

JAPAN INTERNATIONAL COOPERATION AGENCY
DEPARTMENT OF WATER AFFAIRS
MINISTRY OF AGRICULTURE, WATER AND RURAL DEVELOPMENT
THE REPUBLIC OF NAMIBIA

THE STUDY
ON
THE GROUNDWATER POTENTIAL EVALUATION
AND MANAGEMENT PLAN
IN
THE SOUTHEAST KALAHARI (STAMPRIET)
ARTESIAN BASIN
IN
THE REPUBLIC OF NAMIBIA

FINAL REPORT

MAIN REPORT

MARCH 2002

PACIFIC CONSULTANTS INTERNATIONAL, TOKYO
IN ASSOCIATION WITH
SANYU CONSULTANTS INC., TOKYO

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PREFACE

In response to a request from the Government of the Republic of Namibia, the Government of Japan decided to conduct the Study on the Groundwater Potential Evaluation and Management Plan in the Southeast Kalahari (Stampriet) Artesian Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

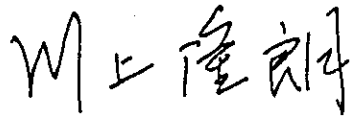
JICA selected and dispatched a study team headed by Mr. Yasumasa Yamasaki of Pacific Consultants International Co., Ltd. to the Republic of Namibia, four times between June 1999 and March 2002.

The team held discussions with the officials concerned of the Government of Republic of Namibia and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Namibia for their close cooperation extended to the team.

March 2002



Takao Kawakami
President
Japan International Cooperation Agency

**THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION
AND MANAGEMENT PLAN
IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN
IN THE REPUBLIC OF NAMIBIA**

March 2002

Mr. Takao Kawakami
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL


Dear Sir,

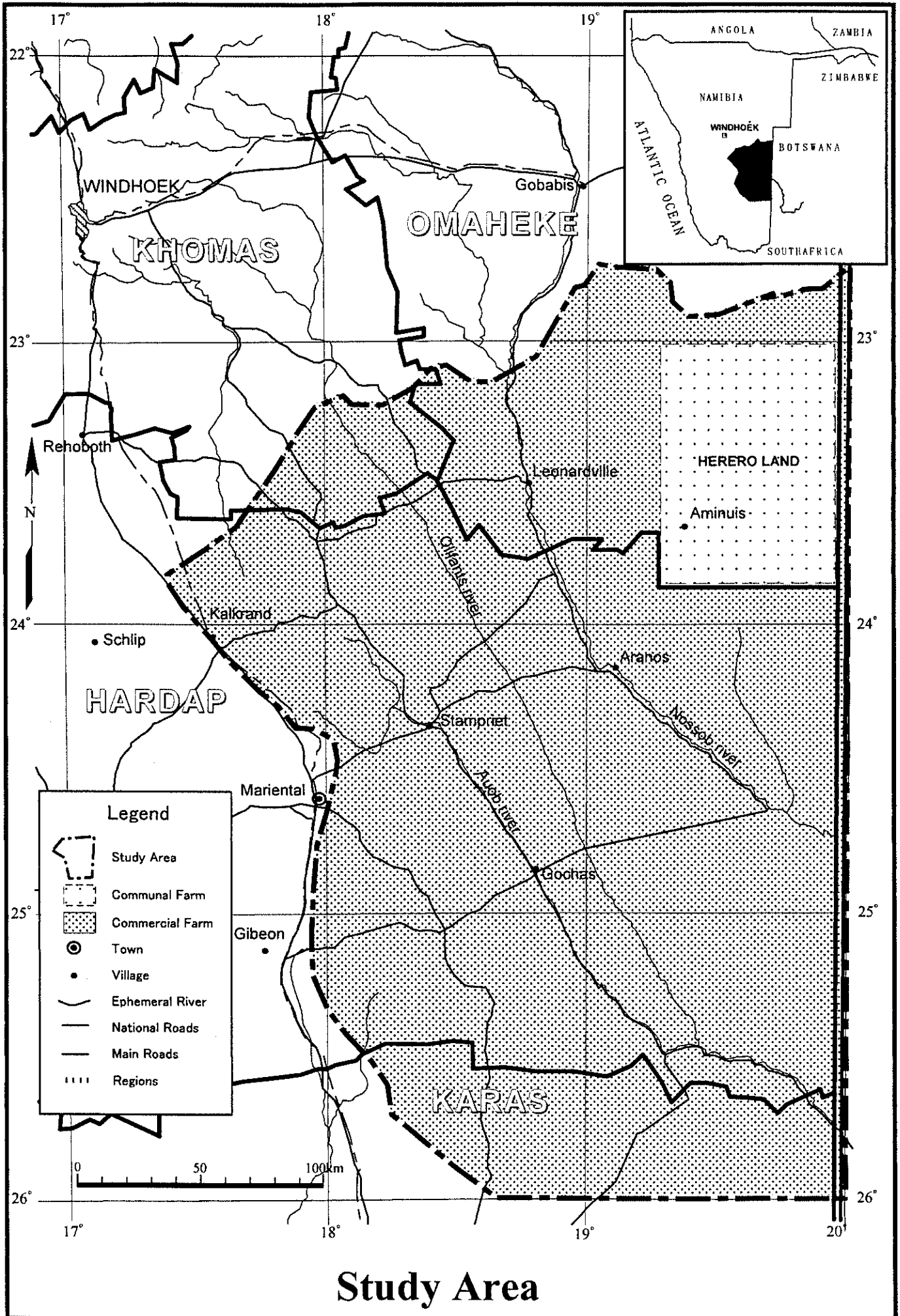
We are pleased to submit the final report entitled "THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN IN THE REPUBLIC OF NAMIBIA". The Study Team has prepared this report in accordance with the contract between Japan International Cooperation Agency and Pacific Consultants International in association with Sanyu Consultants Inc.

This report presents the results of the evaluation of the groundwater resources potential and the groundwater management plan.

All members of the Study Team wish to express grateful acknowledgments to the personnel of your Agency, Ministry of Foreign Affairs, and Embassy of Japan in South Africa, and also to officials and individuals of the Government of Namibia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the sustainable groundwater use in the Stampriet Basin and other relevant projects.

Yours faithfully,


Mr. Yasumasa YAMASAKI
Team Leader



Study Area

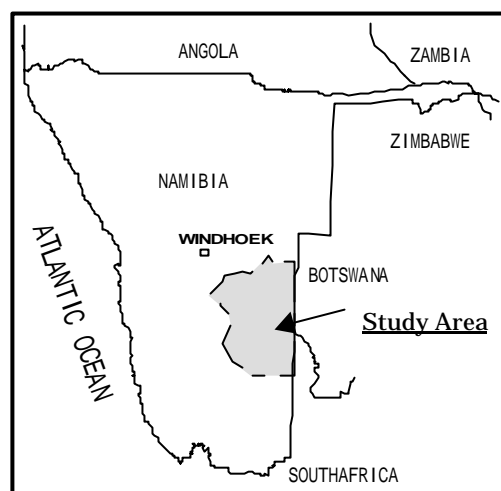
OUTLINE

Background of the Study

The Southeast Kalahari (Stampriet) Artesian Basin (hereinafter referred to as “the basin” or “the study area”) is situated in the southeastern part of Namibia. This basin is the largest groundwater basin in the country, which extends eastwards into Botswana and South Africa.

Groundwater abstraction within the basin is maintained by the regulations prescribed in the Water Act. Extensive groundwater abstraction by commercial and communal farmers occurs in the central area of the western side of the basin. According to some monitoring wells installed during 1978, groundwater levels have been declining continuously since 1980.

Consequently, a Hydrocensus was carried out by the Department of Water Affairs (DWA) during 1986 to 1988 in order to define the impact due to abstraction of the groundwater. Since then, no further study has been done, although, groundwater use has steadily increased to nearly twofold of 1988.



<Location Map of the Study Area >

DWA (Department of Water Affairs) needs to understand the nature of entire aquifer system in order to manage the excessive abstraction. Accordingly, the Government of Namibia requested the Government of Japan to carry out an investigation of the groundwater flow and recharge mechanism of the basin, furthermore, to formulate a groundwater management plan for sustainable groundwater development. This study was carried out during from June 1999 to January 2002.

Objectives of the Study

The objectives of the study are:

- To investigate the groundwater flow regime and recharge mechanism within the Southeast Kalahari Artesian Basin.
- To evaluate the groundwater potential to support sustainable development within the Southeast Kalahari Artesian Basin.
- To formulate a groundwater management plan within the Southeast Kalahari Artesian Basin.
- To achieve technology transfer to counterpart personnel during the course of the study.

Study Area

The study area covers the Southeast Kalahari Artesian Basin (approximately 71,000km²) as shown in the figure at the beginning of the report.

Conclusions

(1) Hydrogeological Structure

The Kalahari, Auob and Nossob Aquifer do not a simple monoclinial feature but a considerably complicated structure. Redefinition of the aquifers was also done through this study. (See Fig.3.6-9)

(2) Groundwater Potential Evaluation

The Auob Aquifer has the highest potential, followed by the Kalahari Aquifer, while the Nossob Aquifer shows the lowest potential. (See Fig.5.3-9 to 11)

(3) Groundwater Flow and Recharge Mechanism

a) Groundwater Flow

Groundwater into each aquifer flows from NW to SE and it was estimated that it takes several thousand years to flow through the whole basin. (See Fig.3.7-1 to 3)

b) Recharge

The major recharge into the basin occurs via direct rainfall feeding the rivers and the fractures as well as the karstic sinkholes that are situated on the rim of the basin. Recharge via these features and structures feed the Kalahari Aquifer directly and this amounts to $105 \times 10^6 \text{m}^3/\text{year}$ in an average rainfall year and $1,550 \times 10^6 \text{m}^3/\text{year}$ during an exceptional rainfall event (on average 1/50 years). Recharge into the Auob Aquifer via the Kalahari Aquifer and the Kalkrand Basalts does occur but this is mainly during the exceptional rainfall events. Recharge into the Nossob Aquifer is negligible and most of the resource in the Nossob Aquifer can be regarded as fossil water.

(4) Water Balance

- a) Under average rainfall conditions, the water level of the Kalahari Aquifer decreases by 5cm/year on average. Even though a 1/50 year heavy rainfall event does reverse the drawdown to some degree for a limited period, it does not prevent the longer term water-level decline under the present conditions.

- b) Groundwater recharge volume is up to 0.5% of total rainfall during a normal rainfall event and 3% during a 1/50 year heavy rainfall event. Most of the rainwater is lost by evapotranspiration. This is exacerbated by the large amount of alien vegetation and attention should be paid to solving this problem.

(5) Groundwater Demand

- a) Of the total groundwater abstracted from the Basin, approximately one half of the volume of $15 \times 10^6 \text{m}^3/\text{year}$ is used for irrigation ($6.88 \times 10^6 \text{m}^3/\text{year}$). Approximately 78 % of the total irrigation use is concentrated in the Stampriet area. (See P.4-12, and Table4.1-3)
- b) Of the total groundwater abstraction from the Basin annually, 66% is from the Kalahari Aquifer, 33% from the Auob Aquifer and only 1% from the Nossob Aquifer respectively.

(6) Groundwater Simulation

- a) Within a 60km square area around Stampriet the drawdown of the groundwater level is remarkable. (See Fig.5.3-12 to 17)
- b) Some wells within the Kalahari Aquifer around the Stampriet area may dry up within the next 30 years if the present condition of water use prevails. (See Tables 5.3-2, 3 and Fig.5.3-18) In view of the present over abstraction taking place, mitigating measures as part of a water demand management plan as described in Chapter 7 of the report should be adopted.

(7) Groundwater Management Plan

- a) Water Demand Management

It is proposed that the irrigation use be reduced by 30% for the short term and that the following countermeasures are suggested:

- i) Start of an awareness campaign regarding the sustainable use of groundwater.
- ii) Proper monitoring of water abstraction volumes.
- iii) Review of permit conditions for water allocation.
- iv) Reduction of over irrigated areas.
- v) Switch to higher value crop cultivation.

- vi) Voluntary reduction in water use by users.
 - vii) Application of more efficient irrigation methods.
 - viii) Pricing of groundwater.
- b) Aquifer Management Plan

An aquifer management plan was set up as follows.

- i) A regional groundwater monitoring plan was set up covering the entire basin as shown in Fig.7.3-2 and groundwater levels should be monitored on a continuous basis.
 - ii) A special groundwater monitoring area was also proposed in an area covering approximately 90km square around Stampriet. (See Fig.7.3-2) Here three additional observation boreholes should be drilled and installed with recorders.
- c) Personal Recruitment

DWA staff should be increased to fill the approved posts in order to do the necessary follow-up work of this study and to implement the groundwater management plan.

(8) Initial Environmental Evaluation

The proposed groundwater management plan is expected to have positive environmental impacts as the groundwater potential in the Stampriet Artesian Basin will be positively affected.

(9) Counterpart Training

During this study, transfer of technical know-how to counter-part personnel was conducted between JICA study members in each field in the form of on-the-job training. The Director of Resource Management and the Deputy Director of Geohydrology also took part in the counterpart-training course in Japan.

Recommendations

- (1) This report be accepted in principle.
- (2) The mean groundwater recharge into the aquifer is limited to 135 Mm³/a, subject to future monitoring management and adjustment.
- (3) An appropriate aquifer management plan, as described in Section 7 of the report, be implemented.
- (4) The criteria for all allocation of water for irrigation should be adjusted as suggested in paragraph 7-1 to ensure that the benefits of using the available water resources are maximized.
- (5) In view of the present over abstraction taking place, mitigating measures as part of a water demand management plan as described in Section 7 of the report should be adopted in cooperation with all water users to reduce the water demand and the local Water Committee should play a major role in this regard.
- (6) Further studies must be done to improve borehole construction and reduce the leakage from the existing groundwater abstraction wells. Furthermore attention must be given to assess and rectify the suspected contamination of groundwater taking place in the Basin, to reduce the loss of artesian pressure and to enhance aquifer recharge from surface runoff in areas where this can be done. The problem of alien vegetation should be addressed.
- (7) The technology used and the results obtained in this study should be utilized to manage other groundwater basins in Namibia.

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OUTLINE

STUDY AREA

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ABBREVIATIONS

ASL	: Above Sea Level
AGL	: Above Ground Level
BGL	: Below Ground Level
CMBM	; Chloride Mass Balance Method
CSAMT	: Controlled Source Audio Magnet Telluric
DO	: Dissolved Oxygen
DRWS	: Directorate of Rural Water Supply
DVS	: Directorate of Veterinary Services
DWA	: Department of Water Affairs
EC	: Electric Conductivity
GDP	: Gross Domestic Product
GPS	: Global Positioning System
GVA	: Gross Value Added
IAEA	; International Atomic Energy Agency
IEE	; Initial Environment Evaluation
IMF	: International Monetary Fund
JICA	: Japan International Cooperation Agency
MAWRD	: Ministry of Agriculture, Water and Rural development
NamWater	: Namibia Water Corporation
SABS	: South African Bureau of Standard
T	: Temperature
TDEM	; Time Domain Electric-Magnetic
TDS	: Total Dissolved Solids
TEM	: Transient Electro Magnetic
USAID	: United States Agency for International Development
USGS	: United States Geological Survey

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

This Study of the Groundwater Potential Evaluation and Management Plan in the Southeast Kalahari (Stampriet) Artesian Basin (hereinafter referred to as “the Study”) was carried out between June 1999 and January 2001.

The Southeast Kalahari (Stampriet) Artesian Basin (hereinafter referred to as “the Southeast Kalahari Artesian Basin” or “the study area”) is situated in the southeastern part of Namibia. The Southeast Kalahari Artesian Basin is the largest groundwater basin in the country, which extends eastwards into Botswana and South Africa. Its area is approximately 71,000km². The basin is almost entirely overlain by the Kalahari Group.

Groundwater from the basin is abstracted by both commercial and communal farmers for their domestic, livestock and irrigation purposes. It is also supplied to the towns of Stampriet, Gochas, Aranos, Leonardville, Aminuis and Onderombapa by the bulk water supply system of NamWater.

Groundwater abstraction within the Southeast Kalahari Artesian Basin has been controlled by Regulations promulgated by the Water Act. Extensive groundwater abstraction by commercial farmers occurs in the northern and central parts of the basin. Groundwater levels have been declining continuously since 1980 according to some monitoring wells.

Subsequently, a Hydrocensus was carried out by the Department of Water Affairs (DWA) from 1986 to 1988 in order to define the impact due to abstraction of the groundwater. Since then, no further work has been done, although, groundwater use has steadily increased to nearly double that of 1988.

In order to manage the excessive abstraction, the DWA needs to understand the nature of entire aquifer system. Accordingly, the Government of Namibia requested the Government of Japan to carry out an investigation of the groundwater flow and recharge mechanism of the Southeast Kalahari Artesian Basin and to formulate a groundwater management plan for sustainable groundwater development.

1.2 Objectives of the Study

The objectives of the Study are:

- To investigate the groundwater flow regime and recharge mechanism within the Southeast Kalahari Artesian Basin;
- To evaluate the groundwater potential to support sustainable development within the Southeast Kalahari Artesian Basin;
- To formulate a groundwater management plan within the Southeast Kalahari Artesian Basin;
- To achieve technology transfer to counterpart personnel during the course of the study.

1.3 Study Area

The study area covers the Southeast Kalahari Artesian Basin (approximately 71,000km²) as shown in the figure at the beginning of the report.

1.4 Implementation of Study

The Department of Water Affairs (DWA) of the Ministry of Agriculture, Water and Rural Development (MAWRD) was assigned as the counterpart organization by the Government of Namibia, while the Japan International Cooperation Agency (JICA) was assigned as the official agency responsible for the implementation of the technical cooperation program of the Government of Japan.

The study was conducted by the Japanese study team, comprising members of the Pacific Consultants International (PCI) and Sanyu Consultants Inc., officially retained by JICA for the study, and the counterpart staff provided by the DWA. The study was commenced in June 1999 and will be completed in March 2002. The total schedule of the study is shown in Table 1.4-1.

The study consists of a hydrological study, hydrogeological study, evaluation of groundwater potential, water use, socio-economic aspects, environmental aspects and the formulation of groundwater management plan.

The members involved in the study are listed below.

Name	Assignment
< Study Team of JICA >	
Mr. Yasumasa YAMASAKI	Team Leader/Groundwater Management Planner
Mr. Norifumi YAMAMOTO	Hydrogeologist (A)
Mr. Tadashi YAMAKAWA	Geologist/Remote Sensing Expert
Dr. Mahbub A. K. REZA	Hydrologist/Water Balance Expert
Dr. Gideon TREDoux	Water Quality/Environmental Specialist
Mr. Kohei SUGAWARA	Geophysicist
Mr. Yuichi HATA	Hydrogeologist (B)/Drilling Expert
Mr. Katsuhiko FUJISAKI	Groundwater Simulation Expert
Mr. Kensuke IRIYA	Socio-Economist
Mr. Akira OGIHARA	Socio-Economist
Mr. Hiroyoshi YAMADA	Coordinator (Hydrogeologist)
<DWA Staff>	
<Title>	
Mr. Piet HEYNS	Director: Resource Management
Mr. Greg CHRISTELIS	Deputy Director: Geohydrology
Mr. Guido Van LANGENHOVE	Deputy Director: Hydrology
Mr. Dudley BIGGS	Deputy Director: Planning
Mr. Don LOUW	Principal Hydrogeologist
Mr. Hartmut STRUB	Senior Hydrologist
Mr. Piet LIEBENBERG	(Irrigation Division, Department of Agriculture)
Mr. Rick Williams	Socio-Economist (Department of Planning)
Mr. Alex KATJUONGUA	Chief Technical Assistant
Ms. Theopauline NGULA	Technical Assistant

Table 1.4-1 Total Schedule of the Study

Year	1999							2000							2001							2002					
	Month	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar				
Work in Namibia	1 st Field Survey							2 nd Field Survey							3 rd Field Survey							4 th Field Survey			5 th Field Survey		
	[4] Submission and discussion of IC/R [5] Existing data collection, review and analysis [6] Landsat imagery interpretation [7] Aerial photo Interpretation [8] Topographical, geological and hydrogeological investigation [9] Existing borehole survey [10] Water usage [11] Preliminary environmental survey [12] Geophysical survey [13] Formulation of study plan for 2nd and 3rd field survey [14] Preparation and discussion of P/R (1)							[15] Test borehole drilling, borehole logging and pumping test [16] Observation of groundwater levels [17] Water quality analyses [18] Renewal of database of boreholes [19] Present water usage and water consumption forecast							[20] Test Borehole drilling, borehole logging and pumping test [21] Observation of groundwater levels [22] Water quality analysis [23] Elevation survey for existing boreholes (DGPS) [24] Survey on meteorology and hydrology [25] Preliminary hydrogeological analyses [26] Groundwater modeling(1) [27] Preparation and discussion of P/R(2)							[34] Discussion of IT/R [35] Groundwater simulation [36] Evaluation of the groundwater potential for sustainable usage [37] Formulation of groundwater management plan			[39] Discussion of DF/R		
Work in Japan	Preparation of the Study														1 st Work In Japan			2 nd Work In Japan			3 rd Work In Japan			4 th Work In Japan			
	[1] Collection, review and analysis of related data and data [2] Examination of study approach and methodology [3] Preparation of IC/R														[28] Hydrogeological analysis [29] Water balance analysis [30] Groundwater modeling (2)			[31] Preliminary groundwater simulation [32] Preliminary evaluation of the groundwater potential for sustainable usage [33] Preparation of IT/R			[38] Preparation of DF/R			[40] Preparation of F/R			
Study Stage	Phase I : Data Collecting and Analysis							Phase II : Groundwater Field Survey							Phase III : Analysis and Evaluation												
Report	Inception Report		Progress Report (1)					Progress Report (2)					Interim Report					Draft Final Report		Final Report							

<Notes> : Completed. IC/R: Inception Report P/R: Progress Report IT/R: Interim Report DF/R: Draft Final Report F/R: Final Report

1.5 Composition of Report

This report consists of four (4) volumes: Summary Report, Main Report, Supporting Report and Data Book.

The Main Report presents the summarized results of all the studies. In Chapter 2, basic information for the study is described. Hydrogeology and groundwater potential evaluation are presented in Chapter 3 and Chapter 5. Water demand and groundwater management plans are described in Chapter 4 and Chapter 7. Chapter 8 deals with the conclusion and recommendations.

Detailed study results are described in the Supporting Reports and Data Book. The contents of the Supporting Report are as follows;

In Chapter 2 through 8, basic information for the study is described. Water supply, demand and groundwater development potential are described in Chapter 9 to 11. Groundwater modelling is described in Chapter 12. Environmental and Socio-Economic aspects are described in Chapter 14 and 13, respectively. Chapter 15 deals with the groundwater value