Chapter 3 Natural Conditions

3.1 General

3.1.1 Outline of the Site Surveys in This Study

The Study Team carried out the following natural condition surveys in Ganh Rai Bay and the Thi Vai River by sub-letting to the local consulting firm in the Phase 1 Study in 2001. The purpose of the surveys are to establish the baseline data and information for planning and design of the required facilities related to the project.

(1) Statistical analysis on meteorological data and hydrological data,
(2) Analysis on historical change in coastline and riverbank,
(3) Current and water quality measurement in June and December 2001,
(4) Seabed materials (sediment) measurement in June and December 2001,
(5) Bathymetric survey in June 2001,
(6) Topographic survey in June 2001,
(7) River discharge survey in October and December 2001, and
(8) Geotechnical investigation in June 2001.

At the same time, the Study Team has collected existing information and reports relevant to the natural conditions in the Study Area to obtain supplementary data. Based on these available reports in the past, and the results of the above surveys and analyses carried out by the Study Team, the natural conditions in the Study Area are summarized hereinafter.

3.1.2 General Picture on Geological and Hydrological Conditions

The Study Area, covering the area from HCM City to Vung Tau City, is located geologically at "the eastern Nam Bo Plains", which has an area of 23,745 km^2, major provinces in which are Dong Nai, Binh Duong, Binh Phuoc, Tay Minh, Ba Ria-Vung Tau and the city of HCM. The plains are covered by ancient alluvial soils.

The Study Area belongs hydrologically to "the Dong Nai River Basin" as shown in Figure 3.1.1 with an area of about 35,000 km^2. The Dong Nai River originates in Lam Dong Province and has a length of 500km. At the upstream portion, it is formed by two rivers, i.e. the Da Dung and the Da Nhim. Flowing down, it absorbs tributaries, the La Nga from the left and the Be from the right. The La Nga River is important because of the existing large water reservoir, i.e. the Tri An Lake.

The Saigon River joins the Dong Nai River in HCM City, an important reservoir, the Dou Tieng Lake, is at the upstream of the Saigon River. On top of that, the existing port complex of HCM City locates along the Saigon River.

The Dong Nai River after passing HCM City is called the Soai Rap, which reaches to the river mouth open to the South China Sea. The estuary of the Soai Rap is a shallow delta. The Long Tau River separates from the Dong Nai, and flows to Ganh Rai Bay, which is the only access to the Saigon Port complex.

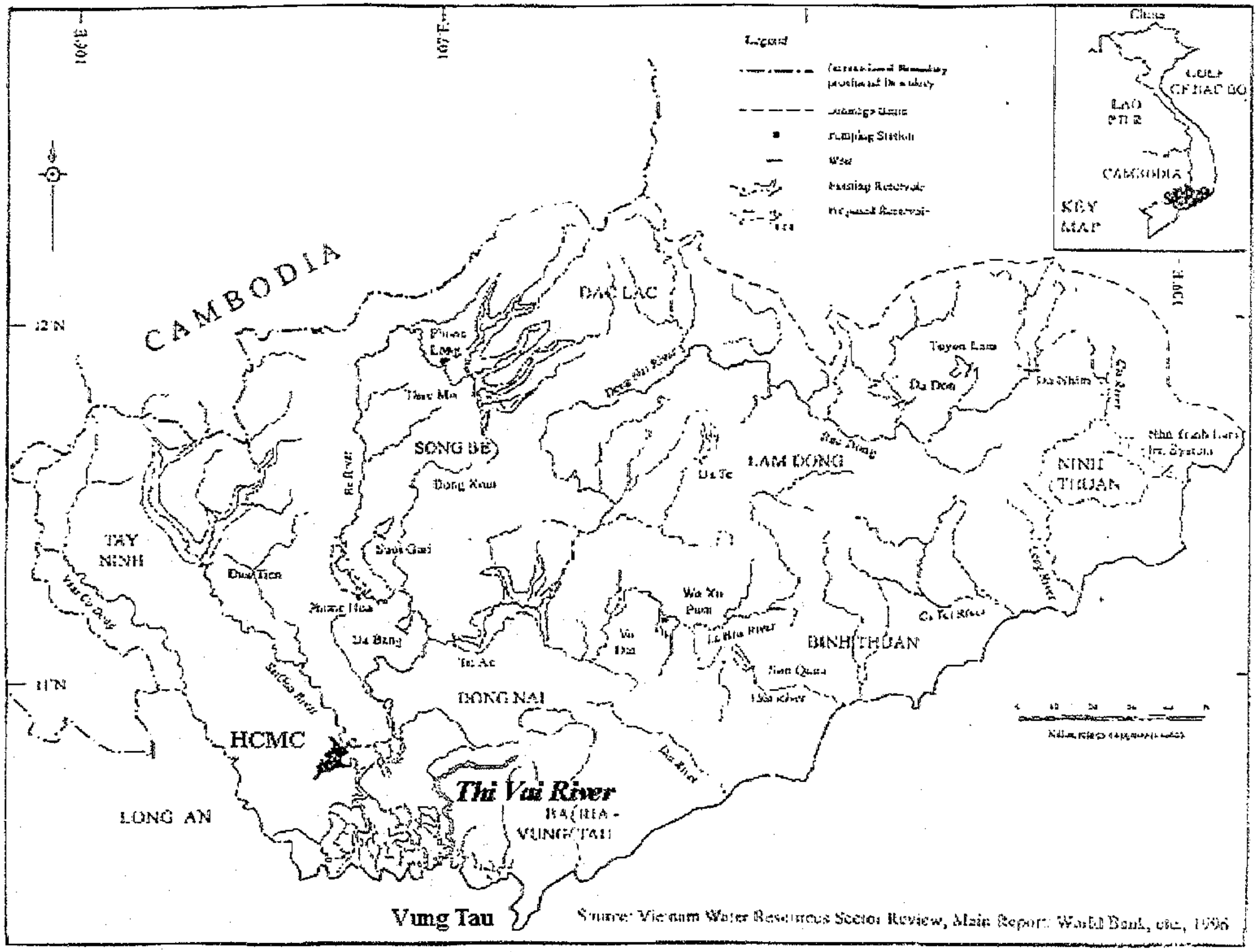


Figure 3.1.1 Dong Nai River Basin

The Thi Vai River is an independent river system from the Dong Nai River. It originates at mountains near Xuan Loc in Dong Nai province, and flows down for about 76 km, exiting into Ganh Rai Bay. The Thi Vai River Basin, which has an area of 520km^2, is 1/60 of the Dong Nai Basin or 1/75 of the Mekong Delta in south Vietnam.

Vung Tau city is located on the sand bank, or the tonbolo formed by the rocky mountains of Nui Lon and Nui Nho, which are made of granite, as the headland. The ports in Vung Tau are in the muddy estuary at the mouth of the Dinh River behind the city.

It is noted that, according to the "Building Code of Vietnam", the plain where HCM City is located is classified geologically as Zone C-IV-1: Plain of South Part, and Vung Tau as Zone C-III-2: Coast of Extreme Southern Central Part.

3.1.3 General Picture on Meteorological and Hydrographical Conditions

The Study Area has a humid tropical climate governed by the monsoon regime in Southeast Asia. There are two main seasons in HCM City, i.e. "the northeastern monsoon" from November to April, and "the southwest monsoon" from May to October. The former corresponds to "the dry season", and latter to "the wet season".

In HCM City, the annual average rainfall amounts to 1,896 mm and the average relative humidity during June to October is 83 %. Average monthly rainfall reaches 270 to 300 mm from June to October. The eastern Nam Bo plains, however, are the only ones in Vietnam that do not submerge during the rainy season, except the coastal region.

Although rare to happen, typhoons attack the southern Vietnam (Nam Bo) in November to December. In recent years, historical damages were recorded along the east coast of Nam Bo due to high waves and surges by Typhoon "*Linda*" in November 1997.

The hydrographical system of the Dong Nai River and the Thi Vai River can be characterized generally by relatively deep water and little transport of alluvium. The lower parts of these rivers are tidal compartments, or the effect of high tides in the sea can advance far into the inland.

3.1.4 General Picture on Coastal and Oceanographic Characteristics

The characteristics of the coastline in the Study Area between the Soai Rap mouth to the Vung Tau Cape are that the shore mostly consists of estuaries and shallow swamps of soft mud covered with dense mangrove forests, except the front coast of Can Gio which has already been protected by artificially constructed seawalls and jetties made of rocks.

The tide in this coast is predominantly "the semi-diurnal." The lowest low water level (LLWL) and the highest high water level (HHWL) recorded in Vung Tau are CDL -0.47 m in 1964 and CDL +4.43 m in 1956, respectively.

The offshore ocean current runs almost parallel to the coastline to South-south-west direction during the northeast monsoon season (October to April), and East-north-east direction during the southwest monsoon season (May to September). The surface speed is not high, or less than 1 knot.

The sea waves are generated by the monsoons, lows, and typhoons. During the northeast monsoon season, the Ganh Rai Bay area is protected by the Vung Tau Cape. During the southwesterly monsoon wind causes wind waves in Ganh Rai Bay, although the wave height is rather limited due to short fetches. On the other hand, typhoons can causes much higher waves, according to the result of visual observation of waves at Vung Tau and analysis of them by Marine Hydro-meteorological Research Center, the expected wave height by typhoons is estimated to be 4.6m in height for 100 year recurrence period.

Movement of sea bottom materials, or "sand-drift", can be caused by the wave-induced current and tidal current. The study or research on sedimentation mechanism in this Study Area has been carried out extensively as detailed in 13.3.

3.2 Natural Conditions in the Survey Area

Based on the collected existing data and the results of the natural condition surveys carried out by the local consultant by the sublet contract during a period of the Site Study in the Phase 1 Study. The natural conditions in the Survey Area are summarized as mentioned hereinafter.

The maximum or extreme values of meteorological data are summarized to prepare the fundamental information for determination of the design conditions as shown in Table 3.2.1 below.

Table 3.2.1 Maximum or Extreme Values of Meteorological Data at HCM City

Meteorological Data	Case	Value	Observed Date	Data Period
Wind	Max.	36 m/s, WSW	23/6/1972	1952-2000 (49 years)
Air temperature	Max.	39.3 °C	7/5/1998	
	Min.	14.1 °C	30/12/1976	
Rainfall	Annual max.	2,463 mm	1966	1952-1987 (36 years)
	Annual min.	1,391 mm	1958	
	Monthly max.	590 mm	9/1968	
	Daily max.	155 mm	30/5/1962	
	Hourly max.	114 mm	10/1981	
Air Pressure	Max.	1,019 mb	2/1962	
	Min.	999 mb	2/1973	
Thunderstorm	Max.	89 days/year	1976	
	Min.	31 days/year	1952	
Sunny hour	Annual max.	2,675 hours	1962	1959-1987 (29 years)
	Annual min.	2,144 hours	1975	
	Monthly max.	305 hours	3/1987	
	Monthly min.	122 hours	9/1977	

Source: Tan Son Nhat Meteorological Station

(1) Wind and Typhoons

(a) Monsoon Wind

The Survey Area located in the Tropical Monsoon Zone. There are basically two prevailing wind seasons in South Vietnam, i.e. the rainy season during May to October and the dry season during November to April as follows. They are characterized by:

Dry season: Wind direction of east to the northeast with average wind speed of 1 to 5 m/sec, and
Rainy season: Wind direction of the west to southwest with average wind speed of 5 to 10 m/sec.

(b) Monthly Wind Velocity

Average and maximum monthly wind velocities at Vung Tau and HCM City are shown in Table 3.2.2 (1) and (2) below. From these tables, it can be seen that monthly average wind velocity through a year of 4.1 m/sec at Vung Tau area is stronger than that of 2.5 m/sec at HCM City. And monthly maximum wind velocity at Vung Tau is stronger than that at HCM City as well due to geographical reason.

Average monthly wind velocity at Vung Tau varies from 3.0 m/sec in August to 5.7 m/sec in February as summarized in Table 3.2.2 (1) below. It is found that average monthly wind velocity in the dry season is harder than that in the rainy season.

Table 3.2.2 (1) Monthly Wind Velocity at Vung Tau
(Measured at Vung Tau Metrological Station during 1928 to 1939 and 1956 to 1976.)

Unit: m/sec.

Wind Velocity	Month												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average	4.7	5.7	5.2	4.7	3.5	3.5	4.2	3.0	3.6	3.5	4.0	4.0	4.1
Maximum	18	18	18	18	18	18	30	15	18	15	18	15	-
Direction	E	SE	SE	SE	WNW	WNW	WNW	WSW	SE	SE	NW	SE	-

Source: Meteorological and Hydrological Report on Thi Vai River and Vung Tau, May 1995

Table 3.2.2 (2) Monthly Wind Velocity at HCM City (1971 to 2000)

Unit: m/sec.

Wind Velocity	Month												Annual Average
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Average	2.3	2.8	3.1	3	2.4	2.7	2.1	2.9	2.4	1.9	2.1	2.1	2.5
Maximum	9.6	9.3	10.5	11.2	15.2	16.9	15.9	15.4	14.4	12.6	10.9	8.7	-
Direction	E	SSE	SE	SSE	SE	WSW	WSW	WSW	W	W	NE	NE	-

Source: Tan Son Nhat Meteorological Station

(c) Maximum Wind Velocity

Maximum wind velocity observed at two meteorological stations in the Survey Area are as follows:

At Vung Tau Meteorological Station recorded during the past 40 years: 30m/s
At HCM City Meteorological Station recorded during the last 30 years: 36m/s

From statistical analysis of annual maximum wind velocities during the past 30 years (1971 to 2000), the estimated wind velocities by probability of occurrence are obtained as shown in Table 3.2.3 below.

Table 3.2.3 Wind Velocity by Probability of Occurrence at HCM City

Unit: m/sec.

Wind Velocity	Probability of Occurrence (%)				
	1	2	3	5	10
Max. Wind	38	35	33	30	26

Source: Study Team

(d) Typhoons and Tropical Depressions

Number of the typhoons and tropical depressions (TD) passed in the coastal area in the south of Latitude 11° North for the past 26 years from 1954 to 1980 was 5 times as shown in Figure 3.2.1. According to wind data observed at HCM City Meteorological Station. Number of wind velocity of more than 20 m/sec which were recorded in the past 60 years at the Station is only four times

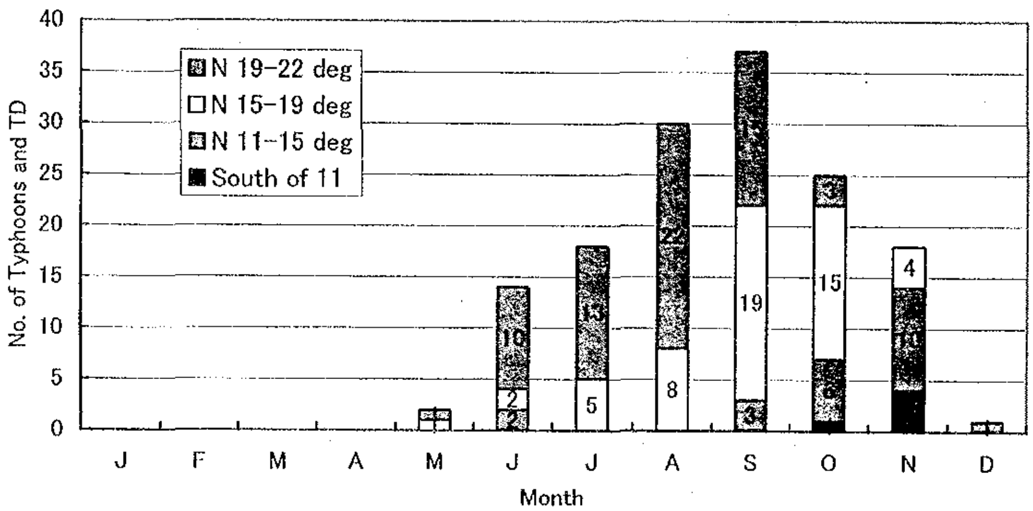


Figure 3.2.1 Number of Typhoons and TD by Region of Vietnam (1954 to 1980)

Source: Report on Storm Characteristics, Marine Hydro-meteorological Center, July 1995

As a sample of typhoons, Figure A 3.2.1 shows the track of Typhoon 9726 called Linda, which passed the southern district of the Survey Area in 1997.

(2) Air Temperature

The monthly average air temperature at HCM City varies from 26.0 ℃ in December to 29.1 ℃ in April as seen in Table 3.2.4 below. Air temperature varies yearly from minimum 18.7 ℃ to *maximum* 36.7 ℃ *in* a year.

Table 3.2.4 Monthly Air Temperature at HCM City (1971 to 2000)

(Unit: ℃)

Air Temperature	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	34.2	35.2	36.2	36.7	36.5	35.1	34.4	34.3	34.0	33.5	33.5	33.5
Average	26.3	27.0	28.2	29.1	28.9	28.1	27.5	27.5	27.4	27.0	26.7	26.0
Minimum	19.0	20.3	23.3	23.7	23.5	23.0	22.7	22.9	22.9	22.4	20.8	18.7

Source: Tan Son Nhat Meteorological Station

(3) Rainfall

(a) Monthly Rainfall

The rainfall in the Survey Area is clearly characterized by two monsoon seasons, i.e. the dry and rainy seasons. As seen in Table 3.2.5, monthly average rainfall at HCM City during 1952 to 1987 is summarized as follows:

Rainy season (May to October): Average monthly rainfall is 206 to 298 mm/month, and
Dry season (November to April): Average monthly rainfall is 4 to 118 mm/month.

Table 3.2.5 Monthly Rainfall at HCM City (1952 to 1987)

(Unit: mm)

Rainfall	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	53	54	60	165	381	491	494	480	590	484	284	128
Average	10	4	9	41	206	298	291	277	303	270	118	37
Minimum	0	0	0	0	70	130	169	68	137	157	29	1

Source: Tan Son Nhat Meteorological Station

(b) Annual Rainfall

According to the data observed at Tan Son Nhat Meteorological Station during 1952 to 1987, and at Ba Ria Meteorological Observatory during 1914 to 1944 and 1960 to 1970, the annual average rainfalls with typical characteristics represented by maximum, minimum and average rainfalls are as shown in Table 3.2.6 below.

Table 3.2.6 Annual Rainfall at Study Area (1952 to 1987)

(Unit: mm)

Rainfall	HCM City Area	Thi Vai River Area
Annual maximum	2,463 (in 1966)	2,834
Annual average	1,896	1,568
Annual minimum	1,391 (in 1958)	-

Source: Tan Son Nhat Meteorological Station, and Ba Ria Meteorological Observatory

(c) Rainfall by Probability of Occurrence

Through statistical analysis of rainfall data observed at Tan Son Nhat Meteorological Station during the past 36 years from 1952 to 1987, the estimated rainfalls by probability of occurrence are obtained as shown in Table 3.2.7 below.

Table 3.2.7 Rainfall by Probability of Occurrence at HCM City

(Unit: mm.)

Meteorological Data	Case	Probability of Occurrence (%)				
		1	2	3	5	10
Rainfall	Annual maximum	2624	2522	2458	2374	2249
	Monthly maximum	602	574	556	532	498
	Daily maximum	199	180	169	154	135
	Hourly maximum	126	116	111	103	93

Source: Study Team

(4) Thunderstorm

According to the data observed at Tan Son Nhat Station during 1952 to 1987, the monthly average thunderstorms occurred 9.4 days in May to June and 0.1 days in February as seen in Table A3.2.1, and annual average number of thunderstorm days is 57.5 days as seen in Table A3.2.2 for HCM City.

(5) Air Humidity

(a) Relative Humidity

Relative humidity changes along the seasons but their difference is not large. As can be seen in Table A3.2.3 (1), the monthly average relative humidity at HCM City (1952 to 1987) is 80 to 85% in the rainy season, whereas it decreases to 70 to 80% in the dry season. The highest moisture of 88 % is recorded in September and lowest one of 62 % in February.

(b) Absolute Humidity

Absolute humidity changes along the seasons but difference is not large as well as relative humidity. As shown in Table A3.2.3 (2), the monthly average absolute humidity at HCM City (1952 to 1987) is 29 to 30 % in the rainy season, which decreases to 23 to 28 % in the dry season. The highest moisture of 31.4 % is recorded in June and lowest one of 18.8 % in May.

(6) Shining Hour

According to the data observed at Vung Tau Meteorological Station from 1981 to 1985, the monthly average shining hour at Vung Tau (1981 to 1985) varies from 180 hours in June (the rainy season) to 301 hours in March (the dry season) as seen in Table A3.2.4 (1). And according to the data observed at Tan Son Nhat Meteorological Station during 28 years from 1959 to 1987, the monthly average shining hour at HCM City (1959 to 1987) is 173 hours in June (the rainy season) and 276 hours in March (the dry season) as seen in Table A3.2.4 (2). It can be said that shining hours at Vung Tau City is longer than HCM City based on these tables.

According to the data observed at Vung Tau Meteorological Station from 1981 to 1985, the annual average of shining hour at HCM City is 2,493 hours as seen in Table A3.2.5.

(7) Evaporation

According to the data measured at Tan Son Nhat Meteorological Station from 1952 to 1981, the monthly average of total evaporation at HCM City varies from 86 mm in October (the rainy season) to 193 mm in March (the dry season) as shown in Table A3.2.6, the values of which correspond to the above-mentioned shinning hour.

According to the same above data, annual average of total evaporation at HCM City is 1,581 mm as seen in Table A3.2.6.

(8) Fog

According to the data observed at Tan Son Nhat Meteorological Station during the same period from 1952 to 1981, the monthly average number of times of fog occurred 4.2 times in May to 8.6 times in January as seen in Table A3.2.7 (1). According to the same above data, annual average number of fog at HCM City is 72.9 times as seen in Table A3.2.7 (2).

3.2.2 Hydrographical and Oceanographic Conditions

(1) Tidal Levels

(a) Chart Datum Line and Average Water Level

The Chart Datum Line (CDL) at Vung Tau and Phu An in HCMC is defined, in relation to the National Datum at Hon Dau (NDL), by the following formulas:

At Vung Tau:	CDL = NDL - 2.887m
At Phu An in HCMC:	CDL = NDL - 2.757m

The Mean Sea Level (MSL) defined in "Tide Tables Vol. II, 2000" by Marine Hydrometeorological Center is +2.59 m at Vung Tau (107° 04' E, 10° 20' N), and +2.30 m at Saigon (106° 42' E, 10° 46' N) above CDL.

According to the Meteorological and Hydrological Report on the Thi Vai River and Vung Tau, May 1995, the annual average water level in Thi Vai during April 1990 to March 1991was -24 cm, which is 7 cm higher than that of Vung Tau.

(b) Representative Water Levels calculated based on Japanese Technical Standard

Based on data observed at Vung Tau and Phu An, the Study Team obtained the following representative tidal levels, which are generally applied in Japan, as shown in Table 3.2.8 (1) and (2) below, respectively.

Definitions of such tidal levels are as follows:

a. Highest High Water Level (H.H.W.L): The highest water level recorded at tidal observatories once in the past for at least 30 years. The H.H.W.L. occurs in unusual weather conditions such as storms, typhoons and floods.

b. High Water Level (H.W.L.): The average water level of the monthly highest water levels and the second monthly highest water levels during a certain period of at least five years.

c. Mean Sea Level (M.S.L.): The average water level of the hourly water levels during a certain period of at least five years.

d. Low Water Level (L.W.L.): The average water level of the monthly lowest water levels and the second monthly lowest water levels during a certain period of at least five years.

e. Lowest Low Water Level (L.L.W.L.): The lowest water level recorded at tidal observatories once in the past for at least 30 years.

Table 3.2.8 (1) Representative Tidal Levels at Vung Tau based on Japanese Standard

Tidal Levels	Abbreviation	Vung Tau	
		Level (m)	Data Period
Highest High Water Level	HHWL	+4.43 (1956)	1955-2000 (40 years) missing 6 years
High Water Level	HWL	+3.97	1995-2000 (6 years)
Mean Sea Level	MSL	+2.67	1995-2000 (6 years)
Low Water Level	LWL	+0.58	1995-2000 (6 years)
Chart Datum	CDL	0.00	
Lowest Low Water Level	LLWL	-0.47 (1964)	1960-2000 (35 years) missing 11 years

Source: Vung Tau Station

Table 3.2.8 (2) Representative Tidal Levels at Phu An based on Japanese Standard

Tidal Levels	Abbreviation	Phu An	
		Level (m)	Data Period
Highest High Water Level	HHWL	+4.19 (2000)	1960-2000 (41 years)
High Water Level	HWL	+3.92	1995-2000 (6 years)
Mean Sea Level	MSL	+2.86	1995-2000 (6 years)
Low Water Level	LWL	+1.04	1995-2000 (6 years)
Lowest Low Water Level	LLWL	+0.12 (1968)	1960-2000 (41 years)
Chart Datum	CDL	0.00	

Source: Phu An Station

(c) Water Levels by Nonexceedance Probability

Based on the water levels observed hourly during the recent years from 1995 to 2000 at Vung Tau Tidal Station, the tidal levels by nonexceedance probability were calculated as shown in Table 3.2.9 (1) below and Figure A3.2.2 (1).

Table 3.2.9 (1) Water Level by Nonexceedance Probability at Vung Tau
(Observed hourly during 1995 to 2000)

Accumulated Frequency (%)	1	2	5	10	25	50	75	90	95	98	99
Water Level (cm)	109	101	87	73	41	-4	-77	-141	-175	-208	-228

Source: Vung Tau Station

Note: The highest water level is +1.47m, and the lowest water level is -3.09m in this observation period.

Based on the water levels observed hourly during 1995 to 2000 at Phu An Station, the tidal levels by nonexceedance probability were calculated as shown in Table 3.2.9 (2) below and Figure A3.2.2 (2).

Table 3.2.9 (2) Water Level by Nonexceedance Probability at Phu An
(Observed hourly during 1995 to 2000)

Accumulated Frequency (%)	1	2	5	10	25	50	75	90	95	98	99
Water Level (cm)	121	115	105	95	71	27	-37	-99	-127	-157	-172

Source: Phu An Station

Note: The highest water level is +1.43 m, and the lowest water level is -2.22 m in this observation period.

(c) Representative Astronomical Tidal Levels at Vung Tau and Phu An

According to a report, representative astronomical tidal levels at Vung Tau and Phu An applied in the Survey Area are as shown in Table 3.2.10 below. In this table, Highest Astronomical Tide (HAT) and Lowest Astronomical Tide (LAT) were calculated based on the method explained in a literature "Tidal Computations in Rivers and Coastal Waters" written by J. J. Dronker, North Holland Publishing Company, Amsterdam, 1964.

Table 3.2.10 Astronomical Tidal Levels at Vung Tau and Phu An from Literature

Tidal Levels	Abbreviation	Level (CDL m)	
		Vung Tau	Phu An
Highest Astronomical Tide	HAT	+ 4.06	+4.03
Mean Higher High Water	MHHW	+ 3.61	+3.72
Mean Lower High Water	MLHW	+3.45	+3.56
Mean Sea Level	MSL	+ 2.63	+2.87
National Datum	ND	+2.89	+2.76
Mean Higher Low Water	MHLW	+2.47	+2.48
Mean Lower Low Water	MLLW	+1.08	+1.41
Lowest Astronomical Tide	LAT	+0.11	+0.81
Chart Datum	CDL	0.00	0.00

Source: TEDI South

(d) Tidal Windows

Information of tidal windows at a channel is imperative for ships' navigation. To know the tidal windows at Vung Tau Approach Channel, possibility of occurrence of a tidal level above CDL, Δh, is analyzed based on the Tide Table at Vung Tau in 2001.

The result is shown in Table A.3.2.8 by season and annually. It indicates that the tidal levels less than CDL + 1m occur 132 times a year, the total duration of which is 15.0 days a year, being equivalent to 4.1% of time. The average time when the water level is less than CDL +1m, or the average impassable time, T_w, for a ship that requires the water level of CDL +1.0m, is 2.72 hours per every occurrence.

Similarly, the average impassable time is 5.00, 8.36 and 23.12 hours/time for tidal levels of less than CDL +2, +3, and +4m, respectively.

The monthly variation of the average impassable time is shown in Figure A.3.2.3. The impassable time is slightly longer in summer than those in other seasons.

(2) Wave Conditions

(a) Wave Observations

There is only limited data available with respect to the waves in the Survey Area. Table 3.2.11 shows the list of wave observation stations relevant to the Survey Area.

Table 3.2.11 List of Wave Observation Stations

Station	Position		Start Time of Observation	Wave Measurement Equipment
	N	E		
Vung Tau	10° 20'	107° 04'	1979	Stereo Scope
Can Dao Island	8° 41'	106° 35'	1979	Estimate by Eyes
Oil-Rig Bach Ho (Vietnam-Russia)	-	-	1985	Automatic Wave Meter
Oil-Rig Block 03 (Vietnam-Canada)	-	-	1992	Automatic Wave Meter

Source: Report on Wave Characteristics, Marine Hydrometeorological Center, 1995

The maximum observed wave height and the statistically estimated wave by the Marine Hydrometeorological Center based on the above data are given in Table 3.2.12 and Table 3.2.13 below, respectively. It is noted that the maximum offshore wave height recorded at Bach Ho Oil-Rig was 10.5 m as shown in Table 3.2.12.

(b) Wave Height in Ganh Rai Bay

It has been said that wave height in the Survey Area is not high. As can be seen in Table A3.2.9, the wave height of more than 2 m was not recorded during a whole year from 1986 to 1987 in Ganh Rai Bay. It is to be noted, however, that the duration of the observation is limited.

According to the data observed at Sao Mai and Nghinh Phong 1986 to 1987 as seen in Table A3.2.10, wave characteristics when the largest wave height occurred are, the maximum wave height (H) is 1.20 m, wave period (T) is 3.8 sec, and wave length (L) is 45 m at Sao Mai. Their values are $H = 1.97$ m, $T = 5.9$ sec and $L = 57$ m at Nghinh Phong.

(c) Waves in Offshore Area

According to "Global Wave Statistics", maximum significant wave heights by wave directions in the Vietnamese offshore area are summarized as seen in Table A3.2.11. It is reported that the highest maximum significant wave height expected in Vietnamese offshore area is 9 to 10 m from the wave direction of NW.

Table 3.2.12 Maximum Wave Heights Observed in the Past

Station	Observed Period	Direction	Maximum Wave Height (m)	Time Occurred
Vung Tau	1979 - 1993	SW	3.0	20 June 1979
Can Dao Island	1979 - 1993	NE	3.5	5 January 1980
Offshore of Vung Tau - Can Gio	1960 – 1982	NW	8.5	January
Oil-Rig Bach Ho	1985 – 1988	--	10.5	27 December 1987
Oil-Rig Block 03	1992	--	11.0	26-27 June 1992

Source: Report on Wave Characteristics, Marine Hydrometeorological Center, 1995

Table 3.2.13 Estimated Extreme Wave Heights in the Past

(Unit: m)

Stations	Recurrence Period (years)			
	10	50	75	100
Vung Tau	3.2	3.7	4.1	4.6
Can Dao Island	3.4	4.3	5.0	5.5
Bach Ho Oil-Rig	13.5	15.0	16.5	17.5
Offshore in Vung Tau-Can Gio Area (Reported by sailing ships)	10.0	11.5	12.7	13.5

Note: Based on daily observation and statistical treatment by logarithmic normal distribution.

Source: Report on Wave Characteristics, Marine Hydrometeorological Center, 1995

(3) Water Flow and Currents

(a) Maximum Current Speed

According to the results of a study, the maximum current velocity in the Thi Vai River is about 2.5 m/sec at the mouth of the Cai Mep estuary, and 1.33 m/sec at Thi Vai site as summarized in Table A3.2.12.

(b) Current Measurement

The Study Team conducted current measurement twice in June and December, 2001, at a total of seven points in Ganh Rai Bay. Direction and current speed at three depths were measured simultaneously by means of a total of four current meters during the consecutive 15 days and nights (from 14 to 29 June, and from 2 to16, 2001) at one-hour intervals. The measurements were carried out by means of three current meters at the three main observation points, V1, V2 and V3. Meanwhile, in the specified days and nights of the spring tide period simultaneously with the above observation periods, measurement was conducted during the consecutive 25 hours at one-hour interval by means of one additional current meter at four sub-observation points, V4, V5, V6 and V7.

The maximum current velocities observed at each point in both periods of flood tide and ebb tide were presented in Table A3.2.13 and Figure 3.2.2 (1) for June, and (2) for December. As can be seen in these figures, the currents are predominantly reversing, and directions of current in both cases nearly parallel to the existing navigational channel, which is desirable to minimize the sedimentation in the channel.

(4) Ocean Current

According to information provided by the Japan Oceanographic Data Center of the Japan Maritime Safety Agency, velocity of ocean current at sea surface in offshore of the Survey Area is as summarized in Table A3.2.14.
The velocity of ocean currents was calculated based on the statistical data from 1953 to 1994. The average velocity of ocean currents varies from 0.0 to 0.8 knot. Example of the ocean current in July and January, when the strongest Northeasterly and Southwesterly currents occurred respectively, are shown in Figure A3.2.4.

(5) Seabed Materials Measurement

The Study Team carried out seabed materials (sediment) measurement in June and December at a total of nine points consisting of seven points where current measurement was done and other two points in front of the southern coastline of Can Gio. Then, grain size analysis was performed to know median diameter (d_{50}) of seabed materials in Ganh Rai Bay.
As can be seen in Figure 3.2.3 (1), the size,d_{50} varies from about 1.3 mm (most rough size in this measurement) at the mouth of the bay (Vung Tau Approach Channel), 0.2mm in the middle of the Approach Channel, 0.1 mm in front of Can Gio, and 0.06 mm (most fine size) at the inner part of the bay.

(6) Water Quality

(a) Water Temperature

The monthly average water temperature in the Thi Vai River and Vung Tau varies from 26 to 32℃. The highest water temperature ,or 34.5℃, occurs in May and lowest water temperature, or 26℃, occurs in January as shown in Table A3.2.15.

(b) Water Salinity

Water salinity in Ganh Rai Bay is not so much different from that of the usual seawater, or 25 to 30 per mill, as seen in Table A3.2.16.

(c) Water Quality Measurement

The Study Team conducted water quality measurement in terms of suspended solids (SS) along with salinity, temperature, bulk density and transparency at three depths. Samples of water in three depths were taken at the same seven points with the current measurement as shown in Figure 3.2.2 (1).

The result of the measurement is summarized in Table A3.2.17, which can be interpreted as follows:

- High values of SS are observed at V3, V6 and V7 locating near the mouths of the rivers.
- Salinity varies 26.5 to 32.7 per mill. Salinity on the surface is smaller than that on the bottom, which is the effect of discharge of river water.
- Water temperature varies 26.5 to 32.4 ℃. Temperature is higher on the surface than that on the bottom.
- Bulk density of water varies 1.008 to 1.014, which reflect mixture with the river water.
- Transparency is small, or 0.3m to 1.7m.

(7) Visibility on the Sea

Characteristics of the visibility distance on the sea are as shown in Table A3.2.18. It is said that the percentage of days of less than 10 km visibility is 15%, according to the observed data at the oil-rig of Bach Ho.

(8) Storm and Flood

It is known that an area of Thi Vai and Vung Tau has not been affected by flood. The surge, however, occurs sometimes on the coastal areas due to typhoons, storms or strong monsoon. It is estimated that a rising water of 45 cm was caused by typhoon "*Linda*" in November 1997.

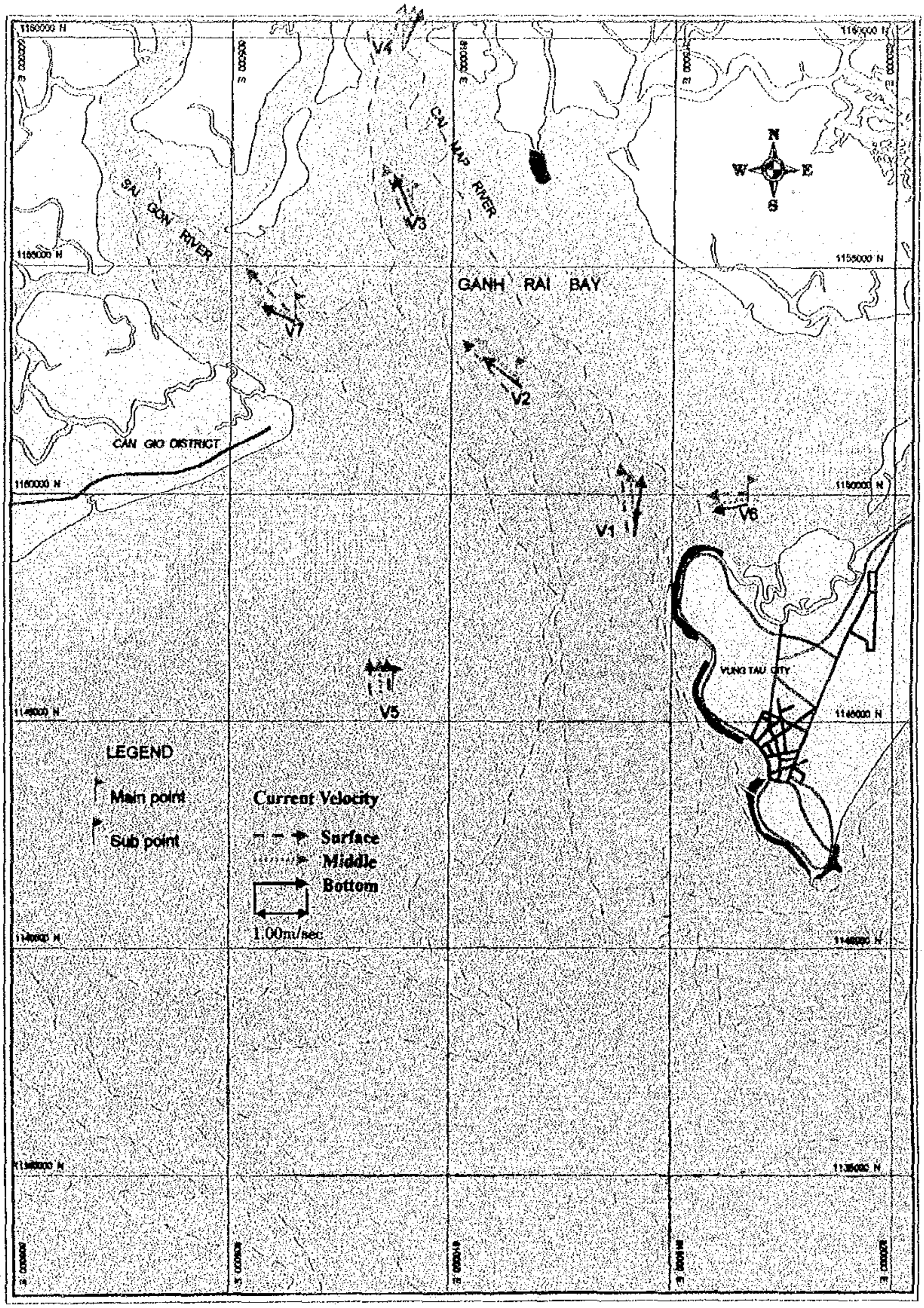


Figure 3.2.2 (1) Maximum Current Velocity during Flood Tide observed from 14 to 29 June, 2001

Source: Study Team

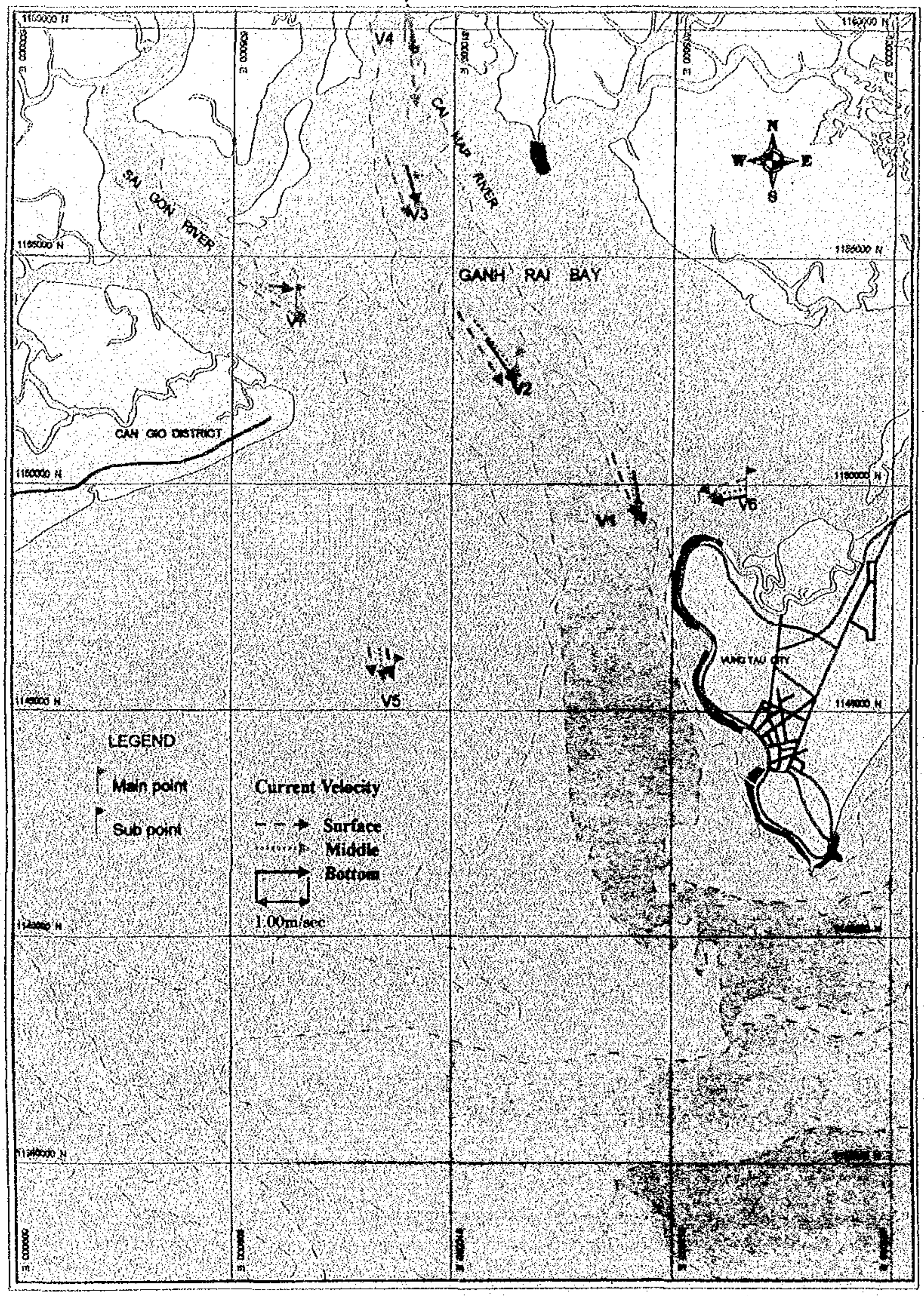


Figure 3.2.2 (2) Maximum Current Velocity during Ebb Tide observed from 2 to 17 December, 2001
Source: Study Team

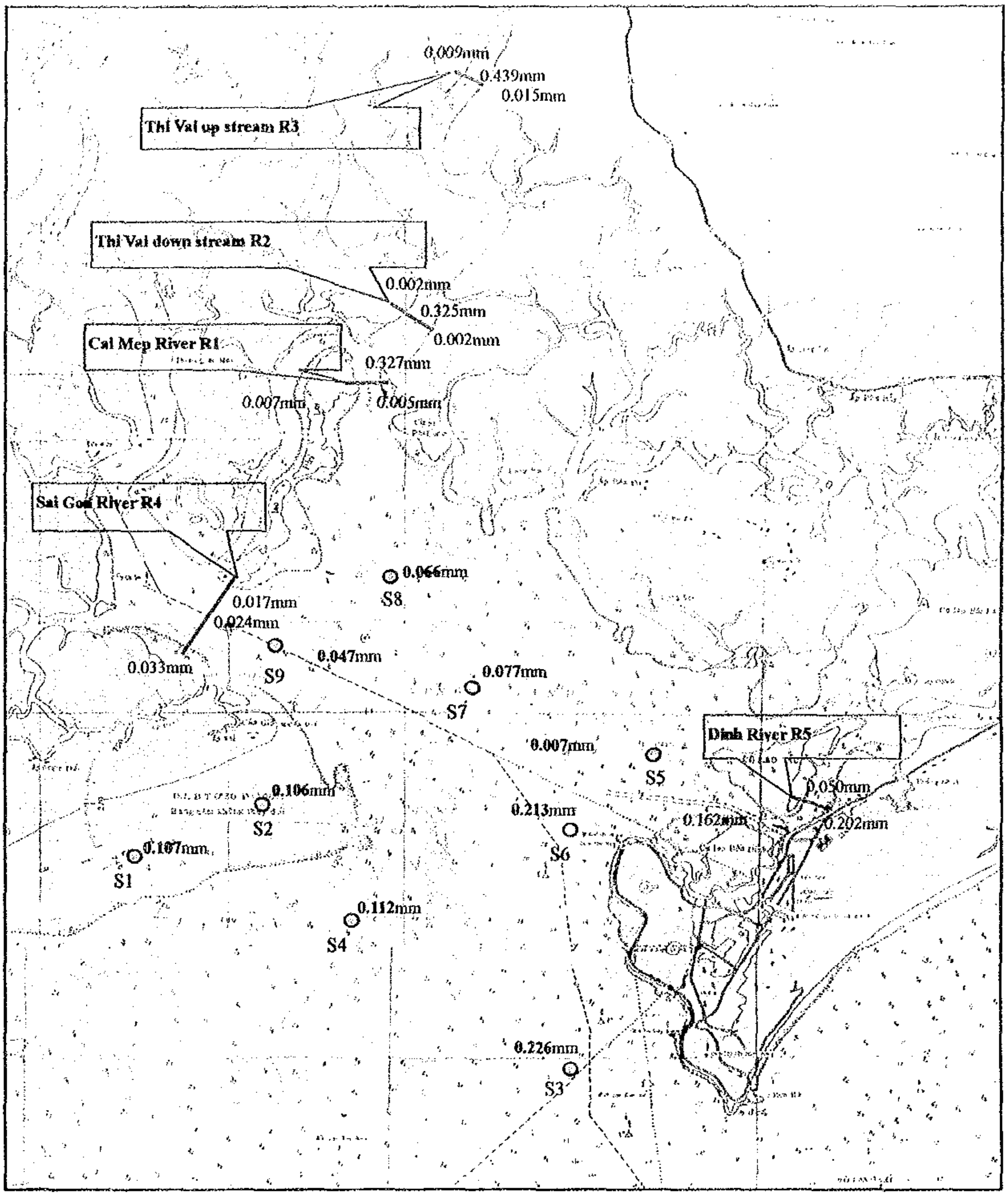


Figure 3.2.3 (1) Distribution of Medium Grain Size (d_{50}) of Seabed Materials in Ganh Rai Bay at the River months (June and October 2001 *Source*: Study Team

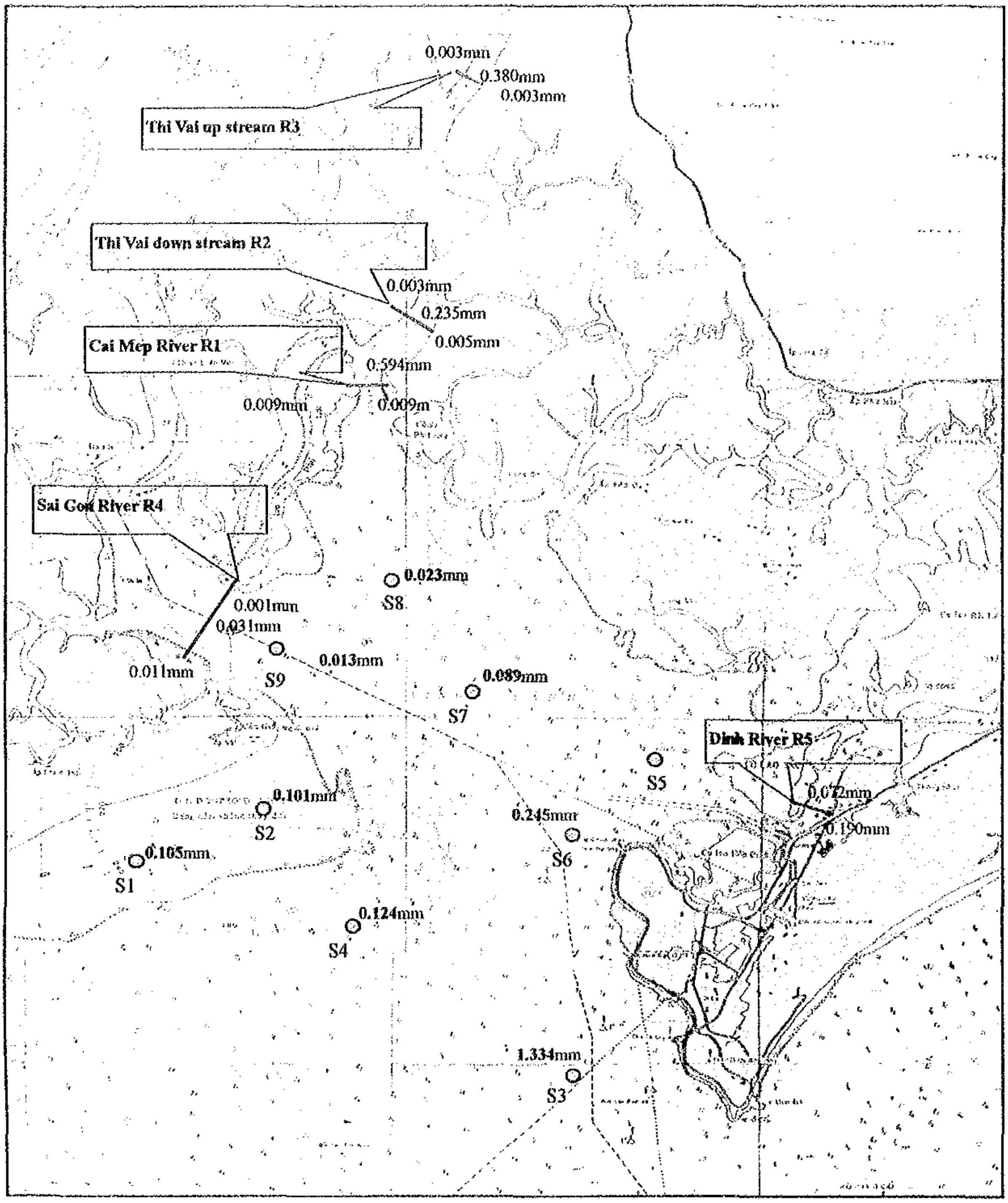


Figure 3.2.3 (2) Distribution of Medium Grain Size (d_{50}) of Seabed Materials in Ganh Rai Bay (December 2001) *Source*: Study Team

3.2.3 Topographic and Bathymetric Survey

(1) Topographic Survey

The Study Team carried out the topographic survey at Cai Mep area (3 km×0.5 km), of which location is shown in Figure 3.2.4, by means of sectioning the survey lines at every 100 m intervals. The result of the survey was presented as the topographic map with a scale of 1/5,000, which is shown in Figure A3.2.5 (1). Those covered by the additional surveys detailed in A.4 are shown in Figure A3.2.5 (2) and Figure A3.2.5 (3).
At the same time the Study Team collected the existing topographic maps covering Thi Vai and Vung Tau sites to be applied for the preliminary design.

(2) Bathymetric Survey

The Study Team carried out the bathymetric survey with a total sounding length of 574 km at every 100 m intervals of sounding lines at Cai Mep (720 ha), Phu My (600 ha), and Vung Tau (600 ha) of which locations are shown in Figure 3.2.4.

An echo sounder of dual-frequency type with 200 kHz and 33 kHz was used in order to distinguished possible fluid mud on the seabed.

The result of the survey was presented in a set of seven bathymetric charts with a scale of 1:10,000, showing depth contours by every one meter. In this regard two sets of the bathymetric charts were prepared based on the frequencies of echo sounder i.e. 200 kHz and 33 kHz. These bathymetric maps are shown in Figure A3.2.6 (1) through Figure A3.2.6 (4), which cover the results of the original and additional surveys conducted as detailed in A4. Additional Natural and Environmental Condition Surveys. And its cross sections are shown in Figure A3.2.7.

There are several characteristic features of water depth, which are found in the Thi Vai River. The river bottom of left side up to the confluence with the Go Gia River is deeper at the upper portion. On the contrary the river bottom of right side turns to be deeper at downstream portion in the Cai Mep site. The maximum depth is about 64m at the exit of the Thi Vai River, or near the estuary in front of the Cai Mep site. The location of a water depth of more than 15 m is located about 300 m away from the left riverbank at downstream portion in Cai Mep site.

The river bottom of left side is deeper at upper portion, 10 m depth contour is located at about 50 m away from the riverbank. Meanwhile, the river bottom of left side turns to be shallower at the down portion. For example, the 10 m depth contour is located at about 250 m away from the riverbank in Thi Vai site.

The difference of depths between echoes at 200 kHz and 33 kHz is minimal in all sections of the Thi Vai River. In other words, there is no significant fluid mud accumulated on the riverbed, because of strong current.

There found, however, the fluid mud with an about 1.5 m difference at the mouth of the Dinh River, or at the basin of Vung Tau Petroleum Technical Service Company (PTSC) in Vung Tau.

3.2.4 Geotechnical Conditions

The Study Team carried out geotechnical investigation, comprising two under-water boreholes and one on-land borehole each at three sites in the Survey Area, i.e. Cai Mep, Thi Vai, and Vung Tau. A total of nine holes were drilled as shown in Figure 3.2.4.

Geotechnical investigation aims at collecting the soil properties for defining design soil conditions. The most interesting subjects are:

- Soil strength and consolidation characteristics of the very soft layer of clay or clayey silt, existing at the surface and the upper portion of earth, which definitely affects construction cost in case that soil improvement works is needed as their countermeasures, and

- Depth of "bearing layer" for foundation pile structure.

In order to confirm the exact elevation of the bearing layer, at least one borehole out of the three boreholes at each area was drilled up to the hard bearing layer of which N-value is more than 50.
The soil strata features in the Survey Area can be briefed as follows:

- Depth of the soft clayey silt layer on the surface with N-value of less than 3 varies from 16 m to 34 m at Phu My site, 29 m to 30 m at Cai Mep site, and 8 m at Vung Tau site. It is anticipated that soil improvement will be necessary in these three planned areas.

- Elevation of bearing layer for foundation pile structure with N-value of more than 50 varies from -46 m to –52 m at these three sites. It is anticipated that large-size steel pipe piles will be necessary in these three planned areas.

Figure 3.2.5 (1), (2) and (3) show soil profile at three sites, i.e. Thi Vai, Cai Mep and Vung Tau, respectively.

Table A3.2.19 (1), (2), and (3) show the summary of laboratory tests of soil samples at Thi Vai site, Cai Mep site, and Vung Tau site, respectively. In addition,

Figure A3.2.8 (1), (2) and (3) show the soil laboratory test results of very soft layer (surface layer) at Thi Vai site, Cai Mep site, and Vung Tau site, respectively.

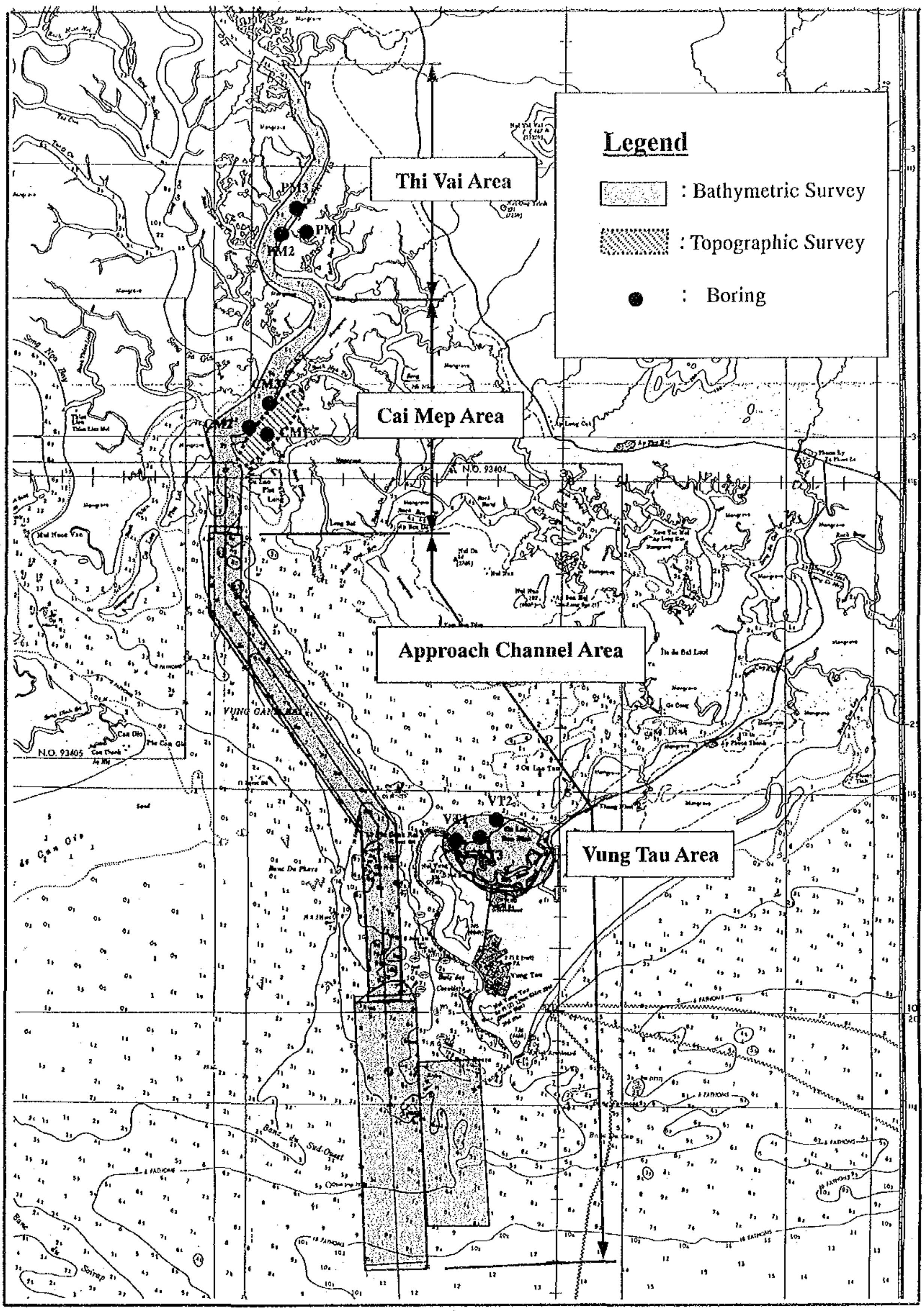


Figure 3.2.4 Locations Map of Natural Condition Survey Carried Out by the JICA Study Team

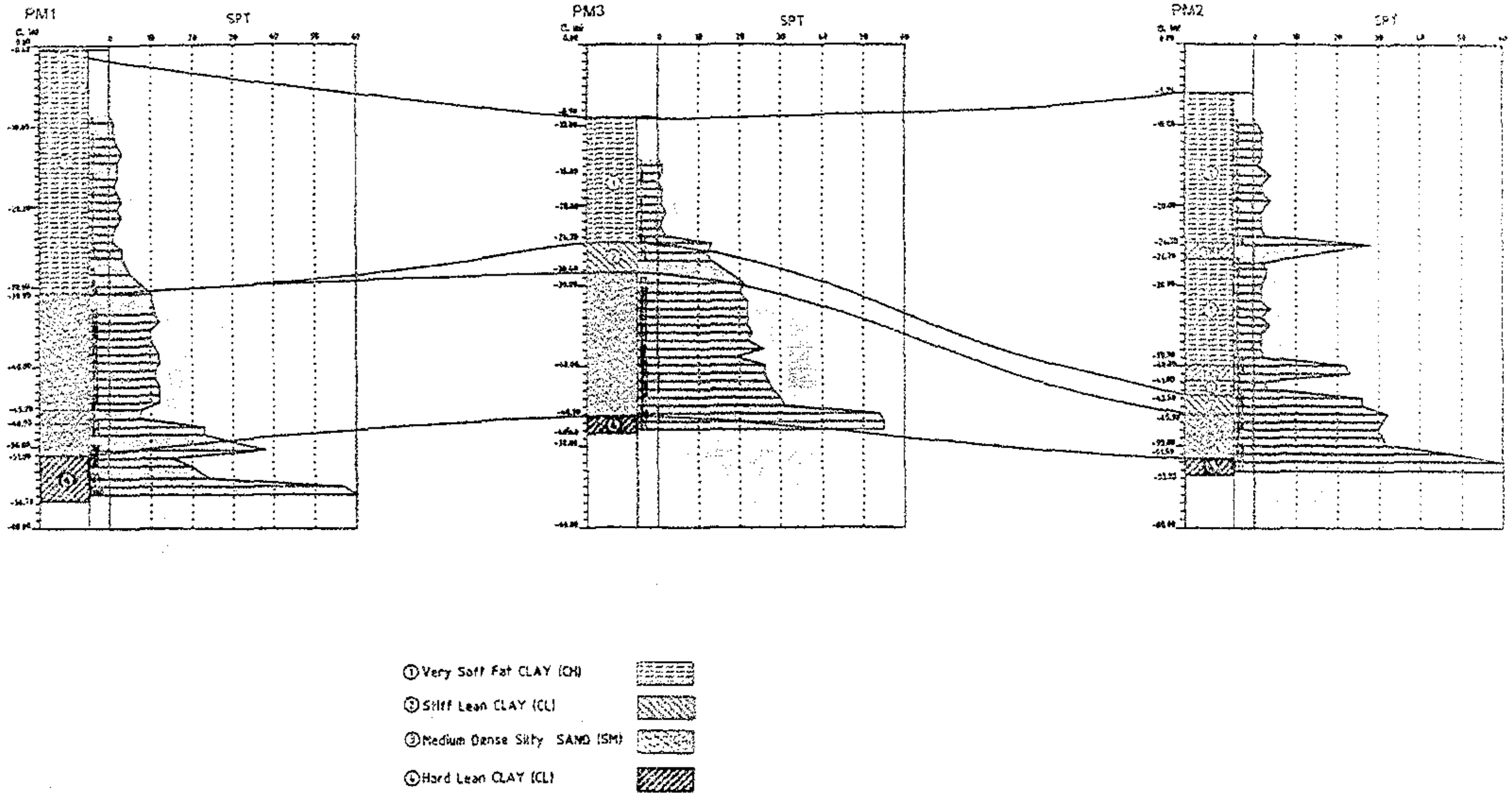


Figure 3.2.5 (1) Soil Profile of Thi Vai
Source: Study Team

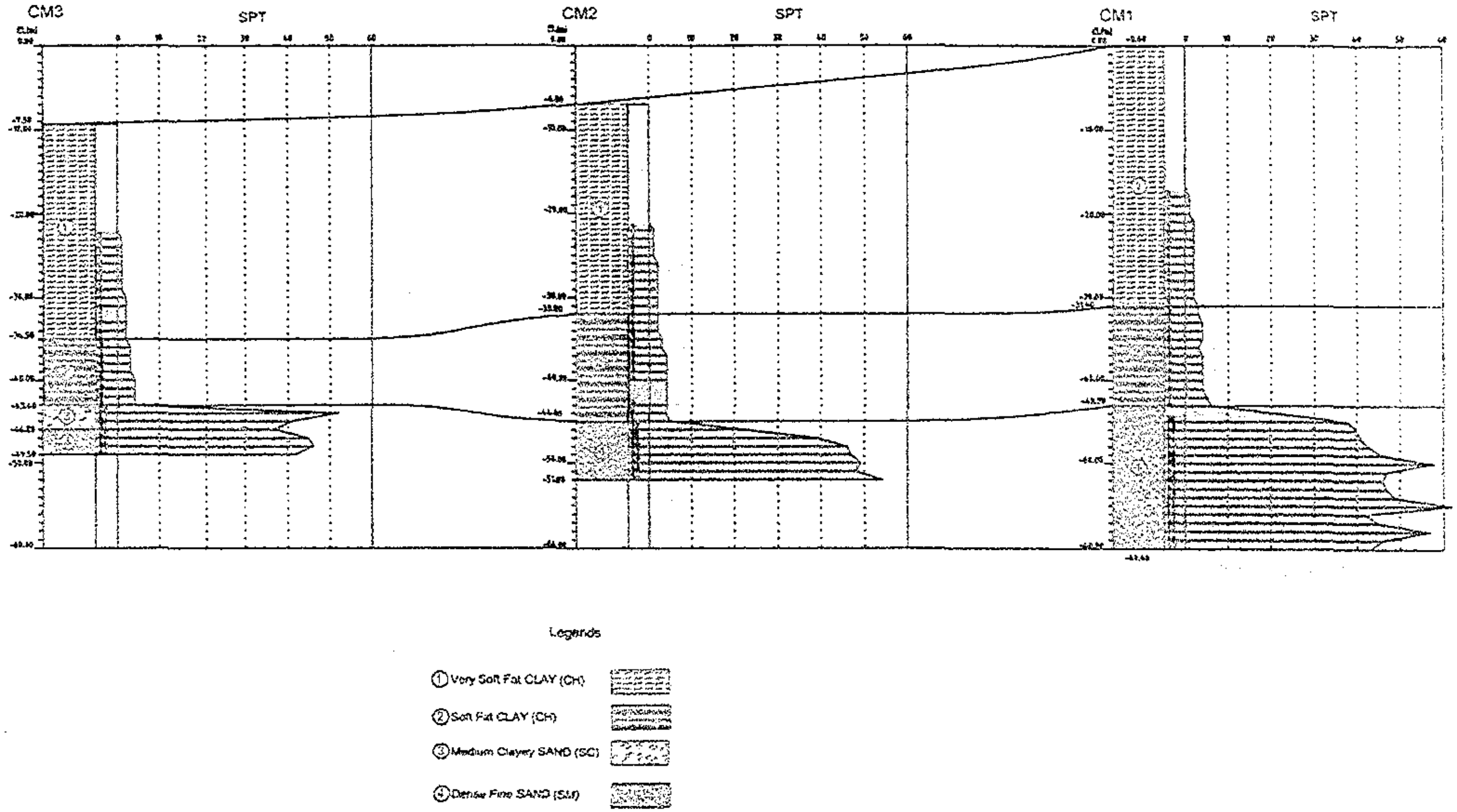


Figure 3.2.5 (2) Soil Profile Cai Mep

Source: Study Team

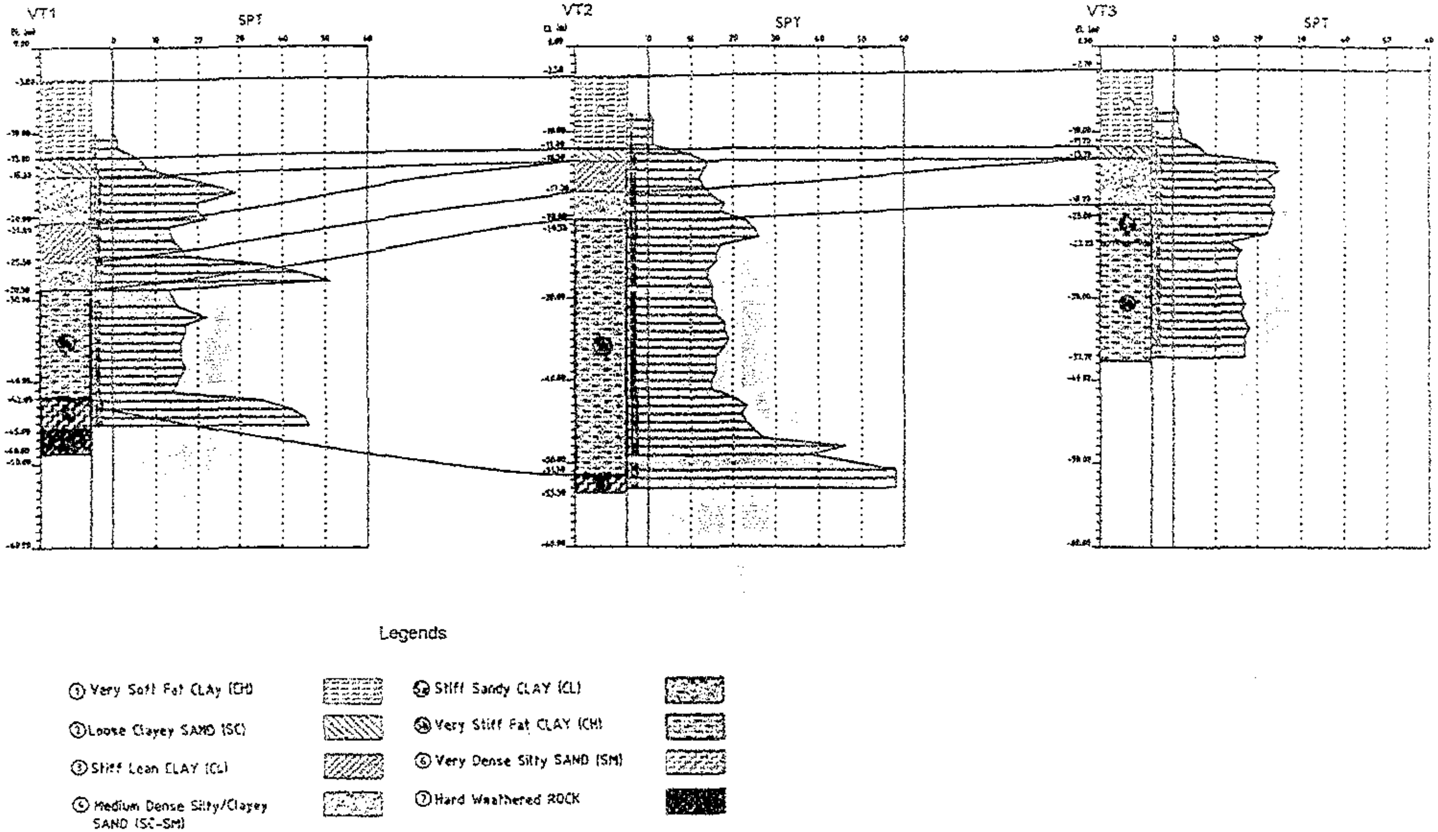


Figure 3.2.5 (3) Soil Profile of Vung Tau

Source: Study Team

3.2.5 Seismic Conditions

Earthquake intensity is important factor for designing port facilities. Internationally, the level of earthquake intensity is divided into 12 degrees for easy judging just after suffering an earthquake. Therefore, this intensity level can be decided by man-feeling of shaking degree of the ground and movement of furniture, or extent of damage to buildings, etc.

While, for engineering purpose, seismic force has to be decided in compliance with seismic acceleration on the ground surface when an earthquake attacks. The seismic coefficient method is prevailing in use for determination of the seismic force. Analyzing the data obtained from networks of observation points and damage of quaywalls or structures, the relationship between seismic coefficient and seismic acceleration on the ground surface gradually becomes clear.

Figure 3.2.6 shows the zoning map of seismic levels in Vietnamese territory. It is used to determine the coefficient, taking account of subsoil conditions. Concerning port facilities, TCCV 4116-85 (Vietnam technical standard for port construction promulgated by the Ministry of Transport in 1985) regulates a procedure how to calculate seismic force. According to this zoning map, seismic intensity in southern region is classified as 6 to 7 degree, which correspond to seismic coefficient of 0.05.

3.3 Sedimentation and Maintenance of Channels

3.3.1 Siltation and Sedimentation in Navigation Channels

(1) General Picture of Siltation and Sedimentation

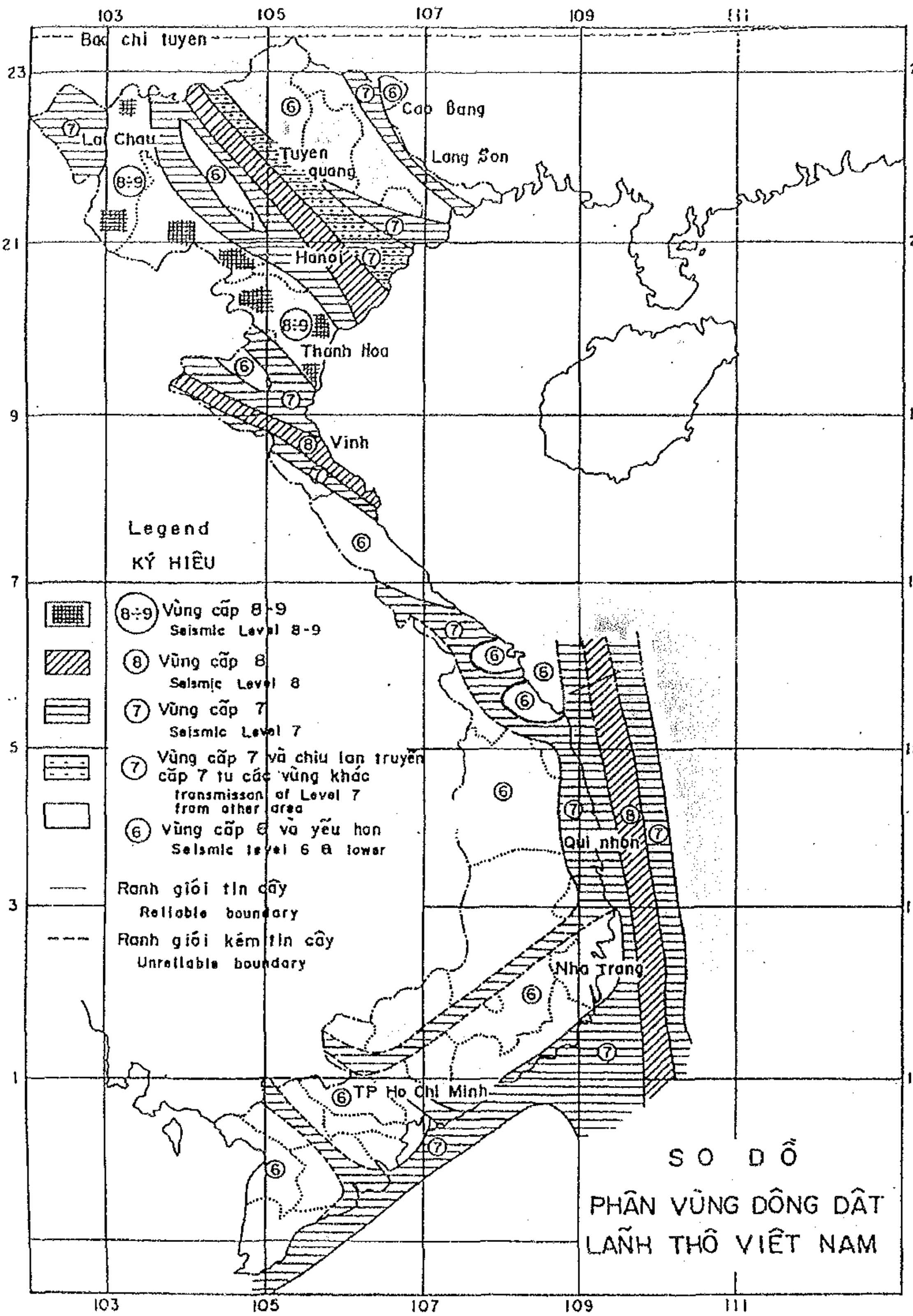
1) Past Studies on Siltation and Sedimentation

There are very limited analytical studies on siltation and sedimentation in the Survey Area in the past. They include hydrometeorological study at Ganh Rai Bay (Southern Center of Hydrometeorology, 1992), hydrology, sediment and water quality study in the Dong Nai - Saigon river system (Southern Institute of Eater Resources Research, 1994) and hydrographical measurement at Go Dau and Thi Vai in the Thi Vai River (1998). Their studies are confined, however, to measuring physical characteristics such as conditions of currents and sediments, not to analyzing siltation and sedimentation.

2) Macroscopic Phenomena judged by Satellite Photographs

To understand overall macroscopic picture of the phenomena, it is useful to investigate satellite photographs. There are useful examples of such photographs taken by SPOT Satellite such as a photograph taken on February 21 1999 (at 10:16:22 local time, which correspond to the low water level, or the end of ebb current).

The photograph shows the rough image on the extent of river water diffusion in the sea from the Soai Rap mouth and in Ganh Rai Bay, tracks and directions of main ebb current, etc. This photograph also implies that the scale of siltation and sedimentation phenomena may be larger at the Soai Rap mouth than at Ganh Rai Bay.



Source: TEDI

Figure 3.2.6 Zoning Map of Seismic Intensity Levels in Vietnamese

(2) *Historical Change in Coastlines and Riverbanks*

The Study Team collected available aerial photographs issued in three chronologically different years, i.e. 1954 (4 photos), 1977 (103 photos), and 1990-1992 (198 photos) with a scale of about 1/14,000, topographic maps with a scale of 1/25,000 (12 maps), and bathymetric charts with scales of 1/75,000 to 1/250,000. A computer superimposed the waterfront lines indicated in these photographs and maps in different years.

Then, historical change in the waterfront lines, i.e. coastlines and riverbanks, was analyzed through comparison of the plotted waterfront lines in different years. The results are briefly summarized in Table 3.3.1 below.

It is noted that the exact time when these photographs were taken could not clarified, except for the years when they were taken, due to lack of such information. Therefore, it is unable to make adjustment of tidal levels on each photograph. It is still valuable, however, that the results of the analysis of historical change in waterfront lines might reflect the qualitative tendency of scouring or sedimentation phenomena.

Table 3.3.1 Historical Change in Coastlines and Riverbanks

Area	Description on Change in Coastlines or Riverbanks
Soai Rap River	- Changes of riverbank are mainly found at the bending portions and confluence portions. - The most significantly changed portions are at the confluences of Soai Rap river-Vam Co river, and Soai Rap river-Nha Be river. - At the mouth of the Soai Rap River, it is apparent that the coast of Can Gio is extended to the river mouth.
Thi Vai River	- Little changes are found at almost all bending portions. - Considerable changes by eroding are found at the concave portions of Thi Vai and Cai Mep sites as seen in Figure 3.3.2. - On left side bank at the estuary (in front of Cai Mep site) considerable changes by eroding are found.
Vung Tau Site *(Ben Dinh-Sao Mai)*	-This area is located behind a peninsula, and the coastline is stable.
Can Gio Coast	- Coastline is inconsiderably changed with about 25 m advancement of the coastline by sedimentation.

Source: Study Team

As an example, the historical change of the riverbank at Thi Vai and Cai Mep sites is shown in Figure 3.3.1. As can be seen in this figure, there could be scoring at Thi Vai and Cai Mep sites with magnitudes of 50 m to 75m and 25 to 50m, respectively, for 13 years from 1977 to 1990.

This phenomenon can be understood from the fact that both of the two sites are located at the concave portion of the Thi Vai River.

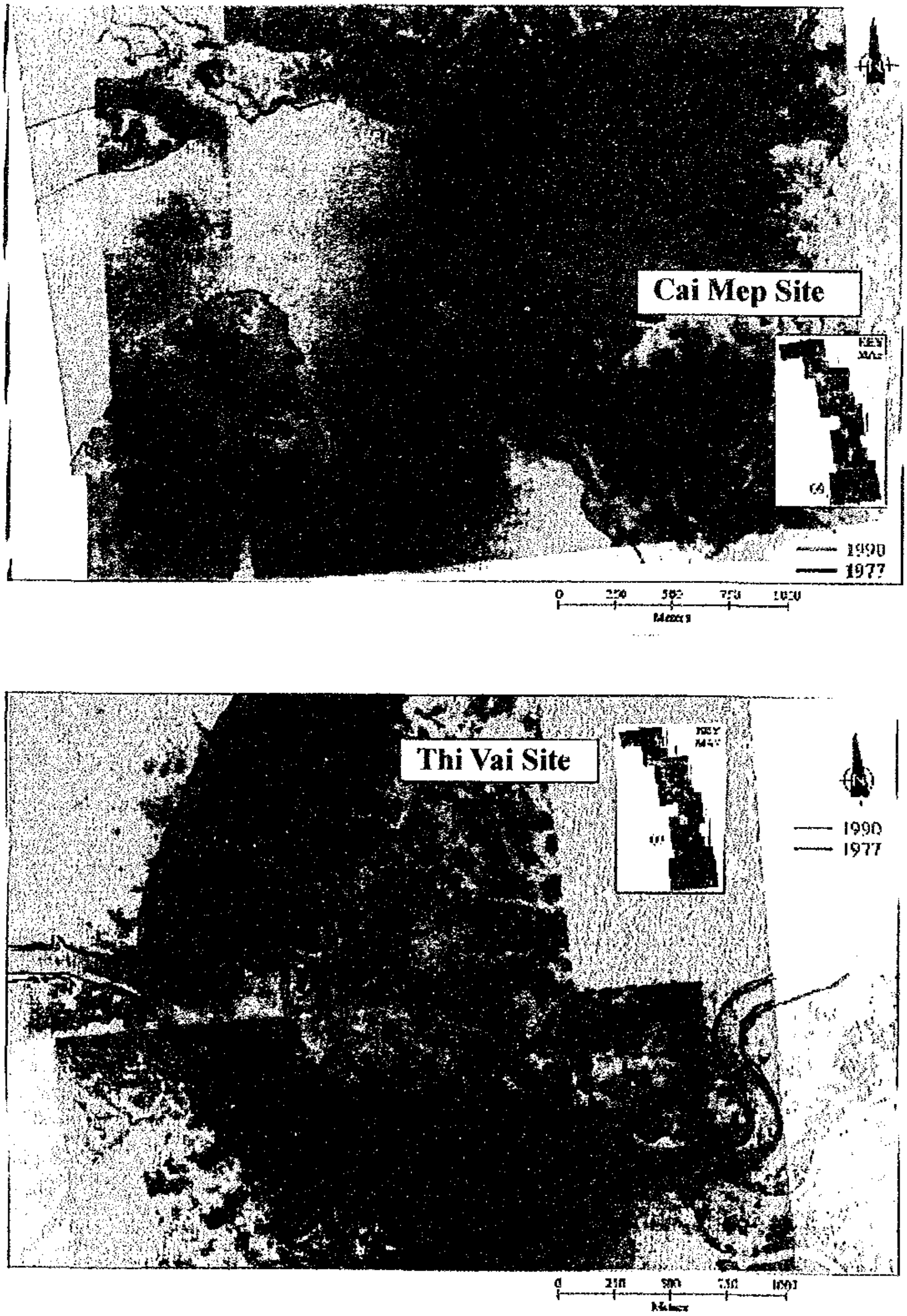


Figure 3.3.1 An Example of Historical Change of Riverbanks at Thi Vai and Cai Mep
Source: Study Team

(3) *Characteristics of Sedimentation and Siltation*

1) Characteristics of Current in Ganh Rai Bay

The current measurements was carried out by the Study Team for 15 days and nights at three main points in/near the channel at Ganh Rai bay and for 25 hours at four sub-points, the results of which were explained in **3.2.2** (3), and illustrated in Figure 3.2.2 (1) and (2).

As a result of the survey, an important fact was revealed that the currents at these points have a nature of rather clear reverse current at flood and ebb tides. Their current vectors at spring and neap tides are illustrated and shown in Figure 3.3.2 and Fig Figure A 3.3.1, respectively. It is demonstrated that the dominant directions are reversing and are significantly parallel with the directions of the existing channel, the phenomenon of which is advantageous from the viewpoint of minimizing the siltation and sedimentation in the channel.

2) Characteristics of Sediments in Ganh Rai Bay

Characteristics of sediments on the seabed and their distribution are important parameters, suggesting the causes and results of siltation and sedimentation such as current speed, origin and direction of movement of sediments.

The sampling of sediments on the seabed and measurement of their physical properties were also conducted in the Study at the same points with those of the current measurement, and the results have introduced in **3.2.2** (5).

Although the number of the sampling points is limited, i.e. seven points, the difference in the median diameter by location is clearly identified as illustrated in Figure 3.2.3.

In front of the Can Gio Coast the bed material consists simply of the fine sand. This is a proof of relatively strong action of wave-induced and tidal currents and resultant sand-drift phenomenon. At outside of the mouths of the Thi Vai River and the Sai Gon River, the sediments are silt, implying the siltation due to decrease in current speed after the water comes out of the river mouths and spread at the open area in the bay. In the main channel in front of the Vung Tau Cape, the median diameters of the seabed materials show coarser fine sand. This could be due to stronger current collecting the water from several rivers flown in the bay, and by more direct actions of tidal currents and waves. At the outside of the Dinh River the bed material has the finest diameter in the bay, i.e. almost clay. This could be due to the calm condition of the area owing to the effect of the Vung Tau Cape.

3) Characteristics of River Bed Materials

In this Study riverbed materials are sampled at 10 points at Thi Vai and Cai Mep areas in the Thi Vai River and 5 points at Ben Dinh-Sao Mai area in Vung Tau under the Environmental Survey. Their locations are shown later in Figure 4.4.2. Another data source is the sieve tests of surface soils in the river taken by the geological investigation of this Study at Thi Vai, Cai Mep and Vung Tau.

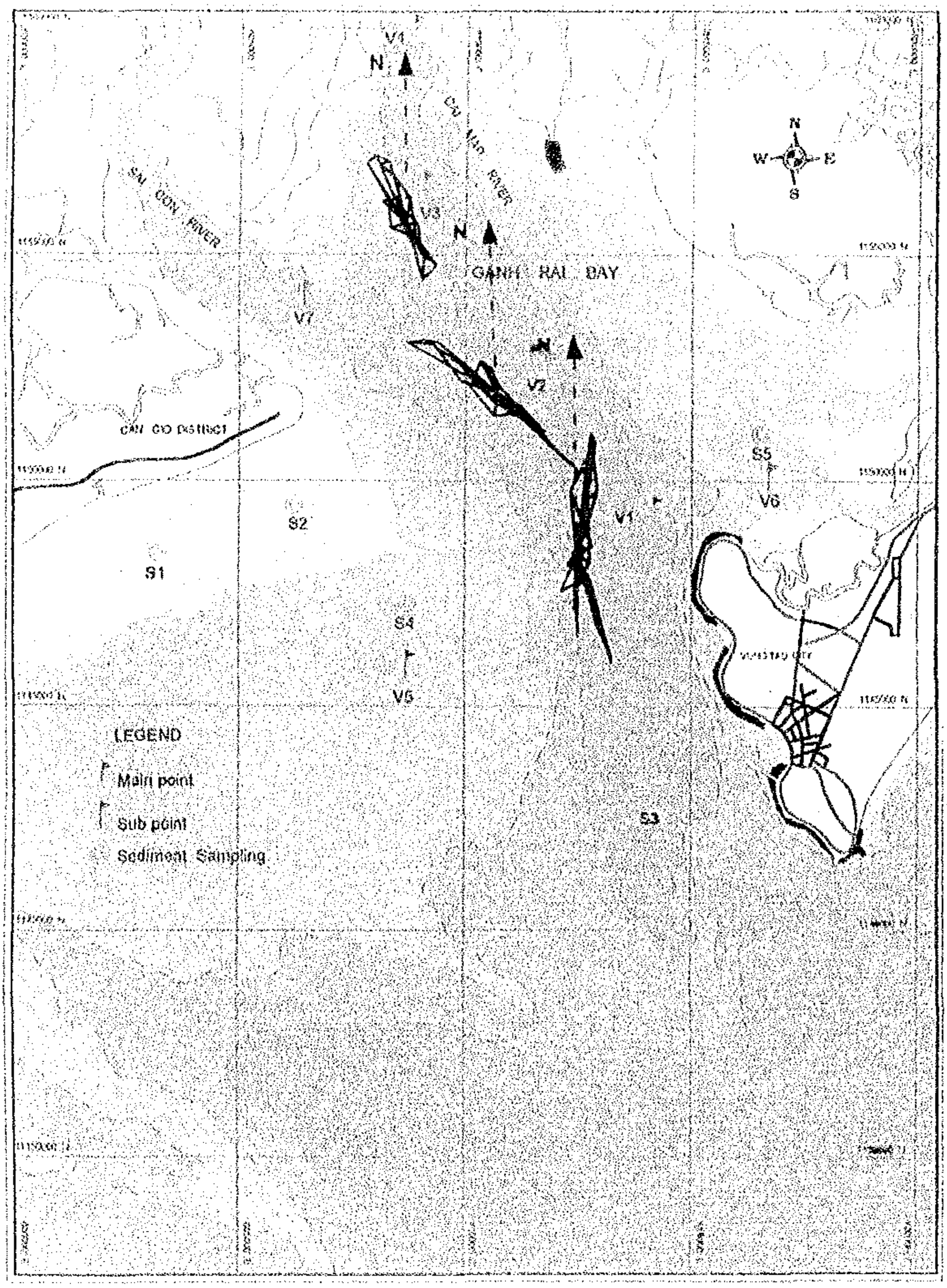


Figure 3.3.2 (1) Current Vectors at Seabed in Ganh Rai Bay measured during Spring Tide (24 and 25 in June 2001) *Source*: Study Team

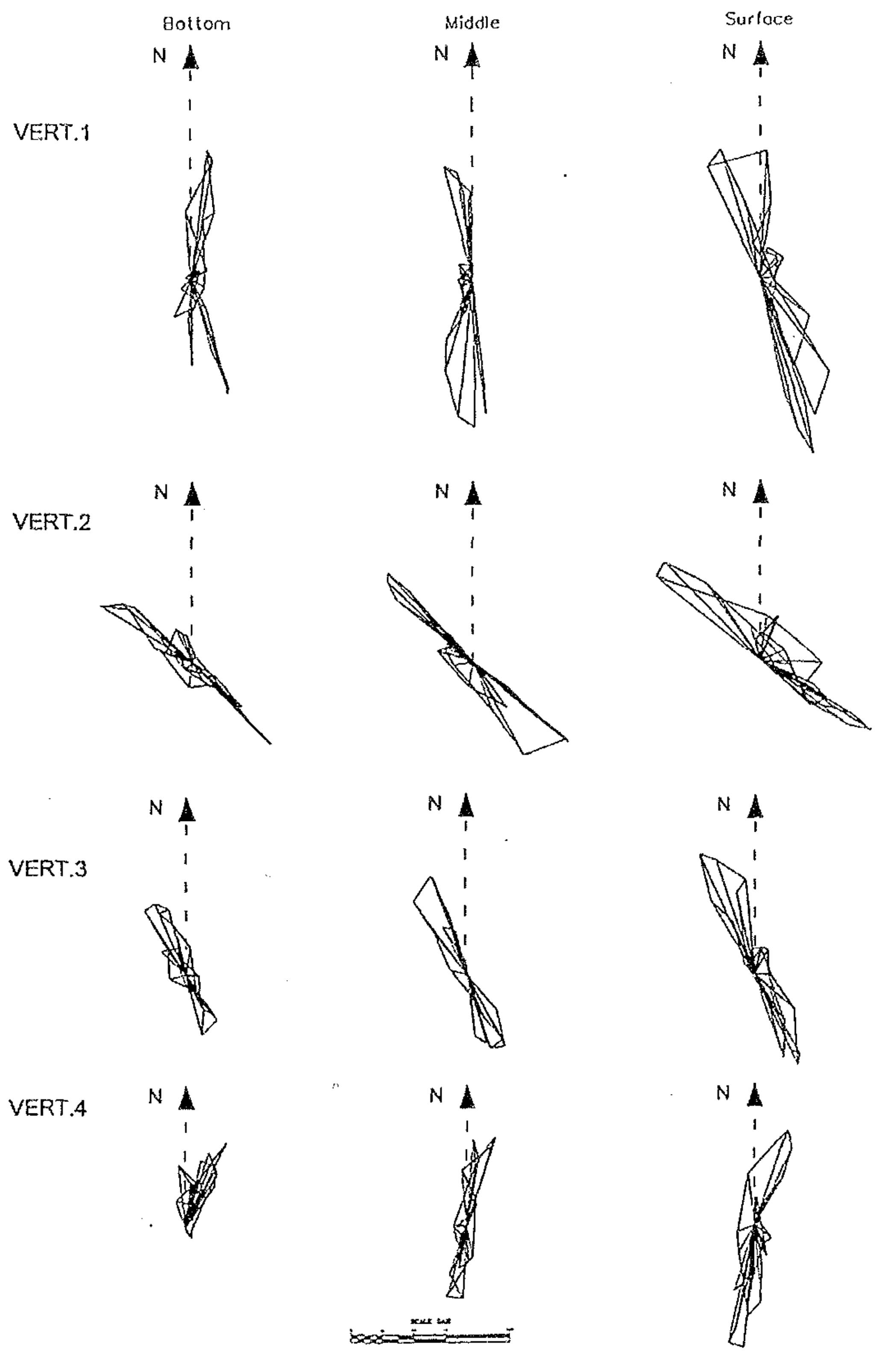


Figure 3.3.2 (2) Distribution of Current Vectors in Ganh Rai Bay measured at Three Depths during Spring Tide (24 and 25 in June 2001) *Source*: Study Team

The samples of the Environmental Surveys are taken by means of a grab of about 10 kg in weight. It was found that the bed material at the center of river flow was too hard to sample by this device. Hence, the sampling points are moved to the places where the sampling became possible.

The sampling points of the Geological Investigation are 2 points in the river each at the three Study Areas. They are located rather close to the shore as shown in Figure 3.2.4. They are not taken from the exact surface of the bed, but from 1 to 3.5 m deep from the bed surface.

The median diameters of these data show that places near the flow center are of coarse or fine sand, and near the shore of silt. This data imply that the current speed in the river varies significantly by place relative to the flow center. It might be difficult to expect siltation, nor sedimentation, at the flow center where the strong current occurs and the water depth is deep.

(4) Cross Sectional Characteristics of the River and Channels

1) Cross Sectional Profiles

The cross sections of the Thi Vai River and the Channels in Ganh Rai Bay measured under this Study are shown in Figure A. 3.2.7. In the Thi Vai River meandering of the river provides, generally speaking, deeper depth at concave portions and shallower depth at convex portions due to the effect of deviation of the flow center.

The deepest depth in the Thi Vai River is found at the corner of the river mouth. It looks like a valley as seen from the sounding record shown in Figure A 3.3.2 (1). The current speed at this point was difficult to measure. The current speed at about 170m down stream from this point, i.e. Vertical No. 4 (608858 mE, 1159735 mN: Depth = CDL -35m), is 0.8 m/sec at all three depths during the flood tide as shown in Table A 3.2.13. Relationship between the depth and current speed at the very deep sections is yet to be studied.

Another typical echo sounding record of the cross section in front of Cai Mep Area is shown in Figure A 3.3.2 (2). The deepest depth is about CDL –30m on the left. It is characteristic that there are 4 ripples with a height of about 5 m on the left submerged bank, the depth of which is from about –20 m to -30 m. The number of the ripple decreases in its downstream sections, and the it disappears at about 300m downstream. In consideration of the soft bed material and relatively shallow depth, this phenomenon might imply the effect of disturbances or eddies of the river flow.

2) Fluid Mud on the Bottom

The cross sections shown in Figure A 3.2.7 present the depths measured by a dual frequency echo sounder. The difference in the depths between those by 200 kHz and 33 kHz can be understood as a layer of sparse materials such as fluid mud which consists of silt and/or clay with ample water. Existence of this kind of light material suggests a possibility of occurring siltation.

Such difference was not be recorded in the Thi Vai River, except in some ditches between the ripples on the submerged bank, thickness of which is less than 0.5 m.

Significant difference in the depths is confirmed at Cross Section No. 27 at the mouth of the Dinh River in front of Ben Dinh Sao-Mai Area in Vung Tau. The thickness of this layer is about 1.5 m. This area is the place where siltation is most probably taking place, and, in fact, maintenance dredging has been carried out regularly.

3.3.2 Maintenance of Navigation Channels

(1) Maintenance System in Viet Nam

1) Institutional System

Until the 1980's, most of navigation channels in Vietnam were managed by the government, or by the Viet Nam Maritime Safety Bureau (VMS) under VINAMARINE. After the introduction of the Doi Moi policy, channels for Corporations and private entities were developed and have been managed by them. The VMS still maintains the roles of management, operation and maintenance of major public channels in Vietnam.

The planned ships for channel operation/maintenance and design dimensions of navigation channels are shown in Table A 3.3.1 and Table A 3.3.2, respectively. The Saigon – Vung Tau Channel is planned and maintained by the VMS at the depth of CDL –8.5 m (shallowest depth CDL – 7.0 m), the width of 150 m, and side slope from 1/5 to 1/7 for 25,000 DWT ships. It takes account of the additional water level of 3 m to 4 m by tides. The Dong Nai Channel has the planned ship of 15,000 DWT. The Thi Vai Channel has deeper natural depth except some shallow portions, and 80 m in width at the straight portion of the channel for 30,000DWT ships up to Thi Vai and for 10,000 DWT ships between Thi Vai and Go Dau.

2) Financial System and Investment for Maintenance of Channels

The cost of maintenance dredging of navigation channels under the management of the VMS is borne by the users in the form of the channel due.

Table A 3.3.3 shows the investment cost in the year 2000 by the VMS for the 12 major channels in Vietnam. A total of 11 billion VND was spent for the maintenance of Sai Gon – Vung Tau Channel in 2000. This amount ranked second next to Hai Phong Channel.

(2) Volume Dredged at Sai Gon – Vung Tau Channel

In order to maintain the channel from Vung Tau to Saigon Port Group to keep the planned depth of CDL -8.5, the VMS made dredging works with the volume shown in Figure 3.3.3 for the past 5 years.

They consist of approximately 20% for Saigon area (at Navioil and p75-79), 10% for Ganh Rai Bay, and 70% for the Long Tau River. The areas in the Long Tau River where considerable dredging works were carried out are, from the upstream, at Propontis, Mui L'est, Mui Kervella and Dan Xay, all of which are located in the middle of the length of the river. Among them, the dredged volume at Mui L'est was the largest, constituting about 30% of the total volume.

(2) Method and Equipment for Maintenance Dredging

Maintenance dredging is sublet to Vietnamese contractors who own dredgers. In Viet Nam, there are three major marine work companies. Among them, Viet Nam Waterway Construction Company (VINAWACO) is the largest one being capable of dredging. Dredging fleet of VINAWACO is shown in Table A 3.3.4. In the southern region of Viet Nam, Waterway Dredging Company No.2 (WDCO No.2) under VINAWACO operates cutter suction dredgers, and Maritime Dredging Company No.2 (MADRECO No.2) also under VINAWACO uses suction hopper dredgers and backhoe dredgers. Large size grab dredgers for slope dredging are not available in Viet Nam.

In the case of the Sai Gon-Vung Tau Channel, the dredging works are carried out by trailing suction hopper dredgers. The dredged materials were dumped at the designated places. So-called agitation dredging by a trailing suction hopper dredger is not employed at this channel.

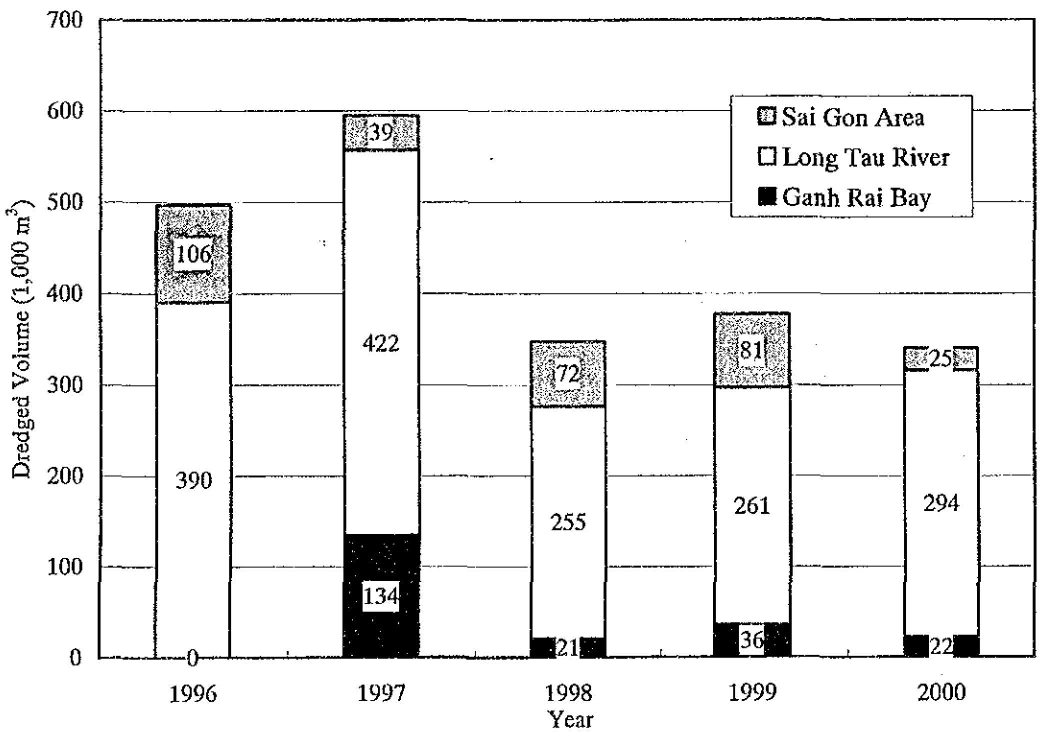


Figure 3.3.3 Dredged Volume in the Sai Gon – Vung Tau Channel from 1996 to 2000
Source: VINAMARINE

More detailed descriptions and analysis of siltation and sedimentation as well as maintenance dredging are presented later in 13.4 .