JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE [illegible] REPUBLIC OF VIET NAM
MINISTRY OF AGRICULTURE AND RURAL DEVELOPMENT

THE MASTER PLAN STUDY
ON
[illegible] RIVER AND SURROUNDING BASINS
WATER RESOURCES DEVELOPMENT

FINAL REPORT

VOLUME IV

APPENDIX VIII [illegible]
[illegible]
[illegible]

[illegible]

NIPPON KOEI CO., LTD., TOKYO JAPAN

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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

THE MASTER PLAN STUDY ON DONG NAI RIVER AND SURROUNDING BASINS WATER RESOURCES DEVELOPMENT

FINAL REPORT

VOLUME IX

APPENDIX VIII FLOOD MITIGATION AND URBAN DRAINAGE
APPENDIX IX SALINITY INTRUSION

AUGUST 1996

NIPPON KOEI CO., LTD., TOKYO JAPAN

This Report consists of

Volume I	Executive Summary	
Volume II	Main Report	
Volume III	Appendix I	Socio-economy and Institution
Volume IV	Appendix II	Topography and Geology
	Appendix III	Meteorology and Hydrology
Volume V	Appendix IV	Natural Environment
Volume VI	Appendix V	Hydropower Generation
Volume VII	Appendix VI	Agricultural Development and Irrigation
Volume VIII	Appendix VII	Domestic and Industrial Water Supply
Volume IX	Appendix VIII	Flood Mitigation and Urban Drainage
	Appendix IX	Salinity Intrusion
Volume X	Appendix X	Formulation of Master Plan
Volume XI	Data Book	

The cost estimate was based on the December 1995 price level and expressed in US$ according to the exchange rate of US$ 1.00 = Vietnamese Dong 11,014 = Japanese Yen 101.53 as of December 15, 1995.

LIST OF ABBREVIATIONS

AFS	Agriculture and Forestry Service (PC)
CEMMA	Committee for Ethnic Minorities and Mountainous Areas
DCWSSS	Design Company for Water Supply and Sanitation System (HCMC-PC)
EA	Environment Assessment (Multi-lateral Lending Agencies)
ECSP	Evaluation Commission for State Projects
EIA	Environmental Impact Assessment
ENCO	Ho Chi Minh City Environmental Committee
EVN	*General Company of Electricity of Viet Nam (Abolished and renamed in November 1995 as Vietnamese Power Corporation)*
FIPI	Forest Inventory and Planning Institute (MOARD)
GCOP	Governmental Committee on Organization and Personnel
GDLA	General Department of Land Administration
GDMH	General Department of Meteorology & Hydrology
GOV	Government of Viet Nam
GSO	General Statistical Office
HCMC	Ho Chi Minh City
HEC	Ho Chi Minh Environment Committee (HCMC)
HIDC	Hydraulic Investigation and Design Company (MOARD)
HPC	Ho Chi Minh People's Committee (HCMC)
HSDC (or SDC)	Ho Chi Minh Sewerage and Drainage Company (HCMC)
HWSC (or WSC)	Ho Chi Minh Water Sypply Company (HCMC)
IDD	Irrigation and Drainage Department (MOARD)
IEE	Initial Environmental Examination
IER	Institute for Economic Research (HCMC-PC)
IHPH	Institute of Hygiene and Public Health (MOPH)
IM	Institute of Mines (MOID)
INVESCo	Investment Company for the Development of Water Sector (HCMC-PC/TUPWS)
IOE	Institute of Energy (MOID)
IURP	Institute of Urban and Rural Planning (HCMC-PC/Construction Service)
IWRE	Institute of Water Resources Economics (MOARD)
IWRP	Institute of Water Resources Planning (MOARD)
IWRR	Institute of Water Resources Research (MOARD)
JICA	Japan International Cooperation Agency (Japan)

This Report consists of

Volume I	Executive Summary	
Volume II	Main Report	
Volume III	Appendix I	Socio-economy and Institution
Volume IV	Appendix II	Topography and Geology
	Appendix III	Meteorology and Hydrology
Volume V	Appendix IV	Natural Environment
Volume VI	Appendix V	Hydropower Generation
Volume VII	Appendix VI	Agricultural Development and Irrigation
Volume VIII	Appendix VII	Domestic and Industrial Water Supply
Volume IX	Appendix VIII	Flood Mitigation and Urban Drainage
	Appendix IX	Salinity Intrusion
Volume X	Appendix X	Formulation of Master Plan
Volume XI	Data Book	

The cost estimate was based on the December 1995 price level and expressed in US$ according to the exchange rate of US$ 1.00 = Vietnamese Dong 11,014 = Japanese Yen 101.53 as of December 15, 1995.

LIST OF ABBREVIATIONS

AFS	Agriculture and Forestry Service (PC)
CEMMA	Committee for Ethnic Minorities and Mountainous Areas
DCWSSS	Design Company for Water Supply and Sanitation System (HCMC-PC)
EA	Environment Assessment (Multi-lateral Lending Agencies)
ECSP	Evaluation Commission for State Projects
EIA	Environmental Impact Assessment
ENCO	Ho Chi Minh City Environmental Committee
EVN	*General Company of Electricity of Viet Nam (Abolished and renamed in November 1995 as Vietnamese Power Corporation)*
FIPI	Forest Inventory and Planning Institute (MOARD)
GCOP	Governmental Committee on Organization and Personnel
GDLA	General Department of Land Administration
GDMH	General Department of Meteorology & Hydrology
GOV	Government of Viet Nam
GSO	General Statistical Office
HCMC	Ho Chi Minh City
HEC	Ho Chi Minh Environment Committee (HCMC)
HIDC	Hydraulic Investigation and Design Company (MOARD)
HPC	Ho Chi Minh People's Committee (HCMC)
HSDC (or SDC)	Ho Chi Minh Sewerage and Drainage Company (HCMC)
HWSC (or WSC)	Ho Chi Minh Water Sypply Company (HCMC)
IDD	Irrigation and Drainage Department (MOARD)
IEE	Initial Environmental Examination
IER	Institute for Economic Research (HCMC-PC)
IHPH	Institute of Hygiene and Public Health (MOPH)
IM	Institute of Mines (MOID)
INVESCo	Investment Company for the Development of Water Sector (HCMC-PC/TUPWS)
IOE	Institute of Energy (MOID)
IURP	Institute of Urban and Rural Planning (HCMC-PC/Construction Service)
IWRE	Institute of Water Resources Economics (MOARD)
IWRP	Institute of Water Resources Planning (MOARD)
IWRR	Institute of Water Resources Research (MOARD)
JICA	Japan International Cooperation Agency (Japan)

MOAFI	*Ministry of Agriculture and Food Industry (Abolished and integrated into the new MOARD)*
MOAP	Ministry of Aquatic Products
MOARD (New)	Ministry of Agriculture and Rural Development (Created in October 1995 by the merger of the former Ministry of Water Resources, Ministry of Agriculture and Food Industry and Ministry of Forestry)
MOC	Ministry of Construction
MOCI	Ministry of Culture and Information
MOD	Ministry of Defence
MOE	*Ministry of Energy (Abolished and integrated into the new MOID)*
MOET	Ministry of Education and Training
MOFI	Ministry of Finance
MOFO	*Ministry of Forestry (Abolished and integrated into the new MOARD)*
MOFA	Ministry of Foreign Affairs
MOHI	*Ministry of Heavy Industry (Abolished and integrated into the new MOID)*
MOID(New)	Ministry of Industry (Created in November 1995 by the merger of the former Ministries of Heavy Industry, Light Industry and Energy)
MOJ	Ministry of Justice
MOIT	Ministry of Interior
MOLI	*Ministry of Light Industry (Abolished and integrated into the new MOID)*
MOLWISA	Ministry of Labour, War Invalids and Social Affairs
MOPH	Ministry of Public Health
MOPI (New)	Ministy of Planning and Investment (Formed from a merger of the former SPC amd SCCI)
MOSTE	Ministry of Science, Technology and Environment
MOTC	Ministry of Transport and Communications
MOT	Ministry of Trade
MOWR	*Ministry of Water Resources (Abolished and integrated into the new MOARD)*
MPAC	Ministrial Project Appraisal Committee
NEA	National Environment Agency
NGO	Non-Governmental Organization
NIAPP	National Institute for Agricultural Planning and Projection
NPAC	National Project Appraisal Committee
OECC	Overseas Environmental Cooperation Centre
OECF	Overseas Economic Cooperation Fund (Japan)
PC	People's Committee (executive arm of the People's Council)

PCC	Power Construction Company (VPC)
PIDC	Power Investigation and Design Company (VPC)
PPC	Provincial People's Committee (City People's Committee = CPC)
SBV	State Bank of Viet Nam
SCCI	*State Committee for Cooperation and Investment (Abolished and integrated into the new MOPI)*
SFEZ (or SFEA)	Southern Focal Economic Zone (or Southern Focal Economic Area)
SIWRP	Sub-Institute of Water Resources Planning (MOARD-IWRP)
SIWRR	Southern Institute of Water Resources Research (MOARD)
SPC	*State Planning Committee (Abolished and integrated into the new MOPI)*
SRV	Socialist Republic of Viet Nam
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Education Fund
UNIDO	United Nations Industrial Development Agency
VPC (New)	Vietnam Power Corporation (the former General Company of Electricity of Viet Nam = EVN)
WASECO	Water and Sewerage Construction Company (MOC)
WB	World Bank
WHO	World Health Organization
WPMI (IWRPM)	Water Planning and Management Institute (MOARD)
WRD(or WRS)	Water Resources Department or Water Resouce Service (PC)
WSC	Water Supply Company (under Construction Services of the PC)

Note : Abbreviations in *Italics* are no more existent (already abolished and integrated in November 1995).

Measurements

Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer
ft	=	foot
yd	=	yard

Electric Measurements

V	=	Volt
A	=	Ampere
Hz	=	Hertz (cycle)
W	=	Watt
kW	=	kilowatt
MW	=	Megawatt
GW	=	Gigawatt

Area

cm^2	=	square centimeter
m^2	=	square meter
ha	=	hectare
km^2	=	square kilometer

Other Measures

%	=	percent
PS	=	horsepower
^{0}	=	degree
10^3	=	thousand
10^6	=	million
10^9	=	billion

Volume

cm^3	=	cubic centimeter
l	=	litre
kl	=	kilolitre
m^3	=	cubic meter

Derived Measures

m^3/s	=	cubic meter per second
kWh	=	Kilowatt hour
MWh	=	Megawatt hour
GWh	=	Gigawatt hour
kVA	=	kilovolt ampere

Weight

g	=	gram
kg	=	kilogram
ton	=	metric ton

Currencies

US$	=	US Dollar
VND	=	Vietnamese Dong

Time

s	=	second
min	=	minute
h	=	hour
d	=	day
y	=	year

Volume IX

Appendix VIII

FLOOD MITIGATION AND URBAN DRAINAGE

APPENDIX VIII

Flood Mitigation and Urban Drainage

TABLE OF CONTENTS

Pages

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

The existing situation of flooding in the Study Area is first clarified from the flood mitigation viewpoint, and then flood discharge is estimated under the conditions with and without reservoir(s). On the basis of these study results, basic matters of flood mitigation and drainage are discussed for respective flood-prone areas in the Study Area.

The Ministry of Agriculture and Rural Development (MOARD) is in charge of water resources management. All the activities related to water resources such as water use and flow regulation are under the administration of the Ministry.

Activities related to the flood mitigation are principally managed by the MOARD and the urban drainage by the MOARD or the Ministry of Construction (MOC). Water quality matters are handled by the Department of Science - Technology and Environment (DSTE). Administrative agencies in charge of respective activities are outlined as follows:

	Administrative Agencies		
Activity	Flood mitigation	Urban drainage	Water quality
Investigation	MOARD	MOARD or MOC	DSTE
Planning	MOARD	MOC	DSTE
Design	MOARD	MOARD or MOC	DSTE
Construction	Company under MOARD	Company under MOARD and MOC	-
Operation and maintenance	Central or provincial company under MOARD	Provincial company under MOC	Provincial company under DSTE

The Ministry of Agriculture and Rural Development has responsibility to prepare policies and instructions related to the water resources management, and at present is preparing the water law to submit to the National Assembly for approval.

2. EXISTING CONDITIONS

2.1 Basin and River System

The Dong Nai River system consists of the main Dong Nai, La Nga, Be, Saigon, East Vam Co and West Vam Co rivers, the catchment area of which is 40,683 km^2 in total. About 10% of the total basin (4,168 km^2) is located outside of the country, i.e. in Cambodia. Except for the East Vam Co River, almost all the river basins are located in the territory of Viet Nam as presented below:

Basin Area

River	Basin Area (km^2)	
	Whole Basin	Inside Country
Main Dong Nai	14,979	14,979 (100%)
La Nga	4,093	4,093 (100%)
Be	7,427	7,201 (97%)
Saigon	4,717	4,316 (91%)
East Vam Co	8,546	5,005 (59%)
West Vam Co (Left bank area)	921	921 (100%)
Total	40,683	36,515 (90%)

In the above Table, the basin area of the West Vam Co River is not for the whole but limited to the left bank area.

Overall longitudinal profiles of these rivers are prepared based on the topographic map with a scale of 1 to 250,000 as given in Figure 2.1. The channel slope of each river is outlined as follows:

Channel Slope

River	Channel Slope
Main Dong Nai	1/4,500 (L), 1/1,060 (M), 1/230 or more (U)
La Nga	1/1,200 (L), 1/120 or more (U): Abrupt change
Be	1/5,200 (L), 1/70 or more (U): Gradual change
Saigon	1/5,200 (L), 1/850 (U)
Vam Co	1/4,000: Mild slope as a whole

Note: L, M and U indicate lower, middle and upper reaches, respectively.

The Dong Nai River is closely related to the development of the economic triangle zone, which is one of the focal economic development zones in the country and includes the towns and city of Ho Chi Minh City, Bien Hoa and Ba Ria-Vung Tau as development centres.

2.2 General Features of the Rivers

General features of the main Dong Nai River and its major tributaries are studied from the flood disaster viewpoint based on the topographic maps with a scale of 1 to 50,000. Major interesting points along the river and their distance from the river mouth are summarized in Table 2.1. In this study, the distance of interesting points is measured from the river mouth unless otherwise described.

Based on Figure 2.1, channel slope and degree of meandering are measured as shown in Figure 2.2. Sinuosity index (SI) is introduced to present the degree of meandering as defined below:

$$SI = (Lc - Ld) / Lc$$

where

SI : sinuosity index; null for straight channel, getting larger for severe meandering and one at maximum,

Lc : unit channel length (Lc = 10 km : constant), and

Ld : aerial distance between the beginning and ending points of the channel corresponding to Lc (km).

The mean values of sinuosity index calculated for the Main Dong Nai River and its major tributaries are summarized below:

Sinuosity Index

River	Stretch	Mean SI-value
Main Dong Nai	Mouth to 300 km	0.27
La Nga	Mouth to 160 km	0.41
Be	Mouth to 160 km	0.42
Saigon	Mouth to 140 km	0.37
East Vam Co	Mouth to 210 km	0.27
West Vam Co	Mouth to 140 km	0.31

There are two types of meandering in general, i.e. free meandering and forced meandering. The free meandering is formed freely by the water and sediment flows and would be seen in the sedimentary geography as an alluvial plain. The forced meandering is formed by the scouring actions of water flow and the foundation materials to resist the scouring, and would be seen in the river channels lying in the mountain area. The free meandering is generally unstable and would cause erosion and sedimentation problems.

The morphological characteristics of the main Dong Nai and its major tributaries are discussed below based on Figures 2.1 and 2.2.

(1) Main Dong Nai River

The main Dong Nai River forms a valley in the reaches of 290 km point upward. Flood problems are not important in these reaches. Channel profile of the Dong Nai River is unique with two steep slope reaches, the lower and upper rapids.

The lower rapids extend from 154 km point (near the confluence with the Be River) to Tri An dam (160 km) with an average slope of 1/180. The upper portion of the lower rapids is now submerged under the Tri An reservoir, and the tail water of the reservoir reaches the foot of the upper rapids.

The upper rapids extend from 200 km point (near the confluence with the La Nga River) to around 230 km (near Ta Lai station) with an average slope of 1/550. In the upstream reaches of the rapids, the channel slope is gentle, and the sinuosity index gets higher. Flood-prone areas such as Ta Lai and Cat Tien are located there.

Forced meandering prevails in the upstream reaches of 140 km point, whilst in the downstream reaches free meandering seems to prevail. Along the reaches of free meandering, flood-prone areas such as Tan Uyen/Vinh An, Long Thanh/Thu Duc and Nhon Trach are located.

(2) La Nga River

In the upper reaches from 150 km point, the La Nga River forms a valley and there exist few settlements. In the lower reaches from the confluence with the Dong Nai River to 54 km point, the channel slope is steep. The average slope is 1/830 in these reaches, and rapids and falls are seen in places.

In the upper reaches from 54 km point, channel slope gets milder abruptly and an extensive plain extends up to around 135 km. In the plain the river channel meanders severely with a high sinuosity index. Extensive flood-prone areas such as Tanh Linh and Duc Linh are located in this plain.

In the steep slope reaches downstream of 54 km point, the La Nga River forms forced meandering, and in the plain area from 54 to 135 km point it forms free meandering.

(3) Be River

The lower and middle Be River has a mild slope of about 1/5,200. The river curves its route on the plateaus of around 50 m MSL, forming a valley. Alluvial plain is not found along the Be River.

The channel meanders severely in the lower reaches of 100 km point by the action of forced meandering. Settlements along the river are few due to the deep valley, and thus flooding problems of the Be River are not serious.

(4) Saigon River

The Saigon River forms a valley in the upstream reaches of 130 km point. The slope of the river is very mild, resulting in less than 10 m MSL even at 130 km point.

From the section at around 130 km to 60 km (near the confluence with the Thi Tinh River), the Saigon River is confined by low plateau ranging 10 to 30 m MSL, having a narrow alluvial plain (1 to 3 km wide) developed along the river course.

In the downstream reaches from 60 to 13 km (near the Ben Luc River), the river forms free meandering confined by discontinuous low plateau with a 2 to 5 km wide alluvial plain. The river channel in this stretch is connected with the East Vam Co River and others in-between channels and canals. The major connecting channels are the Rach Tra canal and the Ben Luc River.

Meandering of the Saigon River is moderate except for some sporadic severe meandering reaches.

The urban area of HCMC develops mostly on the isolated plateau ranging 3 to 10 m MSL. Flood-prone areas such as Thay Cai, Vin Loc A & B, Van Hai and Le Minh Xuan, extending in the low-lying land lower than 2 m MSL, are located between the Saigon and East Vam Co rivers and receive the affects of flood water caused by the inter-action of river flow and tides.

(5) East and West Vam Co Rivers

Both the East and West Vam Co rivers are located on the eastern boundary of the Mekong delta and their slope is very mild. The river channel forms free meandering with moderate sinuosity index. Flooding in these areas is, in general, shallow in depth but extensive in area.

2.3 Meteo-hydrology

(1) *Climate and Rainfall*

Two stations, Lien Khuong station in Da Lat and Tan Son Nhat (or Tan Son Hoa) station in Ho Chi Minh City (HCMC), are selected to compare the climate in the upper and lower basins of the Dong Nai River. Monthly rainfall, temperature and relative humidity of two stations are shown in Figure 2.3 for comparison.

Rainfall is most distinctive in the basin's climate, and the rainy season is clearly observed. The rainy season, in which monthly rainfall exceeds 100 mm, lasts for seven months from

May to November in HCMC and from April to October in Da Lat, i.e. one month delay for the former. Rainfall in the rainy seven months accounts for 93 % of annual rainfall of 1,792 mm in HCMC, whilst 89 % of annual rainfall of 1,610 mm in Da Lat. During the rainy season, monthly rainfall evenly distributes with slight difference in high peaks. On the other hand, the minimum monthly rainfall occurs in February in HCMC and January in Da Lat.

Changes of monthly air temperature are slight throughout the year at both the stations; monthly air temperature in HCMC ranges from the minimum value of 25.9°C in December to the maximum of 29.3°C in April with an annual average of 27.4°C, while that of Da Lat ranges from 19.4°C in December to 22.8°C in May with an annual average of 21.2°C.

The monthly relative humidity varies with the similar tendency to rainfall in general. The relative humidity in HCMC ranges from the minimum value of 69.8 % in February to the maximum of 84.3 % in September with an annual average of 77.5 %. In Da Lat, the relative humidity varies from the minimum of 70.2 % in March to the maximum of 88.7 % in October with an annual average of 80.8 %.

(2) Runoff

Runoff characteristics in the Dong Nai River basin are examined based on the discharge data collected at three stream gauging stations, i.e. Tri An in the main Dong Nai River, Phuoc Hoa in the Be River and Dau Tieng in the Saigon River, as summarized in Table 2.2 and Figure 2.4. Discharge records are not available for the West and East Vam Co rivers, since the channel flow of these rivers is subject to tidal movements.

Tri An and Dau Tieng stations are located at the outlet of Tri An and Dau Tieng reservoirs respectively, and thus the discharges of these stations are subject to artificial control. Discharge at the Phuoc Hoa station in the Be River shows relatively natural runoff due to the fact that the basin area upstream of the Thac Mo reservoir built in the Be River is 2,200 km^2, accounting for 38 % of the basin area upstream of the Phuoc Hoa station.

Features of average monthly discharge observed at three stations are summarized below, showing peak runoff in August at Tri An and in September at Dau Tieng and Phuoc Hoa:

Features of Monthly Discharge

River Station	Dong Nai Tri An	Be Phuoc Hoa	Saigon Dau Tieng
Catchment area (km^2)	14,025	5,765	2,700
Maximum			
Month	August	September	September
Monthly discharge (m^3/s)	1,421	574	132
Specific discharge ($m^3/s/km^2$)	0.101	0.100	0.049
Minimum			
Month	March	April	April
Monthly discharge (m^3/s)	48	15	20
Specific discharge ($m^3/s/km^2$)	0.003	0.003	0.007
Annual average			
Discharge (m^3/s)	542	199	56
Runoff height (mm)	1,217	1,090	648
Max.-min. ratio	30	38	6.6

In the above Table, the max.-min. ratio is worked out as a ratio of the maximum monthly rainfall to the minimum and would be an index to show the degree of change in channel flow throughout a year.

Runoff at Tri An and Phuoc Hoa stations shows the similar features with an annual runoff height of 1,217 mm and 1,090 mm and the max.-min. ratio of 30 and 38, respectively. On the other hand, Dau Tieng station presents different runoff features from the other two; about half in annual runoff height and about 20 % in the max.-min. ratio. This fact indicates that the difference of discharge in the dry and rainy seasons is markedly small in comparison with the other two stations.

2.4 Past Flood Disasters

(1) Meteorological Causes of Floods

The rainy season in the Dong Nai River basin begins in April/May and ends in October/November. Runoff gradually increases from May and channel water level rises. The strong rainstorm occurred under these conditions would bring about a large flood. The strong rainstorm with a wide rainfall area, which rarely occurs, is caused by typhoon and/or hovering front. Rainfall most frequently occurred in the Study Area is shower, which sometimes has high intensity but does not always cause serious flood due to its short duration and small rainfall area.

(2) Flood-prone Areas

Figure 2.5 shows the flood-prone areas in the Study Area. Flooding in the Study Area can be classified into three types, i.e. flooding due to flush runoff (1st type flood), flooding due to passage of flood flow through topographically insufficient sections (2nd type flood), and stagnancy of flood water due to high water level of trunk channel and sea tide (3rd type flood).

The 1st type flood, which has quick rising and draining, usually occurs in the upstream reaches of the Dong Nai River, the La Nga River and the Be River with a short time duration. This type of flood would not inundate a large area, resulting in little serious damage due to rapid drain.

The 2nd type flood causes inundation in a large area. This type of flood occurs in the Cat Tien plain (Lam Dong province) in the upper Dong Nai River and the Tanh Linh-Duc Linh (Binh Thuan province) plain in the La Nga River, and the similar type of flood occurs also in the Vinh An (Dong Nai province) - Tan Uyen (Song Be province) areas in the middle reaches of the Dong Nai River. In the Tanh Lin-Duc Linh and Vinh An-Tan Uyen sites, inundation sometimes lasts for more than a month. The floods cause damages mainly to agricultural crops, public facilities and private houses.

The 3rd type flood occurs in the lower reaches of the Dong Nai River, the Saigon River and the Vam Co River. Because of low-lying lands affected by tides, these areas are inundated for a long time period of one to several weeks, and the damages to agricultural crops are serious. The typical areas subject to this type of flood are found in Long Thanh and Nhon Trach in the lower Dong Nai River, and in Le Minh Xuan, Pham Van Hai and the areas along the Thay Cai canal in Ho Chi Minh City and Long An province.

(3) Major Past Floods

The basin experienced serious flood damages in the year 1932, 1952, 1964 and 1978 since the year 1930. The flood in the year 1952 is considered as the recorded largest and the 1978-flood as the biggest one in recent years. Markedly big floods have not been observed since the year 1978.

The 1952-flood attacked the Study Area from October 18 to 24. Estimated peak discharge in Bien Hoa is reported to be about 12,000 m^3/s with a return period of 80 to 100 years. The flood was caused by typhoon with long-lasting heavy rain over a wide area.

The 1978-flood took place during the period from the end of August to the beginning of September. The return period of 1978-flood is estimated to be about 10 years. The south-west monsoon stationed in the South under the effect of some storms in the Central and the North caused heavy rain in the basin. In the year 1978, the Mekong River system also experienced a very big flood with peak discharge in October.

(4) Flood Disasters in the Coastal River Basins

Since coastal rivers are short in length and have a steep slope, floods in these rivers emerge and withdraw rapidly, and thus a big flood rarely happens. But once it occurs the flood always causes severe damages in the lower plains such as Phan Rang plain, Luy River plain and Phan Thiet plain. The flood usually occurs in September, October and November.

The Phan Rang River experienced a historically big flood on December 17, 1964, which is considered to have a 50 to 100-year return period. Besides that, there was another large flood in the year 1979 as well, caused flood damage in the Phan Rang plain.

2.5 Existing River Facilities and Previous Studies

According to the data and information collected, there are existing river facilities as summarized in Figure 2.6. These facilities, which are in general small and are placed sporadically, have functions for flood mitigation, drainage and salinity prevention.

As for the suburban area of HCMC (Thay Cai, Vin Loc A & B, Van Hai and Le Minh Xuan areas), improvement of the drainage system has been proposed under the Hoc Mon-Bac Binh Chanh Irrigation Project. Study for the project was carried out in the year 1994 under the assistance of International Bank for Reconstruction and Development (IBRD).

There are four (4) large existing reservoirs in the Dong Nai River basin and one (1) reservoir under construction. Name and commissioning year of these reservoirs are as follows:

a) Da Nhim reservoir/Dong Nai River : 1965 or before
b) Dau Tieng reservoir/Saigon River : 1985
c) Tri An reservoir/Dong Nai River : 1988
d) Thac Mo reservoir/Be River : 1994
e) Ham Thuan reservoir/La Nga River : Under construction.

These reservoirs, except for the Da Nhim reservoir located far from the flood-prone areas under the study, have more or less a flood retention function whether or not they have been planned with a flood control purpose. Especially, Dau Tieng and Tri An reservoirs would have large flood retention effects to the downstream reaches of the Dong Nai and Saigon rivers, respectively.

2.6 Existing Flood and Drainage Problems and Approach for Mitigation

Based on the discussions in the previous Sections, existing flood and drainage problems in the Study Area are summarized as follows:

a) Major flood-prone areas in the Study Area are:

- Upper Dong Nai River area: Cat Tien and Ta Lai areas;
- La Nga River area: Tanh Linh and Duc Linh areas;
- Middle Dong Nai River area: Tan Uyen and Vinh An areas;
- Lower Dong Nai River area: Long Thanh, Thu Duc and Nhon Trach areas;
- Suburban area of HCMC: Thay Cai, Vin Loc A & B, Van Hai and Le Minh Xuan areas;
- Urban area of HCMC; and
- Coastal river basins: Phan Rang, Luy, Phan Thiet and Ca Ty River basins.

b) Existing problems in the above areas are flooding and inundation caused by flush flood, flood runoff from the upper basin, local heavy rain and high tide. Besides flooding, water pollution is another problem in the urban area of HCMC.

c) In order to cope with the flood and drainage problems, the following measures are conceivable in general:

- Retention of flood runoff by reservoirs and ponds,
- Flood dike to protect the area from flooding brought from the upper basin,
- Channel excavation to increase flow capacity by widening and deepening its section, normalizing channel alignment and removing obstacles to release flood flow smoothly,
- Drainage of interior water caused by local rainfall with sluices and drainage pumps,
- Dike and tide check gate to prevent the area from sea water intrusion during the high tide and interior drainage during the low tide, and
- For water pollution problems, reduction and treatment of industrial and domestic waste are necessary at the source as well as dilution or flushing of the polluted water in the channel.

d) There are three (3) reservoirs in the Study Area for flood mitigation. They are Dau Tieng reservoir (Saigon River; commissioning in the year in 1985), Tri An reservoir (Dong Nai River; 1988) and Thac Mo reservoir (Be River, 1994). Ham Thuan reservoir (La Nga River) is now under construction. According to the information collected, major past floods took place before the construction of these reservoirs, and thus the flood mitigation effect of these reservoir should first be examined.

e) Design flood discharge should be discussed by incorporating effects of the proposed reservoirs as well as the existing and ongoing ones.

f) Flood mitigation plans will be discussed for the respective flood-prone areas, since the situation and necessary measures are different.

3. STUDY ON FLOOD DISCHARGE

3.1 Basic Flood Discharge

To evaluate the flood mitigation effects by the existing and proposed structural measures, the basic flood discharge with return periods of 2, 5, 10, 20, 50, and 100 years is predicted in Appendix III with the basin boundary and runoff system configuration as given in Figure 3.1. Study results are summarized in Table 3.1, whilst Figure 3.2 shows the predicted hydrographs of 100- and 20-year floods. Conditions and assumptions applied for the above estimate are briefly presented below:

a) Hyetograph of Probable Rainfall: The hyetograph of rainfall is prepared on daily basis so as that the sum of rainfalls continuously distributed for 1, 2, 3, 10, 15 and 20 days coincides with the total of the specified probable rainfall. This arrangement is made by considering the fact that the time of concentration for the whole basin is estimated at about 3 days and that the runoff would be subject to retardation for a couple of weeks due to flooding and reservoir operation.

b) Mean Basin Rainfall: Thiessen method based on the selected rain gauge stations is applied to estimate mean basin rainfall.

c) Base Flow: Average of monthly discharge in August and September is assumed to be the base flow for the design discharge calculation, since most of the past major floods occurred in the month of August and September.

d) Basin and Channel Conditions: The same conditions as those for calibration are assumed for the calculation of the basic design discharge. No reservoir besides Da Nhim reservoir is taken into account for the estimate of basic flood discharge.

3.2 Flood Discharge with Existing and Proposed Reservoirs

Reservoirs have, more or less, flood mitigation effects by their retention function, whether or not they are planned with a flood control function. There are four (4) major existing reservoirs and three (3) proposed reservoirs in the Dong Nai River basin as follows:

a) Main Dong Nai River
- Dong Nai No. 3 :Proposed
- Dong Nai No. 4 :Proposed
- Tri An :Existing

b) La Nga River

- Ham Thuan :Existing (under construction)

c) Be River

- Thac Mo :Existing
- Fu Mieng :Proposed

d) Saigon River

- Dau Tieng :Existing.

For evaluating the flood mitigation effects by reservoir, flood runoff is analyzed under two conditions with the above four existing reservoirs and all the seven reservoirs including three proposed ones by applying 20- through 100-year probable rainfalls. Table 3.1 shows the predicted flood peaks, whilst Figures 3.3 and 3.4 depict flood hydrographs predicted under the condition with the existing four reservoirs and all the existing and proposed seven reservoirs, respectively.

Conditions and assumptions applied for the above analysis are principally the same with those of the basic flood discharge except for the retention effect by reservoir. In order to evaluate the flood retention effects of the reservoir, following two are assumed:

- Water level stays at Full Supply Level (FSL), when flood comes into the reservoir; and
- Flood water is released from the ungated spillway constructed as part of the dam.

Relying on the above assumptions, the relationship between reservoir storage(S) above FSL and outflow from the reservoir would be expressed by the following equation under the assumption that a control section appears at the crest of spillway:

$$S = Ar\, Q^{2/3} / (g^{1/3} B^{2/3}) \qquad \text{or} \qquad S = k\, Q^{p}$$

where

S	: reservoir storage (m^3),
Q	: outflow from the reservoir (m^3/sec),
k, p	: storage functions of the reservoir;
	$k = Ar / (g^{1/3} B^{2/3})$, $p = 2/3$,
Ar	: reservoir area at FSL (m^2),
B	: spillway width (m), and
g	: acceleration of gravity (m/sec^2).

Reservoir area (Ar), spillway width (B) and estimated storage functions (k and p) of the reservoir are summarized in Table 3.2.

4. STUDY ON FLOOD MITIGATION AND DRAINAGE

Flood mitigation and drainage plans are studied for the following areas based on the identified flood-prone areas in the Study Area (refer to Figure 2.5):

- Cat Tien - Ta Lai area,
- La Nga River area,
- Lower Dong Nai and related rivers,
- Suburban area of HCMC,
- Urban area of HCMC, and
- Coastal river basins.

Study may be different in depth by the areas, depending on the measures necessary for the respective areas and availability of data and information.

4.1 Cat Tien-Ta Lai Area

(1) Study Area

Cat Tien-Ta Lai area in the upper Dong Nai River has been suffering from flooding due to long-lasting runoff of the Dong Nai River with a total basin area of 8,850 km^2 at the Ta Lai site (refer to Figure 4.1).

The area has not been developed yet so much and is designated as Cat Tien National Park and its buffer zone which are to be protected from development.

(2) Flood Disasters

No written data and information on flood disasters are available for the Cat Tien-Ta Lai area. Some presentation is however made on the flood disasters based on the verbal information obtained during the flood damage survey.

Flood features are similar in both of the Cat Tien and Ta Lai areas. Big floods normally occur in August or September, and due to the topographically narrow river sections and large flood runoff from the upper Dong Nai River, flood inundation takes place every year. An inundation depth of about 0.5 m lasts for about a month with a high depth of about 3 days. Among the large floods so far occurred, the 1978-flood is recognized as the biggest one.

The flood brings about flood inundation and river bank erosion, causing damages to settler's houses, paddy fields and perennial trees. Structures and facilities for flood control are not available in this area.

(3) Existing Channel Capacity

Any channel data and previous study are not available for the Cat Tien-Ta Lai area. In order to estimate the existing channel capacity in this area, an attempt is made using daily discharge records available for years of 1988 through 1990.

Figure 4.2 shows the relationship between the rate of change of daily discharge (dQ/Q) and corresponding daily discharge (Q_t) at the Ta Lai station. Actually, the rate of change is calculated by $(Q_{t+1}-Q_t)/Q_t$. The rate would get smaller when large flooding or storage takes place in the upper river reaches. On the Figure, the rate gets smaller at around 500 m^3/s to 900 m^3/s, indicating that retardation due to flooding starts at around 500 m^3/sec. The existing channel capacity of the Dong Nai River in the Cat Tien-Ta Lai reaches is thus roughly estimated at around 500 m^3/s.

(4) Design Flood Discharge

Based on the result of analysis in Chapter 3, basic flood discharge and flood discharge under with-reservoir conditions have been estimated at the Cat Tien and Ta Lai sites as follows:

Estimated Peak Flood Discharge: m^3/s

Probable Flood	100-year	50-year	20-year	10-year	5-year	2-year
(Cat Tien Site)						
Existing (no reservoir)	6,590	5,810	4,789	4,022	3,256	2,202
With No. 3 and 4 reservoirs	4,499	3,814	3,201	2,237	2,269	1,621
(Ta Lai Site)						
Existing (no reservoir)	6,558	5,843	4,904	4,198	3,495	2,529
With No. 3 and 4 reservoirs	5,136	4,448	3,800	3,308	2,814	2,129

In consideration of the flood retention effect of the proposed Dong Nai No. 3 and No. 4 reservoirs, flood mitigation problems in Cat Tien-Ta Lai area are discussed as follows:

a) Existing channel capacity in the Cat Tien-Ta Lai areas is estimated at around 500 m^3/s, although it is a preliminary estimate. The capacity corresponds to only 10 % of the 20-year basic discharge and 20 % for the 2-year basic discharge.

b) By the construction of Dong Nai No. 3 and No. 4 reservoirs, the 20-year flood is expected to be lowered to about 67 % of the basic discharge, but still much bigger than the existing channel capacity.

c) Owing to the effect of the No. 3 and No. 4 reservoirs, the 5-year flood under the present condition would be raised up to the return period of 20 years.

(5) Flood Mitigation Measures

The primary flood mitigation measure for the Cat Tien-Ta Lai area would be channel improvement by diking system to prevent from flooding and channel excavation in the downstream reaches to accelerate drainage in the flood-prone areas. The channel improvement measures, however, should be adopted carefully since the channel improvement in the upper reaches might cause flooding in the downstream reaches.

On the other hand, the area has not been developed yet so much and is designated as Cat Tien National Park and its buffer zone which are to be protected from development.

In view of the above, intensive flood mitigation measures should not be taken for the Cat Tien-Ta Lai area. Instead, the flood mitigation effects of the Dong Nai No. 3 and No. 4 reservoirs proposed in the upstream reaches are taken into account. In fact, Dong Nai No. 3 and No. 4 are proposed as ones of master plan projects in this study as discussed in Appendix X.

(6) Summary and Recommendations

a) Cat Tien-Ta Lai area suffers from long-lasting flooding. The flood brings about damages to settler's houses, paddy fields and perennial trees due to flooding and river bank erosion.

b) Causes of flooding in this area are mainly flood runoff from the vast Dong Nai River basin and shortage of channel capacity (only 20 % of 2-year flood discharge).

c) It is expected that by the proposed Dong Nai No. 3 and No. 4 reservoirs, about 33 % of basic flood discharge would be reduced. However, the peak flood discharge is still much bigger than the existing channel capacity.

d) Cat Tien-Ta Lai area is designated as the reserved national park, and thus intensive flood mitigation measures are not acceptable. In addition, the existing flooding areas contribute as natural flood retention areas for the downstream reaches.

e) Recommendations:

- A layout plan clearly showing the boundaries of park area to be reserved and other areas for settlement and farming should be established prior to the establishment of flood mitigation plan for this area.
- In order to fill the immediate need, local dikes to protect the existing settlement areas and farm lands are recommended as a flood mitigation measure by paying due attention to the reserved national park.

4.2 La Nga River Area

(1) Study Area

An extensively depressed land extends along the river stretches of about 79 km long between Phu Dien and Ta Pao gauging stations. The depressed land, called as the La Nga River area in this study, has been suffering from long-lasting flood inundation. Basin area totals 3,060 km^2 at the Phu Dien station and 2,000 km^2 at the Ta Pao station (refer to Figure 4.3).

A small portion of the La Nga area has been designated as Bien Lac Wet Land Reserve, which is located in the swamp area of the Lang Quang River, i.e. the southern part of the national highway connecting Vo Xu and Xa Duy. This area must be protected from the development.

(2) Flood Disasters

Written data and information on the flood disasters for the La Nga River area are not available. Based on the verbal information obtained in the filed, features of flood disasters in the La Nga River area are briefed here.

Big floods occurred during August through October in the year of 1978, 1980, 1982, 1984 and 1994, however, it is not clear which flood was the biggest.

During the flood season, flood water overflows on the flood plain twice to three times. The flood inundation lasts for 10 to 15 days for a flood. Rising of flood water level is not so quick that people have enough time for flood evacuation. During the 1978-flood, water level rose by 2.0 m in a day but no casualties were reported. Even so, agricultural crops such as paddy, maize and sugarcane suffer from damages. River channel in the flood plain is susceptible to change.

A dike exists on the left bank of the La Nga River for about 13 km long stretches from Vo Xu toward the downstream direction. This dike was constructed in the year 1978 by Binh Thuan Water Resources Services. At Vo Xu there is a pumping station to irrigate the area protected by the dike. A submerged fixed weir made of stone pitching has also been provided at the outlet of the depressed area near Phu Dien in order to make pumping sure at Vo Xu by raising the water level. No other noticeable river structure is not found in this area.

(3) Existing Channel Features

Longitudinal profile and cross sections of the La Nga River surveyed in March 1989 are collected for the stretches from the Ta Pao station to the Phu Dien station located at the inlet and outlet point of the La Nga depressed area, respectively.

Based on the called data, longitudinal profiles of the lowest river bed, river bank elevation and water level during the surveyed period are prepared as shown in Figure 4.4. In the Figure, bankful channel capacity is also computed by applying the uniform flow formula, in which a Manning's roughness coefficient of 0.030 is assumed. From the Figure, the following could be read:

a) River flow in March which is one of the driest months shows a very gentle surface gradient in the stretches between Phu Dien and Vo Xu.

b) Profile of river banks indicates that the flood-prone area of the La Nga River can be divided into two at Vo Xu; upper and lower flood-prone areas with an elevation gap of about 3 m. The lower flood-prone area is larger than the upper one.

c) Bankful channel capacity is estimated at about 150 m^3/s for the channel in the lower flood-prone area and about 350 m^3/s in the upper one.

d) The lowest river bed profile surveyed at the intervals of about 600 m shows that the lowest river bed exists about 25 km upstream of the Phu Dien station. In the about 12 km long stretches upstream of the Phu Dien station, the river bed is high with shallow water depth. Although geological conditions are not investigated in field yet, the river bed of these stretches is possibly made of hard materials. If so, the channel excavation to lower the flood water level would require high costs.

Channel capacity is examined by using daily discharge recorded at the Phu Dien and Ta Pao stations. At first a relationship of daily discharges observed at both stations in the year 1987 through 1990 is established as given in Figure 4.5. The envelop curve in the relationship shows how the runoff from the Ta Pao station reduces in the stretches up to the Phu Dien station; that is, flood runoff much reduces when discharge at the Phu Dien station is greater than 130 m^3/sec. This indicates inundation takes place between the stretches of both stations when discharge is 130 m^3/s or more at the Ta Pao station. On the other hand, the relationship between the rate of change of daily discharge (dQ/Q) and corresponding daily discharge is also prepared as shown in Figure 4.5 by using the same discharge records measured at Phu Dien from the year 1987 to 1990. On this Figure the rate gets smaller at around 180 m^3/s.

Judging from the above, carrying capacity of the existing channel in the stretches between Ta Pao and Phu Dien is preliminarily estimated at around 150 m^3/s, which coincides with the estimated bankful channel capacity in the lower flood-prone area.

(4) Design Flood Discharge

Based on the result of analysis in Chapter 3, basic flood discharge and flood discharge under with-reservoir conditions are compared at the Ta Pao site as follows:

Estimated Peak Flood Discharge: m³/s						
Case	100-year	50-year	20-year	10-year	5-year	2-year
(Ta Pao Site)						
Existing (no reservoir)	2,100	1,890	1,614	1,406	1,196	896
With Ham Thuan reservoir	1,551	1,390	1,186	1,034	899	708

In consideration of the flood retention effects of Ham Thuan reservoir under construction, flood mitigation problems in the La Nga River area are discussed as follows:

a) Existing channel capacity in the Ta Pao-Phu Dien areas is in the range of 150 m^3/s to 350 m^3/s which corresponds to only 9 % to 22 % of the 20-year basic discharge and 17 % to 39 % of the 2-year basic discharge at Ta Pao.

b) With the completion of Ham Thuan reservoir, the 20-year discharge would be lowered to about 73 % of the basic discharge, but still bigger than the existing channel capacity.

c) Owing to the effect of the Ham Thuan reservoir, 5-year discharge under the present condition would be raised up to the return period of 20 years and 20-year discharge up to 100 years or more.

(5) Flood Mitigation Measures

Ham Thuan reservoir would have a function of runoff retention as presented in the previous Sub-section.

Channel improvement by diking system and channel excavation would be primary flood mitigation measures for the La Nga River area. Adverse effects of the channel excavation would not be so serious for this area, since the flood water drained from the flood-prone areas empties into the Tri An reservoir through the steep slope channel in the downstream reaches.

In order to accelerate the drainage in the depressed area, channel excavation in the outlet sections near Phu Dien was conceived initially. But this measure was discarded because another 12 km long shallow sections were found just upstream of the Phu Dien station, and thus the excavation was deemed to require high costs.

Channel improvement shall be planned as component works of the agricultural development project in the Ta Pao area, which is in fact selected as one of master plan projects in this study. Hydraulic effects of the channel improvement are discussed as mentioned below.

(6) Hydraulic Effects of Diking System

Diking system protects the existing flood-prone areas from flooding. However, the dike would cause another problem to raise the water level and to increase the runoff in the downstream reaches. Even if there is such a problem, hydraulic effects of the diking system are examined for the following typical cases by using the 10-year basic discharge:

- DM0-DK0: Existing condition (no reservoir and no dike),
- DM1-DK0: With Ham Thuan reservoir and no dike,
- DM1-DKL: With Ham Thuan reservoir and diking system only in the lower flood-prone area, and
- DM1-DKLU: With Ham Thuan reservoir and diking systems both in the lower and upper flood-prone areas.

Drainage analysis is made under the following conditions and assumptions:

a) Flood-prone area is divided into two; upper and lower flood-prone areas. Water storage is assumed to be level in each flood-prone area.

b) For respective areas, elevation-area-volume curves are prepared based on the topographic maps with a scale of 1/10,000 prepared in the year 1987, which are partly adjusted by the 1/50,000 map. However, the elevation-area relationship is inherently preliminary one, since the available contour lines have an interval of 10 m.

c) Stage-discharge curves are prepared at Vo Xu for the connecting channel of the upper and lower flood-prone areas and at Phu Dien for the outlet channel by applying uniform flow calculation. In the calculation, the Manning's roughness coefficient is assumed at 0.030 for the low water channel and 0.060 for flows in the flood plain.

d) The analysis is made for 20 days with a time step of 3,600 sec for DM0-DK0 and DM1-DK0, and 900 sec for DM1-DKL and DM1-DKLU.

With the information on the elevation-area-volume curves, 10-year flood discharge and stage-discharge as given in Table 4.1, maximum water levels are calculated as summarized below:

Calculated Maximum Water Level

Case	Upper area			Lower area			Total
	Qin (m^3/s)	Hu (m MSL)	Au (km^2)	Qin (m^3/s)	Hl (m MSL)	Al (km^2)	A (km^2)
DM0-DK0	1,798	110.96	35.9	1,643	107.69	17.9	53.8
DM1-DK0	1,426	110.61	29.5	1,487	107.51	17.5	47.0
DM1-DKL	1,426	110.60	29.3	1,487	107.54	0.8	30.1
DM1-DKLU	1,426	111.34	6.2	1,810	107.95	0.8	7.0

Figure 4.6 shows further details of calculation results.

In the upper flood-prone area, the maximum water level decreases by 0.35 m due to the retention effects of the Ham Thuan reservoir, but increases by 0.74 m due to confining of flood water in the dikes. In the lower flood-prone area, the maximum water level decreases by 0.18 m due to the reservoir effect and increases by 0.44 m due to the construction of dike.

(7) Summary and Recommendations

a) La Nga River area suffers from long-lasting flooding of 10 to 15 days. Agricultural crops such as paddy, maize and sugarcane are subject to flood damages.

b) Causes of flooding in this area are mainly flush flood runoff from the steep upper basin and depressed topography. Channel capacity is markedly low, being about 150 m^3/s and 350 m^3/s in the lower and upper flood-prone areas, respectively.

c) Owing to the runoff retention effect of Ham Thuan reservoir which is now under construction, the 20-year discharge would be lowered to about 73 % of the basic discharge and the 5-year discharge under the present condition would be raised up to the return period of 20 years, but still far bigger than the channel capacity.

d) Based on the drainage analysis for the area, the maximum water level in the upper flood-prone area decreases by 0.35 m due to Ham Thuan reservoir, but increases by 0.74 m due to dike construction, while in the lower area the water level decreases by 0.18 m due to the reservoir and increases by 0.44 m due to dike construction.

e) The La Nga area also includes a part of the reserved national park. Drastic changes of inundation conditions in the reserved areas are not allowed. On the other hand, some part of the area has already been developed as fertile agricultural lands with mechanical irrigation systems and the area still has high potential for agricultural development in future.

f) Recommendations

- Layout plan should be prepared to clarify the areas to be reserved and to be developed. The areas to be developed would need flood mitigation measures by means of channel improvement such as diking systems.
- The flood mitigation should be planned and implemented in complying with the regional development scheme such as agricultural development.
- These development and flood mitigation activities should be implemented by paying due attention to conservation of the reserved park area.

4.3 Lower Dong Nai and Its Related Rivers

4.3.1 Study Area

Lower Dong Nai and its related rivers extend in the lower reaches of the Dong Nai, Saigon, East Vam Co and West Vam Co rivers (refer to Figure 4.7), constituting vast flat and low-lying areas.

4.3.2 Flooding and Inundation

Since the year 1930, the basin experienced serious flood damages in the year 1932, 1952, 1964 and 1978. Among them, the flood in the year 1952 is considered as the biggest. It is said that markedly big floods have not been observed since the year 1978. Sub-Institute of Water Resources Planning (SIWRP) and provincial governments have carried out the detailed survey on floods in the year 1952 and 1978. According to the survey, principal features of these floods are summarized below.

(3) Features of 1952-Flood

The flood attacked the Study Area from October 18 to 24, 1952. Since there were little data and information remained on the flood, the Dong Nai River Master Plan Team of the SIWRP carried out flood survey in the year 1980 along the main Dong Nai River from Tri An to Nha Be.

Estimated flood peak discharge in Bien Hoa was about 12,000 m^3/s with a return period of 80 to 100 years.

Cause of flood: Flood was caused by typhoon with continuous heavy rain over the wide area. Maximum daily rainfalls recorded at major rain gauge stations were as follows:

Maximum Daily Rainfall during 1952-flood

Station	Buon Ma Thuot	Vung Tau	Da Lat	Di Linh	Bao Loc	Tuc Trung	Saigon	Ben Cat	Binh Ba
Rainfall (mm)	148	127	375	422	254	327	113	427	220

Flood water level: Flood water levels were surveyed based on the flood marks and other vestige of the flood associated with the information from senior residents. Flood water levels thus obtained are summarized as follows:

Maximum Water Level during 1952-flood

Location	Flood level (m MSL)	Distance from Tri An (km)	Remarks
Tan Dinh	11.04	28	right bank
Binh Thanh	7.80	45	right bank
Phuoc Thanh	5.68	50	left bank
Tan Hanh	5.60	53	left bank
Bien Hoa City	4.80	60	right bank
Hiep Hoa	4.13	62	left bank
Long Binh	3.43	70	left bank
Long Dai	2.35	73	left bank
Thanh My Loi	1.50	90	left bank
Nha Be	-	102	left bank

Profile of flood water levels of the 1952-flood is shown in Figure 4.8 together with that of 1978-flood.

Conditions of flooding: Since the 1952-flood is an old event, there is no recorded data on the flood damage. According to the field survey and interview, the flooding extended for a width of about 3 to 4 km on both river banks of the reaches from Tri An to Bien Hoa. In some places, it extended up to 10 km. The areas close to the river were inundated with a depth of 3 to 7 m. Most of cottages were collapsed, and cattle, poultry, fruits and vegetables in the inundated areas were washed away.

(4) Features of 1978-Flood

The flood took place during the period from the end of August to the beginning of September, 1978. The return period of 1978-flood was estimated to be about 10 years.

Cause of flood: The flood was caused by the heavy rain over the basin. At the beginning of August, the low-lying areas were already inundated due to preceding rainfalls. This made the inundation more serious.

At the end of August, south-west monsoon stationed in the southern part of the basin under the effect of some storms in the central and northern part of the basin. This resulted in heavy rainfall in the basin, especially in the central basin of the Dong Nai River and the upper basin of the Be River. The following Table shows the monthly, 10-day and daily rainfalls recorded at various stations in the basin during the 1978-flood:

Rainfall during 1978-flood

Station	Monthly rainfall of August(mm)	10-day rainfall in the last 10 days of August(mm)	Max. daily rainfall in August(mm)
Da Lat	283	134	40
Bao Loc	741	354	72
Phuoc Long	637	333	96
Tay Ninh	166	72	-
So Sao	340	212	75
Tan Son Nhat	296	159	86
Phan Thiet	200	107	30
Vung Tau	278	169	52
Long An	211	102	60
Moc Hoa	199	119	70
Bien Hoa	-	204	80

In the upper basins of the Dong Nai and La Nga rivers, heavy rain continued for 5 days from 24th to 28th of August with the rainfall as follows:

5-day Rainfall from August 24 to 28 in the Year 1978

Station	Bao Loc	Di Linh	Ta Pao
5-day rainfall (mm)	207	150	101

Flood water level: The highest flood water level of the La Nga River at Ta Pao was 121.19 m MSL. On the main Dong Nai River, the highest flood water level was recorded on August 28 at Tri An and on September 3 at Bien Hoa. The flood peak reduced remarkably in the downstream reaches and dimmed by high tides. The highest flood level recorded along the main Dong Nai River is listed below (refer to Figure 4.8):

Flood Water Level during 1978-flood

Station	Flood level (m MSL)	Distance from Tri An sta. (km)
Tri An	49.07	0.00
Tan Dinh	7.37	28.00
Bien Hoa	2.07	60.00
Cat Lai	1.48	90.00
Nha Be	1.48	102.00

Water level of the Be River increased quickly due to heavy rain in the upper basin. Flood water of the Be River together with that of the main Dong Nai River raised the river water level and caused inundation in places such as Tan Uyen district of Song Be province and Vinh An district of Dong Nai province.

As for the Saigon River, the flooding was not so severe because rainfall in this basin was not so heavy. The highest water level at Dau Tieng was 5.98 m MSL on September 1 and 1.13 m MSL on September 4 at Thu Dau Mot. Flood of the Vam Co River occurred with a delay of 5 to 7 days after the flood of the Dong Nai River. The highest flood level at Moc Hoa was

2.69 m MSL on September 11. Because the flood of the East Vam Co River was small compared with that of the West Vam Co River, flood water of the West Vam Co River overflowed into the East Vam Co River. It is noted that in the year 1978, the Mekong River system also experienced very big flood with a peak in October.

Flood damages: According to the results of investigation made by the Services of Water Resources of related provinces in the middle of September 1978, the flood damages are outlined as follows:

Damages due to 1978-flood

Province	Death Toll (Person)	Damaged houses (Number)	Damaged road (km)	Paddy crops Inun-dated (ha)	Paddy crops lost (ha)	Cereals (ha)	Cattle (Number)
Binh Thuan	0	0	0	5,290	1,717	31	-
Dong Nai	11	1,634	19	6,110	2,620	203	4
Song Be	0	200	1.5	200	1,300	-	-

Notes:

- Paddy crops for the wet season (October 1 to January 15) and the summer-autumn season
- No data were available for Tay Ninh, Long An provinces and Ho Chi Minh City.

4.3.3 Characteristics of Existing Channels

Channel sections were surveyed by JICA Study Team during the period from December 1994 to February 1995. The survey covered the major rivers related to the study as shown below:

Stretch of River Survey

River	Stretch(km)	Section(nos.)
Lower Dong Nai	85 km from the river mouth	17
Saigon	60 km from the confluence with the Dong Nai River	11
East Vam Co	120 km from the confluence with the Dong Nai River	22
West Vam Co	120 km from the confluence with the East Vam Co	22
Others	River	6

Based on the survey results, characteristics of the existing river channels are studied on longitudinal profile, river width, cross sectional area, mean depth, ratio of mean and maximum depth and the existing channel flow capacity.

The channel profiles and channel flow capacity so calculated are given in Tables 4.2 and 4.3 respectively and are depicted in Figure 4.9. The channel characteristics of each river read from those Tables and Figure are summarized as follows:

a) River bank elevation

River Bank Elevation

River	Average(range: m MSL)
Dong Nai	1.95(1.17 to 4.63)
Downstream of 94.3 km point	1.51(1.17 to 1.93)
Upstream of 94.3 km point	2.70(1.41 to 4.63)
Saigon	1.60(0.83 to 2.98)
East Vam Co	1.27(0.78 to 2.83)
West Vam Co	1.47(1.01 to 2.65)

- River bank of the Dong Nai River gets higher in the upstream reaches of Bien Hoa bridge (94.3 km point).
- Elevation of banks of other rivers is flat and low, in particular, bank elevations of the East and West Vam Co rivers are low as a whole, being equal to or lower than the high tide levels.

b) River bed elevation

River Bed Elevation

River	Lowest bed(m MSL)	Mean bed(m MSL)
Dong Nai	-33.63 to -7.34	-9.99(-18.72 to -4.79)
Saigon	-21.62 to -11.69	-9.10(-11.52 to -5.84)
East Cam Co	-28.59 to -7.85	-10.14(-19.90 to -6.05)
West Vam Co	-19.16 to -7.92	-7.79(-10.99 to -3.65)

- The deepest river bed is -33.63 m MSL at the 46.5 km point of the Dong Nai River, followed by -28.59 m MSL at the 25.9 km point of the East Vam Co River.
- Channel depth is equal for the surveyed stretches of the East Vam Co River, increasing toward the downstream direction.

c) Channel width and sectional area

Channel Width and Sectional Area

River	Width(m)	Area(1,000m^2)	Mean depth(m)
Dong Nai	1,053	11.8	11.69
	(3,101 to 292)	(31.2 to 3.3)	(20.16 to 7.04)
Saigon	308	3.2	10.46
	(628 to 146)	(5.6 to 1.4)	(12.93 to 6.94)
East Vam Co	346	3.7	11.27
	(1,675 to 136)	(12.6 to 1.6)	(21.38 to 7.55)
West Vam Co	186	1.7	9.11
	(362 to 107)	(3.7 to 0.8)	(12.32 to 5.08)

d) Mean and maximum depth ratio (Hm/Hmax)

Hm/Hmax

River	Average(range)
Dong Nai	0.66(0.80 to 0.52)
Saigon	0.61(0.90 to 0.47)
East Vam Co	0.65(0.81 to 0.50)
West Vam Co	0.57(0.77 to 0.40)

- The ratio shows a tendency to increase toward the downstream reaches in general.

e) Channel capacity

Existing Channel Capacity, m^3/s

River	Stretch	Q for MSL	Q for MHWL
Dong Nai	d/s of the confluence with the Saigon R.	14,000	8,100
	u/s of the confluence with the Saigon R.	6,200	4,100
Saigon	d/s of the confluence with the Rach Tra C.	2,200	1,400
	u/s of the confluence with the Rach Tra C.	890	570
E. Vam Co	d/s of the confluence with the W. Vam Co R.	4,200	-
	d/s of Xuan Khanh	870	-
	u/s of Xuan Khanh	650	-
W. Vam Co	d/s of Tuyen Nhon	960	-
	u/s of Tuyen Nhon	330	-

Note: d/s shows downstream, while u/s for upstream.

- The channel flow capacity is estimated with uniform flow by assuming the surface slope and a Manning's roughness coefficient of 0.030 commonly to all river channels.
- The surface slope is assumed by considering the tide level at the lowest end of the Dong Nai River and the ground elevation of the river bank. Two different tide levels are assumed at the river mouth, i.e. mean sea level (0.00m MSL) and mean high water level (MHWL: 1.27 m MSL). The following Table shows the assumed water level at the lowest end of each river and the estimated surface slope used for the uniform flow calculation:

Conditions for Calculation of Channel Flow Capacity

River	MSL		MHWL	
	WL (m MSL)	Slope	WL (m MSL)	Slope
Dong Nai				
Downstream of 94.3 km point	0.00	1/ 49,600	1.27	1/150,000
Upstream of 94.3 km point	1.90	1/ 17,100	1.90	1/ 17,100
Saigon	1.20	1/ 90,000	1.67	1/218,000
East Vam Co	0.42	1/206,000	1.41	Level
West Vam Co	0.59	1/132,000	1.41	Level

4.3.4 Design Flood Discharge

According to the result of analysis in Chapter 3, basic flood discharge and flood discharge under with-reservoir conditions have been estimated for the Dong Nai River and the Saigon River at their confluence as well as Thu Dau Mot for the latter as follows:

Estimated Peak Flood Discharge, m³/s

Case	100-year	50-year	20-year	10-year	5-year	2-year
(Dong Nai River)						
Without (no reservoir)	10,784	9,871	8,635	7,673	6.688	5,411
With existing 3 reservoirs	8,980	8,187	7,284	6,586	5,858	4,843
With 6 reservoirs	8,266	7,501	6,712	6,095	5,478	4,580
(Saigon River)						
- Confluence with the Dong Nai						
Existing (no reservoir)	2,274	2,029	1,706	1,461	1,223	929
With Dau Tien reservoir	1,147	1,029	872	754	635	486
- At Thu Dau Mot						
Existing (no reservoir)	2,200	1,954	1,667	1,466	1,254	937
With Dau Tien reservoir	1,227	1,099	930	803	675	495

It is noted that:

- Existing three reservoirs include Ham Thuan, Tri An and Thac Mo.
- Six reservoirs include Dong Nai No. 3, No. 4 and Fu Mieng as well as the above existing three reservoirs.

Taking into consideration the flood retention effects of the existing Tri An, Thac Mo and Dau Tieng reservoirs as well as the proposed Fu Mieng, Dong Nai No. 3 and Dong Nai No. 4 reservoirs, flood mitigation problems in the lower Dong Nai area are discussed below:

(1) Lower Dong Nai River

a) Average existing channel capacity of the lower Dong Nai River upstream of the confluence with the Saigon River is estimated at 6,200 m³/s, corresponding to about 72% of 20-year basic discharge and being almost equivalent to 5-year basic discharge. Under this condition, historically big floods such as 1951- and 1978-floods occurred.

b) At present Tri An and Thac Mo reservoirs are under operation in the main Dong Nai and Be rivers, whilst Ham Thuan dam in the La Nga River is under construction. With these reservoirs, safety of the existing channel would be raised up to about 7-year discharge or 85% of the 20-year discharge.

c) In addition to these existing reservoirs, three reservoirs are proposed in the main Dong Nai and Be rivers. With these reservoirs, safety of the existing channel has been raised up to about 15-year discharge or 92% of the 20-year discharge.

(2) Saigon River

a) Average existing channel capacity of the Saigon River downstream of Thu Dau Mot is estimated at 2,200 m^3/s, corresponding to about 100-year basic discharge. The Saigon River downstream of the Rach Tra canal has enough capacity to release flood water except for the period of high tides.

b) Average existing channel capacity of the Saigon River upstream of Thu Dau Mot is estimated at 890 m^3/s, corresponding to about 52 % of 20-year basic discharge.

c) Dau Tieng reservoir, lying upstream of the Saigon River, is under operation. With this reservoir, safety of the existing channel has been raised up to the 20-year discharge even for the upstream reaches of the Rack Tra canal.

4.3.5 Flood Mitigation Measures

In order to attain flood mitigation in the lower Dong Nai and its related rivers, two aspects of problems should be solved, i.e. flooding problems due to flood water from the upstream basin and inundation problems due to local storm. Generally speaking, the former flooding problems need studies from the basinwide viewpoint, and the latter inundation problems can be discussed locally for the area which needs measures.

The flooding problems of the lower Dong Nai and Saigon rivers due to flood water from the upstream basin can be said to have been solved substantially by the runoff retention function of the existing reservoirs, although the channel capacity of the main Dong Nai and Saigon rivers is partly lower than the 20-year discharge. Thus, the matters to be dealt with in the lower Dong Nai area are the inundation problems which are caused by the inter-action of local heavy rains and high tides.

Continuous diking system with sluices would be a primary measure for both the flooding and inundation problems in this area. The dike could also have a function as rural roads. The sluice should have dual functions to drainage rain water and to prevent from salinity intrusion. Furthermore, the sluice also should allow the navigation where it is required.

4.3.6 Summary and Recommendations

a) The areas along the lower reaches of the Dong Nai, Saigon and East and West Vam Co rivers are flat and low-lying, suffering from river flooding and inundation due to local heavy rains and high tides.

b) The areas experienced big floods in the year 1932, 1952, 1964 and 1978, which were caused by typhoon or stationing of the south-west monsoon. These floods brought about serious damages to private houses and properties, public facilities, agricultural crops and livestocks.

c) Tri An, Thac Mo and Dau Tien reservoirs play an important role for the flood mitigation in these areas. With these reservoirs, safety of the existing Dong Nai River has been raised up to about 15-year discharge and the Saigon River up to 20-year or more. The floods mentioned in b) are those occurred before the commission of these reservoirs.

d) Flooding problems in these areas have substantially been solved and major problems remained are inundation due to local heavy rains and high tides.

e) Recommendations

- Although flooding problems have substantially been solved, the channel capacity is partly lower than the 20-year discharge. The sites which need measures should be investigated in detail based on the topographic survey and verbal information from local people.
- River and channel system in the areas are complicated with such functions as floodway, drainage, water supply, irrigation and navigation. Functions of these rivers and canals should be investigated and clarified in planning flood mitigation measures.
- Continuous diking system with sluices would be a primary measure for flooding and inundation problems. The dikes and sluices should however be applied by taking into consideration the functions of the rivers and canals.

4.4 Suburban Areas of Ho Chi Minh City

(1) Study Areas

Suburban low-lying areas of Ho Chi Minh City (HCMC) such as Pham Van Hai, Le Minh Xuan and areas along the Tay Cai canal are the typical ones suffering from long-lasting inundation affected by local heavy rains and high tides.

(2) Inundation

Inundation in the suburban areas of HCMC commonly occurs by joining the long-lasting high intensity rainfall with the spring tide. In particular, continuous inundation takes places in the areas of Cu Chi and Hoc Mon. However, it is not so difficult to drain the inundated water in these areas due to the location near the large rivers and affected by the tidal movement.

On the other hand, the areas such as Pham Van Hai farm, Le Minh Xuan farm, and A and B communes of Vinh Loc in Binh Chanh district are low-lying areas located rather far from the large rivers with small tidal movement. Due to these reasons, gravity drainage in these areas is inherently difficult. Besides the poor natural drainage, the areas receive storm runoff from surrounding higher lands, resulting in the long-lasting inundation of one to two weeks. September and October are the months to be susceptible to inundation due to heavy rain and high tide.

Inundation, which occurs every year with an areal extension of thousands hectares (0.5 to 0.8 m in depth), gives damages to agriculture production such as paddy, sugarcane and pineapple. Flood in October, 1989 caused serious inundation to the suburban areas of HCMC. According to the investigated data, inundation extended over an area of about 28,000 ha with ground level lower than 1.4 m MSL. Inundated areas by land use are summarized as follows:

Inundated Areas of the Year-1989 Flood by Land Use

Land use	Inundated area (ha)	Percentage
Paddy	22,324	79.8
Vegetable, cereals	1,806	6.5
Pineapple	1,525	5.4
Sugarcane	1,608	5.7
Eucalyptus	329	1.1
Fish ponds	420	1.5
Total	28,012	100

The inundation lasted almost for a whole month of October with a peak on October 17 to 18. A vast area of 2,350 ha was still under water on October 28 in the low-lying lands of Pham Van Hai and Le Minh Xuan farms.

The causes of 1989-flood are summarized as the joint action of various factors as follows:

a) Heavy rainfalls over the whole basin: Accumulated rainfall from October 1 to 10 was 100 mm to 200 mm depending on the stations, whilst for a time period of October 11 to 18, rainfall accumulation was 180 mm which was the highest during the time period of the year 1977 to 1989.

b) Flood release from the reservoir: Tri An and Dau Tieng reservoirs spilled out flood water in this period; about 1,250 m^3/s to 1,500 m^3/s from Tri An reservoir and about 200 m^3/s from Dau Tieng reservoir.

c) High river water levels affected by tide: Water level in the rivers was high affected by the spring tide, being 1.42 m MSL at Phu An of the Saigon River, whilst 1.44 m MSL at Nha Be of the Dong Nai River on October 18.

(3) Drainage Improvement Measures

Two principal measures are necessary for this area, i.e. (a) measure to prevent from flooding of the Saigon and East Vam Co rivers and (b) measure to drain local storm water by use of tidal movement. The flooding problem of the Saigon River has been substantially solved by the runoff retention of Dau Tieng reservoir. Thus, the principal problem to be tackled in this area would be drainage of local rain water and prevention of river water spilling out during high tides.

Continuous diking system with sluices would be a primary measure for both the flooding and inundation problems in these areas. The dike could also be used as rural roads. The sluice should have dual functions to drain rain water and to prevent from salinity intrusion. Furthermore, the sluices should allow the navigation where it is required.

A drainage plan has been proposed for Hoc Mon-Bac Binh Chanh Irrigation Project to solve the inundation problem in the project area as discussed below.

(4) Drainage Plan for Hoc Mon-Bac Binh Chanh Irrigation Project

Improvement of the drainage system in the project area has been proposed under the Hoc Mon-Bac Binh Chanh Irrigation Project. Study for the project was carried out in the year 1994 under the assistance of International Bank for Reconstruction and Development (IBRD), proposing the channel systems which commonly serve for both irrigation and drainage as shown in Figure 4.10 and Table 4.4. Principal project features are presented below:

a) Construction of 13 major sluices along the main canals to prevent from salinity intrusion and to control the drainage discharge;

b) Improvement of 52.6 km long existing main canals (A, B and C link canals and Tan Kien creek) and construction of 1.8 km long main canal in the Tan Kien system;

c) Improvement and construction of secondary and tertiary canals;

d) Construction of nine minor sluices along the main canals to prevent from salinity intrusion and to control drainage discharge;

e) Construction of automatic gates at the head and stoplog gates at the end of the secondary canals to allow two-way flow for irrigation and drainage purposes and to prevent acid water from entering into the system;

f) Construction of stop-log structures (1 m high and 0.6 m wide) at the head of each tertiary unit;

g) Construction of five drainage pumping stations along the An Ha canal, replacing old structures;

h) Construction of weirs for the purposes not only to regulate the flow in the secondary canals but also to prevent the polluted water from entering into the system; and

i) Construction of 42.8 km long dikes along the Thay Cai and Ngang canal for salinity and flood control purposes.

(5) Summary and Recommendations

a) Suburban areas of HCMC such as Tay Cai, Van Hai, Le Minh Xuan and Vinh Loc A and B are located in the topographically depressed area and have been suffering from long-lasting inundation caused by the inter-action of local heavy rains and spring tides.

b) The inundation occurs every year in thousands hectares of lands and gives damages to agriculture production such as paddy, sugarcane and pineapple.

c) Improvement of canals with diking system and sluices would be a primary measure, and a drainage plan has been proposed for Hoc Mon-Bac Binh Chanh Irrigation Project.

d) Recommendations

- Drainage improvement should be planned in complying with the development schemes of the area.
- Drainage plan proposed for the Hoc Mon-Bac Binh Chanh Irrigation Project should be implemented by giving top priority in this area.

4.5 Urban Area of Ho Chi Minh City

4.5.1 Existing Drainage System

(1) Drainage System of HCMC

Ho Chi Minh City (HCMC), which is one of the most important economic and industrial centres in the country, has a total area of 2,029 km^2 and a population of 4.5 millions. Three-fourths of the population concentrate in 12 urban districts with a total area of 140 km^2, or 6.9 % of the whole city area.

Since the city is located in a low-lying land with many canals, drainage as well as sewage has been a problem since its establishment. In addition, rapid urbanization in recent years brought about damages and overload to drainage and sewerage facilities, causing serious urban inundation along with water pollution.

Existing drainage system of HCMC is a combined type commonly used to drain rain water, domestic sewage and industrial waste water. Total length of the existing drainage channel is 661.6 km with 196 outlets, all of which release water into main drainage canals. Most of these sewage and waste water has no treatment facility.

Major drainage canals in the HCMC area are the Tham Luong-Ben Cat-Lai Thieu, Nhieu Loc- Thi Nghe, Lo Gom, Nuoc Len, and Kinh Doi-Kinh Te-Ben Nghe canals. Of them, the Lai Thieu, Thi Nghe and Kinh Te-Ben Nghe canals directly discharge into the Saigon River, and the Lo Gom and Nuoc Len canals drain into the Ben Luc River (Kinh Doi-Kinh Te-Ben Nghe canals). Based on such drainage canal alignment, the drainage systems in HCMC are divided into four as follows (refer to Figure 4.11):

a)	Tham Luong-Ben Cat drainage system	: 9,000 ha
b)	Nhieu Loc-Thi Nghe drainage system	: 5,000 ha
c)	Tan Hoa-Lo Gom drainage system	: 2,115 ha
d)	Kinh Doi-Kinh Te-Tau Hu-Ben Nghe drainage system	: 4,900 ha.

The function of these drainage systems is to receive rain water, domestic sewage and industrial waste water from outlets and to release them to the sea through the Saigon River and the Ben Luc River as well as the Dong Nai River and other rivers in the deltaic area. There is no pumping station for urban drainage.

(2) Evaluation of the Existing Function

According to the evaluation for the function of drainage facilities by Public Construction Department, the existing drainage system has been degraded seriously mainly due to rapid urbanization and budgetary constraint as presented below:

a) Underground sewers and trenches:

- Completely damaged, requiring reconstruction	: 30 %
- Already overloaded	: 12 %
- Damaged, requiring repair	: 40 %
- Slightly damaged, requiring small-scale repair	: 18 %.

b) Main drainage canals: Along the 68 km long main drainage canal, there are 20,000 houses intruded partly or wholly in the canal area, causing reduction in drainage capacity and difficulties in canal maintenance.

c) Outlets: Since the elevation of outlets is lower than the high tide level, drainage capacity is considerably limited, and thus canal water intrudes into the drainage channels during the spring tide period.

d) Sewers and trenches: Sewers and trenches seem to be causing stagnant water and circling flow. Density of existing sewers in the city varies largely from district to district, i.e. 200 m/ha in 3rd district, 181 m/ha in 11th district and 10 m/ha in Binh Thanh district. In other districts few sewer system exists.

4.5.2 Inundation

According to a report on inundation survey, there are 60 areas where heavy and frequent inundation occurs. These inundation-prone areas are located in:

a) East of Binh Thanh district,
b) Southwest of the city, and
c) Depressed areas in the 10th and 11th districts.

Depth and duration of inundation vary from place to place. The maximum inundated depth is 0.8 m, whilst the duration of inundation ranges from 3 hours to 10 hours. This inundation situation in the city mainly relies on the following causes:

a) Drainage systems in the urban area have not been completed yet. Even though the drainage systems in the 1st, 3rd and 5th districts of HCMC are far better than those in other districts, these systems have become aged and their drainage capacity has been lowered;

b) Drainage canals are getting narrow due to deposition of solid waste and squatter's houses constructed encroaching upon the canal;

c) The city is located in the area affected by tides. Drainage of local shower is difficult during the time when the river water level is highly raised by the inter-action of flood runoff from the upper reaches of the Saigon River and the spring tide from the sea; and

d) Structures and houses are often constructed without consideration of the drainage system in the related area.

Losses and hazard caused by the inundation are summarized as follows:

a) Inundation over the roads causes heavy traffic jams in places of the urban streets for a long time and interferes the normal economic activities as well as the people's livelihood;

b) Durability of facilities and structures on ground such as roads is shortened due to frequent inundation during the rainy season; and

c) Inundated water seriously affects living and sanitary environment.

4.5.3 Water Pollution

Water quality in HCMC is probably one of the most serious environmental issues, particularly in relation to economic activities in the city. In terms of water pollution, there are two sources to release water directly to city's drainage system; domestic sewage and industrial waste water. Almost all of these sewage and waste water is released to local drains, streams or rivers without treatment, deteorating water quality in the rivers and drains. What is more, poor maintenance of drains and uncontrolled intrusions by squatters onto drainage facilities worsen the problem. On the other hand, it is reported as the result of uncontrol release of domestic sewage and industrial waste water to local drains and rivers that local groundwater is contaminated.

(1) Domestic Sewage

The domestic sewage includes:

a) washing and bathing water, and
b) toilet water including excrement.

The old parts of HCMC have underground sewers. But the majority of areas have a combination of individual septic systems or utilize urban drainage by local street gutters, ditches and open collection drains. All these waste water drains directly or indirectly to the local rivers or their tributaries, many of which are subject to tidal fluctuations. It is estimated at the moment that an amount of 650,000 m^3/day is collected from all the discharge sources of HCMC, i.e. sewage, industrial waste water and storm water runoff.

Although septic systems exist for many houses, offices, industrial premises and so on, many of these release sewage flows through surface drainage without proper management. Contamination of local groundwater is evident in some analyses undertaken at the wells within HCMC. Storm runoff has a function to flush polluted water accumulated during the dry season. However, discharge capacity of these canals has been reduced by siltation, accumulation of solid waste disposal (garbage), heavy aquatic weed growth and intrusion of squatters onto drainage canal inside embankments.

The water pollution level in these open drains and canals is proved by the fact that the dissolved oxygen (DO) level is consistently "zero" at several monitoring sites during the dry season and very low even in the wet season when storm runoff can flush contaminants.

According to a study, domestic sewage released into the drainage system with an amount of about 270,000 m^3/day would contains:

a) BOD : 50,000 tons
b) COD : 100,000 tons
c) Suspended solid : 75,000 tons
d) Soluble solid : 90,000 tons
e) N_2 : 8,000 tons
f) Phosphor : 960 tons.

Moreover, there is garbage poured directly into the drainage canals, estimating at about 350 to 400 tons/day.

(2) Industrial Waste Water

There exist a number of manufactures and factories within the HCMC administrative area as summarized below:

Number of Manufactures and Factories

District	No. of manufactures	Industry
11th	3,757	Chemicals, rubber, machines, textile, leather and garment
6th	2,660	Mechanics, chemicals, rubber, plastic, food processing, electric and garment
5th	1,971	Mechanics, chemical, rubber, plastic, food processing and wood processing
Tan Binh	2,387	Textile, chemicals, rubber, plastic, food processing and wood processing
1st	2,291	Garment, electric and food processing
Six rural districts	2,655	Food processing, wood and construction materials

Most of these manufacturers, lying in the residential areas, are using old-fashioned equipment for production. It can be easily inferred from this fact that waste water is released to drains without proper treatment.

(3) Appraisal for River Water Pollution

A survey to appraise water pollution was carried out in HCMC in the year 1990 and 1991. Eight basic items such as EC, SS, BOD, COD, NH_4, PO_4, SO_4 and total coliform were selected for the appraisal. Results are summarized as follows:

a) 1st grade water (not polluted) : None
b) 2nd grade water (start of pollution):

- Saigon River; Upstream of Ben Than
- Dong Nai River; Upstream of Hoa An

c) 3rd grade water (slightly polluted):
- Saigon River; From Ben Than to Binh Quoi
- Dong Nai River; From Hoa An to Dong Nai bridge (up to Nha Be during the rainy season)

d) 4th grade water (considerably polluted):
- Saigon River; From Thanh Da to Dan Xay (Duyen Hai)
- Dong Nai River; From Cat Lai to the downstream point of Kinh Doi-Kinh Te-Tham Luong canal

e) 5th grade water (heavily polluted):
- Cho Dem River; From An Lac to Tuan Tuc

f) 6th grade water (badly polluted):
- Tan Hoa-Lo Gom canal
- Nhieu Loc-Thi Nghe canal
- Upper half of Tham Luong canal.

(4) Water Quality Issues and Management

The water pollution situation in HCMC is complex and is characterized by several key factors and issues as follows:

a) Salinity intrusion is a problem in respect of its effects to water quality as drinking water as well as pollution assimilation capacity.

b) Over 100 km long waste water canals in HCMC are severely polluted through the year due to slow flow because of gradients, reduced capacities and tidal effects, i.e. reverse flows on high tides.

c) Flow in waste water canals are minimal through the dry season, so pollution levels increase and aerobic conditions prevail, resulting in serious odour problems in many locations.

d) Contamination of local groundwater is occurring in some industrial estates where controls on discharges are ineffective, e.g. Thu Duc.

e) Extent of water pollution by accidental spillage and uncontrolled runoff from industrial plants and chemical storage depots is unknown at present and could be locally significant, e.g. effects of recent oil spill incident at Nha Be where brackish water is pumped to supply to the downstream aquaculture ponds.

f) Cumulative effects of water pollution, e.g. into Nha Be estuarine sediments, are unknown and could be important to aquatic ecology, e.g. the mangrove area plays a role as nursery areas for Penaeid species prawns.

HCMC Environment Committee (ENCO) issued its Regulations on Environmental Pollution Control in Ho Chi Minh City in May, 1993. These regulations established the basic permissible limits for trade effluents as presented in Table 4.5. These regulations will be extended with specific policies, guidelines and criteria for certain groups of industries.

In general, the basic implementation of pollution control will evolve on the basis of:

a) Requiring all new industrial plants to install waste water treatment facilities so that their discharges can comply with regulations and industry group criteria;

b) Stage-wise improvements of the old treatment plants so that their discharges can be controlled and eventually comply with industrial standards for effluents or discharges to local drains;

c) Installing separate and complete waste disposal systems for all hospitals;

d) Implementation of a proper solid waste disposal programme for the urban area based on landfill (Less than 60 % of HCMC's solid wastes are presently collected);

e) Implementation of remedial measures to rehabilitate and improve waste water canal systems, particularly the Nhieu Loc/Thi Nghe canal (A feasibility study has been completed for this project with assistance of the Singapore Government);

f) Requiring specific waste water treatment plants for major point sources such as hotels; and

g) Expansion and upgrading of pollution control inspectorate including monitoring of specific problem areas such as Nha Be, 4th District, Hoc Mon, Thu Duc and Go Vap industrial zones and problem plants such as seafood processing, textile and small chemical plants, e.g. battery factories.

4.5.4 Previous Studies and Works

Study for Master Plan on Urban Drainage of HCMC is carried out over a time period of the year 1993 to 1996 with full local funds. Although the data and information provided so far from this study are limited, the study seems to have concentrated on the basic survey and investigation of the existing drainage facilities and preparation of repair and improvement programme for secondary and tertiary drains. Improvement of the main drainage canals that the secondary/tertiary drains are connected with is not included. Study is made by dividing the urban area into six sub-areas, and Nhieu Loc-Thi Nghe area has been selected as the top priority area for improvement. Time schedule for the implementation of improvement programme is not definite probably due to the budgetary constraints.

A surface water quality monitoring network comprised of ten stations has been established and is operated jointly by the HCMC Environment Committee (ENCO) and the SIWRP. Weekly sampling and analyses have been undertaken since October 1992. The location of sampling sites and a list of the parameters analyzed for the HCMC water quality monitoring programme are given in Table 4.6 and Figure 4.12.

A systematic inventory for sources of waste water covering premises and their types and volumes of waste water discharges is under preparation as part of the ongoing Environmental Improvement Plan for Ho Chi Minh City. This study is being undertaken on behalf of HCMC Environment Committee (ENCO) with a fund from ADB and a US consulting engineer, Engineering Science, Inc. in joint venture with J.T. Environment Company from Thailand.

4.5.5 *Basic Approaches to Urban Drainage*

Basic approaches to the urban drainage in the HCMC area are summarized as follows:

a) Drainage improvement in the urban area of HCMC needs countermeasures:

  - to protect the area from flooding of the Saigon River and the East Vam Co River;
  - to protect the area from high tides;
  - to drain local rain water as swiftly as possible; and
  - to prevent the area from water pollution, especially in the dry season.

b) As a measure against high water due to flood and tide, continuous diking systems with drainage sluices are conceivable along the Saigon and East Vam Co rivers where flood water overflows.

c) The areas lower than the tide level should be principally protected by dikes with sluices which have functions to check tides during high tide and to drain excess water during the low tide period.

d) Gravity drainage is the most preferable measure for the drainage of local rain water, if the topographic conditions allow. Thus, the drainage area should be first classified into areas by gravity drainage and other areas, and the rain water in the areas drained by gravity should be collected and released as a separate system from others.

e) As to water pollution, two measures should be jointly taken in consideration, i.e. measures to reduce the source of pollution and to purify the polluted water by dilution or aeration.

f) Urban drainage in HCMC is recognized in a serious situation in terms of inundation and water pollution as discussed above. However, an intensive study to formulate an urban drainage plan for HCMC is not included in this master plan study, since the water resources development in the Dong Nai River basin is not directly related to the urban drainage in HCMC. This results in no inclusion of the urban drainage project as the candidates to select the master plan projects (refer to Appendix X) of this study. Taking into consideration the deteriorated condition of urban drainage in HCMC, an intensive study to formulate the urban drainage plan for HCMC shall however be taken up as soon as possible as an environmental protection project.

4.5.6 Summary and Recommendations

a) Since the urban area of HCMC is located in a low land surrounded by rivers and canals, drainage as well as release of sewage and waste water has been a problem since its establishment.

b) The existing drainage system has been degraded seriously mainly due to rapid urbanization and budgetary constraint for drainage works.

c) Inundation occurring frequently in places in the urban area causes hazard to economic activities as well as people's livelihood, damages to public structures and facilities, and deterioration of living and sanitary environment of the city.

d) Water quality of the city and the economic triangle zone is probably the most important environmental issue in this area. Almost all of the domestic sewage and industrial waste water is being released to the canals and rivers without treatment.

e) According to the appraisal of river water pollution conducted in the year 1990/91, Tan Hoa-Lo Gom canal, Nhieu Loc-Thi Nghe canal and upper half of Tham Luong canal are badly polluted.

f) A master plan study on urban drainage of HCMC is carried out with full local funds. The study is, however, limited to the basic survey of the existing drainage facilities and to the preparation for repair and improvement programme of secondary and tertiary drains.

g) Recommendations

- A full-scale master plan study on the improvement of urban drainage in HCMC is recomended to be carried out as mentioned already. The study should cover the drainage and water pollution problems, and the plan to be proposed should be discussed from the global viewpoint, including main drainage canal systems as well as considering future development of the city.
- Considering the recent rapid urbanization of the city, the drainage master plan study should be implemented as soon as possible.

4.6 Coastal River Basins

4.6.1 Existing Basin Conditions

The coastal area is located south of the Dong Nai River basin, facing on the South China Sea. There exist many rivers in the coastal area, and they flow generally toward southeast and pour into the South China Sea (refer to Figure 4.13). Among these, major rivers which suffer from flood damages are the Phan Rang, Luy, Phan Thiet and Ca Ty. General features of these rivers are presented below.

(1) Phan Rang River

The Phan Rang River originates in the highland area higher than 1,000 m MSL near the intersection of three provincial boundaries of Lam Dong, Khanh Hoa and Ninh Thuan (refer to Figure 4.14). The river, which has a total catchment area of 3,432 km^2 and a total river length of 105 km, forms a fan-shaped drainage basin, and most of the major tributaries join the main Phan Rang River near AP Tan My (36.1 km upstream of the river mouth).

At 25.0 km upstream of the river mouth, there exists the Nha Trang weir crossing the river. The weir is a fixed type and is serving for drawing irrigation water. Farm land extends in the downstream reaches of the weir. Railway and National Highway No. 1 cross the farm land. Town of Phan Rang develops along National Highway No. 1 lying 5.4 km upstream of the river mouth. On the left side of the bank downstream of the national highway bridge, earth dike with concrete pile groins has been constructed.

There are two stream gauging stations; Phan Rang and Tan My stations in the Phan Rang River basin. The former is located at the national highway bridge site and the latter upstream of the Tan My bridge.

(2) Luy River

Originating from the Di Linh highlands with the elevation of about 880 m MSL, the Ruy River passes through the mountainous areas and then hilly land from north to south. After passing through the railway bridge lying 38.5 km upstream of the river mouth, the river changes its direction toward east. Collecting tributaries from the left bank, the river finally empties into the sea near the town of Phan Ri Cua (refer to Figure 4.15). National Highway No. 1 crosses the river 14.4 km upstream of the river mouth. Catchment area of the Luy River, which is wholly located in Bac Binh district of Binh Thuan province, is 1,973 km^2 in total with a total river length of about 85 km at the river mouth.

The Dong Moi weir, which is a fixed type, lies 27.5 km upstream of the river mouth, serving as an irrigation water intake. Song Luy station for rainfall and runoff is located 36 km upstream of the river mouth, renewed by JICA under this study.

(3) Phan Thiet River

The Phan Thiet River originates from the Di Linh highlands as the Luy River does. The river, which has a total catchment area of 952 km^2 and a total river length of 70 km, takes almost the straight route toward south and empties into the sea near the town of Phan Thiet (refer to Figure 4.16).

Song Quao weir is proposed 31 km upstream of the river mouth for supplying irrigation water to the farm lands extending in the downstream reaches of the proposed weir site. The detailed design for constructing the weir has been completed.

National highway connecting Phan Thiet and Di Linh takes its route parallel to the Phan Thiet River, and the railway and National Highway No. 1 cross the river 18.2 km and 4.2 km upstream of the river mouth, respectively.

(4) Ca Ty River

The Ca Ty River, called the Kabet River in the upstream reaches, originates from the high mountain area lying northwest of Ham Thuan Nam district, Binh Thuan province (refer to Figure 4.16). The river flows toward the southeast direction and joins the Mong River 24.5 km upstream of the river mouth. After meeting the Mong River, the river flows toward east, joining the Len River (18.1 km point), crossing the railway (15.3 km point) and passing through Phan Thiet at the river mouth. The river has a total catchment area of 775 km^2 and a river length of 77 km at the river mouth.

Ba Bau reservoir exists 22.3 km upstream of the river mouth, and farm lands extend in its downstream areas. Phu Hai weir with intake pumps is constructed to draw irrigation water 9.1 km upstream of the river mouth.

4.6.2 Flood Disasters

(1) General Characteristics of Floods in the Coastal River Basins

Characteristics of the floods in the coastal rivers are summarized as follows:

a) The rivers are short and have steep slope. Floods in these rivers emerge and withdraw rapidly, causing severe damages.

b) Rainfall distribution is uneven in the upstream and downstream basins. Annual rainfall in the upstream basin exceeds 2,000 mm and is small in the downstream basin, e.g. 700 mm in Phan Rang, 900 mm to 1,000 mm in the Luy River and 1,100 mm in Phan Thiet.

c) A big flood rarely happens. But once it occurs, the flood with a sharp peak normally appears, and flood duration is short. Most possible time when large floods occur is September to November.

d) Flood-prone areas are plains extending in the downstream area such as Phan Rang plain of the Phan Rang River, Luy River plain of the Luy River and Phan Thiet plain of the Ca Ty/Phan Thiet River.

(2) Features of 1964-flood in the Phan Rang River

The Phan Rang River experienced a historically big flood on December 17, 1964, which is considered to be a 50 to 100-year probable flood. Conditions of the flood are presented below, although little data and information are available (Source: Water Resources Department, Ninh Thuan Province):

a) At Tan My
- Maximum water level : 44.41 m MSL
- Peak discharge : 5,000 m^3/s

b) At Phan Rang
- Maximum water level : 6.07 m MSL

c) Damages: Inundation in the provincial capital (Phan Rang) caused loss of many houses and crops.

(3) Features of 1979-flood in the Phan Rang River

Because of continuous rainfall from November 12 through 17, soil was fully saturated, and river water stayed at a high level. Under this condition, a heavy rainfall occurred on November 18, raising river water level rapidly with an average increase rate of 10 cm/hour at Phan Rang and 18 cm/hour at Tan My. From 4:00 p.m. on November 18 the flood water submerged National Highway No. 11 at several sections and then National Highway No. 1.

Flood water overflowed both the river banks, inundating extensive areas in Phan Rang town and other areas in the Phan Rang plain.

The flood lasted for about 3 days at Tan My in the middle reaches and 4 days at Phan Rang in the lower reaches as its general feature is summarized as follows:

Outline of the 1979-Flood

Location	Beginning of flood		Flood peak		Flood rise
	H(m MSL)	Time/date	H(m MSL)	Time/date	(m)
Tan My	35.70	7:00pm/17	39.55	4:00pm/18	3.85
Phan Rang	1.12	1:00pm/17	4.87	2:00am/19	3.75

Flood damage data were collected by Ninh Thuan province. According to the data, inundated area was 7,000 ha (mostly paddy field), and crop was lost in 3,750 ha. Besides, the flood caused severe damages to many irrigation facilities of Nha Trinh-Lam Cam system and temporary dams built in the small rivers and streams.

Other losses and damages are reported as follows:

a) National Highway No. 1 was eroded for a total length of 400 m to 500 m due to the flood flow. Other roads in the area were also damaged in places.

b) Some people lost their lives.

c) Loss of livestock is 31 buffaloes, 4 pigs and 3,360 poultry.

d) Property damages are:

- Houses : 64 collapsed and 37 damaged
- Brick-kiln : 3 collapsed
- Pump : 4 swept away.

(4) Features of Disasters of Binh Thuan Province in the year 1993

According to data from Water Resources Department, Binh Thuan province, conditions on flood and other natural disasters of Binh Thuan province in the year 1993 have been appraised as presented below.

Binh Thuan province is suffering every year from disasters such as local passing floods, whirlwind and coast erosion to cause much loss and damages to the residents, although there is little storm directly attacking to Binh Thuan province in recent years. The severe province-wide flood occurred on October 9, 1993, causing losses and damages amounting to a total value of VND 82 billion.

The flood season in the year 1993 began late, especially in the Luy, Ca Ty, Phan Rang and La

Nga rivers, because rainfall was intensive at the beginning of October. The flood with high rainfall intensity marked the following maximum flood water levels at the four selected points:

Flood Water Level in the 1993-Flood

River	Flood water level
Luy	6.41 m(exceeded 0.41 m higher than 3rd warning level)
Muong Man	10.25 m(exceeded 4.25 m higher than 3rd warning level)
Ca Ty(at Phan Thiet)	2.8 m (exceeded 1.3 m higher than 3rd warning level)
La Nga(at Ta Pao)	9.15 m(equals to the 3rd warning)

The areas with severe damages to resident's properties, irrigation facilities, transportation system and buildings were extended in Phan Thiet, Ham Thuan Bac, Bac Binh, Ham Thuan Nam and Ham Tan. Estimated losses and damages were about VND 100 billion as shown in Table 4.7.

4.6.3 Flood Mitigation Measures

Floods in the coastal river basins are the flush type with a sharp peak and a short duration. For this type of floods, runoff retention by reservoir would be effective, and the construction of multipurpose reservoirs is thus proposed as a principal and practical flood control measure in these basins.

In addition, flood mitigation measures by channel improvement and structures are to be considered as remedial measures in the town areas and other important locations. It is to be noted that the channel improvement to protect the agricultural lands shall be planned as component works of agricultural development projects in the area.

4.6.4 Summary and Recommendations

a) There exist many rivers in the coastal area. Among these, major rivers suffering from flood damages are the Phan Pang, Luy, Phan Thiet and Ca Ty.

b) Floods in the coastal river basins are characterized by:

- Sharp peak with a short duration,
- Rare occurrence but big flood once occurred, and
- Flood runoff caused by heavy rainfall in the upper basin; that is, the flooding areas have little rainfall.

c) Runoff retention by reservoir would be effective for this type of floods (sharp peak with a short duration). Channel improvement by diking system and river training structure is effective to protect the town area and agricultural lands from flooding.

d) Recommendations

- Hydrological records such as rainfall and stream flow are limited in the recording periods and locations in the coastal river basins. It is thus required to strengthen the meteo-hydrological observation system for those river basins.
- Flood mitigation measure should be planned in complying with development schemes in the basin.

TABLES

Table 2.1 Distance of Major Interesting Points from the River Mouth

Dong Nai River

Distance (km)	Interesting Points	Elevation (m,MSL)
0.0	River mouth	
21.0	Vam Co R.	
51.3	Long Tau R.	
59.5	Saigon R.	
94.3	Bien Hoa Br.(Rt.316)	
98.3	Railway Br.	
134.1		5.0
150.5	Be R.	
154.2		10.0
155.4		20.0
157.9		30.0
159.6		40.0
160.0	Tri An Dam	
198.2	La Nga R.	
200.7		50.0
202.8		60.0
204.4		70.0
208.9		80.0
216.0		90.0
219.0		100.0
228.0	Ta Lai Sta.	
233.9		110.0
238.2	Da Houai R.	
293.1	Valley in upper reaches	120.0

La Nga River

Distance (km)	Interesting Points	Elevation (m,MSL)
0.0	Dong Nai R.(198.2km)	
5.1	La Nga Br.	
8.7		50.0
17.5		60.0
30.7		70.0
37.5		80.0
44.9		90.0
50.0		100.0
54.1	Rapids in downstream	
95.6		110.0
97.6	Bridge (Vo Xu)	
133.2		120.0
150.0	Valley in upper reaches	

Be River

Distance (km)	Interesting Points	Elevation (m,MSL)
0.0	Dong Nai R.(150.5km)	
1.2	No plain in upper reaches	10.0
42.2		20.0
120.3		30.0
120.4	Road Br.(Rt.13)	
156.4		40.0

Saigon River

Distance (km)	Interesting Points	Elevation (m,MSL)
0.0	Dong Nai R.(59.5km)	<10m,MSL
10.7	Ben Luc R.(New canal)	
12.7	Ben Luc R.(Old ch.)	
17.1	Saigon Br.(Rt.316)	
18.2	End of cut-off channel	
19.0	Bridge	
20.0	Start of cut-off channel	
20.6	Railway Br.	
22.3	Ben Cat R.	
32.9	Bridge	
39.0	Rach Tra Canal	
57.4	Thi Tinh R.	
130.0	Vallay in upper reaches	
132.0	Dau Tieng Dam	
137.7	Tributary(Suoi Ba Hao)	
140.0		<10m,MSL

East Vam Co River

Distance (km)	Interesting Points	Elevation (m,MSL)
0.0	Dong Nai(21.0km)	<10m,MSL
16.1	Rach Cac R.	
34.5	West Vam Co R.	
56.5	Ben Luc R.	
60.8	Tho Thua C.	
74.6	Kinh Xang C.	
108.9	Tan Hoa Town	
134.6	Hieu Thien Town	
205.2	Rach Ben Da R.	
210.0		<10m,MSL

West Vam Co River

Distance (km)	Interesting Points	Elevation (m,MSL)
0.0	E. Vam Co R.(34.5km)	
32.8	Tan An Town	<10m,MSL
45.8	Tho Thua C.	
50.8	End of cut-off channel	
51.5	Start of cut-off channel	
78.9	Tuyen Nhon Town	
121.0	Moc Hoa Town	
136.8	Rach Cai Rang R.	
140.0		<10m,MSL

Table 2.2 Features of Monthly Discharge in the Dong Nai River Basin

<MONTHLY RAINFALL>

	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ave. (mm/mon)	Total (mm/yr)
Tan Son Nhat(mm/mon)	13.1	4.3	11.3	49.6	211.0	309.8	295.8	270.8	331.3	270.9	116.6	47.9	161	1932.4
Da Lat(mm/mon)	7.7	18.7	59.5	163.3	209.1	190.8	232.7	236.6	305.4	250.3	91.7	26.0	149	1791.8

<MONTHLY DISCHARGE>

Tri An Station/ Dong Nai River — Catchment area: 14,025 km²

		Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ave. (m^3/s)	Height (mm/yr)
Max.	$Q(m^3/s)$	133	92	59	92	242	600	1490	2110	1860	1650	817	336		
Min.	$Q(m^3/s)$	73	38	32	37	52	230	538	794	820	914	449	180		
Ave.	$Q(m^3/s)$	106	67	48	58	137	409	750	1421	1350	1296	611	249	542	1,219
	Specific $Q(m^3/s/km^2)$	0.008	0.005	0.003	0.004	0.010	0.029	0.053	0.101	0.096	0.092	0.044	0.018		

Phuoc Hoa Station/ Be River — Catchment area: 5,765 km²

		Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ave. (m^3/s)	Height (mm/yr)
Max.	$Q(m^3/s)$	66	39	24	24	63	348	435	930	790	595	369	153		
Min.	$Q(m^3/s)$	32	16	9	4	11	19	119	246	345	290	154	66		
Ave.	$Q(m^3/s)$	50	27	16	15	35	121	233	503	574	469	244	107	199	1,091
	Specific $Q(m^3/s/km^2)$	0.009	0.005	0.003	0.003	0.006	0.021	0.040	0.087	0.100	0.081	0.042	0.018		

Dau Tieng/ Saigon River — Catchment area: 2,700 km²

		Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ave. (m^3/s)	Height (mm/yr)
Max.	$Q(m^3/s)$	29	26	21	22	27	49	76	116	166	148	108	37		
Min.	$Q(m^3/s)$	24	23	19	19	17	18	38	74	70	102	53	29		
Ave.	$Q(m^3/s)$	27	24	21	20	23	36	58	89	132	128	76	33	56	649
	Specific $Q(m^3/s/km^2)$	0.010	0.009	0.008	0.007	0.008	0.013	0.021	0.033	0.049	0.048	0.028	0.012		

Table 3.1 Summary of Calculated Peak Discharge

Location	Case	Calculated Peak Discharge (m3/s)					
		100-yr	50-yr	20-yr	10-yr	5-yr	2-yr
Cat Tien/ Dong Nai R.	Basic discharge	6,590	5,810	4,789	4,022	3,256	2,202
	With 4 reservoirs	6,590	5,810	4,789	4,022	3,256	2,202
	With 7 reservoirs	4,499	3,814	3,201	2,237	2,269	1,621
Ta Lai/ Dong Nai R.	Basic discharge	6,558	5,843	4,904	4,198	3,495	2,529
	With 4 reservoirs	6,558	5,843	4,904	4,198	3,495	2,529
	With 7 reservoirs	5,136	4,448	3,800	3,308	2,814	2,129
Ta Pao/ La Nga R.	Basic discharge	2,100	1,890	1,614	1,406	1,196	896
	With 4 reservoirs	1,551	1,390	1,186	1,034	899	708
	With 7 reservoirs	1,551	1,390	1,186	1,034	899	708
Phu Dien/ La Nga R.	Basic discharge	1,235	1,130	995	893	792	659
	With 4 reservoirs	1,167	1,075	955	864	775	650
	With 7 reservoirs	1,175	1,075	955	864	775	650
Tri An/ Dong Nai R.	Basic discharge	8,265	7,494	6,459	5,662	4,844	3,915
	With 4 reservoirs	6,257	5,649	4,943	4,427	3,890	3,144
	With 7 reservoirs	5,938	5,284	4,666	4,199	3,717	3,046
Phuoc Hoa/ Be R.	Basic discharge	3,230	3,002	2,691	2,446	2,189	1,805
	With 4 reservoirs	2,388	2,209	1,976	1,801	1,624	1,370
	With 7 reservoirs	1,894	1,778	1,623	1,503	1,378	1,194
Be R.at Dong Nai R.jct.	Basic discharge	3,173	2,941	2,630	2,391	2,146	1,810
	With 4 reservoirs	2,483	2,319	2,116	1,959	1,795	1,551
	With 7 reservoirs	2,200	2,078	1,907	1,774	1,637	1,437
Dong Nai R.at Saigon R.jct.	Basic discharge	10,784	9,871	8,635	7,673	6,688	5,411
	With 4 reservoirs	8,980	8,187	7,284	6,586	5,858	4,843
	With 7 reservoirs	8,266	7,501	6,712	6,095	5,478	4,580
Dau Tieng/ Saigon R.	Basic discharge	3,197	2,828	2,351	1,997	1,645	1,151
	With 4 reservoirs	556	514	459	416	373	309
	With 7 reservoirs	556	514	459	416	373	309
Thu Dau Mot/ Saigon R.	Basic discharge	2,200	1,954	1,667	1,466	1,254	937
	With 4 reservoirs	1,227	1,099	930	803	675	495
	With 7 reservoirs	1,227	1,099	930	803	675	495
Saigon R.at Dong Nai R.jct.	Basic discharge	2,274	2,029	1,706	1,461	1,223	929
	With 4 reservoirs	1,147	1,029	872	754	635	486
	With 7 reservoirs	1,147	1,029	872	754	635	486

Remarks:

1) Basic discharge: With no dam
2) With 4 dams: Including existing Dau Tieng, Tri An and Thac Mo dams, and Ham Thuan dam under construction.
3) With 7 dams: Including proposed Dong Nai No.3, No.4, and Fu Mieng dams in addition to the above 4 dams.

Table 3.2 Storage Functions of Existing and Proposed Reservoirs in the Dong Nai River Basin

RIVER	DAM	FSL (m,MSL)	RES.AREA (km2)	SPILLWAY(m)		P	K (m,sec)
				BxNo.	Total		
DONG NAI	DN NO.3	580	48	12.5x6	75	0.67	1,261,222
	DN NO.4	480	11	12.5x6	75	0.67	289,030
	TRI AN	62	323	16x11	176	0.67	4,806,018
LA NGA	HAM THUAN	605	25.2	11x5	55	0.67	814,236
BE	THAC MO	218	106	11x4	44	0.67	3,974,313
	FU MIENG	75	61	12.5x4	50	0.67	2,100,267
		77	70	12.5x4	50	0.67	2,410,142
	PHUOC HOA	45	38	15x6	90	0.67	884,192
SAIGON	DAU TIENG	24.4	270	10x6	60	0.67	8,232,295

Table 4.1 Conditions for Drainage Analysis (La Nga Area)

Basin: Elevation(H)-Area(V)-Volume(V)

Upper Basin			Lower Basin		
Existing			Existing		
H (m,MSL)	A (km2)	V (mil.m3)	H (m,MSL)	A (km2)	V (mil.m3)
103.5	0	0	101	0	0
110	18.3	59.475	110	21	94.5
115	110.2	380.725	115	131	474.5
120	194.8	1143.225	120	218.8	1349

With Dike			With Dike		
H (m,MSL)	A (km2)	V (mil.m3)	H (m,MSL)	A (km2)	V (mil.m3)
103.5	0	0	101	0	0
110	3.4	11.05	110	0.9	4.05
115	13.8	54.05	115	19.1	54.05
120	21.9	143.3	120	29.4	175.3

Inflow: 10-yr Flood Discharge

Existing (No Dam)					With Ham Thuan DAm				
Basin	Ta Pao	Phu Dien	Qin		Basin	Ta Pao	Phu Dien	Qin	
1013	2013	2015	Upper B.	Lower B.	1013	2013	2015	Upper B.	Lower B.
110.00	181.20	291.20	236.20	55.00	110.00	181.20	291.20	236.20	55.00
114.57	188.19	291.54	245.48	57.29	114.57	185.96	291.48	243.25	57.29
166.12	258.65	296.66	341.71	83.06	166.12	230.30	295.53	313.36	83.06
488.72	783.87	340.36	1028.23	244.36	488.72	559.59	329.22	803.95	244.36
784.29	1406.09	516.48	1798.24	392.15	784.29	1034.24	463.48	1426.39	392.15
356.51	954.68	793.20	1132.94	178.26	356.51	1025.47	687.42	1203.73	178.26
291.87	520.70	893.45	666.64	145.94	291.87	753.29	820.56	899.23	145.94
270.66	513.31	881.70	648.64	135.33	270.66	571.99	864.00	707.32	135.33
262.42	500.75	860.21	631.96	131.21	262.42	521.55	859.68	652.76	131.21
259.01	477.53	838.70	607.04	129.51	259.01	497.58	843.18	627.09	129.51
257.57	484.52	817.78	613.31	128.79	257.57	485.19	824.67	613.98	128.79
245.78	461.85	800.41	584.74	122.89	245.78	471.92	806.61	594.81	122.89
224.80	428.41	779.34	540.81	112.40	224.80	444.83	786.43	557.23	112.40
215.50	397.99	752.55	505.74	107.75	215.50	418.60	761.55	526.35	107.75
211.06	387.41	724.33	492.94	105.53	211.06	399.33	735.13	504.86	105.53
208.86	381.99	699.10	486.42	104.43	208.86	388.56	709.88	492.99	104.43
204.41	374.75	677.38	476.96	102.21	204.41	379.92	687.22	482.13	102.21
197.27	362.61	657.61	461.25	98.64	197.27	369.58	666.52	468.22	98.64
193.61	352.08	638.43	448.89	96.81	193.61	359.74	646.88	456.55	96.81
191.67	347.22	620.64	443.06	95.84	191.67	352.34	628.74	448.18	95.84

Outflow: Stage(H)-Discharge(Q)

Phu Dien		Vo Xu P.S.	
H (m,MSL)	Total Q (m3/s)	H (m,MSL)	Total Q (m3/s)
103	0.0	103	0.0
104	164.2	104	164.2
105	360.8	105	360.8
106	619.9	106	619.9
107	1058.3	107	1058.3
108	1849.3	108	1849.3
109	2899.0	109	2899.0
110	4172.6	110	4172.6
111	5649.8	111	5649.8
112	7316.3	112	7316.3

Table 4.2 Profile of River Channel in the Lower Dong Nai River (1/2)

(Dong Nai River)

Sect. No.	Distance(km) Interval (dX:km)	Distance(km) Cumlat. (X:km)	Elevation(m,MSL) River bank Left	Elevation(m,MSL) River bank Right	Elevation(m,MSL) River bed Lowest	Elevation(m,MSL) River bed Average	River width (W:m)	Sect. area (A:m2)	Depth Max. (Hx:m)	Depth Mean (Hm:m)	Depth Ratio Hm/Hx
R.M		0.0									
DN1	19.8	19.8	1.819	1.190	-14.368	-8.856	3,101	31,157	15.558	10.046	0.65
DN2	5.2	25.0	1.807	1.607	-10.605	-8.161	1,795	17,544	12.212	9.771	0.80
DN3	5.8	30.8	1.932	1.413	-20.600	-12.561	1,146	16,011	21.988	13.977	0.64
DN4	6.6	37.4	1.489	1.424	-12.374	-9.665	1,252	13,885	13.798	11.089	0.80
DN5	4.1	41.5	1.572	1.339	-19.338	-13.469	876	12,973	20.676	14.808	0.72
DN6	5.0	46.5	1.439	1.657	-33.630	-18.723	604	12,170	35.069	20.162	0.57
DN7	5.5	52.0	1.441	1.678	-17.415	-11.455	1,449	18,683	18.856	12.896	0.68
DN8	8.6	60.6	1.326	1.395	-12.599	-7.403	1,508	13,166	13.925	8.729	0.63
DN9	2.6	63.2	1.285	1.838	-15.708	-11.361	785	9,922	16.993	12.646	0.74
DN10	9.3	72.5	1.170	1.287	-23.801	-11.804	867	11,250	24.971	12.974	0.52
DN11	10.2	82.7	1.706	1.409	-13.888	-8.775	765	7,786	15.297	10.184	0.67
DN13	5.6	88.3	1.424	1.448	-7.338	-5.942	862	6,347	11.613	7.366	0.63
DN14	6.2	94.5	2.654	4.629	-16.687	-11.194	317	4,390	19.341	13.848	0.72
DN15	4.9	99.4	3.186	2.245	-8.694	-4.793	808	5,688	12.434	7.038	0.57
DN16	5.3	104.7	3.162	3.422	-12.538	-7.115	415	4,263	15.700	10.277	0.65
DN17	6.5	111.2	4.378	2.740	-15.230	-8.541	292	3,297	17.970	11.281	0.63
Average	-	-	1.987	1.920	-15.926	-9.989	1053	11783	17.900	11.693	0.66
Related Sections											
DN12		78.5	1.353	1.382	-8.239	-4.703	214	1,294	11.542	6.056	0.52
A1			2.210	0.614	-18.933	-10.646	740	8,328	19.547	11.260	0.58

(Saigon River)

Sect. No.	Distance(km) Interval (dX:km)	Distance(km) Cumlat. (X:km)	Elevation(m,MSL) River bank Left	Elevation(m,MSL) River bank Right	Elevation(m,MSL) River bed Lowest	Elevation(m,MSL) River bed Average	River width (W:m)	Sect. area (A:m2)	Depth Max. (Hx:m)	Depth Mean (Hm:m)	Depth Ratio Hm/Hx
R.M		0.0	0.000								
SG1	2.6	2.6	1.170	2.976	-17.768	-7.738	628	5,596	18.938	8.908	0.47
SG2	3.9	6.5	2.263	1.764	-15.341	-8.282	507	5,094	11.105	10.046	0.90
SG3	6.5	13.0	1.405	1.823	-16.170	-11.523	308	3,988	17.575	12.928	0.74
SG4	4.3	17.3	1.707	2.051	-21.615	-11.039	364	4,641	23.322	12.746	0.55
SG7	9.5	26.8	1.447	1.548	-20.417	-9.573	300	3,309	21.864	11.020	0.50
SG8	6.9	33.7	1.076	0.833	-18.512	-11.411	198	2,422	19.345	12.244	0.63
SG9	4.2	37.9	1.392	1.008	-20.327	-10.597	228	2,644	21.335	11.605	0.54
SG10	8.1	46.0	2.126	2.245	-13.976	-8.369	233	2,445	16.102	10.495	0.65
SG11	3.7	49.7	1.188	1.316	-14.930	-7.246	212	1,789	16.118	8.434	0.52
SG12	5.2	54.9	1.622	1.098	-11.693	-5.837	260	1,801	12.791	6.935	0.51
SG13	7.2	62.1	1.164	2.007	-12.752	-8.503	146	1,415	13.916	9.667	0.69
Average	-	-	1.505	1.697	-16.682	-9.102	308	3195	17.492	10.457	0.61
Related Sections											
SG5		2.8	2.828	1.350	-17.588	-10.470	290	3,424	18.938	11.820	0.62
SG6		1.1	1.140	1.763	-19.898	-11.327	269	3,357	21.038	12.467	0.59
A2		1.5	1.472	1.859	-7.729	-2.717	153	640	9.201	4.189	0.46
A3		3.5	3.477	1.759	-2.070	0.116	81	133	3.829	1.643	0.43
A4		1.3	1.250	1.259	-7.497	-2.352	106	380	8.747	3.602	0.41
A5		1.1	1.120	1.198	-6.360	-2.545	119	435	7.480	3.665	0.49

Table 4.2 Profile of River Channel in the Lower Dong Nai River (2/2)

(East Vam Co River)

Sect. No.	Distance(km) Interval (dX:km)	Cumlat. (X:km)	Elevation(m,MSL) River bank Left	Right	River bed Lowest	Average	River width (W:m)	Sect area (A:m2)	Depth Max. (Hx:m)	Mean (Hm:m)	Ratio Hm/Hx
R.M		0.0									
EV1	3.5	3.5	1.499	1.645	-7.849	-6.050	1,675	12,640	9.348	7.549	0.81
EV2	6.8	10.3	1.487	1.683	-17.447	-11.799	775	10,301	18.934	13.286	0.70
EV3	8.2	18.5	1.571	1.358	-16.438	-9.525	912	9,921	17.796	10.883	0.61
EV4	7.4	25.9	1.499	1.480	-28.594	-19.902	460	9,840	30.074	21.382	0.71
EV5	9.1	35.0	1.311	1.852	-12.066	-7.101	526	4,428	13.377	8.412	0.63
EV6	7.7	42.7	1.291	1.228	-15.169	-10.526	256	3,006	16.397	11.754	0.72
EV7	7.9	50.6	1.281	1.275	-11.204	-8.313	272	2,606	12.479	9.588	0.77
EV8	5.7	56.3	1.946	1.551	-9.595	-7.120	286	2,483	11.146	8.671	0.78
EV9	6.1	62.4	1.415	1.306	-16.163	-9.270	209	2,207	17.469	10.576	0.61
EV10	3.2	65.6	1.010	1.028	-17.632	-10.712	220	2,584	18.642	11.722	0.63
EV11	8.9	74.5	1.127	1.119	-20.254	-11.058	176	2,137	21.373	12.177	0.57
EV12	5.4	79.9	0.927	0.874	-19.199	-11.335	165	2,011	20.073	12.209	0.61
EV13	4.6	84.5	1.203	1.141	-17.209	-10.747	182	2,169	18.350	11.888	0.65
EV14	8.6	93.1	0.822	1.217	-12.803	-7.887	210	1,833	13.625	8.709	0.64
EV15	6.0	99.1	0.985	1.584	-16.692	-10.959	156	1,868	17.677	11.944	0.68
EV16	4.0	103.1	0.997	0.987	-15.919	-9.574	166	1,757	16.906	10.561	0.62
EV17	5.9	109.0	0.807	1.307	-20.061	-9.548	190	1,965	20.868	10.355	0.50
EV18	4.0	113.0	0.775	0.938	-17.947	-11.569	136	1,673	18.722	12.344	0.66
EV19	4.0	117.0	1.079	0.886	-14.895	-9.927	161	1,745	15.781	10.813	0.69
EV20	6.1	123.1	2.834	0.959	-16.691	-9.928	148	1,610	17.650	10.887	0.62
EV21	5.1	128.2	1.082	0.912	-21.849	-11.843	163	2,084	22.761	12.755	0.56
EV22	6.2	134.4	1.511	1.056	-15.787	-8.427	168	1,596	16.843	9.483	0.56
Average	-	-	1.294	1.245	-16.430	-10.142	346	3748	17.559	11.270	0.65
Related Sections											
A6		1.4	1.439	1.351	-16.998	-12.127	259	3,492	18.569	13.478	0.73

(West Vam Co River)

Sect. No.	Distance(km) Interval (dX:km)	Cumlat. (X:km)	Elevation(m,MSL) River bank Left	Right	River bed Lowest	Average	River width (W:m)	Sect. area (A:m2)	Depth Max. (Hx:m)	Mean (Hm:m)	Ratio Hm/Hx
R.M		0.0									
WV1	0.5	0.5	1.352	1.349	-18.309	-8.768	362	3,659	19.658	10.117	0.51
WV2	8.3	8.8	1.629	1.459	-17.181	-10.856	246	3,030	18.640	12.315	0.66
WV3	5.1	13.9	1.372	1.613	-14.534	-10.880	280	2,869	15.906	12.252	0.77
WV4	8.6	22.5	1.288	1.196	-16.604	-9.486	219	2,337	17.800	10.682	0.60
WV5	5.7	28.2	1.291	1.251	-16.805	-9.203	222	2,325	18.056	10.454	0.58
WV6	5.3	33.5	1.489	1.767	-16.941	-10.309	185	2,181	18.430	11.798	0.64
WV7	5.5	39.0	1.215	1.477	-16.215	-9.115	212	2,189	17.430	10.330	0.59
WV8	6.1	45.1	1.242	1.180	-14.467	-7.495	189	1,639	15.647	8.675	0.55
WV9	5.6	50.7	1.210	1.178	-19.158	-10.991	172	2,096	20.336	12.169	0.60
WV10	1.2	51.9	1.123	1.268	-17.746	-8.724	190	1,873	18.869	9.847	0.52
WV11	5.6	57.5	1.135	1.300	-12.069	-8.082	191	1,762	13.204	9.217	0.70
WV12	7.6	65.1	1.267	1.226	-14.691	-8.383	159	1,524	15.917	9.609	0.60
WV13	2.6	67.7	1.224	1.011	-15.390	-8.042	167	1,512	16.401	9.053	0.55
WV14	10.3	78.0	1.714	1.487	-16.923	-7.988	131	1,241	18.410	9.475	0.51
WV15	5.4	83.4	1.412	1.348	-15.661	-7.466	142	1,249	17.009	8.814	0.52
WV16	5.3	88.7	1.262	1.471	-12.956	-6.040	164	1,195	14.047	7.302	0.52
WV17	5.5	94.2	1.652	1.372	-12.929	-6.628	139	1,112	14.301	8.000	0.56
WV18	6.3	100.5	1.755	1.640	-11.725	-6.683	107	890	13.365	8.323	0.62
WV19	4.4	104.9	1.409	2.317	-13.018	-4.409	147	852	14.457	5.818	0.40
WV20	5.9	110.8	1.458	2.211	-9.809	-4.133	171	954	11.267	5.591	0.50
WV21	5.1	115.9	1.430	2.645	-7.924	-3.652	151	769	9.354	5.082	0.54
WV22	5.6	121.5	2.489	1.475	-10.263	-3.999	152	834	11.738	5.474	0.47
Average	-	-	1.429	1.511	-14.607	-7.788	186	1731	15.920	9.109	0.57

Table 4.3 Estimation of Existing Channel Capacity in the Lower Dong Nai River

(Dong Nai River) n= 0.030

Sect. No.	Distance(km) Interval (dX:km)	Distance(km) Cumlat. (X:km)	Sect. area A(m2)	Mean Hm(m)	TL=0.00 I/I	TL=0.00 v(m/s)	TL=0.00 Q(m3/s)	TL=1.27 I/I	TL=1.27 v(m/s)	TL=1.27 Q(m3/s)
R.M		0.0								
DN1	19.8	19.8	31,157	10.046	49,600	0.70	21,711	150,000	0.40	12,485
DN2	5.2	25.0	17,544	9.771	49,600	0.68	12,001	150,000	0.39	6,901
DN3	5.8	30.8	16,011	13.977	49,600	0.87	13,905	150,000	0.50	7,996
DN4	6.6	37.4	13,885	11.089	49,600	0.74	10,334	150,000	0.43	5,943
DN5	4.1	41.5	12,973	14.808	49,600	0.90	11,709	150,000	0.52	6,733
DN6	5.0	46.5	12,170	20.162	49,600	1.11	13,493	150,000	0.64	7,759
DN7	5.5	52.0	18,683	12.896	49,600	0.82	15,378	150,000	0.47	8,843
DN8	8.6	60.6	13,166	8.729	49,600	0.63	8,354	150,000	0.36	4,804
DN9	2.6	63.2	9,922	12.646	49,600	0.81	8,061	150,000	0.47	4,635
DN10	9.3	72.5	11,250	12.974	49,600	0.83	9,297	150,000	0.48	5,346
DN11	10.2	82.7	7,786	10.184	49,600	0.70	5,475	150,000	0.40	3,148
DN13	5.6	88.3	6,347	7.366	49,600	0.57	3,596	150,000	0.33	2,068
DN14	6.2	94.5	4,390	13.848	17,000	1.47	6,472	150,000	0.50	2,179
DN15	4.9	99.4	5,688	7.038	17,000	0.94	5,340	17,000	0.94	5,340
DN16	5.3	104.7	4,263	10.277	17,000	1.21	5,152	17,000	1.21	5,152
DN17	6.5	111.2	3,297	11.281	17,000	1.29	4,240	17,000	1.29	4,240
Average(DN1:DN7)			17,489	13.250		0.83	14,076		0.48	8,094
Average(DN8:DN17)			7,345	10.483		0.94	6,221		0.66	4,101

(Saigon River) n= 0.03

Sect. No.	Distance(km) Interval (dX:km)	Distance(km) Cumlat. (X:km)	Sect. area A(m2)	Mean Hm(m)	TL=0.00 I/I	TL=0.00 v(m/s)	TL=0.00 Q(m3/s)	TL=1.27 I/I	TL=1.27 v(m/s)	TL=1.27 Q(m3/s)
R.M		0.0								
SG1	2.6	2.6	5,596	8.908	90,000	0.48	2,672	218,000	0.31	1,717
SG2	3.9	6.5	5,094	10.046	90,000	0.52	2,635	218,000	0.33	1,693
SG3	6.5	13.0	3,988	12.928	90,000	0.61	2,441	218,000	0.39	1,568
SG4	4.3	17.3	4,641	12.746	90,000	0.61	2,814	218,000	0.39	1,808
SG7	9.5	26.8	3,309	11.020	90,000	0.55	1,821	218,000	0.35	1,170
SG8	6.9	33.7	2,422	12.244	90,000	0.59	1,430	218,000	0.38	919
SG9	4.2	37.9	2,644	11.605	90,000	0.57	1,506	218,000	0.37	968
SG10	8.1	46.0	2,445	10.495	90,000	0.53	1,302	218,000	0.34	837
SG11	3.7	49.7	1,789	8.434	90,000	0.46	824	218,000	0.30	529
SG12	5.2	54.9	1,801	6.935	90,000	0.40	728	218,000	0.26	468
SG13	7.2	62.1	1,415	9.667	90,000	0.50	713	218,000	0.32	458
Average(SG1:SG9)			3,956	11.357		0.56	2,188		0.36	1,406
Average(SG10:SG13)			1,863	8.883		0.48	892		0.31	573

(East Vam Co River) n= 0.03

Sect. No.	Distance(km) Interval (dX:km)	Distance(km) Cumlat. (X:km)	Sect. area A(m2)	Mean Hm(m)	TL=0.00 I/I	TL=0.00 v(m/s)	TL=0.00 Q(m3/s)	TL=1.27 I/I	TL=1.27 v(m/s)	TL=1.27 Q(m3/s)
R.M		0.0								
EV1	3.5	3.5	12,640	7.549	206,000	0.28	3,572			
EV2	6.8	10.3	10,301	13.286	206,000	0.41	4,244			
EV3	8.2	18.5	9,921	10.883	206,000	0.36	3,578			
EV4	7.4	25.9	9,840	21.382	206,000	0.57	5,567			
EV5	9.1	35.0	4,428	8.412	206,000	0.30	1,345			
EV6	7.7	42.7	3,006	11.754	206,000	0.38	1,141			
EV7	7.9	50.6	2,606	9.588	206,000	0.33	864			
EV8	5.7	56.3	2,483	8.671	206,000	0.31	770			
EV9	6.1	62.4	2,207	10.576	206,000	0.35	781			
EV10	3.2	65.6	2,584	11.722	206,000	0.38	979			
EV11	8.9	74.5	2,137	12.177	206,000	0.39	831			
EV12	5.4	79.9	2,011	12.209	206,000	0.39	783			
EV13	4.6	84.5	2,169	11.888	206,000	0.38	830			
EV14	8.6	93.1	1,833	8.709	206,000	0.31	570			
EV15	6.0	99.1	1,868	11.944	206,000	0.38	717			
EV16	4.0	103.1	1,757	10.561	206,000	0.35	621			
EV17	5.9	109.0	1,965	10.355	206,000	0.35	686			
EV18	4.0	113.0	1,673	12.344	206,000	0.39	656			
EV19	4.0	117.0	1,745	10.813	206,000	0.36	627			
EV20	6.1	123.1	1,610	10.887	206,000	0.36	581			
EV21	5.1	128.2	2,084	12.755	206,000	0.40	836			
EV22	6.2	134.4	1,596	9.483	206,000	0.33	525			
Average(EV1:EV4)			10,676	13.275		0.41	4,240			
Average(EV5:EV15)			2,485	10.695		0.36	874			
Average(EV16:EV22)			1,776	11.028		0.36	647			

(West Vam Co River) n= 0.03

Sect. No.	Distance(km) Interval (dX:km)	Distance(km) Cumlat. (X:km)	Sect. area A(m2)	Mean Hm(m)	TL=0.00 I/I	TL=0.00 v(m/s)	TL=0.00 Q(m3/s) TL:MSL	TL=1.27 I/I	TL=1.27 v(m/s)	TL=1.27 Q(m3/s) TL:MHW
R.M		0.0								
WV1	0.5	0.5	3,659	10.117	132,000	0.43	1,570			
WV2	8.3	8.8	3,030	12.315	132,000	0.49	1,482			
WV3	5.1	13.9	2,869	12.252	132,000	0.49	1,399			
WV4	8.6	22.5	2,337	10.682	132,000	0.45	1,040			
WV5	5.7	28.2	2,325	10.454	132,000	0.44	1,020			
WV6	5.3	33.5	2,181	11.798	132,000	0.48	1,037			
WV7	5.5	39.0	2,189	10.330	132,000	0.44	953			
WV8	6.1	45.1	1,639	8.675	132,000	0.39	635			
WV9	5.6	50.7	2,096	12.169	132,000	0.49	1,017			
WV10	1.2	51.9	1,873	9.847	132,000	0.42	789			
WV11	5.6	57.5	1,762	9.217	132,000	0.40	711			
WV12	7.6	65.1	1,524	9.609	132,000	0.41	632			
WV13	2.6	67.7	1,512	9.053	132,000	0.40	603			
WV14	10.3	78.0	1,241	9.475	132,000	0.41	510			
WV15	5.4	83.4	1,249	8.814	132,000	0.39	489			
WV16	5.3	88.7	1,195	7.302	132,000	0.35	413			
WV17	5.5	94.2	1,112	8.000	132,000	0.37	408			
WV18	6.3	100.5	890	8.323	132,000	0.38	335			
WV19	4.4	104.9	852	5.818	132,000	0.30	253			
WV20	5.9	110.8	954	5.591	132,000	0.29	276			
WV21	5.1	115.9	769	5.082	132,000	0.27	209			
WV22	5.6	121.5	834	5.474	132,000	0.28	238			
Average(WV1:WV14)			2,160	10.428		0.44	957			
Average(WV15:WV22)			982	6.801		0.33	327			

Table 4.4 Works Proposed for the Implementation of Hoc Mon-Bac Binh Chanh Irrigation Project

Items of Work	Unit	System								Total
		An Ha	West Canal	Link Canal	Canal A	Canal B	Canal C	Tan Kien	Thy Cai	
Pumping Stations	no	5	-	-	-	-	-	-	-	5
Weirs	no	-	-	2	-	-	7	-	-	9
Major Sluices	no	-	1	4	1	1	5	1	-	13
Small Sluices in Main Canals	no	-	-	-	6	1	2	-	-	9
Small Sluices in Secondary Canals	no	26	-	-	5	9	21	20	26	107
Stop-Log Structures in Secondary Canals	no	29	-	8	-	9	10	-	-	56
Stop-Log Structures in Tertiary Canals	no	208	-	48	33	66	141	5	116	617
Dikes	km	24	-	-	-	-	-	-	19	43
Major Bridges	no	-	-	4	-	-	-	-	-	4
Car Bridges	no	3	-	-	-	-	-	-	-	3
Foot Bridges	no	20	-	1	6	11	22	-	20	80
Main Canals	km	-	9	14	7	7	7	9	-	54
Dredging	km	-	9	14	7	7	7	8	-	53
Excavation	km	-	-	-	-	-	-	2	-	2
Secondary Canals	km	50	-	31	14	24	54	15	62	250
Dredging	km	49	-	18	14	24	54	12	39	210
Excavation	km	1	-	13	-	-	-	2	23	40
Tertiary Canals	km	146	-	28	18	33	69	14	57	365
Dredging	km	100	-	2	18	33	27	6	9	193
Excavation	km	46	-	27	-	-	43	8	49	172
On-Farm Development	ha	3,962	-	1,182	588	973	2,199	597	2,696	12,197

Table 4.5 Permissible limits for Trade Effluents

No	Items	Unit	Limit for		
			Public sewer	Water course of	
				I	II
1	Temperature	°C	45	45	45
2	Colour	Livibond		7 units	7 units
3	pH	-	6-9	6-9	6-9
4	BOD	mg/l	200	20	60
5	COD	mg/l	350	60	100
6	Total suspended solids	mg/l	100	30	50
7	Total dissolved solids	mg/l	2000	1000	1500
8	Chloride (as Cl-)	mg/l	1000	400	500
9	Sulphate (as SO_4^{2-})	mg/l	1000	200	300
10	Sulphide (S)	mg/l	0.5	0.2	0.2
11	Cyanide (CN)	mg/l	1	0.1	0.1
12	Detergents	mg/l	20	5	15
13	Oil, grease	mg/l	30	5	10
14	Arsenic (As)	mg/l	3	0.05	1
15	Barium (Ba)	mg/l	10	5	5
16	Tin (Sn)	mg/l	10	5	10
17	Iron (Fe)	mg/l	30	1	20
18	Beryllium (Be)	mg/l	1	0.5	0.5
19	Boron (Bo)	mg/l	5	0.5	5
20	Manganese (Mn)	mg/l	7	0.5	5
21	Phenolic compounds	mg/l	0.4	0	0.2
22	Cadmium (Cd)	mg/l	0.5	0.01	0.1
23	Chromium (Cr^{3+} and Cr^{6+})	mg/l	4	0.05	1
24	Copper (Cu)	mg/l	5	0.1	0.1
25	Lead (Pb)	mg/l	5	0.1	0.1
26	Mercury (Hg)	mg/l	0.5	0.001	0.05
27	Nickel (Ni)	mg/l	3	0.1	1
28	Selenium (Se)	mg/l	3	0.01	0.5
29	Silver (Ag)	mg/l	3	0.1	1
30	Zinc (Zn)	mg/l	6	0.5	1
31	Metals in total	mg/l	6	0.5	1

Notes:

1) **Class I:** Surface water for drinking, cooking and other domestic use
2) **Class II:** Other use of surface water
3) The concentration of toxic mental shall not exceed the limits as specified, individually or in total.
4) Source: "Regulations on Environmental Pollution Control in Ho Chi Minh City" (May 15, 1993)

Table 4.6 Existing Water Quality Monitoring System

No.	Code	Name	River / Canal	Remarks	Authority
1	WS1	Ben Than	Saigon R.	Upstream of new water intake for HCM City (under construction)	HCMCEC
2	WS2	Binh Phuoc	Saigon R.	Upstream of HCM City	HCMCEC
3	WS3	Nha Rong	Saigon R.	Center of HCM City	HCMCEC
4	WS4	Nha Be	Nha Be R.	Below junction of Saigon and Dong Nai Rivers	HCMCEC
5	WD1	Hoa An	Dong Nai R.	Existing water treatment plant for HCM City	HCMCEC
6	WD2	Ben Go	Dong Nai R.	Downstream of Bien Hoa industrial area	SIWRP
7	WC1	Binh Dien	Ben Nghe C.	Tributary of Saigon River on eastern side of HCM City	HCMCEC
8	WC2	Rach Cat	Can Giuoc C.	Tributary of Nha Be River draining south from HCM City	SIWRP
9	WC3	Thi Nghe	Nhieu Loc C.	Waste water Canal in center of HCM City to Saigon River	SIWRP
10	WC4	Tan Thuan	Kenh Tau Hu	Waste water Canal draining across south of HCM City to Saigon Ri	SIWRP

Notes: 1) SIWRP: Sub-Institute of Water Resource Planning.

2) HCMCEC: Ho Chi Minh City Environment Committee.

3) Water sampling frequency is weekly and parameters analyzed are :

Temperature (°C); pH; Electrical Conductivity (mS/s); Dissolved Oxygen (DO);

5-day Biological Oxygen Demand (BOD-5); Total Suspended Solids (TSS); Oil / Grease;

Sulphates (SO_4); Copper (Cu); Lead (Pb) and Mercury (Hg)

4) Source: SIWRP as of 1994

Table 4.7 Damages due to natural Disasters in the Year 1993

(Binh Thuan Province)

(Unit:10^6VND)

Disasters	Month in 1993	General asset/ goods	Agriculture/ aquaculture	Public health/ education	Transport	Irrigation	Total
1. Flood	Aug.	76.0	840.0	-	260.0	100.0	1,276.0
2. Thunder	Sep.	34.5	-	-	-	-	34.5
3. Whirlwind	Sep.	60.0	-	20.0	-	-	80.0
4. Flood	Oct.	24,345.0	34,580.0	11,202.0	8,750.0	3,300.0	82,177.0
5. Draught		-	11,680.0	-	-	-	11,680.0
1st.	Aug.	-	(2,080.0)	-	-	-	(2,080.0)
2nd.	Nov.	-	(9,600.0)	-	-	-	(9,600.0)
6. Storm No.11	Dec.	20.0	400.0	-	-	-	420.0
7. Coast erosion	Dec.	610.0	200.0	50.0	-	-	860.0
Total	10^6VND	25,145.5	47,700.0	11,272.0	9,010.0	3,400.0	96,527.5
	%	26.1	49.4	11.7	9.3	3.5	100