社会開発調査部報告書

THE STUDY
ON
GROUNDWATER
DEVELOPMENT PROJECT

LIST OF REPORTS

DOMINICAN REPUBLIC
INSTITUTO NACIONAL DE AGUAS POTABLES
Y ALCANTARILLADOS

THE STUDY ON GROUNDWATER DEVELOPMENT PROJECT IN THE WESTERN REGION DOMINICAN REPUBLIC

VOLUME II

MAIN REPORT

AUGUST 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the Dominican Republic, the Government of Japan decided to conduct a Study on Groundwater Development Project in the Western Region and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Dominican Republic a study team, headed by Dr. Masaichi Nakayama of Kokusai Kogyo Co., Ltd., and composed of members from Kokusai Kogyo Co., Ltd., and Sumiko Consultant Co., Ltd. three times between October 1990 and June 1992.

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

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Dominican Republic for the close cooperation they extended to the team.

August, 1992

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

August 1992

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Yanagiya

Letter of Transmittal

We are pleased to submit to you the development study report on the Groundwater Development Project in the Western Region, Dominican Republic. The report contains the study results on the potentiality of groundwater resources in the four western provinces of Dominican Republic, the master plan of water resources development including the water supply plan for 158 villages in the same region, and the implementation plan for 58 priority villages.

This report consists of three separate volumes of Summary, Main and Supporting Reports. The Summary Report states concisely the whole study results. The Main Report describes the study background, socio-economic situation, potentiality and plan of groundwater development and the implementation plan and recommendation for the 58 priority villages. The Supporting Report contains the conditions applied in planning, details of each study results, and reference figures and cost estimation data of facilities and systems in water supply plan and implementation plan.

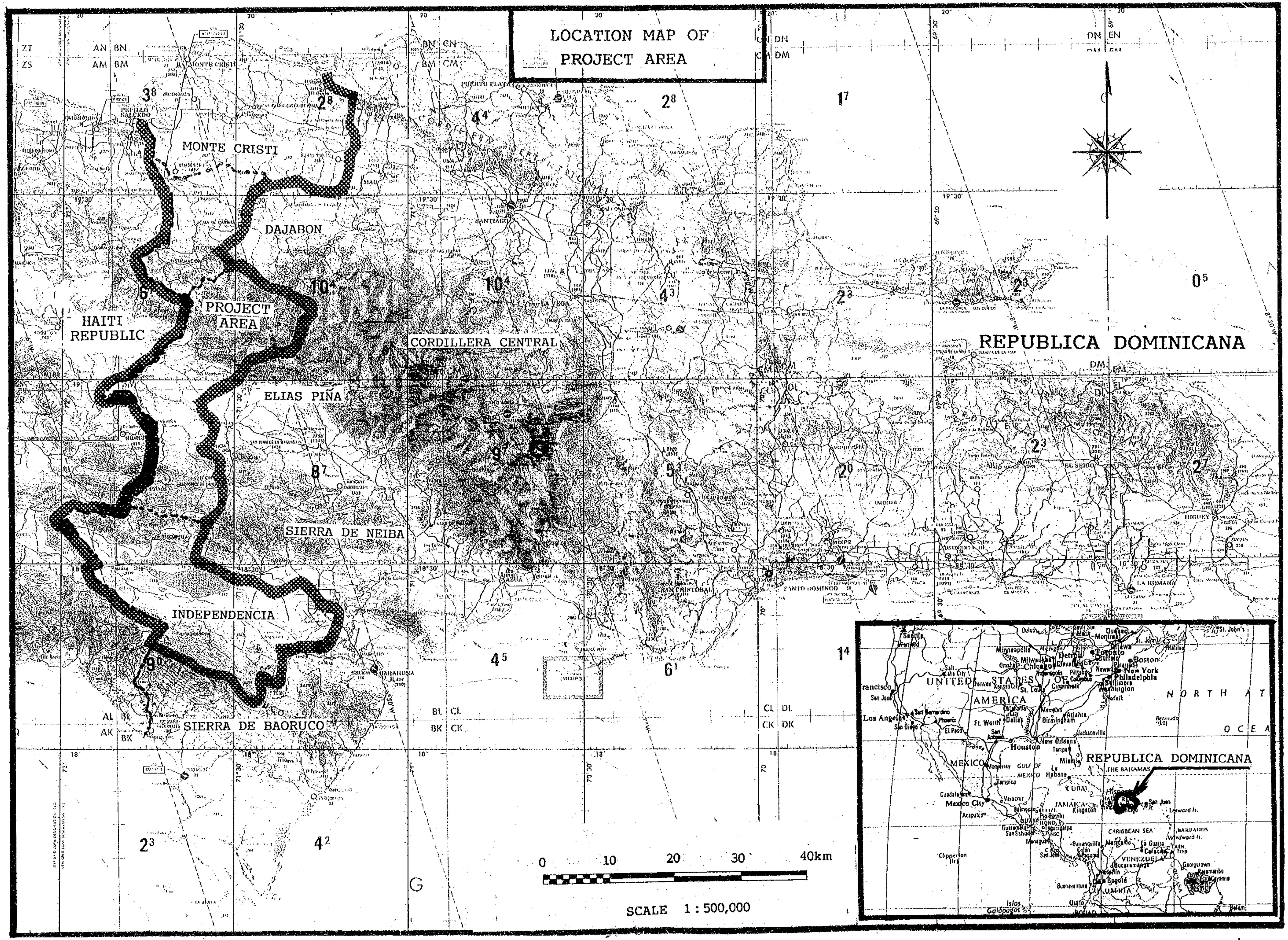
In view of the water shortage conditions, of the need for socio-economic development and of national security in the Western Region, as a whole, we recommended that Dominican Republic Government implement this Project as a top priority.

We wish to take this opportunity to express our sincere gratitude to your Agency and the Japanese Embassy at Santo Domingo. We also wish to express our deep gratitude to the authorities concerned of Dominican Republic Government for the close cooperation and assistance extended to us during our investigation and study.

Very truly yours,

M. Nakayama

Masaichi Nakayama
Team Leader
The Study on Groundwater Development Project in the Western Region, Dominican Republic


LOCATION MAP OF
PROJECT AREA
MONTE CRISTI
DAJABON
PROJECT
AREA
HAITI
REPUBLIC
CORDILLERA CENTRAL
ELIAS PIÑA
SIERRA DE NEIBA
INDEPENDENCIA
SIERRA DE BAORUCO
REPUBLICA DOMINICANA
SANTIAGO
LA VEGA
SANTO DOMINGO
SAN CRISTOBAL
LA ROMANA
HIGUEY
EL SEIBO
BARAHONA
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PUERTO PLATA
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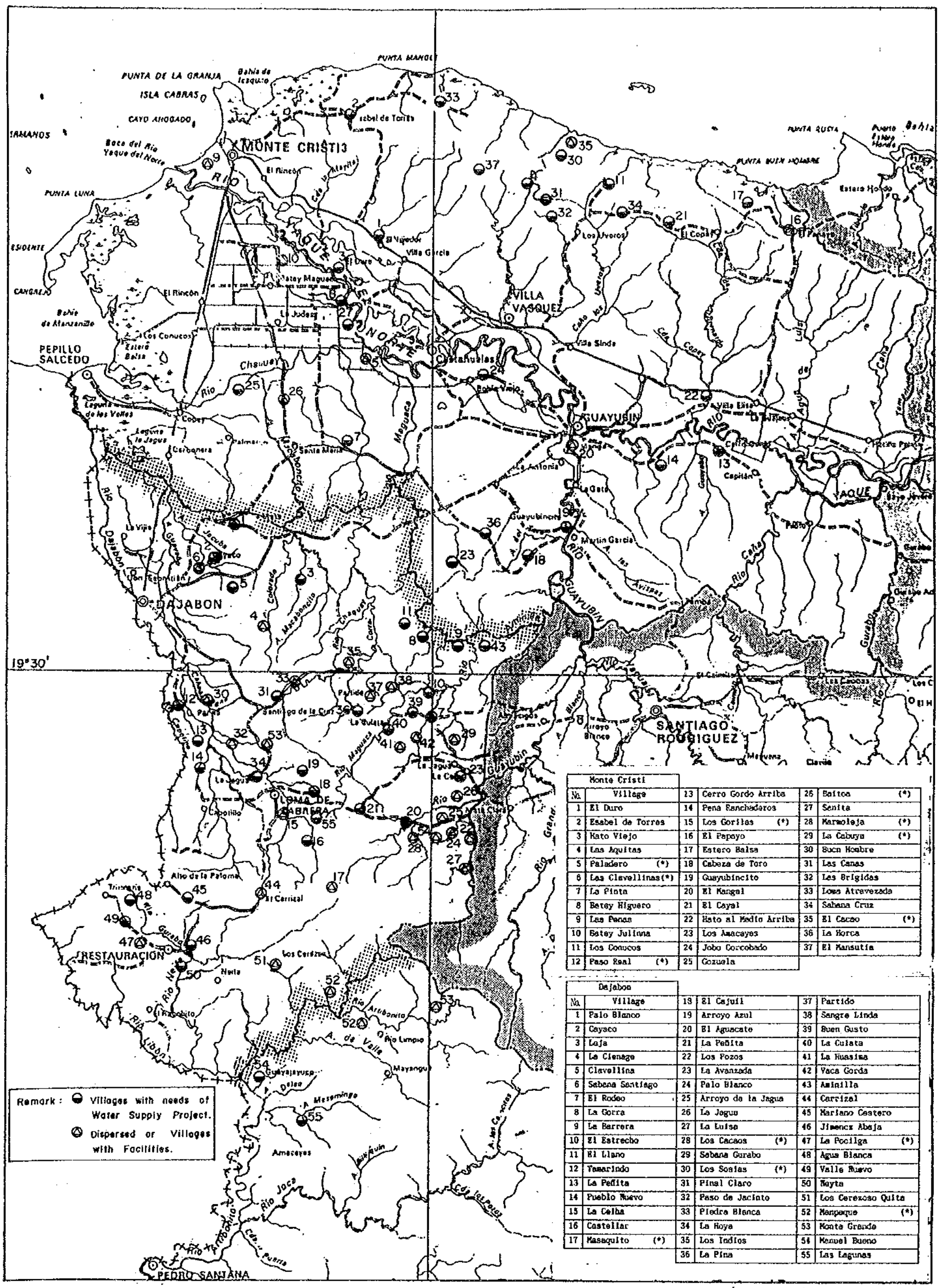
UNITED STATES OF AMERICA
MEXICO
NORTH AT
OCEA
REPUBLICA DOMINICANA
CARIBBEAN SEA
VENEZUELA

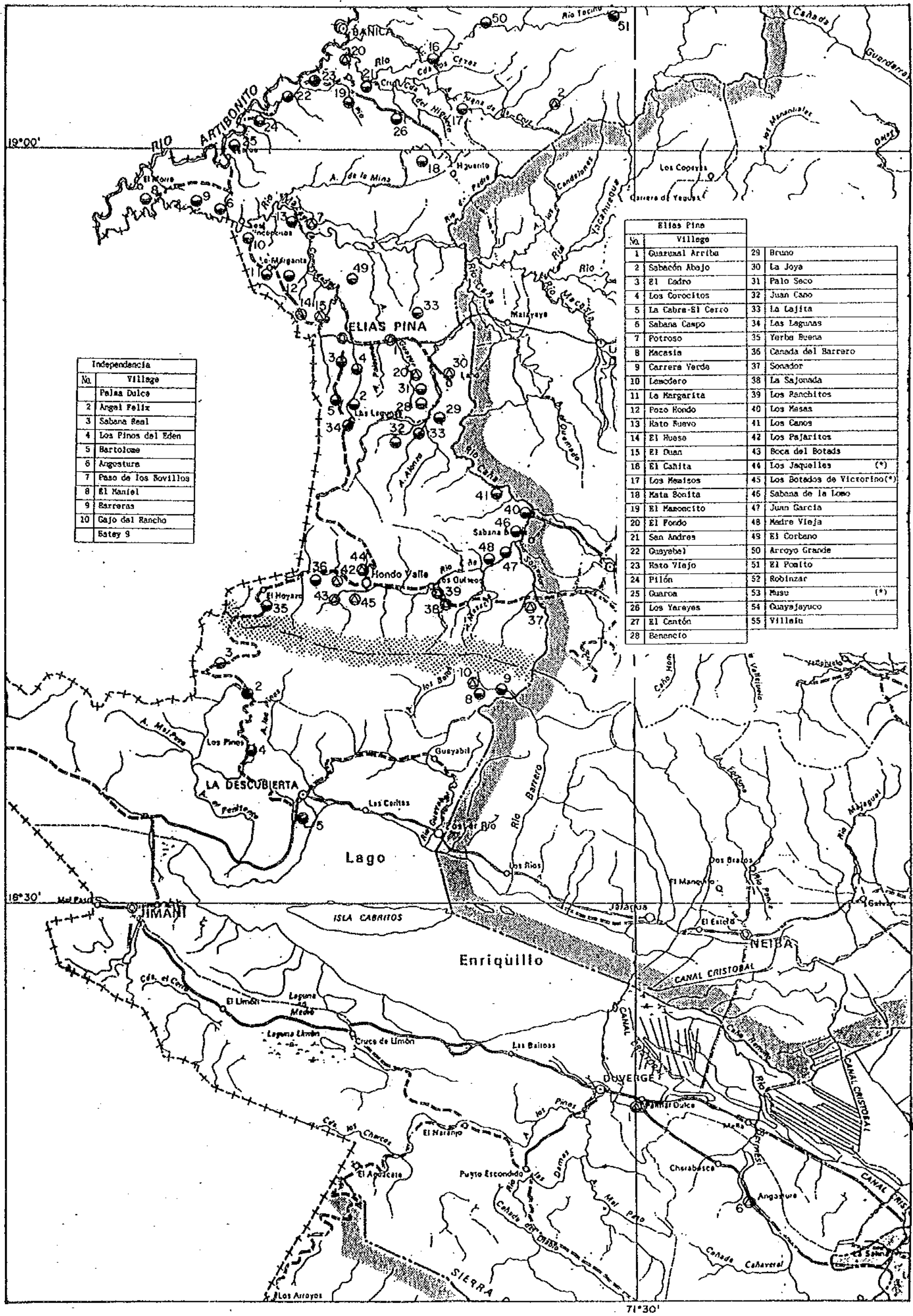


Monte Cristi					
No.	Village	13	Cerro Gordo Arriba	26	Baitoa (*)
1	El Duro	14	Pena Ranchadaros	27	Senita
2	Esabel de Torres	15	Los Gorilas (*)	28	Marmoleja (*)
3	Hato Viejo	16	El Papayo	29	La Cabuya (*)
4	Las Aguitas	17	Estero Balsa	30	Buen Hombre
5	Paladero (*)	18	Cabeza de Toro	31	Las Canas
6	Las Clavellinas(*)	19	Guayubincito	32	Las Brigidas
7	La Pinta	20	El Mangal	33	Loma Atravezada
8	Batey Higuero	21	El Cayal	34	Sabana Cruz
9	Las Penas	22	Hato al Medio Arriba	35	El Caceo (*)
10	Batey Julinna	23	Los Amacayes	36	La Horca
11	Los Conucos	24	Jobo Corcobado	37	El Mansutia
12	Paso Real (*)	25	Gozuela		

Dajabon					
No.	Village	18	El Cajuil	37	Partido
1	Palo Blanco	19	Arroyo Azul	38	Sangre Linda
2	Cayaco	20	El Aguacate	39	Buen Gusto
3	Loja	21	La Peñita	40	La Culata
4	La Cienaga	22	Los Pozos	41	La Huasima
5	Clavellina	23	La Avanzada	42	Vaca Gorda
6	Sabana Santiago	24	Palo Blanco	43	Aminilla
7	El Rodeo	25	Arroyo de la Jagua	44	Carrizal
8	La Gorra	26	La Jagua	45	Mariano Castero
9	La Barrera	27	La Luisa	46	Jimencz Abaja
10	El Estrecho	28	Los Cacaos (*)	47	La Pocilga (*)
11	El Llano	29	Sabana Gurabo	48	Agua Blanca
12	Tamarindo	30	Los Sosias (*)	49	Valle Nuevo
13	La Peñita	31	Pinal Claro	50	Neyta
14	Pueblo Nuevo	32	Paso de Jacinto	51	Los Cerezoso Quita
15	La Ceiba	33	Piedra Blanca	52	Manpaque (*)
16	Castellar	34	La Hoya	53	Monte Grande
17	Masaquito (*)	35	Los Indios	54	Manuel Bueno
		36	La Pina	55	Las Lagunas

Villages Location Map (1/2)

0 5 10 15 km



Independencia	
No.	Village
	Palma Dulce
2	Angel Felix
3	Sabana Real
4	Los Pinos del Eden
5	Bartolome
6	Angostura
7	Paso de los Novillos
8	El Maniel
9	Barreras
10	Gajo del Rancho
	Batey 9

Elias Pina			
No.	Village		
1	Guaruaal Arriba	29	Bruno
2	Sabacón Abajo	30	La Joya
3	El Cadro	31	Palo Seco
4	Los Corocitos	32	Juan Cano
5	La Cabra-El Cerro	33	La Lajita
6	Sabana Campo	34	Las Lagunas
7	Potroso	35	Yerba Buena
8	Macasia	36	Canada del Barrero
9	Carrera Yerda	37	Sonador
10	Lamedero	38	La Sajonada
11	La Margarita	39	Los Ranchitos
12	Pozo Hondo	40	Los Mesas
13	Hato Nuevo	41	Los Canos
14	El Hueso	42	Los Pajaritos
15	El Duan	43	Boca del Botada
16	El Cañita	44	Los Jaquelles (*)
17	Los Mesisos	45	Los Botados de Victorino(*)
18	Mata Bonita	46	Sabana de la Loma
19	El Maroncito	47	Juan Garcia
20	El Fondo	48	Madre Vieja
21	San Andres	49	El Corbano
22	Guayabal	50	Arroyo Grande
23	Hato Viejo	51	El Pomito
24	Pilón	52	Robinzar
25	Guaroa	53	Musu (*)
26	Los Yareyes	54	Guayajayuco
27	El Cantón	55	Villalu
28	Benancio		

Villages Location Map (2/2)

0 5 10 15 km

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND GLOSSARY

CAASD	Santo Domingo Water Supply and Sewage Corporation
CCT	Computer Compatible Tape
CIDA	Canadian International Development Agency
CORAASAN	Santiago Water Supply on Sewage Corporation
FUDECO	Foundation for Community Development
GNP	Gross National Product
GTZ	German Technical Cooperation Agency
IDB	Interamerican Development Bank
IDSS	Dominica Institute of Social Insurance
IGU	Geographic Institute of Santo Domingo University
IICA	Inter-American Institute for Agricultural Cooperation
IMF	International Monetary Fund
INAPA	National Institute for Potable Water Supply and Sewerage
INDRHI	National Institute of Water Resources Development
JICA	Japan International Cooperation Agency
NGO	Non-Governmental Organization
OAS	Organization of American States
ONAPLAN	National Planification Office
PAHO/WHO	Pan American Health Organization /World Health Organization
PLANDZF	Border Zone Development Plan
PLANAR	Rural Waterway National Plan

PLANIACAS	National Plan for Groundwater Development and Control
SESPAS	Ministry of Public Health and Welfare
SSID	Dominican Churches Social Service
TM	Thematic Mapper
UNEPLAN	Executive Office for National Rural Waterway Plan
USAID	United States Agency for International Development

UNITS

Length

mm	:	millimeter
cm	:	centimeter
m	:	meter
km	:	kilometer
inch	:	25.4 mm
ft	:	foot = 12 inch-30.48cm
mille	:	5,280 feet = 1,629km

Area

cm^2	:	square centimeter
m^2	:	square meter
km^2	:	square kilometer
ha	:	hectare
Ta	:	tarea = 625 m^2

Capacity

ℓ	:	liter
m^3	:	cubic meter
hm^3	:	million cubic meter
$g\ell$	:	gallon = 3,785 lit

Weigh

g	:	gram
mg	:	kilogram

Others

h	:	hour
min	:	minute
sec	:	second
cm/sec	:	centimeter per second
m^3/sec	:	cubic meter per second
ℓ/sec/km^2	:	liter per second per square kilometer

CHAPTER I

INTRODUCTION

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INTRODUCTION

1.1 Authorization

This Final Report was prepared in accordance with the Scope of Work for the "Study on Groundwater Development Project in the Western Region of the Dominican Republic" (hereinafter referred to as 'the Project'), agreed upon between the Instituto Nacional de Aguas Potables y Alcantarillados (INAPA) and the Japan International Cooperation Agency (JICA) on February 13, 1990.

This Final Report deals with the study on the Project based on the results and analyses of the first and second field survey and works in Japan conducted between October, 1990 and March, 1992.

1.2 Project History

The National Development Plan of the Dominican Republic placed high priority on the development of the western border. Accordingly, the "Border Area Development Plan" was formulated in 1987 through the technical cooperation of the Organization of American States. In connection with the implementation of this Plan, in 1988 INAPA requested the Government of Japan for Grant Aid for the rural water supply project in the four provinces located along the western border of the country.

In response to the request, the Japanese Government conducted a project formulation survey in March 1989, pointing out, as a result, the need to undertake a study designed to assess the potential of groundwater development. In November 1989, the Government of the Dominican Republic requested the Government of Japan technical cooperation for the study on groundwater potential and the preparation of a rural water supply plan for the four provinces along the western border.

The Japanese Government dispatched the JICA Preliminary Study Team in February 1990 to the Dominican Republic, reaching agreement on the Scope of Work of the Project. Survey activities commenced in October 1990.

1.3 Objectives of the Study

The objectives of the Study are as follows:

1) To evaluate the development potential of groundwater and alternative water resources in the four western provinces: Monte Cristi, Dajabón, Elias Piña, and Independencia.

2) To prepare the water resources development plan including a rural water supply plan for the158 villages in the four western provinces.

3) To perform technology transfer to INAPA's counterpart personnel in the course of the Study.

1.4 Scope of Work

1.4.1 Study Area

The Study Area is located in the western region of the Dominican Republic, covers the four provinces - Monte Cristi, Dajabón, Elias Piña, and Independencia - along the border of the Republic of Haiti, and measures 6,527km^2.

1.4.2 Study Components

The Study included both field survey and home office components.

1) Field Survey
   (1) Collection, collation and analysis of all data and information relevant to the Project;
   (2) For groundwater and surface water development planning: topographical, hydrological, meteorological, hydraulic and geologic survey, water resources development and utilization survey, electric prospecting, test well boring, test pumping, etc;
   (3) For water service supply planning: socio-economic survey; water demand and supply survey, water service facilities adjustment, operation and maintenance survey;
   (4) For operation and maintenance planning: survey of current water production and supply system and existing operation and maintenance structure;
   (5) For facilities design: labor and materials cost survey, labor and material availability survey, topographical study.

2) Home Office Works
   (1) Analysis of existing water demand, and future demand projection in the study area; and the formulation of a water supply plan on the basis thereof;

(2) Evaluation of groundwater and surface water characteristics and development potential; and, on the basis thereof, formulation of a groundwater and surface water development plan;
(3) Integration of preliminary design of groundwater development and water supply facilities and construction cost;
(4) Formulation of an operation and maintenance plan for water production and supply facilities;
(5) Formulation of a proposed Implementation Plan; and
(6) Project Evaluation.

1.5 Activities and Composition of The Study Team

The Team undertook field and home office works in the following stages.

First Stage	Field Work:	October 1, 1990 - January 28, 1991
	Home Office Work:	September 18, 1990 - September 29, 1990
		December 1, 1990 - December 15, 1990
		January 29, 1990 - February 27, 1991
Second Stage	Field Work:	July 7, 1991 - February 28, 1992
	Home Office Work:	September 5, 1991 - November 3, 1991
		February 17, 1992 - March 30, 1992

All field work was conducted in cooperation with the INAPA officials.
The study flow chart is shown in Fig. 1.1. Major activities of the Study Team were as follows:

1) On October 1st, 1990, the initial group (team leader and two other individuals) of Team members arrived in Santo Domingo to discuss the basic study orientation and schedule with the concerned INAPA officials.

2) On October 16, 1990, based on roughly two weeks of field survey and investigation, as well as discussions with concerned INAPA officials, an Inception Report was prepared and submitted to INAPA.
On the basis of this report, further discussions were held with the said involved officials, and basic orientation on groundwater, surface water and water supply development planning was determined.

3) On January 26th, 1991, Progress Report I embodying the results of approximately four months of field survey was submitted to INAPA. The contents of said report were discussed in detail with officials of the said agency.

4) On July 19th, 1991 an Interim Report embodying the detailed results of first field survey and home office works conducted in February 27, 1991 was submitted to INAPA. The contents of the report were likewise discussed in detail with concerned INAPA officials.

5) Second field survey was completed by February 26th, 1992 and in that date Progress Report II embodying the results of the eight month - second field survey work was submitted to INAPA.

6) The Draft Final Report was submitted to INAPA on June 9, 1992, and discussions were held with the INAPA officials about the said Draft Final Report.

7) In order to maximize transfer of technology, all works during the field survey components of the Study were carried out jointly with the INAPA officials. Emphasis was particularly placed on collation of well boring and test pumping techniques.

   The INAPA officials and Study Team members involved in the Study are listed below.

<u>INAPA</u>	
Executive Director	Mr. Manuel De La Cruz
Former Executive Director	Mr. Eduardo Estrella
Deputy Executive Director	Mr. Marco Rodriguez
Former Deputy Executive Director	Mr. Jaime Valerio
Deputy Technical Director	Mr. Carlos Leal
Assistant Executive Director	Mr. Jose Alberto Infante
Chief of Institutional Development Office	Mr. Carlos Barrientos
Chief of Engineering Department	Mr. Juan Garcia
Chief of Water Quality Laboratory	Mrs. Mercedes Rodriguez
Chief of UNEPLAN	Mrs. Martina Reyes
<u>Counterpart Personnel</u>	
Coordinator	Mr. Ramon Polanco
Geologist	Mr. Hector Dario Jimenez
Hydrologist	Mr. Pablo De La Mota
"	Miss Magaly Garavito
Geophysicist	Mr. Carlos Quesada
"	Mr. Isaias Villa
"	Mr. Rosendo Ramirez
"	Mrs. Alexandra Oviedo
"	Miss Joselyn Rodriguez

Water Supply System Designer	Mr. Angel Monegro
"	Miss Cesarina Nivar Senra
"	Mr. Manuel Aybar
"	Mr. Ramon Francisco
Well Drilling Supervisor	Mr. Jose Antonio
Well Driller	Mr. Cesar Sanchez
"	Mr. Pedro Sanchez
"	Mr. Basilio Pinares
"	Mr. Jose Ricardo Javier
Pumping Test	Mr. Abraham Mercedes Bido
"	Mr. Marcos Willy Morel
"	Mr. Julio Tejera Perez
"	Mr. Daniel Felix Soriano
Socio-economist	Mrs. Mari Dominguez
"	Miss. Xiomara Peralta

<u>JICA</u>

Chairman, Advisory Committee	Mr. Hidetomi Oi
Planning, Coordination	Mr. Shuzo Koike

<u>JICA Study Team</u>

Team Leader	Dr. Masaichi Nakayama
Hydrogeologist	Mr. Koichi Shinoda
Hydrologist	Mr. Ikuro Inamori
Geophysicist	Mr. Naoyoshi Takahashi
"	Mr. Yuichi Shiokawa
Well Drilling Supervisor	Mr. Yasumori Yoshioka
"	Mr. Hirotaka Nishimoto
"	Mr. Katsuya Kamisato
"	Mr. Takashi Tamura
"	Mr. Masatoshi Tanaka
Water Supply System Planner	Mr. Akira Naotsuka
Water Supply System Designer	Mr. Shinichi Matsunaga
Socioeconomist	Dr. Masaru Obara

CHAPTER II

STUDY BACKGROUND

CHAPTER II

STUDY BACKGROUND

2.1 National Background

2.1.1 General

1) Geography

The Dominican Republic covers a surface area of 48,442km2 and occupies the eastern two-thirds of the Hispaniola, which is second only to Cuba among the Greater Antilles islands, as far as land area is concerned. The country is bordered to the north by the Atlantic Ocean, to the south by the Caribbean Sea, to the east by Mona Passage which separates it from the neighboring island of Puerto Rico, and to the west by the Republic of Haiti.

The Dominican Republic is traversed by four mountain ranges which are all extended in the NW-SE direction. The main mountain range, the Cordillera Central, is located around the central area of the country along the NW-SE axis and forms the Pico Duarte, which at 3,175m is the highest mountain of the Antilles. The second mountain range is the Cordillera Septentrional, which is extended to the north of the Cordillera Central in a parallel manner and separates Cibao Valley from the Atlantic Coast. The third mountain range is the Sierra de Neiba, which is parallel to the south of the Cordillera Central in such a way that the San Juan Valley is formed in between. Lastly, the Sierra de Baoruco in the southern part of the island is separated from the Sierra de Neiba by the Enriquillo Basin of the salty Enriquillo Lake which is 40m below sea level (See Fig. 2.1).

The National Institute for Hydraulic Resources (INDRHI) divided the Dominican Republic into 14 major hydrological basins. The main basins are formed by the Rio Yaque del Norte, the Rio Yaque del Sur, the Rio Yuna, the Rio Nizao, the Rio Ozama, and the Rio Artibonito. The study comprises parts of the Yaque del Norte River Basin, Dajabon River Basin, Artibonito River Basin, and the Enriquillo Lake Basin (See Fig. 2.2).

The yearly average temperature of the country is 26°C. Although the seasons can not be clearly distinguished, generally the rainy season lasts from May to October, while the dry season lasts from November to April. It is quite hot from April to October, and considerably cool from November to March due to the breeze coming from the Atlantic Ocean. Hurricanes and tropical cyclones occasionally hit the country during the rainy season. Rainfall is usually very localized, and the annual precipitation varies widely from less than 700mm in the western Monte Cristi province to more than 2,100mm in the central provinces of Sanchez Ramirez, Samana and Monseñor Nouel.

2) Political Administration

The national administration is conducted through the typical division of power into three branches: Executive, Legislative and Judicial. The Executive Branch consists of the President of the Republic, 12 Ministries and other administrative offices. The 1966 Constitution empowers the President with vast authority, one of them being the appointment of Ministers, Provincial Governors, military personnel and government officials.

The country was, as of February 1986, administratively divided into one National District, 29 Provinces, 136 Municipalities and 648 Sections. The 1981 Population Census showed 41 cities (Santo Domingo, Provincial Capitals, and population centers with 10,000 or more inhabitants), 269 "villas" (head town of municipal districts and communities with 1,000 to 10,000 inhabitants), and 432 "aldeas" (other concentrated population centers). The cities, "villas" and "aldeas" accounted for 62% of the total population, and the rest consisted of dispersed population.

Local authorities, such as Mayors and City Assembly Members, are elected by popular vote for four-year terms. The municipality exercises legislative and administrative powers within its jurisdiction, but the typical municipality has insufficient human and financial resources, despite receiving 20% of national tax revenues as grants from the Central Government.

In 1981, the Central Government divided the country into three Regions (Cibao, Southeast and Southwest) and seven sub-regions, in order to improve administrative controls and regional development planning (see Fig. 2.3). Of the four provinces included in this Study, Monte Cristi and Dajabon belong to the Cibao Occidental Sub-region of the Cibao Region, Elias Piña belongs to Valle San Juan Sub-region, and Independencia belongs to the Lago Enriquillo Sub-region. The latter two sub-regions belong to the Southwest Region.

2.1.2 Social Situation

1) Population

The 1990 population of the Dominican Republic was estimated at 7,100,000, having increased with an annual growth rate of 2.99% between the 1970 Census and the 1981 Census. During the intercensal period, urban population grew six times faster than rural population and comprised 52% of the total population in 1981. This percentage was estimated to have gone up to 59% in 1990. Correspondingly, rural population was estimated to have decreased from 48% to 41% between 1981 and 1990. Population census data are shown in Table 2.1.

The rapid growth of urban population implies population increase in big cities, especially Santo Domingo and Santiago, while the rural areas are likely to be underpopulated. The overall population density in 1990 was 146 persons/sq.km., being concentrated in the south-central area of the country, due to the presence of large cities, such as the following:

Santo Domingo	2,400,000	inhabitants
Santiago	480,000	〃
La Vega	190,000	〃
San Fco. de Macoris	160,000	〃
San Cristóbal	130,000	〃

2) Households and Housing

The 1981 Population Census results were divided into three groups - National District, Santiago Province, and the rest of the country - and were presented as shown below;

	N.D.	Santiago	Remainder	D.R.
Population	27.6%	9.6%	62.8%	100%
Households	29.0%	9.1%	61.9%	100%
Housing units	29.0%	9.2%	61.8%	100%

As shown in the above summary and Tables 2.2 and 2.3, the National District concentrated a little over one-fourth of the population and housing, while Santiago and the rest of the country accounted for 72.4% of the total population. The average number of members per household or family fluctuated between 4.7 and 5.2, indicating a higher ratio in Santiago and the rest of the country than in the

National District and the whole country. Although the overall family size is similar to other countries, the Census recorded families with 15 members or more, and approximately one family out of five had 8 members or more.

Housing units relative to population was relatively more plentiful in the National District than in the rest of the country. Likewise, while one out of five large houses in the National District and Santiago was found to comprise five rooms or more, only one out of nine houses in the rest of the country was found to do so. More than half of the number of houses in the National District and in the rest of the country were found to have two or three rooms, indicating a 50% ratio in the former and 65% in the latter.

Table 2.3 shows the population equipped with basic house facilities and utilities. About 30% of the total population is equipped with indoor pipes, ranging from 46% in the National District, 41% in Santiago and 22% in the rest of the country. The number of residences making use of water supply pipes installed at public standposts located less than 100m away has reached 27% of the total population, ranging from 32% in the National District, 19% in Santiago and 26% in the rest of the country. The population without water supply pipes totalled 43% in the whole country, 22% in the National District, 40% in Santiago and 52% in the rest of the country.

The number of people using the flush toilet prevailed over latrine only in the National District with a ratio of 6 to 4, while the population using latrine was more than double of that using flush toilet in the rest of the country. Kitchen facilities were available to 86% of the total population, of which more than half is equipped with indoor kitchen. Excluding the National District and Santiago Province, however, outdoor kitchen prevailed with a ratio of 2 to 1. On the other hand, the population with access to electricity amounted to 61% of the total population, but was less than half in areas excluding the National District and Santiago Province. Accordingly, only 1% of the National District population and 0.4% of the total population used electricity for cooking Propane gas is predominantly used in the National District, while firewood and charcoal were preferentially used for cooking in the rest of the country.

3) Sanitary and Health Conditions

The prevailing causes of death in the Dominican Republic are intestinal disorder, digestive troubles, heart ailments, lung and circulatory system diseases, and complications occurring during pregnancy. The mortality rate is 4.3 per thousand, of which 30% are infants of up to 4 years and 23% of less than a year, as shown in Table 2.4.

The Dominican Republic strives to eradicate the problems occurring during pregnancy (the highest ranking death cause), and child death rate by promoting mother and child protection, the betterment of public health, and other related programs. Main causes of infant mortality are shown in Table 2.5.

The free medical treatment given by the Ministry of Health is the main facet of the Dominican Republic's medical system, which is structured into five parts as indicated below.

(1) The Public Hospital within the jurisdiction of the Ministry of Health provides free medical treatments.
(2) The Social Securities Department provides medical treatment at the Social Securities Hospital.
(3) Medical treatment is provided at the Military Hospital for military personnel and their respective families.
(4) Private medical insurance is used for medical treatments provided in private hospitals.
(5) Expenses are paid for by private individuals for medical treatments provided in private hospitals.

The Ministry of Health has been promoting the health and welfare of the population since 1971 by classifying the National District and 29 Provinces into 8 Regional Administrative Units (0 - Ⅶ), for the provision of general medical treatment and free medical treatment to low income groups in five types of medical facilities.

2.1.3 Economic Situation

1) Economic Structure

The Dominican Republic is an agricultural country and farm products usually comprise more than half of the exports. Approximately 40% of the labor force is employed in the primary sector. The economically active population ranges from 10 years of age and over. The gross national product per capita was estimated at US$790 in 1989, indicating an average yearly growth rate of 2.2% in the 1980's.

Since exports depend on a few agricultural products (sugar, coffee and cacao) and mining products (ferronickel), instability in the international market influences the economic situation of the Dominican Republic. Furthermore, the economic structure of the country is heavily dependent on imports, and the deficits in the balance of payments are covered with foreign investments and loans. The economy of the country is heavily dependent on its trading relations with the United States of America, indicating a 67% export and 40% import ratios in 1986.

The share of agricultural products in the GNP decreased from 22.6% in 1970 to 18.6% in 1985. However, agriculture still employs approximately 40% of the labor force and its produce comprises around 60% of the exports. Furthermore, sugar cane cultivation covers about 40% of the agricultural land area, and sugar covers around 20% of the exports. The other traditional agricultural products are coffee, cacao, and tabacco.

The manufacturing sector of the Dominican Republic covered 17.1% of the GDP in 1986. Foodstuff processing, excluding beverage, and sugar accounted for 45% of the industrial production ratio in 1985. Metals and textiles are also important industrial products. Other products are manufactured by the light industry for the domestic market.

2) Recent Developments

After the 1979 hurricane hit, the economy of the Dominican Republic experienced a comparatively high growth rate. The estimated growth rate of the gross domestic product (GDP) was 3.4% per year between 1980 and 1982; remained stationary between 1983 and 1986, during which an adjustment program was implemented under IMF supervision; recovered sharply at 7.9% in 1987 on the strength of a massive increase in public investments; stagnated in 1988 and grew 4.1% in 1989 (see Table 2.6). In 1990, a 5.1% decrease in the GDP resulted in the deterioration of the general economy, but significant recovery was gained in 1991.

The GDP composition shows that the share of the primary sector decreased from 20% in 1980 to 18% in 1988, while the share of the secondary sector increased from 28% to 29% and that of the tertiary sector from 52% to 53% during the same period. However, the primary sector took the lead in terms of employment, employing 46% of the labor force in agricultural activities in 1980, 39% in service activities and 15% in manufacturing activities.

Economic stagnation in the mid 1980's caused a jump in open unemployment which was estimated at 27% in 1986, 19% in 1987 and 17% in 1989. Similarly, inflation began accelerating after remaining moderate during the early 1980's and reached 44.4% in 1988 and 45.4% in 1989. High inflation rates caused an estimated 25% drop in real wages between 1980 and 1989.

The balance of payments (see Table 2.7) statistics show increasing trade balance deficits ranging from US$558 million in 1980 to US$753 million in 1989. The trade deficits could not be offset by the inflow of short-term and long-term capital. A large increase could be observed in remittances from Dominicans working abroad, from US$183 million in 1980 to US$315 million in 1989.

Economic difficulties in the second half of the 1980's led to the accumulation of arrears on external debt. The estimated external debt of the country in 1989 was around US$4,000 million, equivalent to approximately 60% of the GDP, and the debt service was estimated at 29% of export values.

To reactivate the economy, the Government began taking a series of policy measures in the second half of 1990, and a stand-by agreement was reached with the IMF in June 1991. The agreement agreed upon made funds available for the implementation of economic policy actions and for contingent financing. These measures, coupled with the strengthening of public finance and the re-scheduling of external debt, appeared to have been effective in controlling inflation and stabilizing the economy.

2.1.4 National Development Plan & Water Supply Sector

1) Development Objectives

The objectives of the Dominican Government are the following:

(1) To concentrate Government actions on the development of high potential areas on the basis of reallocation of public finance and by providing incentives to private investors.

(2) To eliminate the inter-regional economic and social disparities by improving the quality of life of marginal groups, taking simultaneous actions on the social and economic fronts.

(3) To promote tourism development centering around attractions chosen in strategic locations throughout the country.

(4) To rehabilitate the economic and social infrastructures, to take advantage of backward and forward linkages of construction activities.

The Dominican Government formulated an integrated development plan for seven western provinces in 1987, including water supply as one component.

2) Water Supply Objectives

Specific water supply objectives, set within the framework of the United Nations International Drinking Water Supply and Sanitation Decade, was to provide safe water to 85% of the urban population and 80% of the rural population by 1990. The Dominican Government, by using its own funds, has practically completed the water supply objectives for urban areas during the 1980's.

In terms of policy, water supply and sanitation are accorded the highest priority at the national level, as they are regarded as essential elements for the socioeconomic development of the country. Accordingly, the Government policy is to protect and preserve water resources and to appropriate sufficient financial resources for the rational utilization of water.

The highest priority for water supply is given to those communities in rural and marginal urban areas without water supply services or with unsatisfactory services. Investment efficiency is to be maximized in water supply works, that is, the widest possible water supply coverage from a given level of investment is to be pursued. Moreover, public participation is to be promoted, in order to get people, especially women, involved in solving their water supply and sanitation problems.

3) Water Supply Strategy

The strategy for water supply development is to be based on low cost solutions, giving preference to groundwater, and taking a step-by-step improvement in service level, from hand pumps to windmills and house connections. The quality of water supplied is to be improved, personnel capabilities are to be strengthened at all levels, so as to increase operation efficiency. Revenues are to be maximized by applying cost-based water rates and expenditures are to be minimized, to eliminate the need for subsidies. Finally, selective use is to be made of technical and financial cooperation offered by bilateral and multilateral agencies.

The water supply and sanitation sector of the Dominican Republic has received technical and financial assistance from several bilateral and multilateral organizations such as IDB, USAID and GTZ. IDB has particularly financed water supply systems for concentrated rural communities included in the PLANAR Projects Ⅰ, Ⅱ and Ⅲ. Bilateral organizations such as USAID and CIDA, and a number of NGO's, provide assistance for water supply in dispersed rural communities. On the other hand, permanent technical assistance is provided to water supply institutions by WHO/PAHO of the United Nations.

2.1.5 Present Conditions of Water Services

1) Water Service Institutions

(1) Government Institutions

The development and supply of drinking water in the Dominican Republic are the responsibilities of the following five Government Institutions.

Name	Responsibilities
Ministry of Public Health and Social Welfare (SESPAS)	Supervision of water supply works by INAPA, CAASD, CORAASAN
National Institute of Hydraulic Resources (INDRHI)	Implementation of water resources development and special water supply projects
National Institute of Water Supply and Sewerage (INAPA)	Nationwide development and supply of water and sewerage system, excluding Santiago and Santo Domingo
Santo Domingo Water Supply and Sewerage Corporation (CAASD)	Development and supply of water and sewerage system of Santo Domingo
Santiago Water Supply and Sewerage Corporation (CORAASAN)	Development and supply of water and sewerage system of Santiago

Table 2.8 and Table 2.9 show the budgets of the three main water supply institutions for 1989. It can be seen that INAPA and CAASD had similar budgets, both in terms of income and expenditures. CORAASAN, on the other hand, had a total budget amounting to about 10% of INAPA and CAASD. Income from sale

of goods and services was good for CORAASAN, amounting to one-half of INAPA and one-third of CAASD. Construction expenditures were about 60 times higher for CAASD and INAPA than for CORAASAN.

For water supply purposes in the Dominican Republic in 1990, 63% of total population was under INAPA jurisdiction, while 37% was under the jurisdiction of CAASD and CORAASAN. As can be seen below, 60% of the urban population was under the jurisdiction of CAASD and CORAASAN, but 95% of the rural population was under the INAPA jurisdiction.

	Total Population (1,000)	Urban Population (1,000)	Rural Population (1,000)
Dominican Republic	7,170 (100.0)	4,205 (100.0)	2,965 (100.0)
CAASD & CORAASAN	2,646 (37.0)	2,527 (60.0)	149 (5.0)
INAPA	4,494 (63.0)	1,678 (40.0)	2,816 (95.0)

(2) Non-Governmental Organizations (NGO)

The two relevant NGO's for water supply are the Dominican Church Social Service (SSID) and the Foundation for Community Development (FUDECO).

a) Dominican Churches Social Service (SSID).

The SSID prepared a five-year water supply and sanitation plan (1990 - 1994) for the northwestern region of the country, setting the following goals.

1. Construction of 80 rain water storage tanks per year, with a capacity of 1,000 gallons each, and 25,500 beneficiaries
2. Construction of 100 latrines per year
3. Expansion of water supply and sanitation activities to 14 additional communities
4. Rehabilitation of 50 water supply systems
5. Construction of 50 hand pump wells
6. Drilling of 50 tube wells
7. Education programs and organization of water committees

The SSID is active in areas with critical water supply and sanitation problems, where the community residents show strong interests in participating in the solution of their problems.

b) Foundation for Community Development (FUDECO)

Having started its activities in Loma de Cabrera in 1972 under the umbrella of the American Foundation "Save the Children", FUDECO became a fully independent Dominican institution in 1979 by virtue of Law 520. Presently, FUDECO is active in approximately 120 communities near the border, with an estimated total of 50,000 beneficiaries, operating from the main office in Santo Domingo and two decentralized offices in Loma de Cabrera and Las Matas de Farfán.

FUDECO provides assistance on a wide array of fields, from farming techniques, health, agroindustry, reforestation, to construction of housing and schools. FUDECO emphasizes appropriate technology and use of local materials.

With German assistance, FUDECO constructed 20 rural water supply systems which require no electricity for water catchment and conduction. FUDECO has been implementing a program to reduce infant mortality by minimizing incidence of diarrhea, respiratory illness and malnutrition, and by promoting vaccination and family planning.

2) INAPA

(1) INAPA Organization

The National Institute for Potable Water Supply and Sewerage (INAPA) was established by virtue of Law 5994, which was subject to several amendments over the years, in July 30, 1962.

INAPA is an autonomous institution with a nationwide jurisdiction over the health sector, endowed with juridic personality, own resources, and fully authorized to negotiate contracts and obligations.

At the top of the INAPA organization is the Administrative Council, which is composed of five members: the Undersecretary of Public Health as the Council President, the Undersecretary of Public Works, the Deputy Governor of the Central Bank, the Undersecretary General of the National Planning Board, and the Executive Director of INAPA who is appointed by the President.

The Executive Director and the Deputy Executive Director oversee the activities of the three Deputy Directors in charge of the technical, operation and administrative aspects.

The Technical Deputy Director has jurisdiction over the Engineering Department, which includes Projects, and over the

Hydrology Department, which includes windmills. The Deputy Director for Operations is responsible for the Operations Department, the Electromechanical Department, and rural water supply, in which the country is divided into eight zones. The water supply systems of Dajabon, Loma de Cabrera, Monte Cristi and Guayubin are in Zone I, while those of Elias Piña, Duvergé and Jimani are in Zone VIII. Responsibilities of the Deputy Director for Administration include General Services Department, which is in charge of Transportation and Workshop, and the Financial Department, which is in charge of budget and accounting.

Directly dependent from the Executive Director and the Deputy Executive Director is the Commercial Department, which is responsible for metering, billing, collection and customer services.

INAPA had 2,214 employees in 1990 and plans to employ 2,342 employees in 1992. Information on these employees are incomplete and outdated, making it difficult to evaluate the INAPA human resources. However, qualified personnel is admittedly scarce, especially among the middle and lower ranks. The available personnel is recognized to be inadequately allocated among different activity areas. The lack of a personnel management system and low compensation prevailing within INAPA induce its personnel to seek better working conditions in the private sector.

INAPA is responsible for the direction and oversight of all matters concerning adequate supply of potable water, for the treatment and disposal of waste water, for the assignment of priorities in water supply, sewerage and storm sewer systems, for the operation and maintenance of existing or future facilities for water supply and sewerage, and for the conservation and rational utilization of all waters under public domain.

(2) INAPA Water Supply Service

The following facilities were operated by INAPA in 1990:

- 311 water supply systems,
- 228 windmills,
- 20 urban sewerage systems,
- 4 rural sewerage systems, and
- 2 tourist area sewerage systems.

Water supply facilities relied heavily on pumping (66%) as opposed to gravity (32%) and mixed (2%) systems. Around 30% of water supply facilities were equipped with treatment plants of rapid or slow filtration systems. Of the estimated 338,692 house connections under INAPA jurisdiction in 1990, only 58,888 (17%), of which only 54% were estimated to be in working condition, were metered.

The quality of supplied water was inadequate, and sanitary control wasobserved in only 25% of the water supply systems. Results of sanitary control showed that, with a few exceptions, quality standards were not met (see Table 2.10). One of the reasons for the deficient quality in Santo Domingo and Puerto Plata was the existence of poorly-equipped and understaffed laboratories causing difficulties in the timely arrival of water samples and the expected feedback from the laboratory for taking corrective actions at the local level. Unaccounted-for water was estimated at 48% of the total water produced, due to losses in distribution pipes, illicit connections and wastes.

Despite the above difficulties, 63% of the country's total population depend on INAPA for water supply, that is, 95% of the rural population and 40% of the urban population. As shown in Table 2.11, 55% of the population, that is, 80% of the urban population and 40% of the rural population, under INAPA jurisdiction in 1990 were receiving water supply services. However, only 30%, of which 56% is from the urban area and 14% the rural, had house connection water services.

More importantly, population without water services accounted for 45% of the total population, that is 20% of the urban population and 60% of the rural population.

Excluding the wind and hand pump service areas, INAPA collects water fees for water supplied through house connections. Water charges differ depending on metered or non-metered services, area, and the number of faucets.

Water service fee in urban areas is classified into residential, commercial, industrial, and special uses. The monthly water rates charged by INAPA for domestic use range from 6.80 to 39.00 RD$ per month, depending on the number of faucets. INAPA managers are aware that these rates are low, and that cost-based water rates should be implemented. The water rates being charged by INAPA are shown in Table 2.12.

INAPA water supply services in urban areas are classified into six categories depending on population size, which in turn defines the quantity of water supplied per capita per day, as shown in Table 2.13. Likewise, water supply services in rural areas are classified into three categories, as shown in Table 2.14.

(3) INAPA Finance

The INAPA income statements and balance sheets for 1988 and 1989 are shown in Table 2.15 and 2.16. However, the generally accepted financial analyses of these data are meaningless as a means to assess strengths and weaknesses, due to the high level of subsidies made necessary by the low operating revenues which cover only about half of the operation and maintenance costs. These facts are well known to the new INAPA managers who are studying every possible way to improve the situation.

INAPA investments during the 1981 - 1990 period amounted to RD$458.2 million (US$78.9 million) and came mostly from domestic funds appropriated from the central government budget. Likewise, foreign debt service was covered by the central government funds. It should be noted that INAPA investment figures do not show the whole picture, as a significant portion of investments in water supply was undertaken by the Office for Coordination and Supervision of Government Works, which is directly dependent from the President of the Republic, and by the Ministry of Public Works.

On the other hand, INAPA investments with foreign funds during the 1981 - 1990 period amounted to US$8.1 million from the IDB for the PLANAR Ⅲ Project. Donations under the heading of equipments, technical cooperation and training amounted to US$810,000, mainly from IDB, GTZ, WHO/PAHO, OAS and CIDA.

Water rates are recognized to be too low to cover operation costs, let alone capital costs, causing INAPA to incur high financial deficits. This requires a heavy subsidy from the Central Government for payroll, electricity, capital investments, debt and interest payments on domestic and foreign loans.

(4) INAPA Plan

Projections of recent investment levels, technology and service standards result in unacceptably low coverages estimated to be 65% for water supply and 20% for sewerage in the year 2000.

Hence, INAPA recently formulated alternative plans to increase coverage by the year 2000.

Alternative Plan 1
This plan requires an investment of US$405 million which is equivalent to 3 times the average investment of the 1986 - 1990 period. The goal is to provide water supply to the entire urban population and 80% of the rural population, in addition to providing sewerage to 50% of the urban population.

Alternative Plan 2
This plan requires an investment of US$489 million which is equivalent to 4.8 times the average investment of the 1986 - 1990 period. The goal is to provide water supply to the entire population under INAPA jurisdiction, in addition to providing sewerage to 60% of the urban population.
Details of the alternative plans are shown in Tables 2.17, 2.18 and 2.19.

2.2 Regional Background

2.2.1 Study Area

The four provinces included in the Study Area are Monte Cristi, Dajabon, Elias Piña and Independencia. These provinces accounted for 13.4% of the area of the country, and 4.4% of the overall population according to the 1981 Population Census. Table 2.20 shows some socioeconomic indicators of the Study Area.
The four western provinces are comprised of 21 municipalities indicated in Table 2.21. The budgets of these municipalities are shown in Table 2.22 as an illustration of their limited resources.

2.2.2 Economic Activities

These Provinces are mostly dependent on agriculture. Rice and sugar cane are generally produced in the lowland along big rivers, in such areas as south of Elias Piña, which is situated west of San Juan Valley, and Monte Cristi and Dajabon of Western Cibao Valley. The hilly districts, however, are more involved in the production of cassava, corn, beans and the livestock industry.
The 1981 Agricultural Census data was intended only for farms greater than 12.5 ha. The land utilization and types of crops by

provincial and national categories are shown in Tables 2.23, 2.24 and 2.25. It can be seen that, in terms of both harvested acreage and production, the four provinces together accounted for less than 10% of the country in 1981.

Well developed irrigation canals, especially main canals, could be observed everywhere in the Study Area. However, irrigated crops other than rice appeared to be limited to a few like melon and onion in localized areas basically determined by flat topography and adequate soil. Although published data did not include up-to-date agricultural and other economic activities by province, the following impressions based on recollections of field trips taken through the four provinces were made.

1) Dajabon Province

In the south, agroforestry involving such combinations as pine and guandul, and coffee under broad leaved trees were observed. Peanut is an important cash crop in the area and trucks are often seen transporting large loads of unshelled peanuts. The existence of cottage industries in the south could be inferred from the processed peanuts sold in small packages alongside roads and sweets made of milk.

Toward the east and north of the province, cattle ranching appeared to be predominant, even though the mountain topography of the area indicated poor pasture. Milk production was presumed to be plentiful, as numerous boys and girls were seen carrying a couple of milk containers on horseback or motorcycles. Tobacco cultivation was also observed in the area.

The west of the province appeared to be dry with predominantly bushy vegetation, but undergrown grass made cattle ranching possible.

2) Monte Cristi Province

Except for the northern dry land, this province is the most prosperous of the four in terms of agriculture, which is basically of irrigated crops. It is a traditional tobacco producing area, and drying sheds for tobacco leaves could be seen everywhere in the province.

In addition to the traditional rice and tobacco products, many new crops are being introduced. Onion and melon are seen cultivated on large expanses of irrigated flatlands. Former cotton lands are being used for tomato production, suggesting that farmers in the area are very much market oriented and sensitive to changes in market conditions.

A huge plantation of aloe vera, complete with a processing plant so as to process the aloe leaves for export as additives for cosmetic products, was also seen in the area.

3) Elías Piña Province

Rice farms were ubiquitous and appeared to be well managed, under irrigation and mechanization, with structures for water control. According to local information, rice harvest is conducted twice a year in the area.

Plots cultivated with peanuts were quite a common sight along roads. Other important crops in the area are beans, guandul, onion, plantain and banana. Cassava cultivation could be seen everywhere, indicating its importance for consumption.

4) Independencia Province

A large expanse of dryland, interspersed with fertile and lush valleys could be observed. The valleys are cultivated with large plantations of palm, banana and plantain. Large number of banana and plantain vending stalls can be seen along the main roads.

On flatlands, mechanized farming of melon and cucumber under irrigation appears to be of growing importance.

2.2.3 Population

The Study Area accounts for 4.4% of the country's population, with a population density of 36 persons/km^2, which is only 31% of the country's average population density. Rural population comprises 65% of the Study Area population. Demographic indicators are shown in Table 2.26.

According to a study conducted by ONAPLAN in 1983, the population of the area showed a high outmigration rate, especially toward Santiago and Santo Domingo. This phenomenon is gradual, starting with migration to small regional cities, then to middle size regional cities, and finally to the big cities.

1) Cibao Region (Monte Cristi and Dajabón)

Pepillo Salcedo → Dajabón

Partido → Loma de Cabrera → Dajabón

Restauración → Loma de Cabrera

Dajabón → Mao

Las Matas S.C. → Guayubín → Sabaneta → Mao → Santiago

Castañuelas → Villa Vásquez → Mao

Monte Cristi → Villa Vásquez

2) San Juan Valley Sub-region (Elias Piña)

El Llano → Comendador

Hondo Valle → Comendador → S. Juan → S. Domingo

Bánica / Pedro Santana → Comendador

3) Lake Enriquillo Sub-region (Independencia)

Cristobal → Cabral → Neiba

Postrer Rio → V.Jaragua → Neiba → Barahona → S.Domingo

La Descubierta → Jimani → Neiba

The 4 western provinces are divided into 21 municipalities, with a total population of 235,602 (1981 Census). There are 100 villages with a population of more than 400; 152 villages with a population of 200‡400; and 418 villages with a population of less than 200.

The 100 villages with a population of more than 400 constitutes approximately 50% of the rural population, while the 152 villages with a population of 200 to 400 constitutes 25% of the rural population (see Table 2.27).

The number of individuals per household in the area averages 4.5, which is 0.5 less than the overall average.

2.2.4 Water Supply Service

1) General Conditions

The Study Area shows rich topographic variations ranging from low areas of 40 m below sea level to mountain plateaus of more than 2,000 m. Consequently, there are large regional differences not only in hydrological and meteorological conditions, but also in socioeconomic

conditions such as village distribution and accessibility as well as type and structure of industries.
Being restricted by physical and socioeconomic conditions, the level of water supply to the area residents has wide regional differences.
The general conditions of the water supply services in the 4 provinces are shown in Table 2.28 and Fig. 2.4 and are as summarized below.

(1) Monte Cristi Province

a) There are hand pump wells and wind pump wells in the main villages of the northern mountain area. However, the groundwater is too salty for drinking, whereby it is used only for miscellaneous purposes. Drinking water is distributed by tank lorries, in addition to rain water stored by the area residents.

b) The water sources of the central lowland area of the Yaque del Norte river basin are the branch rivers of Yaque del Norte, Guayubin, and La Cana. River water is purified in the treatment plant of the water supply system, however, a part of the village relies on hand pump wells.

c) The water sources of the eastern area of the Yaque del Norte left bank river basin are Guayubin, Inaja, and Cana rivers. The surface water is purified in the treatment plant of the water supply system. The downstream areas, on the other hand, get their water supply from hand pump wells and from the nearest irrigation canal.
Groundwater along the border of Dajabon Province, however, is too salty for drinking.
The Salcedo Lake is the source of water for the Pepillo Salcedo water supply system.

(2) Dajabon Province

a) The areas in and around Dajabon City get their drinking water from the modern water supply system which uses the Dajabon River as the water source.

b) The towns located in the hills and plateaus in the center and south of the province get good water services through the water supply system, which uses Maguaca, Capotillo and Neita rivers as water sources.

(3) Elias Pina Province

a) The Comendador area gets its water from the water supply system which uses the Las Carreras Canal as water source. Hand pump wells are also used.

b) The Pedro Santana area, located in the northwest, has a water supply system which pumps up surface water from the Artibonito River. In the areas of Sabana Cruz and Higuerito near Pedro Santana, groundwater based water supply system services are provided through house connections.

(4) Independencia Province

a) There are 8 water supply systems providing services through house connections in the northern bank area of Lake Enriquillo. Water sources are abundant spring water existing in the alluvial fan formed in the south of the Neiba Mountains. Water is taken either directly from springs or from rivers where spring water flows into.

b) The southern bank basin of Lake Enriquillo uses abundant groundwater or spring water to provide services through 6 water supply systems. In the western area of the southern bank, water is provided by the Jimani water supply system, which uses the Jimani Canal as water source. However, the canal's water has become increasingly turbid in recent years, and the area is confronted with problems of rising water treatment expenses.

2) Water Supply Service Coverage
The service population of the 4 western provinces is estimated to be approximately 43%, excluding those using hand and wind pump wells (see Table 2.29).

2.2.5 Need for Water Supply Services

Although the Study Area is blessed with abundant water resources, it is hindered by its geographical and topographical conditions. The development of water for domestic use, especially for the estimated 800 rural villages, and the improvement of social infrastructure are lagging behind.

As previously stated, INAPA's systematic water services for the area takes place along easily accessible trunk roads. On the other hand, in hard-to-reach inland villages, the difficulty to secure water during the dry season aggravates depopulation due to migration to urban areas.

Based on these circumstances, the development and stable supply of safe water for domestic use will satisfy the residents' oldest and essential demand, and will contribute to stabilize and improve their living conditions. The incidence rate of gastroenteritis and disentery in the four provinces is shown in Table 2.30.

Furthermore, provision of water supply will contribute to prevention of depopulation and migration to urban areas and the resulting disintegration of rural villages. The ensuing favorable effects will consist of activation of regional production, and prevention of population concentration in urban areas. The development of water supply for domestic use in this area, therefore, is regionally and nationally of extreme importance.

CHAPTER III

THE PROJECT AREA

CHAPTER III

THE PROJECT AREA

3.1 Landform and Geology

3.1.1 Project Area

The Area is situated between 71°00' and 71°45' of west longitude and between 18°15' and 20°00' of north latitude. It lies in a N-S direction at a length of 200 km, in an E-W direction at a length of 20~70 km, and encompasses 6,527 km^2.

3.1.2 Remote Sensing

The geological and morphological investigations of this Area were carried out using the available remote sensing data such as satellite images and aerial photographs. Landforms, land use conditions and vegetation were also studied. The kind of data collected for this study are listed below.

1) Collected Data

(1) LANDSAT images
LANDSAT TM-5 (digital data) employed for computer image analysis.
The situation is as follows:
Path 008 and Row 046 to 047. Date: October, 06, 1987

(2) Aerial Photographs
The panchromatic aerial photographs (325 pieces) taken by the Geographic Institute of Santo Domingo University (IGU) in 1983 - 1984 at a scale of 1:50,000, were employed in the Study.

(3) Topographic Maps
The base maps at a scale of 1:100,000 used in the Study were compiled from the 31 sheets at a scale of 1:50,000 published by IGU.

2) Interpretation of Satellite Images and Aerial-photographs
Using the LANDSAT images and aerial photographs, the elements listed below were interpreted mainly from the viewpoint of photo-geology.

Kind of Image	Method	Elements of Photo Interpretation
LANDSAT (false color)	Mono-scopic observation	Major landforms, Relief, Structural landforms, Ridge system, Ridge-forms, Drainage pattern, Drainage density, Photographic texture, Photographic color tone, Photographic lineament.
Aerial photographs	Stereo-scopic observation	Micro relief, Photographic texture, Photographic tone, Photographic lineament. Drainage pattern, Drainage density, Cuesta, Pediment, Pediplain, Karst landform, Fan, Talus, terrace, Coral reef, Erosion surface, Landslide, Plain, Basin, Flood plain, Marsh, Lake. Fault, Anti-and Synclinal structure, Scarp, Vegetation cover (distribution and density) - Forest, Grass land, Bare land, Savanna, Desert, Plantation, Cultivated land.- Main roads, Build-up area

3) Computer Image Analysis of LANDSAT-TM Data
   The LANDSAT TM data is obtained in the form of CCT (computer compatible tape), which can be processed by the digital image analysis system to produce desired images.
4) False Color Image
   Land cover classificationand water content classification images are prepared for this Study in addition to the principal component image. The geometric correction is then followed by the preparation of false color images, the color synthesis of three (Band 2, 3 and 4) out of seven bands of TM data.

The principal component image at a scale of 1:100,000 was prepared by edge emphasis technique to clarify the boundaries of land use, geology, topography, and others.

Examples of the three (3) kinds of images are shown in Fig. 3.1 to Fig. 3.3.

3.1.3 Landform

1) General Landform

The western region of the Dominican Republic, which is the proposed Project Area, is formed of mountain ranges extending in a northwest to southeast direction, and hills and plains alternating systematically from north to south. From the north, these mountains and plains are classified into the following seven geomorphic provinces such as ① Cordillera Septentrional ② Llano de Yaque del Norte, ③ Cordillera Central, ④ Valle de San Juan, ⑤ Sierra de Neiba, ⑥ Cuenca de Enriquillo, and ⑦ Sierra de Baoruco.

Cordillera Septentrional faces the Atlantic Ocean forming long and narrow hilly-mountainous districts ranging from an altitude of 200 to 400 m above sea level. The Project Area has limited rainfall throughout the year and scarcely wooded fields full of cacti which are mostly used for pasture. Some of these fields are partly used for tobacco production.

Cordillera Central is the largest in the Republic, extending from the Republic of Haiti to Santo Domingo, the capital city. There are 23 mountains in the Republic with an elevation of more than 2,000 m. The Pico Duarte Mountain is the highest with an elevation of 3,175 meters.

The Project Area is parallel to the watershed of Rio Bernar which flows northwards (with Rio Dajabon downstream) and Rio Artibonito flowing southwards. Both rivers form the border of Haiti. Owing to the relatively low elevation of the area, roads were laid out across the mountains, and small towns or villages straggle along these roads.

Sierra Neiba and Sierra Baoruco are the southeast extensions of the Haiti Mountains. The ridges of these mountains are elevated up to more than 2,000 m.

Llano de Yaque del Norte is located between Cordillera Septentrional and Cordillera Central. Rio Yaque del Norte flows west and forms a wide plain of about 50 m in elevation at the basin.

Valle San Juan is located between Cordillera Central and Sierra de Neiba.

Rio Macasia collects water from the north and south mountains in the central part of this valley and flows westwards into Rio Artibonito. This basin forms a wide plain which develops into hills in the fringes. The plain elevates at 200 to 300 m and the land is mainly used for cultivation and pasture. The 300~400 m elevated hills are used for pasture.

Lago Enriquillo is a lake - 40 m in elevation located between Sierra de Neiba and Sierra Baoruco. This is a graben area formed by the tectonic movement and the side of the mountains facing the graben forms a steep slope. Due to this, many rivers flowing down from both mountains form large alluvial fans at the exit of the graben.

2) Drainage System

Fig. 3.4 shows the drainage system around the Area.

In Cordillera Septentrional, small-scale drainages stream down south in a parallel pattern, but due to their very small sizes and little rainfall (600 to 700 mm/year), they become intermittent streams.

Rio Yaque del Norte is a large river with a total catchment area of 7,000 km^2. Its upperstreams extend over occupying 2/3 of the area. The outside area includes the catchment areas of large tributaries such as Rio Bao, Rio Amina and Rio Mao, and the upperstreams of the forementioned Rio Gurabo, Rio Caña and Rio Guayubin.

Rio Yaque del Norte has a violently meandering main channel and many small buried channels. Along these channels many traces of flood are observable by airphoto interpretation.

In the southern side area of Rio Yaque del Norte, an alluvial flood plain of 0~50 m above sea level in elevation can be found.

This wide and flat plain has been utilized as a rice field, cotton farm, vegetable farm, large-scale banana plantation and urban area.

A marsh and a desert-savanna area utilized as a large-scale salt field can be seen near the sea coast.

The sea coast forms a beach barrier and offshore coral reefs are distributed along the coast line.

Because the dams for agricultural-use, water intakes and irrigation canals are constructed in various places in the catchment area, it is very difficult to calculate discharge and water balance in the Area.

Rio Artibonito and its tributaries contain relatively rich discharge owing to much rainfall (2,000 to 2,200 mm/years) in the Cordillera Central.

Further, one half of the Rio Macasia catchment area is also extended

over the Project Area.
There are no large rivers to the south of Sierra de Neiba.
At the north and the south coast of Lago Enriquillo, groundwater passing through the karst mountains, the fans and the old coral reefs, springs out here and there.

3) Landform Classification

Landforms were classified based on LANDSAT images and aerial photograph interpretations, as shown in Fig. 3.5.
As shown in this figure, the mountain zone (dense contour line and dark in color) and the hilly to plain zones (less dense to rough and white in color) are parallely extended in a NWW direction to the SEE direction.
In the false color image, mountains and hilly to plain zones are clearly distinguished as shown in Fig. 3.1.
Mountains are deep to dark red in color at the relatively central parts and suggest wide distribution of dense forests, while the surrounding parts of a much lighter red in color suggest few vegetation cover.
The ridge and drainage pattern are clearly interpreted in the mountains and form the erosion-proceeded landforms.
Owing to richer water contents (humidity), hilly to plain areas are blue to dark blue in color.
Different false color tones range in accordance with the degree of cultivation, vegetation cover and water contents.
Detailed characteristics of each seven morphologic provinces mentioned before are described in the Supporting Report.

4) Land Use and Vegetation-Cover Classification

In order to clarify land cover, vegetation cover, and land use conditions, land cover classification image was prepared by color synthesis of six bands (except Band b of far infrared wave length) of LANDSAT TM data, as shown in Fig. 3.2.

Fig. 3.6 shows the land cover and land use conditions.
Detailed characteristics of each seven morphologic provinces are described in Supporting Report A.

3.1.4 Geology

The geology of the Area is mainly composed of various metamorphic rocks, intrusive rocks, volcanic rocks and sedimentary rocks ranging from the Cretaceous to the Quaternary age.
These rocks and formations are distributed in a NNW - SSE direction in concordance with the extending direction of the main mountain ranges (see Fig. 2.1).

1) Metamorphic rocks
This rock group forms the base of the Area, and it is believed that the intrusive rocks of magmatic origin and the sediments of submarine volcanic origin were kinematically metamorphosed by the tectonic movement during the period ranging from later Mesozoic to early Cenozoic. This rock group is widely distributed in Cordillera Central.

2) Intrusive rocks
The intrusive rocks such as granite, tonalite, and rhyodacite to rhyolite intrude the metamorphic rocks mainly distributed in Cordillera Central.
Age of intrusion is assumed to be from later Mesozoic to early Cenozoic. Other ophiolitic rock group of unknown age, such as pyroxenite and gabbro, are distributed, too.

3) Volcanic rocks
Volcanic rocks are distributed locally forming small-scale rock bodies in Cordillera Septentrional, Cordillera Central, Sierra de Neiba and Sierra de Baoruco.

4) Sedimentary rocks
The sedimentary rocks in the Area are mainly of the Tertiary and Quaternary Systems.
The Palaeogene system of the Tertiary system consists mainly of limestone found in the mountain area of Cordillera Central, Sierra de Neiba and Sierra de Baoruco.
The Neogene system is composed of conglomerate, sandstone, mudstone and limestone found in the hilly to lowland area of Cordillera Septentrional, Llano de Yaque del Norte, Valle de San Juan, and in the surroundings of Lago Enriquillo. Some formations can be spanned from the Palasogene to Neogene age.
The Quaternary system are distributed in Llano de Yaque del Norte and Cuenca de Enriquillo.

Geological distribution of these rocks are generally in agreement with the morphological structure of the provinces.

5) Stratigraphy

In this Study, the stratigraphy of the Area was established based on the Atlas Geologico y Mineralogico de la Republica Dominicana, 1969, scale 1:250,000. The standard stratigraphic order and symbols are shown in Table 3.1 after the above mentioned Atlas.

Geological distribution of these rocks are generally in agreement with the morphological structure of the provinces.

The Project Area can be roughly divided into 3 geological regions.

- Northern region: Cordillera Septentrional and its southern part (Rio Yaque del Norte basin), mainly composed of Tertiary to Quaternary formations, and partly of Mesozoic formation of unknown period.

- Central region: Cordillera Central, made up of volcanic rocks and metamorphic rocks of the Cretaceous age.

- Southern region: Valle de San Juan, Sierra de Neiba and Sierra de Baoruco, chiefly of the Tertiary and Quaternary formations.

(1) Cordillera Septentrional

a) The geology of this province is chiefly composed of the Tertiary formations ranging from the Eocene to the upper Miocene or Pleistocene.

b) Formation Emcg

This is the lowest formation of the Tertiary system in Cordillera Septentrional and is restricted in distribution. This formation is observed in the eastern marginal piedmonts and the western margin of the Area.

Conglomerate, calcareous sandstone and shale prevail in the east, while shale is mainly distributed in the west.

They are generally controlled by fissures extending in the E-W to W-NW direction. This formation is inferred to be a Flysh deposit of Eocene to middle Oligocene age.

c) Formation O'Mce

This formation is distributed in the northern half of Cordillera Septentrional and is extended in a NWW to SEE (N70°W)

direction, 4 to 6 km in width and more than 60 km in length.
This formation is a series of alternating beds of calcareous sandstone (biomicritic limestone to biosparite) and calcareous siltstones to shale, and is accompanied by coral reef limestone at the upper most horizon.
It has been inferred to range from lower Oligocene to upper Miocene or Pliocene in age.

d) Formation Mice
This formation is distributed along the southern side of the Formation O'Mce, and is also in fault contact with the latter. It forms dissected hilly mountains and gentle relief hills of less than 400 m in elevation.
It is generally composed of alternating beds of fine to coarse grained calcareous sandstones and fine to medium grained sandy shale.
In the upper horizon, it sometimes contains interbedded conglomerate beds and sometimes underlies gravel beds.
The formation often strikes N70°~80°W, dips 15° to 30° south and north and is in concordance with the trend of the Cordillera Septentrional. A long wavelength undulation is noticeably seen in the NWW-SEE direction, and a small-scale repetitive folding structure is suggested with an axis oriented in the same direction.

e) Formation Mmca
This formation is distributed along the southern area of the planation surfaces in the central part of Cordillera Septentrional. It is 1 to 4 km in width and 20 km in length.
The alternating beds of this formation are made up of coarse and little porous calcareous to pebbly sandstone and calcareous shale to siltstone, and contain interbedded conglomerate beds.
The fossiliferous limestone bed sits on the uppermost horizon of the alternating beds. The alternating beds tend west-northwest and dip 15°to more or less north in the northern side.
In the southern side, the beds tend east-northeast and dip 15° to 30° south suggesting the possibility of an anticlinal structure.
Under microscopic observation, the calcareous sandstones or shales are identified as biomicrite.

f) Formation Mscm

The consolidated and unconsolidated conglomerate to gravel beds are distributed in the eastern plain and the central hills of the Area.

In the eastern piedmont area this formation is composed of alternating beds of massive calcareous sandstone to pebbly sandstone, shale to siltstone and half-consolidated pebble to gravel beds. Gravels predominate in the dissected hilly area but are sometimes rarely observed in the plain area.

In the central hilly area, this formation is composed of alternating beds of massive coarse sandstone and siltstone, and contains somewhat consolidated interbedded, lenticular and overlain conglomerate beds. The interbedded parts dip to about 20° to 30° and the overlain parts are almost horizontal.

The sedimentary environment of these gravel beds involve many problems that have to be solved.

Formation Mice, Mmca and Mscm are correlated with the lower to upper Miocene age, or with the upper Miocene to Pleistocene. Each member of these formations are similar and varied in their lithology and lithofacies, but have contrasting features as they show somewhat remarkably differing topographic and serial photographic patterns.

(2) Llano de Rio Yaque del Norte

a) The Neogene system at the southern side of Rio Yaque del Norte is distributed widely along the river and at the gentle and low relief hilly northern piedmont area of Cordillera Central.

b) Basal metamorphic rocks

These basal rocks are distributed in the upstream area of Rio Chacuey and Rio Maguaca, the dissected hilly mountain area. They are composed of shale, phyllitic shale and phyllite, and are predominant in the thin bedding plane.

They strike generally in a N-S direction and dip 50° to 70° south.

The geologic age is unknown but is assumed to be of the upper Cretaceous age.

c) Formation Mice

This formation is distributed at the dissected low relief hills and the intramountainous hill area of the southmost zone of Llano de Rio Yaque del Norte. It is composed of alternating beds of pebbly to coarse sandstone and siltstone and is accompanied by basal conglomerate bed.

This formation is generally strongly weathered, strikes west-northwest and dips about 10° north.

d) Formation Mmca

This formation is basically correlative with the Formation Mmca of the Cordillera Septentrional, and conformably or slightly uncomformably overlies formation Mice. The lower parts are alternating beds of calcareous sandstone and siltstone and contain quite an amount of fossils. The upper parts are porous fossiliferous limestone partly containing intercalated conglomerate beds.

Under microscopic observation, this limestone is identified as biomicritic limestone.

e) Formation Mscm

A gravel bed is distributed at the western confluence of Rio Guayubin and Rio Yaque del Norte. This gravel bed is correlative with the conglomerate and gravel beds at the northern side of Rio Yaque del Norte, but is not so thick and is restricted in distribution.

f) Alluvial Deposits

The Quaternary system is distributed in the low and flat area of the lower stream of Rio Yaque del Norte. It appears to be a delta area, but the distribution of the alluvial deposits seems to be unexpectedly thin.

(3) Cordillera Central

The geology of this area is composed mainly of intrusive rocks, a metamorphic complex rock body, sedimentary metamorphic rocks, and limestone ranging from upper Mesozoic to lower Tertiary in age.

a) Intrusive rocks

The intrusive rocks are distributed widely in the upstreams of Rio Masacre, Rio Chacuey, Rio Maguaca and Rio Guayubin. Their rockfacies vary by localities.

Composition is mainly melanocratic, medium grained and

holocrystalline biotite-hornblende quartz-diorite, and tonalite. Sometimes they show a greissose to schistose texture.
Another intrusive rock body is composed of basic to ultrabasic rocks such as peridotite, serpentinite and gabbro. A fissure system of NE-SW direction is predominant.

b) Metamorphic complex
This complex body is distributed widely at the southern side of the intrusive rock body. The complex bodies are composed of slate, shale and phyllitic mudstone of submarine volcanic tuff origin, and was kinematically metamorphosed. They sometimes show igneous rockfacies.
Generally, the complex bodies indicate compact and hard rocks and are predominant in joints, beddings and sheared cracks.

c) Sedimentary metamorphic rocks
These rocks are distributed at the southern side of the metamorphic complex body, and is composed of graywacke, slates and phyllites. They strike 30°N to 60°W and dip more or less 70° east or west. A small repetitive folding structure is assumed.
The geologic age is supposed to be upper Cretaceous to lower Tertiary.

d) Limestone
Limestone is distributed along the southern marginal zone of Cordillera Central and is in contact with the Mesozoic metamorphic formation by a big fault.

(4) Valle de San Juan
In Valle de San Juan, formations correlated with the Eocene to Plio-Pleistocene age are widely distributed.

a) Formation Eo, Es and Ec
These formations are composed of limestone and are distributed eastward, from Pedro Santana to the eastern mountain area.
The alternating beds of shale, sandstone and comglomerate cover the hilly area and tend east-west and generally dip more or less 50° south .
Conglomerates are distributed at the upper hilly area to the west, but are sometimes found in a scattered pattern.

Continuous cuesta landforms consisting of alternating beds are well observed, too.

b) Formation Pcmg
This formation is distributed in the surrounding area of Elias Piña and forms gently undulated to flat cultivated plains.
It is composed of alternating beds of massive siltstone, massive sandstone, coarse pebbly sandstone, coral limestone and gravel.

c) Formation Mg
This formation is widely distributed in the northern and southern area of Rio Macasia, and is composed of alternative beds of conglomerate, sandstone and siltstone.

d) Alluvial Deposits
Along the channels of Rio Macasia, alluvial deposits, consisting of loose gravel and sand, are distributed at the flooded zone.
In the area of Valle de San Juan, the exact stratigraphic order of each alternating beds of Formation Ec, Pcmg and Mg still remain unknown.

(5) Sierra de Neiba
Sierra de Neiba is mainly composed of Palaeogene limestone and some neogene formations.

a) Formation Oce
This formation is distributed from west to east along Rio Cana from the Hondo Valle to El Cercado.
The formation is composed of alternating beds of siltstone, sandstone and interbedded limestone beds, with siltstone dominating the composition.
This formation strikes N70° to 80°W and dips 50° to 60°N or S, and shows small repetitive foldings.
Judging from lithofacies and well formed cuesta landforms, this formation is possibly correlative with the Formation Pcmg in Valle de San Juan.

b) Formation Mc
This formation is distributed in the north coast of Lago Enriquillo and is in fault contact with the limestone of Sierra

de Neiba.

It is composed of alternating beds of conglomerate and sandstone to silty sandstone.

c) Formation Ec and Oc

Limestones of Sierra de Neiba show violent changes and similar lithofacies. They can be approximately divided into four zones by landform characteristics and aerophotographic pattern. They chiefly consist of alternating beds of limestone and calcareous sandstone but reveal a complex structure with a wide variety of lithofacies such as well stratified parts, well jointed and cracked breccia-like part, massive part and weathered friable sand to powdery parts.

They strike generally N50° to 80°W and dip 20° to 50° N or S. They form gently elongated dome-like landforms and suggest a repetitive folding structure.

These limestone formations are assumed to range in age from Eocene to Oligocene and possibly even to upper Miocene.

(6) Cuenca de Enriquillo

This area forms a low-flat zone of about 10 to 25 km wide and more than 100 km long, extending in an east-northeasterly direction.

This area is assumed to have been formed as a result of an intense plate tectonic movement during the upper Cretaceous to middle Miocene period.

This area is underlain by coral reefs in the western terrain and widely distributed Quaternary lacustrine sediments in the eastern area. Swamps, sandy marshes and savanna are observable in the eastern area.

(7) Sierra de Baoruco

Sierra de Baoruco is composed of Palaeogene limestones and some Neogene formations.

a) Formation UPg and MPc

This formation forms a semi-spindle shaped zone along the south coast of Lago Enriquillo.

This formation is composed of alternating beds of semi-consolidated conglomerates and calcareous fine sandstone to limestone.

It strikes in a NW-NWW-EW direction, dips 20° to 70° north and south, and suggests a repetitive folding structure.

b) Formation Mscy

this formation is composed of alternating beds of siltstone, sandstone and gravel, and is characterized by thick intercalated gypsum and rock salt beds.

They strike NW to EW, dip 45° to 75° north and south, and suggest an anticlinal structure.

Cuesta landforms based on the alternating beds are predominant.

Formations of MPg·MPc and Mscy are possibly from the Miocene to Pliocene age.

c) Formation Oc

This formation is composed of milky white colored limestone with a wide variety of lithofacies such as stratified, massive, brecciated, powdery and intercalated conglomeratic facies. This limestone is identified as micrite under the microscope.

The boundary between the Formation Mscy is assumed to be a tectonic fault line on a somewhat large scale.

This formation generally forms a dome-like anticlinorium which is ascribed to small repetitive foldings.

d) Formation Ec

This formation is mainly composed of limestone and forms the main part of Sierra de Baoruco.

Composition is white to milky white colored, compact and hard limestone with a variety of lithofacies such as well stratified, brecciated and massive. This formation strikes N30° to 70°W and dips NE.

An anticlinal dome-like structure and flat-topped dome-like plateau tending northwest are generally assumed. At the southwest most part of this area, doline-like depressions are observable.

e) Lithofacies of limestone

Limestone beds are widely distributed in Sierra de Neiba to Sierra de Baoruco. They are difficult to classify and arrange in a stratigraphic sequence because of the violent change in the facies and their similar appearances.

Under microscopic observation, each limestone is composed of bioremains and groundmass of carbonate minerals. Bioremains are composed mainly of almost the same species. Degrees of recrystallization are not so different. The grain size of the bioremains of Formation Ec is somewhat coarser than that of Oc. Accordingly, limestones in the southern mountain area are difficult to classify and their geologic age to date is difficult to determine, although they are regarded to be Palaeogene in age.

3.2 Meteorology, Hydrology and Water Quality

3.2.1 Meteorology

1) The Project Area is endowed with remarkable geographical characteristics. It extends from lowlands elevated to less than 10 m, to high mountain ranges with an elevation of more than 2000 m above sea level. The Baoruco, Neiba and Central Mountains, which are the highest mountain ranges, cross the Project Area east to west, while the Northern Mountains form a hilly-mountainous zone of 300 to 400 m in elevation.

   The Project Area extends from 18°20' to 19°55' of northern latitude, and is located in a subtropical zone. The climate is mainly influenced by the Ocean and is comparatively mild.

   The project area was divided into 3 distinctive zones according to mean annual rainfall variations: the arid or semi-arid northern and southern flat lands where rainfall varies from 500 to 700 mm; the humid mountain zone where rainfall exceeds 2,000 mm; and the semi-humid intermediate mountains and hillocks where rainfall varies from 1000 to 1500 mm.

   The mean annual rainfall shows important local variations. However, distinction between dry season and rainy season in the whole area is not always clear.

   Generally, the rainy season covers the period from May to November, exclusive of July, and the period from December to April. July is regarded as the dry season. But in the northern area influenced by the Atlantic Ocean Climate, the winter season from November to May is comparatively rainy.

   Furthermore, hurricanes or tropical cyclones bring heavy rains every year in the rainy season locally causing serious variations in the annual rainfall amount.

2) More than 30 meteorological stations presented in Fig. 3.7 already exist in and outside the Project Area. Most of them are rain gauge stations, and meteorological stations are partially located in the region.
Further, meteorological coverage of the mountain village area is made impossible due to maldistribution of the stations in the towns.
These recorded data will be hardly sufficient, considering the effective information required for the formulation of this Project.
However, long-term observation records consisting of monthly and annual effective rainfall recorded in 25 stations and of measurements of wind, evaporation, humidity, etc., recorded in several stations were collected from INDRHI.
Average values and characteristics of the different climates observable in the Project Area inferred from the collected meteorological data are as follows:

(1) Precipitation
The mean annual precipitation evaluated based on several to 50 years of observation shows an average rainfall of 500 - 700 mm in the southern arid zone; 600 - 750 mm in the northern semi-arid zone; the highest at 1500 - 2000 mm in the Cordillera Central, Neiba and Baoruco Mountain Ranges. On the other hand, the hilly areas at the skirts of the above mountains indicate an annual precipitation of 800 - 1500 mm, although this varies according to geographical conditions.
Annual rainfall in both arid and humid zones shows great monthly and annual fluctuations.
Maximum and minimum annual and monthly rainfall recorded in the past are tabulated below.

	Annual Rainfall	Monthly Rainfall
Max	4652 mm (1960, Restauracion)	857.8 mm (May 1956, Elias Piña)
Min	178.4 (1947, Duverge)	0.0 (Including humid mountain area, many areas)

The annual rainy days observed at the river mouth area of the Rio Yaque del Norte is approximately 50 days; in arid and semi-arid zones, 70 to 100 days; in semi-humid zones, 100 to 130 days; in humid areas about 150 days. However, rainfall duration per day is short (1 or 2 hours). The rainfall pattern is characterized by heavy rains with extremely strong rainfall intensity. The maximum intensity was observed on August 13, 1991, with an hour rainfall of 89 mm from 14.30h to 15.30h. In general, a 35~50 mm/hr intensity is most observable. The maximum 24 hour rainfall, which is 575.4 mm, was recorded at Tamayo on June 16, 1972. The main stations where 24 hour rainfall data are recorded are as follows:

Don Miguel	285 mm	Restauracion	235.8 mm
Duverge	444.5	Monte Cristi	107.0
Elias Piña	196	Jimani	109.7

In general, 60% to 70% of the annual rainfall take place within a 6 month period, that is, April, May, June, September, October and November. However, total rainfall from December to March (4 months) in the northern zone represents 35% of the annual rainfall, which is relatively high in comparison with other areas (15-20%).

(2) Temperature

Excluding the inland mountains where temperature drops to below 10°C in winter, the mean monthly areal temperature ranges between 22°C and 30°C, and the yearly temperature change in each area is small.

(3) Relative Humidity

Humidity in the subject area is comparatively high. Mean annual humidity is 74% in the semi-arid lowland zone of Monte Cristi,

and 84% in the mountainous area of Restauracion.
In general, relative humidity is high during the rainy season and low during the dry season.

(4) Evaporation and Evapotranspiration
According to the evapometers, the annual evaporation in the Project Area varies in accordance with the amount of rainfall; it is high in dry zones with little rain and low in very humid zones.
The mean annual areal evaporation in the Project Area exceeds the mean annual areal precipitation (250 to 300%) at 2000 mm.
In July that is in the middle of the rainy season, rainfall extremely decreases, and vegetation is abundant. Furthermore humidity and evaporation from ground surface is high, evapotranspiration from cultivated crops sometimes amounts to more than 2000 mm in some area.

(5) Direction and Velocity of the Wind
There are few observatories which have wind direction and wind velocity data. As the Project Area is rich in topographical variation, the existing data cannot cover the whole Project Area.
The mean annual wind velocity in the Project Area is from 0.8 to 5.3 m/second. The mean annual wind velocity and wind direction recorded at 3 of the observatory sites are as follows:

Observatory	Area	Mean Wind Velocity	Wind Direction
Monte Cristi	Northern Lowlands	10 km/hour	Northeast
Dajabon	Mountain Foot	5~6 km/hour	Northeast and East
Jimani	Southern Lowland	10 km/hour	East and East-Southeast

(6) Duration of Sunshine and Insolation
The daily duration of sunshine in the Project Area is 12 hours and the general average is 8 hours. Period of long sunshine extends from February to August, with the longest shining hours observable in July. The shortest shining hours take place in December.
Monthly solar radiation observed from March to August exceeds 450 cal/km^2/day; maximum radiation is recorded in July, and is around 500 cal/km^2/day; minimum radiation is 320 cal/km^2/day in

December; mean annual radiation ranges between 420 and 430 cal/km^2/day.

3.2.2 Hydrology

1) River and Hydrological Basin

Most of the surface water in the Project Area runs through the following three river systems:

- the 1st river system consists of the Dajabon River, Chacuey River, Guarabo River/Saladillo Lake, Yaque del Norte River and its tributaries (Cana, Guayubin, Maguaca rivers). These rivers flow from east to west or from south to north through the northern flatlands and hills and then into the Atlantic Ocean;

- the 2nd river system consists of Artibonito River and its tributaries (Tocino, Joca, Macasia rivers). Located in the central and southern mountain region, these rivers flow from north to south along the Dominican and the Haitian Border, and then into the Carribean Sea.

- the 3rd river system consists of Guarabo River and other small rivers that inflow into Lake Enriquillo.

The Project Area can be divided into 6 hydrological basins from these river systems. The summary of each hydrological basin is as follows.

	Catchment Area km^2				
Name	Total	Territory of Haiti	Dominican Territory	Project Area	Main Rivers' Name
Rio Dajabon	380	150	230	230	Masacre
Rio Guarabo/ Lag. Saladilla	172	–	172	172	–
Rio Chacuey	397	–	397	397	–
Rio Yaque del Norte	7044	–	7044	2366	Mao, Cana, Gurabo Guayubin, Maguaca
Rio Artibonito	9000	6386	2614	2614	Joca, Tocino, Macasia, Cana
Lago Enriquillo	3093	140	3193	3193	Mazagual, Barrero, Descubierto

2) River Discharge

The discharge of each river in the Project Area largely varies regionally and seasonally corresponding with the distribution and amount of rainfall and other precipitation characteristics, topography, geological features, vegetation, land use, and other catchment surface characteristics.

INDRHI has arranged many long term effective data containing river discharge records for water resources development.

The monthly/annual discharge of the major rivers is listed in Table 3.2.

Specific discharge and runoff coefficient of the major rivers are as follows.

Name	Annual Total Discharge m^3	Runoff Percentage %	Specific Discharge ℓ/km²/sec
Rio Yaque del Norte	2.230×10^6	36~49	10 - 15
Artibonito	1.630×10^6	26~33	26 - 30
Dajabon (Masacre)	90×10^6	53.1	25.1
Mao	620×10^6	71.6	32.5
Guayubin	308×10^6	43.8	20.5
Chacuey	40×10^6	21.7	15.6
Macasia	182.9×10^6	10.5	3.9

The cumulated discharge in the high-water season, that is May, June, September, October and November, amounts to 60 - 70% of the total annual discharge.

Water is high in May and November, and low in January, February and March.

The drought season is in February or March and during these months, the total discharge is only 5~10% of the total annual discharge.

The major rivers, including tributaries such as, Mao, Gurabo, Guayubin, are highly developed for irrigation and water supply, and many dams, barrages, pump stations, diversion works are constructed in each river.

Accordingly, excluding the main stream of Yaque del Norte and Artibonito, discharge in the drought season at the downstream area of these diversion works is extremely low, reaching zero in many cases.

3) River Water Quality

The value of pH in each river is about 8, but the salinity content, electric conductivity, and turbidity present different values (refer to Supporting Report B). Although the contents of Mg, HCO_3 and Ca are relatively high in the rivers, they do not exceed the maximum permissible value for drinking water (Mg, HCO_3: 150 mg/ℓ, Ca: 200 mg/ℓ).

4) Springs

The Project Area is endowed with various geographical features and geological structures. The humid mountainous area has more than 2000 mm of annual rainfall, and has many abundant springs.

Many springs are especially distributed at the alluvial fans of the northern Lago Enriquillo basin, discharging great quantities of groundwater south of Sierra de Neiba. Springs are widely used as water sources of the water supply or irrigation system.

The principal springs and their corresponding amount of discharge according to the INDHRI survey are as indicated below:

La Descubierta	21.6 ℓ/s
Tierra Nueva	0.9 ℓ/s
Vengan a Ver	2.1 ℓ/s
La Marias	0.2 - 0.4 m^3/s
Las Barias	0.4 - 1.0 m^3/s
Llamado la Zurag	0.26 m^3/s
Roberto en Baitos	0.09 m^3/s
La Chorrera en Baitos	0.04 m^3/s
Merigildo en Baitos	0.17 m^3/s
Grande en Baitos	0.54 m^3/s

These spring waters are used for irrigation and daily use.

3.3 Hydrogeology

The hydrogeology of the Project Area was analysed based on geophysial and test drilling investigation results.

Geophysical prospecting was conducted to assess geological structure, conditions of aquifer, particularly, lithofacies, depth and layer thickness, and to determine depth of drilling. The test drillings were carried out to validate