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JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF LANDS, MINERAL RESOURCES AND ENERGY
REPUBLIC OF FIJI

THE STUDY
ON
GROUNDWATER DEVELOPMENT IN NORTH VITI LEVU
IN THE REPUBLIC OF FIJI

VOLUME II

FINAL REPORT
MAIN REPORT

MAY 1995

NIPPON KOEI CO., LTD.
NIKKO EXPLORATION & DEVELOPMENT CO., LTD.

LIST OF REPORTS

PREFACE

In response to a request from the government of the Republic of Fiji, the Government of Japan decided to conduct a study on Groundwater Development in North Viti Levu in the Republic of Fiji and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Fiji a study team headed by Dr. Noboru Miyamoto Nippon Koei Co., Ltd. 5 times between June, 1993 and May, 1995.

The team held discussions with the officials concerned of the Government of Fiji, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and present report was prepared.

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

I wish to express my sincere appreciation to the officials concerned of the Government of Fiji for their close cooperation extended to the team.

May, 1995

Kimio Fujita
President
Japan International Cooperation Agency

May, 1995

Mr. Kimio Fujita
President,
Japan International Cooperation Agency
Tokyo, Japan

LETTER OF TRANSMITTAL

Dear Sir,

We have the pleasure of submitting to you the Final Report of "The Study on Groundwater Development in North Viti Levu in the Republic of Fiji", in accordance with the Scope of Work agreed upon between the Ministry of Land and Mineral Resources and Japan International Cooperation Agency. The study was carried out for a total period of 24 months from June, 1993 to May, 1995, aiming to evaluate groundwater development potential and to formulate water supply plan in the northern area of Viti Levu.

This report consists of four volumes. The Executive Summary contains the summary of the study result. The Main Report presents the evaluation of groundwater resources and the formulation of water supply plan. The Supporting Report describes the analysis and discussion of hydrogeology, water use, population projection and water demand. The Data Book contains the basic data of the study.

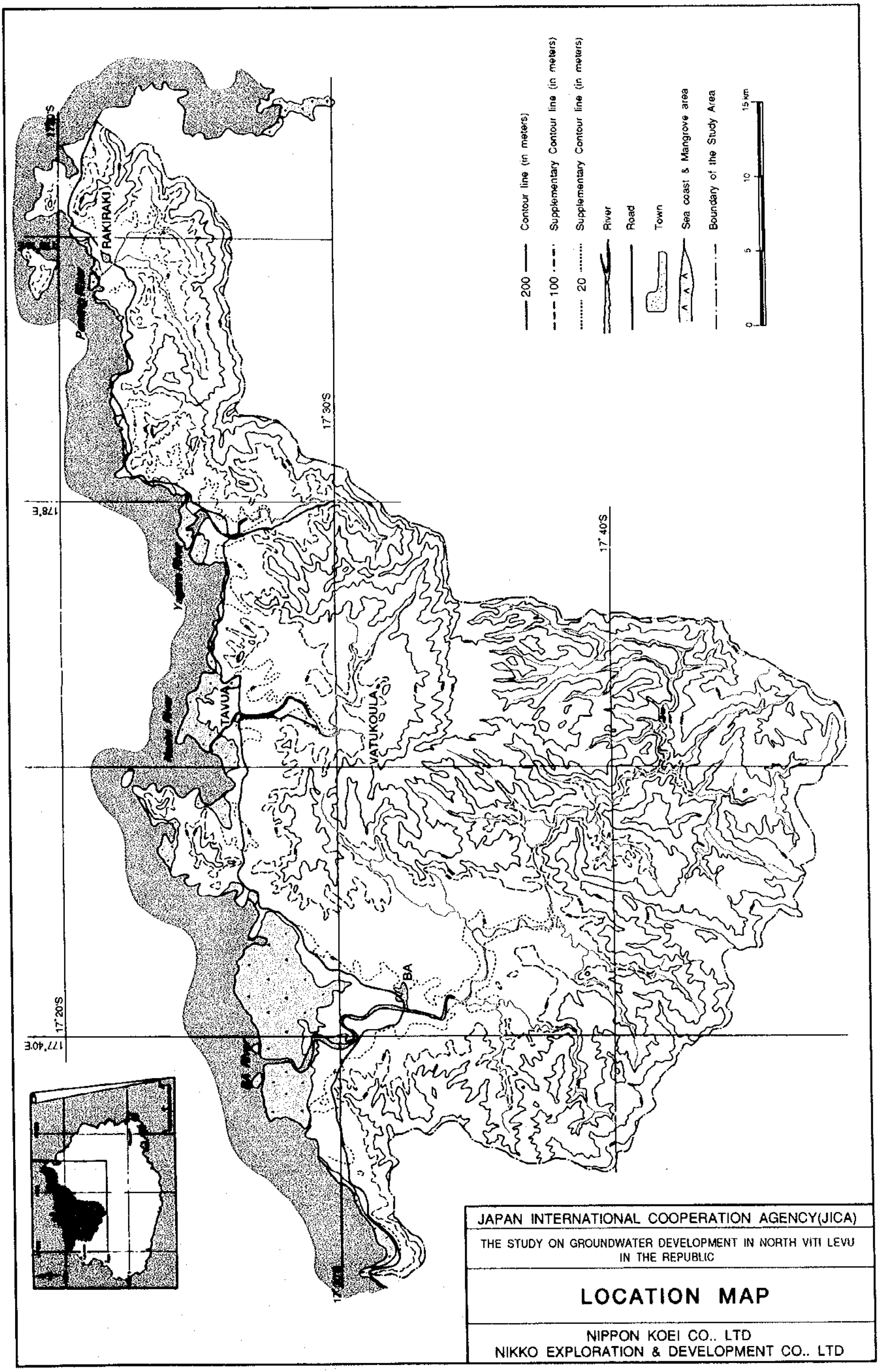
As the result of the scientific study on groundwater resources in the consolidated rock masses underlying the study area, groundwater development potential is locally available but not for the whole area. The water supply schemes were formulated in the limited areas with the groundwater development potential aiming enhancement of the living standard of inhabitants. The study team sincerely hopes that the study result would contribute to the future water supply plan in North Viti Levu.

We wish to express our deep appreciation and gratitude to the personnel concerned of your Agency and Office in Fiji, the Embassy of Japan in the Republic of Fiji, as well as officials concerned of the Government of Fiji.

Sincerely yours,

N. Miyamoto

Noboru Miyamoto
Team Leader
The Study on Groundwater Development
in North Viti Levu in the Republic of Fiji



JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

THE STUDY ON GROUNDWATER DEVELOPMENT IN NORTH VITI LEVU IN THE REPUBLIC

LOCATION MAP

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SUMMARY

The Study on Groundwater Development in North Viti Levu covering an area of 1,567 km^2 was commenced in June 1993 by the JICA study team in cooperation with the Counterpart Team of Fiji. This report describes the results of the study and the groundwater development plan in accordance with the Scope of Works.

The Study Area consists chiefly of mountainous areas in the south, low undulating hills extending from the skirt of the mountainous regions, of lower than 100 meters in elevation, and flat plains along the rivers and coast.

The mountainous areas and low undulating hills are underlain by consolidated pyroclastic rocks and lava formed in the Mio-Pliocene, partly intercalated with sedimentary rocks of sandstone, mudstone, and tuff beds. Alluvial deposits exist on the riverbeds and in the coastal area covering the above mentioned volcanic rocks. A gold mine is being operated in the middle reaches of the Nasivi river.

Geoelectrical soundings were initially carried out on 2,530 spots along the 100 survey lines by the electromagnetic method (VLF) and at 134 spots by Wenner's electrode array. Lower resistivity of the underlying rocks may suggest the occurrence of frequent fractures which could effectively provide groundwater. This is because groundwater is usually assumed to occur in fractures of consolidated rocks below weathered zones.

Detailed electromagnetic soundings (VLF) were carried out in Vutuni, Qara, and Waikowa, along 14 survey lines in order to detect fault zones. Detailed vertical electric soundings to 150 meters in depth were additionally carried out at 77 points with Wenner's electrode array.

Eleven test well sites were selected based on the analyses of the soundings to evaluate the groundwater development potential. Ten test wells were drilled to around 70 meters in depth to detect fractures in hard rock masses and one test well was made to a depth of 36 meters to study the river bed deposits.

Three test wells encountered the Tertiary sedimentary rocks such as tuffaceous mudstone, and sandstone, and other deep test wells penetrated basalt masses and their breccia. Since these rocks are well consolidated, only their fractures contain groundwater. A shallow test well was placed into deposits of gravel and mud under the

Ba riverbed. These deposits are not consolidated but contain an abundance of clayey materials lowering their permeability.

A pumping test was executed on each test well, however, the continuous pumping test was not successful on four test wells due to the poor production of water. In addition, a pumping test was carried out on two existing MRD boreholes. The yield quantities generally ranged from 1.0 to 15.1 l/sec except for the four test wells with poor yields.

Stream runoff was studied for estimating surface water development potential and groundwater recharge, using the Tank Model, was calibrated by a runoff hydrograph observed at the Toge gauging station covering the basin mean rainfall for the past 22 years. The possible development yield, (runoff quantity exceeding river maintenance flow with a 95 percent dependability in the drought standard year), is estimated to be 19.1 million cubic meters per year on the Ba river and 7.9 million cubic meters per year in total on eight other streams.

The recharging amount in the upstream basin during a 10 year drought is estimated to be 495 mm at Toge on the Ba river, 492 mm at Vatukoula, and 319 mm at Vatusekiyasawa, respectively. It is inferred that a major part of the recharged water may return to the stream and a part of it may flow through the ground to the lower basin.

Seven automatic water level recorders were installed in the existing MRD wells in October 1993, and three were placed in the test wells drilled during the study in March 1994, in order to observe seasonal fluctuations of water levels. The lowest water levels appeared in mid January, shortly after the start of the rainy season. The water levels rise towards the end of the rainy season and, gradually decline towards the end of the dry season.

Simultaneous water level observations were carried out in both the dry and rainy seasons on the same wells. The contour lines of the groundwater level are concordant with the regional topography. The annual fluctuations of water levels range from 0.19 to 4.89 meters.

Water quality analyses were carried out in both the dry and rainy seasons on 22 stream water samples and 55 groundwater samples, and 13 water samples collected from the pumping test wells. From the results it was found that the water is generally potable. Agro-chemicals were not detected in the water samples. However, in some water samples, Fe, Mn, Al, color, and turbidity slightly exceed WHO standards. Hazardous constituents such as Cadmium, Arsenic, and Chromium were found in some of the water samples of the Vatukoula area.

No regularity in the concentration level of the constituents was found either by region or between shallow and deep wells. This suggests that a major part of the groundwater circulates locally in a limited area.

The groundwater balance was studied in the selected lower basin of the right bank of the Ba river using the simulation method in order to evaluate the groundwater development potential in connection with the water supply plan. The Tank Model was applied for estimating the recharging amount and the MODFLOW model was applied to simulate the groundwater flow. It is anticipated that 410 m^3 per day of groundwater will be constantly pumped by the three existing and one new test wells in the selected area, without being affected by sea water intrusion.

Using the 1986 census and the official growth rate, the population of each community in the Study Area was forecast from 1991 to 2011. The 2011 population of the Study Area was estimated at 138,852. The population in areas with regional water supply systems will increase to 60,189 in 2011 from 49,122 in 1991, an average annual growth rate of 0.7 percent, and in the areas without regional water supply systems the population will increase to 78,664 in 2011 from 49,814 in 1991, an average annual growth rate of 1.84 percent.

The domestic demand in the areas with regional water supply systems was about 6,510 m^3 per day in 1991, increasing to 10,170 m^3 per day by 2011, in the areas without regional water supply systems was about 3,990 m^3 per day in 1991, increasing to 6,290 m^3 per day by 2011.

In the overall water supply development plan, nine schemes with water supply systems were formulated using groundwater sources. These schemes are classified into four types: "single community system", "expansion for regional system", "supplemental water source for regional system" and "emergency water source system". The source of water for these schemes is the existing test wells drilled by JICA team or MRD and one proposed production well.

The result of the economic analysis carried out on these nine schemes indicates that the Rabulu scheme has a high economic internal rate of return. The Vutuni Creek and the Vatuyaka schemes have low economic internal rates of return, however, these rates are expected to rise, provided the income of households also rises.

The environmental impact of groundwater development was based on five factors: land subsidence, sea water intrusion, influence to the existing wells, groundwater pollution, and health. Serious environmental impacts are unforeseen in regard to these nine schemes under the reasonable groundwater development.

In order to mitigate the present water shortage problems, three schemes, the Vutuni, the Vatuyaka and the Rabulu were finally selected for more detailed study. The preliminary design of the water supply systems was based on the topographic survey result. These schemes will be constructed within the period of 18 or 19 months following the completion of the Study and will provide potable water for 1,805 inhabitants in the target year 2011.

The construction cost for these three priority schemes is estimated at F$ 1,542,000. An operation and maintenance system is also recommended.

Scheme	Served population	Construction* cost (F$)
Vutunu Creek	314	320,711
Vatuyaka	561	464,249
Rabulu	930	756,950
Total	1,805	1,541,910

* Without the construction cost of a water source well.

It is recommended that the proposed priority schemes be urgently implemented.

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ABBREVIATIONS

AES	Agricultural Experimental Station
APHA	American Public Health Association
AWWA	American Water Works Association
EPA	Environmental Protection Agency (United States)
FEA	Fiji Electricity Authority
FMS	Fiji Meteorological Service
FSC	Fiji Sugar Corporation
GDP	Gross Domestic Product
GNP	Gross National Product
GOF	Government of Fiji
GOJ	Government of Japan
JICA	Japan International Cooperation Agency
MFARD	Ministry of Fijian Affairs and Regional Development
MLMRE	Ministry of Lands, Mineral Resources and Energy
MOH	Ministry of Health
MRD	Mineral Resources Department
PWD	Public Works Department
WEF	Water Environment Federation (United States)
WHO	World Health Organization
EIRR	Economic Internal Rate of Return
FIRR	Financial Internal Rtae of Return
O&M	Operation and Maintenance
El	Elevation
HWL	High Water Level
LWL	Low Water Level
WL	Water Level

ABBREVIATIONS OF MEASUREMENT

Length

cm = Centimeter
m = Meter
km = Kilometer
ft = Foot
yd = Yard
mm = Milimeter
inch = Inch

Area

cm^2 = sq.cm = Square centimeter
m^2 = sq.m = Square meter
ha = Hectare
km^2 = sq.km = Square kilometer

Volume

cm^3 = cu.cm = Cubic centimeter
l = lit = liter
kl = Kiloliter
m^3 = cu.m = Cubic meter
gal. = Gallon
MCM = Million Cubic Meters

Weight

mg = Milligram
g = Gram
kg = Kilogram
ton = Metric ton
1b = Pound

Time

min = Minute
sec = Second
hr = Hour
d = Day
yr = Year

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt

Other Measures

% = Percent
PS = Horsepower
° = Degree
' = Minute
" = Second
°C = Degree centigrade
10^3 = Thousand
10^6 = Million

Derived Measures

m^3/s = m^3/sec = Cubic meter per second
cusec = Cubic feet per second
mgd = Million gallon per day
kWh = Kilowatt hour
MWh = Megawatt hour
kVA = Kilovolt ampere
mg/l = Milligram per liter
meg/l = Milliequiralent per liter
MS/cm = Micro Siemens per centimeter
ppm = Part per million
NTU = Nephelometric turbidity unit
lpcd = Liter per capita per day

Money

F$ = Fijian Dollar
US$ = US dollar
J.Yen = Japanese Yen

1. INTRODUCTION

1.1 Background of the Study

The Republic of Fiji consists of more than 300 islands dispersed over an area between longitudes 165°50' east and 178° west, and latitudes 16° and 20° south. It has a total area of 18,272 km^2, and Viti Levu, the largest of the islands occupies about 10,429 km^2. Suva, the capital city, is situated on its southeastern coast.

Fiji's Gross Domestic Product (GDP) was F$ 1,955 million (approximately US$ 1,368 million) or F$ 2,635 per capita (approximately US$ 1,845) in 1991. The main domestic industries are sugar cane production and tourism. Agriculture accounts for about 20 % of gross domestic production. According to the population census of 1986, the total population of the country was 715,375 and the annual rate of population increase was about 2 % over the past 10 years. About 38.7 % of the inhabitants live in urban areas.

Viti Levu, where the Study Area is located, forms an ellipse of 146 km from east to west and 106 km from north to south, and has a high relief topography which was formed by volcanic activity. The island is meteorologically divided into dry and wet zones by the Nadrau plateau located in the center of the island with an altitude of more than 1,000 m, and is subject to the southwesterly trade winds.

Precipitation of 2,000 mm to 4,800 mm is usually recorded in the southern part of the island, while in the northern part a relatively lower precipitation of 1,000 mm to 3,000 mm is usually recorded. There are clearly two different seasons, the dry season from May to November and the rainy season from December to April. Less precipitation is expected in the northern part during the dry season.

The Study Area is located in the northern coastal zone of Viti Levu and is bounded by the southern watershed, from which rivers flow across the northern area from south to north, the watershed of the Penang river in the east, and the eastern end of the Lautoka water supply system in the west, as shown in the Location Map. The Study Area is estimated to cover an area of about 1,567 km^2.

There are three water supply systems in the Study Area covering urban areas such as Ba, Tavua, and Rakiraki. These systems which chiefly use surface water, supply about 64 % of the inhabitants. The remaining 36 % of the inhabitants depend on water from private wells and rainwater collection tanks. Springs and creeks provide water for people living in mountainous areas.

Since the urban areas in the Study Area depend mainly on rivers for their water supply, serious water shortage problems repeatedly occur in the dry season. Even in rural areas, by the end of the dry season, water is occasionally unobtainable from creeks and springs. Therefore, groundwater development is urgently required for the urban and rural areas where, at present, water supply facilities are in poor condition and surface water source capacities are inadequate and unreliable.

Even though water saturation of the volcanic sediments which overlie the northern part of the island is relatively high, groundwater seems to quickly drain off into the sea because the mountains are so close to the coastline with only narrow plains between them. Groundwater development in this area is not an easy task because of these topographic and geologic conditions. Therefore, groundwater development technical assistance from technically developed countries is eagerly desired. The Government of Fiji (GOF) considers that " an adequate, reliable, and safe water supply", by solving the repeated water shortage problems, is one of the most important targets of the National Development Plan (Policies and Strategies for the Short and Medium Term), before the year 2000.

Because of these reasons, GOF in July 1992, requested the Government of Japan (GOJ) to provide technical assistance for the groundwater development in the northern part of Viti Levu , which has been continuing since 1989. In response to this request, the Japan International Cooperation Agency (JICA) dispatched a Preparatory Study Team for the preparation of the Scope of Works (S/W). The S/W was signed between the Minister for Lands and Mineral Resources and the Leader of JICA's Preparatory Study Team on December 14, 1992.

1.2 The Scope of Works

The objectives of the Study are to evaluate groundwater resources potential and formulate a groundwater development plan for the provision of an adequate, reliable, and safe water supply in the Study Area. The target year of the groundwater development plan was discussed with the Mineral Resources Department (MRD) and the Public Works Department (PWD) and the year 2011 was decided. The transfer of knowledge from the JICA Study Team to the counterpart personnel provided by MRD and PWD, was carried out during the study period through on-the-job training (OJT) and training in Japan. Equipment and materials necessary for the Study were prepared by JICA and transported to Fiji during the Study period. The equipment and materials are listed in DATA BOOK-E.

The Study commenced in May 1993 and will be completed by May 1995. It comprises three phases: Phase 1 (basic study) from May 1993 up to mid-November 1993, Phase 2 (detailed study and analysis) up to mid-August 1994, and Phase 3 (planning) up to mid-May 1995. The general work flow is shown in Fig. 1.1.1. The S/W are as follows:

Phase 1 (May 1993 - October 1993):

(1) Review and analysis of previous studies and existing data
- (a) Socio-economic conditions
- (b) Relevant ongoing and planned projects
- (c) Water supply systems
- (d) Water demand
- (e) Existing well data
- (f) Topographical, geological, and hydrogeological maps
- (g) Satellite and aerial photographs
- (h) Land use
- (i) Physical conditions
  - Meteorology, hydrology, and hydraulics
  - Geology and geography
  - Vegetation and soil
- (j) Environmental conditions
- (k) Laws, regulations, policies, and customary practices
- (l) Institutions, organizations, and administrations
- (m) Others

(2) First field investigation
- (a) Field reconnaissance
  - General
  - Existing facilities
  - Geology
  - Environmental aspects
- (b) Survey on the condition of water utilization
- (c) Survey on water demand conditions
- (d) Preliminary hydrogeological mapping
- (e) Selection of points for the geophysical survey

(f) Geophysical survey
(g) Estimation of groundwater resource potential
(h) Classification of areas based on groundwater resource potential
(i) Selection of test boring sites

Phase 2 (November 1993 - August 1994):

(1) Second field investigation
   (a) Detailed geophysical prospecting
   (b) Test boring
      - Geophysical logging
      - Pumping test
      - Water quality test
   (c) Hydrological investigation
   (d) Simultaneous observation of groundwater levels

(2) Study and analysis
   (a) Water quality analysis
   (b) Water balance analysis
   (c) Water demand projection
   (d) Evaluation of groundwater resource potential

Phase 3 (September 1994 - May 1995):

(1) Groundwater development planning
   (a) Supplementary survey
   (b) Formulation of water supply systems
   (c) Implementation schedule
   (d) Operation and maintenance
   (e) Estimation of costs and benefits of the Project
   (f) Social and economic analysis
   (g) Environmental impact assessment

1.3 General Work Progress

In accordance with the Scope of Work agreed upon between GOF and JICA, the Study on Groundwater Development in North Viti Levu has been carried out by the JICA Study Team in collaboration with counterparts. The Study, which consists of three phases, commenced in July 1993 and completed by May 1995. The work schedule is shown in Fig.1.3.1.

1.3.1 Work Progress in Phase 1

Phase 1 consisted of preparatory works at home, the first field investigation, and the first home work, including data collection and a review of the existing reports. At the beginning of the first field investigation, the outline of the work schedule and plan of operation for the Study were explained and discussed with MRD.

(1) Preparatory works at home

(2) First field investigation

During the period from the beginning of July 1993 to the middle of October 1993, the following works were performed by the JICA Study Team in cooperation with its counterparts.

1) Submission of the Inception Report : The Inception Report was submitted to MRD and explained by the JICA Study Team at the beginning of July 1993.

2) Geological investigation : A geological investigation was carried out at the initial stage of the study period by an analysis of the existing data, interpretation of the aerial photographs, and a supplemental field reconnaissance in representative sites, for the collection of basic information on the Study Area. The results of the study are summarized in a land form classification map, a land use classification map, and a geological map. These maps cover the whole Study Area of about 1,567 km^2.

2) Geophysical prospecting:

- Electromagnetic sounding: Electromagnetic sounding was carried out using a VLF resistivity meter GEONICS EM16R to confirm faults and fractured zones. 2,530 measurements were made on 100 survey lines of about 500 m in length with a 20 m interval between the observation points.

- Electric sounding: Vertical electric sounding with a Wenner electrode array was carried out using a resistivity meter, OYO McOHM model-2115, on 134 survey points for detecting subsurface geological structures.

3) Meteorology and Hydrology investigation : The main activities were data collection and arrangement of the following hydrological and meteorological data in the Study Area and surrounding area.
   - Hydrological data: daily runoff, runoff rating curve, river water level;
   - Meteorological data: daily precipitation, air temperature, evaporation, relative humidity, sunshine duration.

4) Hydrogeological investigation : The following surveys were carried out on about 500 existing wells in the Study Area:
   - Confirmation of the location, depth, diameter, purpose, and pump type;
   - Measuring of the yield, static water level, EC value, water temperature, and pH.

   Simultaneous groundwater level observation in the dry season was carried out in the selected existing wells. 7 automatic water level recorders with shelters were installed at the MRD test wells. 3 proposed and 8 tentatively proposed sites for test wells were selected in the Study Area.

5) Water quality analysis : A water quality survey was carried out in the dry season from August to September 1993. 61 water samples were collected for the water supply analysis and geochemical investigation and 10 samples were collected for the agrochemical analysis. The water quality analysis and the hydrogeological investigation were carried out by the National Water Quality Laboratory of PWD, Fiji. The agrochemical analysis was carried out in Japan.

6) Survey of the water supply system and water use : The present condition of the existing water supply system and its use were confirmed in the field investigation of this stage. A questionnaire survey on the present condition of water use in 59 communities was carried out. Women's role in water use (woman in development) was clarified by means of an interview survey in the rural area.

7) Socio-economic survey : During this stage, the socio-economic situation of Fiji and the socioeconomic background of the Project area were clarified by means of the collected data.

(3) First home work

During this period, from the middle of October 1993 to the middle of November 1993 the following works were performed by the JICA Study Team in Japan:

1) Geophysical prospecting analysis;
2) Meteorology and Hydrological analysis;
3) Hydrogeological analysis;
4) Water quality analysis;
5) Socio-economic analysis;
6) Preparation of the Interim Report (1).

1.3.2 Work Progress in Phase 2

Phase 2 consisted of a second field investigation, including the submission of the Interim Report (1), and a third field investigation.

(1) Second field investigation

During the period from the middle of November 1993 to the end of March 1994, the following works were performed by the JICA Study Team in cooperation with its counterparts.

1) Submission of the Interim Report : The Interim Report (1) was submitted to MRD and explained by the JICA Study Team in the middle of November 1993.

2) Geophysical prospecting : Detailed electromagnetic and electric sounding were carried out at the proposed and alternative test well drilling sites.

3) Meteorological and hydrological investigation : The main activities carried out in this period were additional meteorological data collection and measurement of the runoff of small creeks during the rainy season.

4) Hydrogeological investigation : Simultaneous groundwater level observations were carried out in the rainy season in the selected existing wells. Three automatic water level recorders with shelters were installed at JICA's test wells

5) Water quality analysis : A water quality survey was carried out in the rainy season from February to March 1993. 61 water samples were collected for the water supply analysis and the geochemical investigation and 10 samples were collected for the agrochemical analysis.

6) Test well drilling : Test well drilling was carried out by the JICA-MRD Study Team utilizing a used rotary drilling rig at three selected sites.

(2) Third field investigation

During the period, from the middle of May 1994 to the end of August 1994, the following works were performed by the JICA Study Team in cooperation with its counterparts.

1) Test well drilling : Test well drilling was carried out at eight selected sites by the JICA-MRD Study Team using a new JICA rotary drilling rig and a used MRD rotary drilling rig.

2) Pumping test : A pumping test was carried out by the JICA-MRD Study Team at 11 test well sites and two existing MRD wells.

3) Water quality analysis : A water quality analysis was carried out at JICA's test wells. 12 water samples were collected for the water supply analysis and the geochemical investigation.

4) Meteorological and hydrological investigation : The main activities of this period were additional meteorological data collection and measurement of the runoff of small creeks during the dry season. A water balance analysis was carried out using a tank model.

5) Hydrogeological investigation : Simultaneous groundwater level observations were carried out in the dry season in the selected existing wells. An evaluation of the properties of the geological log and water well design of the test wells was carried out.

6) Water supply system: The amount of water consumed and demanded was determined through the field survey. The construction criteria and construction cost data were confirmed

7) Socio-economic Survey : During this period, the population projections for the Project area were clarified.

8) Groundwater resources evaluation: During this period, a preliminary groundwater resources evaluation was carried out in the Ba Uplands using a groundwater simulation model.

1.3.3 Work Progress in Phase 3

Phase 3 consisted of a second home work, a fourth field investigation, a third home work, fifth field investigation, and fourth home work including preparation of the Final Report .

(1) Second home work

During this period, from the beginning of September 1994 to the end of October 1994, the following works were performed by the JICA Study Team in Japan:

1) Hydrogeological analysis;
2) Preparation of a hydrogeological map and a groundwater evaluation map;
3) Formulation of an optimum pumping plan using a groundwater simulation model;
4) Formulation of a groundwater development plan;
5) Cost estimates for the groundwater development plan;
6) Project evaluation;
7) Preparation of the Interim Report (2).

(2) Fourth field investigation

During the period from the beginning of November 1994 to the end of December 1994, the following works were performed by the JICA Study Team in cooperation with its counterparts.

1) Submission of the Interim Report : The Interim Report (2) was submitted to MRD and explained by the JICA Study Team in the middle of November 1993.
The proposed groundwater development plans were discussed, and three priority schemes were selected from them.

2) Following supplemental investigations were carried out for the preliminary design of the three priority schemes.
   - Topographic survey by the counterparts using local consultants
   - Data collection for construction planning and cost estimates
   - Detailed investigations on water supply areas and transmission pipe routes.

(3) Third home work

During this period, from the beginning of January 1994 to the beginning of March 1995 the following works were performed by the JICA Study Team in Japan:

1) Formulation of the water supply plans;
2) Formulation of the implementation programs;
3) Formulation of the operation and maintenance plans;
4) Estimation of the Project costs;
5) Project evaluation;
6) Environmental impact assessment;
7) Preparation of the Draft Final Report;
8) Preparation of the groundwater survey manual.

(4) Fifth field investigation

In March 1995, the Draft Final Report was prepared, and submitted to MRD on March 13, 1995. The JICA Study Team explained the contents of the Report and discussed the result of the Study with MRD and PWD at Suva on 13-14 March, 1995.

(5) Fourth home work

In May 1995, the Final Report was prepared with reference to the comments of MRD and PWD through the discussion, and is sent to MRD.

1.4 Organization of the Study Team

The JICA Study Team dispatched its engineers to the Study Area on the schedule described in the Inception Report, for the execution of the Study. The Study so far has been carried out smoothly by the engineers of the JICA Study Team in cooperation with the personnel of the Counterpart Team. The members of both teams are listed in Table 1.4.1. The assignment schedule of the JICA Study Team is shown in Fig. 1.4.1.

1.5 Training

The transfer of knowledge to the counterpart personnel has been carried out throughout the Study in the field operations and in the office work. Water well drilling techniques and pumping test methods were especially transferred to the MRD drilling team during the test well drilling works.

Two counterparts were also been invited to Japan by JICA to obtain training on groundwater development and water supply design in 1993 and 1994, respectively.

Mr. Prem B. Kumar, the counterpart hydrogeologist of MRD, was invited to Japan for one month from 21 October 1993 to obtain training on groundwater development. During his stay in Japan, he learned groundwater development methods and the environmental control of groundwater development including the subsurface dam reservoir, the monitoring system for protection against land subsidence, and groundwater pollution control.

Mr. John Tavo, counterpart water engineer of PWD, was invited to Japan for three weeks from 13 October 1994 to obtain training on water supply design and planning. During his stay in Japan, he took part in lectures and visited various factories and facilities in order to gain knowledge of the technologies related to water supply and sewerage systems in Japan.

2. STUDY AREA

2.1 Location and Topography

The Study Area is located in the northern coastal zone of Viti Levu and has an area of 1,567 km^2. The Study Area is bounded by the southern watershed from which rivers flow across the northern area from south to north, the northern coast, the watershed of the Penang river on the east, and the eastern end of the Lautoka water supply system on the west, as shown in the Location Map of the Study Area. It lies at 17° 20'S to 17° 50'S longitude and 177° 30'E to 178° 10'E latitude.

The Study Area in general consists of mountains and low hills except for the narrow coastal plains along the northern coast. The southern and eastern marginal part of the Study Area is dominated by a broad expanse of mountains covering more than 70 % of the whole Study Area. The highest mountain is Mt. Naqaranabuluti, with an altitude of 1,127 m.

In the Study Area there are four major drainage systems, the Ba river in the western part, the Nasivi river and the Yaqara river in the central part, and the Penang river in the eastern part. The upper courses of these rivers are characterized by rapids. Extensive meanders and cutoff channels characterize the lower course.

Hilly and gently undulating areas with an altitude of less than 100m are predominant in the four major drainage systems and coastal area covering about 18% of the Study Area. Small creeks dissect these areas, generally resulting in an undulating topography. These areas are normally cultivated for sugar cane.

Talus deposits, including scree deposits are predominantly observed upstream of the Yaqara river and to a lesser degree, upstream of the Ba river. However, development of the areas underlain by these materials seems to be very limited in the steep mountainous areas of the Study Area. Terrace deposits are observed along the major rivers such as the Ba , Nasivi, and Yaqara rivers.

Alluvial deposits are predominantly observed along the four major rivers and the smaller rivers draining directly to the northern sea. Lowlands composed of silty sand materials along the northern coastal zone are submerged when the tide is high and are classified as tidal flats. The results of the landform classification of the Study Area are shown in Fig. 2.1.1, Landform Classification Map.

2.2 Climate

The Study Area which is situated in the northern part of Viti Levu, is mostly classified as the dry zone of the island with an average annual rainfall varying from 1,800 to 3,800 mm. Judged from the monthly rainfall pattern, the rainy season occurs between December and April. The rainy season peak is from January to March, with a monthly rainfall of 300 to 500 mm. The total amount of rainfall which occurs over these three months is about 50 % of the total annual rainfall. The dry season continues from May to October. The monthly rainfall in this period decrease to less than 100 mm.

The seasonal variation of the average temperature is not very significant ranging from 24 °C to 27 °C throughout the year. The average daily maximum temperatures in January are 32.4 °C at Rarawai Mill (Ba) and 31.2 °C at Penang Mill (Rakiraki), while the average daily minimum temperatures in July are 17.0 °C and 20.3 °C. Relative humidity records are not available at Rarawai Mill and Penang Mill. The relative humidity in Lautoka AES ranges from 70 to 80 % during the year.

The average evaporation is 4.9 mm/day at Rarawai Mill and 5.1 mm/day at Penang Mill, equivalent to 1,788 mm and 1,861 mm a year, respectively. The evaporation ratio gradually increases from the beginning of the wet season and decreases forward the end of the wet season. The monthly values range from 100 to 190 mm at Rarawai Mill and 130 to 190 mm at Penang Mill. Evaporation exceeds rainfall in the dry season.

At Lautoka AES, the average annual number of sunshine hours is 2,573 and the monthly variation is relatively minor, ranging from 187 to 237 hours. Records are not available at Rarawai Mill and Penang Mill. The predominant winds are the trade winds from the east or southeast. In general the winds are moderate throughout the year. Along the coast, daytime sea breezes regularly blow. The average wind speed at Lautoka AES is 138 km/day. The mean meteorological data in the Study Area are shown in Table 2.2.1 and Fig. 2.2.1.

2.3 Land Use

The land use survey was carried out in the Study Area based on interpretation of the aerial photographs and field reconnaissance. The present land use pattern is closely related to the topographic condition and vegetation. The land use is classified into seven categories i.e., (a) forestry area, (b) grassy area, (c) sugar cane field, (d) pasture, (e) rock outcrop, (f) urban area, and (g) river bed.

The majority of the forested areas are in the steep mountain region west of the Ba urban area and south of the Vatukoula urban area. Light forest and scrub areas are included in this forestry area. The grassy area is mainly covered by reeds, fern, and weeds and is located in the steep mountain areas. Parts of the grassy area are used for vegetable gardens.

The sugar cane fields occupy the wide open low hill areas along the major rivers such as the Ba river, Nasivi river, and Nakauvadra river. Included in the sugar cane fields are vegetable gardens, and maize fields. Pasture covers the low hill areas of the Yaqara river basin where cattle are left to graze. Non vegetated land consists of rock outcrops, urban areas, and riverbeds, and occupies a very small part of the Study Area.

The results of the land use classification of the Study Area are shown in Fig. 2.3.1 Land Classification Map (1: 10,000). The percentage of area covered by each land use type in this Study and the existing land use map (1:250,000) of Viti Levu prepared by the Directorate of Overseas Surveys in 1963, are summarized as follows:

Land use type	JICA Study 1993		Land use map (1:250,000)1963	
	Area (km^2)	(%)	Area (km^2)	(%)
Forestry area	554.5	35.4	369.4	23.6
Grassy area	496.9	31.7	794.5	50.6
Sugar cane field	447.4	28.5	318.2	20.3
Pasture	31.4	2.0	73.0	4.7
Rock outcrop	17.3	1.1	---	---
Urban area	7.7	0.5	12.5	0.8
Riverbed	12.4	0.8	---	--
Total	1567.6	100.0	1567.6	100.0

According to the above figures, the percentages of forest areas and sugar cane fields have increased from 1963 to 1993 due to the results of there forestation of pine trees and the development of sugar cane field in the grassy areas and pastures in recent years. Rock outcrop and river bed areas in the 1963 land use map are included in other categories.

2.4 Socio-economy

2.4.1 National Socio-economic Background

(1) Administration

The administrations of the Republic of Fiji are composed of four divisions: Central, Western, Northern, and Eastern. Each division is divided into several Provinces, with a total of 15 provinces in the country. Further, the Provinces are divided into Districts (Tikina) ranging from 2 to 14 units. At the lowest administrative level are Communities (or Localities) averaging between 1 and 75 units per District.

MRD and PWD, which are directly related to the present study, belong to the Ministry of Mineral Resources and Energy and the Ministry of Infrastructure and Public Works, respectively. In 1993, MRD had 110 employees and was operated by seven Principal Officers under the jurisdiction of one Director and two Deputy Directors. PWD had about 4,000 employees, of which about 1,000 belong to the Water and Sewerage Section, and was operated by seven Principal Officers and three Divisional Engineers under the control of one Director and two Deputy Directors. The organization charts are illustrated in Fig. 2.4.1 and 2.4.2.

(2) Population

A population census has been conducted eleven times since 1881 and the historic populations since the 1946 census are provided in Table 2.4.1. The population of Fiji reached 715,375 in 1986 rising by 455,737 (about 175 %) since 1946. For the period from 1976 to 1986, the annual growth rate was 1.98 %, the lowest rate of the historic intercensal annual growth rates since 1946. In the 1986 Census, Fijians and Indians which are the two major ethnic groups, recorded populations of 329,305 and 348,704, or 46.0 % and 48.7 % of the total population, respectively.

According to the projections of the Bureau of Statistics, it is expected that Fiji's population will be approximately 942,000 in 2011, increasing by 227,000 since the 1986 population census. The projected annual growth rate for this period average 1.1 %.

(3) Gross Domestic Product (GDP)

Fiji's GDP at current prices amounted to F$ 1,955 million in 1991, an average annual increase rate of 8.1 % from F$ 1,329 million in 1987. The per capita GDP also grew at an average high annual rate of 7.4 % during the same period, and amounted to F$ 2,635 in 1991. However, the real average growth rates were only 2.7 % and 1.9 % per annum for the same period, respectively (Table 2.4.2).

GDP of the agricultural sector, which is the major economic activity sector of Fiji, accounted for about 20 % of the total GDP each year during the period 1985-1989, and the average annual growth rate was 11 % during this period (Table 2.4.3). Sugar cane production accounted for 30 % to 40 % of agricultural GDP, and the average annual growth rate was about 30 % during the same period.

In Fiji, tourism is also an important sector with high economic growth. Therefore, the trade, hotel, restaurant, and cafe industries related to tourism accounted for a high share of GDP, ranging from 15 % to 23 %. The average growth rate of these industries was 16 % per annum during the period 1985-1989.

(4) Agricultural and Manufacturing Products

The major agricultural products of Fiji are sugar cane, copra, paddy, tobacco, cocoa, ginger, fish, and livestock. Of these, productions of copra, tobacco, ginger, and chicken showed high growth at the average annual rate of 13.1 %, 16.9 %, 11.3 %, and 15.2 %, respectively, during the period 1988-1992. While the productions of paddy and beef indicated a negative average annual growth rate of -2.4 % and -7.3 %, respectively.

The processed agricultural products are represented by sugar, coconut oil, flour, butter, cigarettes, and stockfeed. Among them, coconut oil and stockfeed achieved high growth at an annual rate of 12.5 % and 9.0 %, respectively, during the same period, and their respective productions amounted to 9,234 tonnes and 24,601 tonnes in 1992.

In Fiji, sugar cane and sugar are the most important agricultural products. Sugar cane production rose at an annual rate of 3.8 % during the period 1988-1992, and in 1992 the production reached 3,533 thousand tonnes with a harvested area of 73 thousand hectares, that is, 48.6 tonnes/ha. Sugar production amounted to 426 thousand tonnes in the same year, with a average annual rate of 5.1 %.

The major manufacturing industrial products of Fiji include gold, silver, cement, beer, paints, soap, and soft drinks. Silver, cement, and soft drinks showed a considerably high increase rate of 26.4 %, 18.4 %, and 20.2 % per annum, respectively during the period 1988-1992. Gold is among the significant traditional products of Fiji, but its production declined during the same period.

(5) External Trade and Payments

In 1992, Fiji's exports amounted to F$ 653,281,000, an average annual growth rate of 6.1 % during the period 1988-1992. Principal exports are sugar, fish, molasses, cork & wood, garments, and gold. The export of sugar, which ranks first, amounted to F$ 221,281,000 in 1992. Garments and gold ranked second and third in exports in 1992, totaling F$ 105,543,000 and F$ 60,723,000 respectively.

Fiji's imports amounted to F$ 938,448,000 in 1992, an average annual increase rate of 11.0 % since 1988. Major import commodities are manufactured goods, machinery, food, mineral fuel, and chemicals. Manufactured goods and machinery totaled F$ 233,695,000 and F$ 231,867,000, respectively, or 25 % each of the total imports. The average annual growth rate of imports was 11.8 % for manufactured goods and 21.1 % for machinery, during the period 1988-1992.

The external trade balance showed a deficit every year during the period 1988-1992. Its average deficit amount per annum was F$ 260 million. However, this trade deficit has been compensated by services including tourism. As a result, the total balance of the trade and services accounts came to plus F$ 36.5 million in 1991 and F$ 51.8 million in 1992.

The balance of the current account also showed a deficit in the years 1990, 1991 and 1992, due to the unfavorable balance of accounts of investments and private transfers. This deficit was compensated by the capital account in these years. Accordingly, the international payments of Fiji have maintained a favorable balance since 1990.

(6) Government Finance

In 1992, the revenue and expenditure of the Central Government amounted to F$ 550,588,000 and F$ 600,616,000 increasing at the annual rates of 9.4 % and 8.5 % respectively, during the period 1988-1992.

The revenue is represented by two items; (1) income tax and estate and gift duties, and (2) customs and port duties. In 1992, the former amounted to F$ 245,916,000, and the latter amounted to F$ 198,733,000. The average annual rise rates of both revenues were 14.1 % and 9.4 % respectively, during the same period.

On the other hand, expenditure of the Central Government consists mainly of departmental expenditure and public debt charges. In 1992, these expenditures were F$ 451,238,000 and F$ 123,544,000 which accounted for 75 % and 20 % of the total expenditure, respectively. During the period 1988-1992, the former was rising at an average annual rate of 15 %, while the latter was decreasing at an average annual rate of minus 5 %.

The budgets of MLMRE, MRD and PWD, who are closely related to the present study, grew at a high average annual rate of 17.7 %, 18.2 %, and 14.9 % respectively, during the period 1989-1993, and in 1993 they amounted to F$ 13,792,000, F$ 2,977,000 and F$ 100,677,000.

(7) Wage and Prices

According to the wage statistics of Fiji, the labor wage was F$ 12.64 per day on average for all industries in 1989, and its average growth showed a low annual rate of 1.3 % during the period 1985-1989. The electricity sector showed the maximum daily wage of F$ 15.60, and the minimum was F$ 11.36 in the manufacturing sector and F$ 11.92 in the agricultural sector.

Table 2.4.4 shows the consumer price index of Fiji for the period from 1988 to 1992. The average annual inflation for general prices was 6.4 %, of which the service and housing sectors showed comparatively high inflation of 10.8 % and 9.9 % per annum, respectively. In recent years, inflation has been higher than wage rises, causing people to suffer an inevitable decline in their standard of living.

2.4.2 Socio-economic Conditions in the Study Area

(1) General

The socio-economic conditions in the Study Area are based mainly on the result of the questionnaire survey, because the regional socio-economic data except population statistics are unavailable. The questionnaire survey was carried out by the JICA Study Team in cooperation with the counterpart personnel, and concerned the existing socio-economic conditions relating to the water supply and consumption in the Study Area.

The survey was carried out in 59 communities, where the water supply appeared to be insufficient. In addition to the implementation of this survey, a fact-finding inquiry regarding the economy of households was conducted for 179 households, at an average rate of three households per community.

The Study Area is situated on the northern coastal area of Viti Levu, the largest island with an area of 10,429 km^2, and stretches over the Ba and Ra Provinces in the Western Division. It has a total land of 1,567.6 km^2, and contains all of the Ba District and most of the Magodro and Tavua Districts in the Ba province and most of the Rakiraki Districts and a part of the Saivou District in the Ra Province.

(2) Regional Population

Table 2.4.5 presents the population of each province in 1986. Ba and Ra Provinces, which include the Study Area, had populations of 197,633 and 31,285, respectively. The total population of both Provinces, 228,918, accounted for 32 % of Fiji's population.

The distribution of population, number of households, and the average family size in 1986 are shown in Table E-2.2, in APPENDIX E. The contents of the table are summarized below:

Population, Number of Households, and Average Family Size in Districts Related to the Study Area, 1986

Province/ District	Population	Number of Households	Average Family Size (persons/hh)
Ba Province:			
Ba Dist.	44,416	7,675	5.8
Magodro Dist.	6,107	960	6.4
Tavua Dist.	25,509	4,325	5.9
Total	76,032	12,960	5.9
Ra Province:			
Rakiraki Dist.	15,325	2,690	5.7
Saivou Dist.	7,109	1,163	6.1
Total	22,434	3,853	5.8
Total in Study Area	98,466	16,813	5.9

In 1986, the Study Area had an approximate population of 98,500 with 16,800 households. The family size was 5.9 persons/hh on average, consisting of 6.1 persons/hh for Fijians, 5.8 persons/hh for Indians, and 4.9 persons/hh for other ethnic groups.

(3) Existing Socio-economic Conditions of Communities

1) Population, Number of Households and Family Size

In 1986, the population and number of households were 25,933 and 4,448 for 51 communities (except 8 communities where the population figures are unavailable) respectively, accordingly the average family size was 5.83 persons per household. This size is nearly equivalent to the average figure for the Study Area shown in the above table. The distribution according to each Tikina is provided in Section 2.3.2, Appendix-E.

2) Main Occupations and Average Income of Households

The households in the 59 communities are mainly sugar cane plantations. The households which engage in agricultural activities account for 82 % of the total number of households, where 66 % are self-employed and 16 % are wage laborers. The distribution of occupations according to each Tikina is shown in Section 2.3.2, APPENDIX-E.

The Study Area is one of the poorest areas in Fiji. The average monthly income per household in the survey area in 1992 was estimated at F$ 124 (equivalent approximately to the per capita income of F$ 280), consisting of F$ 74 in Ba Tikina, F$ 147 in Tavua Tikina, F$ 80 in Vuda Tikina, and F$ 150 in Rakiraki Tikina (refer to Table E-2.4, Appendix-E). These incomes are quite low compared to Fiji's average GDP per capita of F$ 1,200 in 1992.

3) Consumption and Sources of Domestic Water

Domestic water consumption in 1992, based on information obtained from the leaders of 59 communities, was estimated at 82 lpcd (litter/capita/day) on average and ranged from 20 to 200 lpcd for the 59 communities.

The percentage of water sources used by households is 7 % for the regional water supply system, 26 % for the communal water supply system, and 67 % for other water sources in the rainy season. On the other hand, in the dry season the percentages are

5 %, 15 %, and 80 %, respectively. The detail is described in Section 2.3.3, APPENDIX-E.

4) Distance to Water Sources and Hours Spent Fetching Water

In areas without water supply systems, the average distance to water sources is estimated at 194 meters in the rainy season and 903 meters in the dry season for the 59 communities in the survey area, based on information obtained from the leaders of the respective communities (refer to Table E-2.5 in APPENDIX-E).

On the other hand, based on information obtained through the questionnaires handed out to 179 households in the 59 communities, the average distance to the water sources, are summarized, according to water source and season, below:

Average Distance from Households to Water Sources

Seasons	Water Sources			
	D.W.	T.W.	R.C.S.	Others
Rainy Season	214	15	582	1,361
Dry Season	360	24	1,468	3,125

Note : Unit : meter
D.W. = Dug Wells T.W. = Tube Wells
R.C.S. = Rivers, Creeks and Springs
Others = supply from relatives, acquaintances, etc.

It is noteworthy that the average distance to R.C.S. and other sources in the dry season is over twice the distance in the rainy season. Details are provided in Tables E-2.7 and E-2.8 in APPENDIX-E.

Based on information obtained from the leaders of the 59 communities, the average amount of time which the inhabitants of areas without water supply systems spent to fetch daily water, was estimated at 0.8 hours/day/household (for an average distance of 194 m) in the rainy season and 2.0 hours/day/household (for an average distance of 903 m) in the dry season. In addition, emergency water was supplied by PWD's water tankers to about 25 (42 %) of the 59 communities, for 5 or 6 months during the dry season between 1990-1992.

On the other hand, according to information obtained through the questionnaires handed out to 179 households, the average number of hours spent to fetch water was 1.3 hours/day/household in the rainy season and 2.3 hours/day/household in the dry season. These figures are much higher than the information obtained from the leaders of the communities.

5) Consciousness of Inhabitants with Regard to the Existing Water Supply

According to information obtained from the leaders of the 59 communities, more than 90 % of the total number of inhabitants are dissatisfied with the insufficient amount of water supplied, and 42 % of the inhabitants feel that at present, the water supply costs are expensive, including the cost of operating motors for drawing water from wells, the hours spent to fetch water from the water sources, and the cost of obtaining water from buyers, in areas without a water supply system. A detailed breakdown is presented in Table E-2.6 in APPENDIX-E.

6) Women's activities

The activities of housewives were examined using questionnaires handed out to the leaders of 55 communities (except 4 communities without available data). Housewives in the survey area spend an average of 3.8 hours per day engaged in farming and other activities. The housewives in Tavua and Rakiraki Tikinas spend longer hours engaged in farming or other activities than those in Ba and Vuda Tikinas (refer to Table E-2.4 in APPENDIX-E). This may be due to the fact that the ratio of farming wage labor households to the total number of households in the former two Tikinas is higher than that of the latter two Tikinas, and that many housewives of the wage labor households are involved in farming activities during the day.

7) Waterborne Diseases

The number of cases of waterborne diseases, according to information obtained from the leaders of 59 communities, was estimated at an average of 27,000 persons per annum for the period between 1990 and 1992. This corresponds approximately to one case/person/year (refer to Table E-2.6 in APPENDIX-E).

Tavua Tikina had a comparatively high number of waterborne disease cases, about 2 per person, and 9 deaths per annum. However, almost all of these were simple diarrhea cases, and in general good sanitary conditions are being maintained in these areas.

8) Water Cost per Household and Willingness to Pay

The monthly cost of fetching water per household and the willingness of the inhabitants to pay for water supplied from the system was examined using questionnaires handed out to 179 households in the 59 communities. As a result, 166 samples for the water cost per household and 174 samples for the willingness to pay were obtained.

The average monthly cost of fetching water per household is estimated at F$ 3.0 for the Ba Tikina, F$ 10.1 for the Tavua Tikina, F$ 8.9 for the Vuda Tikina, F$ 2.9 for the Rakiraki Tikina, and F$ 6.4 for the whole survey area (refer to Table E-2.9, APPENDIX-E). These costs correspond to 4.0 %, 6.9 %, 11.1 %, 1.9 %, and 5.2 % of the average monthly income of households, respectively. This ratio is comparatively high, especially in the Tavua and Vuda Tikinas. It is desired that in general this ratio should not be more than 5 %.

The "Willingness to pay" of households is estimated at F$ 5.4 on an average per month for the Ba Tikina, F$ 11.4 for the Tavua Tikina, F$ 5.6 for the Vuda Tikina, F$ 6.8 for the Rakiraki Tikina, and F$ 8.2 for the whole survey area. These seem to be fairly high, judging from the actual monthly payment of F$ 2 or 3 per household, with a water supply system, in the Ba and Ra Provinces.

The amounts mentioned above for the "willingness to pay" correspond to 7.3 %, 7.8 %, 7.0 %, 4.5 %, and 6.6 % of the average monthly income of households, respectively, proving to be rather burdensome for the households.

2.5 Present Water Supply Systems

The Study Area is broadly divided into three districts in view of the water supply system, consisting of Ba, Tavua, and Rakiraki. Ba district embraces three Tikinas (Ba, Vuda in part and Magodro in part) including Ba town, and Tavua district includes two Tikinas (Tavua and Navosa in part) including Tavua and Vatukoula towns. Rakiraki district consists of Rakiraki and Saivou Tikinas including Rakiraki (Vaileka) town.

The water supply in the Project Area is composed of the PWD regional water supply systems, communal water supply systems constructed by communities, privately owned boreholes constructed with governmental subsidies, and water supply systems owned by private companies. Other than these systems, dug wells, tube wells, rainwater roof tanks, and river/creek water are the main sources of supply. In the dry season, many communities face water shortage problems, forcing emergency water to be supplied.

In this section, the present conditions of the water supply systems are described and the roles of the public governmental offices involved in the water supply sector are also set forth.

2.5.1 Public Water Supply Organizations

Planning and design of the regional water supply facilities is conducted in the Head Office of PWD in Suva. Construction and maintenance of the regional water supply facilities in the Study Area is conducted by the Western Divisional Office of PWD in Lautoka. Under the divisional office, PWD has respective branch offices in each district, Ba, Tavua, and Rakiraki, to facilitate operation and maintenance of the systems.

With regard to the water supply plan in the Study Area, various efforts have been emphasized by PWD. The following documents roughly present the latest water supply plan, including the future water demand forecast and recommendations for the extension of the water supply systems. Extensions have been conducted following the recommended plan.

- Ba Regional Water Supply Distribution Study, James Flugan, Peace Corp Volunteers, January 1985 (hereinafter referred to as the "Ba Report")

- Tavua-Vatukoula Regional Water Supply Study, Harrison Grierson Consultants Ltd., May 1985 (hereinafter referred to the as "Tavua/Vatukoula Report")

- Draft Rakiraki Water Supply Master Plan, Fred de Brujin, September 1985 (hereinafter referred to the as "Rakiraki Report")

The following pamphlet was prepared by PWD:

- Tavua / Vatukoula Regional Water Supply Scheme, PWD, November 1989 (hereinafter referred to the as "Tavua/Vatukoula Pamphlet")

PWD is also involved in the communal water supply, the borehole subsidy scheme, and the emergency water supply.

Other than PWD, the Ministry of Health (MOH) and the Ministry of Fijian Affairs and Regional Development (MFARD) are involved in government supported or implemented rural water supply programs. MOH sometimes implements or finances the communal water supply projects.

MFARD carries out communal water supply projects and is also responsible for the emergency water supply. The following report has been prepared by MFARD, in cooperation with United Nations Department of Humanitarian Affairs - South Pacific Office, to understand drought hazards and the vulnerability and conditions of the emergency water supply in periods of drought, for the whole area of Fiji. Recommendations for mitigation of future droughts are described in the report.

- Assessment of Drought Problems in Fiji, MFARD and United Nations Department of Humanitarian Affairs - South Pacific Office, April 1993 (hereinafter referred to as the "Drought Assessment Report")

2.5.2 PWD Regional Water Supply Systems

PWD has three piped water supply systems in the Study Area. The water supply systems cover a large area, with the towns as the water demand centers. Since the systems have spread outside the outskirts of the town areas, they have effectively become regional water supply systems rather than urban water supply systems. The service areas of the existing water supply systems and the future extensions, are shown in Fig. 2.5.1. The outlines of the systems and their existing conditions are briefly explained.

(1) Ba regional water supply system

1) Source of supply

The potable water for the Ba regional system is derived from three surface water sources and four groundwater sources.

The raw water system of the surface water sources consists of gravity and pumping systems. There are two gravity intakes on the upper Varaciva and Nawetavuni rivers and a pumping intake on the lower Varaciva river. The raw water abstracted at the three intakes is conveyed to the Waiwai water treatment plant through raw water mains. The total average flow into the treatment plant is 556 m^3/hr, (= 13,344 m^3/day), and the safe yield in periods of drought over a 15 year return period is estimated in the Ba Report, at 342 m^3/hr (= 8,200 m^3/day). However, the effective safe yield flowing into the treatment plant is only 80 l/sec (= 6,910 m^3/day = 288 m^3/hr) because the raw water mains of the gravity systems join on the way to the treatment plant, and the intakes of the two gravity sources are built with a difference in elevation of 5 m, causing only one gravity intake to function at any given time.

Four groundwater sources, Varavu, Navoli, Koronubu and Veisaru boreholes, are at present in operation for the regional system. The borehole water is pumped up to the service reservoir located in the vicinity of each borehole and delivered to house connections untreated. The boreholes were initially developed as a water source for the communal water supply system in the areas surrounding the boreholes. At present, the boreholes are used as one of the water sources for the regional system, being connected by pipeline.

The locations and features of the water sources are shown Fig. 2.5.2 and Table 2.5.1, respectively.

2) Water treatment plant

The Waiwai water treatment plant was expanded in 1991. The Ba Report states that originally the treatment plant consisted of only pressure filtration using 12 vertical pressure filters with a capacity of 23 m^3/hr each. Although a total capacity of 6,550 m^3/day was possible, it was reduced to about 6,000 m^3/day during heavy rainfall on account of the continual backwashing of the pressure filters due to the high turbidity of the raw water. However, the actual treatment capacity is assumed as 5,500 m^3/day based on the interview survey at the treatment plant.

To augment the production capacity, a primary sedimentation basin was constructed in 1991, and 8 pressure filters were added simultaneously. According to the interview survey, the total capacity was increased to 7,500 m^3/day by the augmentation. The features and present operation mode of the treatment plant are shown in Table 2.5.1. Treated water is directly delivered to the service reservoirs/house connections directly via two storage reservoirs in the treatment plant.

3) Distribution System

There are 5 existing service reservoirs, including the storage reservoirs in the Waiwai water treatment plant and 2 planned service reservoirs. The principal features of each reservoir are shown in Table 2.5.1 and their locations are shown in Fig. 2.5.2. In addition, the service reservoirs of the boreholes serve the nearby areas.

The AC trunk main, 300 mm diameter x 5,394 m long, connects the Waiwai treatment plant to Vaqia reservoir. The trunk main and the Vaqia reservoir were constructed simultaneously in 1989. The purpose of these structures is to augment the water supply on the east bank of the Ba river.

Vunisamaloa reservoir was constructed in 1990 in order to serve Vunisamaloa, Vaqia, Korovuto and Namada areas and the high area of Koronubu and Veisaru borehole zones. The water is pumped up from the Waiwai-Vaqia trunk main through the PVC pumping main, 150 mm diameter x 2,124 m long, at the booster pump station. The booster pump station was constructed in 1990. Two pumps, one for standby, are installed in the pump station. Each pump has 42 m in head and 11.5 l/sec in capacity. Varadoli reservoir used to supply water to the town area, but at present it is used for emergency purposes only as its water level is lower than the Hydraulic Gradient Level (HGL) of the pipeline in the vicinity of the reservoir.

The water for the Tauvagavaga reservoir is pumped up at the Tauvagavaga booster pump station. Two pumps, one for standby, were installed in the pump station. The detailed study for and design of the planned Vadravadra and Vadraulailai reservoirs have not been carried out and the plans are at a conceptual level.

(2) Tavua / Vatukoula regional water supply system

The Tavua waterworks were constructed in the 1950s and had abstracted water from the Nasivi river 800 m upstream of the Kings road bridge. The Vatukoula Gold Mine has its own water supply system which delivered untreated water for domestic and industrial uses to Vatukoula town. The risk of pollution of the water supply system due to chemical deposits of effluent from the mining were of concern for many years, as the abstraction was made downstream of the effluent point.

To cope with the increasing water demand and the risk of pollution, the government decided to develop a new water supply system. This scheme includes an intake on the Nasivi river downstream of the mine intake, but upstream of the effluent point, a treatment plant, and a service reservoir and supersedes the initial intake and treatment plant. The construction commenced in late 1986 with completion in November 1989. The scheme consists of Stage I and II, of which the existing facilities are included in Stage I.

The principle features and location of the regional water supply system are shown in Table 2.5.2 and in Fig. 2.5.3, respectively.

1) Source of supply

The intake is located just downstream of the Emperor Mine Intake on the Nasivi river. Water is abstracted by the submersible pumps as described in Table 2.5.2. The pumps are controlled either manually or by a signal generated by the water level in the main storage reservoir.

The Tavua / Vatukoula report reveals that the mine intake has 6 pumps housed in its intake tower. The pump capacity is $36m^3/hr$ (= 227 l/sec) each, with a pumping head of 120 m. The source capacity at the mine intake was studied and estimated by PWD as 250 l/sec in periods of drought over a 15 year return period. However, it is said that the Emperor Mining Company has water rights to abstract 250 l/sec of water. In periods of drought, there is no water available for the regional system when water is abstracted at the mine intake.

2) Water treatment plant

The water treatment plant consists of the mixing chamber, clarifier and filter. Their features are shown in Table 2.5.2. The treatment plant has been designed to treat 5,500 m^3/day (Stage I), and with future extension, 8,250 m^3/day (Stage II), by when it is envisaged 25,000 people will be served (2005).

The raw water AC rising main, 300 mm diameter x 500 m long, links the intake to the treatment plant. After the treatment process, treated water enters the pump well, from where it is pumped to the main storage reservoir through the clear water AC pipe rising main, 300 mm diameter x 1,050 m long. The booster pumps are controlled automatically by water passing from the treatment plant.

3) Distribution system

The service area at present extends from Tagitagi toward Ba and Nabuna toward Rakiraki including Tavua and Vatukoula towns and the area in between. The service area is planned to expand to cover Rabulu toward Rakiraki including Korovou, Balata, and Malele and Qalela toward Ba .

The water is delivered to consumers mainly through the old distribution pipes which are connected to the main storage reservoir by the distribution mains, AC pipe of 750 m in length and 300 mm in diameter. The storage reservoirs of the old Tavua water treatment plant are used as the service reservoirs of the Tavua town area and its neighboring area. And the Tagitagi reservoir, which was used as the storage tank of the Tagitagi borehole, and is abandoned at present, serves consumers in the west.

A booster pump station is planned at Nabuta about 4 km east, along Kings Road, of the Tavua town, to supply water for the eastern service area up to Rabulu. The plan, however, is still at a conceptual level.

(3) Rakiraki regional water supply system

The Rakiraki regional water supply system has a less documented definite plan and detailed study. The existing condition and proposals for the future extension of the system are set forth in the Rakiraki report, which is, however, at the draft level, and the augmentation plan has been undertaken in part according to the recommendations outlined in the report. PWD has the extension plans of the system, however, these are not documented yet.

Locations of the regional water supply facilities are shown in Fig. 2.5.4.

1) Source of supply

The potable water is derived from three surface water sources consisting of two gravity sources and one pumping source.

Narara and Nakasia creeks, the gravity sources, have a small catchment area at the intake point totaling 3.56 km^2. The available water of these two sources amounts to almost nil in the dry season. It has been reported that the water is usually of an acceptable physical quality for water supply, however, color and turbidity increase during the rainy season and bacteriological contamination is rather high. The Nakasia source consists of upper and lower intake dams. A storage tank was installed at the upper intake. During daytime in drought periods the upper source is closed to fill the storage tank and the lower source is opened to deliver water.

The pipes from the Narara and Nakasia sources join and deliver water to consumers in the upper part of the service area of the system. The joined pipes then connect to the distribution pipes from the town reservoir, which stores the water from the pumping source. Since HGL of the gravity pipe is lower than that of the pipe from the reservoir at the connecting point, the gravity water cannot enter the distribution system in the lower service area when water is delivered from the reservoir. When the yield of the Nakasia source is sufficient, all the gravity water comes from it, suppressing the Narara water, because the Nakasia source is more elevated.

The Nakauvadra pumping source is located 1 km south of the Vaileka town center. The water is pumped up by three pumps through two pressure filters to the storage reservoir (Town reservoir) which has a storage volume of 568 m^3 and WL of

116 m. The water from the pumping source is usually of a reasonable physical quality, but turbidity and color increase after heavy rainfall and bacteriological contamination is rather high. The pumping station has flooded several times.

2) Water treatment

There are no full treatment facilities in the system. Only chlorination has been carried out at both the gravity and pumping sources.

Both the gravity sources are separately chlorinated, in a concrete box located at the upper Nakasia and Narara intakes, by mixing in an amount of hypochlorite solution twice daily. This is a very inaccurate measure of disinfection and quite unreliable on a 24 hour basis. The disinfection method is considered to cause significant bacteriological contamination of both gravity sources. In addition, the Nakasia source is not disinfected during the closing period of the upper source.

The Nakauvadra pumping water is chlorinated in the pump sump at the pumping station by a continuous drip feed of hypochlorite solution. The water is pumped then through the pressure filters. Since the water is chlorinated prior to filtration, a lot of chlorine is absorbed by suspended particles especially after heavy rainfall when the river water displays a high content of suspended solids and a dark color. This chlorination method is inadequate.

3) Distribution system

The system is divided into daytime (5:30~20:30) and nighttime (20:30~5:30). In the daytime, the water from the pumping source is pumped to the Town reservoir and reticulated to the lower part of the service area (downstream of the reservoir) and the upper part of the service area is served with water from the gravity sources. In the nighttime, the pumped water is stored in the Town reservoir and is not reticulated. The water from the gravity sources is delivered to all the consumers in the service area.

When the water is discharged from the reservoir, the gravity water cannot be reticulated to the lower part of the service area.

4) Problems faced and measures to solve them

There are a lot of problems in adequately operating the existing water supply. The problems faced are;

(a) inadequate water treatment of both the gravity and pumping sources,
(b) impossible abstraction from the two gravity sources simultaneously,

(c) impossible reticulation to the lower part of the service area from the gravity and pumping sources simultaneously, and

(d) flooding of the pumping station.

To solve the above problems, the following measures have been considered and implemented in part.

(a)-1 to construct a water treatment plant including chlorination and filtration facilities for the gravity sources

(a)-2 to improve the existing water treatment facilities in the pump station and/or to construct a new water treatment plant for the pumping source

(b)-1 to improve the gravity intake facility by raising up the Narara dam

(b)-2 to duplicate the pipe from the Narara intake

(c)-1 to construct a "Low Level Reservoir" for the gravity sources

(c)-2 to install a bypass pipe in the town area: This installation was done in 1993 not only for problem c) but also for the future extension of the service area described below

(d)-1 to relocate the pump station and to construct new water treatment works

(d)-2 to construct boreholes for replacement of the pumping source

These measures are schematically illustrated in Fig. 2.5.5.

As well as measures to solve the problems faced at present, the future expansion plan of the service area has also been considered at a conceptual level. PWD has a plan to create two service areas as follows: "Town Area" to be served with water from the pumping source via the existing Town reservoir, and "Other Areas" to be served with water from the gravity sources via the planned low level reservoir. To expand the service area toward the east, the installation of the bypass pipe was done as described above. A booster pump station may be constructed, depending on HGL required, to supply water to the edge of the service area in the future expansion.

2.5.3 Other Water Supply Systems

(1) Communal water supply systems

Three governmental offices, MFARD, MOH and PWD, are involved in the implementation and financial assistance of the communal water supply system projects. The systems are organized by only one office, which receive requests from the communities.

Projects conducted by MFARD are carried out under the responsibility of the MFARD District Officer. The projects typically include a borehole with a pump, a storage tank, and a gravitation fed piped water supply. In general, MFARD provides the storage tank and pipes, and the community pay for the other parts, and provide the unskilled labor. MOH, through its district health officers, sometimes implements or finances communal projects as well. Not all the water supply facilities implemented by MFARD and MOH are well engineered, therefore, problems with the facilities have occasionally arisen.

PWD has constructed communal water supply systems under the "Self-help Rural Supply Scheme" which has been implemented by the government during the past 20 years. "Rural Water Supply in Fiji" was prepared by PWD as the manual for the survey, design, and cost estimate of the systems. The survey, design, and cost estimate are carried out by PWD.

The cost of the scheme is apportioned in the following way:

- The cost of the construction material required to complete the system is estimated and the community is required to contribute one-third of the cost.
- The government contributes the remaining two-third of the cost for the construction materials, together with the costs of transportation to the nearest road access or landing point and the provision of skilled labor such as pipe fitters.

Thus, when the scheme is proposed the community is required to provide the following:

- The required funds to be deposited with PWD to cover one-third of the cost of the construction materials.
- Transportation of the construction materials from the ship or nearest road access.
- When construction is being carried out, all necessary unskilled labor and housing for the PWD employees engaged on the scheme.

When the system is completed, PWD maintains the system for a period of 6 months, then it is handed over to the community, which becomes entirely responsible for maintenance and repair.

(2) Borehole subsidy

The objective of this scheme is to encourage private people or groups of people to develop boreholes for water supply by offering a government subsidy towards the cost of the works. The procedure for requesting the subsidy and construction of the boreholes with the subsidy is as follows:

- applications to PWD by a person / people requesting the subsidy
- checking of the applications by PWD and written approval of the subsidy by PWD
- arrangement with a contractor for construction of the borehole and land and site access arrangement by the applicant
- provision of a written notice, at least one day before the commencement of the work by the contractor, to the Divisional Engineer of PWD
- site inspection by PWD within 14 days after the commencement of the work
- admission and payment to the contractor

The contractor shall guarantee the completed borehole for a period of two years from the date of the PWD inspection. In general, applications are not approved in areas where the PWD water supply is available, or where there already is an alternative and reliable water supply. The subsidy only covers the borehole and never exceeds F$1,000 for any one borehole. The pumping equipment, engines, pipework, tanks, and all other fittings, together with their O&M, are entirely the applicant's responsibility.

(3) Water supply systems owned by private companies

The Fiji Sugar Corporation (FSC) water systems supply piped water for industrial use in the FSC factories and domestic use in the employees quarters. The source of the systems is surface water from rivers/creeks. There are two FSC systems, are in Ba and one in Rakiraki. The systems are independent water supply systems of the PWD regional system.

The FSC system in Ba abstracts water from the Samau creek, one of the tributaries of the Ba river. The water is chlorinated at the intake and then delivered to the FSC quarter, located near Ba town. Three boreholes were dug within the quarter for emergency domestic water supply.

The FSC system in Rakiraki, which normally abstracts water from the Tuvavatu river and the Penang river in drought periods, is only used for running the factory, while the Rakiraki regional system is used to serve the staff quarters. FSC has indicated that it will continue to provide its own independent water supply to run the mill. Although in emergency situations a request may be made to PWD to use PWD regional water, no extra allowance needs to be made to provide the sugar mill with water.

The Dayal system was constructed in 1957 prior to the PWD Ba regional system. Water is abstracted at the intake dam on Waise creek and delivered directly to the households without treatment or being stored in a reservoir. The service area of the Dayal system is adjacent to that of the Ba regional system along the northern border, and has been reduced in accordance with the extension of the regional system. Presently the Dayal system serves about 300 households with a charge of F$80 per household annually. However, the collection of the charges is inefficient and the Dayal company would like to sell the system to PWD. The people who use the Dayal System have complained of its poor water quality and insufficient water quantity.

(4) Emergency water supply

The emergency water supply is an arrangement by which the government supplies water for household purposes to those facing serious problems with their normal water supply. The arrangement is not necessarily limited to drought situations, but also includes people suffering from failures in the piped water schemes, areas in which wells dry up or areas where other problems, not directly attributable to the people, exist. However, the emergency water supply is only utilized when larger areas are affected by the continued lack of rainfall, causing normal water sources to be disrupted.

Since 1984, MFARD became responsible for the supply of emergency water to drought stricken areas through the Divisional Offices and the Head Office of MFARD. Although relieved of the task, PWD still handles the transportation/carting to the affected areas. The District Officers of MFARD are responsible for the evaluation of requests and their compilation, and the Divisional Commissioner is responsible for the budget. The government has consistently allocated F$100,000 for this purpose, which at times was insufficient. The highest yearly expenditure on emergency water was in 1987, when F$1,182,701 was spent.

The procedure for requesting and distributing emergency water is as follows:

- complaint/request to the District Officer of MFARD by the Chairman of the Advisory Council or village representative (including a list of people in need of water)
- checking of the request by the District Officer/Health Inspector of MFARD

- request by the District Officer to the Divisional Commissioner of MFARD for emergency supply to his district (with a list of names and settlements)
- approval of the Divisional Commissioner/Planning Officer of MFARD and request to the Chief Water Engineer of PWD to supply emergency water
- instruction from the Chief Water Engineer to the District Water Engineer of PWD to cart water to the specified areas and people

The emergency water supply delivered by trucks with 1,000 gals. water storage tanks, supply each family with two drums of water on a weekly or twice weekly basis. People have to have their own storage drums.

2.5.4 Present Conditions of Water Use

To initially clarify the present condition of water use in the Study Area, all of the communities were identified based on the existing information obtained through the interview surveys at the governmental offices concerned and by site reconnaissance. Out of the communities identified, some communities were selected as facing severe and recurrent drought, and a questionnaire survey was carried out for them in order to grasp the present status of water use in their areas, and to identify the extent of water supply problems and needs for the Project.

Besides, the questionnaire survey aimed at obtaining information on women's roles concerning water use, so called "Women in Development"

(1) Identification of the communities

There are no statistical data/information on the communities other than the population census, and information on the type of water supply system in each community is not well documented. Therefore, identification of the communities in the Study Area was conducted based on the 1986 population census. The lists of communities provided with emergency water supply in 1992, shown in the Drought Assessment Report, were also referred to. The locations of the communities were identified in cooperation with the PWD staff in the Head Office/ Western Divisional Office, as well as in the District Office.

The communities in the Study Area are listed in Table 2.5.3 and their locations are shown in Fig. 2.5.6.

(2) Present water use

The present water use of each community is classified in accordance with the kind/mode of the existing water supply described in Sub sections 2.5.2 and 2.5.3, and listed in Table 2.5.3.

In general, the older villages are traditionally located near adequate water sources, whereas newer settlements are often located in drier areas. These areas are adequate for the crops grown by the settlements, mainly sugarcane, but their water supply is more vulnerable. Moreover, these settlements are often more dispersed, which makes it more difficult to provide them with an adequate water supply. This is the reason that these settlements tend to rely more on privately dug wells.

In the Ba Tikina, there are 68 communities, of which 41 are served with piped water from the Ba regional water supply system and 3 communities will be served in the future. Piped water supply systems have been well developed for the communities. 59 communities in the Ba Tikina, around 85 % , are served with piped water at present.

The Magodro and Navosa Tikinas are located in hilly and/or mountainous areas. Most of the communities are Fijian villages. On account of their locations, it is expected that creeks are adequately used as water sources although the kind of water used is not documented/identified in some communities.

46 communities were identified in the Tavua Tikina. The Tavua/Vatukoula regional water supply serves only 11 communities at present, but will serve 8 more communities after the expansion of the system. Although, a new water treatment plant for the system was constructed, the distribution system has not been well developed. In 1992, 29 communities, around 60 %, were supplied with emergency water.

In the Rakiraki Tikina, 33 communities were identified. The existing Rakiraki regional water supply system serves a limited area in and around Rakiraki town. Almost all of the communities are located outside the present service area. Nevertheless, 21 communities have a piped water supply system, as the communal water supply system has been developed in 19 communities.

Three communities in the Vuda Tikina are located on a narrow plain lying between the mountain and the sea. Due to their topographic conditions, tube and dug wells and small creeks are the dominant water sources in the communities. The communities in the Saivou Tikina are served with creek water from the Rakiraki regional water supply and/or communal water supply systems.

(3) Questionnaire survey

To select the communities for the survey, data on their present water supply and especially their drought problems, were a prerequisite . However, historical data and statistics on drought problems in Fiji are scarce, which makes it difficult to identify the specific areas that experienced drought over the years. In the Drought Assessment Report, it is stated that the provision of emergency water was used as an indicator for drought proneness, since the emergency water supply is not restricted to specific areas. All drought prone areas seem to have been covered by emergency water.

Therefore, the communities where emergency water was supplied in 1992 in the report, were firstly identified as the area, facing water shortages. 74 communities were identified as shown in Table 2.5.4. Among them, slightly affected communities were excluded from the questionnaire survey based on the affected ratio (No of Households/No. of Families affected) and results of the interview survey at the PWD District Office. In due consideration of the geological and hydrogeological aspects, the communities located in the areas in which groundwater potential is not expected were also excluded. Finally, 59 communities were selected for the survey as listed in Table 2.5.4 and their locations are shown in Fig. 2.5.7.

Two kinds of questionnaire form, one for representatives of the community and the other for households, were prepared. The forms for the questionnaires are shown in APPENDIX-D. At first, visits were made to the representatives of the communities to obtain information about the whole area. In addition to this information, three households in each community were interviewed to obtain more detailed information and to confirm the information about the community. In order to avoid collecting partial information, household interviewees were selected, where possible, in consideration of their different types of water use. And women were selected to obtain their opinion in due consideration of women's role in development.

The survey covered 59 communities, of which 6 were Fijian Villages and 53 were Indian settlements. The households in the Fijian villages are densely located, but those in the Indian settlement are scattered. 59 samples from the representatives of the communities and 177 (3x59) samples from households were collected.

In 10 communities, a regional water supply system covers the whole or part of the community however, water shortages and problems, such as insufficient quantity of water and low pressure are encountered, especially in the dry season. Communal water supply systems have been developed in 33 communities. Out of these, 7 communities face problems with their system, such as the water supply facilities not functioning and the inability to repair facilities due to financial problems. Systems are under construction or are to be developed in three communities.

In the communities without a regional or communal system and/or communities where the systems cannot cover all the water demands, tube and dug wells and rainwater are mainly used in the rainy season and tube wells and river/creek water are the dominant water sources in the dry season. The water is usually fetched in pulling drums (44 gal = 200 l) by trucks/vans or bulls in the morning and/or evening. Men carry out this work. Women and children also bring water from the dug wells and creeks, located in the vicinity of a household, by buckets (9~20 l), but this is not the women's specific job, rather it is the men's job. In Fiji, people carrying water on top of their heads has not been seen for 20 ~ 30 years. In general, women perform housework, and some women work on farms.

Emergency water has been supplied every year to almost all of the communities between August and December in the form of two drums of water, on a weekly or twice weekly basis, per household. Water-borne diseases, such as infectious diarrhea, dysentery, typhoid fever, skin disease, and eye infections are generally encountered in almost all of the communities. However, there are no cases of death caused by water-borne diseases.

Based on the results of the survey, the percentage of water used was estimated by the water sources in both the rainy and dry seasons, as shown in Table 2.5.5. An adequate water supply is judged by such as its reliability, quality, and convenience, therefore the regional and communal water supply systems and privately owned tube wells are considered adequate. Therefore, the total percentages of the regional, communal, and tube well water used were regarded as an indication of an adequate water supply and were estimated by each community, as shown in Table 2.5.5.

The present condition of the adequate water supplied is classified into the following three degrees, and also shown in Table 2.5.5.

Degree	Condition	Percentage of Adequate Water Supply
A	Moderate	more than 70
B	Poor	between 20 and 70
C	Extremely Poor	less than 20

2.6 Groundwater Use

2.6.1 Well Inventory

A well inventory survey was carried out at the first and third field investigation by the JICA-MRD Study Team to obtain hydrogeological information and water use data, as shown in DATA BOOK-A.1. As a result, 531 existing wells in total are registered in the Study Area, as shown in Table DATA BOOK-A.2, of which 471 are private boreholes, 37 are dug wells, 12 are PWD boreholes, and 11 are MRD test wells. The location of these registered boreholes and dug wells is shown in Fig. 2.6.1.

Of the 471 private boreholes, 39 have been abandoned due to their poor production of water and 61 have been left unused due to insufficient maintenance of the pumps. Eight out of 12 PWD boreholes have been abandoned, because of poor production of water. Among the 11 MRD test wells, two have been abandoned due to their poor aquifer condition.

2.6.2 Groundwater Use

A considerable amount of groundwater is abstracted for domestic use. Groundwater pumped from private boreholes is usually supplied to each house through house connection pipes. One borehole usually provides water for only one household due to the small discharge rate. An engine driven turbine pump and a centrifugal pump are commonly used by boreholes, however, submersible motor pumps have recently been distributed in accordance with the progress of electrification.

The standard private borehole pump runs for several hours per day with a discharge rate of 0.3 to 0.8 l/sec. Therefore, the daily pumping amount of a standard private borehole is estimated to be 0.38 - 0.76 cubic meters. The estimated amount of groundwater reaches 933 cubic meters per day, in total, for each classified area, as shown in Table 2.6.1. The greatest abstraction of groundwater in the Study Area occurs in the Ba Uplands where around 300 cubic meters of it is pumped daily, both by the private boreholes and by the PWD boreholes of the water supply system. On the other hand, 125 boreholes are concentrated along the coastal plain of Tavarau-Raviravi.

Based on the operation record of the pumps and the measurement of discharge rates using a portable diagonal flowmeter, the annual abstraction amount of groundwater from the four PWD production boreholes was estimated to be 117,365 m^3, as shown in Table 2.6.2. The latter amounts to less than 4 per cent of the whole water supply of the Ba water supply system (See Fig. 2.6.2). Irregularities in the monthly abstraction amounts occurred due to the mechanical maintenance of the pump facilities.