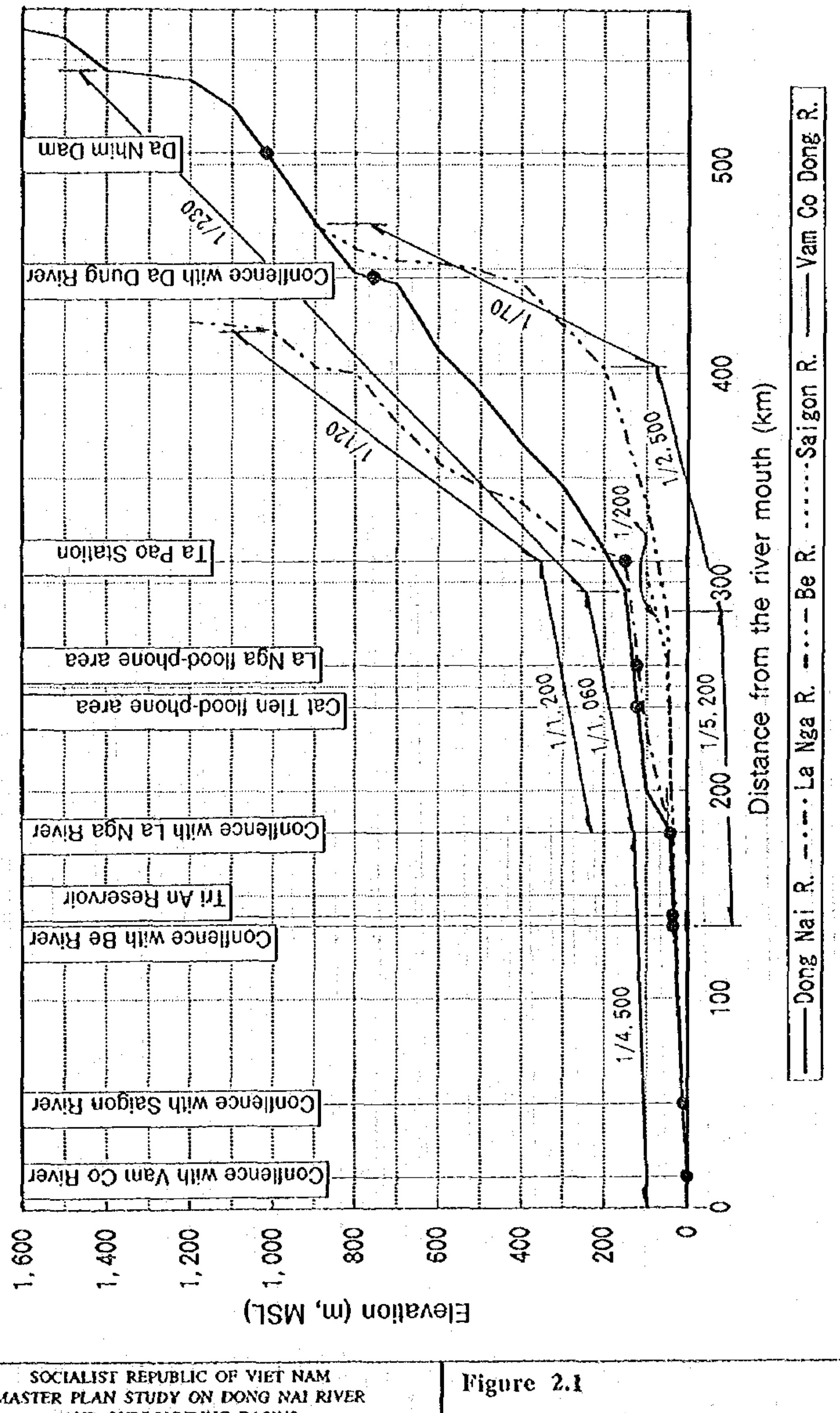
FIGURES



SOCIALIST REPUBLIC OF VIET NAM *MASTER PLAN STUDY ON DONG NAI RIVER* AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 2.1** **Overall Longitudinal Profile of the Dong Nai River System**

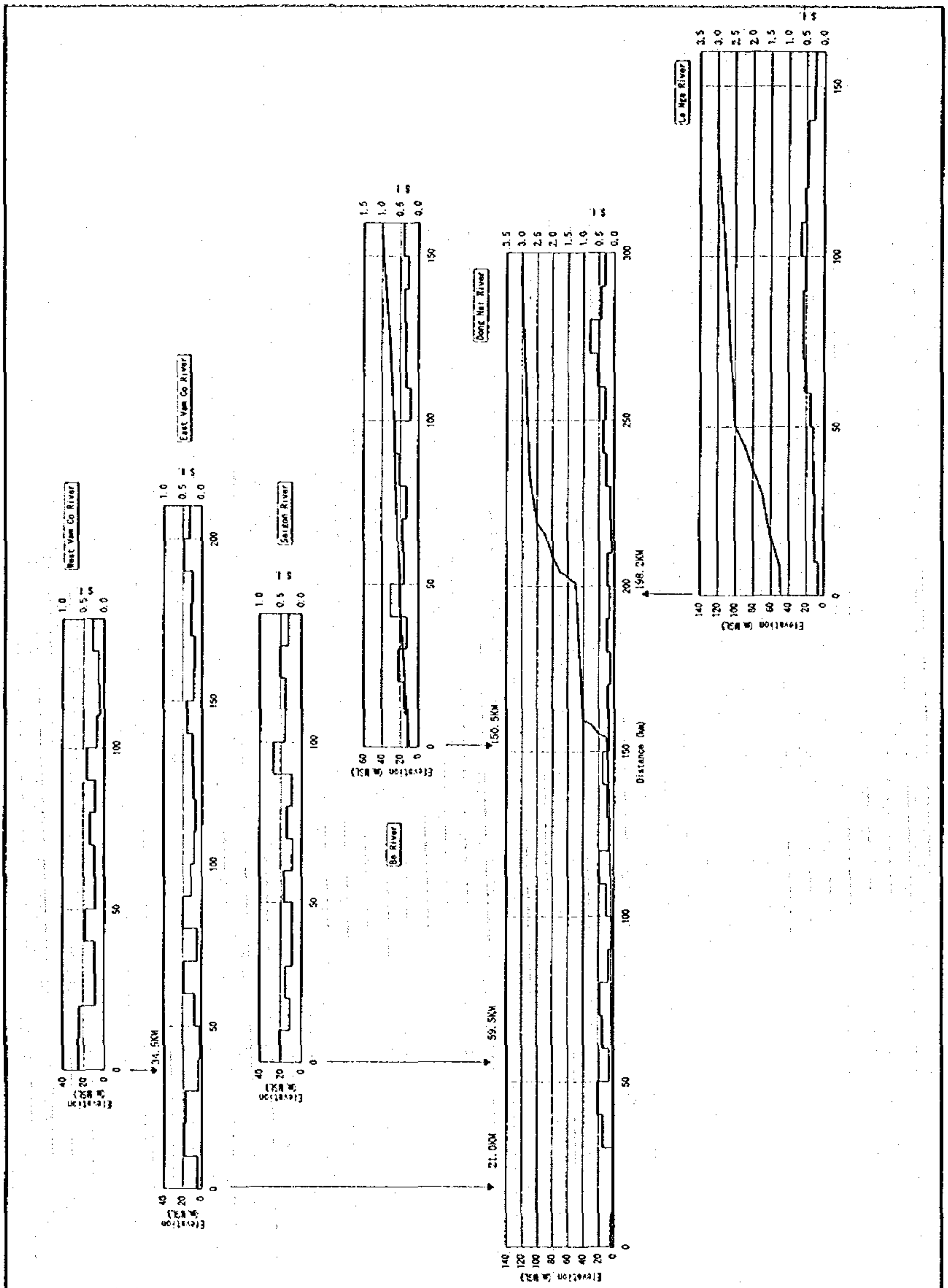


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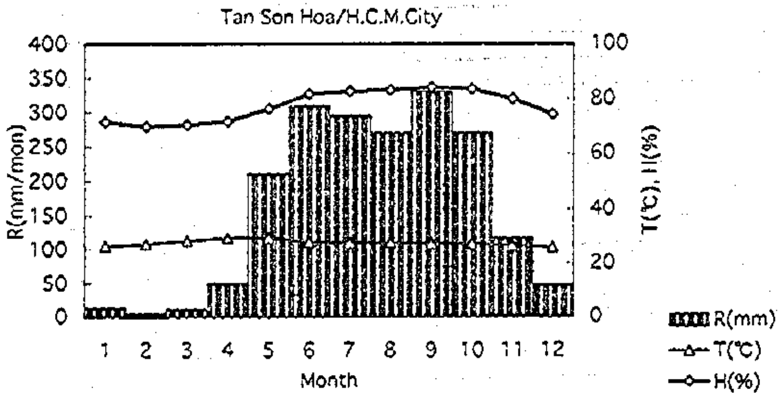
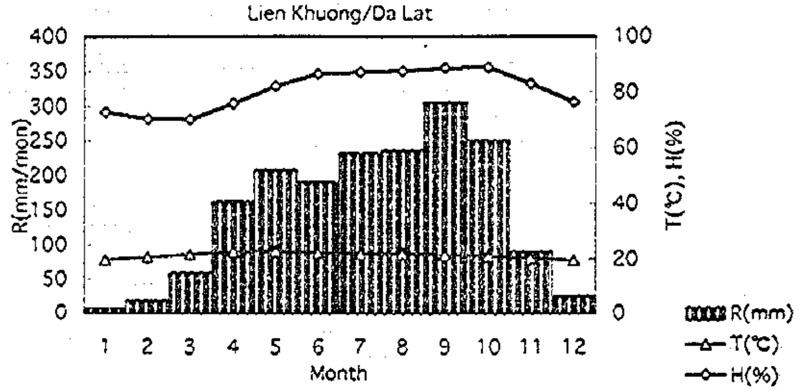
Figure 2.2

Channel Slope and Sinuosity Index of the Rivers in the Study Area





	Tan Son Hoa/H.C.M.City			Lien Khuong/Da Lat		
Month	R(mm)	T(℃)	H(%)	R(mm)	T(℃)	H(%)
Jan	13.1	26.2	71.5	7.7	19.5	72.8
Feb	4.3	26.8	69.8	18.7	20.5	70.4
Mar	11.3	28.1	70.3	59.5	21.6	70.2
Apr	49.6	29.3	71.6	163.3	22.7	75.9
May	211.0	29.1	76.3	209.1	22.8	82.2
Jun	309.8	27.8	81.8	190.8	22.1	86.5
Jul	295.8	27.4	82.7	232.7	21.7	87.2
Aug	270.8	27.3	83.2	236.6	21.7	87.5
Sep	331.3	27.1	84.3	305.4	21.4	88.5
Oct	270.9	27.0	83.7	250.3	21.0	88.7
Nov	116.6	26.5	80.1	91.7	20.3	82.9
Dec	47.9	25.9	74.3	26.0	19.4	76.4
Total	1932.4	-	-	1791.8	-	-
Mean	-	27.4	77.5	-	21.2	80.8

(Remarks)
R: Monthly rainfall
T: Air temperature
H: Relative humidity

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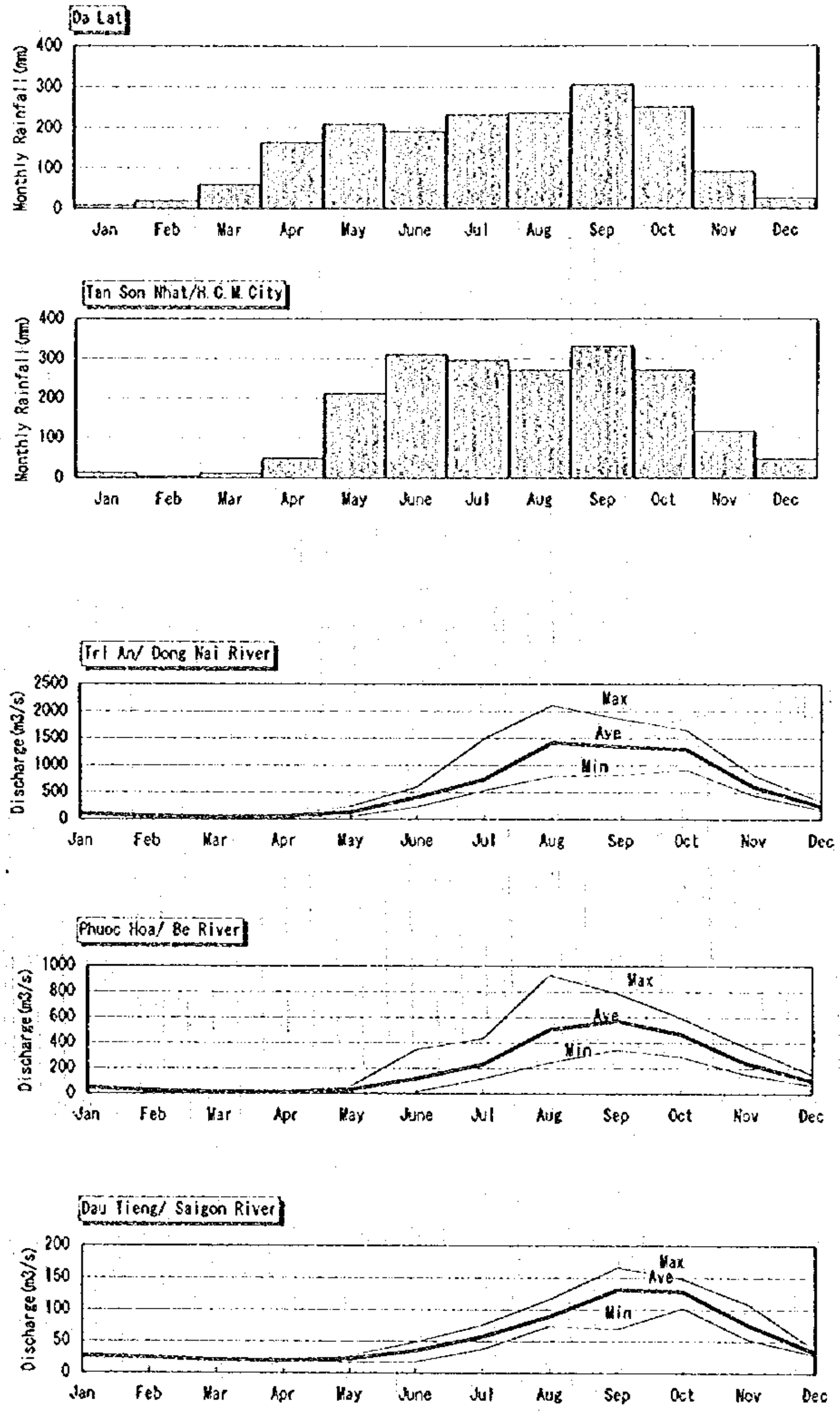
Figure 2.3

Climatic Conditions at Tan Son Hoa and Lien Khuong Stations



Monthly Rainfall and Runoff

SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 2.4** **Monthly Rainfall and Runoff Characteristics in the Dong Nai River Basin**

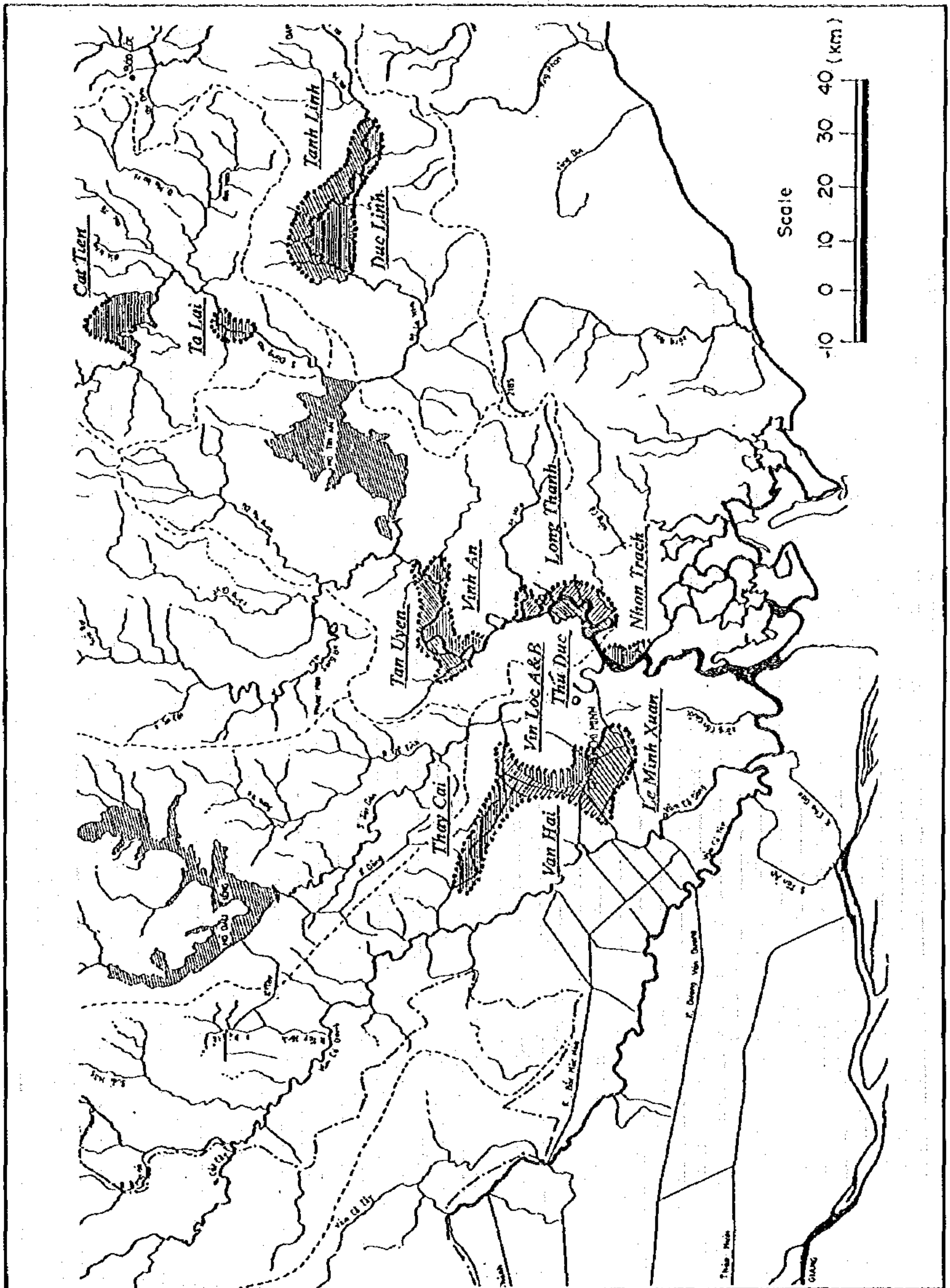


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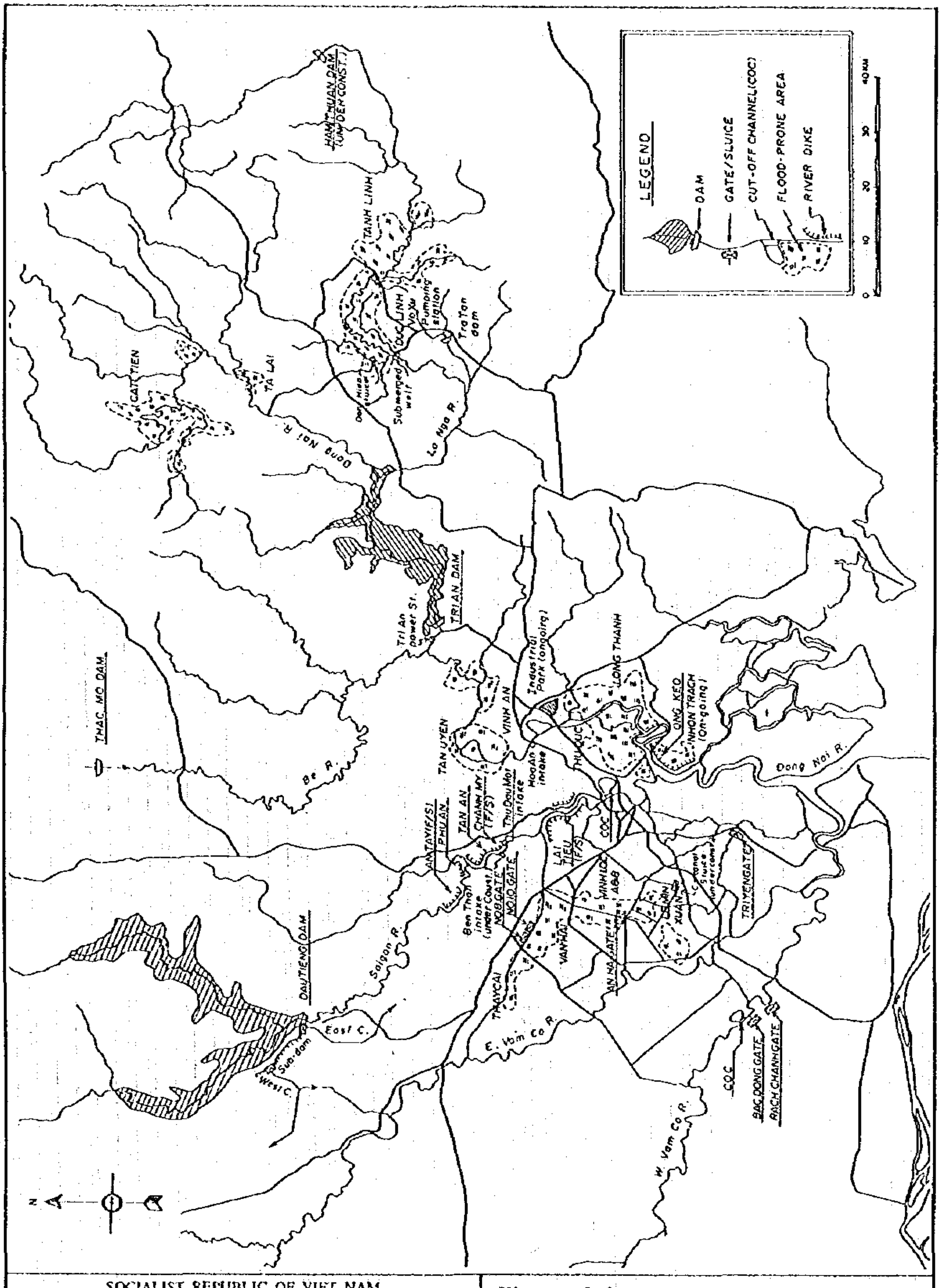
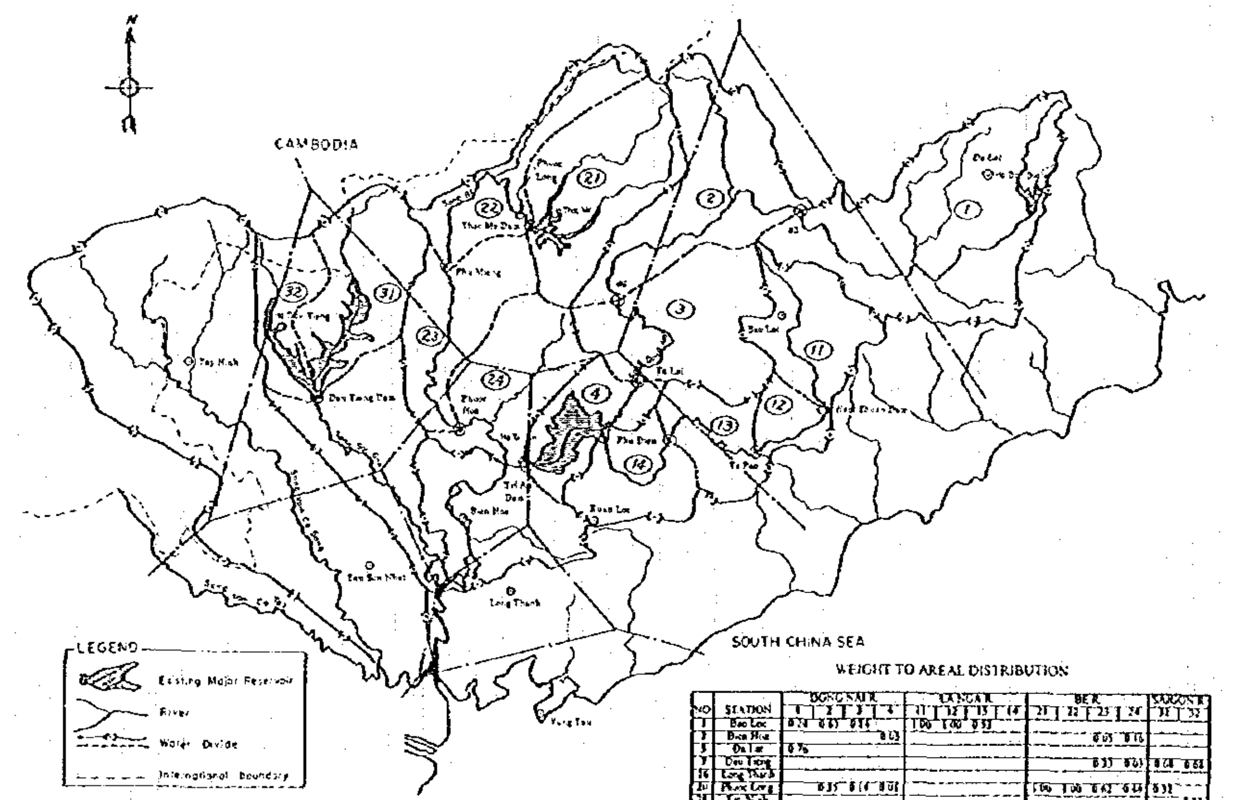
Figure 2.5

Flood-Prone Areas 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 2.6** **Existing River Facilities in the Dong Nai River Basin**



WEIGHT TO AREAL DISTRIBUTION

NO	STATION	DONG NAI R. 1	2	3	4	LA NGA R. 11	12	13	14	BE R. 21	22	23	24	SAIGON R. 31	32
1	Bao Loc	0.24	0.63	0.15		1.00	1.00	0.93							
2	Bien Hoa				0.03							0.05	0.16		
5	Da Lat	0.76													
7	Dau Tieng											0.33	0.61	0.68	0.68
16	Long Thanh														
20	Phuoc Long		0.35	0.14	0.01					1.00	1.00	0.62	0.46	0.32	
24	Tay Ninh														0.32
31	Tan Son Nhat														
33	Vung Tau														
34	Xuan Loc			0.71	0.96			0.07	1.00				0.87		
	TOTAL	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

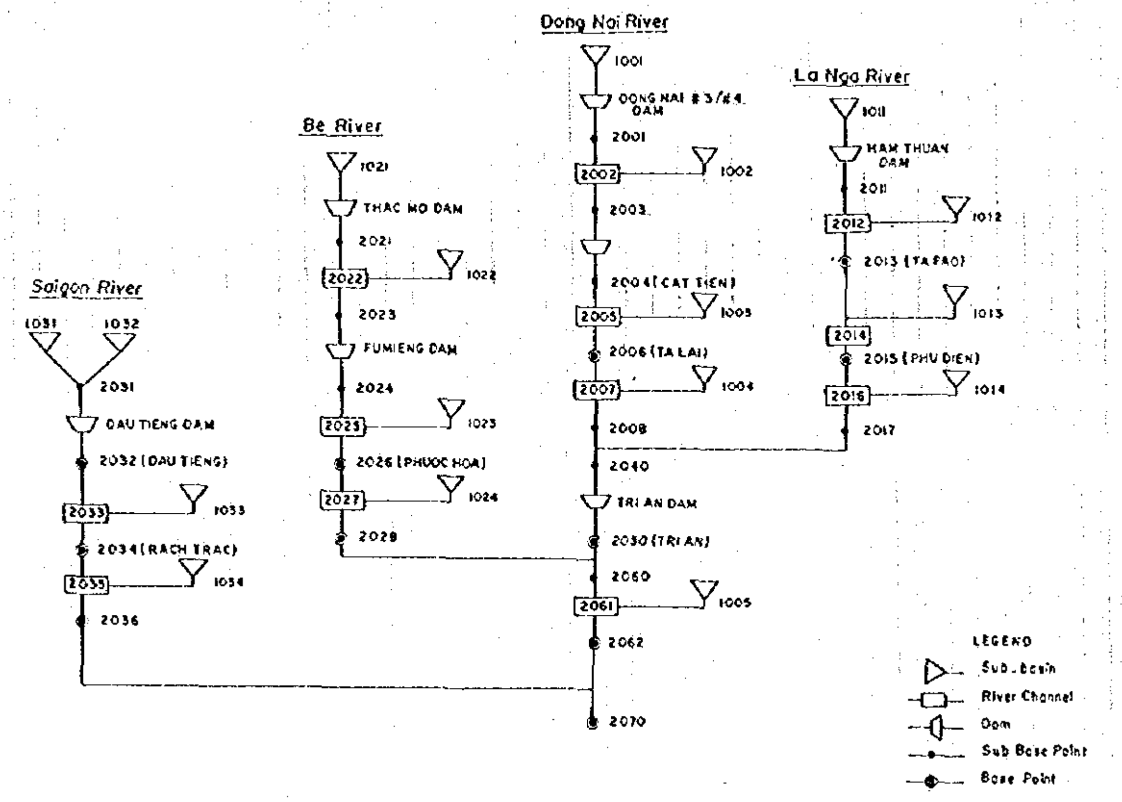


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Figure 3.1

Basin Boundary and Runoff System

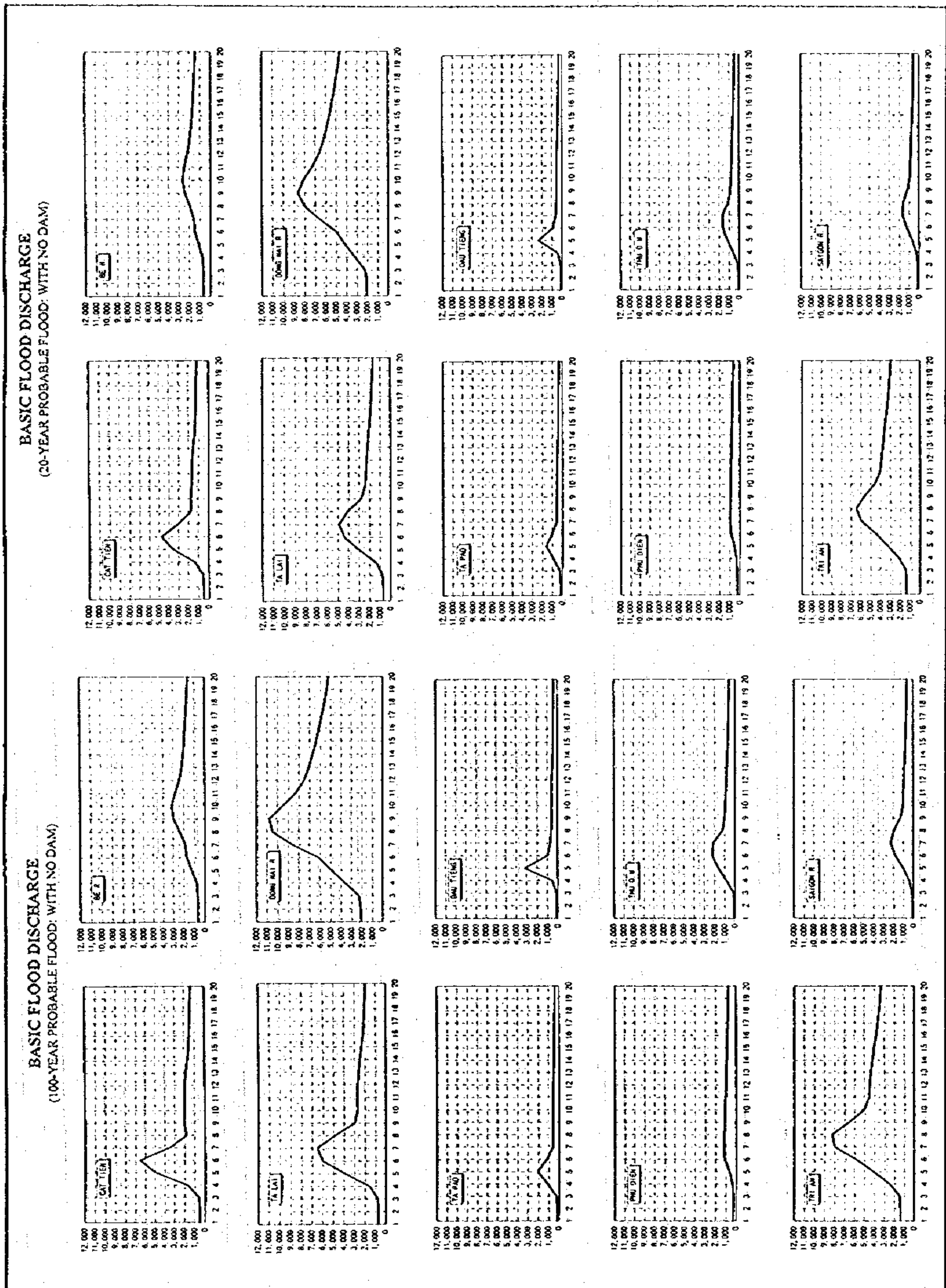

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Figure 3.2

Basic Flood Discharge

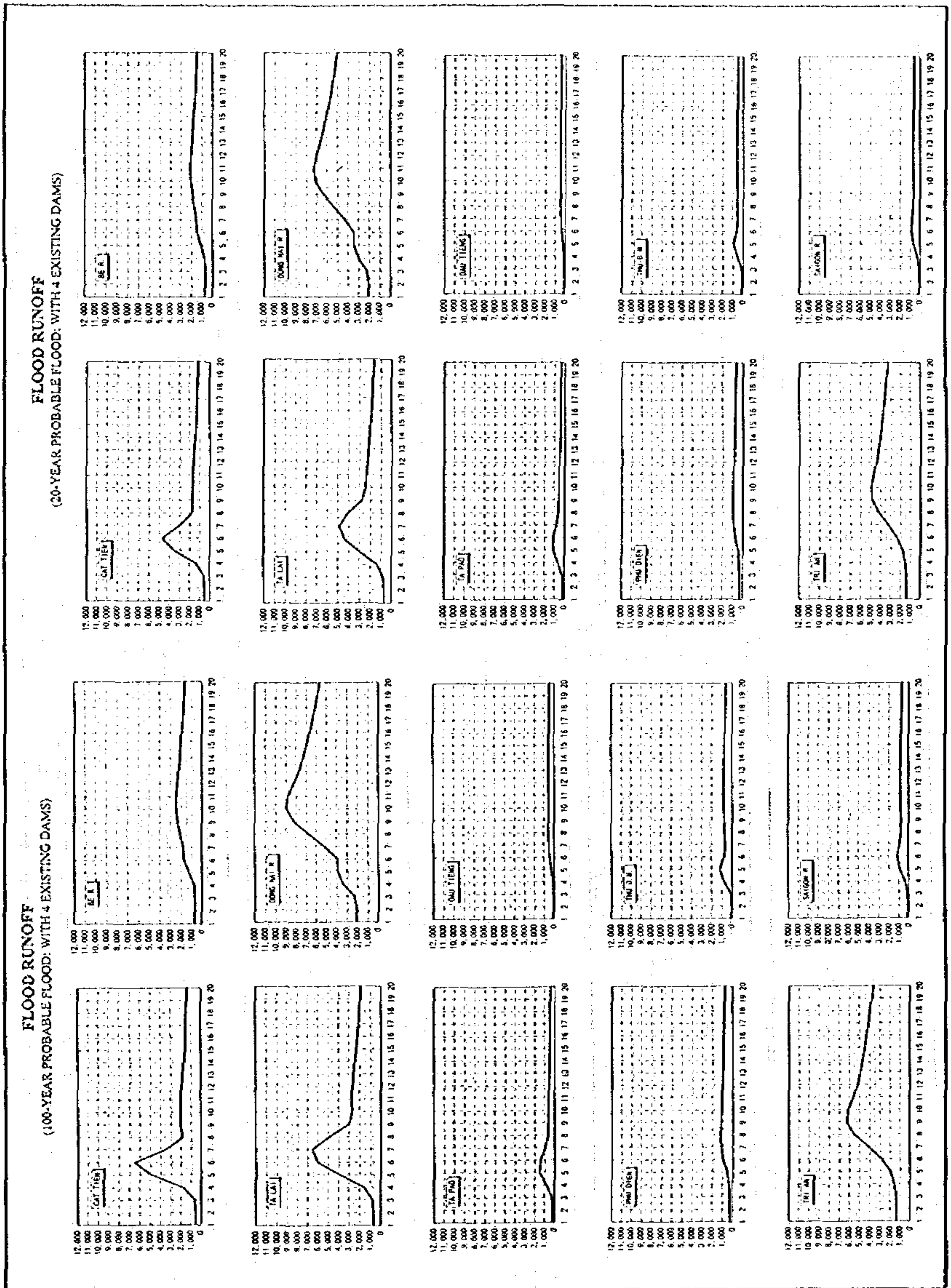

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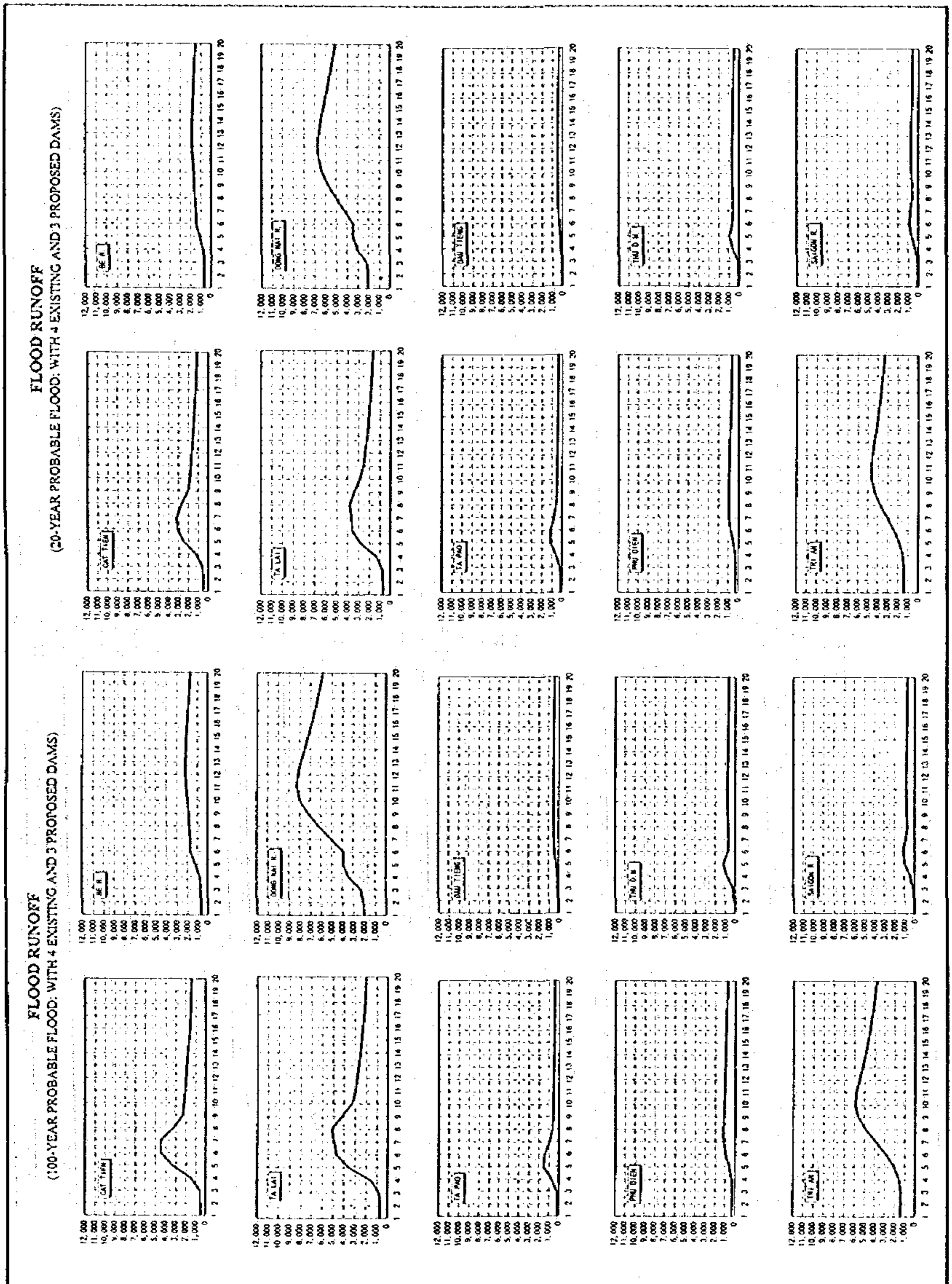
Figure 3.3

Flood Runoff with Existing Four Reservoirs



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** **Flood Runoff with Existing and Proposed Seven Reservoirs**

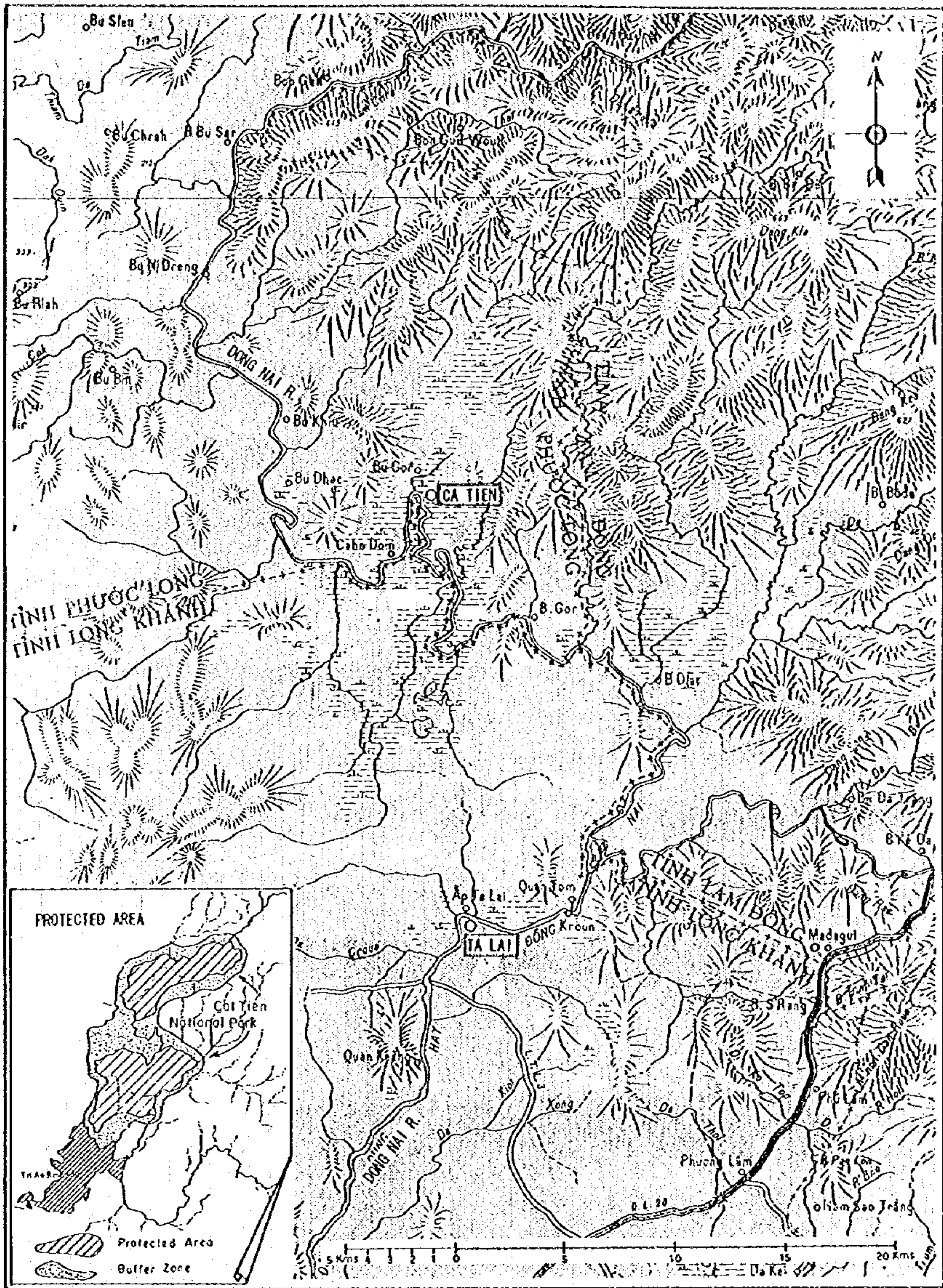


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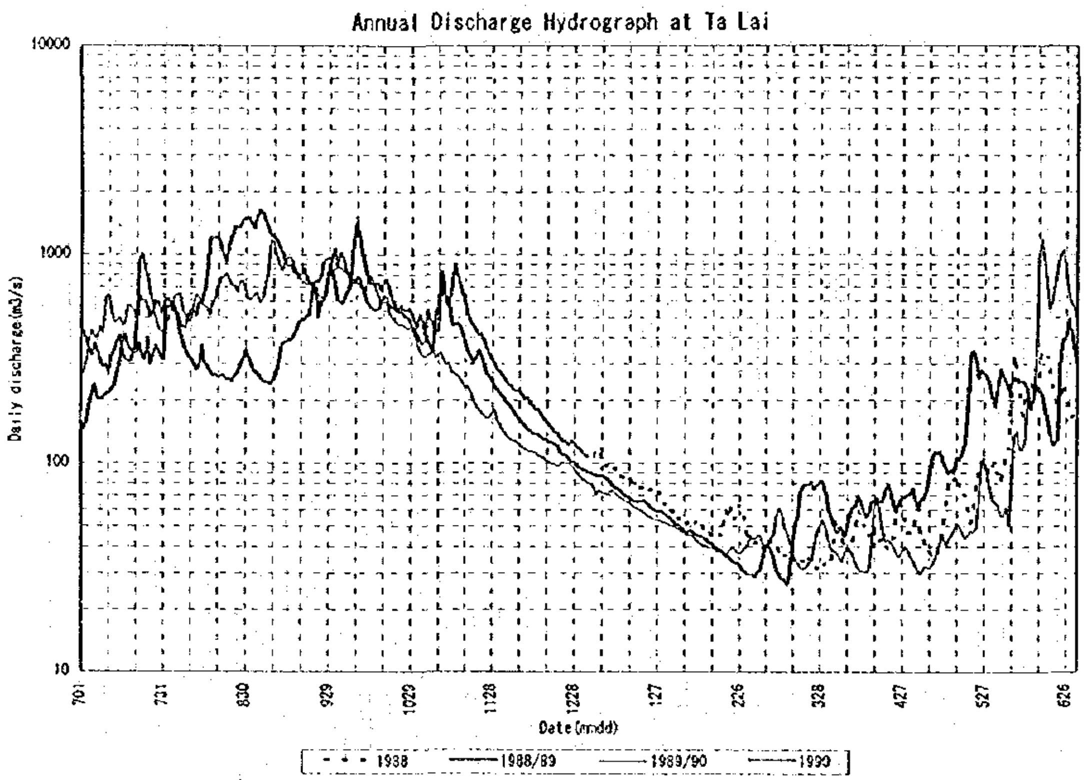
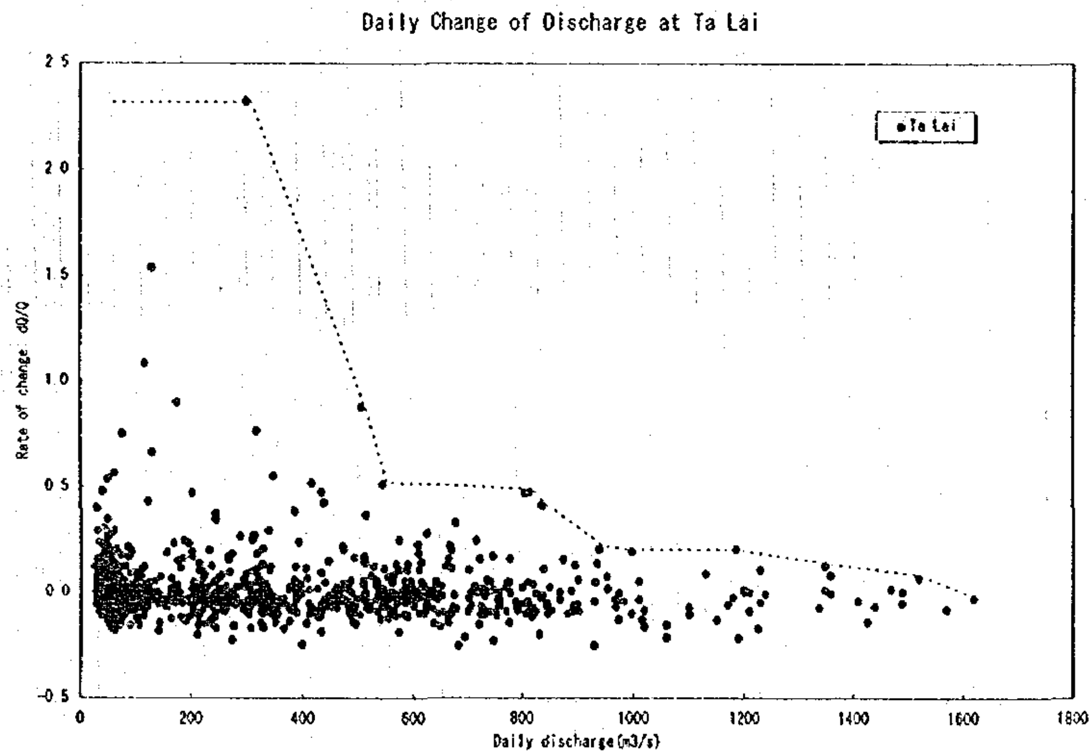
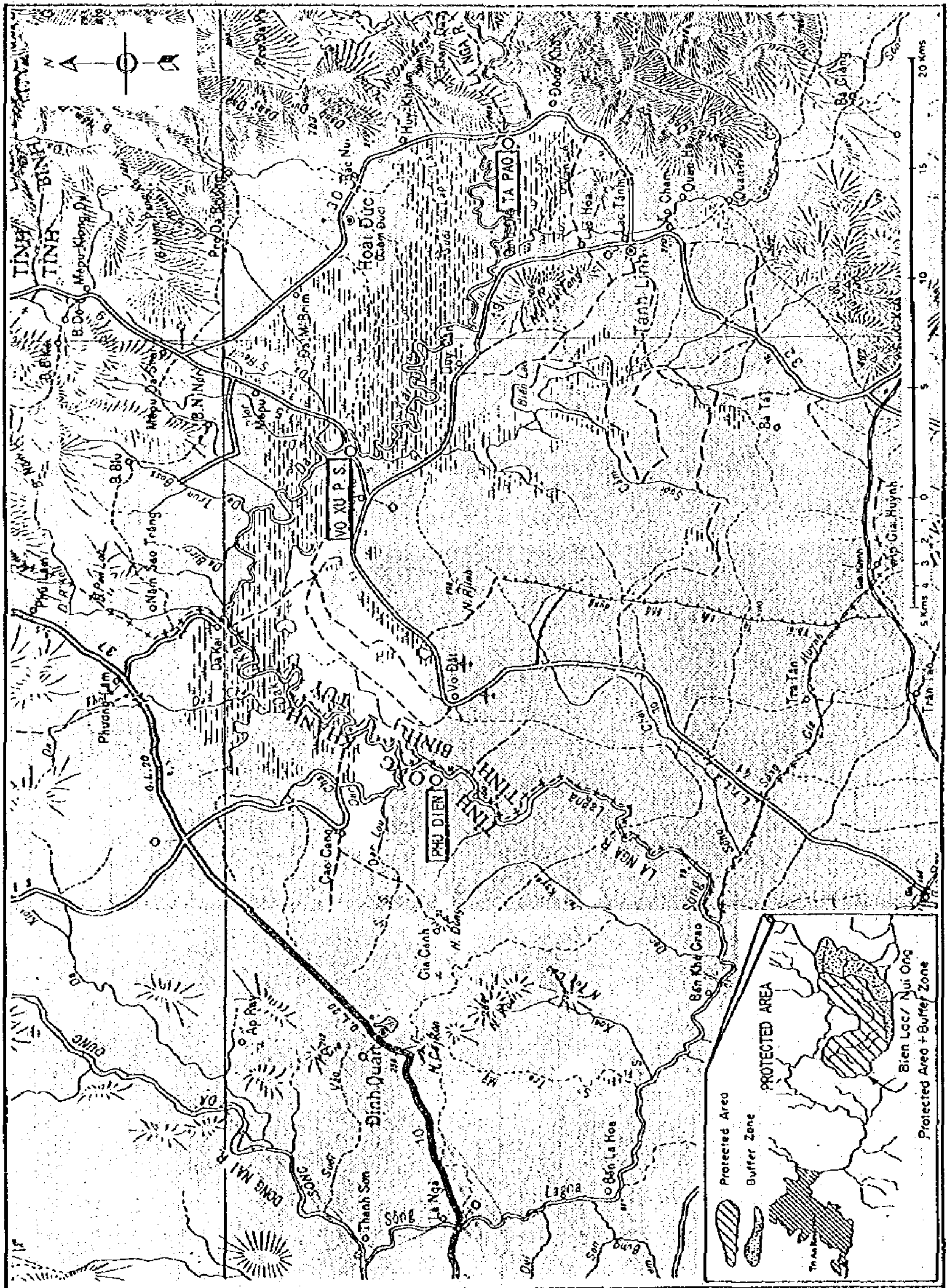
Figure 4.1

Location Map of the Cat Tien-Ta Lai Area





SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 4.2** **Rate of change of Daily Discharge (Ta Lai)**



SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT	**Figure 4.3** **Location Map of the La Nga River Area**
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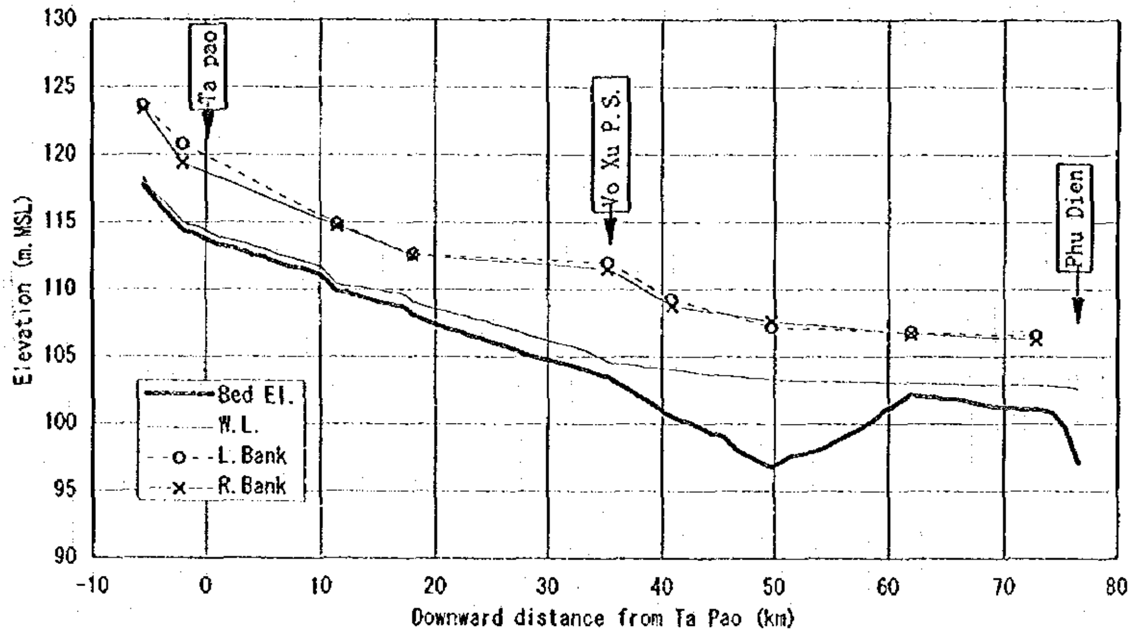

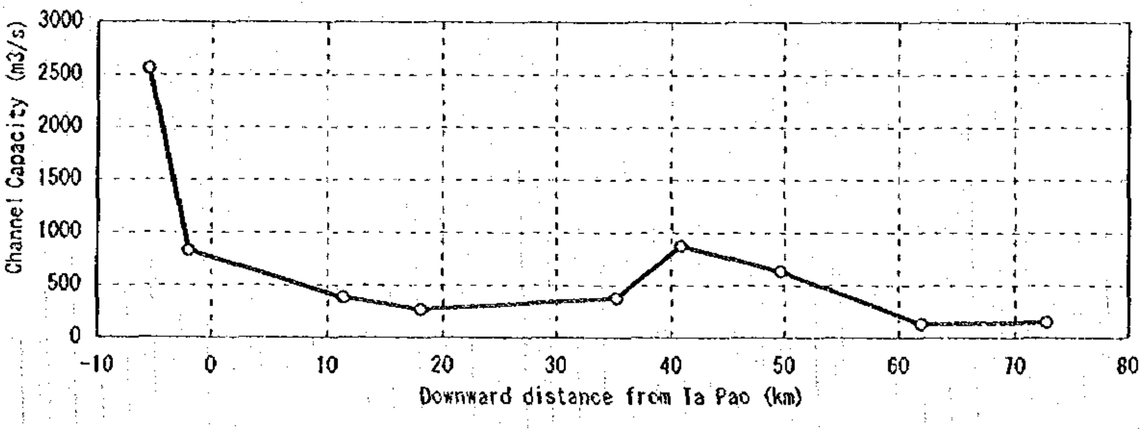

Sec.No.	Dis-tance (km)	River Bank Elev. (m.MSL) L.Bank	R.Bank	Sect. Area (m2)	Channel Width (m)	Mean Depth (m)	Slope (1/I)	Capa-city (m3/s)
M/C 22	-5.46	123.62	123.37	1156.50	418	2.77	882	2,560
M/C 23	-1.96	120.80	119.40	321.80	93	3.47	882	828
M/C 24	11.42	114.89	114.75	233.30	55	4.25	2,875	381
M/C 25	18.07	112.61	112.54	215.82	74	2.92	3,009	268
M/C 25A	35.27	112.01	111.56	531.05	111	4.79	17,551	380
M/C 26	40.87	109.27	108.75	417.72	89	4.70	1,993	875
M/C 27	49.72	107.17	107.61	410.84	64	6.41	5,601	631
M/C 28	61.97	106.79	106.70	264.88	68	3.89	26,064	135
M/C 29	72.77	106.53	106.25	292.44	77	3.79	24,000	153

Distance: Downward distance from Ta Pao
Sect.Area: Sectional area below lower river bank
Capacity: Estimated bankful channel capacity

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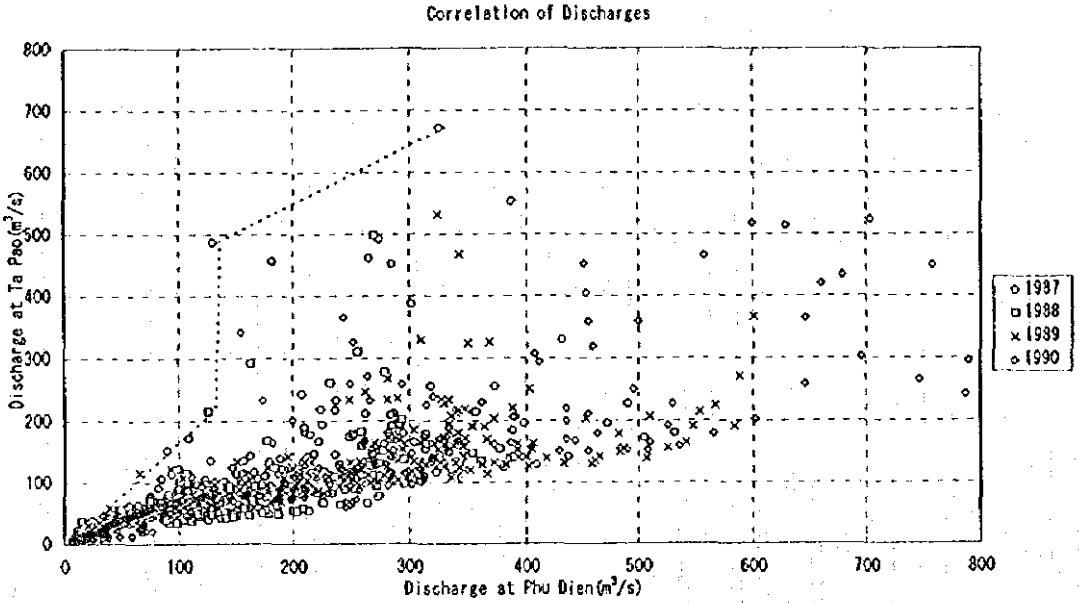
Figure 4.4

Channel Features of the La Nga River



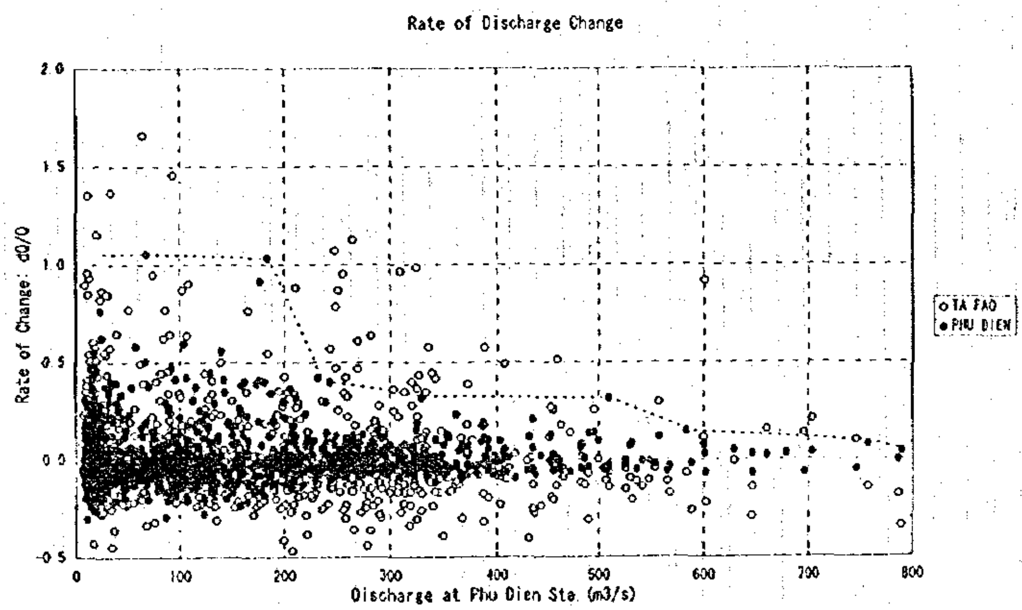


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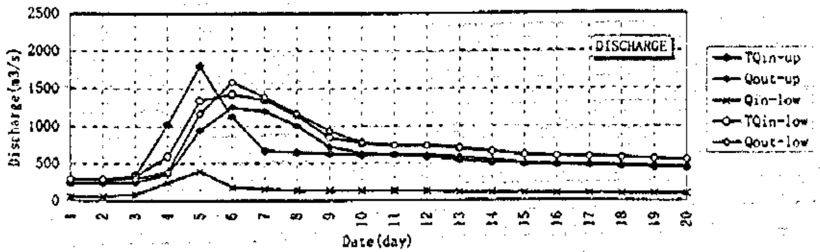
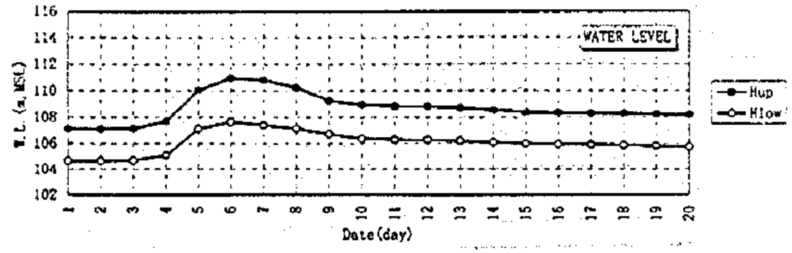
Figure 4.5
Relationships of Daily Discharges at Ta Pao-Phu Dien

CALCULATION OF INLAND DRAINAGE: Q10-DM0-DKO



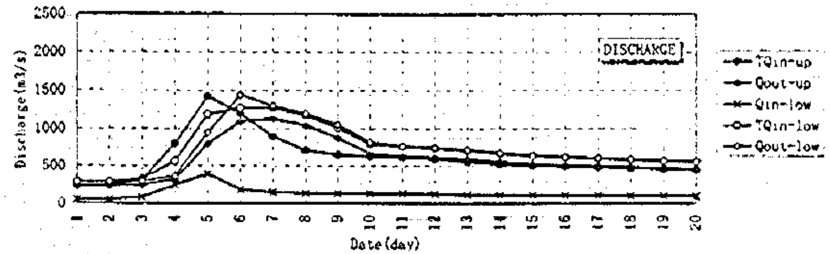


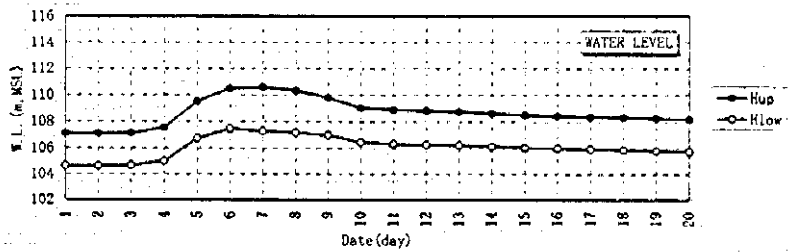
Result of Calculation

DATE (day)	UPPER BASIN TQin (m3/s)	UPPER BASIN V (mil.m3)	UPPER BASIN H (m,MSL)	UPPER BASIN Qout (m3/s)	LOWER BASIN Qin (m3/s)	LOWER BASIN TQin (m3/s)	LOWER BASIN V (mil.m3)	LOWER BASIN H (m,MSL)	LOWER BASIN Qout (m3/s)
1	236	33.1	107.12	236	55	291	38.3	104.65	291
2	245	33.1	107.12	237	57	294	38.3	104.65	291
3	342	33.6	107.18	248	83	331	38.7	104.69	299
4	1,028	38.7	107.73	353	244	597	43.0	105.10	386
5	1,798	63.0	110.05	950	392	1,342	64.5	107.15	1,174
6	1,133	121.2	110.96	1,254	178	1,433	70.0	107.67	1,588
7	667	111.8	110.81	1,206	146	1,352	67.4	107.42	1,388
8	649	74.0	110.23	1,008	135	1,143	64.5	107.15	1,175
9	632	52.6	109.25	722	131	854	60.1	106.72	936
10	607	49.7	108.94	637	130	767	56.3	106.37	780
11	613	48.7	108.83	610	129	739	55.4	106.28	743
12	585	48.8	108.83	612	123	735	55.4	106.28	741
13	541	47.8	108.73	585	112	697	54.7	106.21	712
14	506	46.3	108.56	543	108	651	53.5	106.10	662
15	493	45.0	108.42	508	106	614	52.5	106.00	621
16	486	44.5	108.36	494	104	598	51.9	105.94	604
17	477	44.2	108.33	487	102	589	51.4	105.90	594
18	461	43.8	108.29	477	99	576	51.0	105.86	583
19	449	43.3	108.23	462	97	559	50.3	105.79	566
20	443	42.8	108.18	450	96	546	49.7	105.73	551
MAX	1,798	121.2	110.96	1,254	392	1,643	70.3	107.69	1,607

Remarks. MAX indicates the maximum value of whole caluculation steps.

CALCULATION OF INLAND DRAINAGE: Q10-DM1-DKO





Result of Calculation

DATE (day)	UPPER BASIN TQin (m3/s)	UPPER BASIN V (mil.m3)	UPPER BASIN H (m,MSL)	UPPER BASIN Qout (m3/s)	LOWER BASIN Qin (m3/s)	LOWER BASIN TQin (m3/s)	LOWER BASIN V (mil.m3)	LOWER BASIN H (m,MSL)	LOWER BASIN Qout (m3/s)
1	236	33.1	107.12	236	55	291	38.3	104.65	291
2	243	33.1	107.12	236	57	294	38.3	104.65	291
3	313	33.5	107.16	245	83	328	38.6	104.68	298
4	804	37.2	107.56	321	244	566	42.2	105.02	366
5	1,426	55.2	109.53	801	392	1,193	60.5	106.76	953
6	1,204	91.4	110.50	1,099	178	1,277	68.1	107.49	1,442
7	899	98.2	110.60	1,134	146	1,280	66.3	107.31	1,306
8	707	81.4	110.34	1,046	135	1,182	64.9	107.18	1,202
9	653	57.6	109.80	876	131	1,007	62.0	107.00	1,058
10	627	50.7	109.04	665	130	795	57.3	106.46	822
11	614	49.5	108.90	630	129	758	56.0	106.33	764
12	595	48.9	108.84	614	123	737	55.5	106.29	745
13	557	48.2	108.76	595	112	707	54.9	106.23	721
14	526	46.9	108.62	559	108	667	53.9	106.13	677
15	505	45.7	108.50	528	106	634	53.0	106.05	640
16	493	44.9	108.41	506	104	611	52.4	105.99	616
17	482	44.5	108.36	494	102	596	51.8	105.93	602
18	468	44.0	108.31	482	99	581	51.2	105.88	588
19	457	43.5	108.26	469	97	566	50.6	105.82	572
20	448	43.1	108.21	457	96	553	50.0	105.76	558
MAX	1,426	98.5	110.61	1,136	392	1,487	68.4	107.51	1,465

Remarks: MAX indicates the maximum value of whole caluculation steps.

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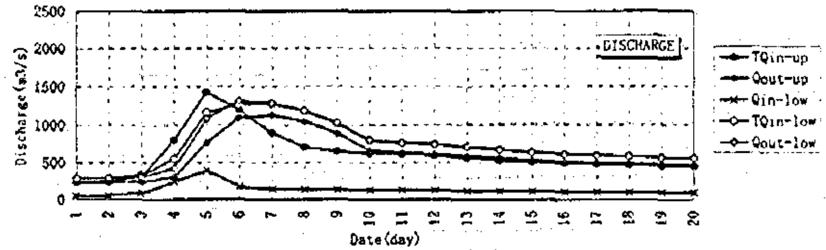
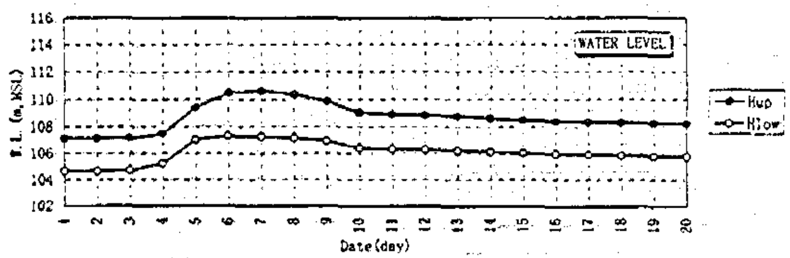
Figure 4.6

Results of Drainage Analysis (La Nga Area) (1/2)

CALCULATION OF INLAND DRAINAGE: Q10-DM1-DKL



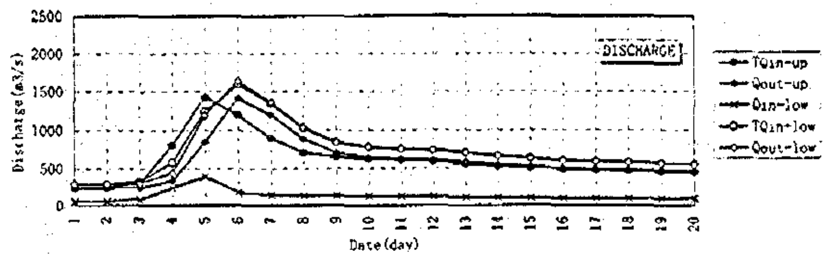


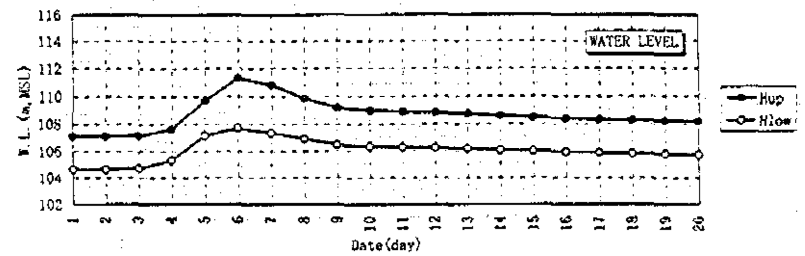
Result of Calculation

DATE (day)	UPPER BASIN TQin (m3/s)	V (mil. m3)	H (m, MSL)	Qout (m3/s)	LOWER BASIN Qin (m3/s)	TQin (m3/s)	V (mil. m3)	H (m, MSL)	Qout (m3/s)
1	236	33.1	107.12	236	55	291	1.6	104.65	291
2	243	33.1	107.12	236	57	294	1.6	104.65	292
3	312	33.4	107.15	243	83	326	1.7	104.71	305
4	804	36.5	107.49	306	244	551	1.9	105.26	428
5	1,426	54.1	109.42	769	392	1,162	2.7	107.03	1,085
6	1,204	90.8	110.49	1,096	178	1,274	2.8	107.33	1,319
7	899	98.2	110.60	1,134	146	1,280	2.8	107.29	1,287
8	707	81.7	110.35	1,048	135	1,184	2.8	107.16	1,186
9	653	58.1	109.85	889	131	1,020	2.7	106.93	1,026
10	627	50.8	109.06	669	130	798	2.4	106.41	800
11	614	49.5	108.91	631	129	759	2.4	106.32	760
12	595	48.9	108.85	615	123	738	2.4	106.28	742
13	557	48.2	108.77	596	112	709	2.3	106.22	715
14	526	46.9	108.63	560	108	668	2.3	106.12	671
15	505	45.8	108.50	529	106	635	2.3	106.04	636
16	493	44.9	108.41	507	104	611	2.2	105.97	612
17	482	44.5	108.36	494	102	596	2.2	105.92	598
18	468	44.1	108.32	483	99	582	2.2	105.86	585
19	457	43.6	108.26	469	97	566	2.2	105.80	568
20	448	43.2	108.23	460	96	556	2.1	105.76	557
MAX	1,426	98.3	110.60	1,135	392	1,487	2.9	107.54	1,487

Remarks: MAX indicates the maximum value of whole caluculation steps.

CALCULATION OF INLAND DRAINAGE: Q10-DM1-DKLU





Result of Calculation

DATE (day)	UPPER BASIN TQin (m3/s)	V (mil. m3)	H (m, MSL)	Qout (m3/s)	LOWER BASIN Qin (m3/s)	TQin (m3/s)	V (mil. m3)	H (m, MSL)	Qout (m3/s)
1	236	6.1	107.12	236	55	291	1.6	104.65	291
2	243	6.2	107.12	237	57	294	1.6	104.65	292
3	313	6.2	107.17	247	83	330	1.7	104.72	306
4	804	7.1	107.65	338	244	582	1.9	105.32	445
5	1,426	10.5	109.71	850	392	1,242	2.8	107.17	1,194
6	1,204	22.5	111.33	1,413	178	1,591	3.0	107.73	1,637
7	899	18.0	110.81	1,203	146	1,349	2.9	107.38	1,357
8	707	10.8	109.83	885	135	1,021	2.7	106.95	1,034
9	653	9.7	109.18	703	131	835	2.5	106.50	839
10	627	9.3	108.99	651	130	781	2.4	106.37	782
11	614	9.2	108.89	626	129	755	2.4	106.31	756
12	595	9.1	108.84	613	123	736	2.4	106.27	740
13	557	8.9	108.76	592	112	705	2.3	106.21	712
14	526	8.7	108.61	555	108	663	2.3	106.11	667
15	505	8.5	108.48	525	106	630	2.3	106.03	633
16	493	8.3	108.40	504	104	609	2.2	105.96	610
17	482	8.3	108.35	492	102	594	2.2	105.91	597
18	468	8.2	108.31	481	99	580	2.2	105.86	583
19	457	8.1	108.25	467	97	564	2.2	105.79	566
20	448	8.0	108.21	456	96	552	2.1	105.74	553
MAX	1,426	22.6	111.34	1,418	392	1,810	3.1	107.95	1,810

Remarks. MAX indicates the maximum value of whole caluculation steps.

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Figure 4.6

Results of Drainage Analysis (La Nga Area) (2/2)

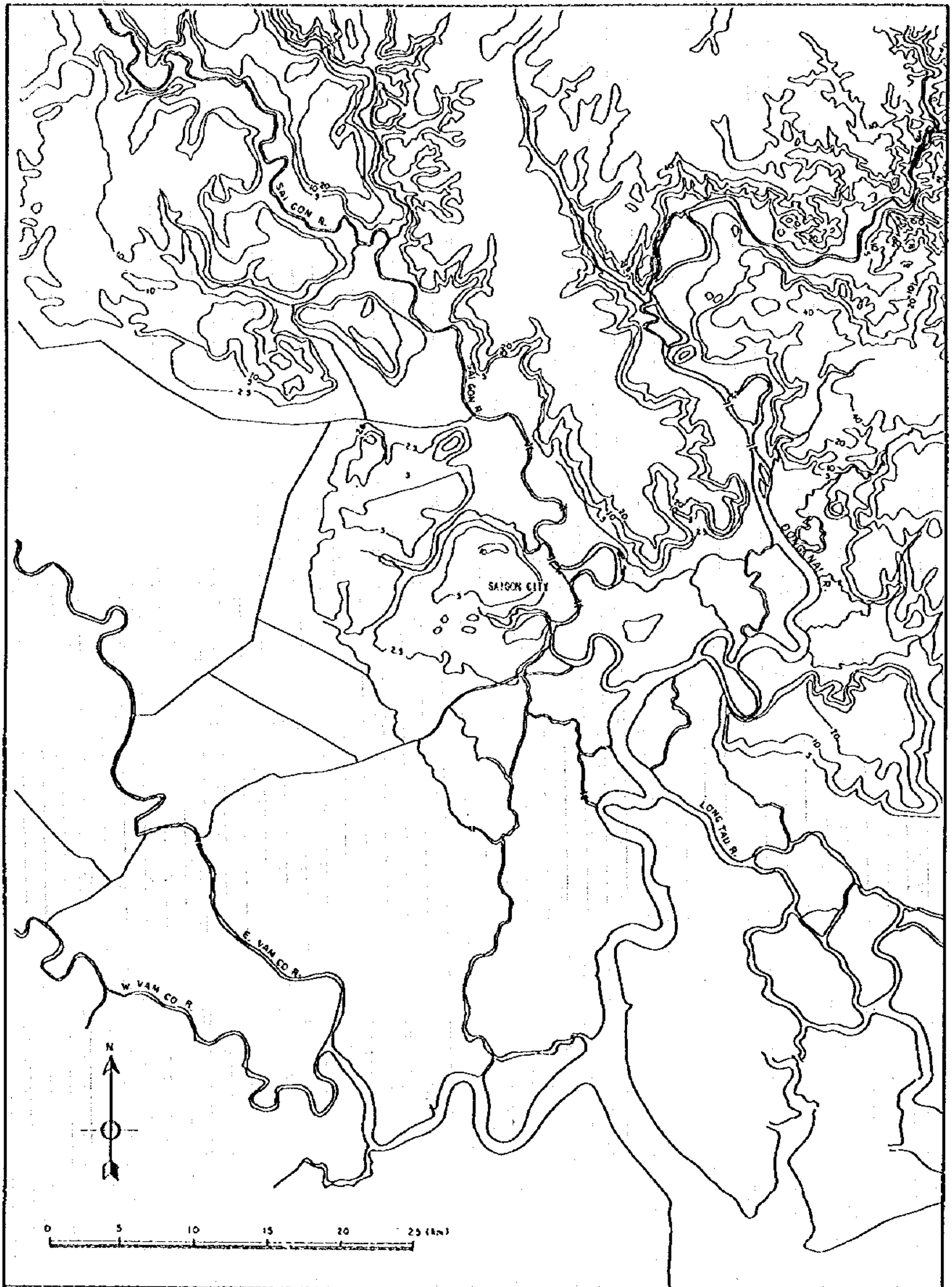

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Figure 4.7

Location Map of the Lower Dong Nai and Its Related Rivers

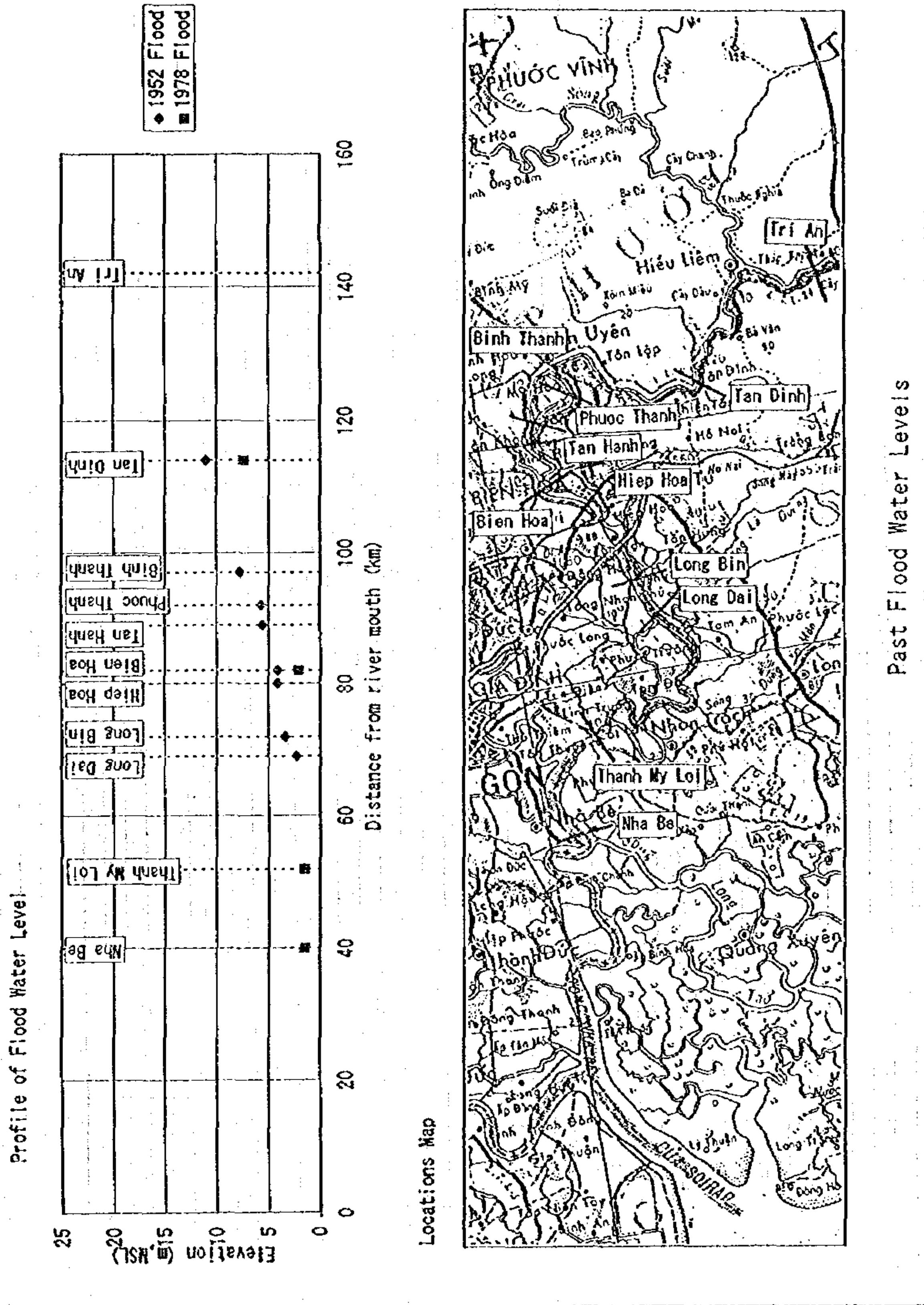

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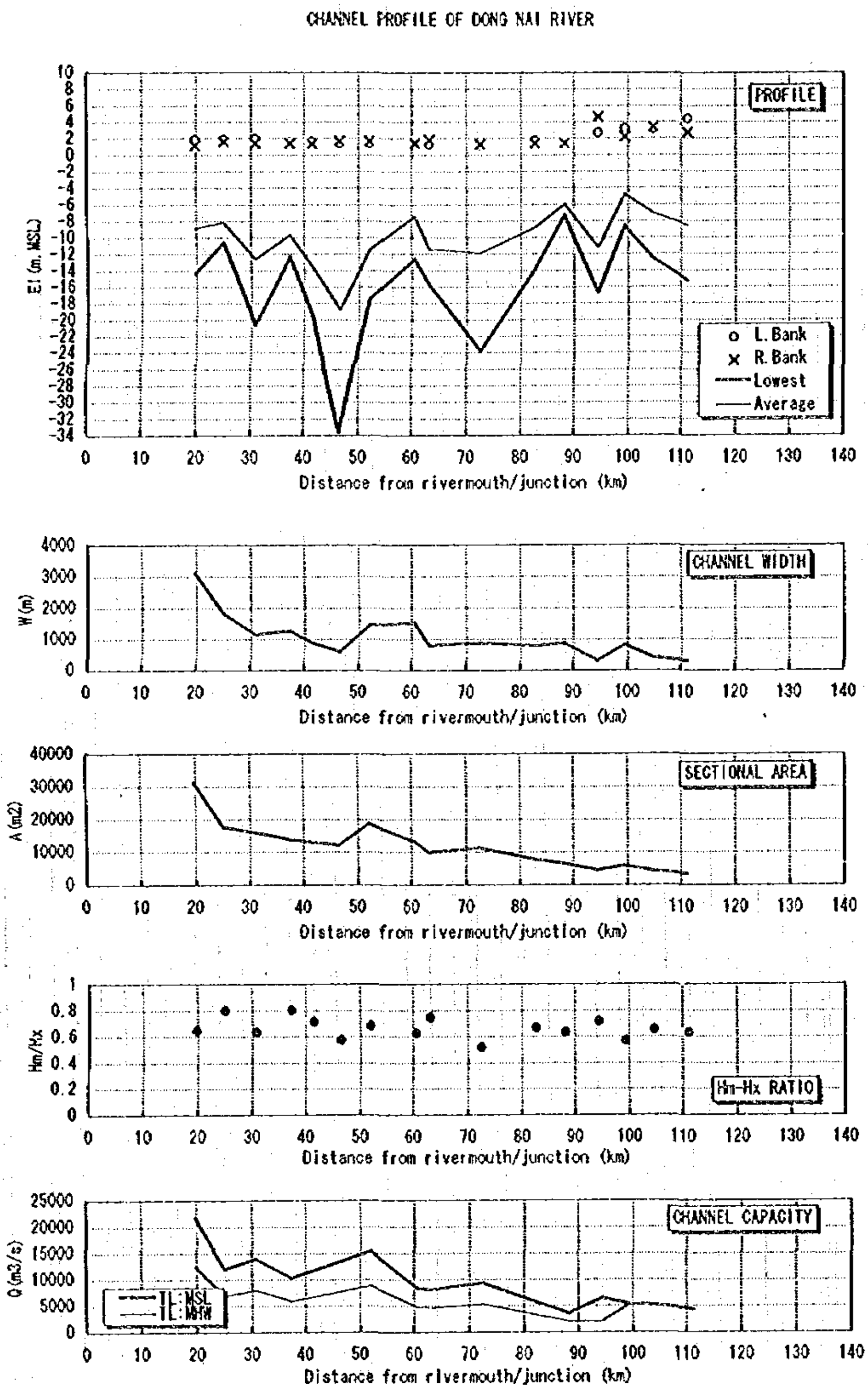
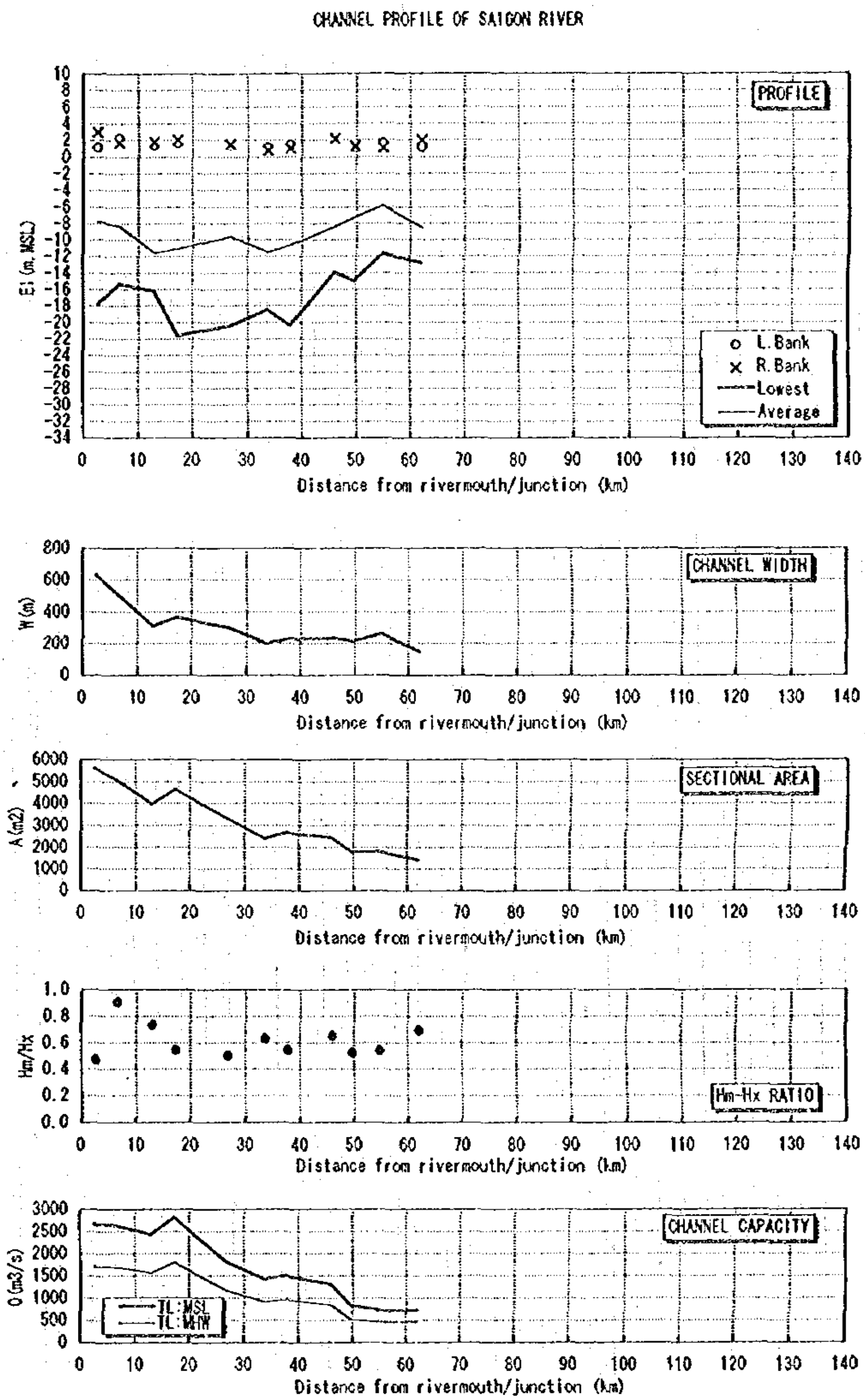
Figure 4.8

Past flood Water Levels in the Lower Dong Nai River



SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 4.9** **Channel Profiles in the Lower Dong Nai River (1/4)**



SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 4.9 Channel Profiles in the Lower Dong Nai River (2/4)

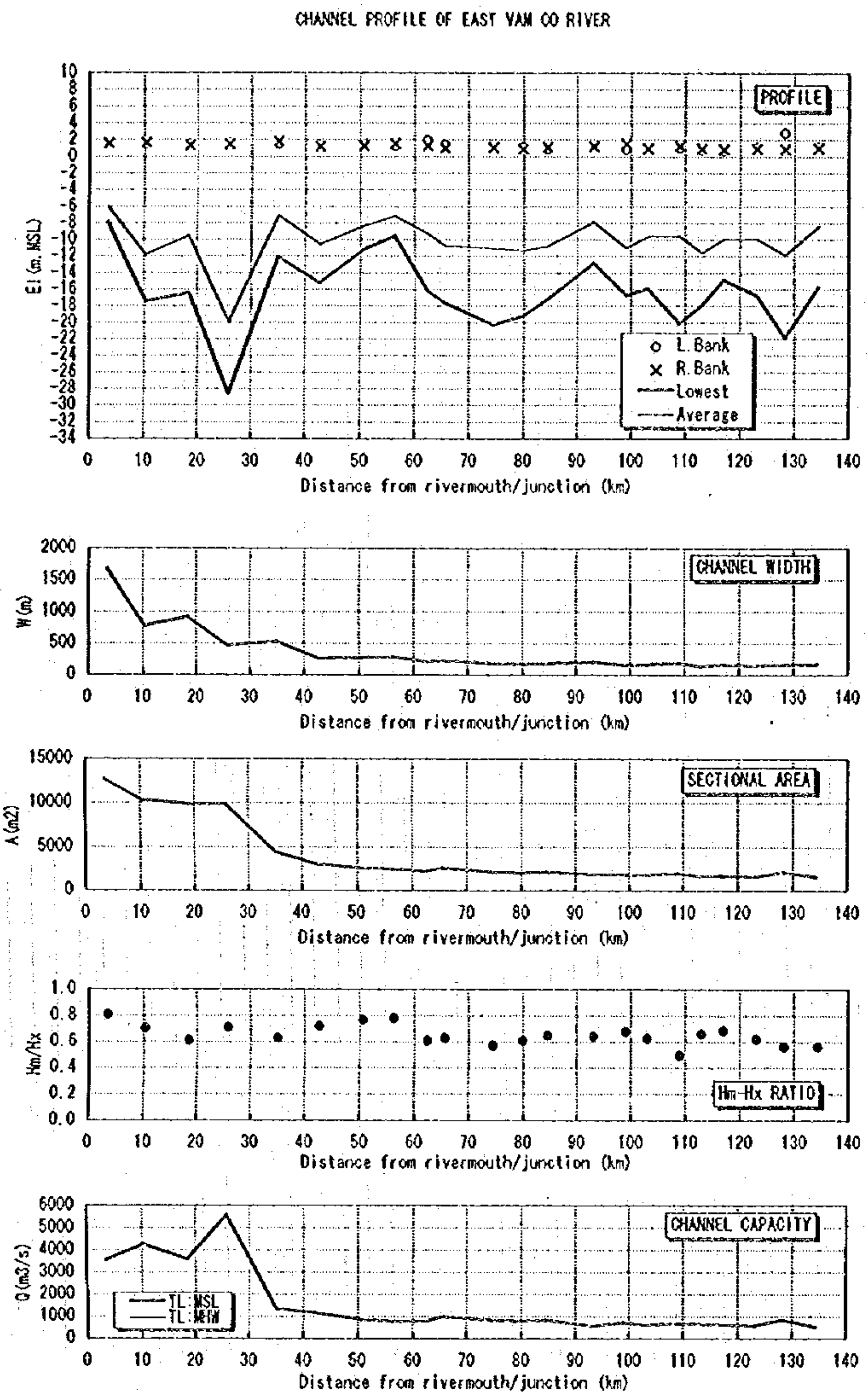


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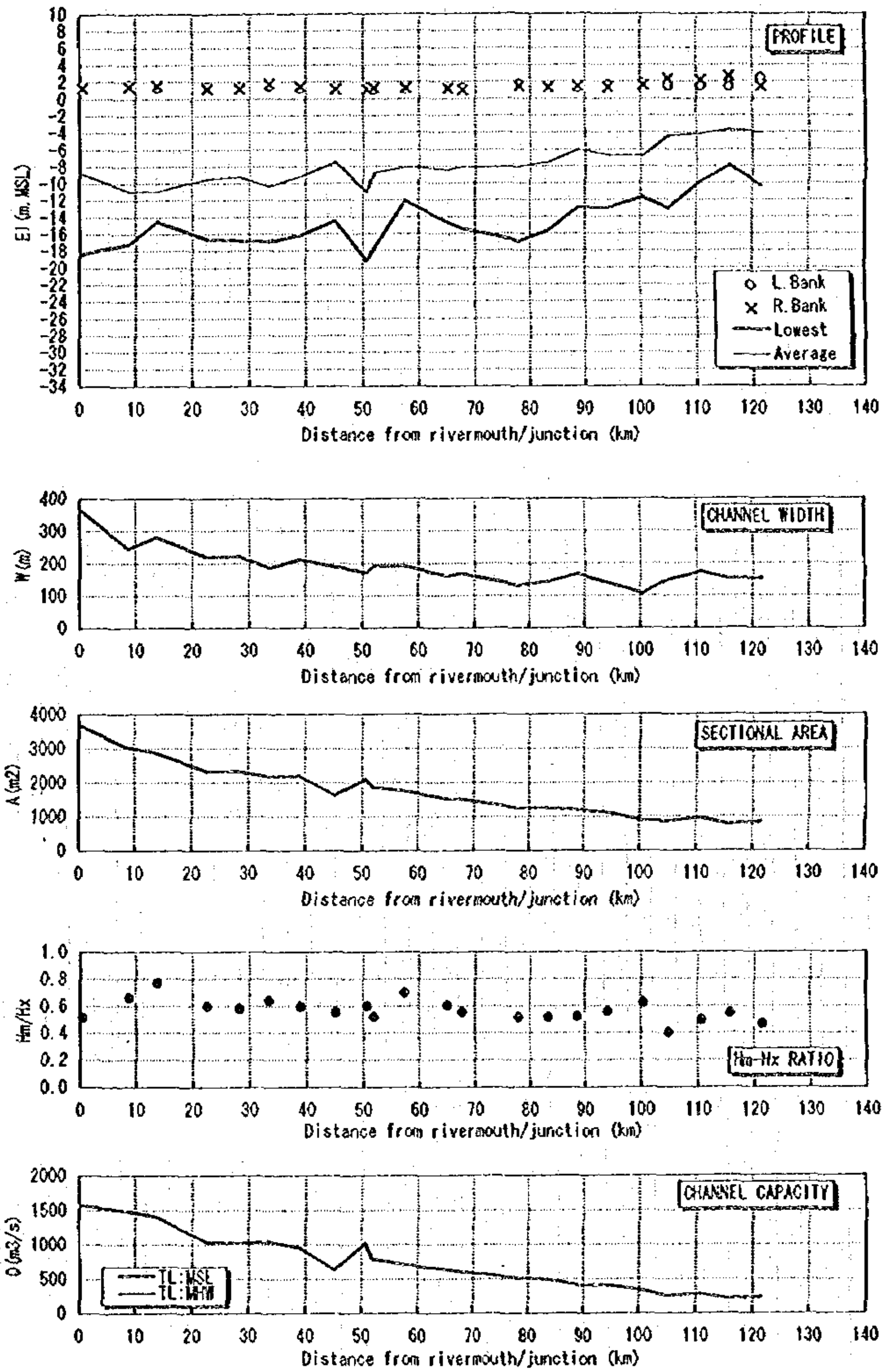
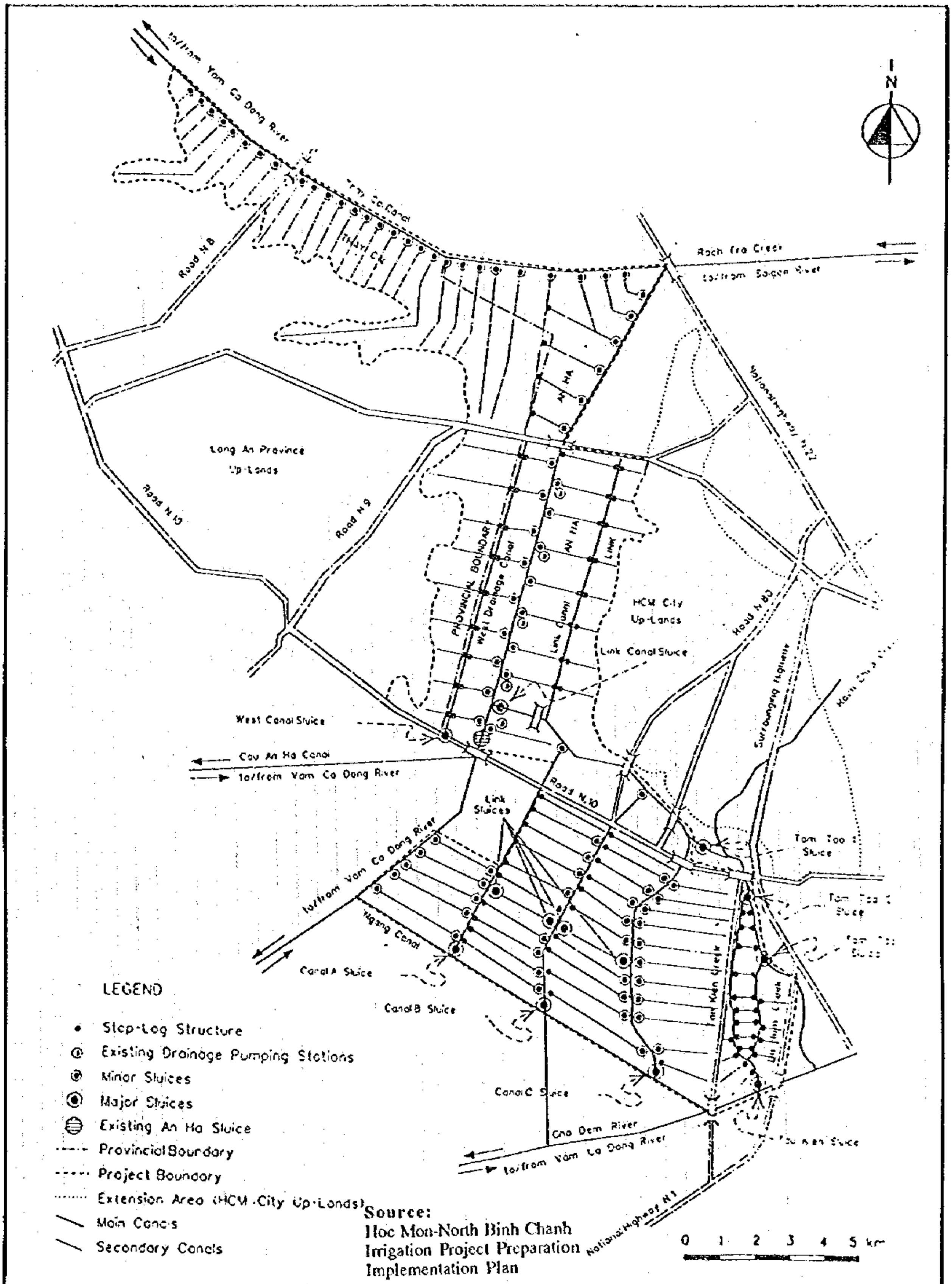
Figure 4.9

Channel Profiles in the Lower Dong Nai River (3/4)

CHANNEL PROFILE OF WEST VAM CO RIVER

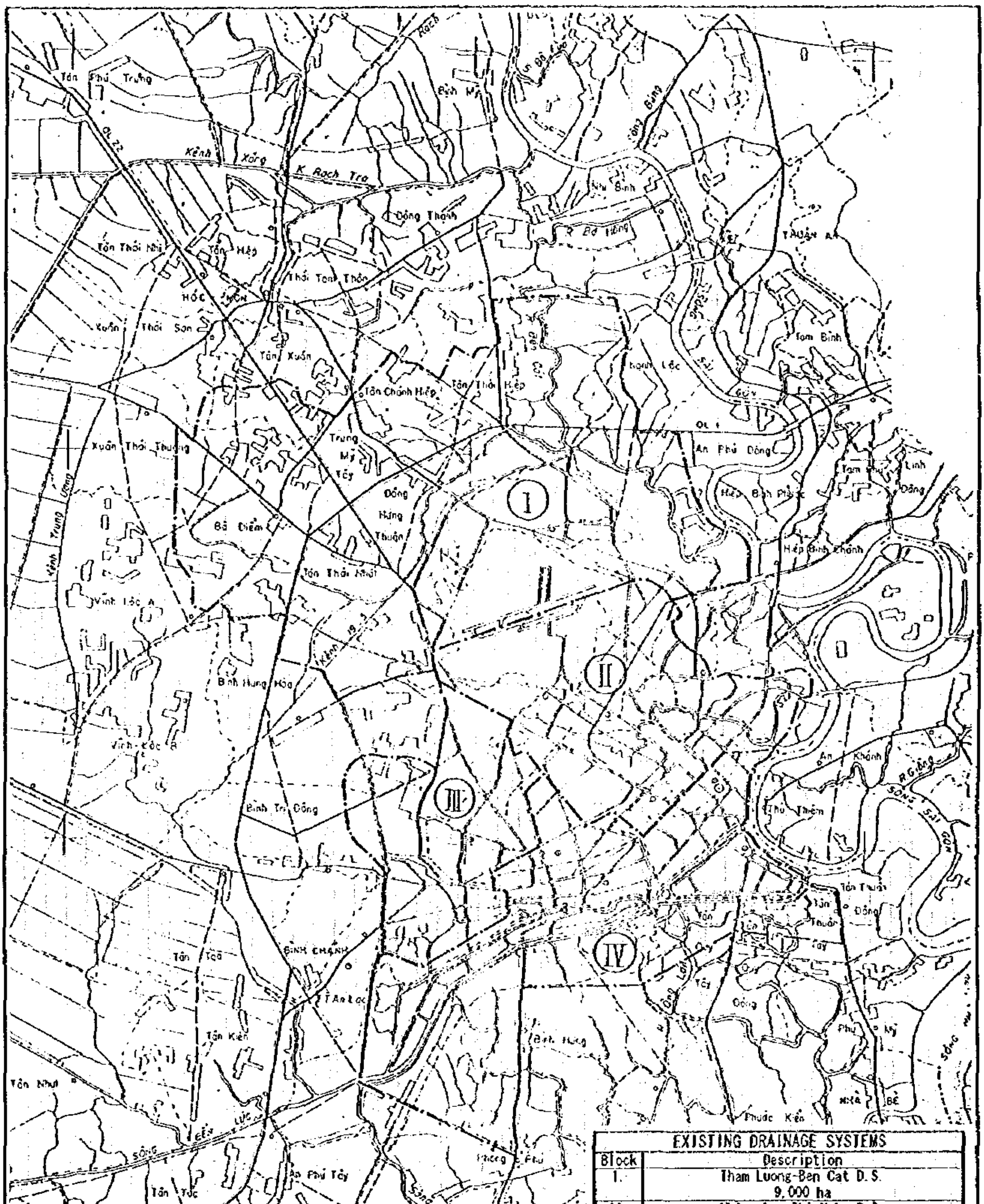


SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 4.9** **Channel Profiles in the Lower Dong Nai River (4/4)**



Source:
Hoc Mon-North Binh Chanh
Irrigation Project Preparation
Implementation Plan

SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT JAPAN INTERNATIONAL COOPERATION AGENCY	**Figure 4.10** **Irrigation and drainage System of the Hoc Mon-Bac Binh Chanh Irrigation Project**



Block	Description
I.	Tham Luong-Ben Cat D.S. 9,000 ha
II.	Nhieu Loc-Thi Nghe D.S. 5,000 ha
III.	Tan Hoa-Lo Gom D.S. 2,115 ha
IV.	Kinh Doi-Kinh Te-Tau Hu-Ben Nghe D.S. 4,900 ha

EXISTING DRAINAGE SYSTEMS

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Figure 4.11

Existing Drainage System in HCMC

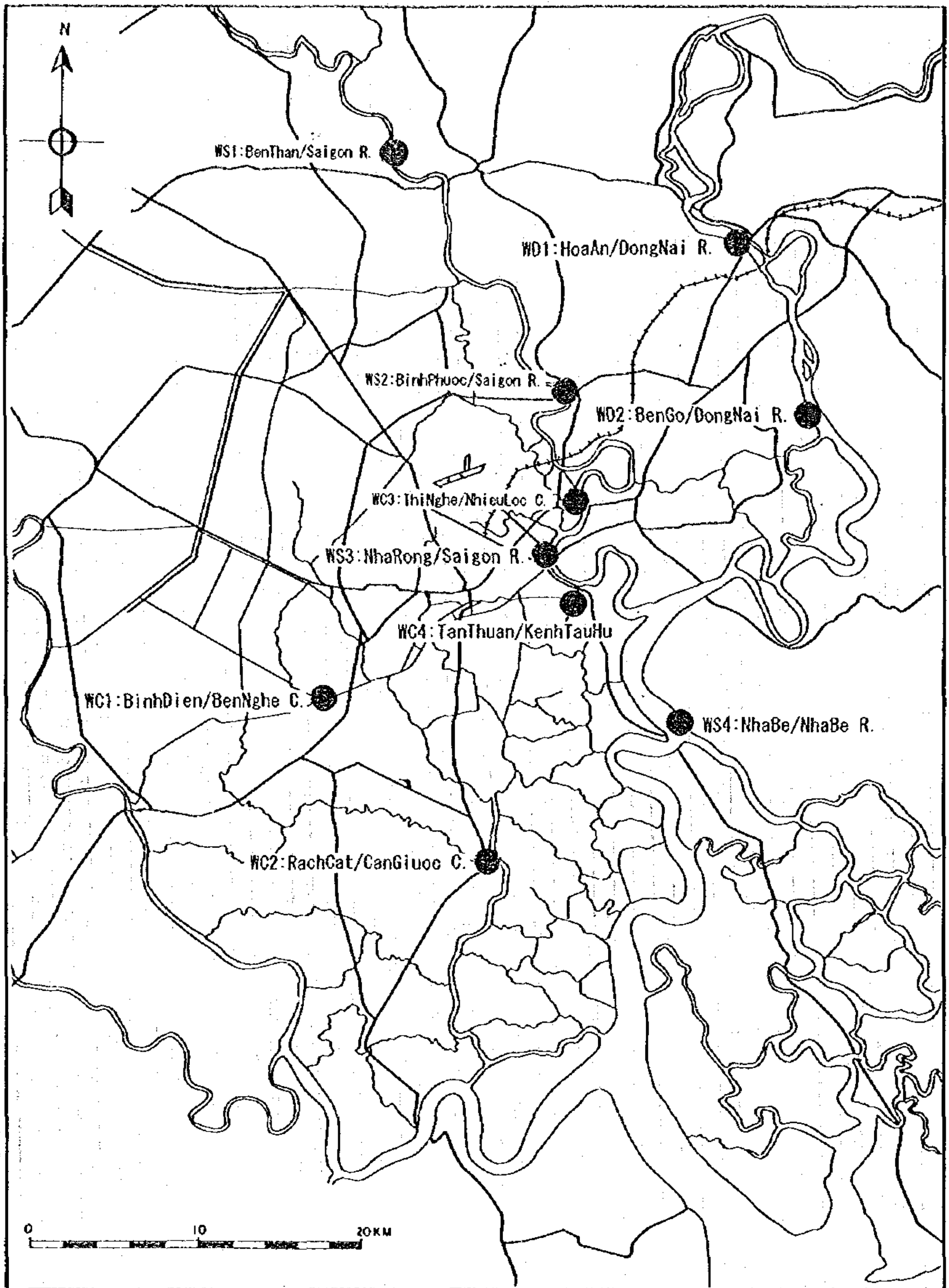

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Figure 4.12

Location of Existing Water Quality Monitoring System

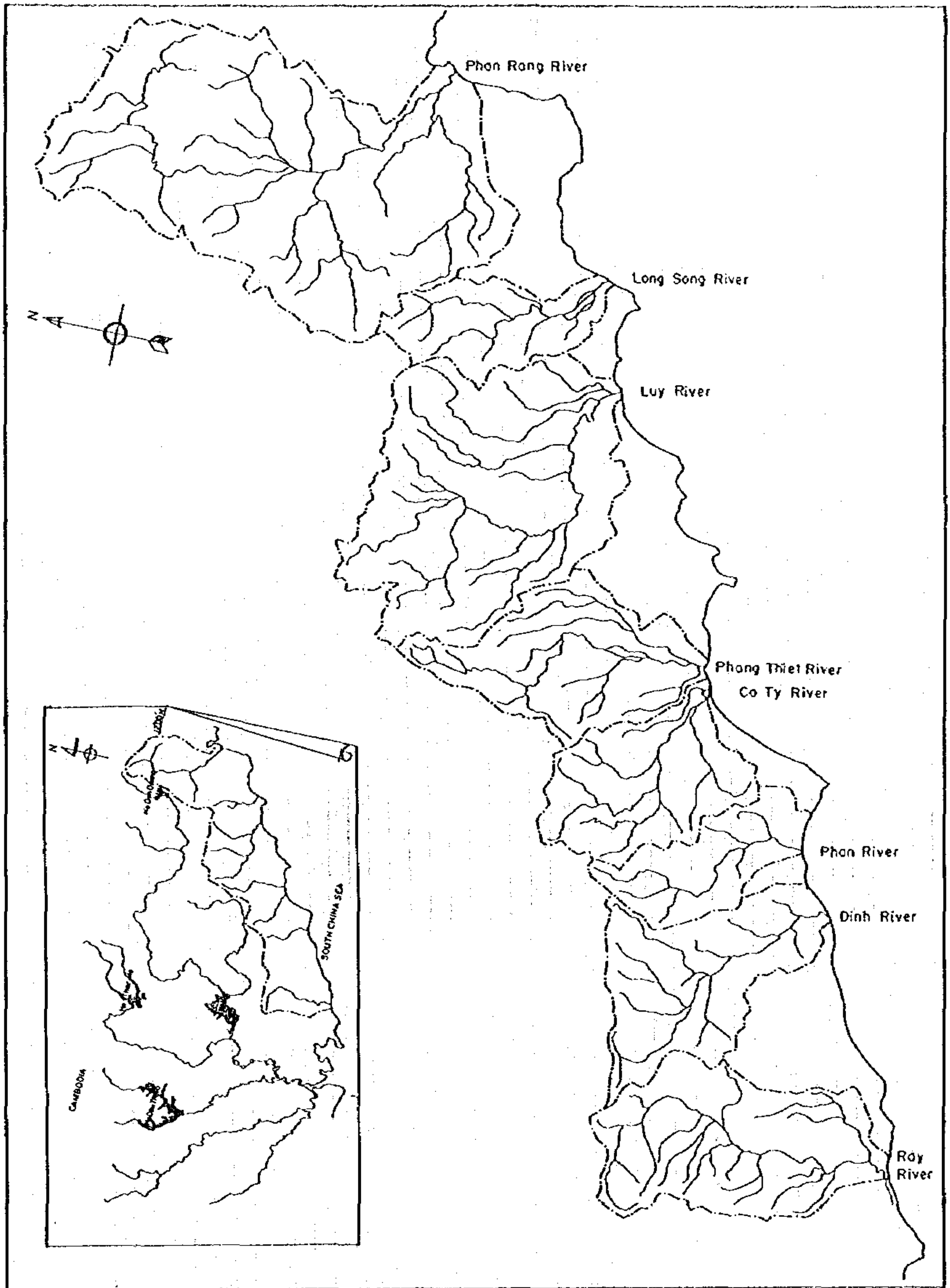

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Figure 4.13

Location of the Coastal River Basins

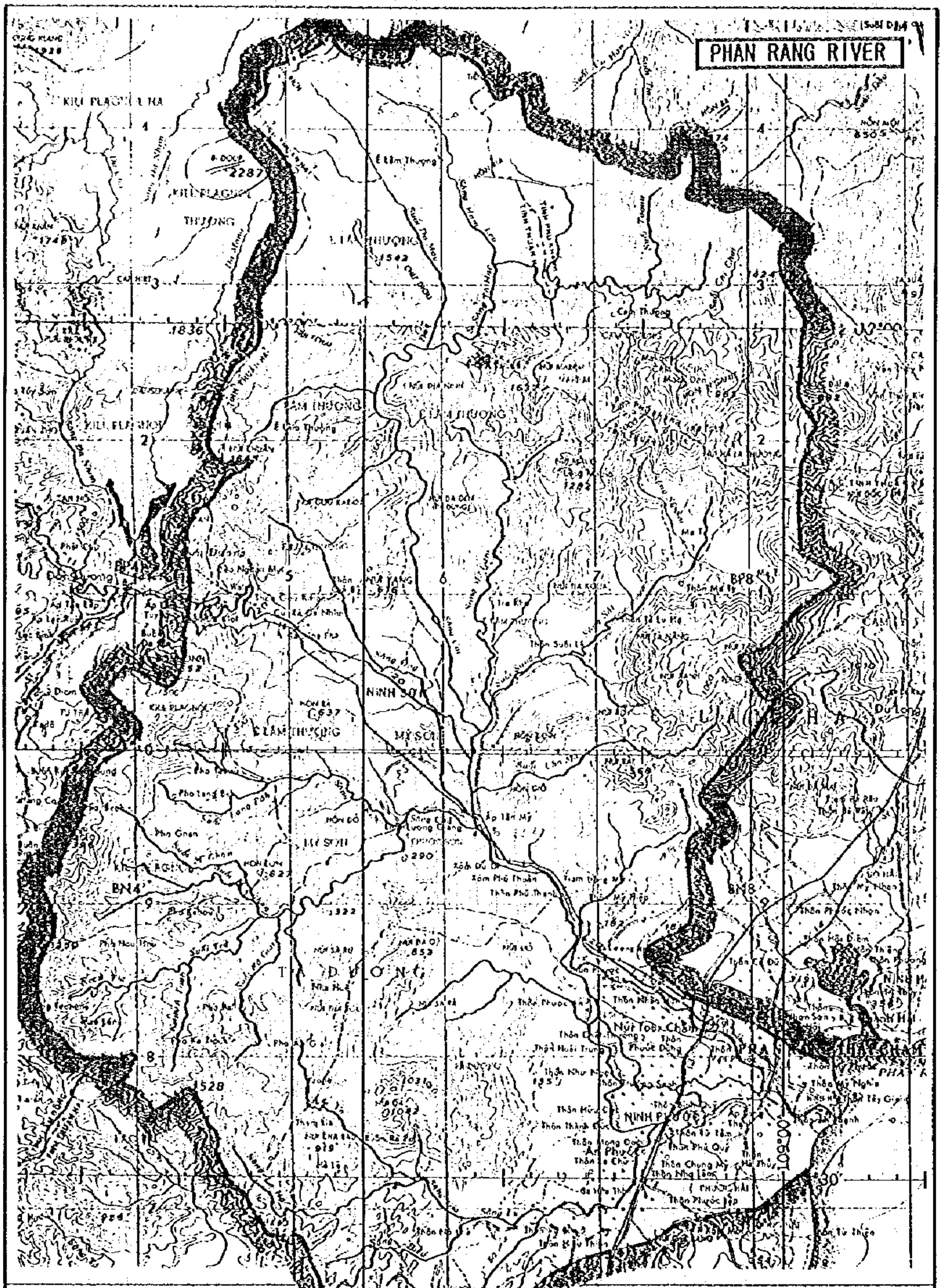

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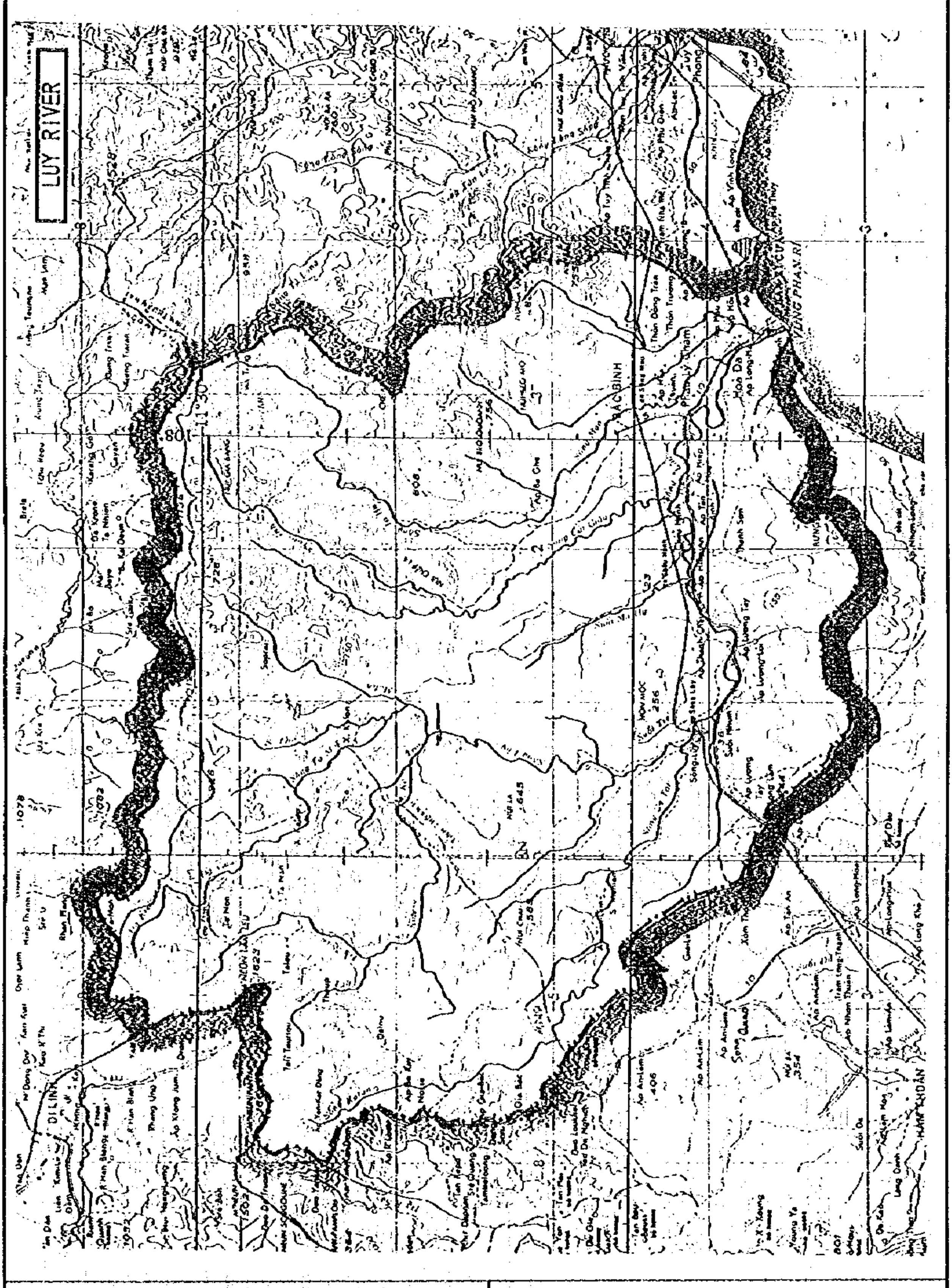
Figure 4.14

Phan Rang River Basin



SOCIALIST REPUBLIC OF VIET NAM MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT	Figure 4.15 Luy River Basin
JAPAN INTERNATIONAL COOPERATION AGENCY	

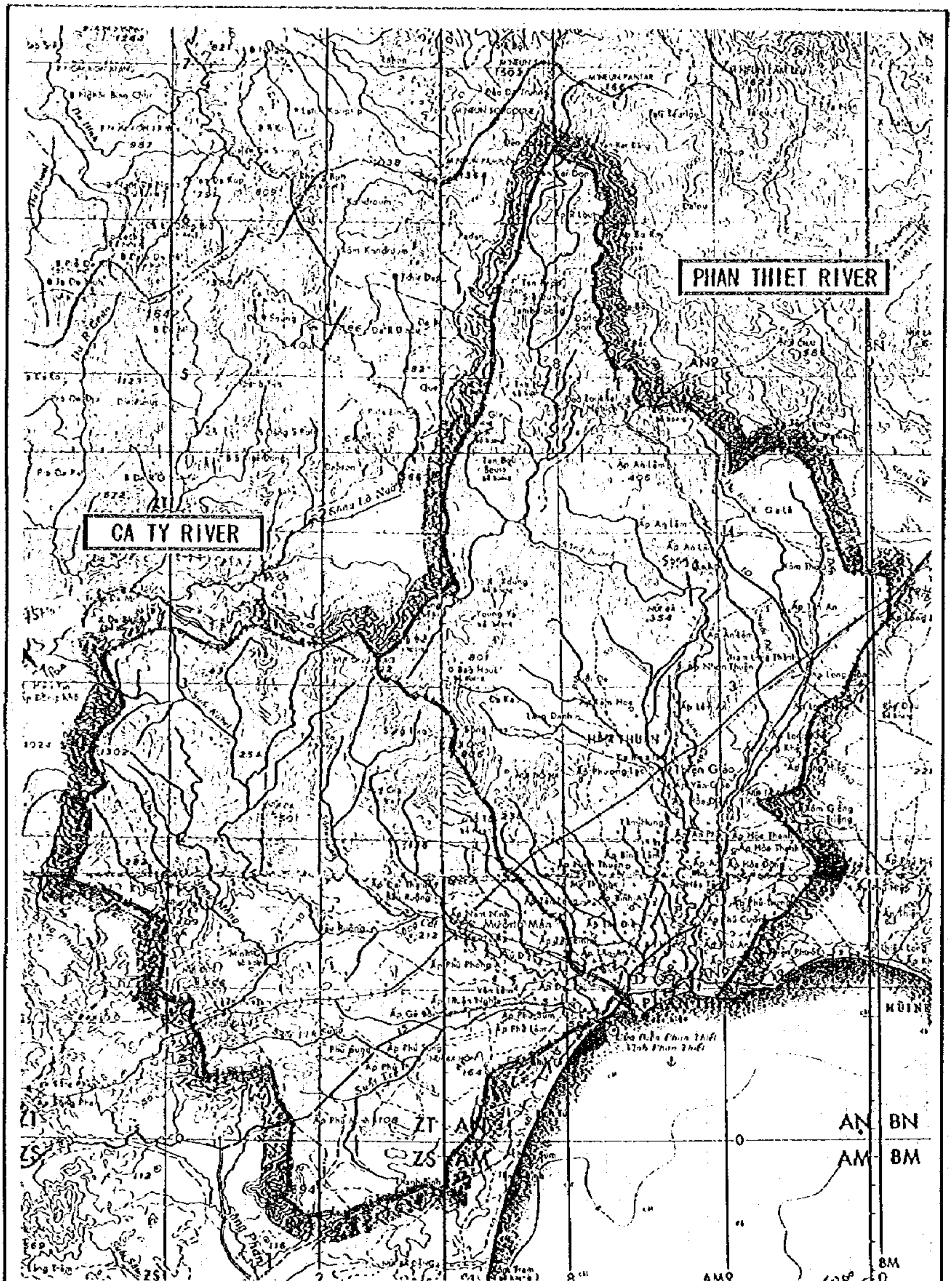


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Figure 4.16

Phan Thiet and Ca Ty River Basins

Appendix IX

SALINITY INTRUSION

APPENDIX IX
Salinity Intrusion

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1. INTRODUCTION

Salinity intrusion problems of the Dong Nai, Saigon and East and West Vam Co rivers are studied for the various channel flows under the existing and proposed development conditions by use of a mathematical simulation model.

The simulation model is prepared based on the latest results of river survey and field observation of salinity intrusion in the Dong Nai, Saigon, and East and West Vam Co rivers undertaken at the end of March, 1995 by the Study Team.

Administratively, the activities related to the salinity intrusion issues are handled by the Department of Science-Technology and Environment (BSTE), while the inland navigation matters which may affect the salinity intrusion problems are managed by the Ministry of Transport and Communications (MOTC) as outlined below:

	Administrative Agencies	
Activity	Salinity	Inland navigation
- Investigation	BSTE	MOTC
- Planning	BSTE	MOTC
- Design	BSTE	MOTC
- Construction	-	Company under MOTC
- Operation and maintenance	Provincial company under BSTE	Provincial company under MOTC

It is noted that the above administrative structure in charge of the salinity intrusion issues is based on the information collected before the reorganization of government agencies carried out in October 1995.

2. EXISTING SITUATION

2.1 River and Channel System

The Dong Nai River multi-furcates into several branch channels in the deltaic estuary, forming a complicated channel network as shown in Figure 2.1. A major branch of the Dong Nai River is the Long Tau-Giua-Nga Bay River (the Long Tau River), which further bifurcates into two; its main stream and the Dong Tranh-Go Gia-Cai Mep River (the Dong Tranh River) used and maintained as a main navigation canal to the Saigon port.

Therefore, the major inlets of sea water into the Study Area are the main Dong Nai River, the Long Tau River and the Dong Tranh River. Sea water further intrudes into the tributaries of the Dong Nai River such as the Vam Co and the Saigon rivers. Through the Vam Co River, sea water intrudes into the Rac Cac River, the East and West Vam Co rivers, the Ben Luc River and other interconnected canals in the low-lying areas located between the Saigon River and the West Vam Co River.

2.2 Channel Flow

The Dong Nai, Saigon, and West and East Vam Co rivers are the major rivers which convey fresh water into the salinity-affected areas. No discharge observation station is located in the salinity-affected areas, since the areas are affected by the tidal movements. The following are the nearest discharge observation stations lying outside the effect of backwater by tide and are available for the study:

Discharge Stations Available for the Study

River	Station	Data Availability	Reservoir
Dong Nai			
Main Dong Nai	Tri An	1982-1986	Da Nhim
Be	Phuoc Hoa	1986-1990	None
La Buong	An Vien	1986-1990	None
Saigon	Loc Ninh	1979-1983	None
East Vam Co	Can Dang	1986-1990	None

Flow-durations at these stations are prepared by using the latest five-year data among available ones as shown in Table 2.1 and Figure 2.2. These show the flow durations under the natural flow condition without artificial control, except for the Da Nhim reservoir. Principal channel flow features are summarized below:

Principal Channel Flow Features

Station	B.A. (km²)	Qmin (m³/s)(1)	qmin (m³/s/km²)	Qmax (m³/s)(2)	(2)/(1)
Tri An	14,025	40	2.82×10^{-3}	2,722	68
Phuoc Hoa	5,765	12	2.16×10^{-3}	1,205	100
An Vien	264	1.1	4.08×10^{-3}	89.4	81
Loc Ninh	500	2.7	5.31×10^{-3}	41.5	15
Can Dang	617	1.2	2.02×10^{-3}	73.6	61

Notes : B.A. : Basin area upstream of the station
Qmin, Qmax : Average of annual minimum and maximum discharge
qmin : Specific annual minimum discharge (= Qmin/B.A.)

The average annual minimum fresh water discharge from each basin is preliminarily estimated based on the specific discharge for each basin as follows:

Estimate of Annual Minimum Discharge

Basin	B.A. (km²)	qmin (m³/s/km²)	Estimated Qmin(m³/s)	Applied station
Dong Nai/La Nga R.		-		
Upstream of Tri An	14,025	2.82×10^{-3}	40	Tri An
Downstream of Tri An	5,047	4.08×10^{-3}	21	An Vien
Be R.	7,427	2.16×10^{-3}	16	Phuoc Hoa
(Sub-total)	(26,499)	-	(77)	
Saigon R.	4,717	5.31×10^{-3}	25	Loc Ninh
West/East Vam Co R.	9,467	2.02×10^{-3}	19	Can Dang
(Total)	(40,683)	-	(121)	

The annual minimum discharge, which most seriously causes salinity intrusion to the affected area, is preliminarily estimated at 121 m³/s as a simple arithmetic sum of the above five rivers without consideration of time coincidence, consisting of 77 m³/s (63%) from the main Dong Nai River, 25 m³/s (21%) from the Saigon River and 19 m³/s (16%) from the West and East Vam Co rivers.

2.3 Existing Salinity Monitoring System

Salinity observation in the Study Area is being carried out since the year 1977 by the Sub-Institute of Water Resources Planning (SIWRP). The observation before the year 1988 was, however, limited only to several stations without simultaneous observation, supplying less enough information to grasp the actual movement of salinity water.

Over a time period of the year 1988 to 1991, SIWRP carried out simultaneous observation at the stations in the Dong Nai River and the Saigon River. Most of the observations were carried out in the dry season, and a total of 12 samples were collected from the water surface near the river bank at every odd hour of a day. Based on the observation, the following reports on salinity observation are prepared for the Dong Nai River and the Saigon River:

- Reports on salinity observation for the Dong Nai River in the year 1988,
- Reports on salinity observation for the Saigon-Dong Nai River in the year 1989 and 1990, and
- Salinity data of 11 stations in the Saigon-Dong Nai River in the year 1991.

2.4 Existing Conditions of Salinity Intrusion

(1) Period and Extent of Salinity Intrusion

The maximum extent of salinity intrusion ordinarily takes place at the end of April when the river flow falls to the lowest. The following Table shows the ordinary period when the salinity concentration remains to be 4 g/l or more at each station:

Period of Salinity Concentration More than 4 g/l

Station	River	Period of 4 g/l or more
Nha Be	Dong Nai River	From Dec. 18 to Jul. 3
Cat Lai	Dong Nai River	From Jan. 15 to May 20
Phu An	Saigon River	From Feb. 10 to May 10
Ben Luc	East Vam Co River	From Feb. 2 to May 25
Tan An	West Vam Co River	From Feb. 10 to May 15

The extent of salinity intrusion is approximately illustrated in Figure 2.3 based on the observed data from the year 1977 to date, showing the maximum intrusion recorded in the year 1977 and the minimum in the year 1989. The maximum extent with the salinity concentration of 4 g/l is estimated for each river as follows:

- Dong Nai River : Near Long Binh
- Saigon River : Below Lai Thieu
- East Vam Co River : Near Xuan Khanh
- West Vam Co River : Near Tuyen Nhon.

(2) Suffering Areas from Salinity Intrusion

Due to the gentle slope and deep channel of rivers, sea water intrudes deeply into lands through the rivers and canals in the Study Area. The areas suffering from salinity intrusion are those in the lower reaches of the rivers and the canals connected with these rivers. They are:

- Lower reaches of the Dong Nai River such as Long Thanh and Nhon Trach districts in

Dong Nai province, and Thu Duc, Nha Be and Can Gio districts in HCMC;

- Lower reaches of the Saigon River such as Cu Chi and Hoc Mon districts in HCMC and Thuan An district in Song Be province; and
- Lower reaches of the Vam Co River such as Duc Hoa, Duc Hue, Ben Luc, Thu Thua, Can Giuoc and Tan Thu districts in Long An province.

The salinity intrusion has brought about adverse effects to the agricultural production and people's daily life in the areas as presented below.

Adverse Effects to Agricultural Production: Effects of salinity intrusion are different principally depending on the areas located on the north and south of the Ben Luc River. In the northern area of the Ben Luc River, the time period of salinity intrusion with a concentration of 4 g/l or more ranges from one month to five months. Double crops a year are possible including winter-spring crop generally from November or December to March. Local people build dikes and sluices to prevent their fields from salinity intrusion and to draw irrigation water by gravity coinciding with tidal movement.

In the southern area of the Ben Luc River, the time period of salinity intrusion with a salinity concentration of 4 g/l or more varies from six to ten months. Due to the long lasting salinity intrusion, cultivation is limited only in the rainy season.

Adverse Effects to People's Daily Life: Among the salinity-affected areas, HCMC and some limited towns are the only beneficiaries of the water supply system. In other areas people have to tap river water or groundwater as a source of drinking water. Therefore, water for domestic use is a serious problem in the areas where the salinity intrusion lasts long. In the northern area of the Ben Luc River, people can use groundwater. However, in the southern area of the river, groundwater is affected by the salinity, so people have to buy water from other areas for their daily use. As a result, people's living standard in the salinity-affected areas is low.

3. FIELD OBSERVATION OF SALINITY INTRUSION

3.1 Field Observation Programme

In consideration of the existing salinity monitoring system and studies made by the Ministry of Agriculture and Rural Development and relevant authorities, a field observation programme for salinity intrusion was prepared and carried out by JICA Study Team in February and March, 1995.

The field observation of salinity intrusion aims to measure the salinity concentration by measuring electric conductivity (EC) through the following three kinds of observation:

a) Sectional observation: Measurement of salinity at various points of a section to delineate cross-sectional distribution of salinity concentration;

b) Longitudinal observation: Measurement of salinity at various sections along the river channel to delineate longitudinal distribution of salinity concentration; and

c) Consecutive observation: Hourly measurement of salinity of river water consecutively during a cycle of tidal movement (25 hours).

The observation sites and their locations are shown in Figure 3.1. Each observation principally includes the following work:

a) Sampling of river water in the sections and at the points specified;

b) Laboratory tests of sampled water to clarify the relationship between EC and salinity concentration as well as EC values of collected samples; and

c) Collection of relevant hydrological records during the observation period.

The observation programme for the salinity intrusion is briefly presented below:

<u>Field Work for Sectional Observation</u>

a) Observation sites: 20 sections

b) Field work items:

- Installation of temporary staff gauge to measure water level;
- Sampling water and bottling with sample code as specified; and
- Taking record of water levels at the beginning and at the end of observation together with notes on flow conditions and direction.

c) Sampling:

- Sampling points at a section : 5 verticals at each 1/6 of water surface width and 5 points of water surface (0.5 m below), 0.25 h, 0.5 h, 0.75 h and river bed (0.5 m above) on each vertical, where h is the water depth on each vertical. Where the vertical depth (h) is less than 5 m, 3 points of water surface, 0.5h, and river bed; and
- Sampling: Twice in a day at the specified time.

Field Work for Longitudinal Observation

a) Observation sites : 60 sites including those for sectional observation

- East and West Vam Co rivers : 20 sites
- Canals between the East Vam Co and Saigon rivers : 20 sites
- Saigon and Dong Nai rivers : 20 sites

b) Field work items:

- Sampling water and bottling with sample code as specified; and
- Taking notes on flow conditions and direction at the beginning and at the end of observation including the place, where the staff gauge is installed, and water level records.

c) Sampling:

- Sampling points at a site: 3 points of water surface (0.5 m below), 0.5 h and river bed (0.5 m above) on the deepest vertical; and
- Sampling : 4 times in a day at the specified time.

Field Work for Consecutive Observation

a) Observation sites: 20 sites same with those for sectional observation

b) Field work items:

- Sampling water and bottling with sample code as specified; and
- Taking record of water levels at the beginning and at the end of observation together with notes on flow conditions and direction.

c) Sampling:

- Sampling points at a site: 3 points of water surface (0.5 m below), 0.5 h, and river bed (0.5 m above) on the deepest vertical; and

- Sampling: Two series of hourly sampling for 25 hours each.

Laboratory Test

a) Measurement of EC with temperature (using the same EC meter in the laboratory)

   - Samples for sectional observation;
   - Samples for longitudinal observation; and
   - Samples for consecutive observation.

b) Salinity concentration test: Same samples used for the EC measurement, selecting 5 samples on the central verticals for each sectional observation section.

Execution : The field observation for salinity intrusion started in the middle of February and completed at the end of March in 1995 as shown in Figure 3.2. Date and time for the observation are decided considering the conditions of tidal movement based on the tide table as follows:

a) Sectional observation: at 10:00 and 17:00 on February 26, 1995

b) Longitudinal observation:

   - 1st day: at 7:00, 11:00, 14:00 and 17:00 on March 1, 1995
   - 2nd day: at 8:00, 12:00, 15:00 and 18:00 on March 2, 1995
   - 3rd day: at 9:00, 12:00, 15:00 and 18:00 on March 3, 1995

c) Consecutive observation:

   - Neap tide: 25 hours from 8:00 on March 12 to 9:00 on March 13, 1995
   - Spring tide: 25 hours from 8:00 on March 18 to 9:00 on March 19, 1995.

3.2 Relationship between EC and Salinity

The EC-values of the sampled water were measured in the laboratory using an EC-meter, YSI 33 S-C-T Meter manufactured by Yellow Springs Instrument Co., Inc. Ohio, USA. This meter has been designed to measure salinity (CL: ‰ or number of grams of salt in kilogram of sample), electric conductivity (EC: μ-mhos/cm or micro-mhos per centimeter) and temperature (°C or degrees Celsius)). This measurement of salinity assumes a standard sea water salt mixture, which means relationship between EC and salinity is fixed to, as they call, standard salt mixture. Temperature adjustments in salinity measurements are manually compensated directly by dial.

In order to clarify the actual EC-salinity relationship of water samples in the Study Area, salinity was also measured by the chemical analysis by using a part of samples collected through cross-sectional observation carried out on February 26, 1995.

Figure 3.3 comparatively shows the relationships between EC-value and salinity obtained for the same samples by chemical analysis (CLc) and gauge reading (CLg). A linear relation is observed between the EC-value and salinity for both the CLc and CLg as expressed below:

- Chemical analysis : CLc = 357 x EC
- Gauge reading : CLg = 576 x EC
- CLg/CLc = 1.61.

It should be noted that the gauge-read salinity (CLg) would give about 60 % higher salinity value than the actual salt mixture. The difference is not small. However, in the present study, gauge-read salinity is decided to use exclusively as an index, i.e. CL-value to show degree of salt mixture by considering the following reasons:

a) Existing salinity records in Ho Chi Minh City as well as Mekong delta have been measured mostly by YSI 33 S-C-T Meter, as widely used in Viet Nam for the measurement of salinity, since it is portable and simple in handling.

b) Salinity analyses and prevention measures in these areas have been made based on the above gauge-read salinity.

c) The use of gauge-read salinity as a salt-mixture index would not substantially cause problems, since the CL-value gives a higher value than the actual one. However, the difference between gauge-read salinity and actual salt mixture should be clarified.

d) Introduction of salinity values other than the current concept may lead misunderstandings and confusion.

3.3 Cross-sectional Salinity Observation

In order to clarify the distribution of CL-values in a channel section, CL-values were measured at 25 points set on five verticals across the river and five points at different depth on respective verticals. The cross-sectional observation was carried out simultaneously at 20 sections at 10 a.m. and 5 p.m. on February 26, 1995. The 10 a.m.-observation happened to be a rising tide and 5 p.m.-observation falling tide.

Results of cross-sectional salinity observation are shown in Table 3.1, telling following findings:

a) Low salinity sections: Observed CL-values are lower than 0.5 g/l for the sections at Moc Hoa, Tuyen Nhon, Hiep Hoa, Xuan Khanh (5 p.m.), Thu Dau Mot, An Son (10 a.m.), Bien Hoa and Long Binh. These stations are excluded from the analysis of cross sectional salinity distribution, since the values are close to the limit of observation by EC meter and the difference smaller than decimal in values has not any substantial physical meaning.

b) Difference between 10 a.m. and 5 p.m. observations: Substantial difference in sectional CL-distribution is not observed between observations at 10 a.m. and those at 5 p.m.

c) Vertical and lateral distribution: In order to look into the vertical distribution of CL-values, ratios of CL-values at water surface (50 cm below the surface: CLs) to river bed (50 cm above the bed: CLb) are calculated on each vertical, whilst a ratio of mean vertical CL-value (CLv) to mean sectional (CLm) is also calculated to see the lateral distribution. These ratios are summarized below excluding data whose CL-values are less than 0.5 g/l:

Vertical and Lateral Distribution of Salinity

Item	Left 1	Left 2	Centre	Right 2	Right 1
CLs/CLb					
Mean	0.94	0.99	0.98	0.95	0.97
Max.	1.20	1.80	1.43	1.10	1.27
Min.	0.44	0.69	0.63	0.57	0.50
CLs/CLb					
Mean	0.99	1.01	0.99	1.01	0.99
Max.	1.22	1.27	1.14	1.30	1.47
Min.	0.41	0.63	0.68	0.77	0.47

It can be said that sectional distribution of CL-values is rather uniform for the whole sections.

d) Salinity mixture type: Salinity intrusion is generally classified into three mixture types; weak mixture which could be simulated by salt wedge model, strong mixture which could be simulated by dispersion model, and moderate mixture as transition. According to Suga, researcher of the Ministry of Construction in Japan, these types of mixture are classified by the ratio of salinity concentrations at surface and bottom (CLs/CLb) as follows:

- Weak mixture : CLs/CLb < 0.1
- Moderate mixture : 0.1<CLs/CLb < 0.5

- Strong mixture : CLs/CLb > 0.5.

According to these criteria, the salinity intrusion in the Study Area falls under the category of strong mixture type, and thus the dispersion model should be adopted for salinity intrusion analysis.

e) *Existing sampling method: SIWRP is conducting periodical salinity observation to* sample surface water near river bank. Judging from uniform sectional distribution of CL-values, ratios of CLs/CLb and CLv/CLm, the SIWRP sample can be said in general to represent the CL-value of the whole of a section.

3.4 Longitudinal Salinity Observation

Longitudinal salinity observation is undertaken to grasp the longitudinal distribution of CL-values in the complicated channel network. The observation was conducted for three days by dividing the survey area into three river systems which respectively consist of 20 observation sections as follows:

a) March 1,1995 : West and East Vam Co river system

b) March 2,1995 : East Vam Co and Saigon river system

c) March 3,1995 : Saigon and Dong Nai river system.

Measurements were made at three different depths on the central vertical of each section four times a day at 7:00, 10:00, 14:00 and 17:00. Observation results are shown in Table 3.2 and Figure 3.4, suggesting the following:

a) Difference in time: Difference among four CL-values observed at different times in a day is small in general.

b) Extent of intrusion: Salinity of 4 g/l extends up to the Kinh Moi-Ben Luc River during the observation period, while along the Saigon-Dong Nai rivers the salinity was pushed down to Nha Be or lower. Salinity of 1 g/l reached up to AP Nha Tho for the West Vam Co River, Xuan Khanh for the East Vam Co River, Hiep Binh for the Saigon River and Phu Huu for the Dong Nai River .

c) Role of major channels in salinity intrusion: It is seen that the East Vam Co River is inducing the salinity into the land, while the Saigon and Dong Nai rivers are pushing down the salinity. The Kinh Moi-Ben Luc River connecting the channel laterally plays an important role to level off the salinity.

3.5 Consecutive Salinity Observation

The 25-hour consecutive salinity observation was conducted simultaneously at 20 sections to observe the effect of tidal movement to the salinity concentration and its propagation. The consecutive observation data are also used for the calibration of the salinity intrusion model.

The observation was made twice during the neap tide and the spring tide as follows:

a) Neap tide observation: From 8:00 a.m. on March 12 to 9:00 a.m. on March 13, 1995, and

b) Spring tide observation: From 8:00 a.m. on March 18 to 9:00 a.m. on March 19, 1995.

During the spring tide observation on March 18/19, hourly discharge measurements were also carried out at some selected sections using current meters.

Results of the consecutive salinity observation are shown in Table 3.3 and Figure 3.5 for the selected sections where CL-values exceed 0.5 g/l. From these data the following are observed:

a) Sections of high CL-value: Out of 20 sections for consecutive salinity observation, the CL-values higher than 0.5 g/l were observed only at 5 stations. They are Cau Noi, Can Giuoc, Nha Be, Ben Luc and Bin Dien for both observations on March 12/13 and March 18/19, 1995.

b) Response to tide: Rather smooth response of CL-value to tidal movement was observed at Cau Noi, Can Giuoc, Nha Be and Ben Luc, while that of Cau Noi was erratic. Variation of CL-values is smaller during neap tides and larger during spring tides. Response at Binh Dien was weak.

c) Time Lag: Time lag between tide and CL-value, comparing the tidal peaks and bottoms to the peaks and bottoms of the CL-values, is scaled up in Figure 3.5 for five sections as follows:

Time Lag between Tide and Salinity

	Cau Noi (hr)	Can Giuoc (hr)	Nha Be (hr)	Ben Luc (hr)	Binh Dien (hr)
(Mar. 12/13)					
Peak 1	N.C	2	4	5	N.C
Bottom 1	N.C	2	3	4	N.C
Peak 2	N.C	2	N.C	3	N.C
Bottom 2	N.C	N.C	N.C	N.C	N.C
(Mar. 18/19)					
Bottom 1	2	2	2	4	N.C
Peak 1	1	1	4	4	N.C
Bottom 2	2	3	3	4	N.C
Peak 2	2	3	3	4	N.C
Ave. time (hr)	1.8	2.1	3.2	4.0	-
Distance (km)	42.0	34.9	51.3	77.5	-
Ave. speed (m/s)	6.5	4.6	4.5	5.4	-
(km/hr)	2.3	17.0	16.0	19.0	-

N.C: not clear

The above Table tells that the time lag between tide and salinity proportionally increases as travel distance from the estuary increases toward the upstream direction with 4- to 5-hour delay for a travel distance of 70 to 80 km.

The variation of flow and CL-value at seven sites, Tuyen Mhon, Tan An, Xuan Khanh, Ben Luc, Phu An, Cat Lai and Nha Be, is shown in Table 3.4 and Figure 3.6 against water levels at the estuary and those seven sites. These data are used for calibrating the parameters given in the salinity intrusion model which is discussed in subsequent Chapter 4.

4. SALINITY INTRUSION ANALYSIS

4.1 Preparation of Salinity Intrusion Model

A salinity intrusion model in the lower Dong Nai, Saigon, East Vam Co and West Vam Co rivers (Dong Nai System) is prepared to evaluate the change of salinity intrusion under the various channel flow conditions, which would be caused by the water resources development in the upstream reaches. The salinity intrusion model of the Dong Nai River system so prepared requires to simulate:

- Unsteady flow under the change of sea tide and channel discharge,
- Channel discharge distribution in the complicated channel network, and
- Salinity intrusion by dispersion type.

It is also considered necessary to keep consistency with the salinity studies made for the Mekong delta, since the Dong Nai River system is located adjacent to or partly included in the Mekong delta, and furthermore since the intensive salinity studies for the delta have already been carried out.

4.1.1 Methodology

(1) Basic Equations

The basic equations applied for the analysis of salinity intrusion are as follows:

Equation of continuity:

$$B\frac{\partial H}{\partial t}+\frac{\partial Q}{\partial x}=q$$

Equation of motion:

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+gA\frac{\partial H}{\partial x}+\frac{g}{C^2AR}\frac{Q^2}{}=0$$

Equation for dispersion of salinity:

$$\frac{\partial S}{\partial t}+U\frac{\partial S}{\partial x}=D\frac{\partial^2 S}{\partial x^2}+\varphi-\sigma S$$

where

∂ : Partial differentiation

Q : Channel discharge

x : Distance along channel
t : Time
A : Flow area
H : Water level
g : Acceleration of gravity
R : Hydraulic mean depth of channel
C : Chezy's coefficient for uniform flow
B : Channel width
q : Total inflow/outflow such as rainfall, lateral inflow/outflow, etc.
S : Salinity concentration over a section
U : Flow velocity
φ : Unit area inflow/outflow of salinity load
σ : Unit area inflow/outflow of water
D : *Dispersion coefficient.*

(2) Configuration of Channel Network

The channel network model principally consists of:

- Channel: To link two nodes or one node and boundary,
- Node: Junction of channels,
- Boundary: Point where boundary condition is given, and
- Channel section: Point on the channel where sectional data are given.

Configuration of the channel network for the Dong Nai River system is illustrated in Figure 4.1.

(3) Boundary Conditions

In the model two kinds of boundaries are considered, i.e. discharge boundary and water level boundary. The following major boundaries are incorporated in the Dong Nai River system:

a) Discharge boundaries:

- Tri An: Discharge released from the reservoir
- Be River: Inflow from the tributaries
- Thi Tinh River (a tributary of the Saigon River): Inflow from the tributaries
- Dau Tieng: Discharge released from the reservoir

b) Water level boundaries:

- Go Dau (East Vam Co River)

- Moc Hoa (West Vam Co River)
- River mouth: Tide level.

4.1.2 Calibration of Model

The salinity intrusion model is calibrated using the field data collected on March 18/19, 1995. Based on the result of calibration, simulation is carried out for a time period of 15 days from March 5 to March 19 with a time step of 30 minutes.

The calibration consists of two steps; the first step is to simulate the recorded channel flow conditions such as water level and discharge, adjusting the conditions of channel section and network and other hydraulic factors. After confirming that the model simulates the channel flow satisfactorily, the calibration for salinity intrusion is carried out as the second step, adjusting the factors related to the dispersion of salinity. Boundary conditions for the calibration are adopted as given in Table 4.1 based on the recorded data.

The result of calibration is shown in Figure 4.2 for some selected sections, illustrating the simulated water level, discharge and salinity in comparison with the observed values.

4.1.3 Conditions for the Evaluation of Salinity Intrusion

Salinity concentration at various sections of interest and distribution of salinity are calculated using the simulation model for a period of 15 days with a time step of 30 minutes. The same boundary conditions used for the calibration are adopted principally for the simulation except for the case requiring the modification of the boundary conditions.

There is a standard on salinity concentration in using river water as a water source of domestic and irrigation supply as follows:

a) CL < 4 g/l: For an irrigation water source according to the practice in the Study Area and the Mekong delta, and

b) CL < 0.25 g/l: For a municipal water source according to Provisional Environmental Criteria, 1993; Ministry of Science, Technology and Environment.

The result of simulation for salinity intrusion will be used for judging the suitability as a water source of water supply and irrigation projects in terms of salinity concentration.

4.2 Study on Channel Flow and Salinity

4.2.1 Channel Flow Requirement in the Dong Nai and Saigon Rivers

HCMC and Bien Hoa have intakes at Hoa An and Thien Tan in the Dong Nai River respectively for their municipal water supply, whilst Thu Dau Mot town seeks a source of water supply to the Saigon River with an intake near the town. HCMC is now constructing another intake at Ben Than about 1.7 km upstream of the Thu Dau Mot intake site in the Saigon River. Salinity concentration of river water at these intake sites should be kept at 0.25 g/l or lower throughout the year as a raw water of domestic water supply.

There is no specific rule at present to release maintenance flow from the Tri An reservoir for securing the salinity concentration level to 0.25 g/l or lower at Hoa An in the Dong Nai River, however, turbine discharge of the Tri An hydroelectric power plant is set at 230 m^3/s in the normal dry season even with possibilities of smaller release through the dry season in a drought year. In the Saigon River, a water amount of 20 m^3/s is released from the Dau Tieng reservoir in the dry season for salinity prevention. With the flow from the Thi Thinh River, a main tributary of the Saigon River, a flow of more or less 25 m^3/s would be secured at the Thu Dau Mot intake site in the dry season.

A level of salinity concentration at the Hoa An site in the Dong Nai River and three sites in the Saigon River, i.e. the confluence with the Thi Tinh River, Thu Dau Mot and An Son, is calculated by the simulation model under various combinations of river flows of the Dong Nai River and the Saigon River; that is, the former ranges from 50 m^3/s to 300 m^3/s and the latter varies from 10 m^3/s to 100 m^3/s. Discharge in the Dong Nai River indicates a sum of water released from Tri An reservoir and runoff from the Be River, whilst water released from the Dau Tieng reservoir plus runoff from the Thi Tinh River is treated as discharge in the Saigon River.

Results of the simulation are summarized in Figure 4.3. From the simulation result, the following can be read:

a) Hoa An site: Salinity at the Hoa An site is estimated to be less than the allowable limit (0.25 g/l) even for the discharge combination of 50 m^3/s in the Dong Nai River and 10 m^3/s in the Saigon River.

b) Thu Dau Mot site: Salinity at the Thu Dau Mot site is estimated to be less than 0.25 g/l for any case more than 20 m^3/s in the Saigon River. The same result is obtained when the flow of the Dong Nai River is greater than 200 m^3/s.

c) Salinity for the case of D100S25: For the discharge combination of 100 m^3/s in the

Dong Nai River and 25 m^3/s (existing maintenance flow) in the Saigon River, salinity at the Hoa An site and the Thu Dau Mot site is estimated at 0.05 g/l and 0.23 g/l, respectively, both satisfying the allowable limit. A flow of 100 m^3/s at Hoa An in the Dong Nai River and 25 m^3/s at the Thu Dau Mot site in the Saigon River is therefore concluded to be maintained throughout the year for salinity intrusion. This result is incorporated as a boundary condition in the simulation model of the optimal water allocation study discussed in Appendix X.

Further detailed simulation results of salinity intrusion for the case of D100S25, i.e. 100 m^3/s in the Dong Nai River and 25 m^3/s in the Saigon River, are summarized in Figures 4.4, 4.5 and 4.6 and Table 4.2. Figure 4.4 presents variation of salinity concentration during a calculation period of 15 days at three selected sites, Nha Be, Cat Lai and Hoa An. Figure 4.5 presents the distribution of the maximum values of salinity concentration during the calculation period, whilst Figure 4.6 and Table 4.2 show the longitudinal distribution of the maximum and minimum values of salinity concentration during the calculation period.

4.2.2 Channel Flow Requirement in the East Vam Co River

(1) Low Flow Discharge of Existing Channel

Discharge records are not available for the reaches of the East Vam Co River subject to the salinity study, since the river is located in the tide-affected area. According to a verbal information obtained from SIWRP, a channel discharge of 20 to 25 m^3/s is necessary at Xuan Khanh to secure the river water suitable as an irrigation water source. It is further informed that the channel discharge at Xuan Khanh consists of 10 to 15 m^3/s from the East Vam Co River itself and the release from the Dau Tieng reservoir for remaining.

It is assumed in the present study that low flow discharge of the East Vam Co River itself is 10 m^3/s and that the supply from the Dau Tieng reservoir is also 10 m^3/s. The low flow discharge at Xuan Khanh is, therefore, assumed to be 20 m^3/s under the present condition.

(2) Simulation of Salinity Intrusion

A trans-basin scheme from the Be River is contemplated for the development of HCMC-Long An delta in the Study Area. In the scheme, irrigation water is to be led to the East Vam Co River upstream of Xuan Khanh via Dau Tieng reservoir and its west canal from the Be River.

In order to evaluate the influence of salinity intrusion to further irrigation development in the HCMC-Long An delta, salinity distribution is simulated for various channel discharges at Xuan Khanh. However, the channel discharge at Xuan Khanh cannot be input directly, since channel discharge changes time by time due to the effect of tide. Thus, water levels observed during the calculation period of 15 days at Go Dau are instead used by the transaction to add or deduct a fixed value for all the values observed for 15 days. The channel discharge estimated from the water level by such transaction is used for the salinity simulation by taking hourly average discharges during the calculation of 15 days.

A relationship between discharge and salinity at Xuan Khanh estimated based on the above transaction is obtained as illustrated in Figure 4.7, whilst the distribution of maximum salinity computed for various discharges at Xuan Khanh is shown in Figure 4.8, suggesting following things:

a) Salinity concentration is estimated at 2.0 g/l for 10 m^3/s which corresponds to discharge from the East Vam Co River without supply from Dau Tieng reservoir.

b) Salinity is estimated at 1.7 g/l for 20 m^3/s which corresponds to the existing low flow discharge consisting of 10 m^3/s from the East Vam Co River and 10 m^3/s from Dau Tieng reservoir.

Salinity concentration at Xuan Khanh is lower than the allowable limit of 4 g/l even for the low flow discharge of 10 m^3/s. Taking into consideration the facts that the boundary conditions given for the West Vam Co River involve uncertainties by the influence from the Mekong River and that an allowable limit of salinity concentration of 4 g/l is required more strict conditions for irrigated agriculture development, a flow of 20 m^3/s is set as the boundary condition of the East Vam Co River at Xuan Khanh for the optimal water allocation study discussed in Appendix X.

4.3 Study on Influence of Channel Improvement for Inland Navigation

Channel improvement works for inland navigation by deepening and widening the river channel in the deltaic estuary may affect the salinity intrusion. From this viewpoint, existing conditions and plans of the inland navigation are reviewed, and then the effect of channel improvement to the salinity intrusion is evaluated.

4.3.1 *Inland Navigation*

(1) Existing Inland Navigation

HCMC has a key port for inland navigation in this area. The port is linked with three (3) international lines to Phnong Penh and Konponcham in Cambodia and Vuong Kham in Laos;

two (2) domestic sea lines to Vung Tau and Mekong delta via Tieu mouth of the Tieu River and Dinh An mouth of the Hau Giang River, and to Hai Phong, Da Nang and Quy Nhon; and many other trans-provincial lines.

According to "Network of Inland Waterways and Highways in the Lower Mekong Delta" by WATCO and information obtained from Saigon Port Authority, there are seven (7) primary waterways for navigation in the Study Area as summarized in Table 4.3 and Figure 4.9:

a) From HCMC to Vung Tau,
b) From the Dong Nai mouth to Tri An,
c) From Cat Lai to Ben Suc in the Saigon River,
d) From HCMC to Ben Keo in the East Vam Co River,
e) From HCMC to Moc Hoa in the West Vam Co River,
f) From HCMC to My Tho/Mekong delta via the Dong Nai-Vam Co rivers, and
g) From HCMC to My Tho/Mekong delta via the Can Giuoc-Vam Co rivers.

(2) Navigation Improvement Plan

During the time period from the year 1991 to 1993, a master plan study on Mekong delta was carried out under the State Planning Committee in cooperation with ministries and local authorities concerned. As a component project of the master plan, a recovery and improvement plan of two main waterways in the Mekong delta was proposed and its feasibility study has been completed. Two routes proposed for the improvement are deemed to correspond to the existing route from HCMC to My Tho/Mekong delta via the Kinh Te canal, the Cay Kho River, the Can Giuoc River and the Vam Co River.

Regarding the navigation improvement plan of the Can Giuoc-Vam Co rivers, no detailed data and information are available except for the following:

a) River reaches of the Can Giuoc River between two confluences with the Vam Co River and the Cay Kho River:

- Canal depth : 3 m
- Canal bed width : 90 m

b) River reaches of the Cay Kho River-Kinh Te canal between two confluences with the Can Giuoc River and the Saigon River:

- Canal depth : 2 m
- Canal bed width : 70 m.

4.3.2 Influence of Channel Improvement

In order to evaluate the influence of channel improvement for the Kinh Te canal, the Cay Kho River and the Can Giuoc River to the salinity intrusion, the navigation canal section is assumed as follows:

a) Canal section is trapezoidal with side slopes of 1 on 2;

b) Water depth is set below mean low water level of tide (MLWL), which is assumed to be -2.00 m MSL based on the study results of tide levels as follows:

- MLWL at Vung Tau : -2.24 m, MSL
- MLWL at Saigon Port : -1.72 m, MSL.

Simulation analysis for the salinity intrusion is made for the following cases:

a) Case-0: Existing channel

b) Case-1: Improved channel proposed by Mekong delta master plan

- Can Giuoc River: a water depth of 3 m (assumed bed elevation: -5.00 m MSL) and a river bed width of 90 m
- Cay Kho River-Kinh Te Canal: a water depth of 2 m (assumed bed elevation: -4.00 m MSL) and a river bed width of 70 m

c) Case-2: Improved channel assumed for the present study

- Can Giuoc River: a water depth of 3 m (assumed bed elevation: -5.00 m MSL) and a river bed width of 90 m
- Cay Kho River-Kinh Te Canal: Same section with the Can Giuoc River.

For both the cases, i.e. Cases 1 and 2, channel improvement will be made mainly for the Cay Kho River and Kinh Te Canal, although the Case-1 works are of small scale. Distribution of the estimated maximum salinity for respective cases is shown in Figure 4.10.

According to the result of simulation, changes in salinity are slight, and adverse effects brought about by the channel improvement would not be substantial for both the cases, i.e. Cases 1 and 2.