper Sandstone

A total of four (4) existing borehole sites were surveyed. Three of them, except for E-3, have good yields of 36-76 l/min (0.6-1.3 l/sec), and their apparent resistivities ranging between 40-60 ohm-metre continue to a depth of 40 m . Furthermore, E-9 does not seem to be argillized even if it has a resistivity of less than 10 ohm-metre. And it can be said that this characteristic of sandstone is different from mudstone.

iv) Upper/Lower Mudstone

The existing E-2 site has a yield of 23 1/min (0.4 1/sec) and a range of resistivity between 70-100 ohm-metre. However, the low resistivity zone of 10-20 ohm-metre shown at P-27 might be altered into clay and become a poor aquifer due to blocking by clay/silt.

v) Granites/Gneisses

It can be said that a low apparent resistivity between 100-300 ohm-metre may be a necessary condition for a good aquifer of these rocks, based upon the survey results performed in the Phase 1 Project.

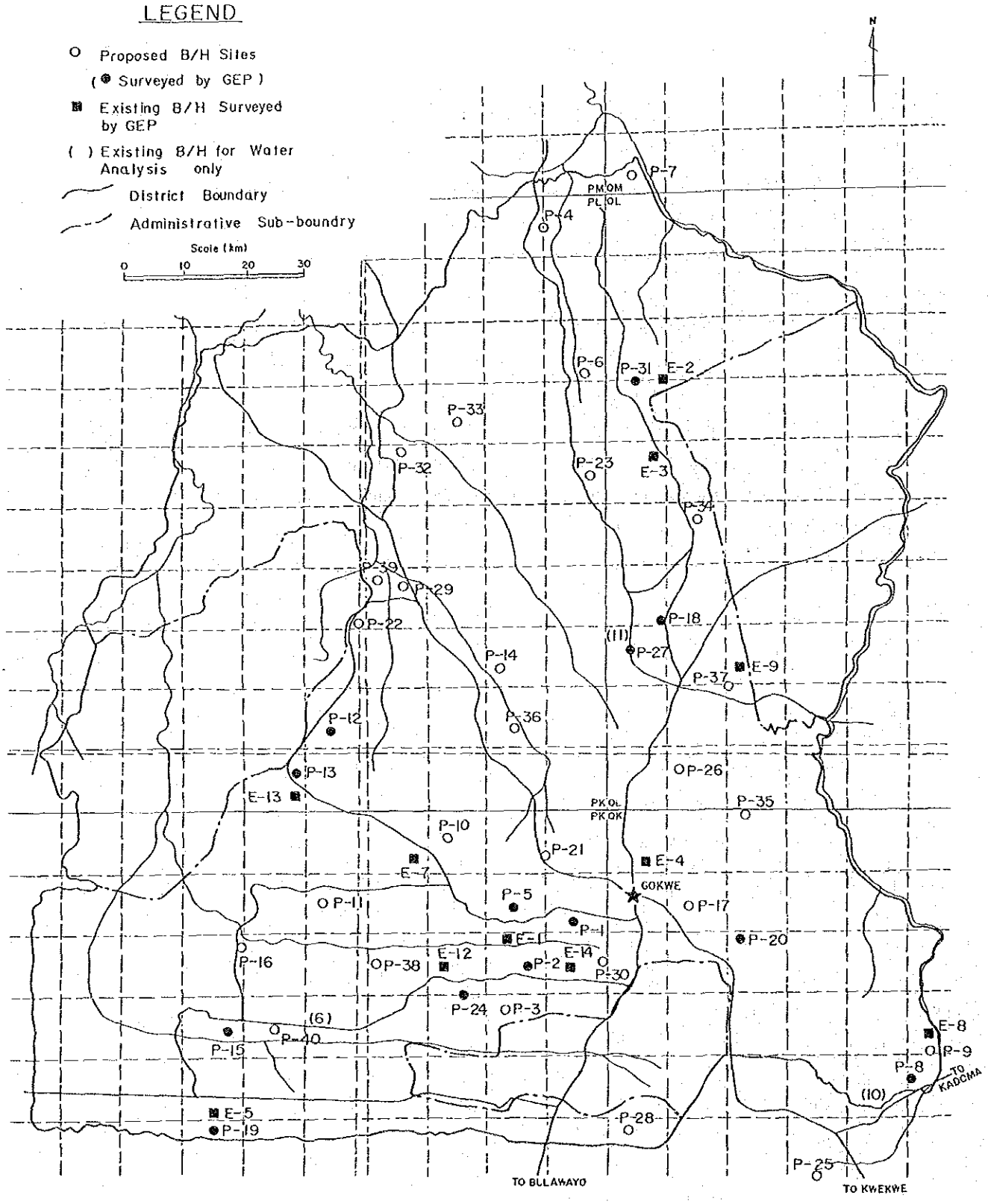


Fig. 3-3-1 LOCATION MAP FOR GEP SURVEY

Table 3-3-1. List of GEP Survey Sites

NO.	NAME		Grid Ref.	Geology	Elevation (m)
P-1	MLALATI	T/SHIP	PK887822	Sand	1,170
P-2 (1)	MATETA I	T/SHIP	PK856733	Sand	1,220
P-2 (2)	"	"		Sand	1,130
P-5 (1)	CHIURAI	Sch.	PK845836	Sandstone	1,130
P-5 (2)	"			Sandstone	1,130
P-8	KRIMA	Vill	QK500575	Granite	1,065
P-12	MASUKA	Sch.	PL536148	Sandstone	955
P-13	MAGAZO	Vill	PL483039	"	1,160
P-15	MATURA	Sch.	PK375634	"	1,130
P-18	CHIRAPE	T/SHIP	QL095300	"	920
P-19	MKOKA	Sch.	PK370491	Sand	1,125
P-20	NDHLIZIYANA	Vill	QK235794	Basalt	1,200
P-24	GAWA	T/SHIP	PK759719	Sandstone	1,140
P-27	GWIRAWAKANYA	Sec.	QL025254	Mudstone	855
P-31	MYUMVUDZI	Sch.	QL057703	Mudstone	800
E-1	GAWA	CLINIC	PK842806	Sandstone	1,140
E-2	MVUMVUDZI	Sch.	QL064700	Mudstone	795
E-3	RUPENYU	CLINIC	QL079597	Sandstone	820
E-4	MITI	Vill	QK043916	Basalt	1,200
E-5	MKOKA	Sch.	PK365500	Sand	1,140
E-7	MANYONI	Sch.	PK684933	"	1,180
E-8	BLUE GUM	Dip	QK522620	Gneiss	1,060
E-9	NHAU	Vill	QL227223	Sandstone	880
E-12	GAWA	Sch.	PK735724	"	1,120
E-13	MAGAZO	Vill	PL500031	"	1,170
E-14	NYARADZA	Sch.	PK945727	Sand	1,260

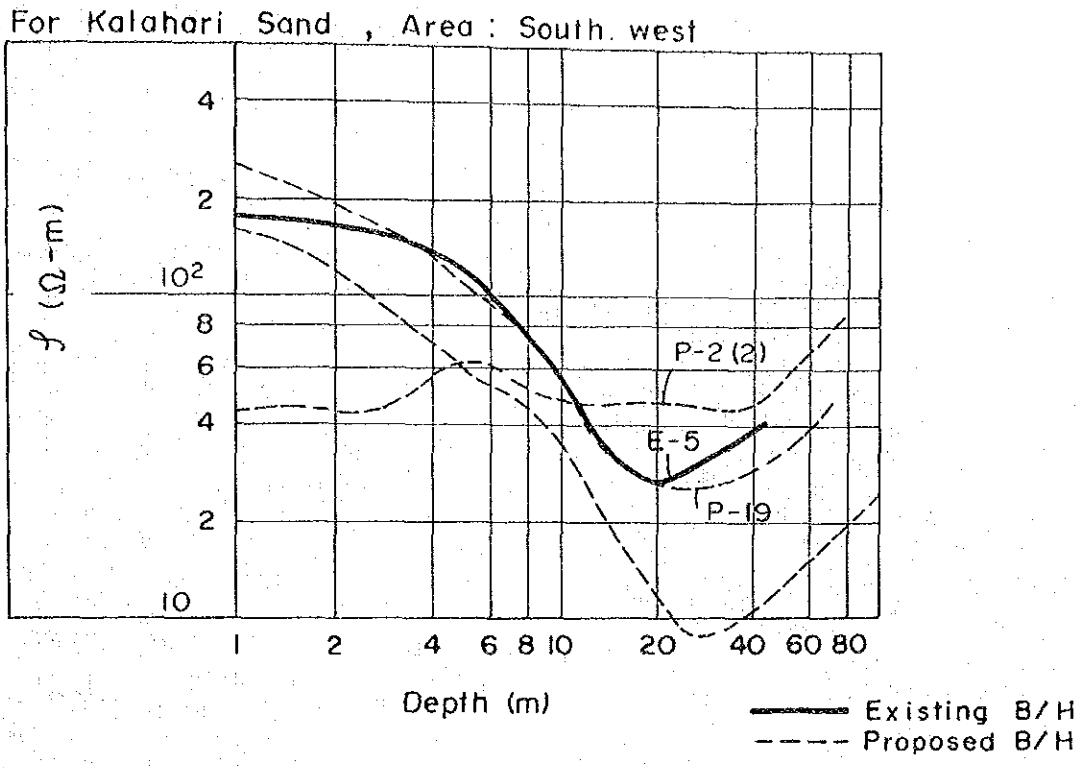
Table 3-3-2. Data on Boreholes on Which was Performed GEP, in Gokwe Area

(Provincial office: 1959 - 1984)

GEP NO.	B/H No.[1]	Geology	EL. (m)	B/H Depth (m)	Yield (l/sec)	Rest Level (m)
E-1	N/D[2]	Sandstone	1,140	-	-	-
E-2	V-2348	Mudstone	795	51	0.38	50
E-3	ND-3	Sandstone	820	81	0.25	29
E-4	V-1903	Basalt	1,200	27	1.88	12
E-5	V-3125	Sand	1,140	52	0.60	46
E-7	V-1691	Sandstone	1,180	78	1.27	52
E-8	N/D	Gneiss	1,060	-	-	-
E-9	V-1321	Sandstone	880	76	1.18	53
E-12	N/D	Sandstone	1,120	-	-	-
E-13	N/D	Sandstone	1,170	-	-	-
E-14	V-1577	Sand	1,260	142	0.15	59
Average				72	0.82	43

Note; 1) Borehole Number in the Record kept by Provincial office of MEWRD.

2) No Data



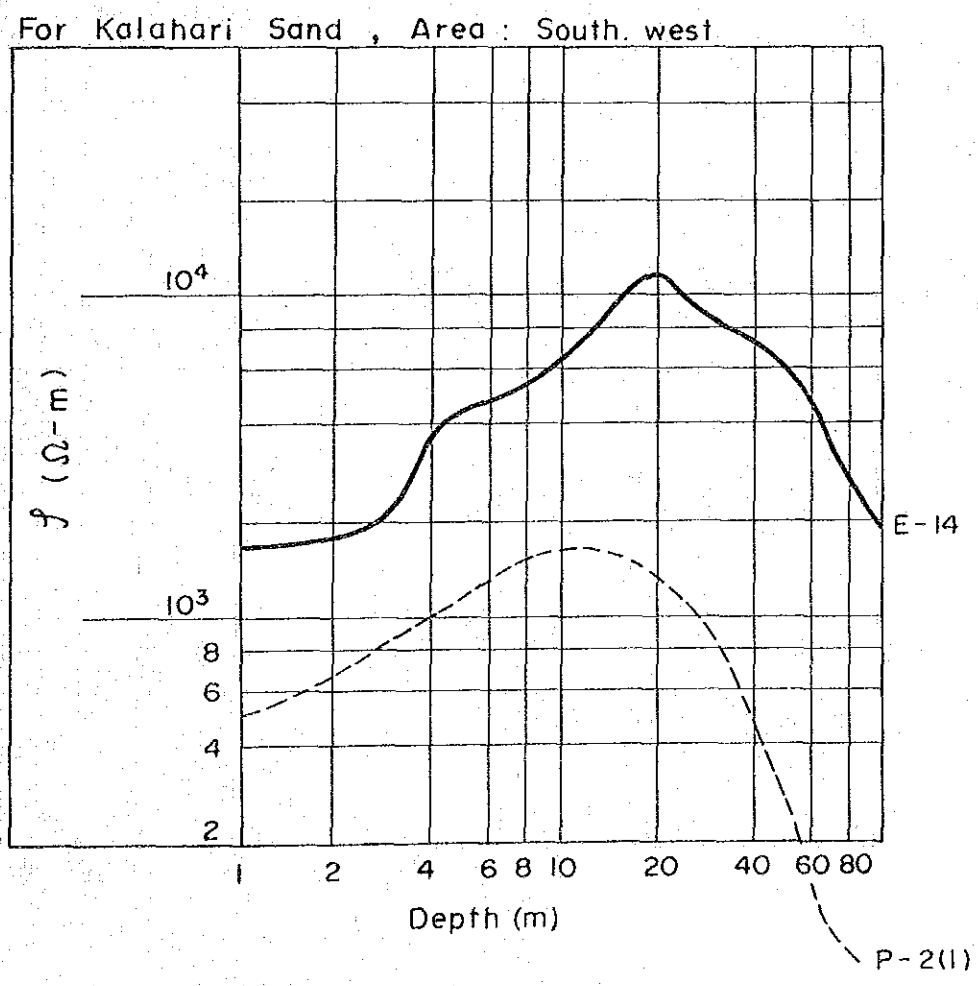
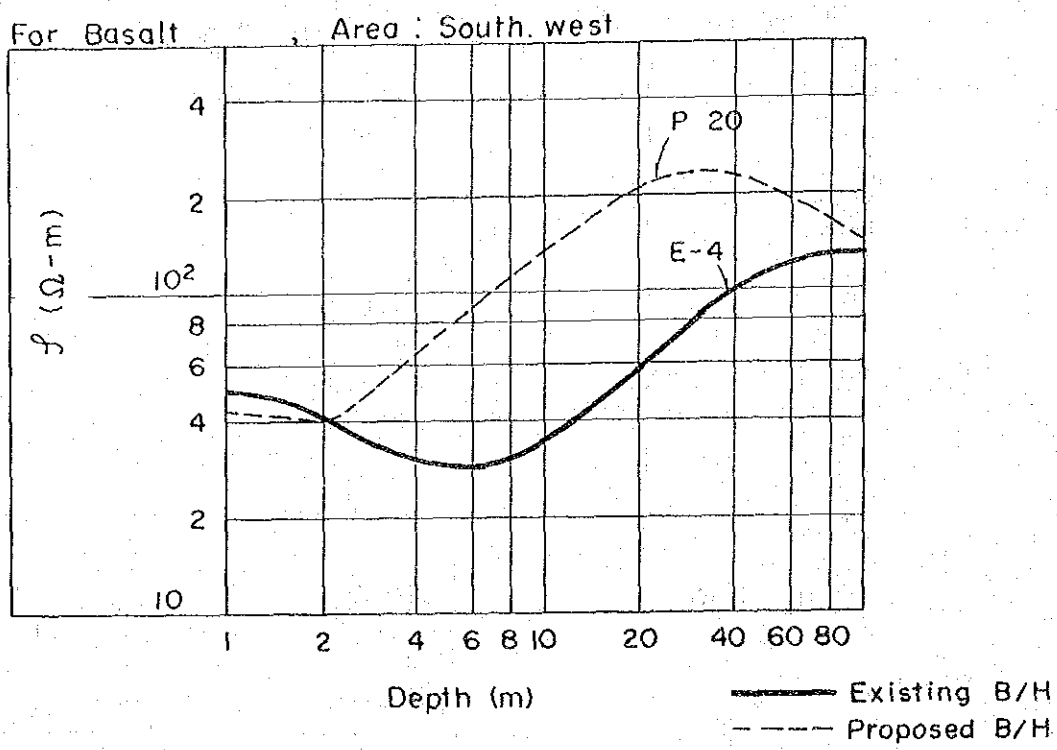


Fig. 3-3-2 (1) ρ-a Curves of GEP.



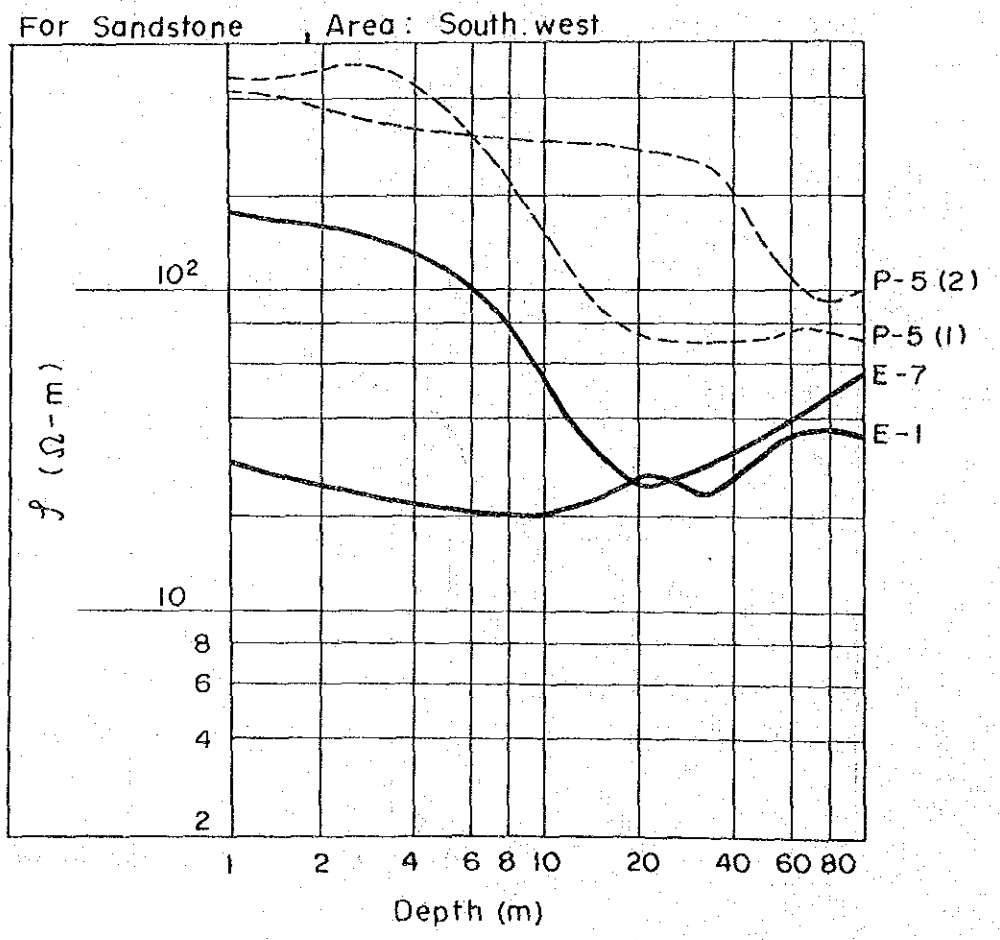
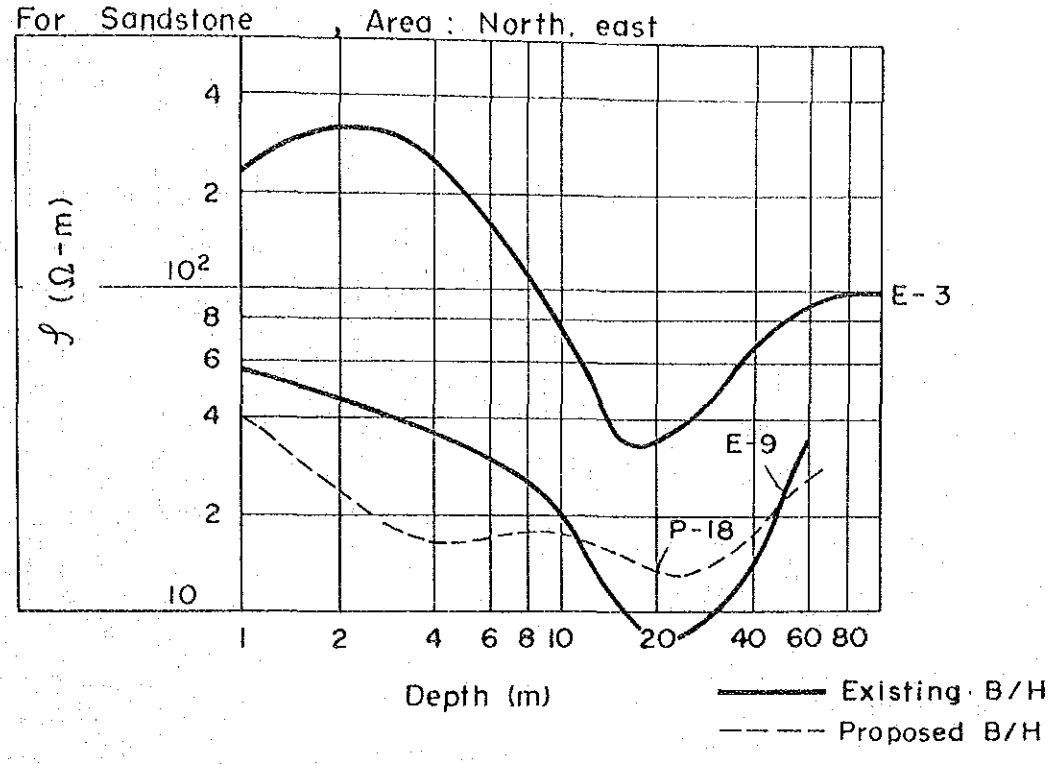


Fig. 3-3-2 (2) ρ-a Curves of GEP.



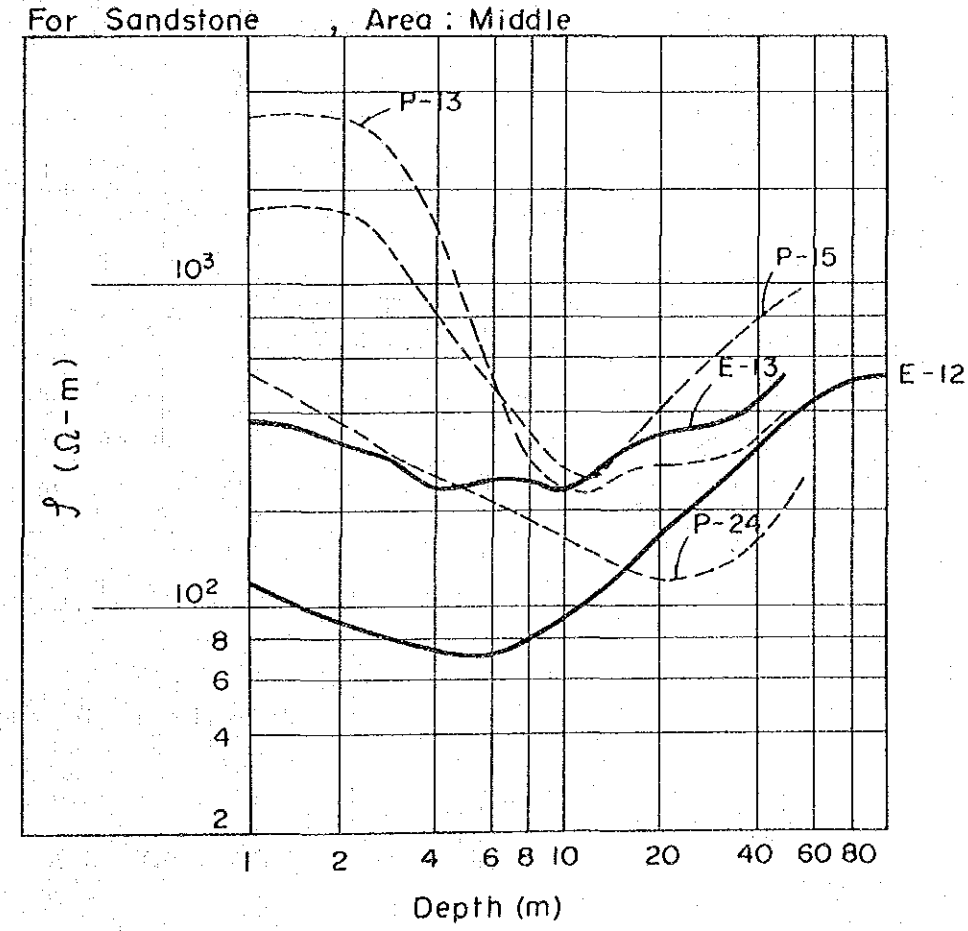
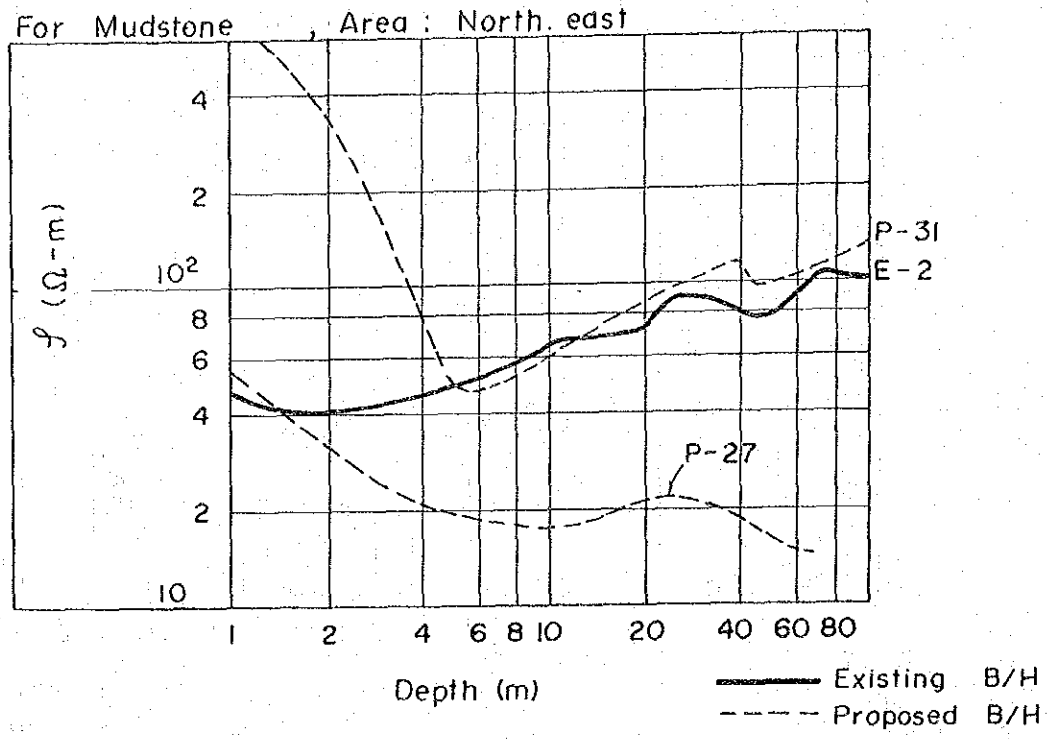


Fig.3-3-2 (3) ρ-a Curves of GEP.



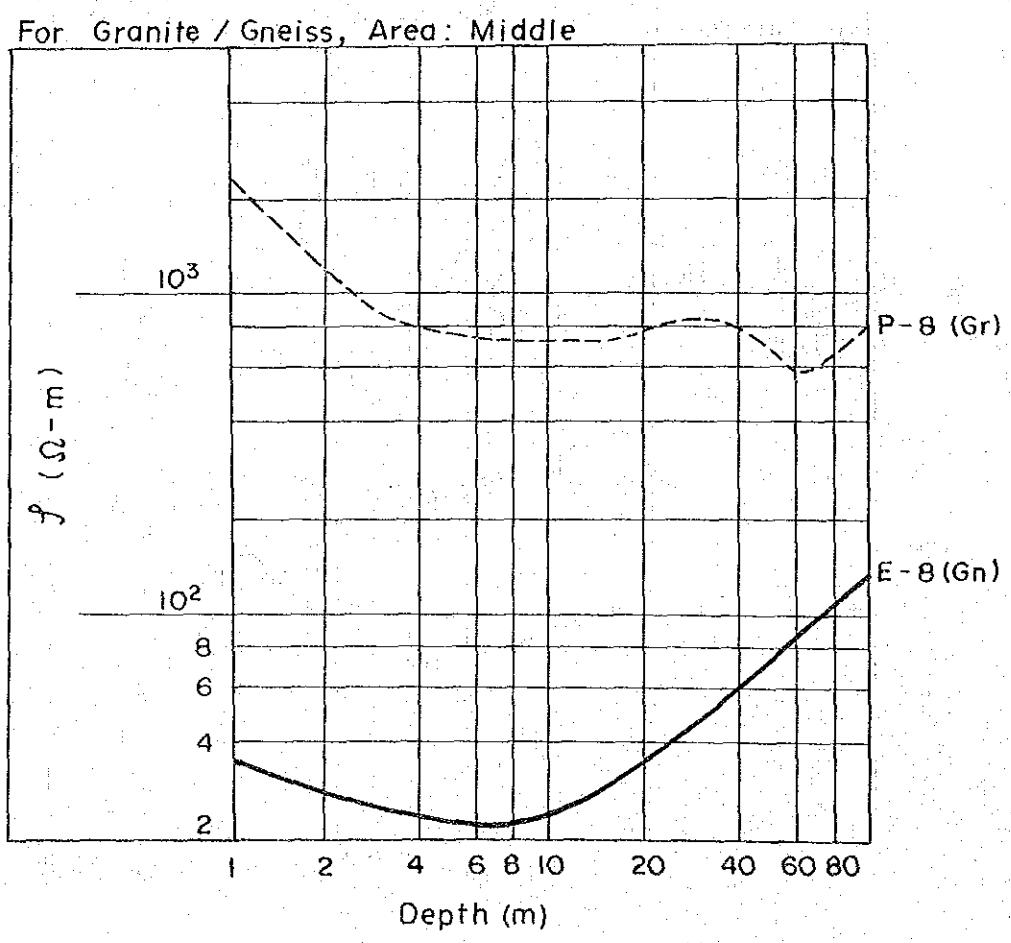


Fig.3-3-2 (4) ρ-a Curves of GEP

3-4. Data on Existing Boreholes

There are over 600 boreholes in Gokwe. The record of about 330 boreholes are kept at the Provincial Office of MEWRD; however, there is no record of the location of 45 of these boreholes. Therefore, the total number of boreholes of which the location is clear and data are available is 285. The borehole data are summarized in Tables 3-4-1 and 3-4-2 by borehole depth (under 100 m and over/equal to 100 m, and rest level) and yield. These tables point out the following:

(1) Borehole Depth

Boreholes in Gokwe are generally deep, and the ratio of those under 50 m in depth is only 20 percent. A location map of deep boreholes (over or equal to 100 m) is given in Fig. 3-4-1. This figure shows that deep boreholes are distributed in hilly lands with 1,000-1,200 m elevation located in the western part of Gokwe which is geologically composed of Kalahari sands, and in flat lands with 800-900 m elevation which are composed of sandstone/mudstone.

The reason for the deepness of boreholes is considered as follows. In the southwest hilly land the aquifer of Upper Sandstone is deep with deep rest water levels, and in the northeast part, Lower Sandstone located below Mudstone is targeted for development. Among the deep boreholes, boreholes in sandstone are deepest with a depth of 166 m on an average, and 27 percent of them have a depth of over 200 m.

There are no boreholes with a depth of over 100 m in Basement Complex. Groundwater development for Basement Complex is only targeted in weathered zones or fissured zones within a depth of 100 m.

(2) Rest Level

The rest levels of existing boreholes are generally deep, and 23 percent of them have rest levels of over 60 m which are considered a limitation in pumping by usual hand pump. The rest levels are shown in Fig. 3-4-2. However, no boreholes having a rest level higher than 60 m are found in the hilly land located in the southwest part of Gokwe where the elevation is higher than 1,000 m.

The number of deep boreholes which have a depth of over 100 m and rest levels deeper than 60 m is 19 holes (27.9%) out of 68 holes. And the average rest level of shallow boreholes (under 100 m in depth) is 32 m. On the other hand, the average rest level of deep boreholes is 82 m, but that of boreholes located in the mudstone area of the northeast area is higher than others, showing 46 m. This fact might suggest the existence of confined aquifer below mudstone. In order to access the confined aquifer, it is necessary to penetrate thick mudstone, but there is an example which resulted in the dry hole with a depth of 283 m.

(3) Yield

The ratio of dry holes out of the total number of boreholes is 9.3 percent with 8 in sandstone, 16 in mudstone, 2 in basalt and 1 in basement complex. This ratio is calculated based on borehole records which are kept by the Provincial Office. And in consideration of the following factors, the dry hole ratio of the area might increase in the future.

- Normally the records of dry holes are apt to be discarded and sometimes missing from the office while those of successful holes are kept by the office.

- Borehole development is usually commenced from easy sites while leaving difficult sites. Therefore, it becomes increasingly difficult to find favorable sites.

The relationship between depth and yield of deep boreholes (over or equal to 100 m depth) is given in Table 3-4-2.

Out of sixty-eight boreholes there are totally 12 boreholes which are deeper than or equal to 200 m in depth with an average depth of 215.0 m. Four boreholes of 12 have no location data. Four boreholes among 12 are dry and two boreholes have a yield less than 15 l/min (0.25 l/sec). This fact shows that deep borehole development is difficult. And it may be necessary to drill deeper boreholes (about 250-300 m or more) to develop groundwater contained in the Lower sandstone located below mudstone.

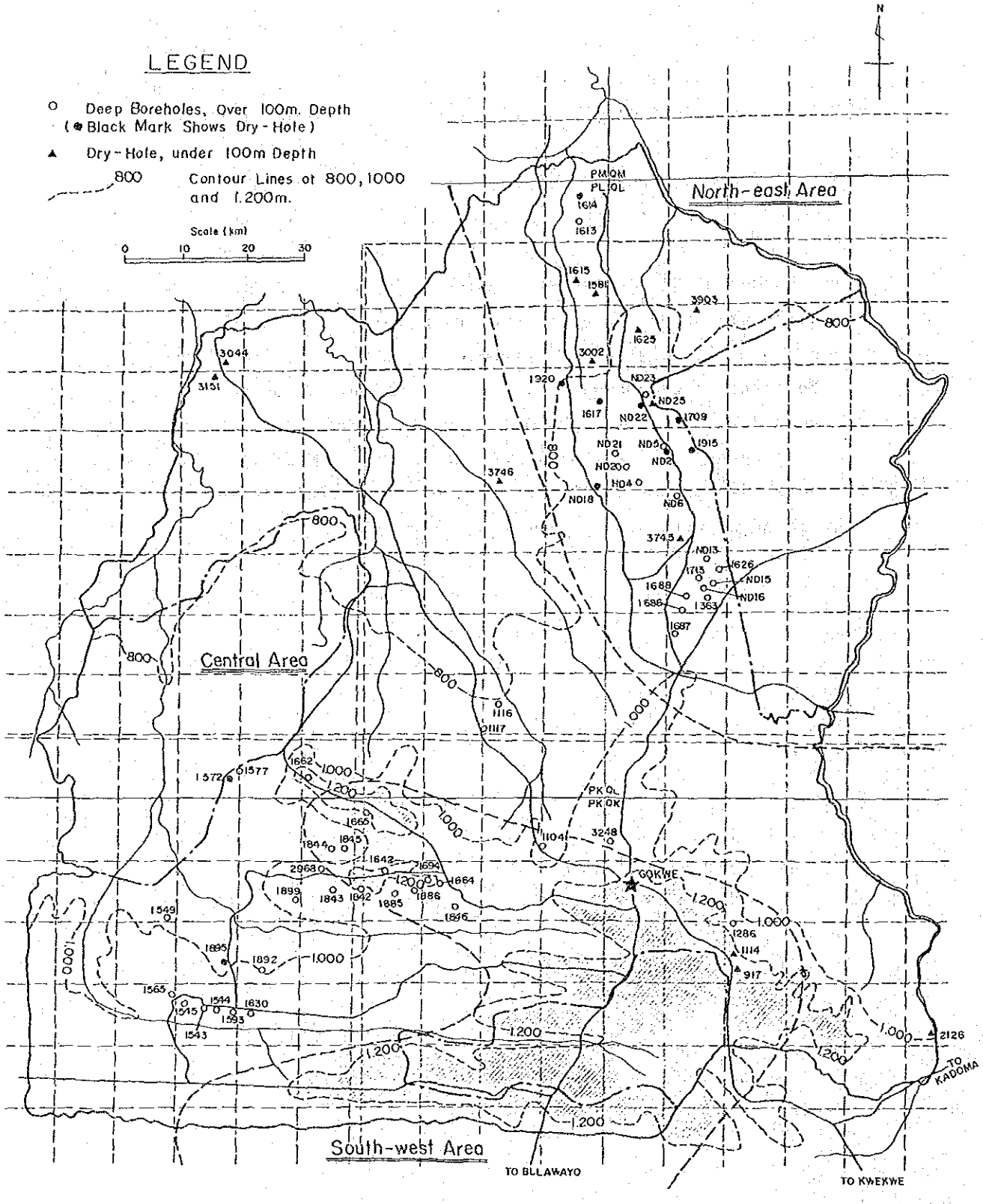


Fig. 3-4-1 LOCATION MAP OF EXISTING DEEP BOREHOLES IN GOKWE

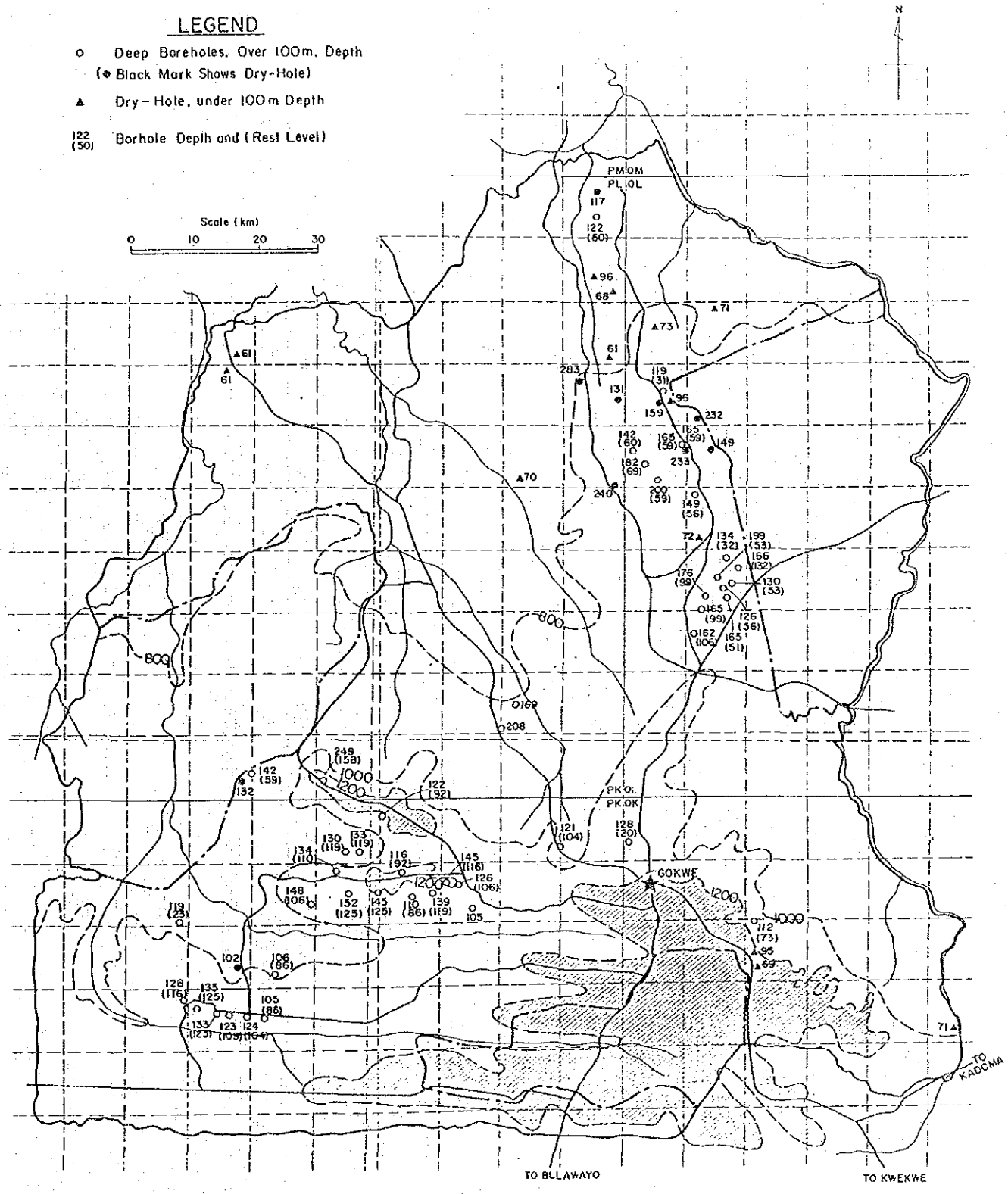


Fig. 3-4-2 BOREHOLE DEPTH AND REST LEVEL OF DEEP BOREHOLES IN GOKWE

Table 3-4-1. Summary of Existing Borehole Data in Gokwe
(for shallow B/H, under/100 m depth)

Area		Southwest		Central					Northeast	
Geology		Ka	SS	Ka	Ba	SS	MS	Base	SS	MS
	Total No.	18 (100%)	52 (100%)	4 (100%)	17 (100%)	19 (100%)	22 (100%)	2 (100%)	33 (100%)	54 (100%)
Yield (l/min)	Dry	0	0	0	2 (12)	5 (26)	2 (9)	1 (50)	0	7 (13)
	- 15	1 (6)	5 (10)	0	1 (6)	3 (16)	6 (27)	0	3 (9)	10 (19)
	16 - 50	3 (17)	17 (33)	4 (100)	4 (24)	4 (21)	4 (18)	1 (50)	18 (55)	14 (26)
	51 -	14 (77)	30 (57)	0	10 (58)	7 (37)	10 (46)	0	12 (36)	23 (42)
	Mean	85	63	33	58	48	58	24	48	49
Depth (m)	0 - 50	4 (22)	12 (23)	2 (50)	10 (59)	3 (16)	12 (55)	0	4 (12)	9 (17)
	51 - 99	14 (78)	40 (77)	2 (50)	7 (41)	16 (84)	10 (45)	2 (100)	29 (88)	45 (83)
	Mean	68	64	45	52	69	48	65	73	67
Rest Level (m)	0 - 40	8 (50)	35 (69)	1 (50)	8 (80)	6 (55)	20 (100)	0	13 (46)	32 (70)
	41 - 60	7 (44)	12 (23)	1 (50)	1 (10)	4 (36)	0	1	10 (36)	11 (24)
	61 - 99	1 (6)	4 (8)	0	1 (10)	1 (9)	0	0	5 (18)	3 (6)
	Dry	0	0	0	2	5	2	1	0	7
	No data	2	1	2	5	3	0	0	5	1
	Mean	39	34	29	23	40	13	32	44	33

Note: Ka-Kalahari Sands, SS-Sandstone, Ba-Basalt, MS-Mudstone, Base-Basement Complex.

Table 3-4-2. Summary of Existing Boreholes Data in Gokwe
(for deep B/H, over/equal 100 m depth)

Area		South-west		Central		North-east		
Geology		Ka	SS	Ba	SS	Ba	SS	MS
	Total No.	14 (100%)	11 (100%)	3 (100%)	3 (100%)	1 (100%)	21 (100%)	15 (100%)
Yield (l/min)	Dry	0	1 (9)	0	1	0	1 (5)	7 (47)
	- 15	1 (7)	2 (18)	1	1	0	5 (24)	3 (20)
	16 - 50	7 (50)	2 (18)	1	1	0	13 (62)	4 (27)
	51 -	6 (43)	6 (55)	1	0	1	2 (9)	1 (6)
	Mean	47	51	94	23	(90)	32	24
Depth (m)	100 - 150	11 (79)	11 (100)	3 (100)	1	1	8 (38)	8 (53)
	- 200	3 (21)	0	0	1	0	10 (48)	3 (20)
	- 250	0	0	0	1	0	3 (14)	3 (20)
	- 300	0	0	0	0	0	0	1 (7)
	Mean	132	131	120	159	(139)	166	166
Rest Level (m)	0 - 40	0	1 (9)	1	0	0	1 (5)	4 (50)
	41 - 60	0	1 (9)	0	1	0	7 (35)	3 (38)
	61 - 100	4 (29)	2 (18)	1	0	0	8 (40)	1 (12)
	100 -	10 (71)	6 (64)	1	0	1	4 (20)	0
	Dry	0	6	0	1	0	1	7
	No data	0	0	0	1	0	0	0
	Mean	112	94	66	51	(125)	80	46

Note; Ka-Kalahari Sands, SS-Sandstone, Ba-Basalt, MS-Mudstone.

3-5. Water Quality Tests of Existing Boreholes

Some simplified water quality tests were carried out at the existing boreholes along with GEP survey. Test items were as follows:

i) Temperature (°C)
ii) Electric conductivity (s/cm)
iii) pH
iv) Total coliform (by testing paper)
v) Microorganisms (by testing paper)
vi) Appearance, odour, taste (by human observation)
vii) Fluoride (F; by ion selective pack test)
viii) Nitrate (No_3; by ion selective pack test)
ix) Total Residue

The representative samples were selected and tested in consideration of the conditions of land height, geology, location, etc., to which the samples belonged. The total number of samples is twelve as follows, and test results are given in Table 3-5-2.

Table 3-5-1. List of Test Samples

No.	Location	Grid Ref.	Geology	Elevation (m)
1	Gawa Clinic	PK 842806	Sandstone	1,140
2	Mvumvudzi Sch.	QL 064700	Mudstone	795
3	Rupenyu Clinic	QL 079597	Sandstone	820
4	Miti Village	QK 043916	Basalt	1,200
5	Mkoka Sch.	PK 365500	Sands	1,140
6	Mawisa Sch.	PK 527652	Sands	1,170
7	Manyoni Sch.	PK 684933	Sandstone	1,180
8	Blue Gum Dip	QK 522620	Gneiss	1,060
9	Nhau Village	QL 227223	Sandstone	880
10	Magwazani Village	QK 461568	Granite	1,060
11	Gwurawakanya Sch.	QL 013252	Sandstone	840
12	Gawa Sch.	PK 735724	Sandstone	1,120

The test results are summarized as follows on the basis of the guidelines shown in the Master Plan Report in Zimbabwe, which conform approximately to the WHO's guidelines of Highest Desirable Level.

Table 3-5-2. Results of Water Quality Tests in Gokwe

No.	1	2	3	4	5	6	7	8	9	10	11	12
Temp. °C	25.1	27.9	27.1	23.0	26.0	24.3	23.8	22.5	25.6	25.8	26.5	26.1
Ec (s/cm)	660	1,020	300	530	790	610	130	1,080	860	760	1,630	702
pH	7.0	7.1	7.4	7.2	7.4	6.8	6.9	7.0	7.3	7.4	8.7	7.6
Coliforms	2	0	0	35	0	1	0	10	3	0	0	0
M-Organ	0	1	0	1	0	0	0	0	0	0	0	0
Colour	Brown	Nil	Pale Yell.	Nil	Nil	Nil	Pale Yell.	Pale Yell.	Pale Yell.	Nil	Nil	Nil
Odour	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Taste	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Salty	Good
Residue	390	-	2,250	Nil	Nil	Nil	Nil	Nil	530	Nil	Nil	Nil
* F	0	0	0	0	0	2.5	0	0	0	0	-	-
* No_3	0	7.5	0	0	2.0	0	0	15.0	0	3.5	-	-

Note; F and No_3 were tested in Japan by the Simplified Method using Testing Pack.
(Unit: PPM)

Table 3-5-3. Test Results Comparison between Guidelines of Zimbabwe and WHO

Items	Test Results	Guidelines of Zimbabwe	Guidelines of WHO *1
Ec (S/cm)	130 - 1,630	-	-
pH	6.8 - 8.7	6.5 - 8.5	6.5 - 9.2
F (ppm)	0 - 2.5	3.0	-
NO_3 (ppm)	2.0 - 15.0	10	45
Residue (ppm)	0 - 2,250		1,000

Note: Maximum Permissible Level (MPL)

- pH value of E-11 shows 8.7, and exceeds Zimbabwean guidelines, but satisfies WHO's MPL.

- NO_3 value of E-8 shows 15 ppm, but it satisfied WHO's MPL.

- Coliforms were found in samples E-1, E-4, E-6, E-8 and E-9, and E-4 has the highest number of 35. The existence of coliforms suggests that borehole water is contaminated by surface water, and those holes should be protected by grout seals as much as possible.

- These samples have residues reaching a value of 2,250 at the highest. It can be said that more careful attention should be paid to filter material before casing installation, or casing with selected filter materials should be installed so as to prevent the intrusion of silty materials.

3-6. Synthetic Analysis of Hydrogeology

3-6-1. Hydrogeological Maps

Hydrogeological maps of Gokwe area have been prepared by the team by amending the existing geological and hydrogeological maps based on the study results, field survey, GEP and analysis of borehole data. These maps are shown in Fig. 3-6-1, 3-6-2 and 3-6-3.

The matters mentioned from section 3-2 and the hydrogeological maps have been examined and analysed. Analysed hydrogeological results of Gokwe area are as follows:

3-6-2. Description of Each Type of Hydrogeology

Each hydrogeological unit is shown below.

(1) Kalahari Sands

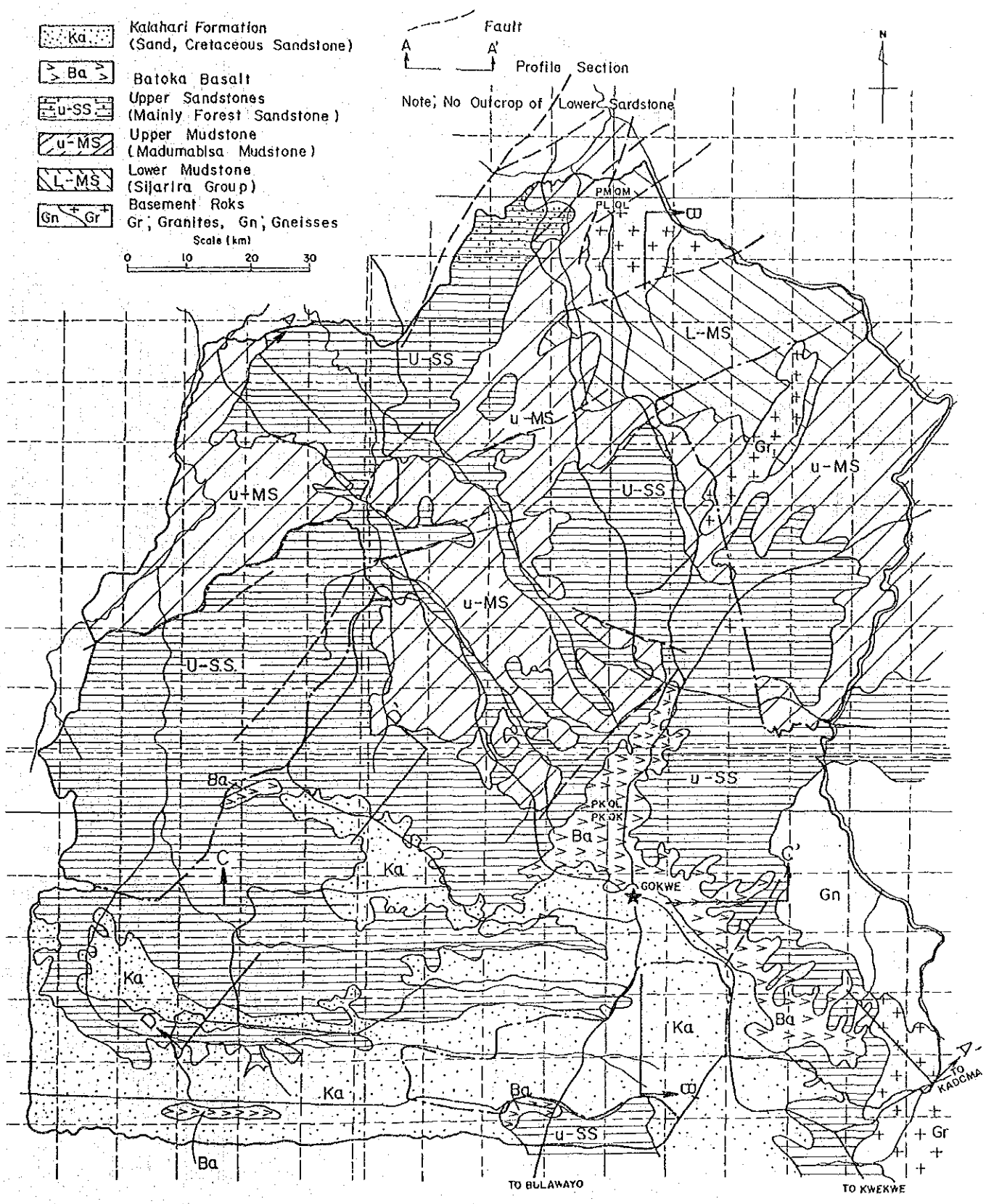
Kalahari Sands partially include sandstone which is distributed in hilly highland, and this formation requires deep borehole drilling due to its deep rest level.

(2) Basalt

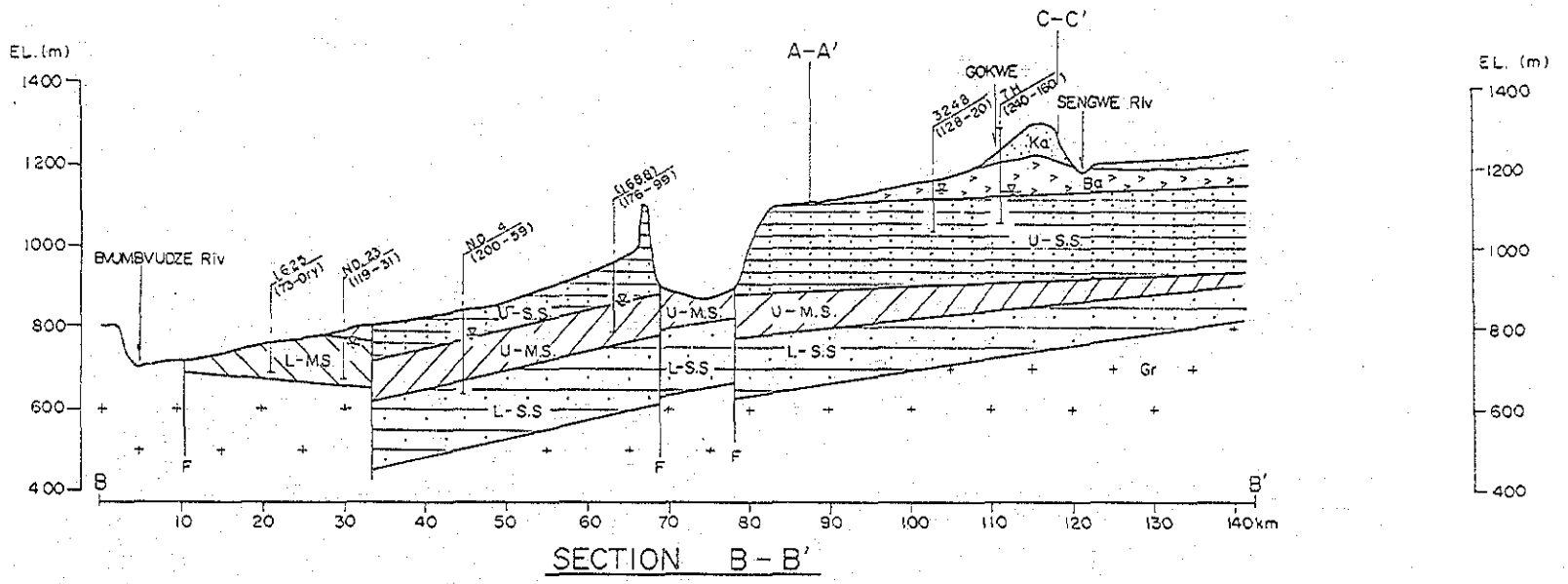
The basalt is also distributed in hilly highlands. The aquifer of the basalt is locally developed. So, the basalt boreholes result in dry holes in some cases and sometimes have a low rest level deeper than 60 m.

(3) Upper Sandstone

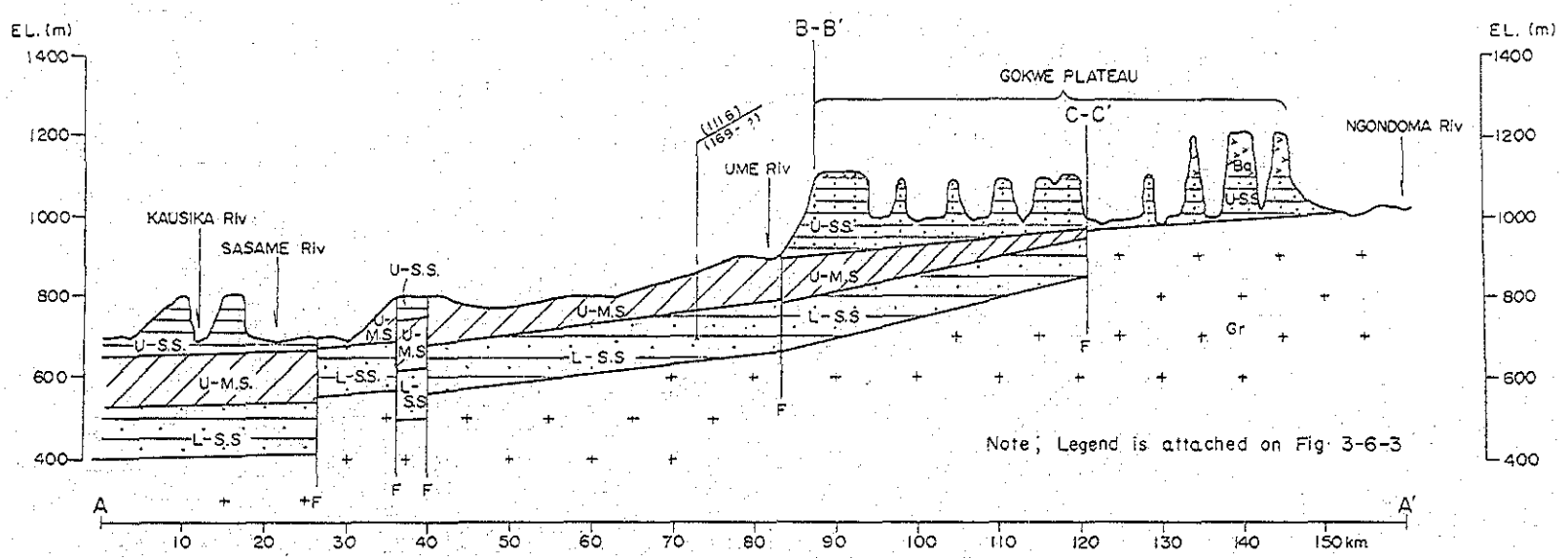
The Upper Sandstone is widely distributed in Gokwe except for in the mudstone areas. This formation needs deep drilling in many



Fig·3-6-1 HYDROGEOLOGICAL MAP OF GOKWE

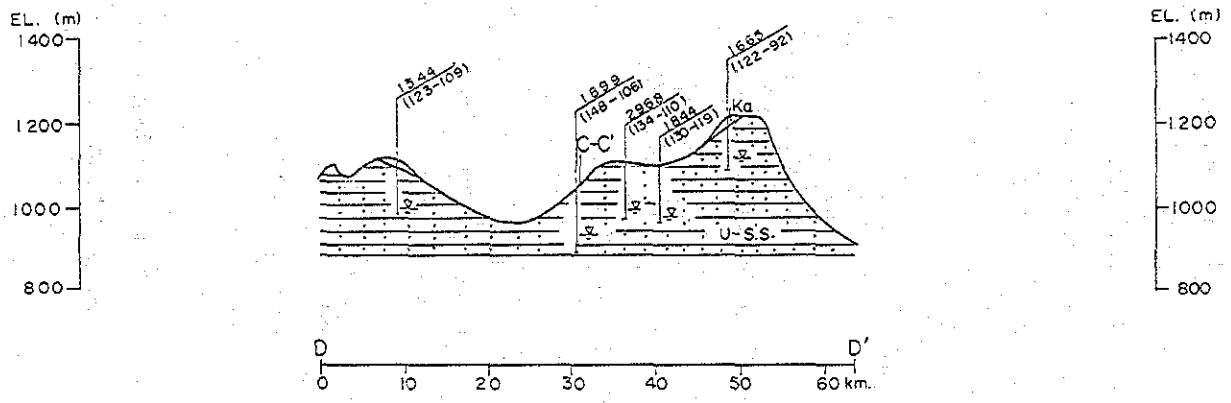


SECTION B - B'

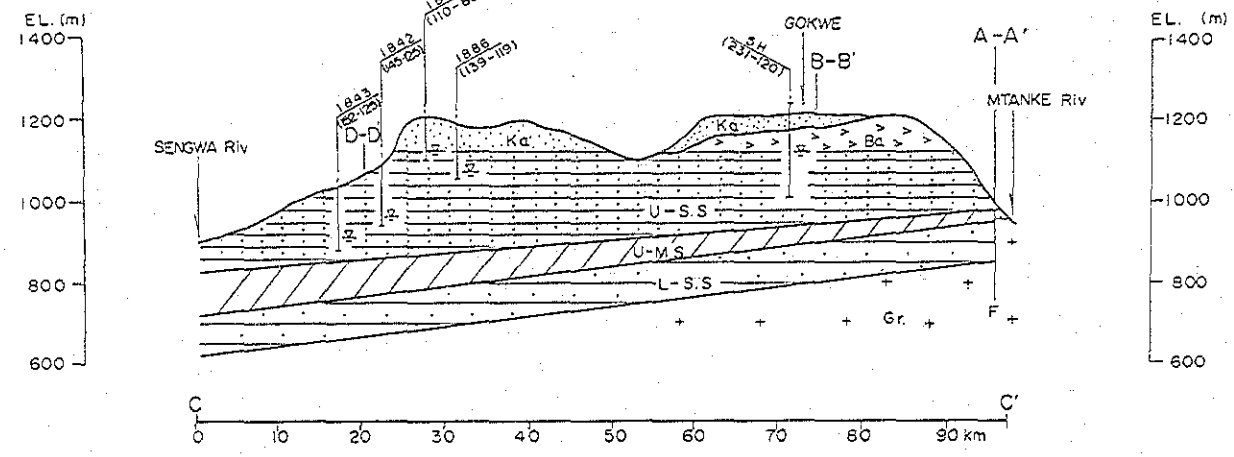


SECTION A - A'

Fig. 3-6-2 HYDROGEOLOGICAL PROFILES



SECTION D – D'



SECTION C – C'

LEGEND

- Ka — Kalahari, Formation (Local Aquifer)
- Ba — Batoka Basalt (Local Aquifer)
- u-S.S — Upper Sandstones (Local Aquifer)
- u-M.S — Upper Mudstone (Confining Layer)
- L-S.S — Lower Sandstone (Regional Aquifer)
- L-M.S — Lower Mudstone (Confining Layer)
- Gr — Basement Rocks (Undifferentiated)
- F ; Assumed Fault

Fig. 3-6-3 HYDROGEOLOGICAL PROFILES

cases due to the deep location of a good aquifer in its formation, and rest levels have a tendency to be deeping as the aquifer is deeper. (See. Fig. 3-6-3) A shallow aquifer is also available. Totally 140 boreholes less than 100 m deep are located in the area. 16 boreholes out of the 140 have yields of less than 15 l/min (0.25 l/sec). A zone having less than 100 ohm-m should be surveyed by GEP for groundwater development.

(4) Upper/Lower Mudstone

These formations can be said unsuitable for groundwater development, since they form a few aquifers, having poor water quality. There are 76 boreholes whose depth is less than 100 m. 25 borehole (33%) among them have yields less than 15 l/min (0.25 l/sec). And there are 15 boreholes whose depth is over or equal to 100 m. 10 boreholes out of 15 have yields less than 15 l/min (0.25 l/sec). The reasons for the above low success rate might be derived from the two cases mentioned below.

i) Drilling work was not completed, and abandoned because no drilling rigs which could penetrate mudstone formations were available.

ii) In the area groundwater development was difficult to begin with, as shown in the case of the 283 m deep dry hole.

(5) Lower Sandstone

This formation forms a regional aquifer. It might be pointed out that the following three boreholes have been drilled in this sandstone.

- ND-20: Depth = 182 m, R.L. = 69.0 m, Yield = 69 l/min (1.15 l/sec)
- ND-4: Depth = 200 m, R.L. = 59.0 m, Yield = 38 l/min (0.63 l/sec)
- No. 1116: Depth = 169 m, R.L. = unknown, Yield = 29 l/min (0.48 l/sec)

Note: R.L. means Rest Level.

From the results of GEP at ND-4 and ND-20, it could be said that the formation forms confined aquifers and if drilling depths were deeper, it could result in higher rest levels.

(6) Basement Complex

This complex forms aquifers in weathered or fissured zones and generally gives a borehole depth ranging between 50 - 70 m. The area of the Phase 1 Project is composed of basement complex in almost the whole area, and the average borehole depth drilled in the Phase 1 area was slightly less than 50 m. It may be considered that a necessary condition for a good aquifer is a sequence of low apparent resistivity which reaches 30 m in depth or deeper.

3-6-3. Location of Existing Deep Boreholes

The existing deep boreholes are concentrated in the following two areas, as shown in Fig. 3-4-1.

(1) Northeast Area

This area is composed of Upper/Lower Mudstones and Upper Sandstone. The mudstone formations have a high rate of dry holes and are generally poor in both quantity and quality of water other than boreholes which reach/insert into sandstone located below

mudstone. The borehole ND-4 shown in Section "B-B'" is 200 m in depth, and it can be judged that ND-4 is intruding into the sandstone and receiving a confined rest level of 59 m.

About 40 percent of the deep boreholes constructed in Upper Sandstone have rest levels of nearly 100 m. However, it can be said that deep zones of Upper Sandstone form good aquifers with a high success probability, as explained by the fact that no dry holes exist. It is, however, a big problem to use a hand pump for rural water supply due to excessively deep rest levels.

(2) Southwest Hilly Area

This area consists of Kalahari Sands and Batoka Basalt with a land elevation of 1,000 - 1,200 m.

The dry hole rate is low, but all the rest levels of deep boreholes are deeper than 60 m. Therefore, it is difficult to withdraw water by usual hand pump in this area.

3-6-4. Hydrogeological Subareas in Gokwe

The hydrogeological conditions in Gokwe District can be divided into the following three subareas from the view points of the composing geology and the results of groundwater development to date. Each area is shown in Fig. 3-4-1.

(1) Southwest; This area consists of Kalahari Sands to Upper Sandstone and forms a highland 1,000-1,200 m in elevation. The groundwater development of shallow aquifers within a depth of 100 m is possible although deep boreholes with a depth of 100 - 200 m shall be constructed in case a big yield is required for water supply to a large population. However,the rest level of deep boreholes is usually deeper

than 60 m, and it is difficult to pump up water by man power without an engine pump.

(2) Central; This is composed of areas other than the southwest and northeast regions. Upper Sandstone and partially Basalt or Mudstone are predominant in this area. The development of deep boreholes to date is limited here. Deep boreholes are only six out of 70 existing boreholes, and the low success rate of drilling in Sandstone and Mudstone area shall be pointed out.

(3) Northeast; This area is mainly composed of Mudstone and deep drilling to a depth over 100 m has been done due to the fact that there are few effective aquifers in Mudstone. Besides, there are 21 (40%) deep boreholes out of the 54 existing boreholes in Upper Sandstone area. It can be said that success rate of existing boreholes, that is, 90% in Sandstone and at a little less than 70% in Mudstone, will go down in the future due to the decrease in suitable sites for development.

3-6-5. Analysis of Existing Borehole Data

Analitical results of the existing borehole data are shown in section 3-4, and summarized as follows:

(1) Borehole Depth

The deep boreholes in Gokwe are remarkably distributed in the southwest and northeast parts. The reason for deep boreholes is considered that in the southwest part the aquifer of Upper sandstone is deep with deep rest water levels and in the northeast part Lower sandstone located below Mudstone is the target of drilling.

(2) Rest Level

The rest levels of existing boreholes are generally deep, and deep boreholes located in the southwest part of Gokwe have rest levels deeper than 60 m from ground surface. The rest levels of deep boreholes located in the northeast part suggest that the confined aquifer exist. There are totally 12 boreholes having rest levels of above 60 m in depth out of 20 located in sandstone areas. However, seven boreholes out of eight located in mudstone areas have rest levels of above 60 m in depth.

(3) Yield

The ratio of boreholes which have yields of 1.0 cum/hr is a little less than 10 percent. The yield of shallow boreholes in the central and the northeast parts is smaller than 1.0 cum/hr with a rate over 30 percent. The yield of deep boreholes in the areas other than Karahali area is smaller than 1.0 cum/hr with a rate over 30 percent, and specially, in the northeast area the rate of the above reaches 67 percent. Therefore, careful investigations shall be conducted for groundwater development constructing deep boreholes in mudstone areas.

3-6-6. Attentions to be paid in Groundwater Development

For groundwater development for rural water supply in Gokwe District, attentions shall be paid to the following points:

(1) Southwest Area:

The shallow boreholes less than 100 m in depth will be mainly developed. In this case, drilling shall be made to

small aquifers locally distributed in this area. Careful siting will be, therefore, required.

The deep boreholes will be constructed for water supply to a large population. As the rest levels of them are deep, it should premise that they will be equipped with engine pumps.

(2) Central Area:

For lifting groundwater by hand pumps, shallow boreholes will be constructed in this area. It can be said that the development of groundwater in shallow aquifers located in sandstone and mudstone layers is considerably risky. To increase the success rate, the following measures can be considered:

° Penetrating the weathered zone, the aquifers of the fissured zone will be developed in fresh sandstone.

° In the mudstone area, the aquifers of sandstone located below the mudstone will be developed.

(3) Northeast Area:

The area is mainly composed of mudstone. The groundwater development in the area will be shifted to deep boreholes from shallow ones because suitable sites to develop shallow aquifers are a few. It is considered that the geological structures in the area are complicated as many faults exist. Even if the siting is carefully made, it would not be easy to attain a high success rate in the area since the area is broad and the vegetation prevails in the area. From the view point of economic efficiency,

it is recommended that one deep borehole equipped with engine pump will be constructed for each of one to three villages.

CHAPTER 4. OUTLINE OF THE PROJECT

4-1. Objectives of the Project

The objectives of the Project are to supply safe drinking water to those people who have no adequate water supply facility, to stabilize and improve their lives, and to contribute to the strengthening of infrastructures for the nationwide economic development.

Improvement of the water supply situations for the people aims at such effects as the suppression of the high occurrence rate of water borne diseases and the reduction of labour force required for fetching water. This is one of the most urgent national policies.

The executing agency, MEWRD, commenced the Master Plan in 1982 and is actively promoting the improvement of the rural water supply. This Project is planned as a part of the national programme.

The Project Area is composed of the following Communal Lands (C. Ls.)

Communal Land	District
Gokwe C.L.	(1) Gokwe District;
Chilimanzi C.L.	(2) Mvuma District;
Shurugwi C.L.	(3) Shurugwi District;
Runde and Mazvihwa C.L.	(4) Zvishavane District;
Mberengwa C.L.	(5) Mberengwa District;

4-2. Outline of the Project

4-2-1. General

The Project is Phase 2 of the project completed in March, 1985. (Phase 1 Project for "Rural Water Supply Project in Midlands Province"). Gokwe C.L. is newly included in the Project Area.

The number of boreholes to be constructed under the Project is given in Table 4-2-1.

Table 4-2-1. Boreholes to be Constructed under the Project

Communal Land	Population (1985)	Proposed B/H Nos.
Gokwe	254,109	40
Chikimanzi	44,432	11
Shurugwei	43,797	11
Runde & Mazvihwa	61,361	16
Mberengwa	165,332	42
Total	569,021	120

4-2-2. Executing Agency

The executing agency of the Project is MEWRD of the Government of Zimbabwe. MEWRD is responsible for the development of water and energy resources. The Groundwater Branch through the Provincial Offices is responsible for the development of groundwater.

The Provincial Water Engineer assigned to each Provincial Office is responsible for surface/groundwater development and water supply planning, etc. to be executed in the Province.

The organization charts of both Head and Province (Midlands) offices are shown in Fig. 4-2-1 and Fig. 4-2-2, respectively. The MEWRD has more than 80 engineers and about 4,000 staff. The staff numbers of the Groundwater Branch and Midlands Provincial Office are 188 persons and about 480 persons, respectively, as of February 1988.

4-2-3. Outline of the Project

(1) Components of the Project

The Project is composed of the following two major components;

- Procurement of equipment and materials for the above.
- Construction of 120 boreholes equipped with hand pumps.

The construction work will be done by the Zimbabwean side. However, the Japanese side will cooperate with the Zimbabwean side for on-the-job training by dispatching Japanese engineers to Gokwe. And equipment and materials will be procured inclusive of a drilling rig and supporting vehicles for Gokwe and materials for the other areas.

(2) Outline of the Project

The Project outline is summarized as follows;

i) The Project will be a part of the programme to achieve the short-term target (1990) described in the Master Plan Report.

ii) Necessary water supply points (W/P) in the Project Area are 2,250 as shown in Table 2-4-3. A total of 1,500 boreholes are needed out of the above 2,250, which is

Fig. 4-2-1 Organization Chart of MEWRD (as of the end of 1987)

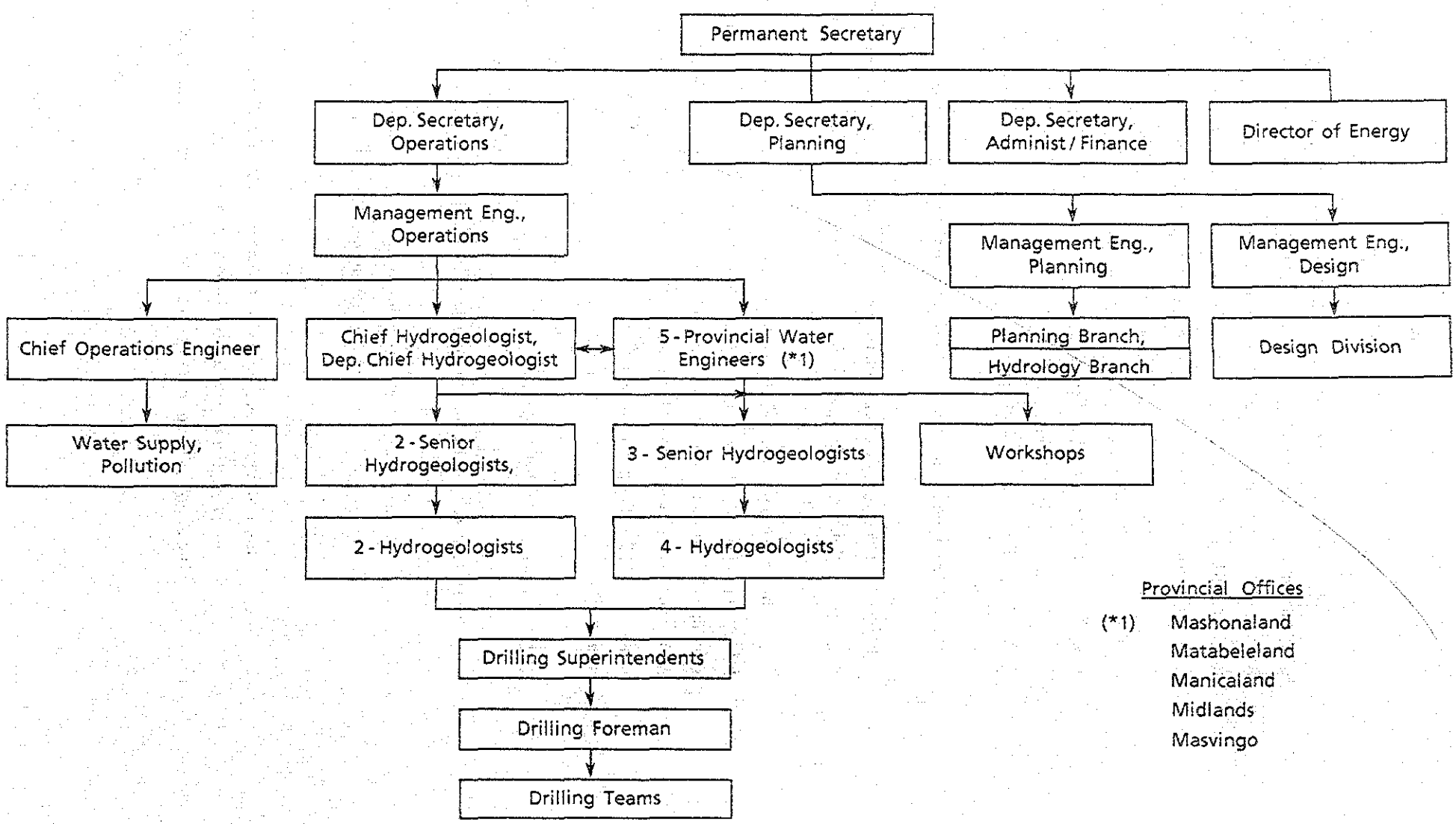
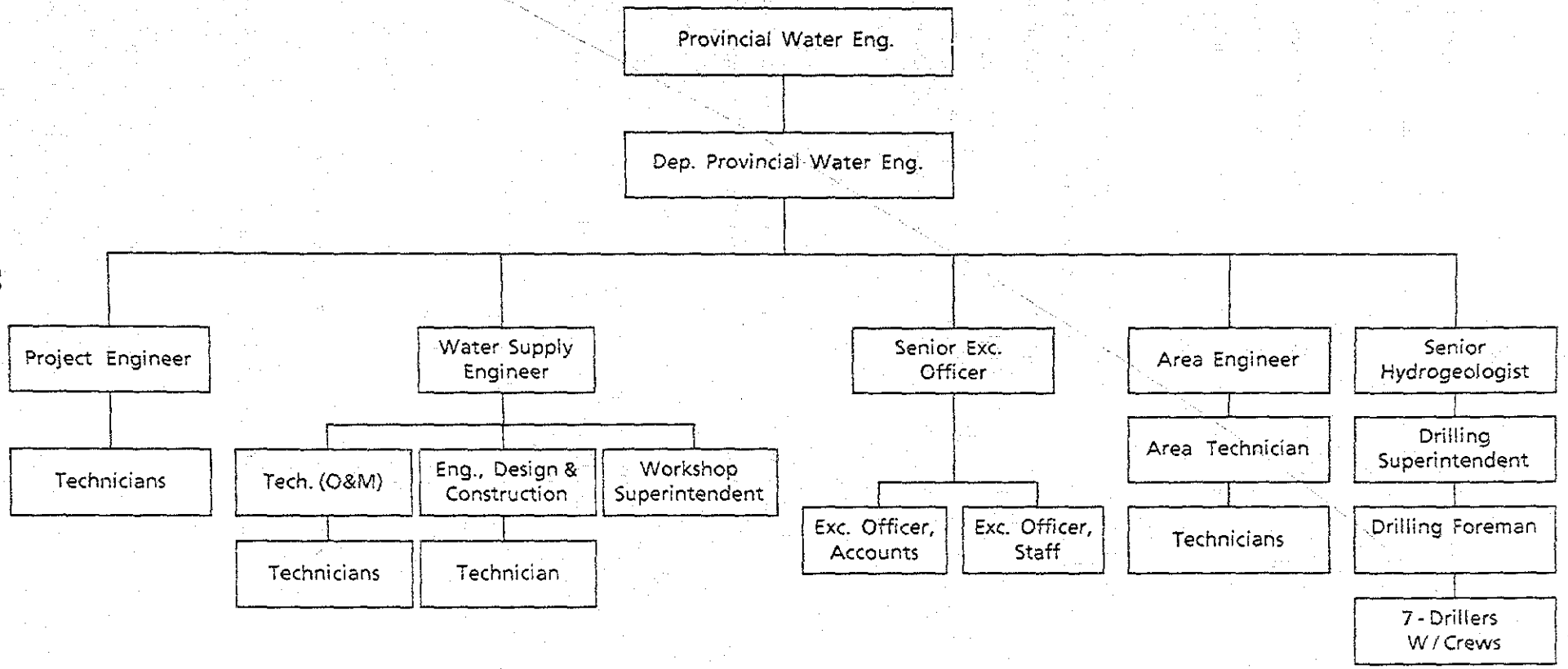


Fig. 4-2-2 Organization Chart of Provincial Water Engineer's Office, Midlands



equivalent to two-thirds. This Project aims to play the role of a bridge stone in implementing the short-term programme by constructing part of the 1,500 boreholes.

iii) Boreholes will be equipped with hand pumps and head works. The borehole diameter will be 100 mm with the exception of 150 mm for a deep borehole which is planned for future operation of an engine pump.

iv) The construction work in Gokwe will be done by the Zimbabwean side using a new rig to be supplied under the Project, in cooperation with Japanese engineers to be dispatched to Zimbabwe.

v) The Project will be executed under Japanese grant aid.

- Gokwe Area

  Supply of equipment consisting of a drilling rig and supporting vehicles and materials necessary for borehole construction.

  Dispatch of Japanese engineers for technical services and/or on-the-job training for construction works.

- Other Areas

  Supply of materials for construction of boreholes by the Zimbabwean side.

4-2-4. Summary of Equipment and Materials

The equipment and materials necessary for the Project

implementation are summarized as follows. And the capacities, specifications, quantities, etc., are examined in CHAPTER 5 "Basic Design".

(1) Equipment

The following types of equipment are necessary for borehole construction,

a) Drilling rig including accessories and tools
b) Supporting vehicles
c) Light vehicles for transportation of materials, equipment and personnel
d) Geophysical survey instrument
e) Borehole test instrument
f) Radio system for communication
g) Mobile workshop
h) Others

(2) Materials

The following materials are necessary for borehole construction

a) Hand pumps
b) Casing pipes
c) Drilling agents
d) Fuel and oil
e) Cement
f) Aggregate
g) Others

CHAPTER 5. BASIC DESIGN

5-1. Design Policy

The basic design of the Project will be conducted in line with the following basic policies and concepts taking into consideration the particular conditions of the country, the Project Area and the system of Japanese grant aid;

(1) To conform to the Phase 1 Project because the Phase 2 Project is the continuation of the Phase 1.

(2) To meet the general criteria and to design economical facilities applicable to the Project Area.

(3) To formulate a construction plan taking into consideration the regional climatic and social conditions (roads, telecommunication, social infrastructure, working habits, etc.)

(4) To select equipment in view of its utilization for further rural water supply projects in Zimbabwe after completion of the Project.

(5) To prepare a rational design taking into account standardization and special conditions of each proposed site with an objective judgement of hydrogeological conditions in Gokwe area.

(6) To provide materials such as casing pipes which are indispensable for implementation of the Project but difficult to secure in Zimbabwe.

(7) To draw up the assignment schedule of Japanese experts for transfer of technical knowledge on equipment maintenance, drilling works, borehole testing and so forth, for further project implementation by the Zimbabwean staff.

(8) To plan boreholes equipped with hand pumps. However, for deep boreholes, to design them so as to adopt engine pumps in the future.

(9) To plan to install improved special hand pumps on the boreholes with deep rest water levels, which will enable to pump up water from 100 m in depth. The engine pumps would be provided by the Zimbabwean side in the future.

5-2. Examination of Design Criteria

5-2-1. Project Area (Gokwe)

The whole Project Area consists of Communal Lands in the five Districts shown in Tab.2-3-1. However, the boreholes in four Districts except for Gokwe will be constructed by the Zimbabwean side at its own cost.

The plans for borehole construction, the procurement of equipment and materials, the construction schedule and so forth will be prepared for Gokwe area only.

The natural and hydrogeological conditions of Gokwe are shown in Chapter 3, and the following can be pointed out for the basic design plan.

(1) Social infrastructures such as roads, communications, accommodation facilities are poorer than those in the other areas.

(2) There is little cultivated land except for "Copper Queen area" located in the northeast part of Gokwe, and a forest area occupies over 50% of the land.

(3) The area can be divided into the following three sub-areas.

i) Southwest sub-area: The formations of Kalahari sands to Upper Sandstone are distributed here. There are shallow aquifers good for groundwater development. A good aquifer is located near the bottom of Upper sandstone under the unconfined condition. It will be difficult to lift water by hand pump due to the deep rest level of over 60 m in deep boreholes with a depth over 100 m.

ii) Central subarea; This subarea is located between i) and iii), and is mainly composed of Upper Sandstone. There is a total of six deep boreholes (three in Basalt area and the other three in Sandstone, with none in mudstone) out of about 70 existing boreholes.

iii) Northeast subarea; There are 36 (about 30%) deep boreholes out of 120 existing boreholes. Groundwater development is more difficult in this area than in the other subareas.