社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT
THE SOCIALIST REPUBLIC OF VIET NAM

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIET NAM

FINAL REPORT

SUMMARY REPORT

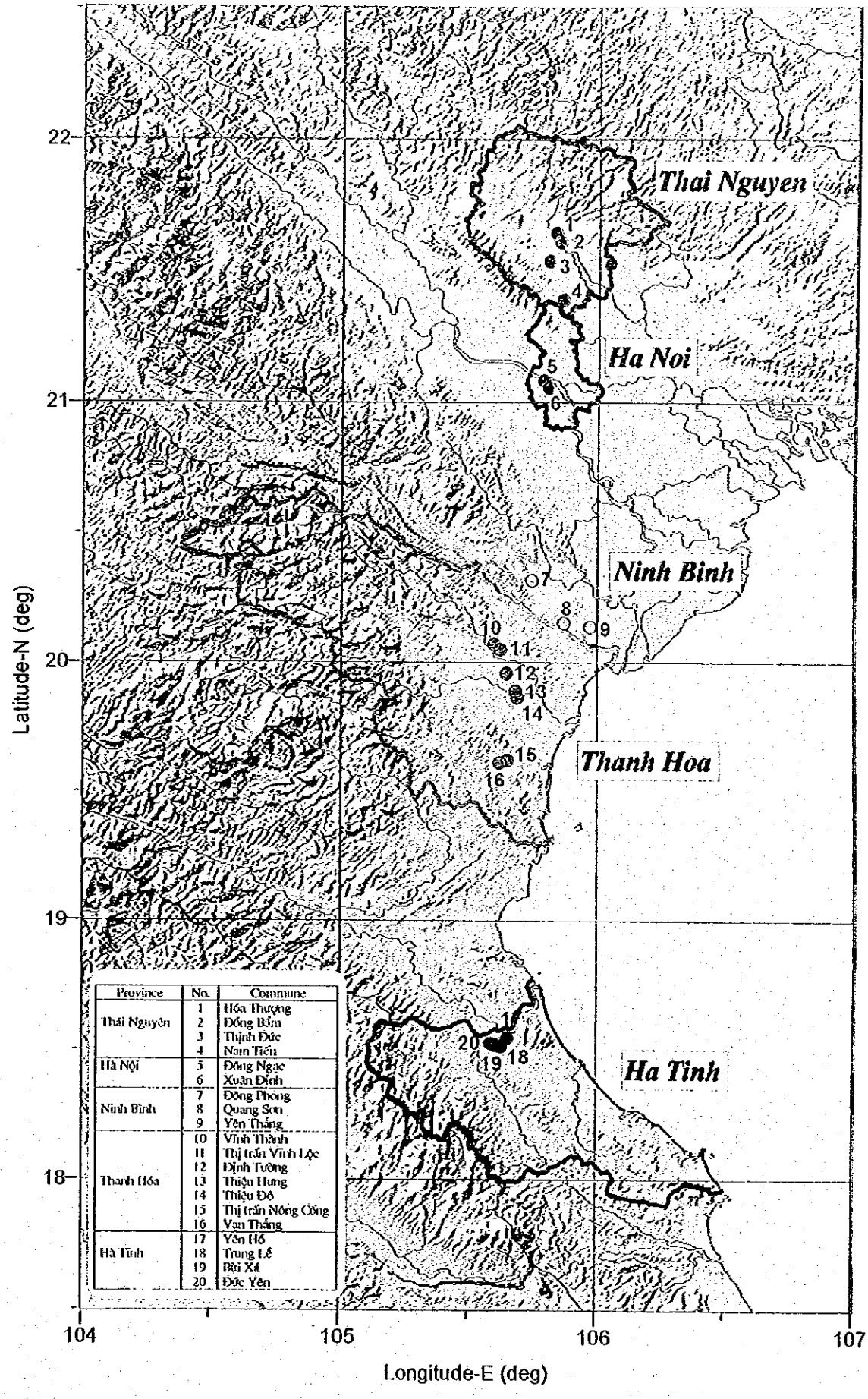
JANUARY 2000

KOKUSAI KOGYO CO., LTD.
OYO CORPORATION

Composition of the Final Report

The final reports are composed of the following 7 volumes.

1.	Summary Report	(Japanese)
2.	Summary Report	(English)
3.	Summary Report	(Vietnamese)
4.	Main Report	(English)
5.	Supporting Report A	(English)
6.	Supporting Report B	(English)
7.	Data report	(English)



Province	No.	Commune
Thái Nguyên	1	Hóa Thượng
	2	Đồng Bẩm
	3	Thịnh Đức
	4	Nam Tiến
Hà Nội	5	Đông Ngạc
	6	Xuân Đỉnh
Ninh Bình	7	Đồng Phong
	8	Quang Sơn
	9	Yên Thắng
Thanh Hóa	10	Vĩnh Thành
	11	Thị trấn Vĩnh Lộc
	12	Định Tường
	13	Thiệu Hưng
	14	Thiệu Đô
	15	Thị trấn Nông Cống
	16	Vạn Thắng
Hà Tĩnh	17	Yên Hồ
	18	Trung Lễ
	19	Bãi Xá
	20	Đức Yên

LOCATION MAP OF THE STUDY AREA

PREFACE

In response to a request from the Government of the Socialist Republic of Vietnam, the Government of Japan decided to conduct the Study on Groundwater Development in the Rural Provinces of Northern Part in the Socialist Republic of Vietnam and entrusted the study to the Japan International Cooperation Agency (JICA).

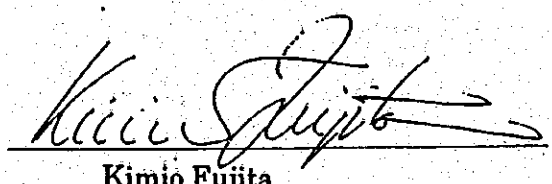
JICA selected and dispatched a study team headed by Dr. Akira Kamata of Kokusai Kogyo Co.,Ltd. and consists of Kokusai Kogyo Co.,Ltd and OYO Corporation to Vietnam, 3 times between August 1998 and November 1999.

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

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

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

January ,2000



Kimio Fujita
President
Japan International Cooperation Agency

January 2000

Mr. Kimio Fujita
President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit the final report of "The Study On Groundwater Development in the Rural Provinces of Northern Part in the Socialist Republic of Vietnam". This report has been prepared based on the field survey and the study conducted during the period from August 1998 to January 2000.

The report contains the study results on the evaluation of groundwater resource in 20 communes of the northern 5 provinces, the water supply master plan and the feasibility study of priority projects based on the groundwater development.

We hope that the implementation of the groundwater development and water supply plan would greatly contribute to the improvement of water supply and sanitation in the study area.

All the members of the Study Team wish to express their sincere thanks to the personnel of your Agency, the Embassy of Japan in Vietnam and the officials and personnel of the Ministry of Agriculture and Rural Development and the Center for Rural Water Supply and Environmental Sanitation for the assistance extended to them.

Very truly yours,

Akira Kamata

Akira KAMATA
Team Leader
The Study on Groundwater Development
in the Rural Provinces of Northern Part
in the Socialist Republic of Vietnam

The Study on Groundwater Development in the Rural Provinces of Northern Part in the Socialist Republic of Viet Nam

Study Period:	August 1998 to November 1999
Counterpart Agency:	Centre for Rural Water Supply and Environmental Sanitation (CERWASS), Ministry of Agriculture and Rural Development

ABSTRACT

1. BACKGROUND

The northern region of Vietnam faces the Gulf of Tong King in the Indochina Peninsula. It is made up of mountains, the Red River downstream delta in the north and west, and narrow coastal plain in the east. The target 20 communes are in the 5 northern provinces and have a total population of approximately 140,000. With the exclusion of the 2 communes in Ha Noi, the area is purely agricultural. Rural residents currently use shallow wells, tube wells, river water and ponds as water sources. These sources were observed to be contaminated, with the majority drying up in summer. There is a shortage of safe and sanitary water supply in the rural area, a condition that significantly impedes improvement in public health conditions and the development of an actively operative social infrastructure. Given this condition, the formulation of a water supply plan through groundwater development is an urgent concern.

2. OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

1) To study the groundwater potential in the 20 communes of the five northern provinces (Ha Noi, Thai Nguyen, Ninh Binh, Thanh Hoa, Ha Tinh).
2) To formulate the master plan (M/P) for groundwater development and water supply targeting the year 2010.
3) To implement the feasibility study (F/S) for the priority projects.
4) To conduct technology transfer for the counterparts.

3. Study Area

The study focuses on the 20 communes in the 5 northern provinces in Vietnam.

4. Groundwater Study

(1) Hydro-geology

Groundwater in the target communes exist in the Quaternary formation and the basement rock (limestone). The gravel and sand layers of the Quaternary formation form the aquifers exploited by the shallow and tube wells in each of the target commune. In Thai Nguyen, Ninh Binh, and Thanh Hoa, the limestone with fractures and cavities form productive aquifers.

(2) Fluctuations in Groundwater Level

With the exclusion of Ha Noi, the groundwater level of existing wells is generally less than 10m below ground surface. In Ha Noi, excessive groundwater pumping has led to a decline in groundwater level at 220 m below mean sea level in the central area of the depression. Groundwater level varies by season due to rainfall fluctuations, and some shallow wells in the target communes dry up in the dry season.

(3) Groundwater Quality

1) Existing Wells

Most shallow well water were detected with coliform bacilli. With the exclusion of the communes in Thai Nguyen, iron levels detected in the majority of the wells in the communes exceed the standard (0.5 mg/ℓ) established by Vietnam for drinking water quality. Manganese levels in most communes were also higher than the established Vietnamese standards (0.1 mg/ℓ), except in Thai Nguyen and Ninh Binh.

2) Test Wells

Of the test wells, those in 8 communes exceeded the standard value for iron, while those in 7 communes had manganese levels higher than the standard value. Chloride ion levels were higher than the standard value in Yen Thang in Ninh Binh, and Duc Yen and Trung Le in Ha Tinh.

3) Ha Noi

The analysis of the water quality of the wells of the Ha Noi waterworks system led to the following observations: iron levels in the well field southwest of Xuan Dinh ranged from 0.0 to 3.3 mg/ℓ in Mai Dich; from 0.1 to 4.7 mg/ℓ in Ngoc Ha; 6.7 to 19.7 mg/ℓ in Ha Dinh. The average manganese levels in these well field also exceed the standard value. Ammonium levels in the Ha Dinh and Ngoc Ha well field were extremely high.

(4) Geophysical Prospecting

Vertical Electric Sounding (VES), Resistivity Image Profiling (RIP), and Very Low Frequency (VLF) prospecting surveys were carried out to determine underground geology and decide the test well drilling points. These surveys were particularly effective in the fault and fractured zones of the limestone area.

(5) Test Wells

Test wells were drilled in 15 places (14 communes) and groundwater was pumped out of these wells. However, the test wells in Yen Thang in Ninh Binh, Trung Le and Duc Yen in Ha Tinh were not possible to convert to production wells due to the high salinity levels detected in the groundwater. Pumping tests were carried out on these wells to calculate the aquifer coefficient.

(6) Groundwater Resource Evaluation

Each factor that affect water balance was studied. Groundwater recharge in the study area was estimated at about 600 mm per annum considering the amount of precipitation, evaporation and surface runoff. The results of the pumping tests were used to estimate the optimal pumpage of every test well: 1,000 to 1,800 m^3/day from the limestone aquifer, 10 to 250 m^3/day from the quaternary aquifer (excluding the communes in Ha Noi).

(7) Groundwater Modeling in Ha Noi

A three dimensional groundwater model was used to predict groundwater levels in Ha Noi area. The results show that new development of groundwater resources in the two communes at the outskirts of Ha Noi expands groundwater level decline in wide area. However, since a huge groundwater amount is already exploited in the Ha Noi area, the development of new groundwater resources in the two communes is predicted to hardly have any impact on groundwater flow system.

5. MASTER PLAN (M/P)

(1) Target and Goal

The M/P was formulated in the 20 communes of the 5 northern provinces. The M/P aims to attain the water supply amount and service coverage rate shown in the table below by 2010 through household connections (Level III).

Year	Service Population	Water Supply Amount m^3/day (ℓ/c/d)	Coverage Rate (%)
2002	74,800	9,170 (123)	50
2005	124,000	16,350 (132)	80
2010	149,700	23,030 (154)	90

Note: (ℓ/c/d) = liter per capita per day

(2) Water Supply Facility Criteria

1) The water to be supplied will be chlorinated. The distribution pipes and water supply pipes will be constantly pressurized as a means to prevent contamination.
2) Basically, groundwater will be the water source.
3) Treatment facilities will be installed for the removal of iron and manganese

(3) Facility Plan

The facilities will consist of: water source (deep wells), treatment plant (filtering pond, sedimentation basin, etc), and distribution system (distribution pond, distribution tower, distribution pipes, etc.)

(4) Implementation of the M/P

The M/P will be implemented by the CERWASS. The CERWASS will generally supervise the planning formulation, actual facility design and construction and the work at every phase, and the operation and maintenance of the facilities until they are handed over to the communes. After the hand over, the communes, as owners of the facilities, will be responsible for their operation and maintenance.

(5) Organizational Plan

This plan will be implemented under the framework of the present rural water supply institutions. To smoothly carry out the plan, a Project Management Unit (PMU) and a National Training Team (NTT) will be established within the CERWASS. For the operation and maintenance of the facilities, a Water Supply and Sanitation (WATSAN) committee, and a Commune Water Supply Organization (CWSO) will be formed under the Commune People's Committee (CPC).

(6) Financial Plan

The residents are assumed willing to pay a water charge based on the huge demand for safe and clean water supply. If set in accordance with the electric bill, the monthly

water charge would amount to VND 1,800 to 4,500/m^3 (3 to 6 % of the income if household is assumed to consume 11m^3/month). The water charge should be fully discussed by the commune residents prior to the construction of the facilities.

(7) Organizational Reinforcement & Sanitary Campaign

For the sustainable operation and maintenance of the water supply facilities, relevant organizations at the central, provincial and commune levels should be reinforced by providing training programs. To improve public health conditions and the sanitary environment in every commune through the use of safe and clean water, a water and sanitation campaign will be carried out through IEC (information, education, and communication) activities.

(8) Investment Cost

This plan is estimated to require an investment of approximately VND 225.3 billion (US$ 16.2 million).

6. PRIORITY PROJECT

(1) Target Area

Of the 20 communes, the 4 communes in Ha Tinh and Nong Cong Town in Thanh Hoa were excluded from the priority project due to poor groundwater quality and low groundwater yield. Accordingly, the priority project covers a total of 15 communes, and an F/S was carried out for these communes.

(2) Policy for Facility Planning

Each commune will be constructed with a water supply facility of its own. However, Vinh Loc Town and Vinh Thanh in Thanh Hoa will share one water supply system.

(3) Water Treatment Facilities

The biological filtration method is adopted basically for the removal of iron and manganese in the water. However, in communes where the levels are lower than the Vietnamese standard for drinking water quality, a simple filtration facility will be used. In the 2 communes at the outskirts of Ha Noi, an alternatives consisting of aeration tower and contact basin/sedimentation pond is planned as the iron and manganese levels are forecast to be higher in these areas.

(4) Project Cost

The priority project (14 water supply facilities in 15 communes) is estimated to incur an

overall cost of VND 191 billion (US$ 13.7 million) based on international prices. The per capita share of the residents in the construction cost varies sharply from VND 2.1million (Thin Duc in Thai Nguyen) to VND 1.2 million (Thieu Do in Thanh Hoa).

(5) Financial Analysis

The results of the analysis of the financial viability of the facilities (construction, operation & maintenance, etc.) revealed that all communes are feasible as the revenues would be larger than the expenses. However, in sparsely populated communes, it is necessary to secure the initial operation fund for several years after construction.

(6) Project Evaluation

From the social viewpoint, the project is expected to bring about a sufficient number of benefits, and should be implemented therefore. The need for the communes to fully study and discuss the details of facility operation and maintenance is of paramount importance to acquiring public consensus and commitment to the project's implementation.

7. RECOMMENDATION

Recommendations were made on the following issues.

(1) Groundwater Development Plan

- Comprehensive groundwater management in Ha Noi
- Items to consider in the development of the limestone aquifer
- Improvement of well drilling techniques

(2) Water Supply Plan

- Development of alternative water resources
- Unification of water supply service coverage
- Ha Noi waterworks system expansion & the 2 communes

(3) Financial Plan

- Understanding of the residents
- Establishment of a reasonable water charge
- Consideration of facility renewal cost

(4) Organizational Plan

(5) Sanitary Environment

- Sanitary education
- Environment

The Study on Groundwater Development in the Rural Provinces of Northern Part of the Social Republic of Viet Nam
Final Report

Summary Report

LOCATION MAP
ABBREVIATION

Contents

PART II GROUNDWATER INVESTIGATION

Exchange Rate

(November 1999)

US$ 1.00=13,941VND=106 Yen
1 VND=0.0076 Yen=US$ 0.000072
1 Yen=US$ 0.009=131.5 VND

List of Abbreviations

CERWASS:	Centre for Rural Water Supply and Environmental Sanitation
CHC:	Community Health Care
CI:	Consulting Institute
CPC:	Commune's People's Committee
CWSO	Commune Water Supply Organization
DANIDA:	Danish International Development Assistance
DARD:	Department of Agriculture and Rural Development
DARDO:	District Agriculture and Rural Development
DF/R:	Draft Final Report
DGMV:	Department of Geology and Minerals of Vietnam
DHC:	District Health Centre
DOF:	Department of Finance
DOH:	Department of Health (provincial level)
DOSTE:	Department of Science, Technology & Environment
DPC:	District Peoples Committee
DPI:	Department of Planning & Investment
EIA:	Environmental Impact Assessment
F/R:	Final Report
FISOLS-95:	Fifth International Symposium on Land Subsidence-95
F/S:	Feasibility Study
GAD:	Gender and Development
GDP:	Gross Domestic Product
GSO:	General Statistical Office
HRD:	human resources development
IEC:	information and education campaign
IC/R:	Inception Report
IT/R:	Interim Report
IEE:	Initial Environmental Examination
JICA:	Japan International Cooperation Agency

KI:	Key Informant
lcd:	litter per capita per day
MARD:	Ministry of Agriculture and Rural Development
MCM:	million cubic meter
M/M:	Minutes of Meeting
MOC:	Ministry of Construction
MOE:	Ministry of Education
MOF:	Ministry of Finance
MOLISA:	Ministry of Labour, Invalids and Social Affairs
M/P:	Master Plan
NGO:	Non-governmental organizations
NIPHEP:	National Institute of Public Health and Environmental Protection
NRWSS:	National Rural Water Supply and Sanitation
ODA:	Official Development Assistance
O&M:	Operation and Maintenance
PCM:	Project Cycle Management
PDM:	Project Design Matrix
PDOSTE:	Provincial Department of Science, Technology & Environment
PDPSC:	Provincial Disease Prevention and Sanitation Centre
PPC:	Provincial People's Committee
P/R:	Progress Report
PRA:	Participatory Rapid Appraisal
RWSS:	rural water supply and sanitation
SPC:	State Planning Committee
SRV:	Socialist Republic of Vietnam
S/W:	Scope of Work
UNICEF:	United Nations Children's Fund
VLF-EM:	Very low frequency-electromagnetic (method)
VM:	Village Mobilizer
VND:	Vietnam Dong
WB:	World Bank
WATSAN:	Water Supply and Sanitation
WID:	Women in Development
WU:	Women's Union

PART 1

GENERAL

PART I GENERAL

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

The economy of the Socialist Republic of Vietnam has remarkably developed in recent years. Due to extensive civil strife, however, the development of the nation as a whole has been slow, particularly in the rural area.

In terms of infrastructure, the rural water supply system was underdeveloped until the 1960s, when the Government of Vietnam started a campaign for the construction of shallow wells, bathrooms and latrines. The program was re-implemented after the Vietnam War, and from the 1980s water supply facilities were constructed in some provinces with the financial support of the United Nations Children's Fund (UNICEF).

Urban and rural water supply and sanitary conditions differ considerably. Only about 20 % of the residents in the rural area receive safe water supply services. Shallow wells and rivers are among the number of water sources predominantly used in the rural area. These sources, however, extremely endanger the health of the residents as domestic wastewater discharge contaminate shallow wells and industrial wastewater pollute river water.

To cope with these conditions, the government prepared the Rural Socio-economic Development Plan to improve the standard of living and solve prevalent social problems. To attain these objectives, the government acknowledges the importance of constructing water supply facilities and improving sanitary conditions in the rural area. In the recent plan, the government aimed to attain a service rate of 80 % by the year 2005 for use of clean water (NRWSS: No.237/1998/QD-TTg).

The above plan entails the implementation of a groundwater development plan and a water supply plan (deep well construction) in five provinces. However, lack of data and information on groundwater development, water supply facilities, and public health and sanitation, hampered the progress of the plan.

Given these circumstances, the Government of Vietnam requested the assistance of the Government of Japan in September 1996 for the conduct of the study. In response to the

official request, the Government of Japan dispatched the preparatory study team to discuss the Scope of Work (S/W). The S/W was established by the Japanese and Vietnamese sides in January 1998.

Based on the S/W, JICA made a contract with the joint venture of Kokusai Kogyo Co., Ltd. and OYO Corporation in August 1998 for the implementation of the study. The study team, which consists of the expert of the joint venture, was dispatched to Vietnam in August 1998 and conducted the first and the second field work in Vietnam till July 1999. This final report presents the results of study carried out through domestic work from September to October, 1999 and discussion on the draft final report between the study team and the Vietnamese side on November 1999.

1.2 Objectives of the Study

The objectives of the study are as follows:

- To study the groundwater potential in the 20 communes of the five northern provinces.
- To formulate the master plan (M/P) for groundwater development and water supply targeting the year 2010.
- To implement the feasibility study (F/S) for the priority projects.
- To conduct technology transfer for the counterparts.

1.3 Study Area

The study covers the 20 communes in the five northern provinces of Ninh Binh, Thanh Hoa, Ha Tinh, Thai Nguyen and Ha Noi. Table 1.1 shows the population and area coverage of the communes.

Table 1.1 Population and Area Coverage of Target Communes

Province	District	Village	1998 Population (in thousands)	Area (km^2)	Density (psn/km^2)
Ha Noi	Tu Liem	Xuan Dinh	15.77	5.58	2,826
		Dong Ngac	6.90	3.62	1,906
Ninh Binh	Tam Diep	Quang Son	7.50	25.40	295
	Yen Mo	Yen Thang	8.53	11.70	729
	Nho Quan	Dong Phong	10.00	7.36	1,359
Thanh Hoa	Nong Cong	Nong Cong Town	5.46	1.08	5,056
		Van Thang	6.66	6.12	1,088
	Thieu Hoa	Thiu Hung	6.75	5.26	1,283
		Thieu Do	7.01	4.12	1,701
	Yen Dinh	Dinh Tuong	6.52	6.14	1,062
	Vin Loc	VinhLoc Town	5.08	0.72	7,056
		Vinh Thanh	5.98	7.46	802
Ha Tinh	Duc Tho	Duc Yen	5.85*	5.50	1,064
		Yen Ho	5.25	7.70	682
		Trung Le	3.40	3.90	872
		Bui Xa	4.31	4.27	1,009
Thai Nguyen	Dong Hy	Dong Bam	5.28	2.90	1,821
		Hoa Thuong	12.80	12.00	1,067
	Pho Yen	Nam Tien	6.27	8.10	774
	Thai Nguyen City	Thinh Duc	6.24	14.80	422
Total			139.44	143.83	965

*1999data

CHAPTER 2 NATURAL CONDITIONS

2.1 Geomorphology

Vietnam is divided into the following 4 regions:

- Northern Highlands
- Red River Delta
- Annamese Highland and the coastal plains
- Mekong River Delta

Highlands make up the northern region as the southern section of the Yunnan Plateau of China spreads out all the way to this region. Fan Si Pan (3,143 m in elevation), the highest peak in Vietnam, is located close to the Chinese border. To the east of the northern highlands is the Red River which faces the Bac Bo Gulf and forms the Red River Delta. The Annamese Highland extends from the southeast to the northeast on the western section of Vietnam, forming the central backbone of the country together with the narrow but extensive coastal plains in the east. The Mekong River runs through Laos and Cambodia all the way to the East Sea. From the Cambodian border to the river mouth, the Mekong River forms a wide but low-lying delta.

Thai Nguyen, one of the five provinces covered in the Study, is located on the northern side of the Red River Delta. It is formed by a stretch of limestone mountains and gently undulating hills. Hanoi Province is also on the Red River Delta, while Ninh Binh is on the southernmost end with limestone hills sporadically situated on the western side. Thanh Hoa is located within the small delta of the Ma River, and is made up of coastal sandy hills and a hilly and mountainous zone on the west side, with the mountains extending all the way to the Annamese Highland. The small delta of the Ca River and the hills that independently run east-west within the delta form the Ha Tinh and Nghe An Provinces.

The target communes in Thai Nguyen Province are located on flat lands in mountainous areas and hilly areas. The target communes in Hanoi Province are located on the right side of the Red River which is classified as the alluvial plain of the Red River Delta. In Ninh Binh Province, Yen Thang Commune is located on a coastal plain with hilly areas, while Quan Song Commune is located on a hilly area made up of limestone. Dong Phong Commune is on an intermountain basin.

In Thai Nguyen Province, Vinh Loc Town and Vinh Thanh Commune are located on an alluvial plain along the Ma River with small hills. Dinh Thuong Commune is located on a flood plain between the Ma and Cho Rivers. Whereas Thieu Hung Commune is located on the left side of the Cho River, Thieu Do Commune is situated on the right side. Both are on an alluvial plain along the Cho River. Nong Cong Town and Van Thang Commune are located on an alluvial plain and hilly areas along the Muc River. The target communes in Ha Tinh Province are located on the right side of the Ca and La Giang Rivers which is classified as an alluvial plain.

2.2 Meteorology and Hydrogeology

2.2.1 Meteorology

Vietnam is tropical in the south and subtropical in the north, which is frequently subject to subtropical monsoons. Heavy rains brought on by the monsoon fall from May to September. On the other hand, the central region gets a lot of rain from August to January during the typhoon season. Rainfall amount in Hanoi in the north, Hue in the central region, and Ho Chi Minh in the south varies: 1,680 mm, 2,956 mm, and 1,949 mm, respectively (see Figure 2.1).

The annual average temperature in Vietnam is 27 °C in Ho Chi Minh in the south, 23 °C in Hanoi and 25°C in Hue. Accordingly, the annual maximum and minimum temperatures in the southern region exceed that of the north from 3 to 5 degrees.

The meteorological data on the provincial capitals in the study area in the past 30 years show differences in rainfall, rainfall patterns and evaporation. Hanoi has the lowest mean annual rainfall among the five provinces, at 1,683.3 mm. The mean annual rainfall in Thanh Hoa and Ninh Binh are 1,728.8 and 1,860.6 mm, respectively. In the northern part of the study area, Ha Tinh has the largest mean annual rainfall at 2,719.9 mm, followed by Thai Nguyen at 2,049.7 mm. In general, the rainy season in the northern part of Vietnam starts in May and lasts until October. However, the mean monthly rainfall peaks early in the northern part of the study area and late in the southern part. The peak can be seen in July in Thai Nguyen, August in Hanoi, September in Ninh Binh and Thanh Hoa, and October in Ha Tinh.

The mean annual temperature in Hanoi is 23.0 °C; the minimum average monthly temperature is 16.6 °C (January) and the maximum is 28.8 °C (July).

Evaporation is low from February to March and high from May to July in the five provinces.

Except in Ha Tinh, the monthly average evaporation was observed to peak twice: first from May to July and second in October. The average monthly evaporation in the south has a wide range: from 60 to 100 mm/month in Thai Nguyen and Hanoi, from 40 to 105 mm/month in Ninh Binh and Thanh Hoa, and from 25 to 135 mm/month in Ha Tinh. On the other hand, the mean annual evaporation decreases from north to south. Hanoi has the highest mean annual evaporation, at 976.5 mm, followed by Thai Nguyen (956.9 mm), Ninh Binh (851.6 mm), Thanh Hoa (816.0 mm), and Ha Tinh (only 800.9 mm).

2.2.2 Hydrology

There are 16 river basins in Vietnam holding a total catchment area of more than 266,000 km^2. Ten of these basins make up over 10,000 km^2 of the total catchment area, that is approximately 80 % of the national territory (331,000 km^2). In addition, 80 % of the national population reside in these basins and 70 % of the GDP is produced therein.

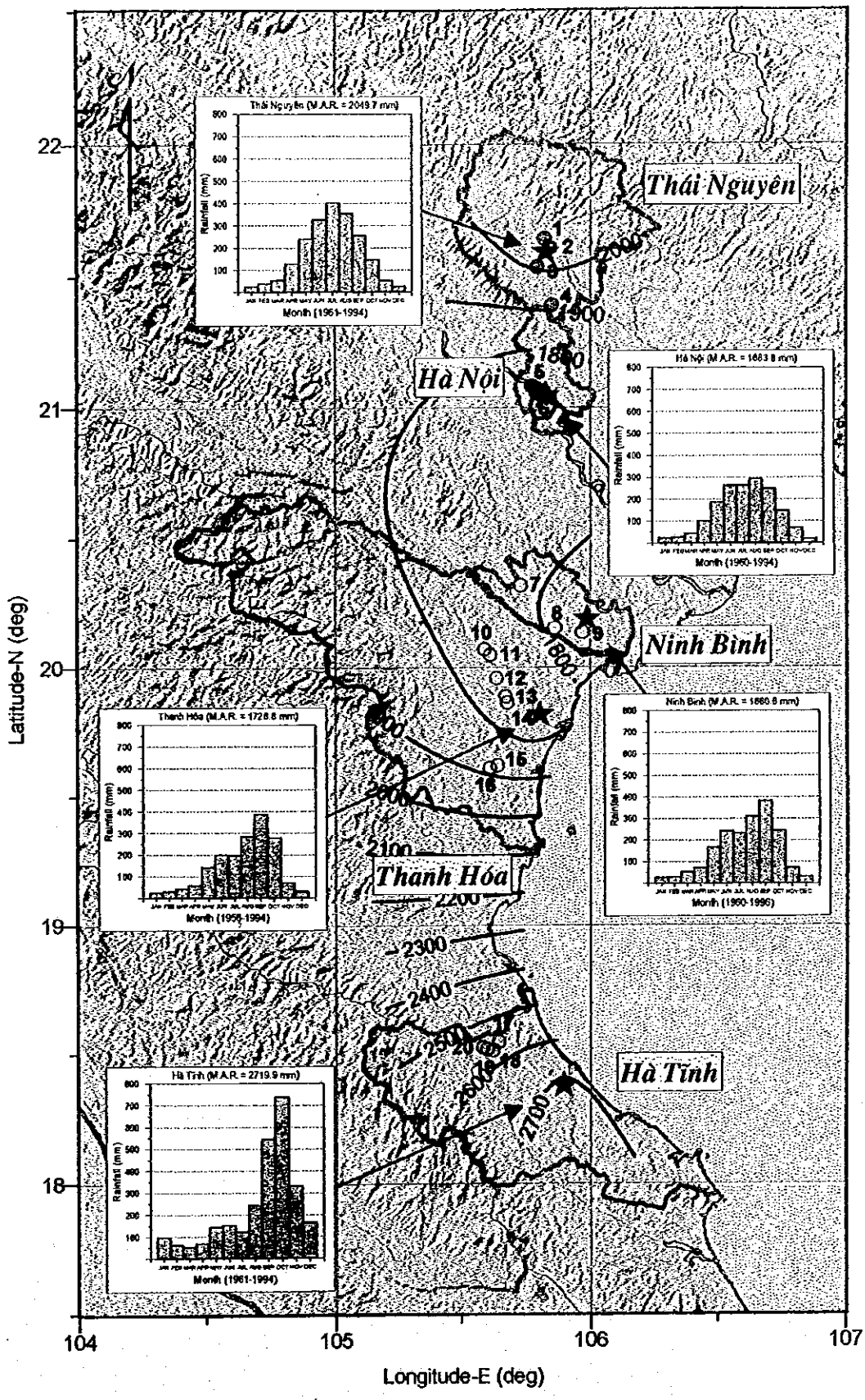
The Mekong River is the biggest river in Vietnam and has a mean annual discharge of 520.6 billion cubic meters (BCM), followed by the Red River and the Thai Binh River, both having a mean annual discharge of 137.0 BCM.

Among the five provinces in the northern part of Vietnam where the target communes are located, Thai Nguyen, Hanoi, and Ninh Binh belong to the Red River basin, whereas Thanh Hoa and Ha Tinh belong to the Ma River basin and the Ca River basin.

The Red River is the second largest river in Vietnam. It originates in China and flows into Vietnam from the northwest to the southeast. About half (87,400 km^2) of the total catchment area (169,000 km^2) lies within Vietnam. The Red River Delta, which has an area of 17,000 km^2, occupies about 20 % of the Red River basin in Vietnam (World Bank, etc., 1996).

The Ma River, which originates in Lai Chau and Son La Provinces of Vietnam as well as Laos, flows from Son La Province to Thanh Hoa Province through Laos. The total catchment area of the Ma River is 28,490 km^2, 17,810 km^2 of which falls in Vietnam. The mean annual discharge is 20.1 BCM (World Bank, etc., 1996).

The Ca River basin is located south of the Ma River basin. The Ca River, which originates in Laos, flows northwest to southeast into the province of Nge An and into the Gulf of Bac Bo east of Vinh City. The Ca River basin has a total catchment area of 27,200 km^2, 17,730 km^2 of which falls in Vietnam. The mean annual discharge is 24.2 BCM (World Bank etc., 1996).



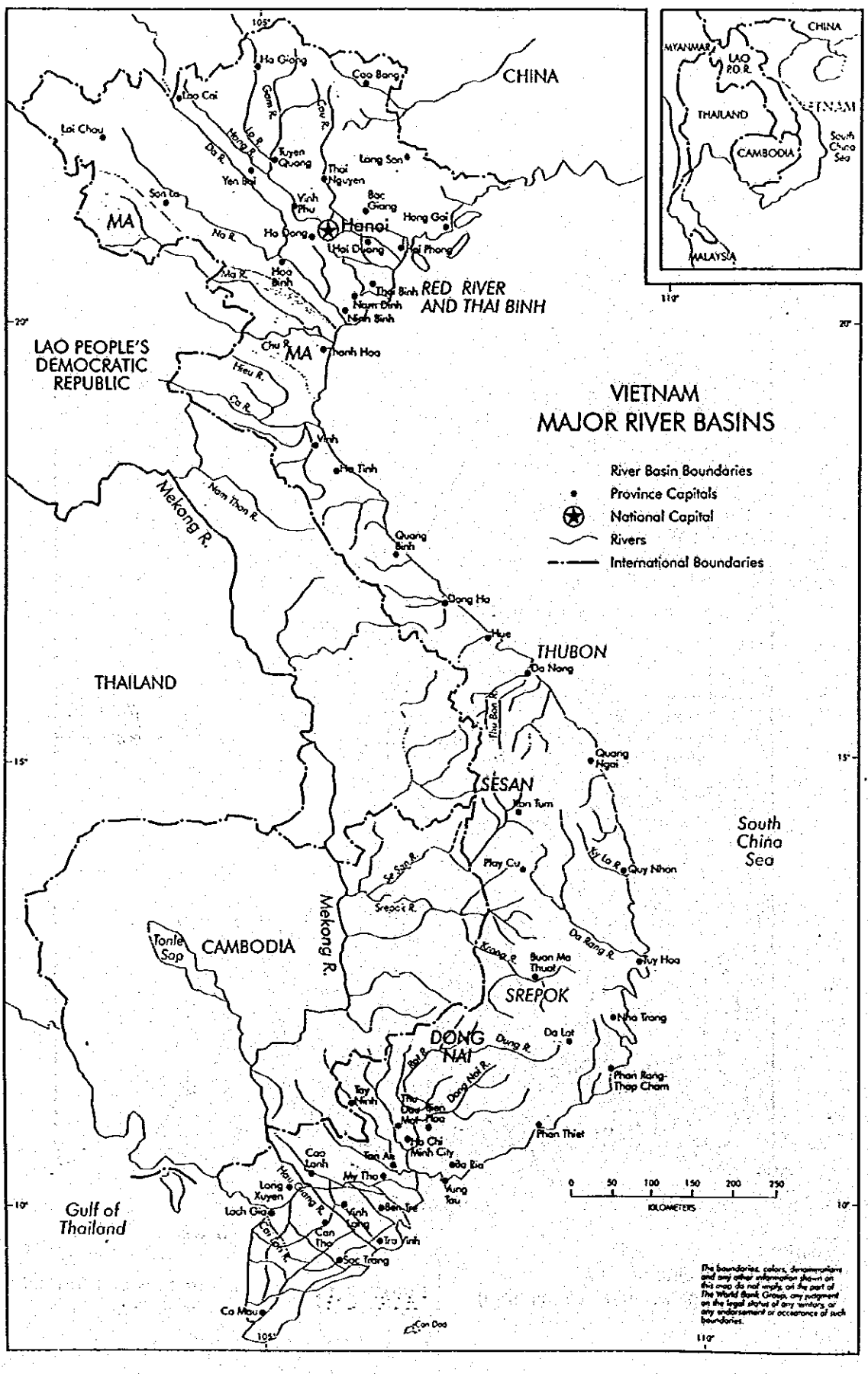
2000 —— Equal Line of Average Annual Rainfall (mm)

Figure 2.1	**Average Monthly and Annual Rainfall in the Study Area**

THE STUDY ON GROUNDWATER DEVELOPMENT IN THE RURAL PROVINCES OF NORTHERN PART IN THE SOCIALIST REPUBLIC OF VIETNAM

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 2.2 Major River Basins in Vietnam



2.3 Geology

2.3.1 Geology

The geology of Vietnam consists of various kinds of sedimentary rocks, igneous rocks and metamorphic rocks from the Archean to Holocene ages. The general geology of Vietnam is described in the "Vietnam National Atlas" (1996).

The oldest rocks are ultrametamorphic rocks found in the Kontum massif in central Vietnam. Proterozoic rocks are mainly found in the Kontum Massif and west of Bac Bo (northern Vietnam). The rocks of Upper Proterozoic to Lower Cambrian mainly consist of weakly metamorphosed schists, distributed in the north and west of Bac Bo, north of Trung Bo (central Vietnam), and the Kontum Massif.

Paleozoic sedimentary rocks are widely distributed in Vietnam. Lower to Middle Cambrian formations distributed in Bac Bo consist of quartz-sericite schist and cherty-calcareous shale. Limestone bearing apatite is found on the right side of the Red River. Green schist from mafic effusive occurs in the basins of the Ma River and the Lo River. Upper Cambrian to Lower Ordovician formations are found in Bac Thai, Cao Bang, Ha Giang, and west of Bac Bo. The main facies is calcareous shale with quartzite and sandstone. Lower Ordovician is unconformably overlain by Ordovician to Silurian formations that are composed of rhythmic terrigenous sediments and chert. The Ordovician to Silurian formations are distributed in Bac Bo and north of Trung Bo.

Silurian to Lower Devonian formations consist of shale, sandstone, and limestone, distributed in the north and west of Bac Bo, and north of Trung Bo. The Lower Devonian formations are comprised of conglomerate, sandstone, silt, and shale, distributed in the east and north of Bac Bo. Lower to Middle Devonian formations are widely distributed in northern Vietnam. They consist of sandstone, shale, and limestone with corals and brachiopods. Middle Devonian formations consist mainly of limestone in Bac Bo, and of sandstone and shale in the north of Trung Bo. Middle to Upper Devonian formations comprise limestone, claystone, and sandstone, distributed in the wide areas of north Trung Bo. Upper Devonian formations are characterized by cherty shale, sandstone, shale, and banded limestone bearing manganese, and distributed in the west of Trung Bo.

Carboniferous formations are composed of conglomerate, sandstone, silt, shale, chert, calcareous shale, and limestone. The limestone of Carboniferous to Permian is 500 to 2,000 m thick, widely distributed in Bac Bo and north of Trung Bo. Except for limestone, Upper

Carboniferous to Permian formations contain basalt in the west of Bac Bo and andesite, dacite, and rhyolite in the Central Highlands and Nam Bo (southern Vietnam).

Upper Permian formations having a new sedimentary cycle unconformably overlie the previous formations. They consist of limestone, silt, shale and bauxite in the east of Bac Bo, north of Trung Bo and Nam Bo. Thick basalt beds are found in the west of Bac Bo.

With Mesozoic sediments, Lower Triassic formations are more than 2,000 m thick, consisting of silt and shale. Felsic effusive is found in the north of Bac Bo and mafic effusive is found in the west of Bac Bo. Middle Triassic formations are composed of terrigenous sediments and felsic effusive in the east of Bac Bo, and of limestone and terrigenous sediments in the west of Bac Bo. Middle to Upper Triassic formations are characterized by continental red beds in the east of Bac Bo, and by black shale, sandstone, and limestone in the west of Bac Bo.

Lower to Middle Jurassic sediments are classified into two types of sequences: continental red sediments distributed in the north of Bac Bo and marine formations with gray terrigenous sediments distributed in central Trung Bo and north of Bac Bo. Upper Jurassic to Cretaceous formations mainly consist of terrigenous sediments with felsic and alkaline effusive in the west of Bac Bo, and sandstone and andesite in the south of Trung Bo. Upper Cretaceous is made up of two types: continental red sediments in the west of Bac Bo and north of Trung Bo, and felsic and subalkaline effusive in the west of Bac Bo and dacite and rhyolite in the south of Trung Bo.

Cenozoic sediments containing conglomerate, sandstone and silt are thick in Hanoi and Cuu Long depressions. Neogene formations comprise coal bearing terrigenous sediments in Bac Bo, and terrigenous sediments with thick interbeds of basalt in the south of Trung Bo and Nam Bo. Plio-Pleistocene sediments are widely distributed in the Mekong Delta, the Red River Delta, and other areas. Tholeiitic basalt and doleritic basalt are distributed in the Bao Loc plateau and Song Be, Xuan Loc, and Vinh Linh, dated as Late Miocene to Pleistocene. Quaternary basaltic layers are distributed in the south of Trung Bo and Nam Bo. Pleistocene to Holocene sediments are widely distributed in the Mekong Delta, the Red River Delta, and other coastal plains.

2.3.2 Tectonics

Vietnam is a part of the Southeast Asian lithosphere plate, which consists of Precambrian continental block, Paleozoic folded belts, different superimposed structures, and present

marginal sea.

On the basis of analyzing structural-formational complexes in conformity with the plate tectonics concept, the Vietnamese territory is divided by Tran Van Tri, etc., (1986) into the following main tectonic units:

- The Vietnam-Laos Folded Belt
- The Sino-Vietnamese Folded Belt
- The Indochina Folded Belt
- The Mesozoic superimposed structures
- The Cenozoic superimposed structures
- The structures of eastern Vietnam marginal sea.

The boundaries between the main folded belts are often marked by deep-seated faults which are associated with melangeophiolite assemblages in connection with the activities of Benioff of Paleopacific type in Sino-Vietnamese and Paleotethys in the Vietnam-Laos folded belt.

In the northern part of Vietnam, NW-SE strikes are dominant in major geotectonic lines. However, the strikes bend from Thai Nguyen to the northeastern part of Vietnam, in the E-W to NE-SW direction.

2.3.3 Mineral Resources

Vietnam is rich in various minerals, with high density per surface unit. For metallic resources, Vietnam possesses iron, chromite, manganese, lead, zinc, copper, gold, tin, titanium, stibium, boxite, rare earths, and radioactive minerals. Non-metallic resources include coal, Neogene lignite, graphite, oil and gas, apatite, kaolin, siliceous sand, materials for construction such as cement, etc.

In Thai Nguyen, there are mines of titanium, tin, iron as well as baryte, lead-zinc, and gold. Ninh Binh produces cement, iron, mercury, and pyrite. Thanh Hoa yields precious stones, copper, chromium, iron, and titanium. In the northern part of Nge An are mines of tin, chromium and arsenic, and Ha Tinh has mines of titanium and iron.