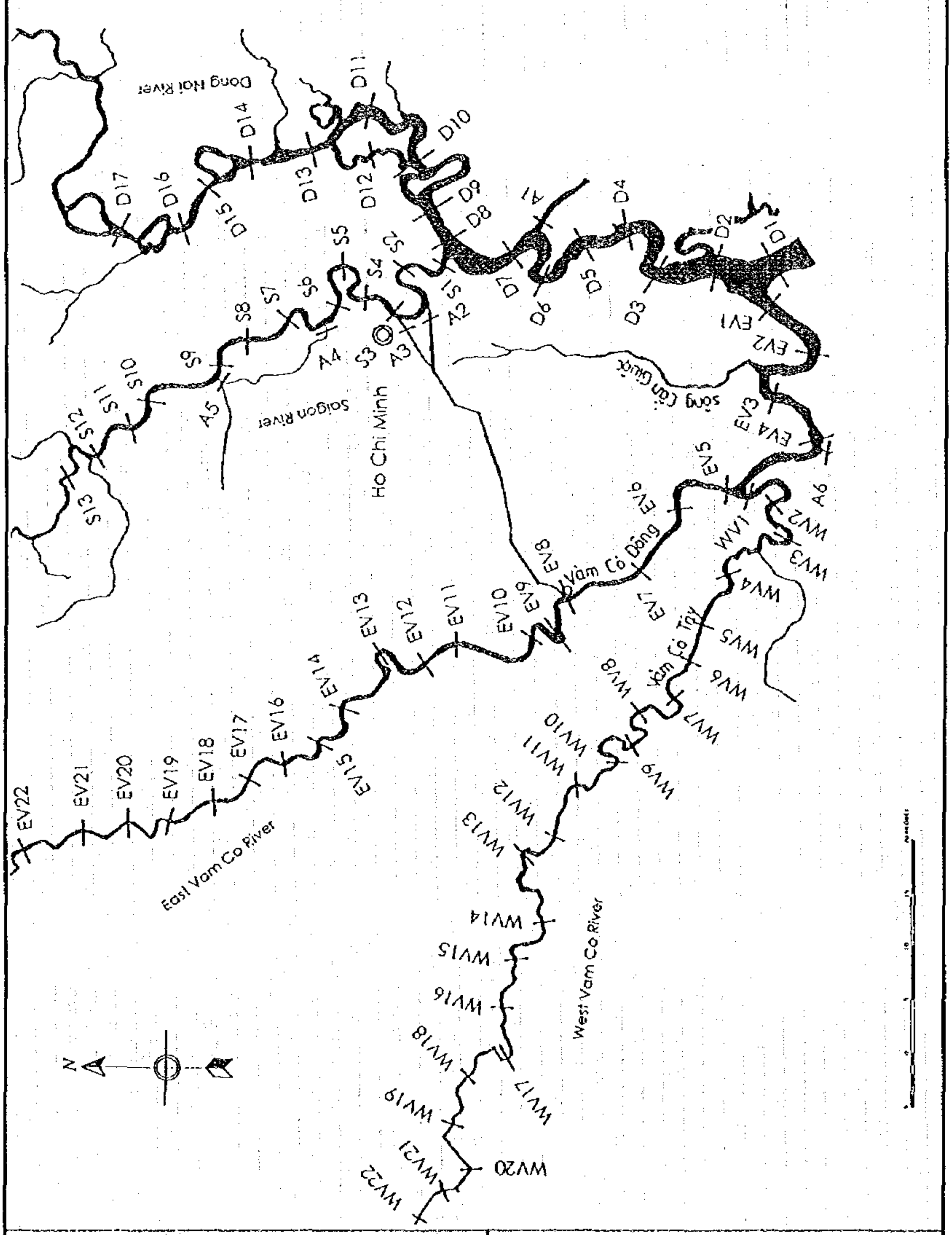
FIGURES



SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 1.1** **Locations of River Cross Section and Profile Survey**

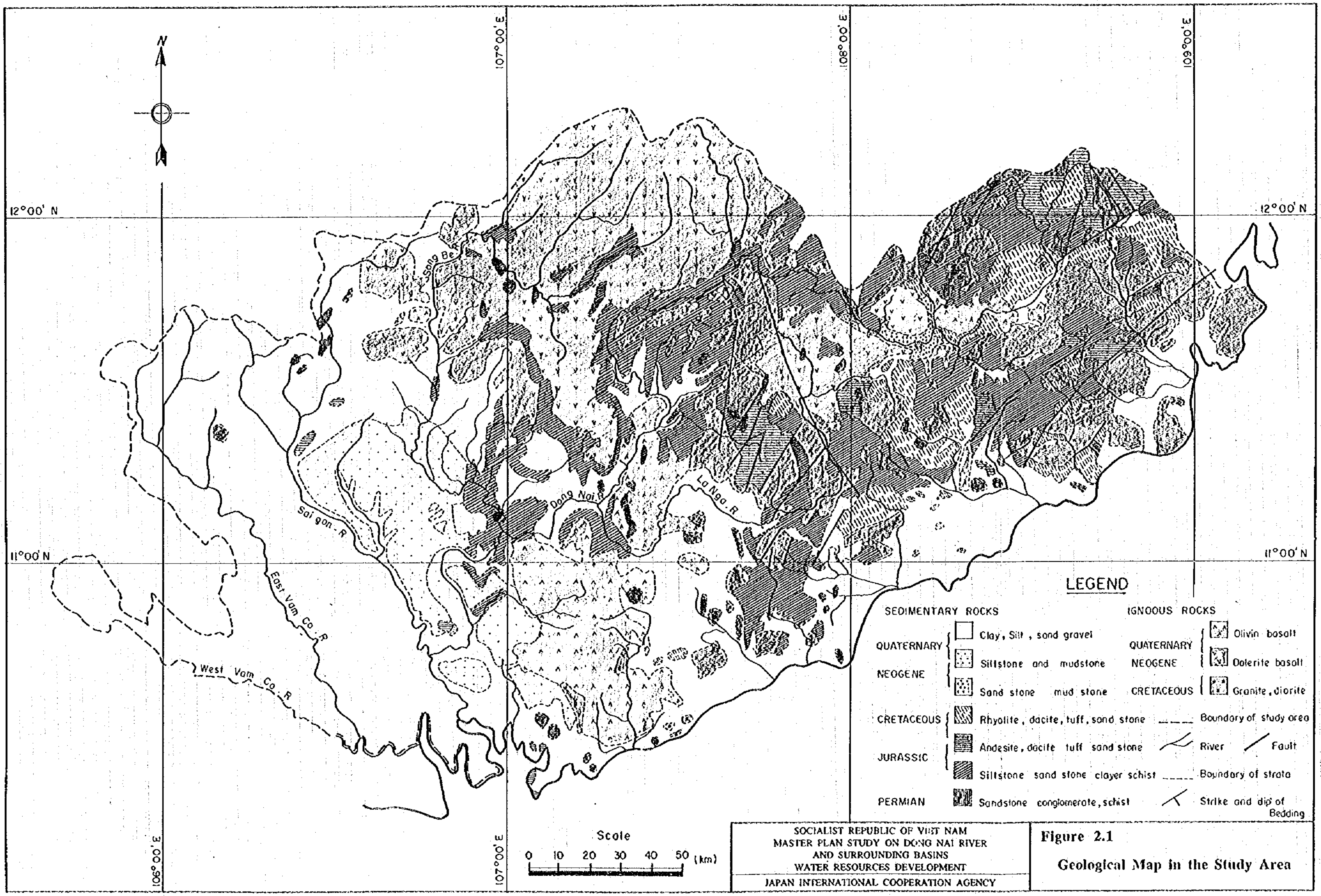
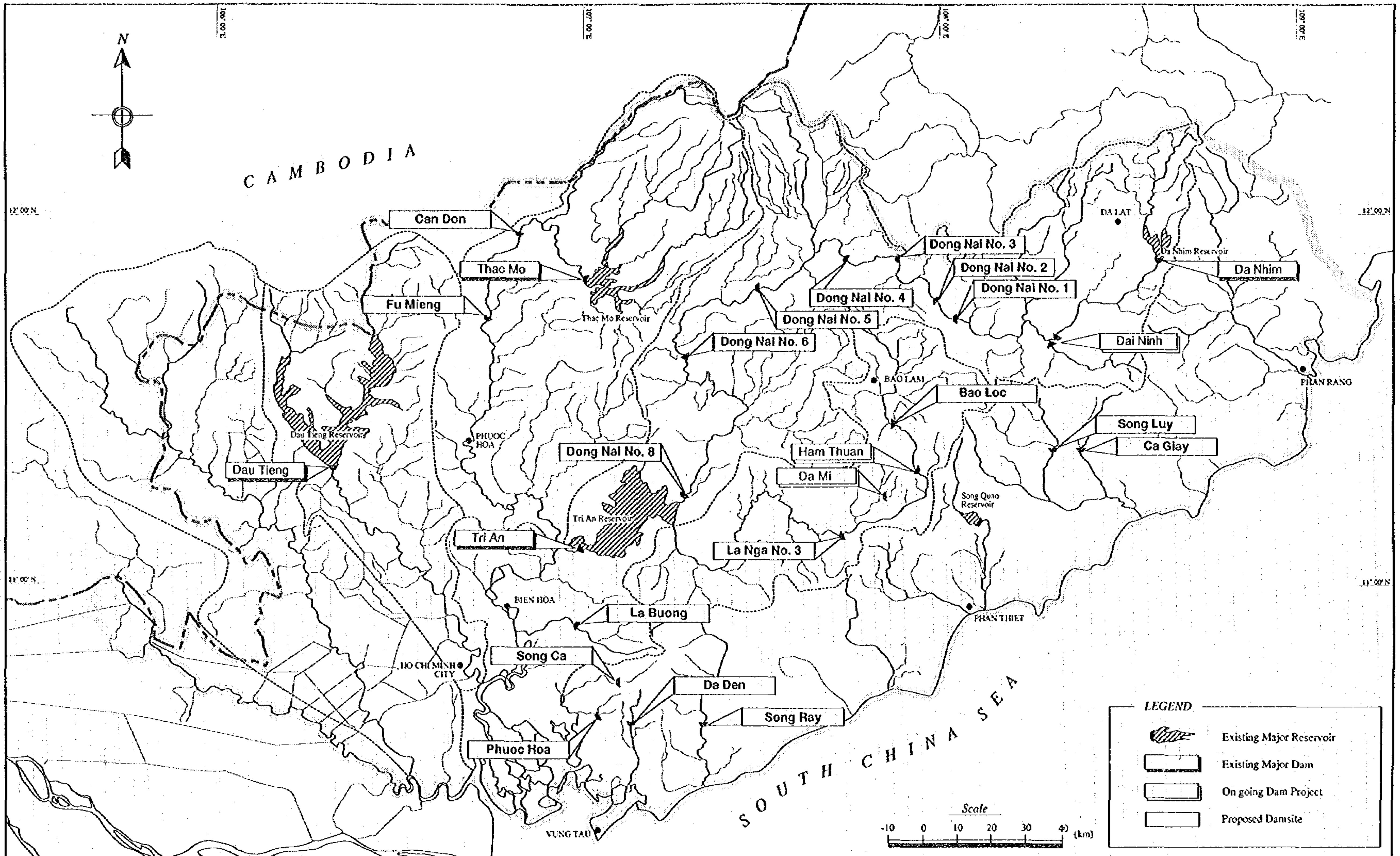


Figure 2.1

Geological Map in the Study Area



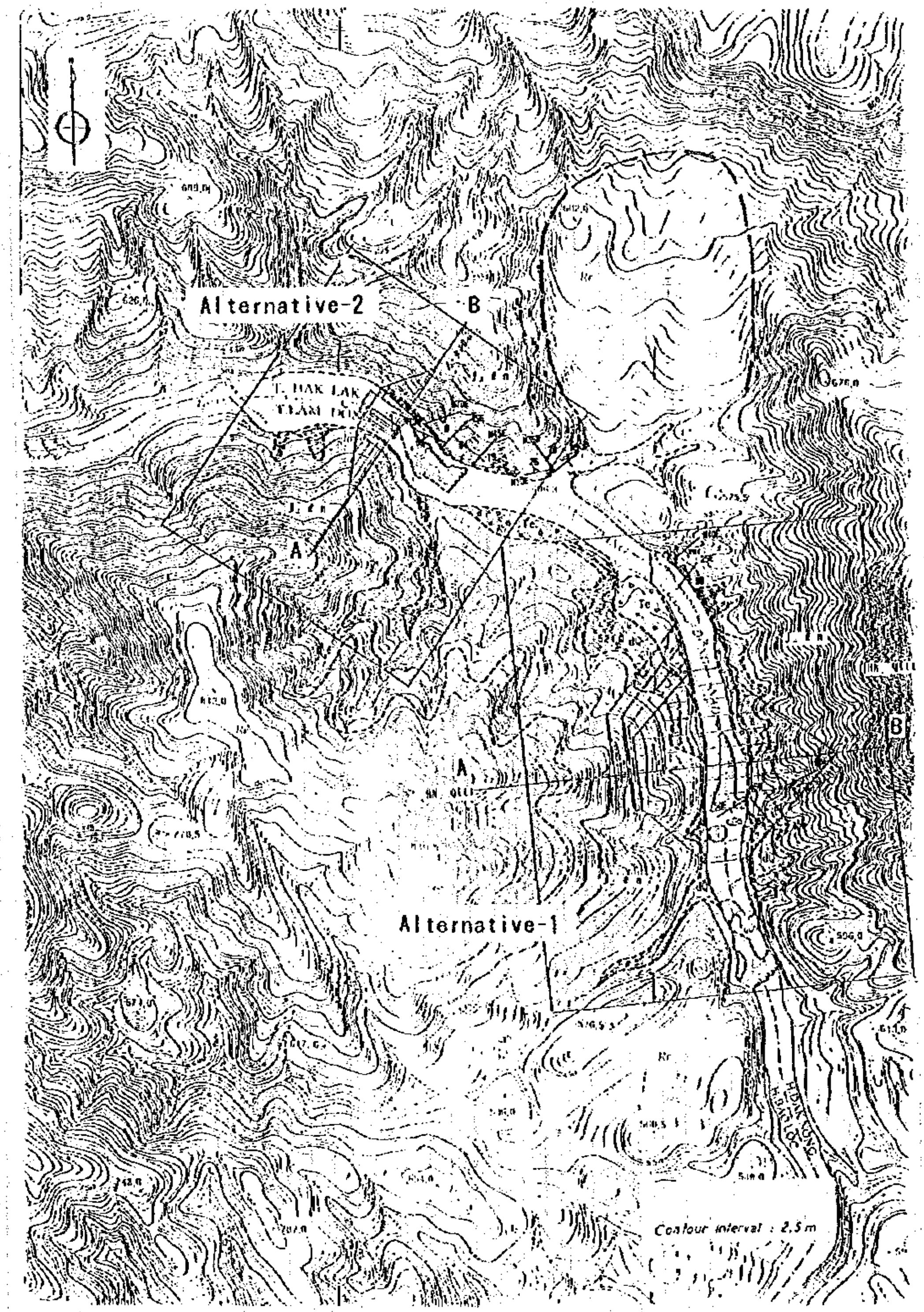
SOCIALIST REPUBLIC OF VIET NAM
MASTER PLAN STUDY ON DONG NAI RIVER
AND SURROUNDING BASINS
WATER RESOURCES DEVELOPMENT

JAPAN INTERNATIONAL COOPERATION AGENCY

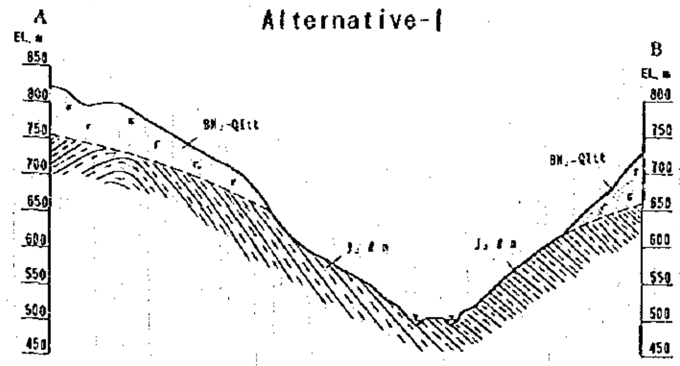
Figure 2.2

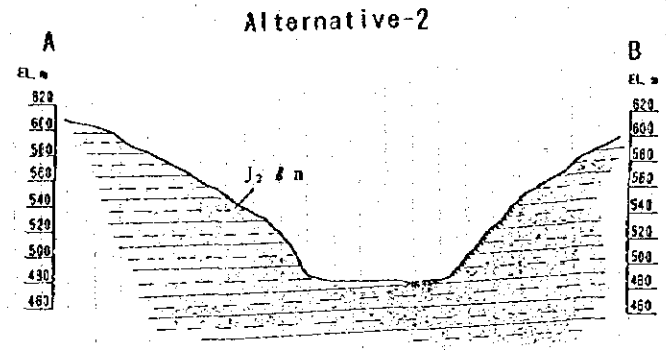
Location of Damsites Proposed in the Study

GEOLOGICAL MAP
OF THE DONG NAI No.3 AREA



SCALE 1:20, 000





LEGEND

- Quaternary
  - dQ — Deluvial deposits ; Sand, gravel, Pebble
  - Tl — Terrace deposits : Sand , silt , granule
- Pliocene-Lower Pleistocene
  - βN₂-QIlt — Túc Trưng Formation : Olivine basalt
- Middele Jurassic
  - J₂ℓn — Formation : Sandstone siltstone , shale , hornfels
- Strike and dip of strata
- Strike and dip of joint
- Geological boundary
- Geological section AB
- Land slide

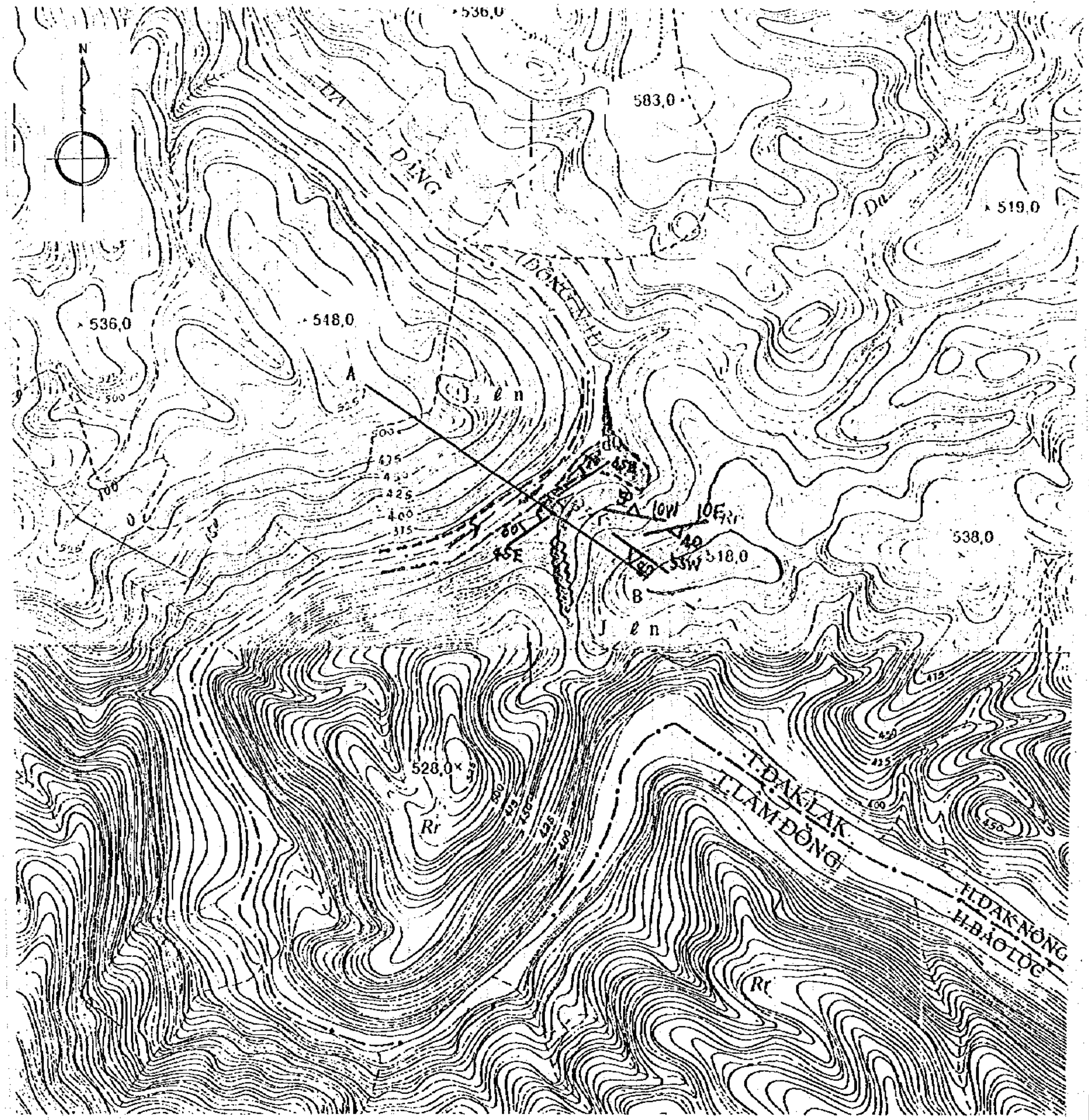
SOCIALIST REPUBLIC OF VIET NAM
MASTER PLAN STUDY ON DONG NAI RIVER
AND SURROUNDING BASINS
WATER RESOURCES DEVELOPMENT

JAPAN INTERNATIONAL COOPERATION AGENCY

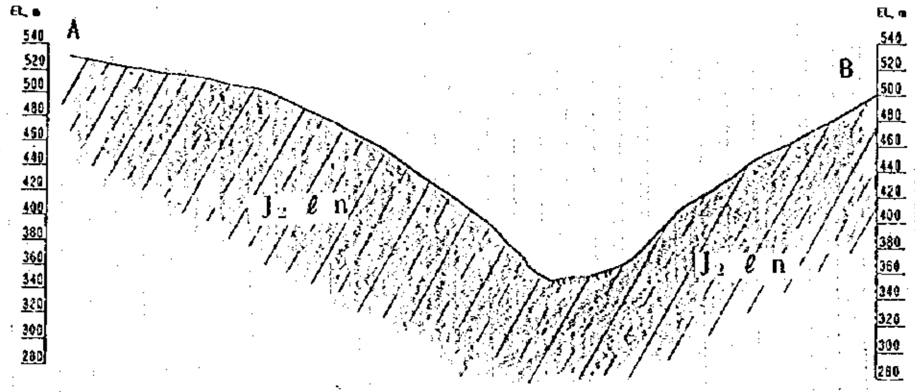
Figure 2.3

Geological Map of Dong Nai No.3 Damsite

GEOLOGICAL MAP
OF THE DONG NAI No.4 AREA



SCALE 1 : 10, 000

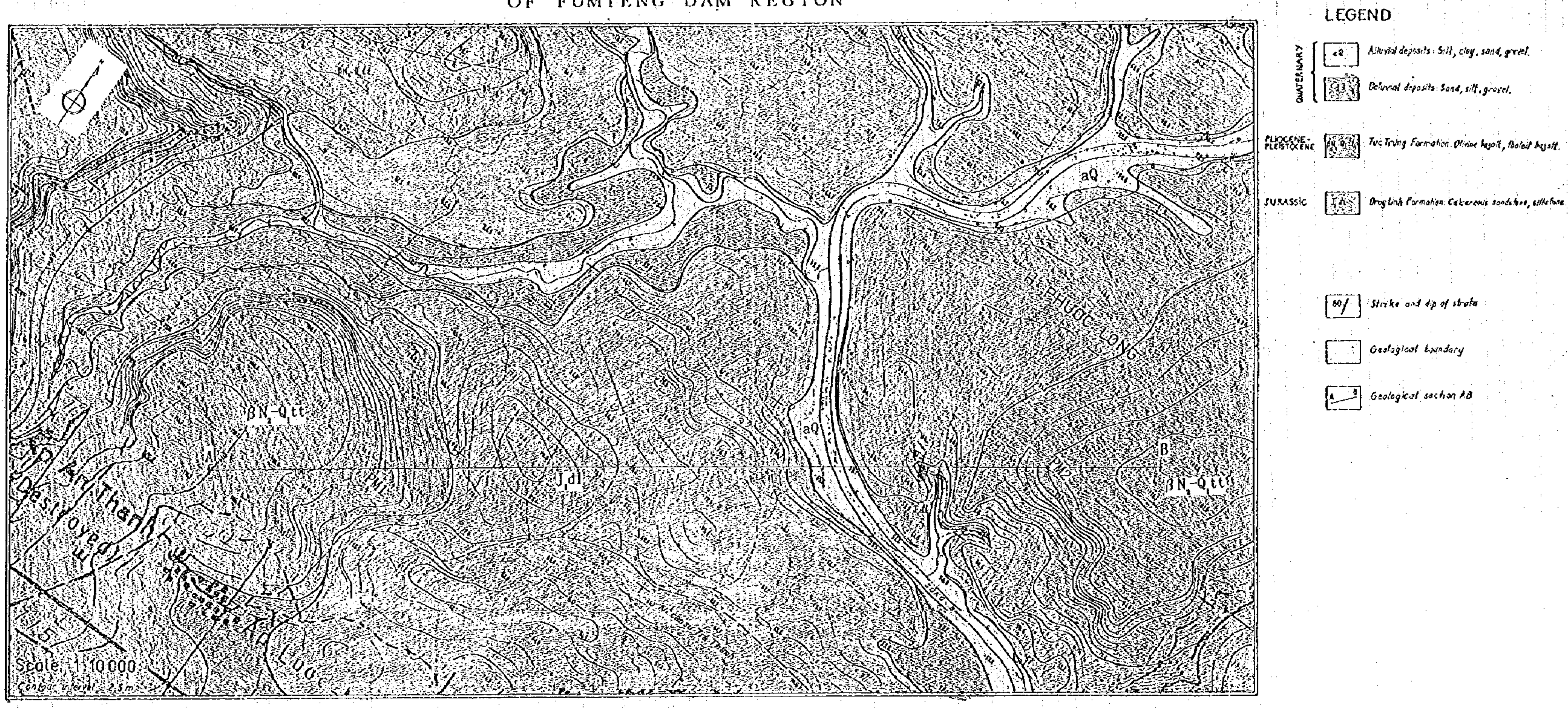


LEGEND

Quaternary	dQ	Deluvial deposits : Sand, gravel, Pebble
	Te	Terrace deposits : Sand, silt, granule
Pliocene - Lower Pleistocene	βN₂-QI tt	Túc Trung Formation : Olivine basalt
Middele Jurassic	J₂ ℓn	Formation : Sandstone siltstone, shale, hornfels
		Strike and dip of strata
		Strike and dip of joint
		Geological boundary
		Geological section AB

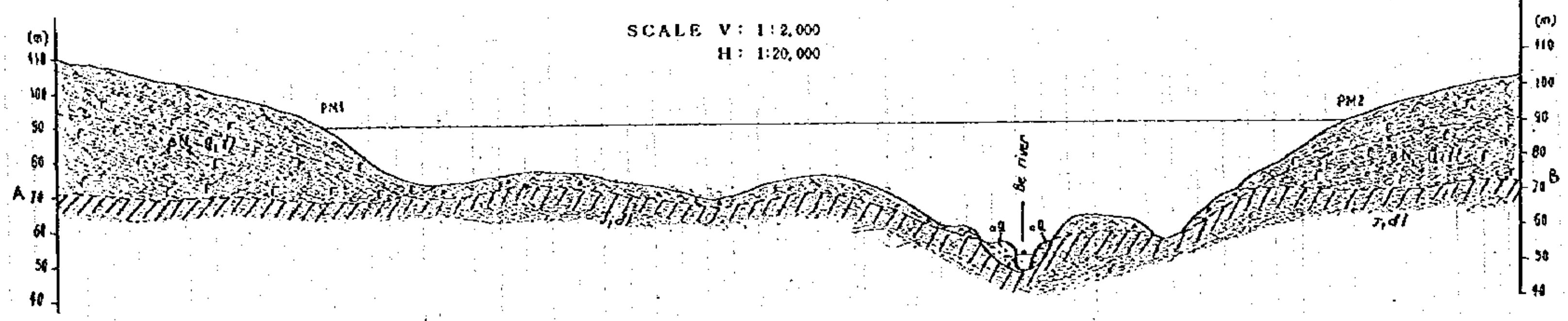
SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT	**Figure 2.4**
JAPAN INTERNATIONAL COOPERATION AGENCY	**Geological Map of Dong Nai No.4 Damsite**

GEOLOGICAL MAP
OF FUMIENG DAM REGION

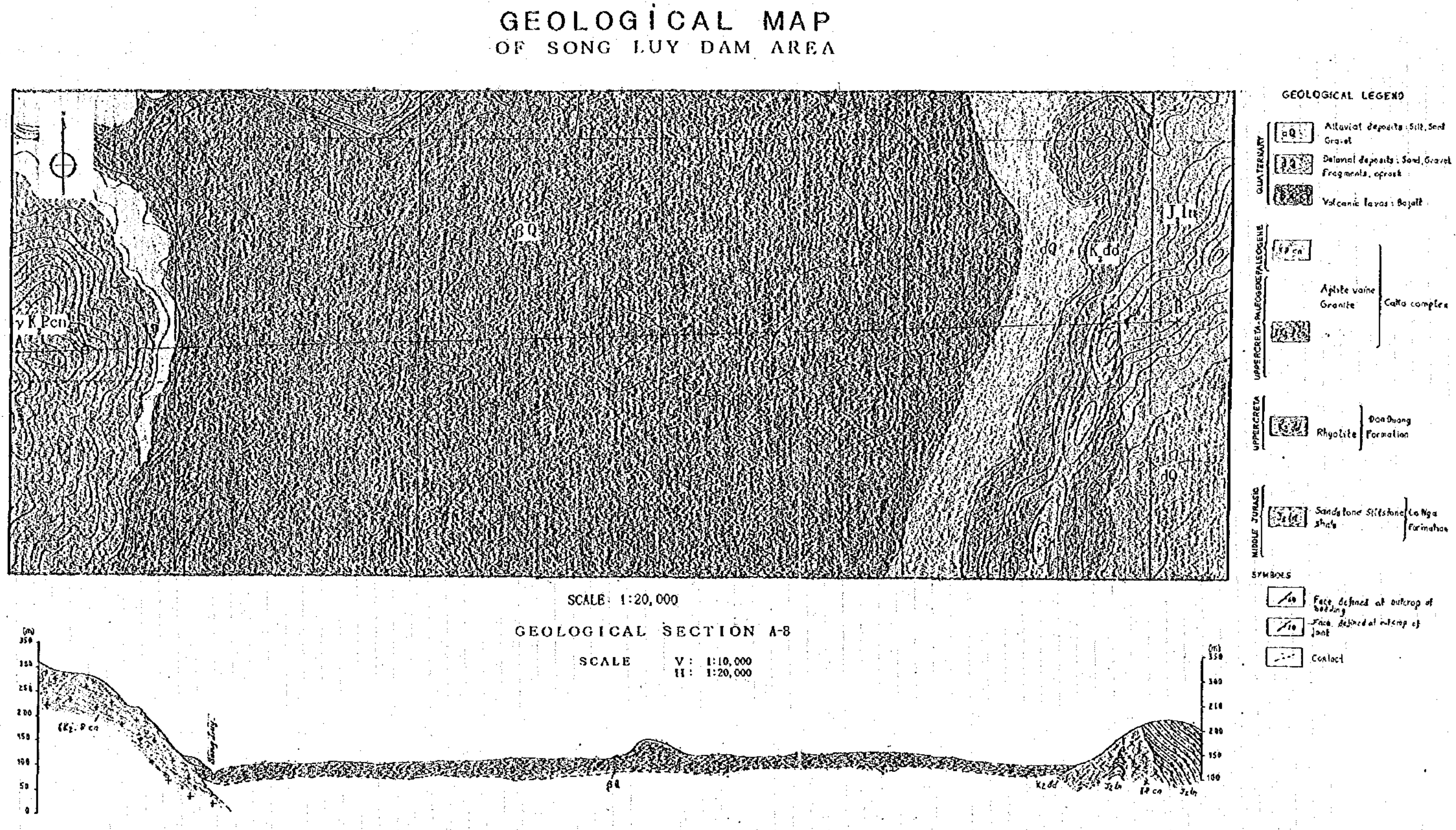


GEOLOGICAL SECTION A-B

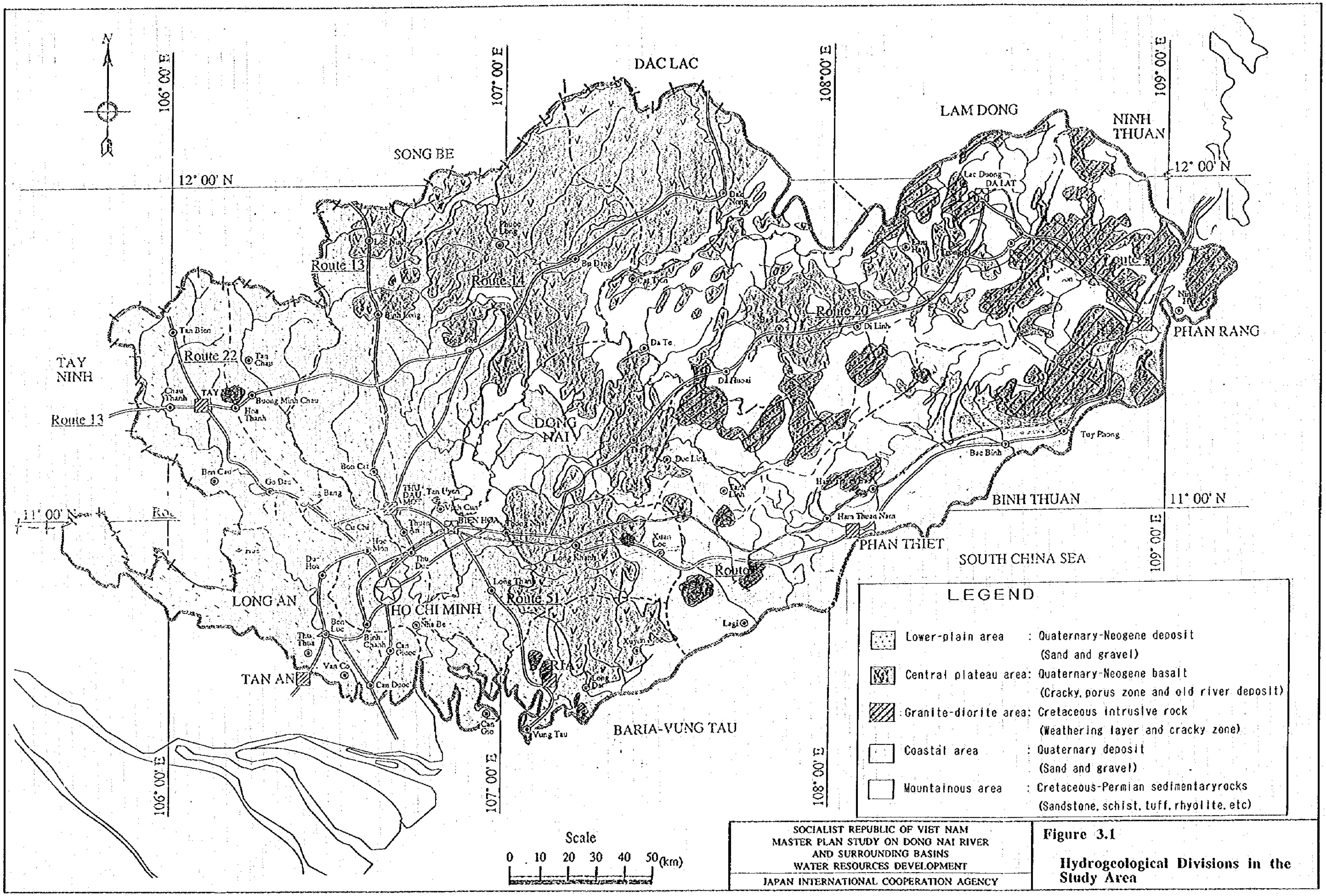
SCALE V: 1:2,000
H: 1:20,000



SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT	**Figure 2.5** **Geological Map of Fu Mieng Damsite**
JAPAN INTERNATIONAL COOPERATION AGENCY	



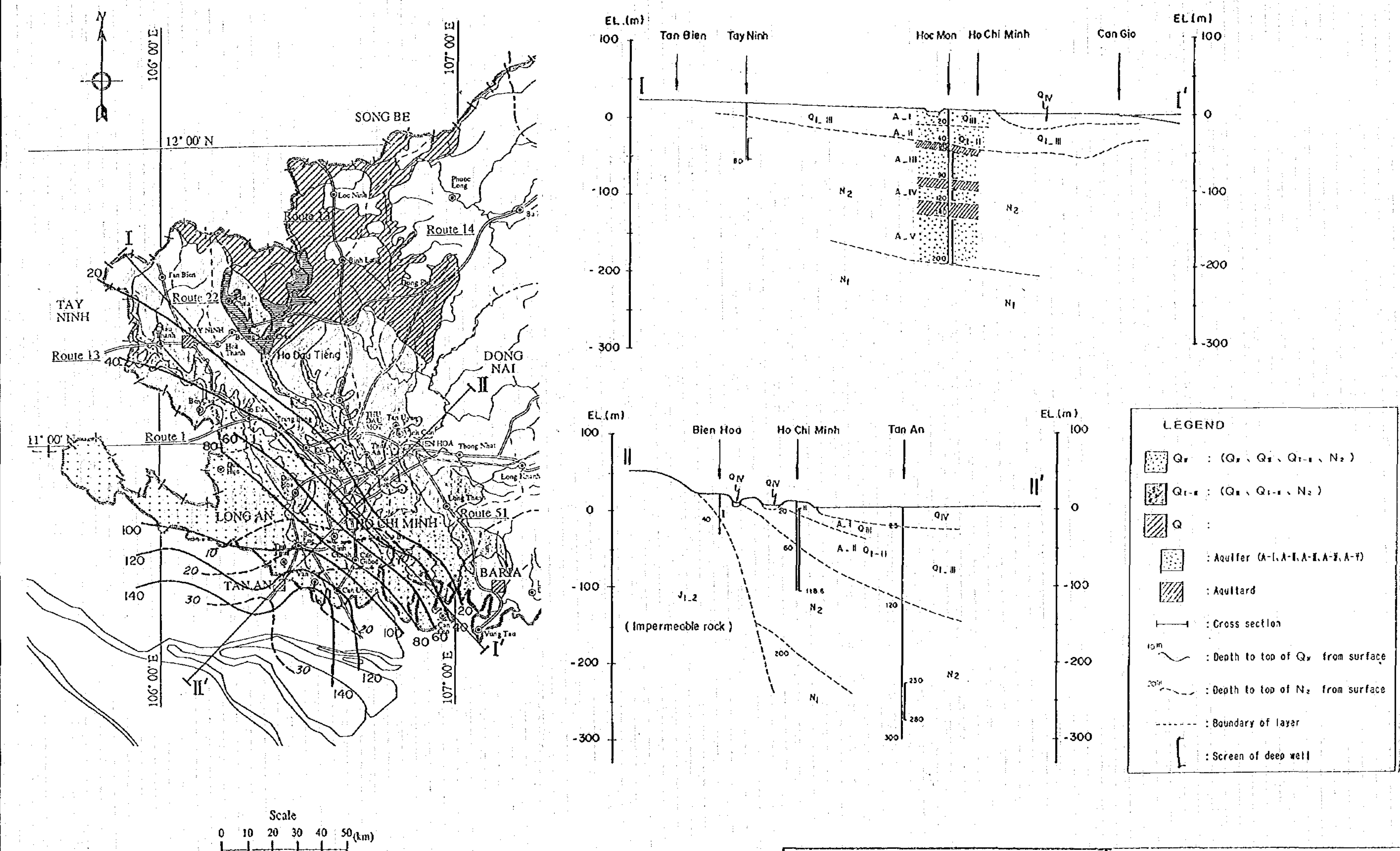
SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 2.6** **Geological Map of Song Luy Damsite**



SOCIALIST REPUBLIC OF VIET NAM
MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS
WATER RESOURCES DEVELOPMENT
JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 3.1

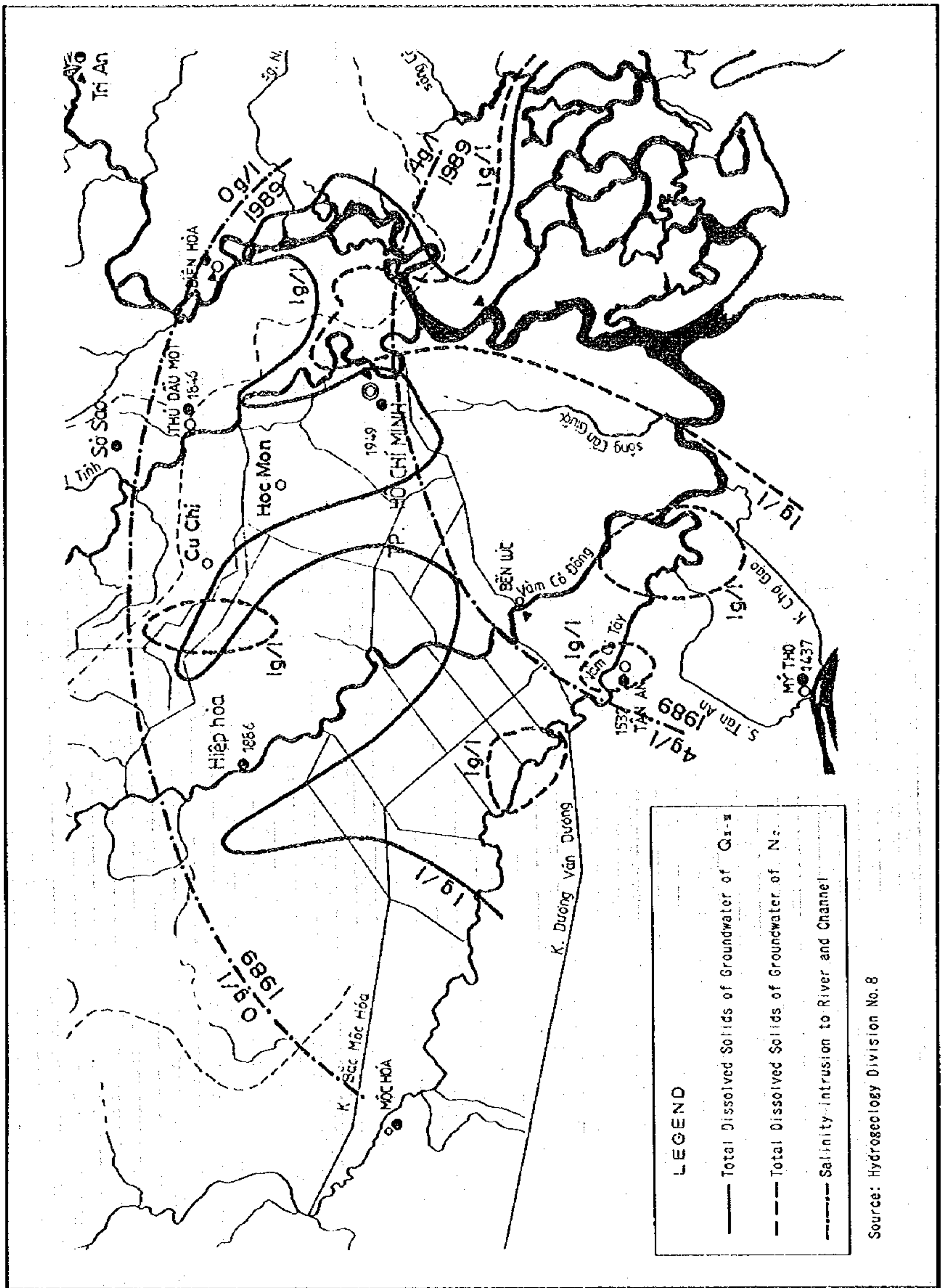
Hydrogeological Divisions in the Study Area



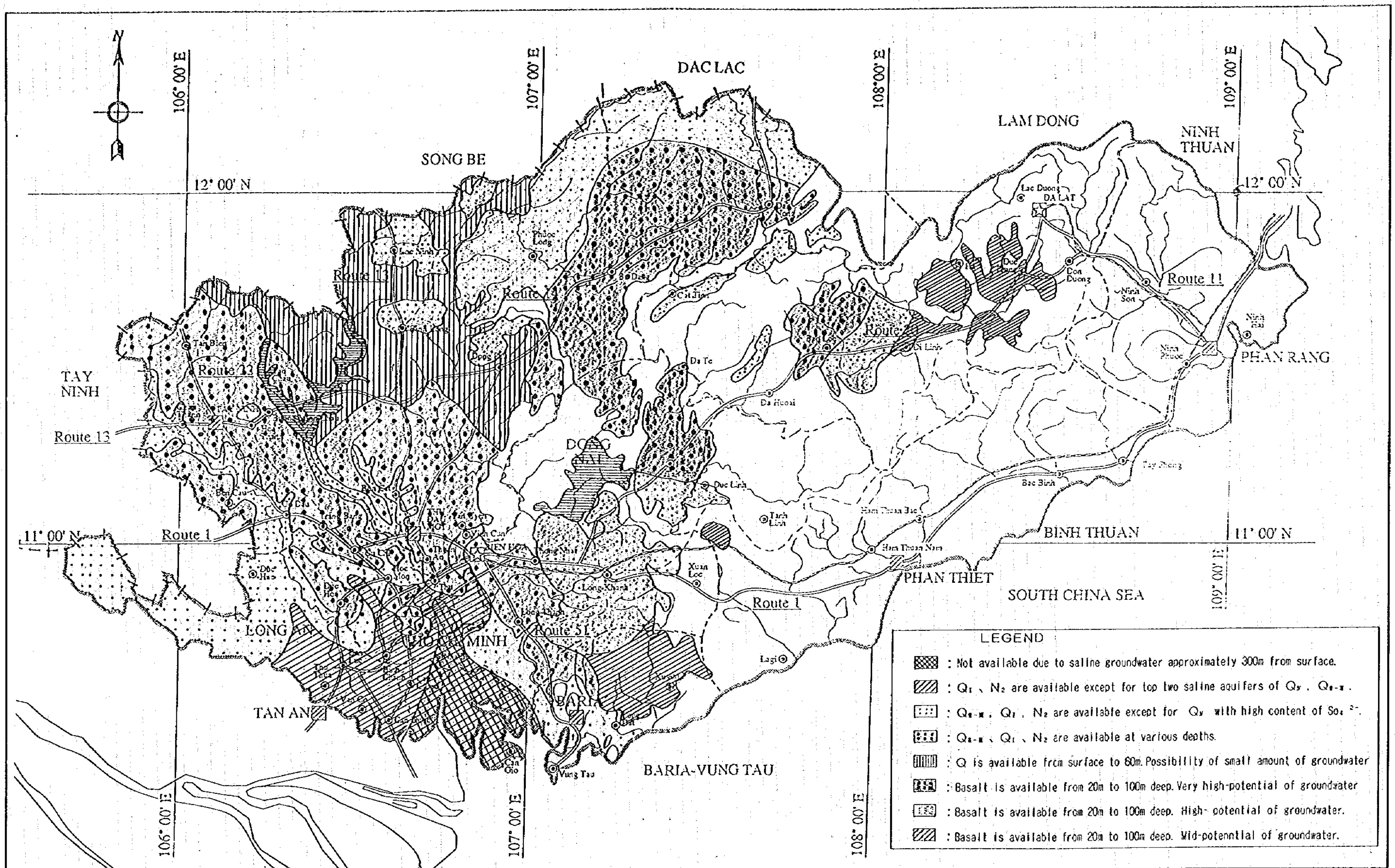
SOCIALIST REPUBLIC OF VIET NAM
MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS
WATER RESOURCES DEVELOPMENT
JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 3.2

Hydrogeological Map and Cross Section in the Lower Plain Area



SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 3.3** **Extent of Salinity Intrusion to Aquifer, Q_{II-III} and N_2**



SOCIALIST REPUBLIC OF VIET NAM
MASTER PLAN STUDY ON DONG NAI RIVER
AND SURROUNDING BASINS
WATER RESOURCES DEVELOPMENT

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 3.4

Development Potential of Groundwater

Appendix III

METEOROLOGY AND HYDROLOGY

APPENDIX III
Meteorology and Hydrology

TABLE OF CONTENTS

Pages

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The Study Area is divided into seven basins/zones; river basins of the Dong Nai, Saigon, Be, La Nga, West Vam Co and East Vam Co, and the coastal zone covering Binh Thuan, Ninh Thuan and Ba Ria-Vung Tau provinces. The catchment area of these basins/zones obtained from the topographic map of 1:250,000 is measured at 48,471 km^2 in the Study Area as summarized below:

River	Definition of Catchment Area	Catchment Area (km^2)	Study Area (km^2)
Dong Nai	confluence at the Be River including the La Nga basin	14,979	14,979
Dong Nai	from confluence at the Be River to estuary	4,093	4,093
Be	confluence at the Dong Nai	7,427	7,201
Saigon	confluence at the Dong Nai	4,717	4,316
West Vam Co	confluence at the East Vam Co excluding the west bank area	921	921
East Vam Co	including estuary	8,546	5,005
Coastal zone	estuaries with north-eastern bound of Khanh Hoa/Ninh Thuan province	11,956	11,956
	Total	52,639	48,471

It is noted that an area of 4,168 km^2, which is the difference between the catchment area and the Study Area, lies in Cambodia.

2. METEOROLOGY

2.1 Available Data and Records

The experience of data collection for the master plan study made it to be noted that there is a serious problem of hydrological and meteorological data management in Viet Nam. Officially, both meteo- and hydro-data are collected by the General Department of Meteorology and Hydrology. However, other governmental agencies such as Power Company No. 2 under the Ministry of Industry, the Ministry of Agriculture and Rural Development, Economic Institute and so on are also collecting hydrological data at the sites of their interest, which sometimes are very crucial data for a basin planning. Meteorological and hydrological data are therefore scattered around in Viet Nam, which may result in serious inefficiencies for the Government itself to plan or to coordinate developmental activities for the country.

During the master plan study, in several occasions, the Study Team found differences in the daily/monthly observed data for a same site presented in reports prepared by various agencies. Reconciling these variations in data held by different agencies was not always possible, mainly due to the difficulties within the government's organizational schemes in disclosing the crucial data required to clarify the differences. However, with the continuous support of the Official Counterpart Agency, the Sub-Institute of Water Resources Planning, confirmation was obtained to utilize the daily rainfall and discharge data obtained from the Institute for the basic hydrological analysis of the master plan study.

2.1.1 Rainfall Data

There exist 74 rain gauges in the Study Area; five in the Be River basin, ten in the Saigon River basin, six in the East and West Vam Co River basins, 13 in the La Nga River basin, 23 in the Dong Nai River basin and 17 in the coastal zone. Basins in the Study Area are shown in Figure 2.1 and existing rainfall gauges are represented in Figure 2.2.

Rainfall data collected at these stations on daily basis are first sent to the provincial centres of meteorology and hydrology. Thereafter, these provincial centres send the collected data to regional Hydro Meteorological Centres for data compilation, scrutiny and storage. There are three regional centres covering the Study Area, and their management provinces are as follows:

a) Southern Region Hydro Meteorological Centre (Ho Chi Minh City):

- Ba Ria-Vung Tau province,
- Dong Nai province,
- Song Be province,

- Tay Ninh province, and
- Ho Chi Minh City Special district.

b) Highland Region Hydro Meteorological Centre (Play Ku):

- Dac Lac province, and
- Lam Dong province.

c) South-Central Region Hydro Meteorological Centre (Nha Trang):

- Binh Thuan province, and
- Ninh Thuan province.

Collected data are scrutinized at these regional hydro-meteorological centres and are sent to the General Department of Meteorology and Hydrology in Hanoi for central database management. Table 2.1 gives an inventory of rain gauges in the Study Area, whilst Figure 2.3 shows the recorded period of their observation.

Mean annual rainfall for each basin in the Study Area was calculated based on the monthly rainfall data for 36 gauging stations out of 74 made available by the Government of Viet Nam. These gauging stations are considered, by the Sub-Institute of Water Resources Planning (SIWRP), as the representative rainfall gauging stations. According to the SIWRP, these 36 representative rainfall stations were selected mainly because of the sufficient number of years for the observed duration. Rainfall stations with a short observed period as well as the ones with unreliable data were not included as a representative station.

2.1.2 Climate Data

In the Study Area, there are 20 climate stations as depicted in the Figure 2.4, operated by the above-mentioned regional hydro-meteorological centres, observing air temperature, evaporation by Piche, relative humidity, wind direction and velocity and sunshine hours. Table 2.2 shows the available record length of these climate data.

The climate station at Than Son Hoa (Than Son Nhat) in Ho Chi Minh City was visited by the hydrologist of the JICA Study Team with his counterpart staff. All climate-observing instruments situated within a 26 m by 26 m enclosed territory were well maintained. This station possesses an automatic rain gauge (tipping-bucket type with recording paper exchanged daily; Russian manufacture), anemometer at 10m height with a wind direction indicator, sunshine recorder, Stevenson screen housed maximum/minimum thermometers, wet and dry bulb hygrometer and Piche evaporimeter. An automatic thermometer to measure air-temperature and an automatic hygrometer to observe humidity (Russian manufacture) were also functioning. Atmospheric pressure is measured by a barometer (Chinese manufacture) situated within the station office. Readings from thermometers and hygrometers are made eight times a day. Recorded data are well maintained and they are considered acceptable. The measured records are transmitted to the Southern Regional Hydro-Meteorological Centre of Ho Chi Minh City once a month for data processing.

2.2 Climate

The Study Area is located in the tropical monsoon zone. In the period of May to October, a high prevailing pressure in the central Asia forms South-West monsoon, bringing humid air from the Thai Gulf to the Dong Nai River and surrounding basins and causing the rainy season. The North-Eastern monsoon brings northern dry wind from the Asean Continent during the period of November to April when the southern hemisphere is in summer. This dry wind does not create considerable precipitation to the Study Area, bringing the dry season.

2.3 Rainfall

An isohyetal map (refer to Figure 2.5) was prepared based on the monthly rainfall records of the 36 representative gauges in the Study Area obtained from the Government as given in Tables 2.3, as well as some additional mean annual rainfall records obtained from various sources.

From the above isohyetal map, the mean annual rainfall for the Study Area was estimated at 1,945 mm. Furthermore, the isohyetal map revealed that the highest rainfall is measured in and around the Dac Te River with 2,800 mm a year. The mean annual rainfall decreases gradually toward the south-west direction and reaches 1,400 mm at the estuary of the Dong Nai River. On the contrary, the mean annual rainfall decreases hastily toward the south-east direction, i.e. the coastal area, and reaches less than 800 mm around the Phan Ri-Mui Dinh area.

2.4 Air Temperature

Air temperature in the Study Area is lowest in winter (December and January) and increases as season approaches into spring as given in Tables 2.4 and 2.5. On the other hand, air temperature reaches highest during the summer in the April/May period. It can be observed from both Tables that there is no significant difference in air temperature throughout a year. Furthermore, air temperature decreases with the increase in elevation. In Tan Son Hoa (elevation 9 m) mean annual air temperature is found to be 27.4 °C, whereas in Xuan Loc (elevation 180m) 26.8 °C, and in Bao Loc (elevation 850 m) 21.7 °C. While the daily data are not obtained, it is said that air temperature difference in a day is approximately 7 to 8 °C.

2.5 Relative Humidity

Mean annual relative humidity in the Study Area varies in a range of 77.4 % at Tan Son Hoa climate station to 85.6 % at Bao Loc climate station as presented in Tables 2.6 and 2.7. Relative humidity is high in the rainy season from June to October, reaching 85.8 %.

2.6 Evaporation

Table 2.8 presents mean monthly evaporation in millimeters, whilst monthly evaporation for Table 2.9. The observed mean value is 102.1 mm/month. Evaporation is measured by Piche in most of the climate stations (except in Da Lat, Bao Loc, Lien Khuong, Phan Thiet and Tan Son Nhat Airport where evaporation measurement is obtained by pan). Seasonal variation shows that evaporation is high in the dry season, especially in March with a value of 162.8 mm per month. Maximum evaporation was measured at the Dong Xoai station with a mean monthly evaporation recording of 138.4 mm per month, however, it is noted that this data was only obtained through one-year observation. Meanwhile, a monthly evaporation of 121.1 mm is recorded at the Phan Thiet climate station.

2.7 Sunshine Hours

In the Study Area, mean monthly sunshine hours vary from 5.4 hours in August to 9.1 hours in February as presented in Table 2.10. The average sunshine hours in the Study Area are found to be 7.2 hours. On the other hand, Table 2.11 shows monthly sunshine hours for each station.

2.8 Wind Velocity and Direction

The monthly wind velocity and direction are presented in Table 2.12. Seasonally, in the rainy season during May to October, prevailing wind from South-West is formed by the high pressure in the Central Asia as noted previously. Table 2.12 also confirms that the North-Eastern monsoon brings northern wind during the dry season from November to April.

3. HYDROLOGY

3.1 Study on Rainfall Data

A primal objective to study rainfall data is to clarify rainfall characteristics such as probable rainfall, rainfall intensity and other rainfall features for determing the design discharge in the flood runoff analysis.

3.1.1 Probability Analysis

A total of 12 rain gauges, which are well scattered in terms of aerial distribution with the long-term observation, are selected from among 74 existing rain gauges (refer to Figure 2.2) available in the Study Area, and the annual maximum point rainfalls of 1, 2, 3, 4, 10, 15 and 20 continuous days for those 12 stations are computed as summarized in Table 3.1.

Table 3.1 furthermore shows the probable rainfalls for each rainfall duration obtained for the return period of 2 to 1,000 years by applying the Gumbel method. Following summarizes the estimated probable rainfalls of those 12 stations with a return period of 20 and 100 years for 1-day and 3-day durations:

(Probable Rainfall)

Station	1-day rainfall (mm)		3-day rainfall (mm)	
	20-year	100-year	20-year	100-year
Di Lin	139.8	182.6	201.5	258.9
Bien Hoa	143.6	176.4	217.0	270.4
Da Lat	209.8	289.3	302.3	407.6
Dau Tieng	203.3	263.1	265.0	333.0
Long Thanh	199.6	259.9	269.7	344.1
Phan Thiet	134.3	172.2	185.2	236.7
Phan Rang	192.9	256.4	278.0	368.5
Tan Son Nhat	133.6	160.3	191.7	226.3
Tay Ninh	145.6	178.8	213.4	261.7
Phuoc Long	195.1	247.3	249.3	300.4
Vung Tau	171.0	220.6	215.6	271.2
Xuan Loc	201.8	268.4	257.9	329.2

The Da Lat station has the largest probable rainfalls among 12 stations, whilst the smallest appears in the Tan Son Nhat station.

3.1.2 Rainfall Intensity for the Short Duration

Rainfall intensity for the short duration less than one day is discussed for planning of small basin area such as urban drainage. It is noted in Viet Nam that there are neither standards for rainfall intensity formulae nor curves which can be used for the planning purposes.

For the short duration of rainfall less than one day, references available for the study are thus limited. The Study Team obtained the following data to deal with the rainfall intensity for the short duration:

a) Maximum Recorded Rainfall: Historical maximum rainfall records at Ho Chi Minh City (HCMC) and Da Lat were obtained from data book prepared by the former Meteorology Agency in HCMC. Although probability of these rainfalls is not known, the obtained maximum recorded rainfall for various durations is summarized as follows:

(Maximum Recorded Rainfall : mm)

Duration(min.)	HCMC	Da Lat
15	41.2	46.4
30	59.0	72.0
45	83.7	82.0
60	89.3	84.0
90	95.0	84.6
120	112.2	100.1
180	116.2	104.3
1 day	179.0	185.0
Period of data	19 yrs(1953-1971)	18 yrs(1954-1971)

b) Probable Rainfall Intensity Curve: On the other hand, the Study Team obtained a probable rainfall curve, the source of which is unknown, for the Tan Son Nhat station. From this curve, probable rainfall depths for each return period and the duration are read as follows:

(Probable Rainfall : mm)

Return P.	Probable Rainfall(mm)						
(year)	5	10	15	20	30	45	60
2	12.2	21.2	28.0	34.2	44.1	56.0	62.3
5	15.8	26.8	34.0	42.1	54.6	70.5	80.0
10	18.6	31.0	38.0	47.7	61.0	78.9	90.8
20	21.5	35.2	41.8	52.1	68.5	85.9	100.2
50	25.1	41.8	46.8	58.0	73.9	96.0	114.2
100	28.0	46.4	50.9	62.2	79.2	103.2	125.0

c) Daily-Hourly Rainfall Formulae: According to the guideline for the maximum discharge calculation prepared by the Hydrology Department, then Ministry of Water Resources in the year 1975, the following formulae are suggested to use in Viet Nam for obtaining hourly rainfall from daily rainfall:

- For the southern part of Viet Nam:

  $Rt/Rd = (1.1/T^{0.3})(t^{1.86}/24)^{0.35} = 0.294t^{0.65}$ for $t \leq 2.0$ hours

  $Rt/Rd = 1.1(t/24)^{0.35} = 0.362t^{0.35}$ for $t > 2.0$ hours

- For the northern part of Viet Nam:

  $Rt/Rd = (1.1/T^{0.4})(t^{2.33}/24)^{0.3} = 0.281t^{0.7}$ for $t \leq 2.8$ hours

  $Rt/Rd = 1.1(t/24)^{0.3} = 0.424t^{0.3}$ for $t > 2.8$ hours

where

Rt/Rd : ratio of rainfall in t-hour to one-day rainfall,

t : rainfall duration (hour)

T : limit of rainfall duration for the adoptation of the formulae (T=2.0 hours for the southern Viet Nam and T=2.8 hours for the northern Viet Nam).

It should also be mentioned here that the formula for the duration of t>T, i.e. $Rt/Rd = (t/24)^k$ refers to the Sherman-type rainfall intensity formula, which also shows the similar form of the formula formerly used in Japan (k=1/3 by Mononobe and k=1/2 by Takahashi). It is considered that the coefficient of 1.1 in the above formula is the ratio of the 24-hour rainfall to the daily rainfall.

The above formulae were examined and compared each other with data given in a) and b) as presented in Figure 3.1 to evaluate their mutual conformity and reliability. From this study the following could be concluded:

a) The maximum rainfalls recorded at the Tan Son Nhat and Da Lat stations are similar with a small difference of intensity. These maximum rainfall records are considered to be in the same range of 20- to 50-year probable rainfall.

b) The daily-hourly rainfall formula agrees with the maximum recorded rainfall for the duration more than three hours. For the duration less than one hour, the daily-hourly formula and the 20-year probable rainfall have similar distribution characteristics. The daily-hourly rainfall formula utilized in Viet Nam seems to represent the rainfall characteristics of the area. In case where hourly rainfall data are not available, those hourly rainfall data can be estimated from daily rainfall by using the formula.

c) A probable rainfall curve developed for the Tan Son Nhat station agrees with other data available for Tan Son Nhat. Therefore, the rainfall curve so developed is used for urban drainage studies in Ho Chi Minh City. However, it is recommended that the source of this rainfall curve at Tan Son Nhat be clarified or that the curve itself be replaced by valid data with the clarified source.

3.1.3 Rainfall Intensity for the Long Duration

Discussed here is the rainfall intensity for a long duration more than one day, which is used for the flood mitigation plan of large river basins such as the Dong Nai River.

For the study of relationship between the rainfall intensity and the duration for a longer time period, probable rainfall noted in the previous Sub-section is used.

Table 3.2 and Figure 3.2 present the probable rainfalls for several rainfall durations predicted at the Da Lat and Tan Son Nhat stations. Observing the above data, the relationship between n-day (Rn) and 3-day (R_3) probable rainfall could be expressed by the following equation for the duration more than 3 days:

$$Rn = R_3(D/3)^{0.43} \text{ for } D \geq 3 \text{ days}$$

where
- Rn : n-day rainfall,
- R_3 : three-day rainfall, and
- D : duration of rainfall in days.

The n-day rainfall in the Study Area can thus be estimated approximately from 3-day rainfall by the above equation.

3.1.4 Rainy Day Rainfall

Average monthly rainfall and the average number of rainy days in a month were studied as shown in Figure 3.3 for two stations, Lien Khuong in Da Lat and Tan Son Nhat in HCMC, and these are summarized below:

(Average Monthly Rainfall and Rainy Days)

Month	Lien Khuong			Tan Son Nhat/ HCMC		
	Monthly rain.(mm) (1)	Rainy days (days) (2)	(1)/(2) (mm/day) (3)	Monthly rain.(mm) (4)	Rainy days (days) (5)	(4)/(5) (mm/day) (6)
Jan.	7.7	3.7	2.1	13.1	2.1	6.3
Feb.	18.7	1.3	14.4	4.3	0.5	8.6
Mar.	59.5	2.7	22.0	11.3	1.6	7.1
Apr.	163.3	6.2	26.3	49.6	3.4	14.6
May	209.1	11.4	18.3	211.0	10.7	19.7
Jun.	190.8	13.3	14.3	309.8	13.6	22.8
Jul.	232.7	15.8	14.7	295.8	14.7	20.1
Aug.	236.6	16.3	14.5	270.8	15.4	17.6
Sep.	305.4	14.3	21.4	331.3	15.0	22.1
Oct.	250.3	9.3	26.9	270.9	14.6	18.6
Nov.	91.7	7.3	12.6	116.6	8.8	13.3
Dec.	26.0	3.8	6.8	47.9	5.6	8.5
Total	1,791.9	105.4	17.0	1,932.2	106.0	18.2

Annual rainfall is larger in HCMC, but the number of rainy days in a year is almost the same for both stations. The average rainy day rainfall, which is worked out by diving monthly rainfall by the number of rainy days, has two distinct peaks in March/April and October in Da Lat, while in HCMC the rainy day rainfall distributes more evenly during the rainy season. This suggests that, in the upper basin of the Dong Nai River, rainfall of higher intensity be apt to occur at the beginning and end of the rainy season.

3.2 Study on Runoff Data

3.2.1 Available Data and Records

(1) Discharge data

There are 15 discharge stations in the Study Area as given in Figure 3.4. These stations owned by the regional hydro-meteorological centres are operated by reading staff gauges manually; normally four times in a day during the dry season and eight times in a day during the rainy season. These observed water levels are converted to discharge using the rating curve developed for each station.

The rating curves are calibrated each year by carrying out discharge measurements and cross-sectional survey. Thus, discharge data so obtained are judged reliable. Availability of discharge records at these stations is shown in Figure 3.5.

(2) Water level data

There are 23 water level stations mainly in the downstream reaches of the Dong Nai and Vam Co rivers where backwater by tidal effects is significant (refer to Figure 3.6). These water level stations, which are established for the survey of salinity intrusion, are operated by the Regional Hydro-Meteorology Centre of Ho Chi Minh City. Water levels are measured by automatic gauge in most of these stations. Since the year 1982, the unified bench mark of Ha Tien national station (in the northern Viet Nam) has been used in these stations. Therefore, data obtained prior to the year 1982 would require careful calibration in analysis. Availability of water level records at these stations is shown in Figure 3.7.

3.2.2 Runoff Characteristics

Monthly runoff data observed at 15 discharge stations were collected from the Government as presented in Table 3.3. Mean annual runoff and specific discharge for those stations were computed as shown below:

Hydrological Characteristics at 15 Stations

Station Name	Catchment Area (km^2)	Mean Annual Runoff (m^3/sec)	Specific Discharge (cms/km^2)
An Vien	264	7.6	0.0288
Can Dang	617	10.79	0.0175
Dai Nga	373	17.29	0.0464
Dau Tieng	2,700	57.7	0.0214
Dran	775	21.92	0.0283
Loc Ninh	500	11.63	0.0233
Luy	982	12.60	0.0123
Nha Trinh (before Da Nhim const.)	2,140	62.24	0.0291
Phu Dien	3,060	120.93	0.0395
Phuoc Hoa	5,765	217.07	0.0377
Phuoc Long	2,215	101.54	0.0458
Ta Lai (without Dran catchment)	8850	299.08	0.0338
Ta Pao	2,000	75.78	0.0379
Thanh Binh	294	8.5	0.0289
Tri An (without Dran catchment)	14,025	542.0	0.0386

Mean annual runoff observed in the basins of the Dong Nai River (both mainstream and its tributaries; Dran, Ta Lai, Tri An and Thanh Binh) falls in a range of 0.0283 cms/km^2 at the upstream tributary, Dran, to 0.0386 cms/km^2 at Tri An in terms of specific discharge, while in the Be River basin, the specific discharge of mean annual runoff varies from 0.0377 cms/km^2 at Phuoc Hoa to 0.0458 cms/km^2 at Phuoc Long. In the La Nga River basin, the specific discharge ranges between 0.0379 cms/km² at Ta Pao and 0.0464 cms/km² at Dai Nga. In the Saigon River basin, it varies from 0.0214 cms/km² at Dau Tieng to 0.0233 cms/km² at Loc Ninh. The specific discharge of the East Vam Co River is found to be 0.0175 cms/km² at Can Dang.

3.2.3 Data Scrutiny

Scrutiny of runoff data obtained at the 15 discharge stations in the Study Area was attempted by computing the runoff coefficient.

Annual rainfall in the draining area of each discharge station was estimated by drawing the Thiessen polygons for the 35 rainfall gauging stations as given in Figure 3.8. The Bu Dang gauging station was not included in polygon since the obtained data for Bu Dang only had a sample of 5-year monthly rainfall. The relationship between the annual rainfall estimated above and the annual runoff depth, which is computed by dividing annual accumulated runoff by catchment area, is depicted by discharge station as given in Table 3.4. The runoff coefficient, which is a ratio of total runoff depth to total rainfall, was calculated for the gauges as follows:

Station	Rainfall (mm)	Runoff Depth (mm)	Runoff Coefficient
An Vien	2,114.2	913.1	0.43
Can Dang	1,918.2	553.8	0.29
Dai Nga	2,558.1	1,469.9	0.57
Dau Tieng	2,038.7	650.3	0.32
Dran	1,767.2	895.2	0.51
Loc Ninh	1,987.1	736.0	0.37
Luy	1,486.8	406.9	0.27
Nha Trinh	1,334.3	921.1	0.69
Phu Dien	2,462.5	1,252.6	0.51
Phuoc Hoa	2,359.2	1,188.8	0.50
Phuoc Long	2,424.2	1,453.7	0.60
Ta Lai	2,385.2	1,070.4	0.45
Ta Pao	2,462.4	1,201.6	0.49
Thanh Binh	1,733.8	915.7	0.53
Tri An	2,388.5	1,218.0	0.51

In analyzing the above-obtained runoff coefficients, there is a tendency that the runoff coefficients of the East Vam Co River and Saigon River basins fall in a range of 0.29 at Can Dang to 0.37 at Loc Ninh. Similarly in the Dong Nai delta, runoff coefficients are found to be in a range of 0.43 at An Vien to 0.51 in Phu Dien. Runoff coefficients increase in the mountain area where annual rainfall is higher than the delta. In this mountain area, the runoff coefficients have a tendency to fall between 0.51 at Dran and 0.60 at Phuoc Long.

On the other hand, the runoff data at Nha Trinh can be judged to be less reliable due to the fact that the runoff coefficient of 0.69 at Nha Trinh is high when compared with the runoff coefficient of nearby stations (0.51 at Dran and 0.53 at Thanh Binh).

Flow duration curves for the selected 13 gauging stations were prepared in the series method as given in Figure 3.9 and Table 3.5.

3.2.4 Discharge Measurements

As part of the verification of discharge data made available, intensive discharge measurements have been performed during the Phase II field work in order to estimate the accuracy of existing water level versus discharge curve (H-Q curve) now being used at the selected discharge stations. The following sites are verified by measuring stream flow rate and recording the water level by the existing staff gauge at each station:

- Ta Lai gauging station;
- An Vien (La Buong) gauging station;
- Ben Than gauging station;
- Phuoc Hoa gauging station; and
- Ta Pao gauging station.

Discharge measurements were taken place at the above selected sites from June 19 to August 05, 1995, with the following schedule:

Site	Ta Lai	La Buong	Ta Pao	Phuoc Hoa	Ben Than
1st measurement	22-Jun	23-Jun	24-Jun	25-Jun	26-Jun
2nd measurement	1-Jul	2-Jul	3-Jul	4-Jul	5-Jul
3rd measurement	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul
4th measurement	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul
5th measurement	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul
6th measurement	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug

For all the above measurements, results are presented in the following Tables and Figures: samples of discharge observation records in Tables 3.6; samples of discharge calculation sheets in Tables 3.7; samples of cross section of gauging station in Figure 3.10; rating curve values for each site in Table 3.8; and rating curves together with the observed data in Figure 3.11. The maximum discharge observed during the field work period was also obtained from each discharge station and they are also plotted in Figure 3.11. Summary of the discharge measurements performed is as follows:

	1			2			3		
Station	Day	H (cm)	Q (cms)	Day	H (cm)	Q (cms)	Day	H (cm)	Q (cms)
Ta Lai	22-Jun	1,056	114.53	1-Jul	1,136	359.23	11-Jul	1,174	488.87
An Vien	23-Jun	413	1.72	2-Jul	538	19.28	12-Jul	516	15.99
Ta Pao	24-Jun	556	38.73	3-Jul	647	101.87	13-Jul	694	136.80
Phuoc Hoa	25-Jun	1,202	192.57	4-Jul	1,296	242.21	14-Jul	1,174	167.74
Ben Than	26-Jun	34	451.92	5-Jul	120	-733.61	15-Jul	145	-725.42

Station	4			5			6		
	Day	H (cm)	Q (cms)	Day	H (cm)	Q (cms)	Day	H (cm)	Q (cms)
Ta Lai	17-Jul	1,110	357.81	24-Jul	1,114	249.65	1-Aug	1145	396.26
An Vien	18-Jul	517	14.81	25-Jul	429	13.11	2-Aug	448	6.09
Ta Pao	19-Jul	627	75.25	26-Jul	519	58.95	3-Aug	502	67.35
Phuoc Hoa	20-Jul	1,144	169.92	27-Jul	954	64.74	4-Aug	964	66.68
Ben Than	21-Jul	78	-545.55	28-Jul	98	-324.61	5-Aug	118	730.80

Observing the rating curves together with the observed data obtained by the discharge measurements, it is concluded that the observed data in general match with the existing rating curves. No significant error in the obtained data when compared with the rating curve was found.

Ben Than station is considered as a key station for salinity intrusion simulation study and water supply programme for Ho Chi Minh City and its vicinities. As observed during the discharge measurement, estimating the discharge from the H-Q curve developed for the Ben Than station is not reliable and is not recommended due to backwater of tidal waves. However, detailed and reliable continuous water level data at Ben Than are crucial for accurate forecasting and water demand/supply analysis. The Government is thus ready to fully utilize water level data obtained at the Ben Than station for this purpose.

3.3 Low Flow Analysis

3.3.1 Introduction

The objective of the low flow study is to obtain daily runoff data at discharge stations for a continuous period of 30 years and to obtain a non-dimensionalized storage-draft curve at each discharge station. These daily discharge data are to be used later for the development and analysis of storage-draft curve at each dam site in the Study Area. Prediction of these daily discharge data is solely based on the daily rainfall and discharge data made available by the Government.

Runoff data at the discharge stations in the Study Area are not available for a continuous period of 30 years, but available for rainfall data. This situation encourages to predict 30-year continuous runoff data at a discharge station by applying a rainfall-runoff simulation model. In this low flow study, Tank Model developed in Japan is used as the simulation model to predict 30-year continuous runoff data. Of course, measured discharge data are used for the calibration of parameters in Tank Model.

(1) Available Data

At the end of December 1994, daily rainfall records for 18 gauging stations located within the Study Area were provided for the application of Tank Model by the Government together with daily discharge records for 11 discharge stations. Hydrological analysis performed during field work II was based on the daily rainfall and discharge data obtained from the counterpart agency.

(2) Procedure of Simulation

The basic procedure of Tank Model simulation is as follows:

a) Tank Model is initially constructed at each gauging station for the duration of observed years. The concept of the model is described in the following Section.

b) The calibration of the model parameters is mainly carried out in terms of the following aspects:
   - mean monthly runoff, and
   - runoff coefficients.

c) Daily runoff at each discharge station is generated on daily basis by using the calibrated model for continuous 30 years including the observed period.

d) In the preparation of natural daily runoff at each gauging station, the simulated daily runoff is used instead of recorded runoff when they are judged to be unreliable or not available due to interrupted data collection. Therefore, the natural daily runoff at each gauging station is supplemented by generated runoff for the period of 30 years. The estimated natural runoff is examined further by the double mass curve method to check its reliability and consistency.

(3) Basic Concept of Tank Model

Tank Model was first developed by Professor Sugawara of the Science and Technology Agency in Japan and is widely used for the low flow and flood analysis of the water resources development planning in Japan.

The basic concept of Tank Model is to consider a river basin into several storage tanks and is to predict runoff from the basin by calculating storage volume and runoff volume from each storage tank. This basic concept is presented in Figure 3.12. As shown in Figure 3.12, the tube on the right side of the tank represents the runoff whereas the tube at the bottom of each tank represents the percolation of water stored in the tank to the soil layer below. Precipitation is first stored in the upper tank. Stored water percolates into lower soil layer or if the upper tank's volume reaches the height of the tube, it would result as runoff from the tank. The second tank receives the water supply from the first tank and the stored water either percolates into the third tank (lower soil layer) or results as runoff from the tank. The same process is applied for other tanks beneath.

The depth of water released from a tube is given by the following relation:

$$I = C * H$$

where: I = depth of water released (mm/day),
C = tube coefficient, and
H = water depth above hole (mm).

3.3.2 Calibration of Model

(1) Applied Tank Model

For the low flow simulation of the Study Area, a total of 16 tanks (4 tanks vertically combined and 4 tanks horizontally combined) are applied. Each tank represents each runoff mechanism in the watershed. The top tank corresponds to the surface runoff, the second tank to the subsurface runoff and the third and fourth tanks to base flow from the groundwater zone.

In the process of simulation, daily rainfall depth is placed into the top tank and the depth of water released from a hole is calculated by the above equation. Water from the bottom hole is put into the second tank and the same process is repeated to the fourth tank. The depth of stream runoff is given as the sum of the water released from the side holes of four tanks. Loss due to evapotranspiration is expressed by subtracting the depth of daily evapotranspiration from the storage of the top tank.

(2) Mean Basin Rainfall

As noted before, prediction of discharge for several decades by hydrological simulation depends on the availability, reliability and consistency of the rainfall data to be used in any runoff models.

The daily basin rainfall for each discharge station is estimated by means of weighted average of the available rainfall stations in the Study Area. In order to obtain such rainfall, a correlation method was used to supply missing rainfall data. It should be mentioned here that, in general, correlation factors of the available rainfall stations were found relatively low probably due to long distance between rain gauges. Basin rainfall for each discharge station was then obtained by applying weighted average against the catchment area of the available rainfall stations.

(3) Evaporation Ratio

The monthly evaporation data were obtained during the first field work period. Mean evaporation in mm/day was estimated for each discharge station from the available data and was entered into Tank Model.

(4) Observed Runoff Data

Recorded daily data for the discharge stations are utilized to calibrate the simulated data.

(5) Calibration

The simulation model developed for each discharge gauging station is calibrated as mentioned above by examining the following two aspects of the calculated runoff:

- mean monthly runoff, and
- runoff coefficient.

Calibration of runoff on daily basis is not valid because area distribution of rainfall is not usually uniform in the basin and the mean basin rainfall obtained does not necessarily coincide with the peak in the observed runoff. This is further true in this calibration model, since for some discharge gauging stations such as Song Luy and Can Dang, the number of rain gauges was not enough for the prediction of daily basin rainfall. Calibration by two ways is as follows:

a) Daily Runoff: Daily runoff simulated by the model for each discharge station is compared with the observed mean monthly runoff for the selected stations as shown in Figure 3.13.

The simulated runoff is satisfactorily similar to the observed runoff for the observed period for each gauging station, considering reliability of rainfall data used in the Tank Model simulation.

b) Runoff Coefficient: Table 3.9 presents the results of low flow analysis by Tank Model in terms of runoff coefficients of observed and simulated runoff together with error of simulation. Runoff coefficients of simulated and observed values are compared and the rates of difference in percentage (in terms of runoff value) were estimated. It should be mentioned here that the mean discharge as well as mean annual rainfall presented in Table 3.9 is for the duration of observed years and not for the 30 predicted years. Calibrated results confirmed the fact that the difference in the outflow is rather large when the basin rainfall data were represented by only one or two rainfall stations. This is especially true for the values obtained for the Song Luy, Can Dang and La Buong stations. Results obtained for other stations are considered to be acceptable with a range of difference from 0.00 to 8.48 %.

3.3.3 Low Flow Analysis for the Selected Damsites

Estimated mean monthly runoff for each discharge station for the duration of 30 years is obtained based on the daily simulated runoff so obtained. These estimated mean monthly runoff for each discharge station is presented in Table 3.10.

Based on the estimated 30-year mean monthly runoff, storage-draft curves for each station were prepared as presented in Figure 3.14. The storage-draft curve is a diagram to show the relationship between the draft rate and the active storage volume required in the reservoir to warrant the constant draft rate throughout a year. The curve is non-dimensionalized by annual inflow volume in ordinate and mean discharge in abscissa. The storage-draft curve so prepared will be used to develop the development scale of multi-purpose reservoir schemes.

Based on the above result of the low flow analysis, monthly inflow at the proposed damsites for a duration of 30 years was prepared. In order to estimate the discharge at the proposed damsites, the basins draining at the proposed damsites were subdivided into several sub-basins. The sub-basins so divided are presented in Figure 3.15.

(1) Dong Nai River Basin

As for the damsites in the Dong Nai River basin, damsites of Dai Ninh, Dong Nai No. 3, Dong Nai No. 4, Dong Nai No. 6 and Dong Nai No. 8 are considered. For the Dai Ninh damsite, calibrated results of the Thanh Binh gauging station were utilized to obtain the inflow at the damsite since the Thanh Binh gauging station is the closest station located near the Dai Ninh damsite when compared with the location of other gauging station available in the mainstream of the Dong Nai River, i.e. Ta Lai station. Discharge characteristics, such as specific discharge and runoff coefficient of Dai Ninh damsite, would be similar to those of the Thanh Binh station than those of the Ta Lai station. Discharge for the Thanh Binh station obtained from the Tank Model simulation, as shown in Table 3.10, has been converted into the Dai Ninh damsite by utilizing the catchment area and the mean annual rainfall estimated as presented in Table 3.11. Furthermore, to consider the water balance of the Dong Nai River basin as a whole, an adjustment was made to balance the overall discharge in the downstream reaches of the Dong Nai River at the Ta Lai station. The estimated runoff at the Dai Ninh damsite is presented in Table 3.12.

(2) Other Damsites along the Dong Nai River

As for other damsites along the Dong Nai River; that is, Dong Nai No. 3, Dong Nai No. 4, Dong Nai No. 6 and the sub-basin between Dong Nai No. 6 and the Ta Lai station, results of the Tank Model simulation for the Ta Lai gauging station, as shown in Table 3.10, were used since Ta Lai is the only gauging station located along the mainstream of the Dong Nai River. As performed for the Dai Ninh damsite flow, catchment area, estimated mean annual rainfall and water balance adjustment factor obtained by taking percentage of the total rainfall volume of each sub-basin to the total rainfall volume of Ta Lai basin minus Dai Ninh basin, as shown in Table 3.11, were used for converting Ta Lai gauging station discharge to the discharge of damsites in the mainstream of the Dong Nai River. The estimated runoff at these sites is presented in Table 3.12.

(3) Be River Basin

Two discharge stations, Phuoc Long and Phuoc Hoa, exist in the Be River basin for estimating the discharge at damsites in its basin. In order to estimate the discharge of the damsites in the Be River basin, correlations of the monthly observed data for Phuoc Hoa, Phuoc Long and Tri An were calculated. From this analysis, it was found that the monthly discharge of Phuoc Hoa had a higher correlation value of 0.976 against Phuoc Long (0.956) to Tri An. Furthermore, the number of daily discharge data for Phuoc Hoa was larger than that of Phuoc Long. Therefore, in order to estimate flow at the damsites in the Be River basin, the Phuoc Hoa station was applied to all damsites except for Thac Mo, which is located near the Phuoc Long gauging station. Estimated runoff at the Phuoc Hoa and the Phuoc Long stations is presented in Table 3.10. Catchment area, estimated mean annual rainfall and percentage of the total rainfall volume of each sub-basin to the total rainfall volume of Phuoc Hoa basin minus Thac Mo basin are presented in Table 3.11. Estimated runoff at these damsites is presented in Table 3.12.

(4) La Nga River Basin

For the La Nga River basin, the result of Tank Model for the Dai Nga station revealed to be more accurate than that of Ta Pao gauging station by the fact that the range of difference between the simulated and observed values was 5.71 % at Ta Pao and -1.42 % at Dai Nga. Therefore, discharge data obtained for the Dai Nga gauging station, as presented in Table 3.10, were converted for estimating the discharge at the Ham Thuan and La Nga No. 3 damsite by using the catchment area and mean annual rainfall estimated as presented in Table 3.11. Estimated runoff at these sites is presented in Table 3.12.

(5) Saigon River Basin

Along the Saigon River, there exists only one discharge station, the Loc Ninh discharge station. Estimated discharge for the Loc Ninh gauging station, as presented in Table 3.10, was utilized to estimate the monthly inflow at the Dau Tieng damsite. Catchment area and mean annual rainfall estimated as specified in Table 3.11 were applied. Estimated inflow at the Dau Tieng damsite is presented in Table 3.13.

(6) Discharge in the Coastal Area

As a representative station within the coastal area, discharge for the Song Luy gauging station was simulated during the home office work of Phase I. Due to the availability of rainfall data in the basin, the simulated result was less satisfactory when compared with simulation results for other stations. However, the estimated monthly runoff for the Song Luy station is presented in Table 3.10 for reference.

In discussing the Song Luy station, it should be mentioned that the Dong Moi weir which has a catchment area of 1,090 km^2 was constructed before the year 1975 along the Luy River. The Study Team has received verbal confirmation from the gauging station representative that the Song Luy gauging station has no backwater effect from the weir.

3.4 Flood Runoff Analysis

Flood runoff analysis was carried out mainly with two objectives, i.e. to estimate basic design discharges in the river channel and at major facilities and to evaluate hydraulic effects of such structures as dam reservoirs. Prior to the model preparation, flood runoff records and past major floods in the Study Area were reviewed. A flood runoff simulation model was prepared for calibration based on the past flood data. The design discharge was calculated by using the simulation model so prepared.

3.4.1 Flood Runoff Records and Past Major Floods

(1) Flood Runoff Records

Flood runoff data are available at the following stations in the Dong Nai River system:

(Available Runoff Data)

Station	River system	Basin area (km^2)	Period of data
Thanh Binh	Da Dung/Dong Nai	294	11yr:1980-90
Ta Lai	Dong Nai	8,850	4yr:1987-90
Dai Nga	La Nga/Dong Nai	373	11yr:1979-82,84-90
Ta Pao	La Nga/Dong Nai	2,000	14yr:1977-90
Phu Dien	La Nga/Dong Nai	3,060	4yr:1987-90
Tri An	Dong Nai	14,025	9yr:1980-88
Phuoc Long	Be/Dong Nai	2,215	14yr:1977-90
Phuoc Hoa	Be/Dong Nai	5,765	17yr:1973,75-90
An Vien	La Buong/Dong Nai	264	13yr:1978-90
Loc Ninh	Saigon/Dong Nai	500	9yr:1975-83
Dau Tieng	Saigon/Dong Nai	2,700	3yr:1976-78
Can Dang	E. Vam Co/Dong Nai	617	15yr:1976-90

The annual maximum flood discharges are selected based on the daily discharge records for each station and are listed in Table 3.14.

(2) Selection of Past Major Floods

Major floods occurred in the past are selected for the study of flood runoff characteristics in the Dong Nai River and surrounding basins as well as for the preparation of flood runoff simulation model. For selecting major floods occurred in the past, the following documents and information are referred to:

- Annual maximum rainfall with several durations,
- Monthly maximum daily rainfall,
- Monthly maximum daily discharge, and
- Verbal information obtained during flood damage survey.

Old floods, which are significant in the flood runoff analysis but are available with little rainfall/discharge data, are excluded from reference. Based on the above information, the following floods are selected to analyze in detail:

- August 1978 flood,
- September 1978 flood,
- September 1982 flood,
- August 1984 flood,

- August 1986 flood,
- August 1987 flood,
- August 1990 flood, and
- September 1990 flood.

Availability of the daily rainfall and runoff records is shown in Table 3.15 for the selected flood events.

3.4.2 Preparation of Flood Runoff Model

Storage function method is selected as the model to apply to the flood runoff analysis. For the preparation of flood runoff model, a runoff system model is first prepared for the whole basin, followed by the calibration to determine the constants given in the storage function equation. In fact, the river basin is divided into sub-basins and river channels, and then the constants for each sub-basin and river channel are determined based on the actual rainfall and runoff records observed in the past.

(1) Basic Concept of the Simulation Model

<u>Storage Functions for the Basin</u>

Runoff from sub-basins is simulated with the storage functions expressed by the following equations:

$$S_l = kQ_l^P$$
$$dS_l/dt = (1/3.6) \cdot f \cdot r \cdot A - Q_l$$
$$Q_l(t) = Q(t+T_l)$$

where

S_l	:	basin storage (m^3),
Q_l	:	runoff from sub-basin(m^3/sec) in consideration of time lag(T_l),
k, p	:	basin constants,
t	:	time in seconds,
d/dt	:	differentiation,
f	:	runoff coefficient,
r	:	mean basin rainfall (mm/hr),
A	:	catchment area (km^2), and
T_l	:	time lag.

Basin constants of k and p in storage function and time lag (T_l) are initially estimated by the following empirical formulae developed in Japan:

$k = 40.3,\ \ p = 0.5$

$T_l = 0.0470\ L - 0.56$ (T_l in hours) for $L > 11.9$ km

$T_l = 0$ for $L \leq 11.9$ km

where L : stream length from the point of interest to the farthest point of basin in km, and

T_l : time lag in hour.

The above constants are adjusted afterward based on the rainfall and runoff records in the Study Area through calibration procedures.

Storage Functions for the River Channel

Principally the same basic equations as in the basin runoff are applied to the channel runoff calculation as follows:

$$S_l = kQ_l^p$$

$$dS_l/dt = \mathrm{sum}(f_i I_i) - Q_l$$

where

f_i : inflow rate,

I_i : inflow, and

$\mathrm{sum}(f_i I_i)$:total of effective inflows.

Initial channel constants, k and p, are estimated by the following equations derived from the Manning's formulae:

$$k = (n^{3/5} B^{2/5} L)/I^{3/10}$$

$$p = 0.6$$

where

n : Manning's coefficient of roughness,

B : average river channel width (m),

I : average river channel slope, and

L : river channel length (m).

The time lag (T_l) for channel is initially estimated by the following empirical formulae developed in Japan:

$T_l = 7.36/10^4 L I^{1/2}$ (Tl:hour)

where

L : channel length (km), and

I : channel slope.

(2) Runoff System Model

The runoff system model consists of base points, sub-basins and river channels as mentioned below.

Base Points : A base point is defined as a location along river course to simulate the flood runoff for determining design flood runoff and assessing effect of flood mitigation by alternative schemes.

The following discharge gauging stations are selected as the base points for the flood runoff studies:

(Base Points for Flood Runoff Analysis)

Base Points	Location	Basin Area(km^2)
Ta Lai	Dong Nai River basin	8,850
Ta Pao	La Nga River basin	2,000
Phu Dien	La Nga River basin	3,060
Tri An	Dong Nai River basin	14,025
Phuoc Hoa	Be River basin	5,765
Dau Tieng	Saigon River basin	2,700

In addition to the above base points, sub-base points are set up at the locations where significant changes in flood runoff are expected such as:

- Confluence of the main river with a major tributary,
- Proposed/existing damsites, and
- Beginning/end points of river stretches divided for flood control planning.

Runoff System Diagram : The Dong Nai River and surrounding basins and their river channels are divided into sub-basins and river channels by taking into account the base points and sub-base points. The sub-basins, river channels and base points so divided are depicted in the runoff system diagram with basin boundaries as shown in Figures 3.16 and 3.17.

The size of sub-basins for the present study is rather large in comparison with the generally recommended size. However, it is judged that further division of basin would not increase the accuracy of simulation, because of the low density of rain gauge stations available in the basin and a few discharge measurement stations available for calibration.

(3) Calibration of Model

Past Floods for Calibration : Six major floods are selected for the calibration of flood runoff model as follows:

a) 1978-Flood : From Aug. 19 to Sep. 15, 1978
b) 1982-Flood : From Sep. 01 to Sep. 22, 1982
c) 1984-Flood : From Aug. 03 to Aug. 29, 1984
d) 1986-Flood : From Aug. 03 to Aug. 31, 1986
e) 1987-Flood : From Aug. 11 to Aug. 31, 1987
f) 1990-Flood : From Aug. 13 to Sep. 14, 1990.

Reservoir Operation : There exist four large reservoirs, Da Nhim, Dau Tieng, Tri An and Thac Mo, in the Dong Nai River basin. Operation of these reservoirs commenced as follows:

a) Da Nhim reservoir/Dong Nai R. : 1965 or before
b) Dau Tieng reservoir/Saigon R. : 1985
c) Tri An reservoir/Dong Nai R. : 1988
d) Thac Mo reservoir/Be R. : 1994.

Among the above, only the Da Nhim reservoir is taken into account for the calibration, since runoff records after the operation of reservoir are not available for the other reservoirs.

Mean Basin Rainfall : Thirty four (34) rainfall stations located in and around the Study Area are used to estimate mean basin rainfall by Thiessen Method. The Thiessen polygon and weight to aerial distribution of those rainfall stations are shown in Figure 3.18.

Basic Parameters for Sub-basins and River Channels : For estimating the initial values of basin and channel constants for storage function (k, p and Tl), basic parameters of sub-basins and river channels are obtained as presented in Table 3.16.

Calibration Results : The flood runoff model is calibrated by trial and error approach; that is, the coefficients of rainfall excess and basin and channel constants for storage function such as k, p and Tl are changed so that the calculated runoff can get closer to the recorded runoff.

After a series of trial calculations, the coefficients of rainfall excess and basin and channel constants for storage function are finally obtained as presented in Table 3.17. Runoff hydrographs calculated based on the coefficients and constants so obtained are shown in Figure 3.19, compared with the recorded runoff and daily rainfall at the selected rain gauge stations.

3.4.3 Basic Channel Discharge

(1) Rainfall Hyetograph for Design Discharge Calculation

Based on the results of probable rainfall analysis at the selected stations in the Study Area, rainfall hyetographs for the calculation of design discharge are prepared for the 20- and 100-year return periods at respective stations as shown in Table 3.18.

The rainfall hyetographs are prepared on the daily basis, so sum of 1-day, 2-day, 3-day, 10-day, 15-day and 20-day consecutivly distributed rainfalls should accord with the 20-or 100-year probable rainfalls. Results of probability analysis are directly used for 1-day to 3-day consecutive rainfalls, and the n-day rainfall formulae discussed in previous Section are applied to other probable rainfalls with a longer duration.

This arrangement is made by taking into consideration the fact that the time of concentration for the whole basin is estimated at about 3 days and that runoff would be delayed for a couple of weeks due to flooding to depressed land areas and the retention effect of reservoir.

(2) Mean Basin Rainfall

Mean basin rainfall is estimated by applying the Thiessen method for the probable rainfall estimated for the selected rain gauges. Figure 3.20 shows the Thiessen polygon of the selected rain gauges with the values to multiply for the estimate of mean basin probable rainfall by the weighted average method.

(3) Base Flow

The rainy season normally starts in May and ends in November in the Study Area. During the rainy season, channel flow is kept high. Taking into consideration the fact that past major floods occur in August and September, an average of monthly discharges in August and September is assumed to be the base flow to be added to the direct flood flow for the estimate of the design discharge. The base flow for the respective sub-basis is estimated by multiplying the catchment area by the specific discharge of the representative stations obtained from the average flow of August and September as follows:

(Average Monthly Discharge)

Station	Catchment area(km^2)	Average monthly discharge (m^3/s) August	September	Average	Specific discharge (m^3/km^2)	Available year of data
Ta Lai	8,850	745	879	811	0.0916	1987-1994
Ta Pao	2,000	108	193	151	0.0754	1977-1992
Phu Dien	3,060	312	375	344	0.1123	1987-1994
Tri An	14,025	1,315	1,426	1,371	0.0977	1978-1982
Phuoc Hoa	5,765	540	616	578	0.1003	1973-1993
Dau Tieng	2,700	89	130	109	0.0404	1976-1980

(4) Basin Conditions

The basin and channel conditions used for calibration are assumed to be applicable for the calculation of the basic design discharge; that is, only Da Nhim reservoir is taken into account in the runoff model.

(5) Estimate of Basic Design Discharge

Basic design flood discharge is calculated based on the conditions mentioned above as summarized below:

(Basic Design Flood Discharge)

Station	20-year flood(m^3/s)	100-year flood(m^3/s)
Ta Lai	4,904	6,558
Ta Pao	1,614	2,100
Phu Dien	995	1,235
Tri An	6,459	8,265
Phuoc Hoa	2,691	3,230
Dau Tieng	2,351	3,197

3.4.4 Design Discharge of Spillway for the Dam

Flood discharge at damsites is estimated by applying the same procedure presented in previous Sub-sections for 20-, 100-, 200- and 1000-year probable rainfalls. Probable flood discharge estimated at the existing damsites and other interesting sites is summarized below:

(Flood Discharge Estimated by Runoff Model)

Dam	20-year (m^3/s)	100-year (m^3/s)	200-year (m^3/s)	1,000-year (m^3/s)
Dong Nai 3	4,618	6,696	7,616	9,802
Dong Nai 6	4,598	6,378	7,152	8,947
Ham Thuan	988	1,279	1,404	1,690
Thac Mo	2,153	2,819	3,116	3,832
Fu Mieng	2,695	3,510	3,880	4,781
Phuoc Hoa	2,691	3,230	3,454	4,089
Dau Tieng	2,351	3,197	3,575	4,477
Tri An	6,194	8,018	8,782	10,797

According to the Design Standards for Hydraulic Works (TCVN 5060-90, 1990) in Viet Nam, spillways for the dams given in the above Table fall under the category of Grade-I structures which shall be designed based on the flood with a probability of 0.1 % (1,000-year probable flood).

On the other hand, studies on reservoir schemes have been made at various sites in the Dong Nai River basin, and some of them have been proceeded to the construction. Design discharge of spillway for these existing dams and those studied previously is collected as shown in Figure 3.21, however, the criteria and estimation method of these design values are not always known.

It is said that a relationship between peak discharge and basin area in a similar basin conditions would be expressed by the following Creager's empirical formula:

$$Q_p = C \cdot A^{(A^{-0.05})}$$

where

Q_p: peak discharge (m^3/s),

A : basin area (km^2), and

C : Creager's coefficient.

An attempt is made to estimate the Creager's coefficient (C) based on the spillway discharge data as shown in Figure 3.21. According to the result, the C-value is classified into three in the Study Area as follows:

C = 38 for the main Dong Nai and La Nga rivers,

C = 25 for the Be and Saigon rivers, and

C = 10 for the coastal rivers.

Comparing 1,000-year flood discharge estimated by the runoff model with that calculated by the Creager's coefficient obtained above, it is found that discharge estimated by the Creager's formula is larger than that by the runoff model. This may come from the difference of criteria and method applied for both methods, although collected data on spillway design discharge hardly tell detailed information.

The discharge calculated by the Creager's formula is at this moment decided to be applied for the design of spillway mainly due to the following reasons:

a) Discharge calculated from the Creager's coefficient would be of similar magnitude to that estimated for the existing and proposed dams in the Study Area, and is deemed to be acceptable for the application in the master plan study.

b) Further discussions to compare both the discharge calculations are substantially difficult, since detailed study data on the spillway design discharge are not available for the existing and previously proposed dams.

c) Flood discharge calculated by the runoff simulation model might not be appropriate at some sites in the upper reaches, since the model is calibrated based on the flood data collected in the downstream reaches.

The spillway design discharge for the proposed dams is thus estimated by Creager's formula as follows:

(Design Spillway Discharge)

Candidate dam	Basin area (km^2)	Creager's C	Design discharge (m^3/s)
(Main Dong Nai River)			
Dong Nai No. 1	3,802	38	8,923
Dong Nai No. 2	3,943	38	9,050
Dong Nai No. 3	4,361	38	9,408
Dong Nai No. 4	4,530	38	9,545
Dong Nai No. 5	6,196	38	10,725
Dong Nai No. 6	7,051	38	11,237
Dong Nai No. 8	9,822	38	12,617
(La Nga River)			
Bao Loc	1,150	38	5,389
La Nga No. 3	2,000	38	6,873
(Be R.)			
Can Don	3,440	25	5,645
Fu Mieng	4,410	25	6,216
Phuoc Hoa	5,765	25	6,872

It is noted runoff analysis for flood mitigation in the downstream areas is based on the flood simulation model.

3.5 Sedimentation

A sediment analysis is made to estimate the long-term sediment loads which would be deposited in the reservoir. In the southern part of Viet Nam, sediment samples are taken only for a fixed duration. For example, during JICA Study Team's visit to the Song Be provincial centre at So Sau, sediment samples were taken during the year of 1990 once in a day and were analyzed at the Southern Region Hydro-Meteorological Centre (Ho Chi Minh City). No continuous measurement is made for sediment samples.

In this master plan study, sediment data were obtained from the Ta Pao as well as Phu Dien gauging stations as presented in Tables 3.19 and 3.20. An annual sediment load of 273,964 ton/year is calculated from the sediment and daily discharge data made available for the Ta Pao station, resulting in a denudation rate of 0.114 mm/year.

The Consultant's past experience suggests that the denudation rate in the South-east Asia fall in a few millimeter a year. On the other hand, annual sediment desposition rates measured in the reservoir built in India Subcontinent as well as in the United States are presented in Figure 3.22 and Table 3.21 respectively for reference.

Based on the past experiences of the Consultant and considering the above-mentioned Figure and Table, in the master plan study, the denudation rate of 1.0 mm/year is used as the guideline figure.

3.6 Tides in Saigon Port and Sea

Tides at the river mouth are an important factor for the studies of drainage and salinity intrusion problems. Tide data are available at the Vung Tau port near the estuary of the Dong Nai River and at Saigon port (Phu An Station) in the Saigon River. In this section, basic features of the tide levels at the Vung Tau port and Saigon port are discussed.

3.6.1 Elevation Datum

Mean sea level at Mui Nai (Ha Tien) is referred to present the elevation. Three different elevation datums have been used in Viet Nam, i.e. datum at Hon Dau (Hai Phong), Mui Nai (Ha Tien) and Vung Tau. The Vung Tau datum is no longer used since the year 1944. Hon Dau datum has been used in the northern part of Viet Nam and Mui Nai datum in the southern part. According to the latest information, all the elevation datums over the country of Viet Nam are unified by Hon Dau (Hai Phong) datum since January, 1995. The relationship between Mui Nai and Hon Dau datums is as follows:

0 m, Mui Nai datum = -0.167 m, Hon Dau datum.

In the present study, mean sea level at Mui Nai (Ha Tien) is referred to as "MSL" to present the elevation, unless otherwise mentioned, since almost all the existing hydrological and topographic data in the Study Area are traditionally presented using the Mui Nai datum.

Regarding tide level data, the following datums have been used:

a) Gauge datum for water level observation:

0 m, Vung Tau gauge	= -2.72 m, MSL
0 m, Phu An gauge	= 0.00 m, MSL

b) Datum for tide table:

0 m, Vung Tau	= -2.42 m, MSL
0 m, Saigon port	= -2.59 m, MSL.

3.6.2 Statistical Features of Tides

To look over the tidal movement at Vung Tau and Phu An stations, predicted tides are illustrated in Figure 3.23 by selecting two months of February and March, 1995 when the field investigation for salinity intrusion was carried out. The maximum tidal range is about 3 m at Vung Tau station and about 2.5 m at Phu An station.

Statistical features of the tide at Vung Tau and Saigon Port are studied based on the tide table predicted for the years 1991 through 1995, since hourly tide records for a long time period are difficult to collect. According to the predicted tide table, monthly maximum and minimum tides are extracted as shown in Figure 3.24. Mean values of monthly maximum and minimum tide levels are shown below as a summary:

(Average Predicted Tide Level: 1991to1995)

Month	Vung Tau/Sea		Phu An/Saigon Port	
	Hmax (m, MSL)	Hmin (m, MSL)	Hmax (m, MSL)	Hmin (m, MSL)
January	1.54	-2.22	1.39	-1.67
February	1.40	-1.96	1.27	-1.45
March	1.40	-1.78	1.17	-1.27
April	1.34	-2.16	1.03	-1.63
May	1.32	-2.40	1.01	-1.91
June	1.22	-2.42	0.99	-2.09
July	1.04	-2.42	0.97	-2.05
August	1.00	-2.28	0.99	-1.77
September	1.20	-1.90	1.13	-1.33
October	1.46	-2.06	1.37	-1.35
November	1.64	-2.20	1.43	-1.51
December	1.66	-2.26	1.45	-1.65
Average (Jan-Dec)	1.35	-2.17	1.18	-1.64
Average (May-Nov)	1.27	-2.24	1.13	-1.72

Mean high (or low) water level (MHWL or MLWL) varies seasonally. The MHWL and MLWL are defined, in this study, as an average of monthly highest (or lowest) tide levels. The MHWL at Vung Tau varies for a range of 0.66 m seasonally from the maximum in December to the minimum in August, while the MHWL at Saigon port varies for a range of 0.48 m. On the other hand, seasonal variation of MLWL has two peaks in March and September and bottoms in June/July and December with an annual difference of 0.64 m at Vung Tau and 0.82 m at Saigon port. In the above Table, average values for a whole year and rainy 7 months (May to November) are also shown.

3.6.3 Comparison of Recorded and Predicted Hourly Tides

Hourly recorded tide and predicted one are compared throughout the year 1992. For the evaluation of recorded data, annual mean sea level is first worked out to be -0.08 m MSL for Vung Tau and +0.16 m MSL for Phu An/Saigon port based on the hourly records throughout the year 1992.

Difference between recorded and predicted tide levels is calculated, and the maximum, minimum, and average values are worked out on the monthly basis as shown in Figure 3.25. Averages of monthly maximum and minimum deviation from the predicted tide are +0.50 m and -0.45 m for Vung Tau and +0.68 m and -0.80 m for Phu An. Figure 3.25 further shows the correlation of the recorded and predicted tides at Vung Tau and Phu An stations by using data in February, 1992 as a sample.

Tides are generally predicted based on the astronomical movements. The meteorological effects are not generally incorporated since they are incidental. Recorded tides at Vung Tau and Phu

An stations are deemed to deviate mainly due to the meteorological effects such as atmospheric pressure, wind, rain and runoff. These effects prevail more at Phu An station located in HCMC about 75 km away from the sea along the Saigon River.

3.6.4 Tide Level and Duration

Tide level and its duration are studied based on the hourly observation records of the year 1992 at Vung Tau and Phu An (Saigon port) stations. Result of study is shown in Figure 3.26 and summarized below:

(Duration of Tides in 1992)

Elevation	Duration of tides			
	Vung Tau		Phu An	
(m, MSL)	(hr)	(%)	(hr)	(%)
3.0	0	0.0	0	0.0
2.0	0	0.0	0	0.0
1.5	2	0.0	0	0.0
1.0	449	5.1	725	8.3
0.5	2,593	29.5	3,726	42.4
0.0	4,942	56.3	5,702	64.9
Total	8,784	100.0	8,784	100.0

It is noted that duration of tides is defined as a total period in a year when tide level is higher than the specified elevation.

In the year 1992, water level of the Saigon River was higher than 1.0 m MSL for about 725 hours (8 % of the whole year) and 0.5 m MSL for about 3,726 hours (43 % of the whole year). The maximum and minimum tide levels records in the year 1992 were +1.52 m MSL and -2.80 m MSL respectively at Vung Tau station, and +1.40m MSL and -2.10 m MSL at Phu An (Saigon port) station.

4. INSTALLATION OF AUTOMATIC RAINFALL AND WATER LEVEL GAUGES

4.1 Introduction

In order to improve the hydro-meteorological networks in the Dong Nai River and surrounding river basins, it was decided during the Study period that three automatic water level gauges and seven automatic rainfall gauges would be installed in the Study Area. During the first field work, efforts were concentrated for the selection of sites and installation of automatic gauges.

4.2 Selection of the Sites

4.2.1 Water Level Gauges

Following nine sites were proposed by the Sub-institute for Water Resources Planning and the Study Team as the potential sites:

- Dong Nai No. 6 damsite,
- Dai Ninh damsite,
- Ta Lai gauging station,
- Song Luy gauging station,
- Song Ray River basin,
- An Vien (La Buong) gauging station,
- Ben Than gauging station,
- Tu Dau Mot gauging station, and
- Phuoc Hoa gauging station.

Main reasons for selecting the above potential sites were: a) manpower availability for operation and maintenance of the water level gauge and b) importance of the site itself as a potential site of future water resources development.

Cross-sections for most of the above sites were measured and the highest and lowest water levels were determined by interviewing local residents nearby each site. Morphology of river at the site, soil conditions and availability of man-power for the operation and maintenance of automatic gauges were also taken into account for selecting three sites.

An Vien, Ta Lai and Ben Than gauging stations were selected after careful considerations made by all parties concerned (refer to Figure 4.1). Main reasons for selecting the above sites were as follows:

a) Manpower: All the three sites have personnel already working on daily basis and they are trained in basic measurement of water level by staff gauge (for Ben Than, measurement is made at Thu Dau Mot station). It would be a heavy financial burden for the Vietnamese Government (most of which is now covered by provincial or sometimes district level authorities) to hire, assign and train staff for collection of water level records by staff gauge and for operation/maintenance of automatic gauge.

b) Already available data: All the three sites have already been operating as a hydrological station (for both rainfall and water level), and data have been collected for several years. By installing automatic gauges, reliability of data collected by these stations would be improved and would be able to utilize in the near future.

c) Scatterness and importance of three new sites: All the three sites are located in the key area for water resources development in the Study Area in the near future. Ta Lai station is located in the mainstream of the Dong Nai River possessing the potential of hydropower development. Ben Than gauging station, located downstream of the Saigon River, is considered as a key station for salinity intrusion simulation study and water supply programme for HCMC and its vicinities. Detailed and reliable water level data are crucial for accurate forecasting and water demand/supply analysis, even if a rating curve to estimate runoff is not well established due to tidal effects. An Vien located in the La Buong River basin holds a key for the water supply to the economic triangle zone of HCMC-Vung Tau-Bien Hoa.

Installation of these three water level stations commenced in December 1994 and completed at the beginning of March 1995. Installed water level stations are presented in Figure 4.2.

4.2.2 Rainfall Gauges

Potential sites for the installation of automatic rain gauges were proposed to eliminate the areas where little rainfall data are available. Following 12 sites were proposed as the potential ones to install automatic rainfall gauges:

1. Cat Tien People's Committee,
2. Ngoc Son (Phu Son district People's Committee),
3. Dai Ninh damsite,
4. Tuy Phong (Forest Protection/Control Office),
5. Ta Lai gauging station,
6. Song Luy gauging station,
7. An Vien gauging station,
8. Xuan Loc (Gra Ray People's Committee),
9. Katum People's Committee,
10. Kien Duc People's Committee,
11. Ben Than gauging station, and
12. Phuoc Hoa gauging station.

In deciding the location of automatic rainfall gauges, factors such as availability of man-power for the operation and maintenance of automatic gauges, protection of gauges from theft and scatterness of rainfall station within the Study Area were taken into account. Consequently, the following seven sites have been selected (refer to Figure 4.1):

1. Ngoc Son (Phu Son district People's Committee),
2. Dai Ninh damsite,
3. Song Luy gauging station,
4. An Vien gauging station,
5. Ben Than gauging station,
6. Katum gauging station, and
7. Kien Duc gauging station.

Furthermore, it should be mentioned in selecting the sites for automatic gauges that above points considered have been discussed and agreed among the then Ministry of Water Resources, Hydro-meteorological Service of Viet Nam in Hanoi (Deputy Director General), Southern Regional Hydro-Meteorological Centre of HCMC (Director) and provincial hydro-meteorological centres of concerned provinces. Agreements have been obtained from the People's Committee of provinces concerned.

Installation of those seven rain gauges commenced in December 1994 and completed at the beginning of March 1995. Installed rainfall stations are presented in Figure 4.3.

TABLES

Table 2.1 Inventory of Rainfall Gauges (1/2)

No.	Name of Station	Coordinates	Years	Observation Period (year)
1	AN LOC	107.10 East 11.00 North	52	1915-1944; 1949-1974
2	BAO LOC	107.12 East 10.56 North	54	1929; 1933-1944, 1950-1992
3	BEN CAT	106.35 East 11.09 North	31	1928-1941; 1952-1964; 1980-1992
4	BEN CUI	106.20 East 11.16 North	35	1927-1944; 1950-1966; 1973-1974
5	BEN LUC	106.29 East 10.38 North	10	1982-1992
6	BIEN HOA	106.49 East 10.57 North	64	1907-1944; 1958-1992
7	BINH BA	107.14 East 10.37 North	60	1926-1944; 1946-1974; 1978-1992
8	BINH LONG	106.36 East 11.38 North	59	1914-1916, 1920-1943, 1955-1956, 1960-1974, 1977-1992
9	BOBLA	108.01 East 11.35 North	27	1931-1944; 1957-1968; 1977-1992
10	BU DANG	107.16 East 11.46 North	4	1979-1981, 1984-1985
11	CA NA	108.47 East 11.18 North	24	1939-1944; 1953-1968; 1977-1979; 1984-1992
12	CAM TAM	107.09 East 10.51 North (185 m)	45	1926-1944; 1948-1974
13	CAN DANG	106.00 East 11.30 North	14	1977-1992
14	CAN GIO	106.59 East 10.24 North	11	1978-1992
15	CAT TIEN	107.28 East 11.30 North	7	1985-1992
16	CON SON	Con Son island	51	1907-1908; 1933-1939; 1948-1992
17	DA LAT	108.26 East 11.57 North	61	1910-1911; 1918; 1921-1944; 1954-1974; 1977-1992
18	DA TEH	107.32 East 11.32 North	8	1979; 1982-1992
19	DAI NGA	107.52 East 11.32 North (800 m)	15	(1961-1972; Da Ampi), 1973-1974; 1978-1992
20	DAM' RONG	107.50 East 11.31 North (800 m)	18	1957-1974; 1987
21	DAU GIAY	107.03 East 10.56 North	52	1920-1944; 1948-1974
22	DAU TIENG	106.20 East 11.18 North	52	1927-1944; 1951-1992
23	DI LINH	108.05 East 11.35 North	51	1907-1907; 1911; 1928-1944; 1950-1974; 1978-1992
24	DJIRAMOUR	107.57 East 11.32 North (800 m)	28	1933-1943; 1957-1974
25	DJIRATO	107.58 East 11.33 North (800 m)	11	1960-1970
26	DON DUONG	108.35 East 11.50 North	26	1949-1973; 1984-1986
27	DONG ME	108.52 East 11.40 North	10	1960-1974
28	DONG MOI	108.25 East 11.12 North	19	1959-1963
29	DONG PHU	106.54 East 11.32 North	10	1980; 1984-1992
30	GO DAU	106.16 East 11.02 North	9	1979-1992
31	HAM TAN	107.45 East 10.41 North	43	1927-1941; 1959-1974; 1978-1992
32	HOC MON	106.36 East 10.53 North	14	1977-1992
33	LA BUONG	107.02 East 10.52 North	12	1978-1992
34	LIEN KHUONG	108.23 East 11.45 North	37	1949-1974; 1978-1992
35	LOC NINH (SB)	106.35 East 11.49 North (760 m)	51	1912-1943; 1963-1971; 1979-1992
36	LOC NINH (TN)	106.15 East 11.25 North (760 m)	8	1976-1983
37	LONG THANH	106.56 East 10.45 North	51	1929-1944; 1949-1975; 1985-1992
38	MADAGUI	107.32 East 11.23 North	13	1978-1992
39	MINH RONG	107.49 East 11.36 North (850m)	23	1952-1975
40	MOC HOA	105.56 East 10.47 North	34	1959-1974, 1977-1980, 1982-1993
41	NHA BE	106.44 East 10.40 North	16	1960-1968; 1979-1992
42	NHA HO	108.54 East 11.40 North	13	1961-1967; 1980-1992
43	PHAN LY CHAM	108.31 East 11.13 North	28	1928-1941; 1960-1974; 1979

Table 2.1 Inventory of Rainfall Gauges (2/2)

No.	Name of Station	Coordinates	Years	Observation Period (year)
44	PHAN RANG	109.00 East 11.40 North	47	1927-1944; 1958-1974; 1979-1992
45	PHAN THIET	108.06 East 10.56 North	51	1925-1943; 1957-1974; 1976-1992
46	PHU DIEN	107.07 East 11.04 North	7	1987-1992
47	PHU HIEP	108.30 East 11.43 North	49	1928-1944; 1950-1972; 1978; 1982-1992
48	PHUOC HOA	106.46 East 11.14 North	13	1976-1992
49	PHUOC LE	107.10 East 10.29 North	54	1914-1944; 1960-1970; 1978-1992
50	PHUOC LONG	106.59 East 11.50 North	34	1978-1992
51	SO SAO	106.39 East 11.02 North	63	1914-1944; 1959-1973; 1977-1983
52	SONG LUY	108.21 East 11.12 North	16	1963; 1978-1992
53	SONG MAO	108.30 East 11.15 North	15	1961-1966; 1972; 1984-1992
54	SONG PHA	108.41 East 11.50 North	13	1962; 1965-1966; 1974-1982; 1992
55	SUOI VANG	108.22 East 11.59 North	7	1979-1985
56	TA LAI	107.22 East 11.22 North	10	1978-1980; 1985-1992
57	TA PAO	107.43 East 11.08 North	18	1976-1992
58	TAN AN	105.25 East 10.32 North	57	1911-1930, 1954-1973, 1977-1992
59	TAN MY	108.49 East 11.23 North	14	1978-1992
60	TAN RAI	107.51 East 11.43 North	9	1978-1992
61	TAN SON NHAT	106.42 East 10.47 North	78	1907-1944; 1947-1992
62	TAN UYEN	106.48 East 11.03 North	10	1981-1992
63	TAY NINH	106.10 East 11.01 North	55	1913-1641; 1959-1974; 1978-1992
64	THAC CAN	108.17 East 11.42 North	12	1978-1992
65	THANH BINH	108.18 East 11.47 North	11	1978-1992
66	THONG NHAT	107.02 East 10.57 North	40	1928-1941; 1958-1968; 1978-1992
67	THU DUC	106.45 East 10.50 North	25	1963-1974; 1977-1992
68	THUAN LOI	106.52 East 11.30 North	27	1930-1944; 1951-1964
69	TRANG BOM	107.00 East 10.57 North	39	1928-39,41,1958-68, 1978-1992
70	TRI AN	107.05 East 11.05 North	45	1928-1944; 1948-1965; 1978-1992
71	TUC TRUNG	107.12 East 11.05 North	52	1929-1944; 1948-1974; 1978-1992
72	VO XU	107.37 East 11.10 North	3	1984-1987
73	VUNG TAU	107.05 East 10.20 North	80	1907-1944; 1949-1992
74	XUAN LOC	107.14 East 10.51 North	41	1931-1941; 1948-1973; 1978-1992

Note Bound: Following stations are located at the same site with differerent name by different regime

So Sao=Binh Duong = Thu Dau Mot = Phu Cuong

An Loc = Binh Loc

Binh Long = Chon Thanh (106.37'E - 11.24'N)

Da Ampi = Dai Nga

Table 2.2 Inventory of Climate Stations in the Study Area

No	STATION NAME	PROVINCE	ELEMENT	OBSERVED DURATION	TOTAL	30 40 50 60 70 80 90
1	DA LAT	LAM DONG	T,E,H,W,S	1928-1932,1961-1971,1978-1990	14	
2	BAO LOC	LAM DONG	T,E,H,W,S	1928-1943,1961-1971,1978-1990	50	
3	LIEN KHUONG	LAM DONG	T,E,H,W,S	1949-1971,1980-1990	33	
4	DI LINH	LAM DONG	T,E,H,W,S	1928-1943	6	
5	NHA HO	NINH THUAN	T,E,H,W,S	1961-1966	6	
6	PHAN THIET	BINH THUAN	T,E,H,W,S	1931-1940,1957-1971,1978-1990	38	
7	HAM TAN	BINH THUAN	T,E,H,W,S	1980-1990	11	
8	VUNG TAU	BA RIA-V.T.	T,E,H,W,S	1930-1943,1957-1971,1978-1990	42	
9	XUAN LOC	DONG NAI	T,E,H,W	1934-1937,1959-1971,1978-1990	29	
10	BIEN HOA	DONG NAI	T,E,H,W,S	1962-1964,1978-1990	16	
11	THANH TUY HA	DONG NAI	T,E,H,W,S	1986-1990	5	
12	TAN SON NHAT	HCMC	T,E,H,W,S	1950-1971,1976-1990	36	
13	PHUOC LONG	SONG BE	T,E,H,W,S	1961-1967,1978-1990	18	
14	DONG XOAI	SONG BE	T,E,H,W	1979-1980	3	
15	THU DAU MOT	SONG BE	T,E,H,W,S	1980-1990	11	
16	LOC NINH	SONG BE	T,E,H,W	1963-1971,1980-1990	19	
17	DAU TIENG	TAY NINH	T,E,H,W,S	1962-1968,1978-1990	20	
18	TAY NINH	TAY NINH	T,E,H,W,S	1978-1990	13	
19	HIEP HOA	LONG AN	T,E,H,W,S	1961-1971	11	
20	MY THO	TIEN GIANG	T,E,H,W,S	1962-1971,1978-1990	23	

Note: +T: TEMPRETURE +E: EVAPORATION +H: HUMIDITY +W: WIN +S: SUNSHINE HOURS

Table 2.3 Annual Rainfall Records for 36 Representative Stations

No	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	Bao Loc	60.3	48.9	109.0	186.0	235.4	310.3	419.0	463.0	411.9	313.5	168.8	79.3	2,805.6
2	Bien Hoa	6.0	5.1	13.1	49.6	165.8	231.8	280.9	273.1	291.7	235.3	96.5	27.8	1,676.6
3	Binh Ba	4.0	0.6	6.3	37.4	228.1	295.3	346.4	320.5	338.8	239.3	87.0	28.0	1,931.6
4	Binh Long	9.6	3.1	24.6	88.9	206.8	262.7	311.9	343.0	390.4	260.5	100.2	21.7	2,023.5
5	Bu Dang	1.9	2.7	11.0	120.4	299.1	390.0	270.2	332.8	288.0	356.1	161.9	24.0	2,258.1
6	Da Teh	1.6	1.2	37.8	131.7	278.1	419.6	459.4	627.2	348.4	344.8	178.0	51.8	2,879.6
7	Da Lat	7.7	18.7	59.5	163.3	209.1	190.8	232.7	236.6	305.4	250.3	91.7	26.0	1,791.9
8	Dau Giay	16.1	11.7	26.1	84.6	222.9	305.3	355.4	360.7	391.2	292.3	104.0	42.5	2,212.5
9	Dau Tieng	12.1	8.1	25.9	96.8	230.0	251.4	301.5	290.0	350.1	301.2	130.0	40.6	2,037.8
10	Di Linh	20.7	24.2	53.4	130.5	195.3	236.6	272.4	286.7	307.1	249.8	92.7	39.8	1,909.3
11	Dong Phu	11.8	6.3	23.6	139.1	262.0	361.9	330.1	459.5	451.0	357.6	121.7	11.3	2,535.8
12	Dran	12.2	6.9	20.9	62.6	212.9	170.0	161.1	191.8	297.9	321.3	160.0	61.8	1,679.4
13	Go Dau Ha	8.9	4.6	22.7	80.0	189.0	190.7	204.9	171.6	283.2	490.5	131.3	24.5	1,801.8
14	Ham Tan	0.2	1.0	6.8	39.0	190.6	231.3	299.7	269.2	285.0	208.9	53.3	11.9	1,597.0
15	Lien Khuong	5.1	19.0	48.5	114.4	229.5	180.6	202.9	193.2	282.4	233.3	77.8	23.7	1,610.3
16	Loc Ninh	8.5	11.7	28.2	103.3	239.0	298.8	335.9	364.6	390.9	278.9	96.6	32.1	2,188.6
17	Long Thanh	15.3	6.6	14.7	64.6	219.1	287.9	326.2	299.5	351.1	276.6	107.9	42.8	2,012.4
18	Moc Hoa	10.2	3.6	13.1	52.4	188.2	175.8	192.1	177.2	250.4	300.9	136.6	34.3	1,534.7
19	Nha Ho	8.8	2.3	6.4	22.3	93.5	55.8	67.9	63.7	142.1	135.0	106.3	79.4	783.7
20	Phan Ly Cham	2.2	0.4	1.0	22.0	115.7	81.2	78.0	69.3	123.6	132.9	50.7	19.1	696.1
21	Phan Rang	5.9	1.1	6.3	14.2	58.3	48.7	41.0	46.1	127.8	163.4	147.9	55.3	716.2
22	Phan Thiet	0.9	0.4	5.1	29.5	139.7	149.2	175.4	173.4	196.3	181.7	51.0	13.0	1,115.7
23	Phuoc Hoa	3.3	6.6	22.0	70.1	189.5	303.9	294.9	353.4	357.0	243.3	118.8	17.5	1,980.2
24	Phuoc Le	1.3	1.1	7.3	27.9	177.0	260.4	294.2	252.0	275.4	216.8	67.7	21.4	1,602.4
25	Phuoc Long	10.1	10.6	31.8	111.2	260.5	338.4	407.5	379.4	385.5	295.8	126.2	36.2	2,393.3
26	So Sao	13.9	2.3	22.1	47.4	216.9	273.9	285.3	284.7	322.8	245.7	125.4	41.7	1,882.3
27	Ta Pao	6.3	5.5	28.5	53.8	223.8	401.4	443.3	537.6	354.6	236.4	78.4	19.2	2,388.8
28	Tan An	6.9	2.2	7.1	35.2	169.1	219.7	201.0	186.0	238.1	247.9	126.5	39.1	1,437.6
29	Tan My	1.6	2.9	21.6	30.5	94.5	101.6	108.7	110.6	182.6	191.3	142.7	32.6	1,021.2
30	Tan Son Nhat	13.1	4.3	11.3	49.6	211.0	309.8	295.8	270.8	331.3	270.9	116.6	47.9	1,932.2
31	Tay Ninh	6.0	5.1	26.6	80.9	204.4	234.7	247.2	220.9	323.1	296.6	127.3	34.1	1,806.8
32	Thac Can	3.1	13.6	28.3	69.4	152.6	197.0	193.3	225.9	264.6	193.0	93.3	9.2	1,443.1
33	Trang Bom	10.2	6.6	17.9	72.2	226.0	278.8	317.0	333.0	379.8	269.5	111.0	33.8	2,055.9
34	Tuc Trung	12.5	11.6	39.3	91.4	244.3	299.1	383.9	377.8	396.3	313.8	115.6	40.2	2,325.8
35	Vung Tau	1.9	1.0	5.0	34.1	192.6	209.6	218.5	186.0	216.7	215.8	68.6	20.8	1,370.7
36	Xuan Loc	10.2	13.8	20.8	83.3	229.1	280.8	337.6	376.8	366.2	322.6	108.6	29.6	2,179.4

Table 2.4 Mean Monthly Air Temperature

Unit: °C

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
Bao Loc	20.1	20.9	22.2	23.0	23.2	22.7	22.2	22.0	22.0	21.8	21.1	19.9	21.7
Bien Hoa	23.5	26.6	28.1	29.0	28.6	27.3	26.9	26.7	26.7	26.3	25.9	25.0	26.7
Di Linh	15.8	16.7	18.0	18.9	19.4	19.0	18.7	18.5	18.4	18.0	17.2	15.9	17.9
Dong Xoai	24.5	25.9	27.8	28.1	27.4	26.8	26.1	26	25.8	25	25	23.7	26.0
Lien Khuong	19.5	20.5	21.6	22.7	22.8	22.1	21.7	21.7	21.4	21.0	20.3	19.4	21.2
Loc Ninh	24.5	25.7	27.5	27.7	26.6	26.5	25.7	25.7	25.8	24.9	24.8	23.3	25.7
Phuoc Long	24.1	25.1	26.7	27.5	27.0	25.9	25.3	25.2	25.0	24.8	24.4	23.4	25.4
Phan Thiet	25.1	25.3	26.6	28.4	28.8	27.8	27.2	27.1	26.9	27.1	26.4	25.1	26.8
Tay Ninh	25.8	26.5	27.9	29.0	28.2	27.3	26.9	26.9	26.6	26.3	25.9	25.1	26.8
Thanh Tuy Ha	25.1	25.6	27.3	28.8	28.2	26.9	26.7	26.4	26.3	26.2	25.7	24.5	26.5
Tan Son Hoa	26.2	26.8	28.1	29.3	29.1	27.8	27.4	27.3	27.1	27.0	26.5	25.9	27.4
Vung Tau	25.6	25.8	27.0	28.7	28.9	28.1	27.7	27.5	27.2	27.2	26.6	25.6	27.1
Xuan Loc	24.9	25.7	26.7	28.1	27.8	25.9	25.6	25.5	25.6	25.1	24.7	24.4	25.8
Average	23.4	24.4	25.8	26.9	26.6	25.7	25.2	25.1	25.0	24.7	24.2	23.2	25.0