2.4 Wave Conditions Study

In order to design port facilities of Lach Huyen port, wave forcing condition should be determined appropriately. Around Lach Huyen port area, several wave observations have been previously conducted. One is long-term wave observation data at Hon Dau station, and the other is one-year observation data at the offshore of Lach Huyen channel. In this section, wave estimation has been carried out to determine appropriate wave conditions of Lach Huyen port area. The estimated wave is verified with the available wave observation data. In addition, the design waves in front of the port facilities are calculated by wave transformation simulations.

2.4.1 Existing wave observation data

According to "Report on Port Capacity Reinforcement Plan In Northern Vietnam, September 2009," Hon Dau Station records (3-year period from 2006 to 2008) are analyzed and obtained the frequency in occurrence of wave height and direction as shown in Table 2.4.1. The table shows characteristics of normal waves which are generated by local winds at the area. The wave height more than 1.0 m occupied 8.59% of occurrence. 60% of waves come from directions from E to S. But high waves seem much prevail from SE and S directions.

Table 2.4.1 Frequency in Occurrence of Normal Wave Height by Direction

Wave Direction	Wave Height (m)										Total	
	0 – 0.25		0.25 – 0.5		0.5 – 1.0		1.0 – 1.5		> 1.5			
	Nr	%	Nr	%	Nr	%	Nr	%	Nr	%	Nr	%
N	---	---	3	0.09	57	1.74	8	0.24	1	0.03	---	---
NE	---	---	0	0.00	47	1.43	16	0.49	0	0.00	---	---
E	---	---	184	5.60	844	25.71	63	1.92	5	0.15	---	---
SE	---	---	37	1.13	429	13.07	89	2.71	6	0.18	---	---
S	---	---	4	0.12	149	4.54	75	2.28	13	0.4	---	---
SW	---	---	0	0.00	10	0.30	5	0.15	1	0.03	---	---
W	---	---	0	0.00	1	0.03	0	0.00	0	0.00	---	---
NW	---	---	0	0.00	10	0.30	0	0.00	0	0.00	---	---
Total	1,226	37.34	228	6.94	1,547	47.12	256	7.80	26	0.79	3,283	100

Source: Report on Port Capacity Reinforcement Plan In Northern Vietnam, September 2009: Nippon Koei Co., Ltd. & Associates

According to "TEDI F/S Term-End Report", the following extreme high wave observed at meteorological station in Hon Dau water in a period from 1963 to 1985 is described. Table 2.4.2 shows that the maximum wave height observed at Hon Dau station was 5.6m and is observed twice during about 20 years.

Table 2.4.2 Maximum wave height observed at Hon Dau station

Wave Direction	South	East
Wave Height	5.6 m	5.6 m
Wave Length	210 m	96 m
Date	July 3, 1964	September 20, 1975

Source: TEDI F/S Term-End Report

According to "Report on Port Capacity Reinforcement Plan In Northern Vietnam, September 2009," extreme value analysis by using wave data at Hon Dau observation station for 20 years from 1988 to 2008 was carried out. Table 2.4.3 is the result of extreme value analysis and the extreme wave height probability based on the Gumbel and Weibull distribution is obtained.

Table 2.4.3 Estimated waves based on Hon Dau observation data (1998-2008)

Return Period (Yr)	Wave Height (m)	Wave Period (Sec)
1	1.22	5.8
5	3.18	8.9
10	3.71	9.7
30	4.45	10.8
50	4.77	11.3
75	5.01	11.7
100	5.18	12.0
120	5.28	12.1

Wave Period: estimated by the relationship T=1.5539H+3.9222

Source: Report on Port Capacity Reinforcement Plan in Northern Vietnam: Nippon Koei Co., Ltd. & Associates, September 2009

2.4.2 Wave Estimation

According to Table 2.4.3, the wave height of the return period of 50 years is estimated as 4.77 m. On the other hand, wave height of 5.6 m is observed twice for 20 years from 1965 to 1985 as shown in Table 2.4.2. These results seem not consistent with each other. Therefore, in this study, wave estimation has been carried out by using one-point spectral method in order to clarify the inconsistency and verify the design wave condition. The one-point spectral method is suitable to long-term wave estimation and can estimate wave conditions of wave height, period, and direction form the consecutive wind data at a target location.

1) Wind data

As the wind data required for the wave estimation, the global objectivity analysis data published by Japan meteorological agency were collected. Figure 2.4.1 shows the annually averaged wind speed vectors obtained by the 5-year consecutive wind data from 2002 to 2006, and Figure 2.4.2 and Figure 2.4.3 are the seasonally averaged wind vectors in South China Sea. These figures indicate that no annually dominant wind exists in the area but wind from South-East become dominant in wet (summer) season and wind from North-East in dry (winter) season. This is a characteristic tendency in South China Sea. Also, the wind speed in the gulf of Tonkin, where Lach Huyen located, seems weaker than that in the center of South China Sea.

Figure 2.4.4 shows wind roses based on the wind data near Lach Huyen Port area, and each of them is arranged annually or seasonally. Also, frequency occurrence of wind speed by direction is tabulated in Table 2.4.4. These data indicate that the wind directions of NE, ENE, S, and SSE are frequently occurred in the area, the frequency of which is more than 10 %, respectively. Particularly, in dry (winter) season, the occurrence of more than 10 m/s in wind speed from NE-direction is high and the frequency shows around 14 %.

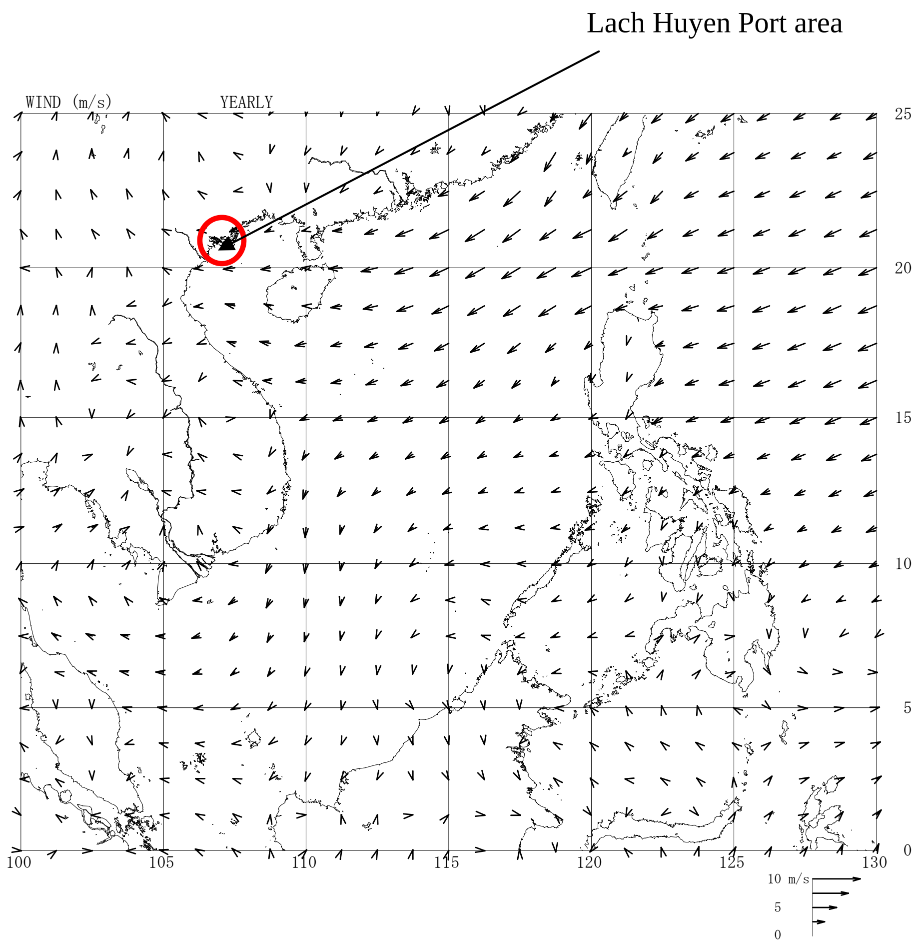
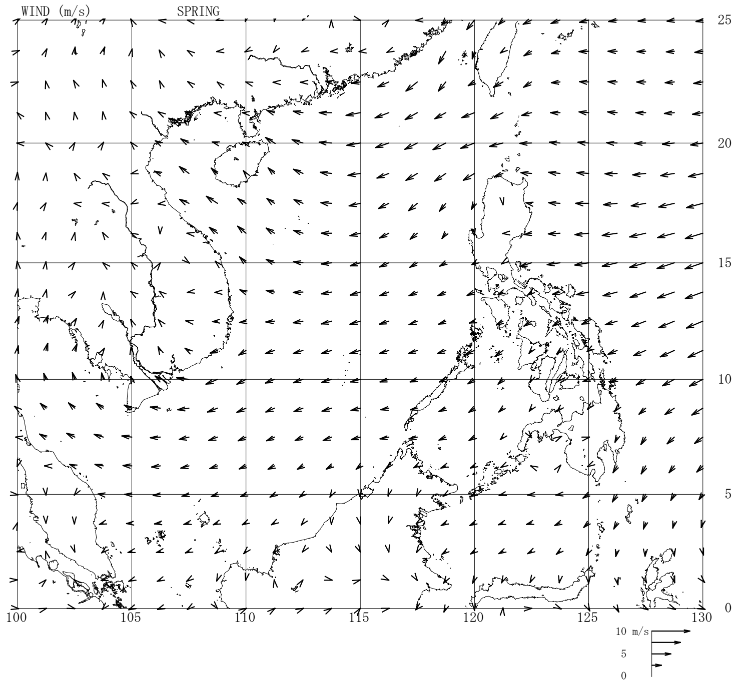


Figure 2.4.1 Horizontal distribution of annually averaged wind vectors based on the global objectivity analysis data published by Japan meteorological agency

Mar - May



Jun - Aug

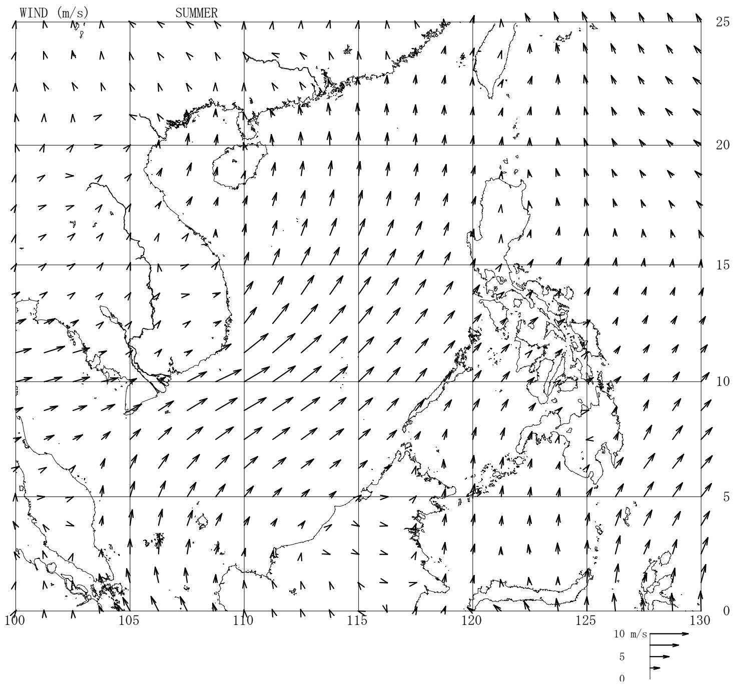
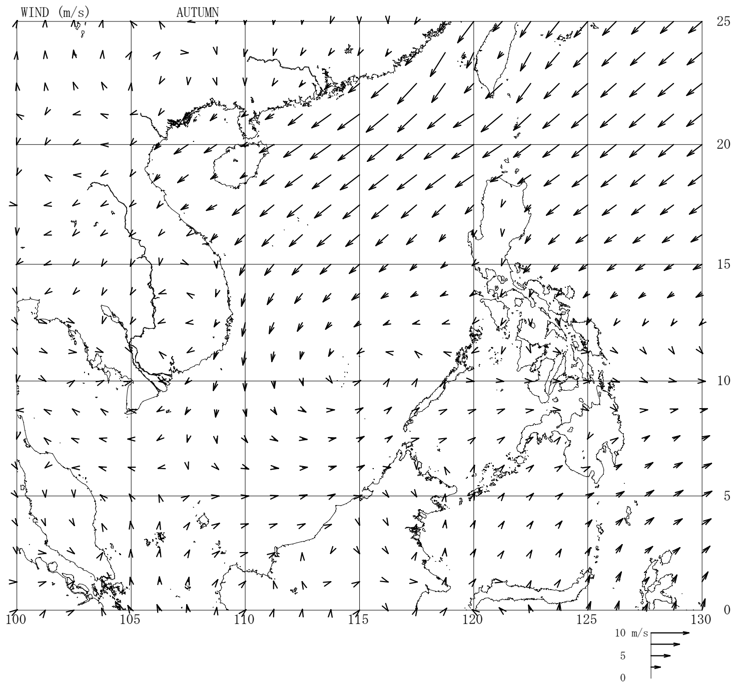


Figure 2.4.2 Horizontal distribution of seasonally averaged wind vectors

Sep. – Nov.



Dec - Feb

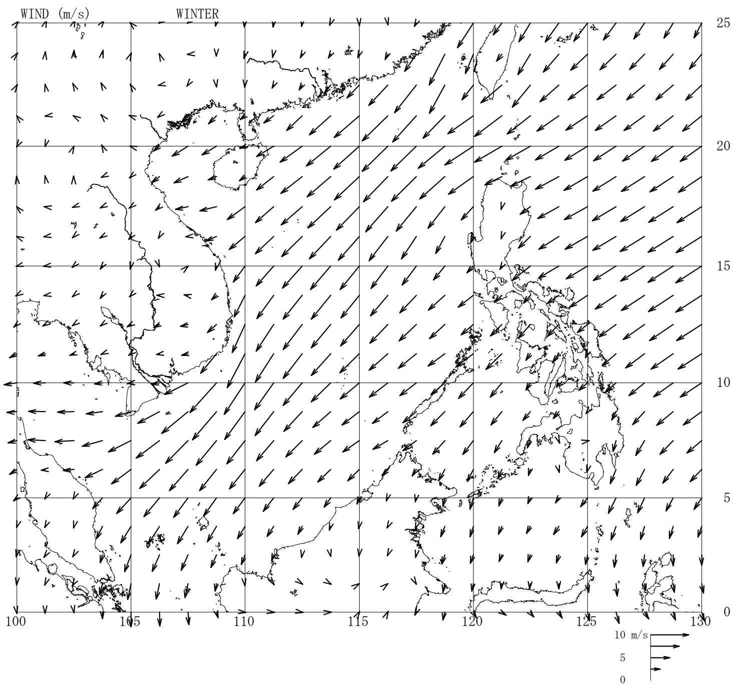
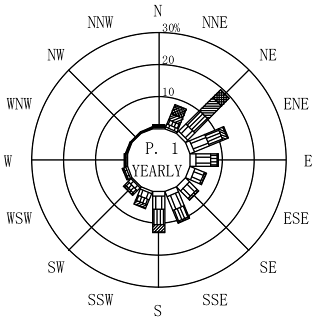
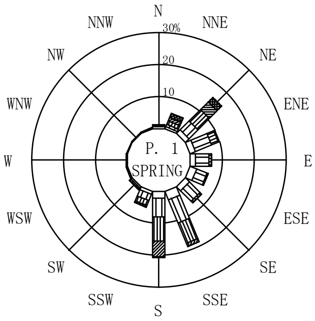


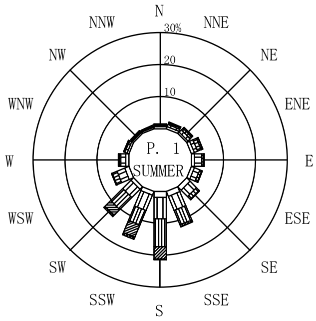
Figure 2.4.3 Horizontal distribution of 3-month averaged wind vectors



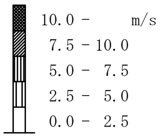
(a) Annual wind rose

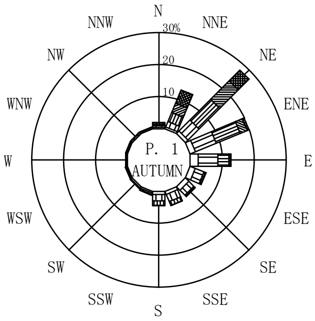


(b) Mar. - May

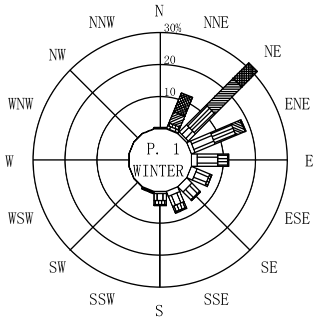


(c) Jun. – Aug.





(d) Sep. – Nov.



(e) Dec. – Feb..

Figure 2.4.4 Annual wind rose and Seasonal wind rose

Table 2.4.4 frequency occurrence of wind speed by direction

YEARLY

U(m/s) \ Direction	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		Total
0.0 - 0.1	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
0.1 - 2.5	33 0.45	41 0.56	75 1.03	108 1.48	130 1.78	127 1.74	130 1.78	129 1.77	106 1.45	56 0.77	39 0.53	38 0.52	27 0.37	19 0.26	12 0.16	14 0.19	1 0.01	1085 14.85
2.5 - 5.0	22 0.30	77 1.05	235 3.22	369 5.05	341 4.67	228 3.12	242 3.31	339 4.64	301 4.12	149 2.04	82 1.12	56 0.77	36 0.49	19 0.26	17 0.23	18 0.25	0 0.00	2531 34.65
5.0 - 7.5	17 0.23	102 1.40	430 5.89	340 4.65	148 2.03	42 0.58	49 0.67	275 3.77	350 4.79	126 1.73	102 1.40	31 0.42	10 0.14	8 0.11	8 0.11	5 0.07	0 0.00	2043 27.97
7.5 - 10.0	12 0.16	152 2.08	431 5.90	113 1.55	19 0.26	3 0.04	4 0.05	38 0.52	167 2.29	85 1.16	47 0.64	3 0.04	2 0.03	2 0.03	3 0.04	0 0.00	0 0.00	1081 14.80
10.0 - 12.5	8 0.11	157 2.15	205 2.81	16 0.22	4 0.05	2 0.03	3 0.04	2 0.03	10 0.14	15 0.21	7 0.10	0 0.00	1 0.01	1 0.01	1 0.01	2 0.03	0 0.00	434 5.94
12.5 - 15.0	2 0.03	65 0.89	41 0.56	3 0.04	0 0.00	0 0.00	1 0.01	0 0.00	1 0.01	0 0.00	1 0.01	1 0.01	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	115 1.57
15.0 - 17.5	0 0.00	4 0.05	5 0.07	1 0.01	0 0.00	1 0.01	0 0.00	0 0.00	0 0.00	0 0.00	1 0.01	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	12 0.16
17.5 - 20.0	1 0.01	1 0.01	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	1 0.01	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	3 0.04
20.0 - 22.5	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
22.5 - 25.0	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
25.0 - 27.5	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
27.5 - 30.0	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
30.0 - 100.0	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00	0 0.00
Total	95 1.3	599 8.2	1422 19.5	950 13.0	642 8.8	403 5.5	429 5.9	784 10.7	935 12.8	431 5.9	279 3.8	129 1.8	76 1.0	49 0.7	41 0.6	39 0.5	1 0.0	7304 100.0

Upper : Number of contents
Lower : Percentage of occurrence

2) Location of wave estimation

The wave estimation by one-point spectral method has been conducted at the location as shown in Figure 2.4.5. This location is E107^{o} in longitude and N21^{o} in latitude. Around the estimation point, wave observation data at Hon Dau station and those at the offshore of Lach Huyen channel are available to verify the wave estimation result. In this study, 3-year observation data from 2006 to 2008 at Hon Dau station and 1-year observation data from July, 2006 to August, 2007 at the offshore of Lach Huyen channel were collected for verification of the following wave estimation.

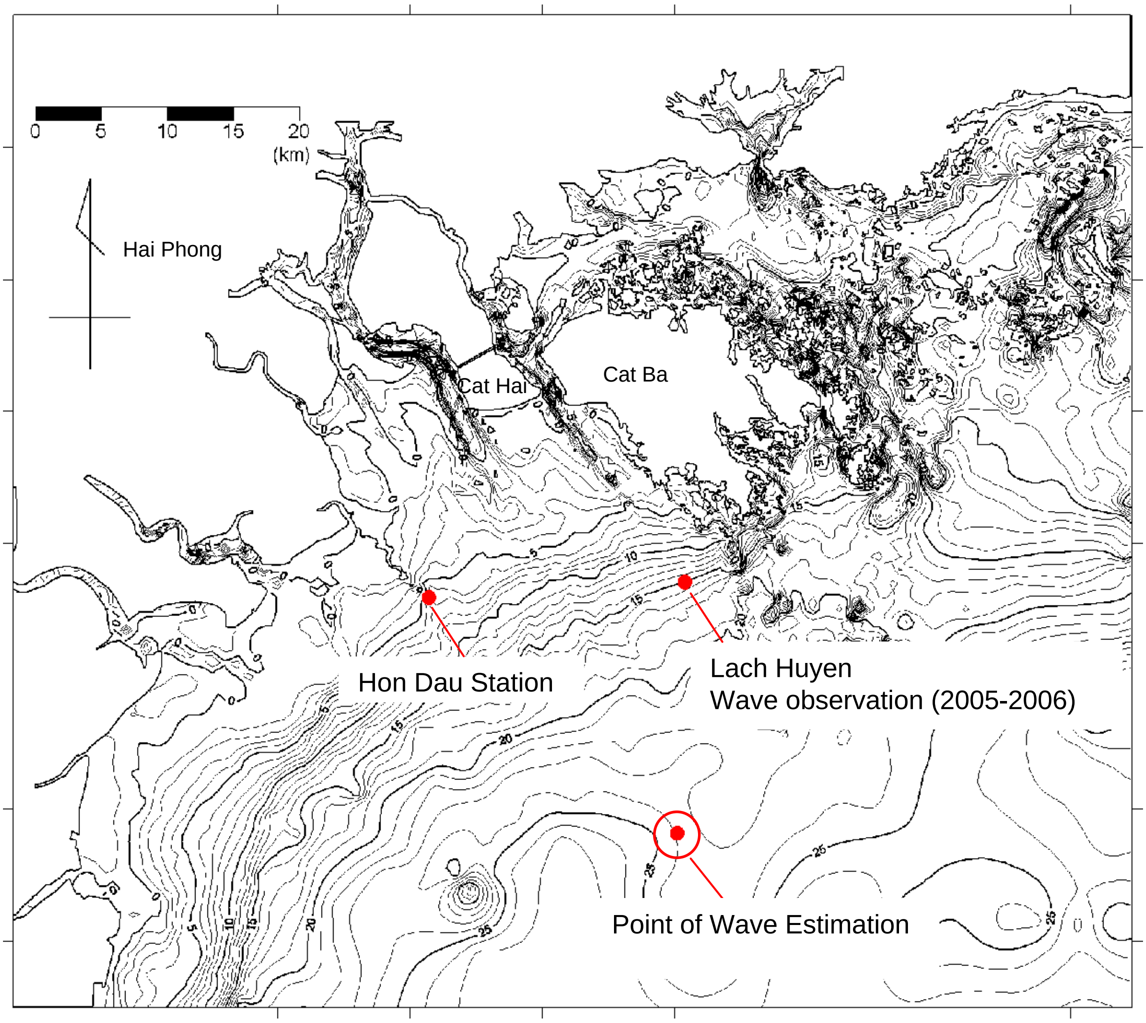


Figure 2.4.5 Location of wave estimation and wave observation stations

3) Offshore wave estimation and its verification

First, wave estimation has been conducted for normal waves to compare between the wave observation data and the estimation result. The wind field extracted from the global objective analysis data is used as the input data, and the time series of the wave height, period, and direction have been calculated. The arrangement of computational points for the one-point spectral method is employed as shown in Figure 2.4.6. The longest fetch is in the SSE-direction.

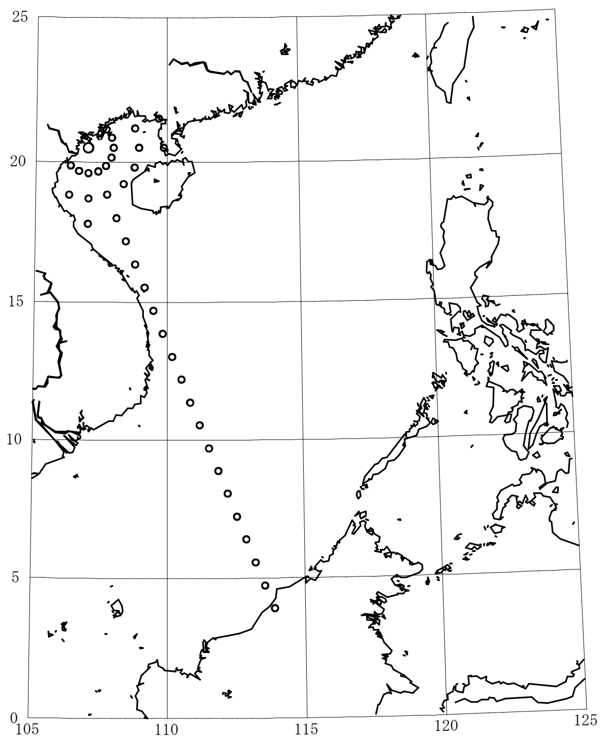


Figure 2.4.6 Arrangement of computational points for wave estimation

Figure 2.4.7 shows that a comparison between the estimated wave height and the observed wave height at the offshore of Lach Huyen Channel. The curve colored black shows the wave estimation result without any modification and the red curve is the result after modification. Figure 2.4.8 shows a correlation between the observed and the estimated (not modified) wave height. As shown in Figure 2.4.7 and Figure 2.4.8, the wave estimation result without modification tends to overestimate the observation data particularly when the wave direction is in particular from NE to ESE. The difference is considered due to sheltering effect of Cat Ba Island. Therefore, by modifying with respect to the wave direction, the reasonable wave height is obtained.

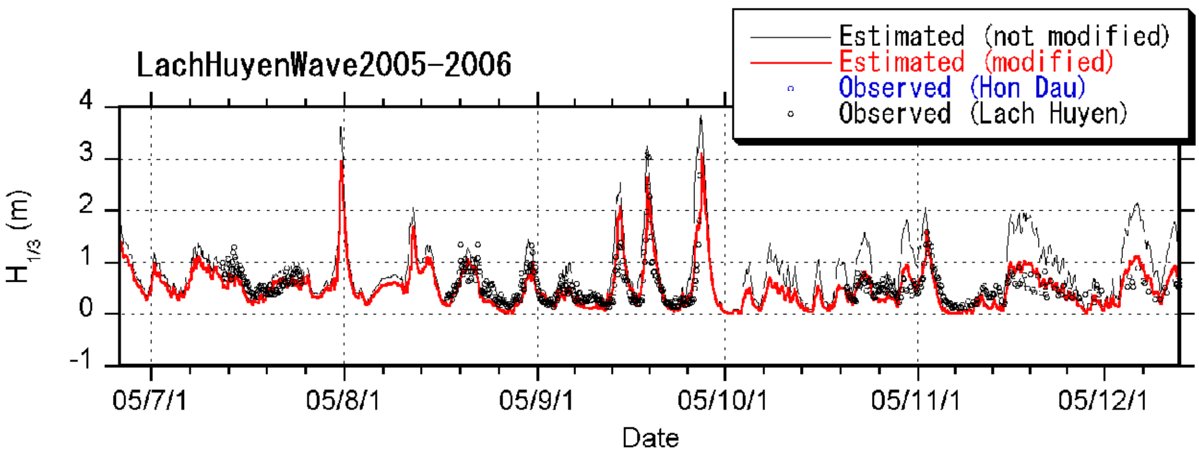


Figure 2.4.7 Comparison between the observed wave height and the estimated wave height

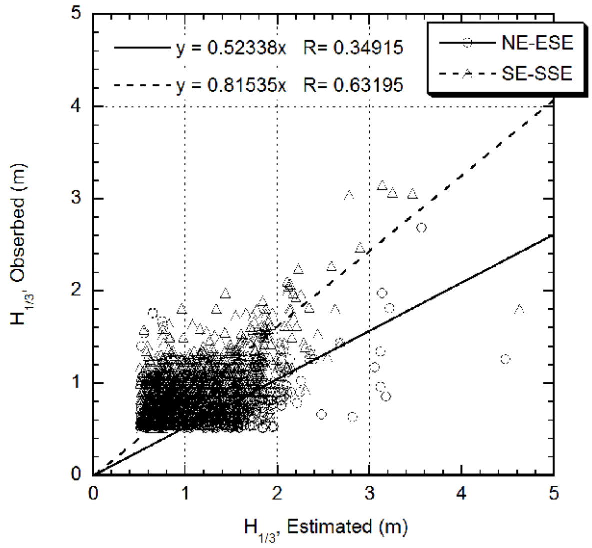


Figure 2.4.8 Correlation of Observed and Estimated wave height ($H_{1/3}$ > 0.5m)

4) Extreme wave estimation

To obtain the extreme wave for Lach Huyen Port area, the wave estimation has been carried out for typhoon conditions. The typhoon conditions for the wave estimation are collected from the UNISYS-database (http://weather.unisys.com/hurricane/), and 133 typhoons for 63 years from 1945 to 2007 are selected to follow the two conditions below.

1. The minimum distance between the center of typhoon and the target location is less than 300 km.

2. The maximum wind velocity is greater than 20 m/s

The selected typhoon tracks are shown in Figure 2.4.9 and the wave estimation has been carried out for the 133 typhoons. The results of wave estimation are also modified with their wave direction by the method described in 3).

For each typhoon, the maximum wave height is extracted. For the extracted data, the extreme statistic analysis has been carried out by using 81 of 133 data which are more than 1.7m in wave height. The wave height of 1.7m is determined as the minimum value of yearly maximum wave height observed at Hon Dau for 3 years from 2006 to 2008.

From the extreme statistic analysis, Weibull distribution (κ=1.4) is selected as the optimum distribution function as shown in Figure 2.4.10 and Figure 2.4.11. The probable wave height and period are obtained as tabulated in Table 2.4.5.

In the table, the wave height with a return period of 50 years is estimated 5.96 m. The value is slightly larger than the maximum wave height observed at Hon Dau station shown in Table 2.4.2 and is considered to be reasonable.

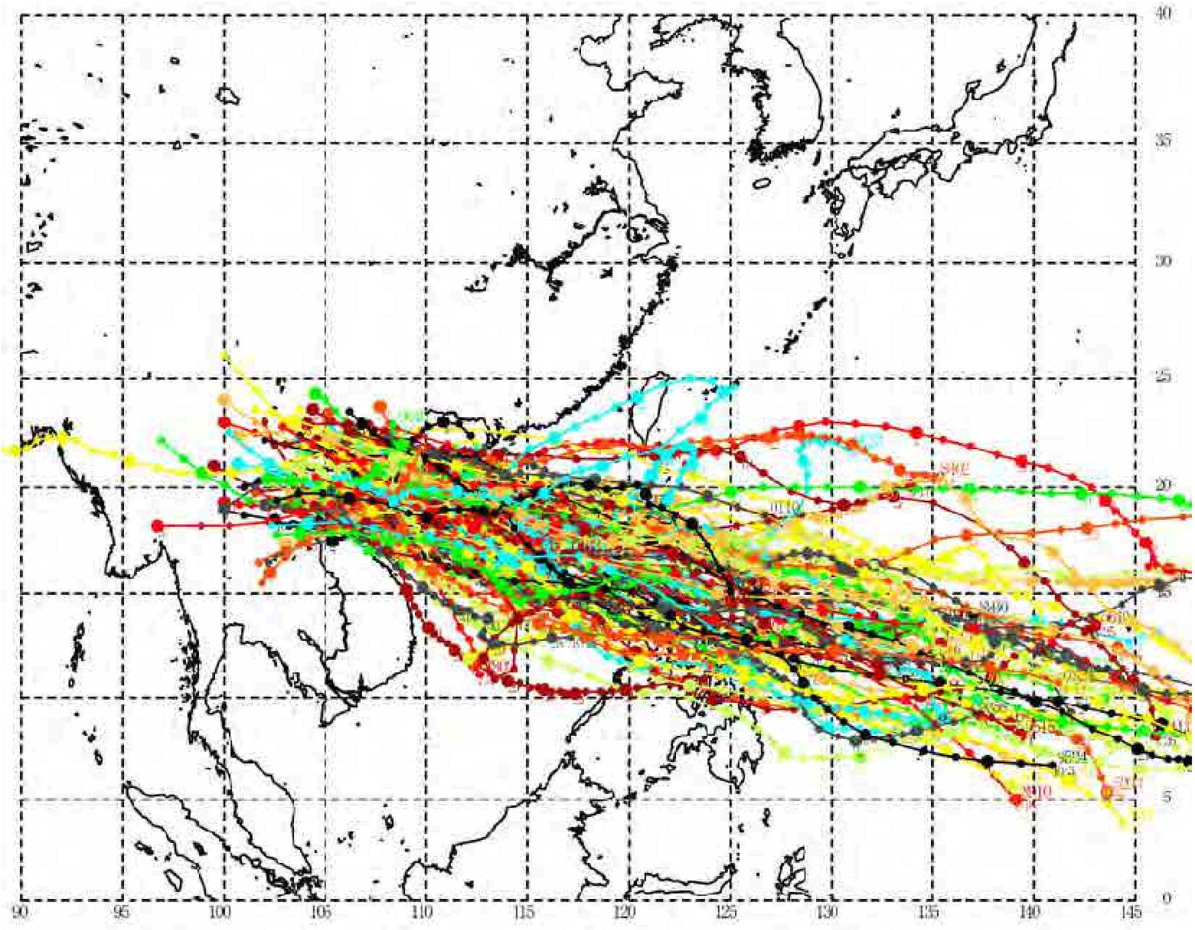


Figure 2.4.9 Extracted typhoon tracks

Table 2.4.5 Estimated probable wave height

Return Period (year)	Wave height (m)	Wave Period (sec)
1	2.30	8.3
5	4.11	11.0
10	4.72	11.8
30	5.59	12.8
50	5.96	13.3
100	6.46	13.8

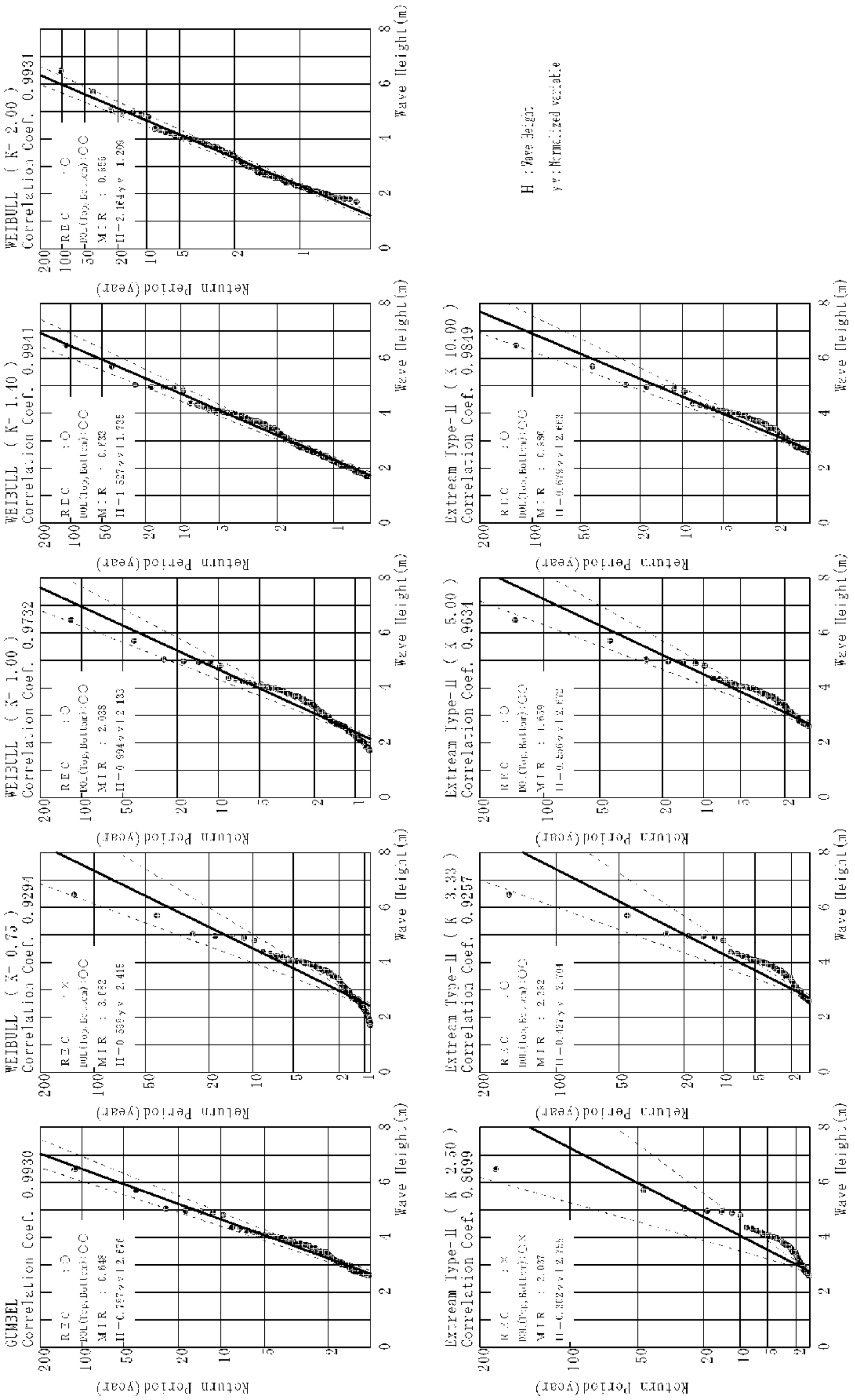
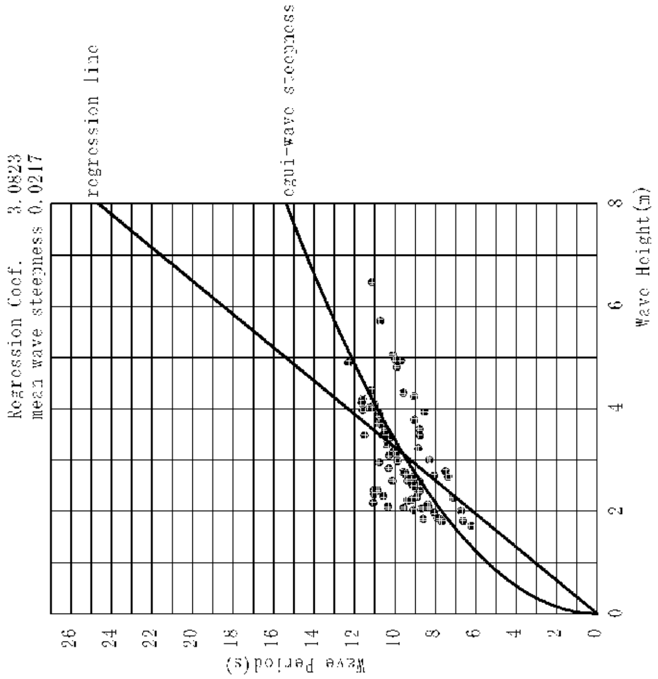


Figure 2.4.10 Results of extreme statistics analysis (Optimum distribution function = Weibull distribution with κ=1.4)



Probable Wave Height (m)

Dist.	GUMBUL	WEIBULL (κ)				Extream type-II (κ)			
		0.75	1.00	1.40	2.00	2.50	3.33	5.00	10.00
MIR	0.648	3.682	2.038	0.633	0.959	3.037	2.392	1.659	0.986
1yr	2.36	2.51	2.38	2.30	2.29	2.64	2.54	2.45	2.39
5yrs	4.07	3.78	3.98	4.11	4.16	3.54	3.71	3.86	3.98
10yrs	4.65	4.50	4.67	4.72	4.67	4.06	4.30	4.49	4.60
30yrs	5.54	5.78	5.76	5.59	5.34	5.24	5.52	5.65	5.65
50yrs	5.95	6.42	6.27	5.96	5.62	5.98	6.23	6.28	6.16
100yrs	6.49	7.33	6.96	6.46	5.98	7.25	7.38	7.23	6.91

Probable Wave Period (sec)

Dist.	GUMBUL	WEIBULL (κ)				Extream type II (κ)			
		0.75	1.00	1.40	2.00	2.50	3.33	5.00	10.00
Correlation	0.9930	0.9294	0.9732	0.9941	0.9931	0.8699	0.9257	0.9634	0.9849
1yr	8.3	8.6	8.4	8.3	8.2	8.8	8.7	8.5	8.4
5yrs	11.0	10.6	10.8	11.0	11.1	10.2	10.5	10.7	10.9
10yrs	11.7	11.5	11.7	11.8	11.7	11.0	11.3	11.5	11.7
30yrs	12.8	13.1	13.1	12.8	12.6	12.4	12.8	12.9	12.9
50yrs	13.3	13.8	13.6	13.3	12.9	13.3	13.6	13.6	13.5
100yrs	13.9	14.7	14.3	13.8	13.3	14.6	14.8	14.6	14.3

Figure 2.4.11 Results of extreme statistics analysis. Probable wave height and Period.
(Optimum distribution function = Weibull distribution with κ=1.4)

2.4.3 Design wave calculation

To design Lach Huyen port facilities, the appropriate wave condition for designing is required. In this section, wave transformation simulations have been carried out to obtain the design wave conditions for the port facilities based on the several incident wave conditions of probable waves estimated in the previous section.

1) Intended Facilities to calculate design wave

Figure 2.4.12 shows the planning general port layout of Lach Huyen port. As shown in the figure, the outer revetment 3,230 m long and the training dike 7,600 m long is presently planned to construct to protect port facilities from waves and channel sedimentation. In this section, the design wave calculation has been carried out for the two facilities of the outer revetment and the training dike.

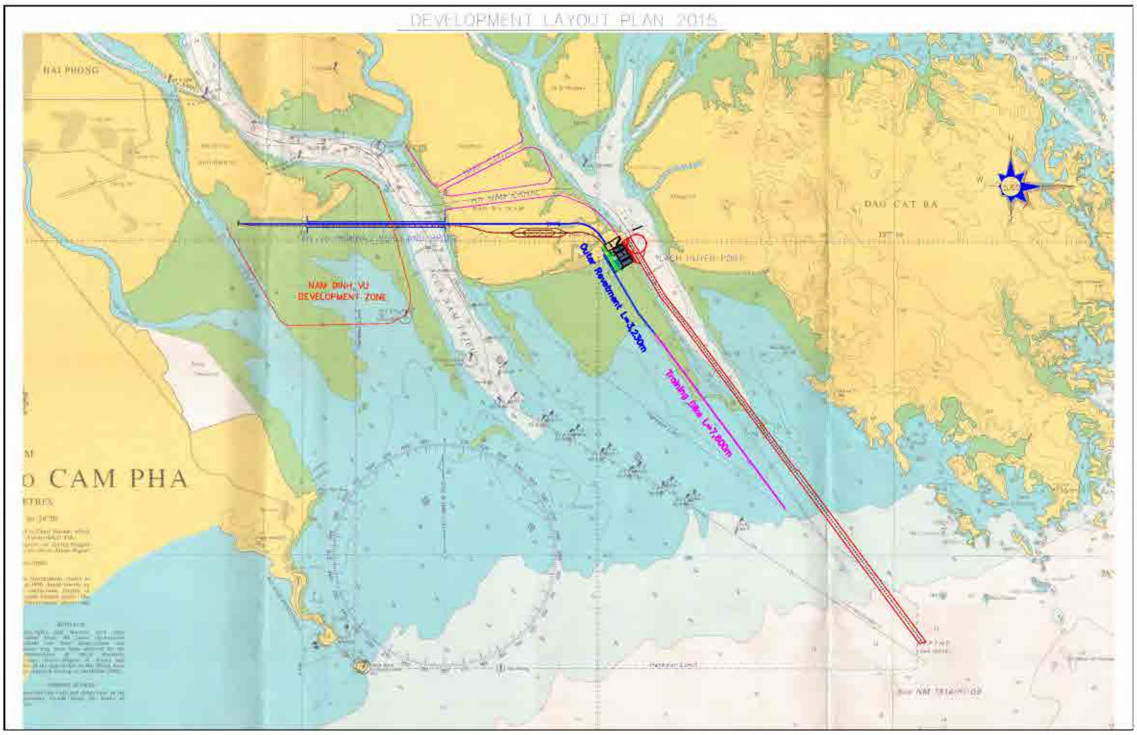


Figure 2.4.12 General Port Layout

Table 2.4.6 Facilities for calculation of design wave

Name of Port	Planned Facilities
Lach Huyen	Outer Revetment (L=3,230 m)
Lach Huyen	Training Dike (L=7,600 m)

The calculation points for design wave are selected totally 29 points as shown in Figure 2.4.13 and the description of the points is shown in Table 2.4.7.

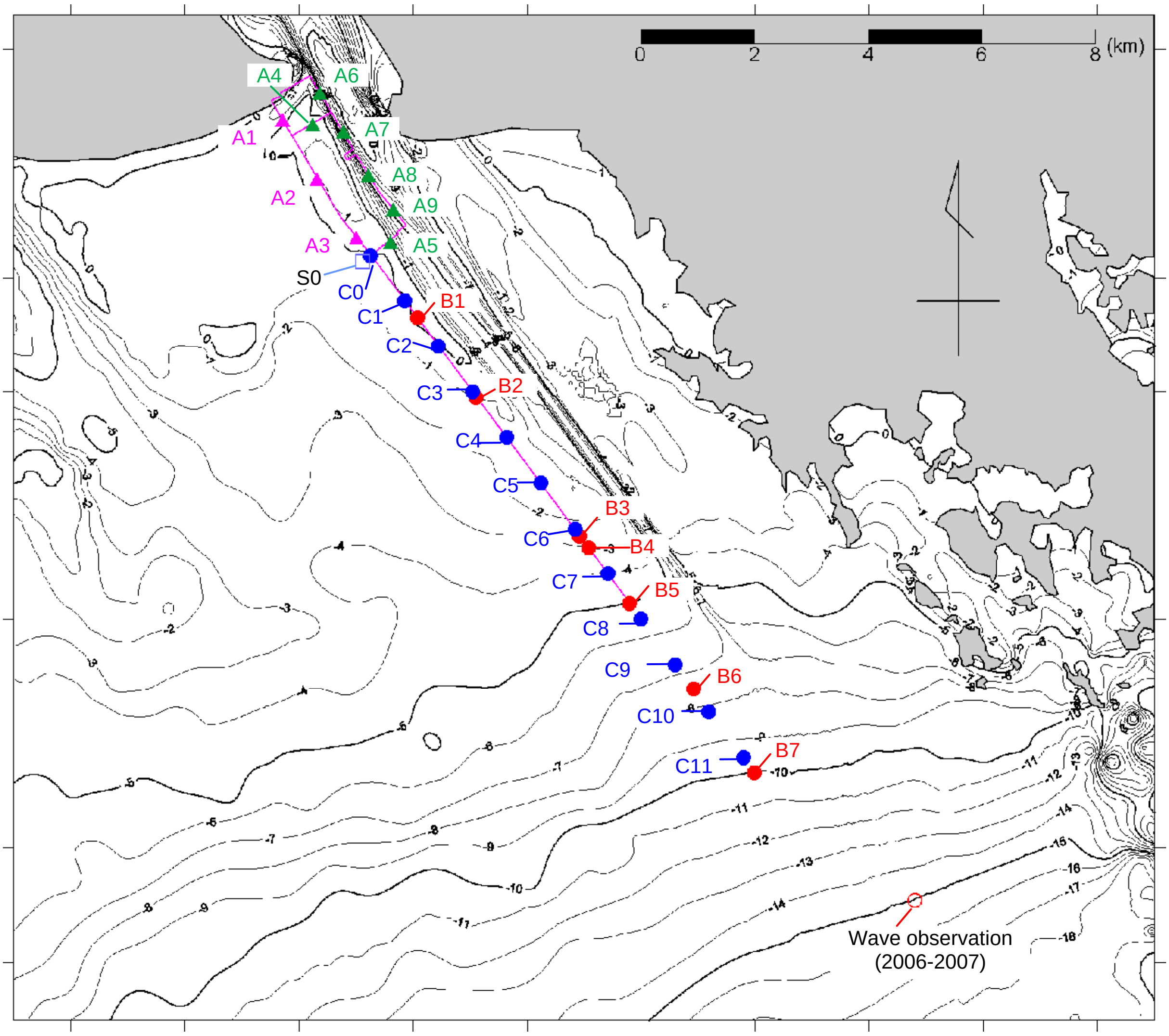


Figure 2.4.13 Locations to calculate design wave

Table 2.4.7 Calculation Points for design wave

Name of Facility	Name of Calculation Pts.	Description
Training Dike	B1 - B7	On the training dike in depth of 0.0, -1.0, -2.5, -3.0, -5.0, -7.5, and -10.0 m, C.D.
Training Dike	C0 – C11	On the training dike with 1 km interval, where C0 is the beginning of the dike and C11 is on the extension line of the dike
Outer Revetment	A1 – A3	On the Outer Revetment
Mooring area	A4 – A9	Positions on wharf protected by the revetment
Other	S0	Point in depth of -0.2m, C.D., near the connection between the revetment and the dike

2) Design offshore wave height and tide level

Offshore wave conditions to calculate the design wave for the port facilities are shown in Table 2.4.6. In this study, the results of the probable waves estimated in section 2.4.2 are used as the input offshore wave condition. For each wave condition, wave transformation calculations have been done with three tide levels of H.H.W.L., H.W.L., and L.W.L. for the wave with a return period of 30 and 50 years, and with two tide levels of H.W.L., and L.W.L. for the return period of 5 and 10 years. Also, for each set of incident wave and tide level, calculations for six wave directions of E, ESE, SE, SSE, S, and SSW have been conducted, and the maximum wave height at each location is extracted as the design wave.

a) Offshore wave

The wave conditions to use the design wave calculations are shown in Table 2.4.8.

Table 2.4.8 List of design offshore wave

Return Period (year)	Wave height (m)	Wave Period (sec)
5	4.11	11.0
10	4.72	11.8
30	5.59	12.8
50	5.96	13.3

Six wave directions of E, ESE, SE, SSE, S, and SSW are employed for the incident wave direction because the dominant wave direction in Lach Huyen port area is observed E and S from the previously wave observations. It is noted that the probable waves estimated in Section 2.4.2 are the adjusted waves with the observation data at the offshore of Lach Huyen channel. Therefore, the probable waves in Table 2.4.8 can be regarded as the wave condition at the wave observation point of the offshore of Lach Huyen channel. Therefore, the input offshore wave height is converted from the value in Table 2.4.8 to offshore condition with respect to the wave direction to use in the following wave transformation simulations and design wave calculations.

b) Tide level

The tide level conditions applied in the design wave calculations are as follows.

H.H.W.L.	+4.43 m, C.D.
H.W.L.	+3.55 m, C.D.
L.W.L.	+0.43 m, C.D.

3) Calculation method of design wave

Calculation method of design wave is as follows. First, the refraction/diffraction coefficient, $K_r \cdot K_d$, is obtained at each location through calculating wave transformation. By using the calculated $K_r \cdot K_d$, the equivalent offshore wave height, H_0' $(= K_r \cdot K_d \cdot H_0$, where H_0 = the deepwater wave height), can be calculated. The design wave height in front of structure, H $(= K_s H_0')$ is evaluated by multiplying the shoaling coefficient K_s to the equivalent offshore wave height, H_0'.

In case the target location to calculate design wave is in the surf zone, the effect of wave breaking should be taken into account. The effect of wave breaking can be read from Goda's diagrams as shown in Figure 2.4.14 to Figure 2.4.17, or calculated from the following approximations. This study calculates the wave breaking effect by the approximations.

$$H_{1/3} = \begin{cases} K_s H_0' & :(h/L_0 \geq 0.2) \\ \min\{(\beta_0 H_0' + \beta_1 h),\ \beta_{\max} H_0',\ K_s H_0'\} & :(h/L_0 < 0.2) \end{cases} \quad \textbf{(2.4.1)}$$

where, β_0, β_1, and $\beta_{\max}$ are coefficients which are defined as,

$$\left.\begin{aligned} \beta_0 &= 0.028(H_0'/L_0)^{-0.38} \exp\left[20(\tan\theta)^{1.5}\right] \\ \beta_1 &= 0.52 \exp[4.2\tan\theta] \\ \beta_{\max} &= \max\{0.92,\ 0.32(H_0'/L_0)^{-0.29} \exp[2.4\tan\theta]\} \end{aligned}\right\} \quad \textbf{(2.4.2)}$$

and h is the water depth, L_0 the offshore wave length, and $\tan\theta$ the bed slope. The maximum wave height, $H_{\max}$ can be calculated in the same manner,

$$H_{\max} = \begin{cases} 1.8 K_s H_0' & :(h/L_0 \geq 0.2) \\ \min\{(\beta_0^* H_0' + \beta_1^* h),\ \beta_{\max}^* H_0',\ 1.8 K_s H_0'\} & :(h/L_0 < 0.2) \end{cases} \quad \textbf{(2.4.3)}$$

and,

$$\left.\begin{aligned} \beta_0^* &= 0.052(H_0'/L_0)^{-0.38} \exp\left[20\tan^{1.5}\theta\right] \\ \beta_1^* &= 0.63 \exp[3.8\tan\theta] \\ \beta_{\max}^* &= \max\{1.65,\ 0.53(H_0'/L_0)^{-0.29} \exp[2.4\tan\theta]\} \end{aligned}\right\} \quad \textbf{(2.4.4)}$$

The shoaling coefficients, K_s is calculated by iteration of the following equations.

$$K_s = \begin{cases} K_{si} & :(h_{30} \leq h) \\ (K_{si})_{30}(h_{30}/h)^{2/7} & :(h_{50} \leq h < h_{30}) \\ K_s(\sqrt{K_s} - B) - C = 0 & :(h < h_{50}) \end{cases} \quad \textbf{(2.4.5)}$$

where K_{si} is the shoaling coefficient calculated by Eq. (2.4.6), the K_s is calculated by iteration of the following equations.

$$K_{si} = \frac{1}{\sqrt{\left\{1 + \frac{4\pi h/L}{\sinh(4\pi h/L)}\tanh\frac{2\pi h}{L}\right\}}} \quad \textbf{(2.4.6)}$$

$$\left(\frac{h_{30}}{L_0}\right)^2 = \frac{2\pi}{30}\frac{H_0'}{L_0}(K_{si})_{30} \quad \textbf{(2.4.7)}$$

$$\left(\frac{h_{50}}{L_0}\right)^2 = \frac{2\pi}{50}\frac{H_0'}{L_0}(K_s)_{50} \quad \textbf{(2.4.8)}$$

$$B = \frac{2\sqrt{3}}{\sqrt{2\pi H_0'/L_0}}\frac{h}{L_0}, \qquad C = \frac{C_{50}}{\sqrt{2\pi H_0'/L_0}}\left(\frac{L_0}{h}\right)^{3/2} \quad \textbf{(2.4.9)}$$

$$C_{50} = (K_s)_{50}\left(\frac{h_{50}}{L_0}\right)^{3/2}\left\{\sqrt{2\pi\frac{H_0'}{L_0}(K_s)_{50}} - 2\sqrt{3}\cdot\frac{h_{50}}{L_0}\right\} \quad \textbf{(2.4.10)}$$

where and h_{30} and $(K_{si})_{30}$ are the water depth and K_{si} satisfied with Eq.(2.4.7), h_{50} the water depth satisfied with Eq.(2.4.8), and B, C, and C_{50} are the coefficients calculated by Eqs. (2.4.9) and (2.4.10).

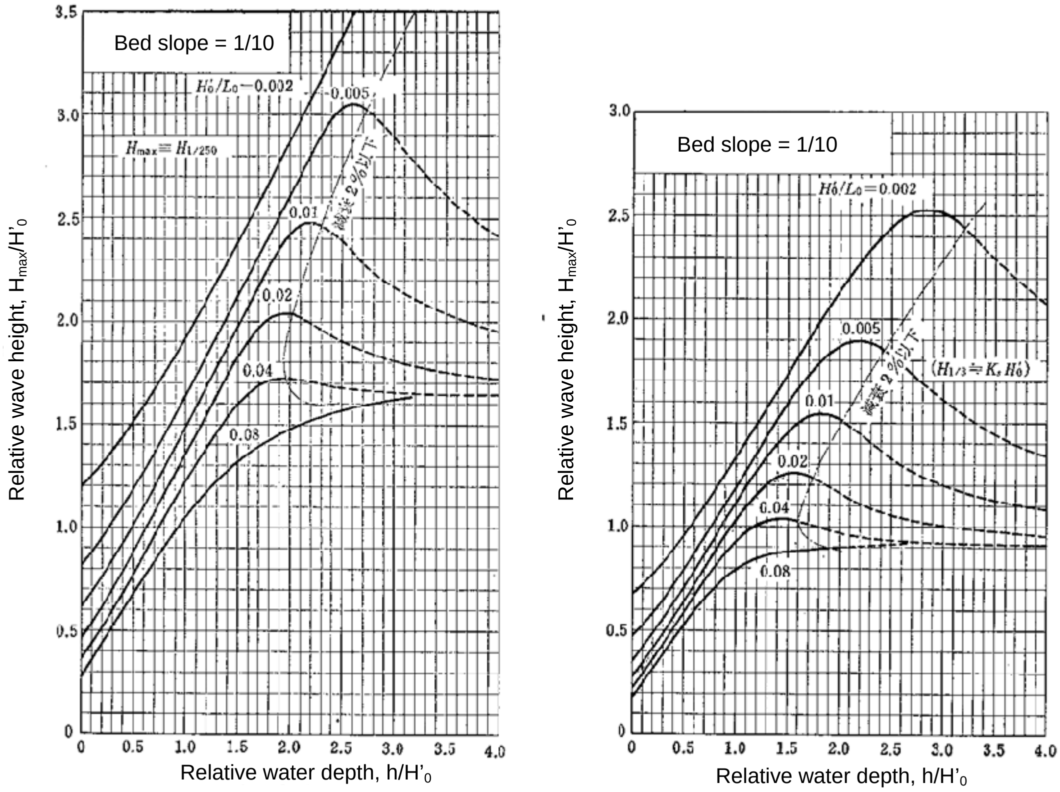


Figure 2.4.14 Diagram for wave height in surf zone (for seabed gradient =1/10)

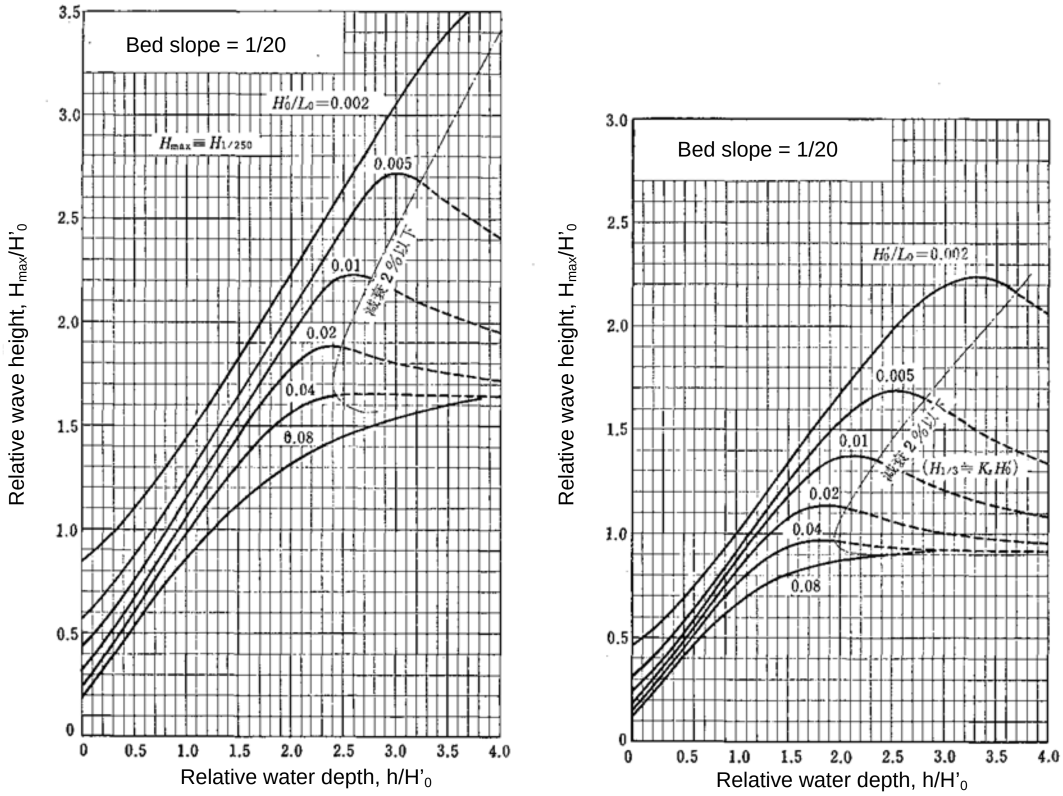


Figure 2.4.15 Diagram for wave height in surf zone (for seabed gradient = 1/20)

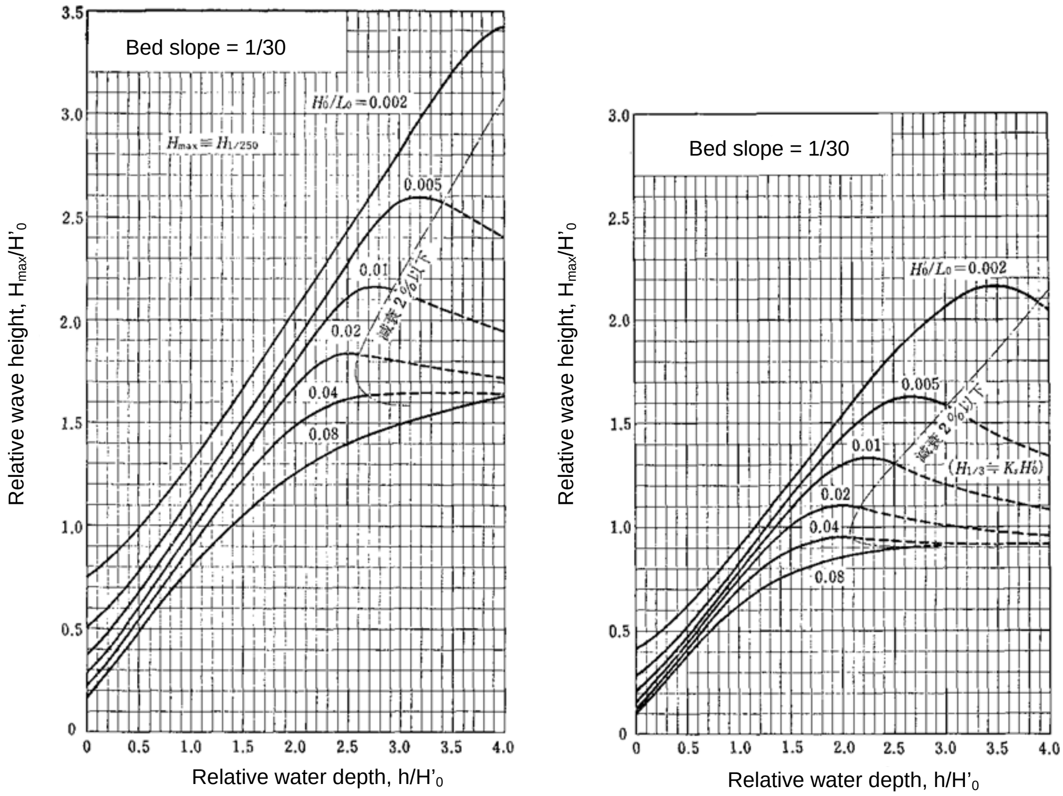


Figure 2.4.16 Diagram for wave height in surf zone (for seabed gradient, 1/30)

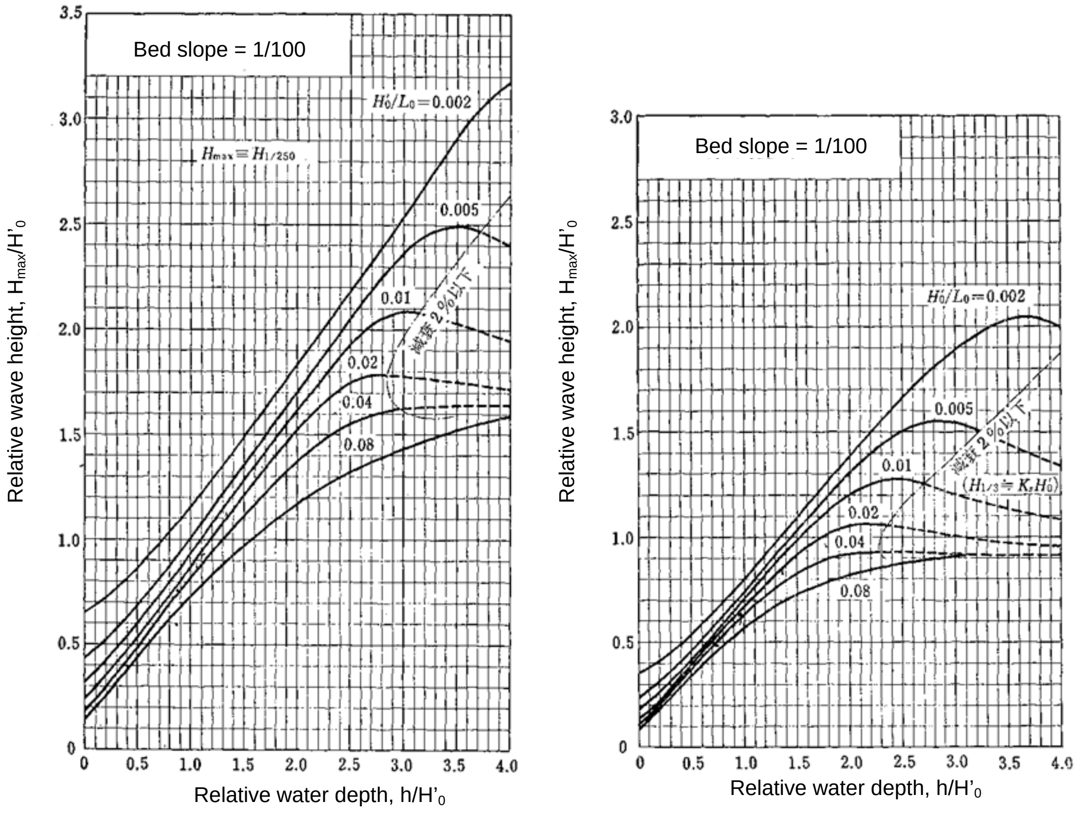


Figure 2.4.17 Diagram for wave height in surf zone (for seabed gradient, 1/100)

4) Other Calculation Conditions

The following conditions are also set for the design wave calculations.

a) Bed slope

The seabed slope at each calculating location is given by the averaged bed slope in the range of water depth from $1.5H_0'$ to $2.5H_0'$ in front of the structure.

b) Design Depth

The design depth is set as the water depth at each calculating location.

c) Refraction/Diffraction Coefficient and wave direction

The refraction/diffraction coefficient and the wave direction at each calculation position are given by the result of wave transformation calculation.

d) Spreading parameter, S_{max}

The directional spectrum is needed in calculating wave transformation and the spreading parameter, S_{max} should be a given parameter. The value of Smax is usually 10 for wind waves, 75 for swell, and 25 for the intermediate between wind waves and swell waves. In this study, S_{max} = 25 is used all design wave calculations in the following.

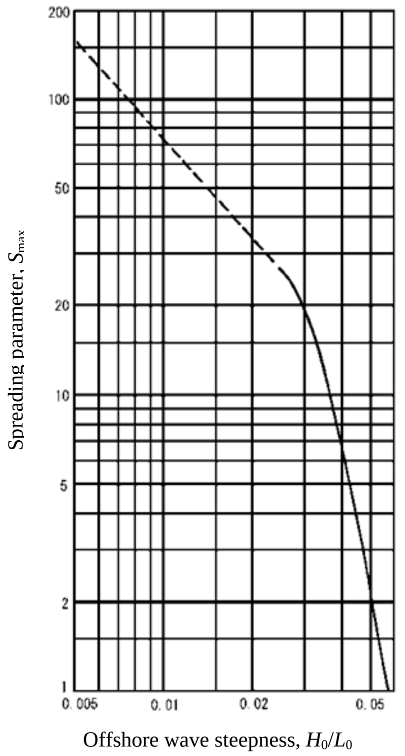


Figure 2.4.18 Relation between spreading parameter, Smax and offshore wave steepness, H_0/L_0

5) Wave transformation calculation

a) Computational Domain

A computational grid is prepared for wave transformation calculation. The grid is made based on the water depth data of the result of bathymetric survey in November, 2009 and the depth data read from the chart. The mesh size is 20m x 20m.

Three types of structure condition have been applied to the calculations of wave transformation as shown in Figure 2.4.20.

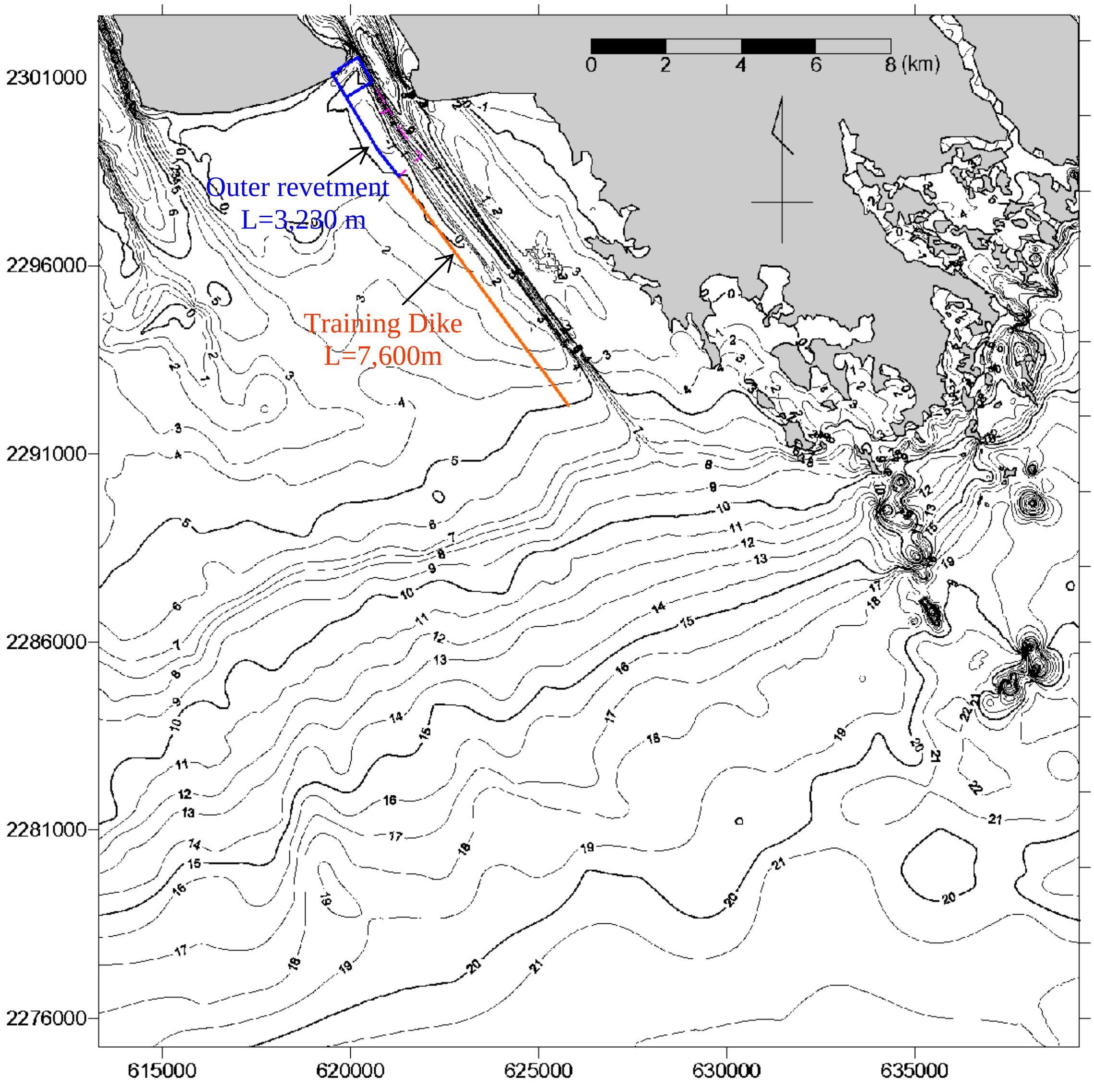


Figure 2.4.19 Depth contour map for wave transformation calculation (cell size=20m x 20m)

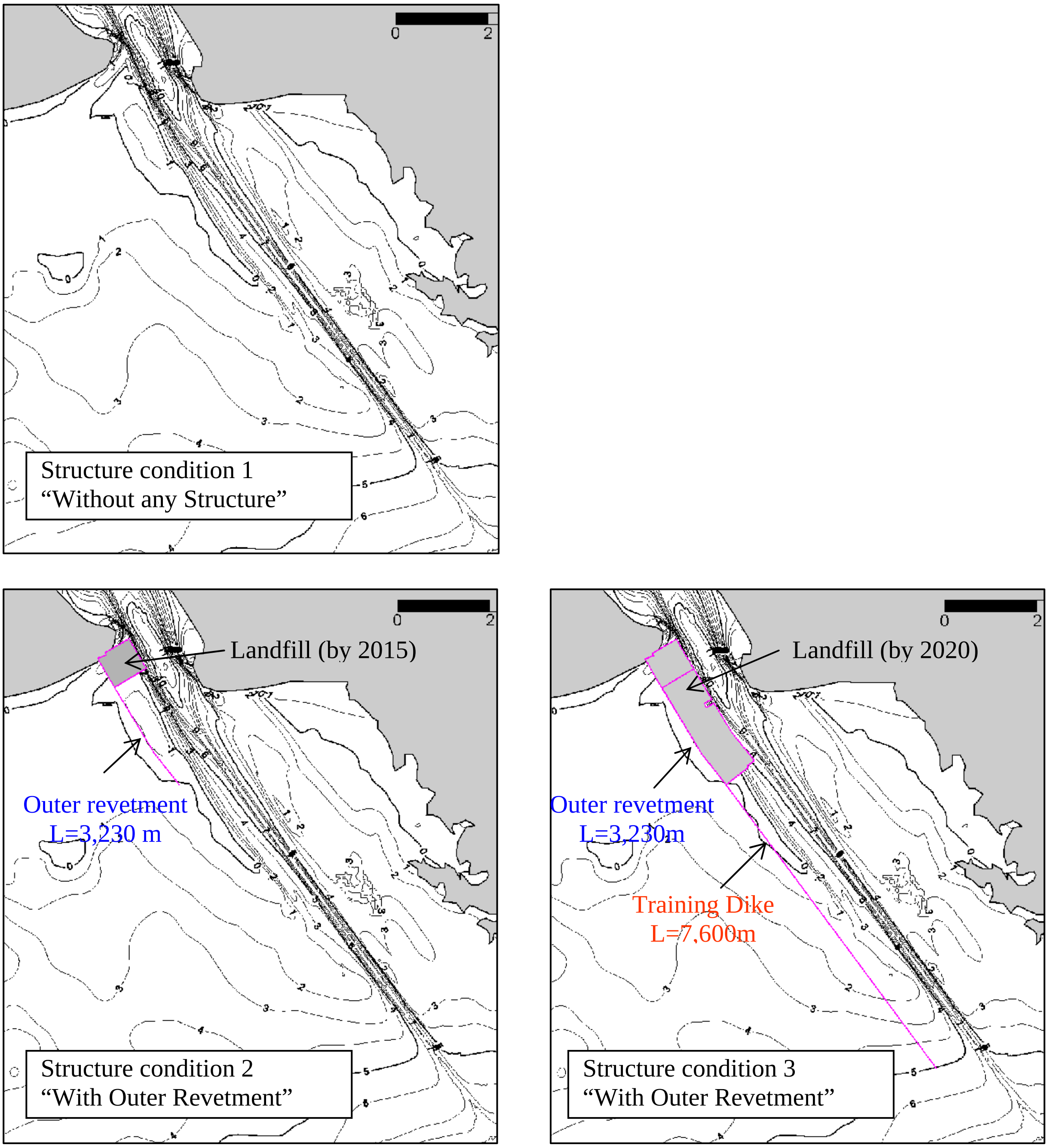


Figure 2.4.20 Structure condition for calculation of wave transformation

b) Calculation of wave transformation

For numerical analysis of wave transformation, the wave energy balance equation with addition of the wave diffraction term and the energy dissipation term by breaking is employed. The basic equation of the model is written as,

$$\frac{\partial}{\partial x}(SV_x)+\frac{\partial}{\partial y}(SV_y)+\frac{\partial}{\partial \theta}(SV_\theta)=\frac{\kappa}{2\sigma}\left\{(cc_g\cos^2\theta S_y)_y-\frac{1}{2}cc_g\cos^2\theta S_{yy}\right\}-\varepsilon_b S \qquad \textbf{(2.4.11)}$$

where, $S(f,\theta)$ is the directional wave spectral density, (x,y) are the horizontal coordinates, θ the wave direction measured counterclockwise from the x axis, ε_b the coefficient of energy dissipation, and the characteristic velocities, (V_x, V_y, V_θ), are defined as follows:

$$V_x = c_g \cos\theta \quad \textbf{(2.4.12)}$$

$$V_y = c_g \sin\theta \quad \textbf{(2.4.13)}$$

$$V_\theta = \frac{c_g}{c}\left(\frac{\partial c}{\partial x}\sin\theta - \frac{\partial c}{\partial y}\cos\theta\right) \quad \textbf{(2.4.14)}$$

where c is the wave celerity and c_g the group velocity. The first term in the right side of Eq. (2.4.11) is the additional term for representing wave diffraction, where σ is the wave angular frequency and κ is the coefficient to optimize the degree of diffraction, the typical value of which is 2.5.

To obtain design wave at target locations, the refraction/diffraction coefficients is required. Therefore, in the following calculations, wave transformation without wave breaking is calculated at first, and the effect of wave breaking is added after calculation of the refraction/diffraction coefficient by the method described in the section 3).

c) Results of wave transformation calculation

Wave transformation calculations have been carried out for total 180 cases (= 3 structure conditions x 3 tide levels x 2 waves of 50 and 30 years of return period x 6 wave directions + 3 structure conditions x 2 tide levels x 2 waves of 10 and 5 years of return period x 6 wave directions). Examples of the results of wave transformation calculations are shown in Figure 2.4.21 to Figure 2.4.26. These are the results of the incident wave with a return period of 50 years, the conditions of which are H.H.W.L. in tide level, E and SSE in wave direction, and the three different structure conditions. For each condition, the distribution of the refraction/diffraction coefficient and the distribution of wave direction are shown.

From these figures, it is confirmed that even though the incident wave is in the E-direction, wave direction around the training dike become in the direction along the dike. It is also confirmed that the contour lines of the refraction/diffraction coefficient concentrate near the Lach Huyen channel indicating that the wave deformation occurs due to the complex topography.

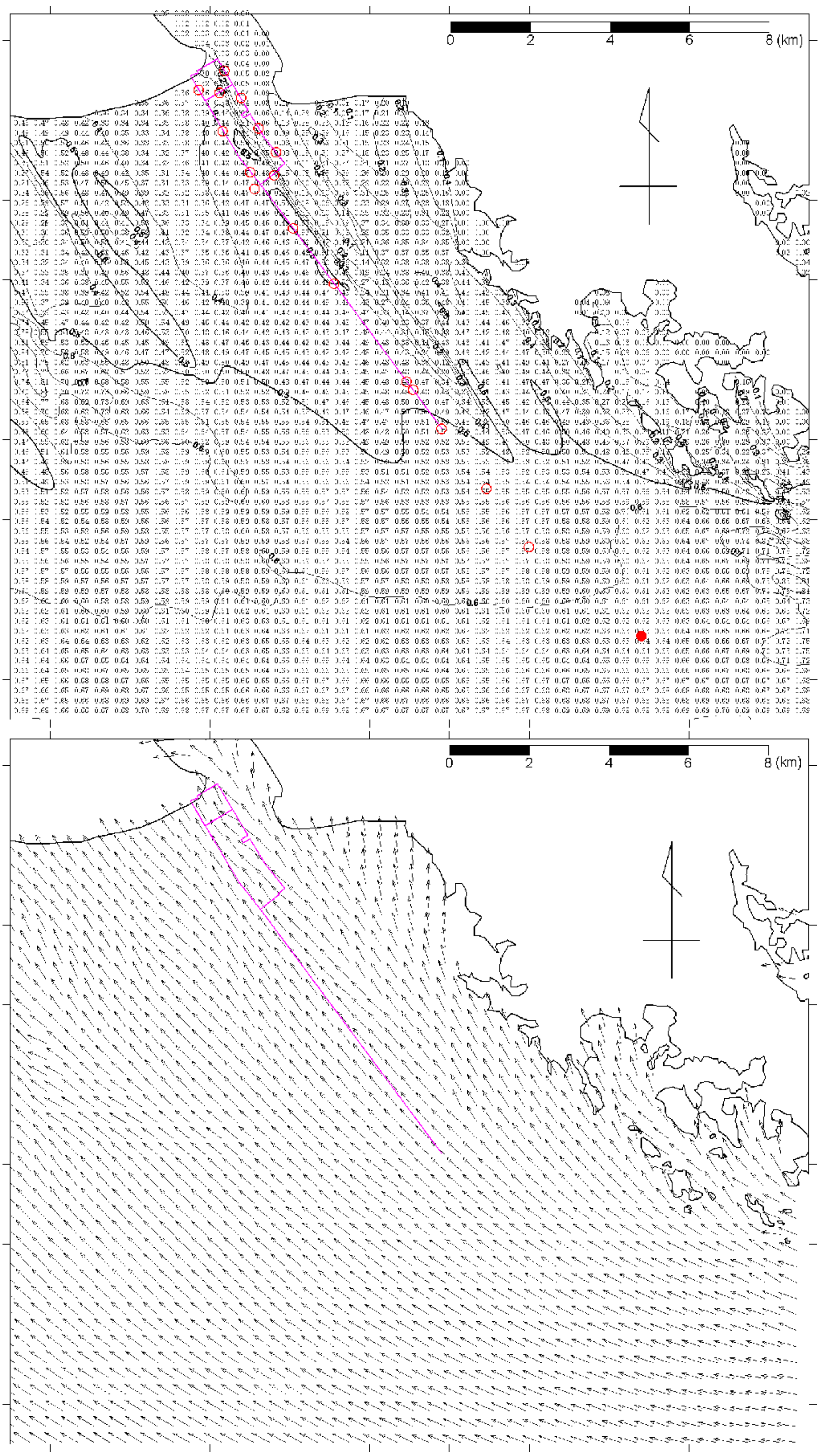


Figure 2.4.21 Distribution of Refraction/Diffraction Coefficient and wave direction (Wave with a return period of 50 years, T=13.3 sec, θ = E, W.L.=H.H.W.L., Without Structures. The red blank circles are calculation points of A1 to A9, B1 to B7, and S0)

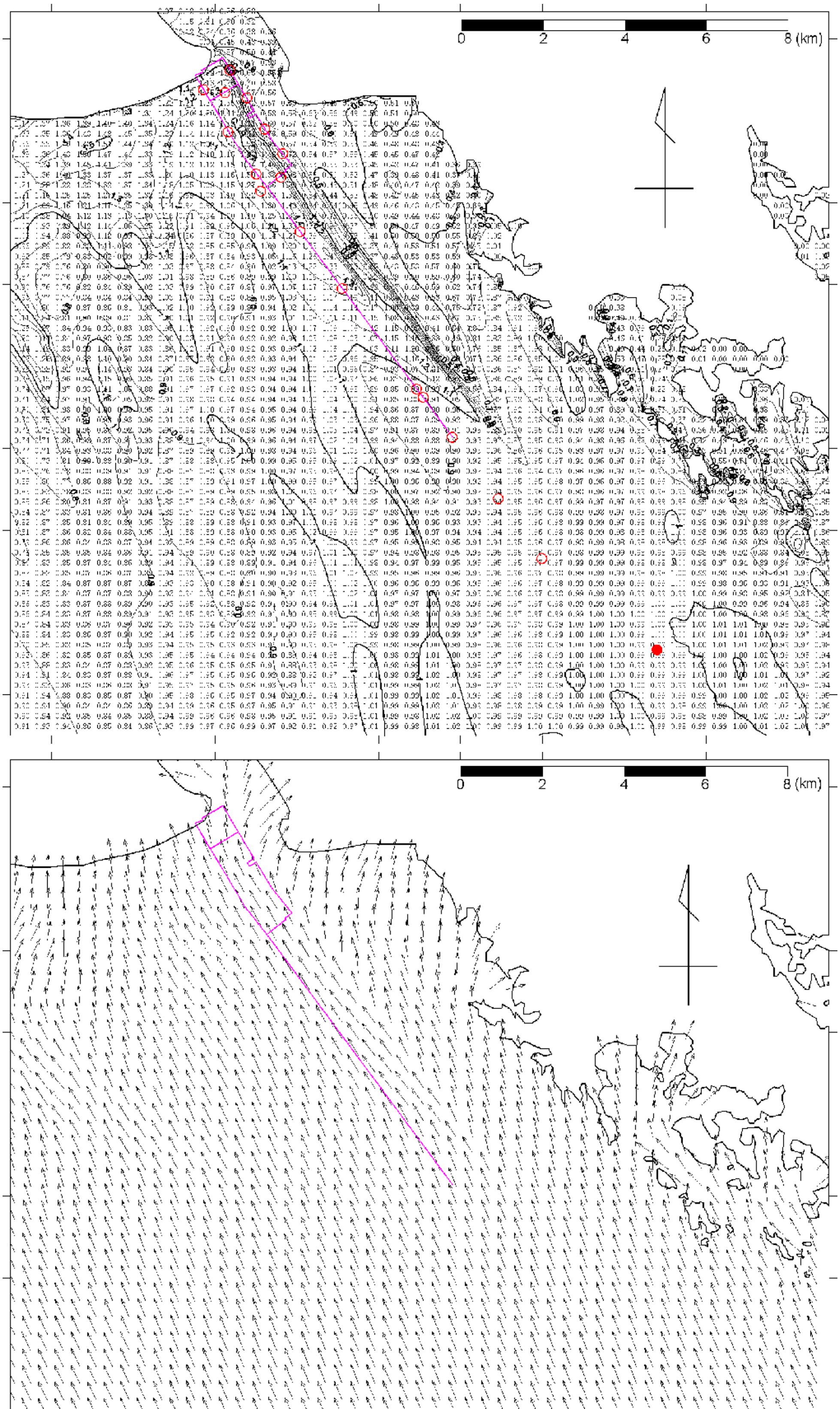


Figure 2.4.22 Distribution of Refraction/Diffraction Coefficient and wave direction (Wave with a return period of 50 years, T=13.3 sec, θ = SSE, W.L.=H.H.W.L., Without Structures. The red blank circles are calculation points of A1 to A9, B1 to B7, and S0)

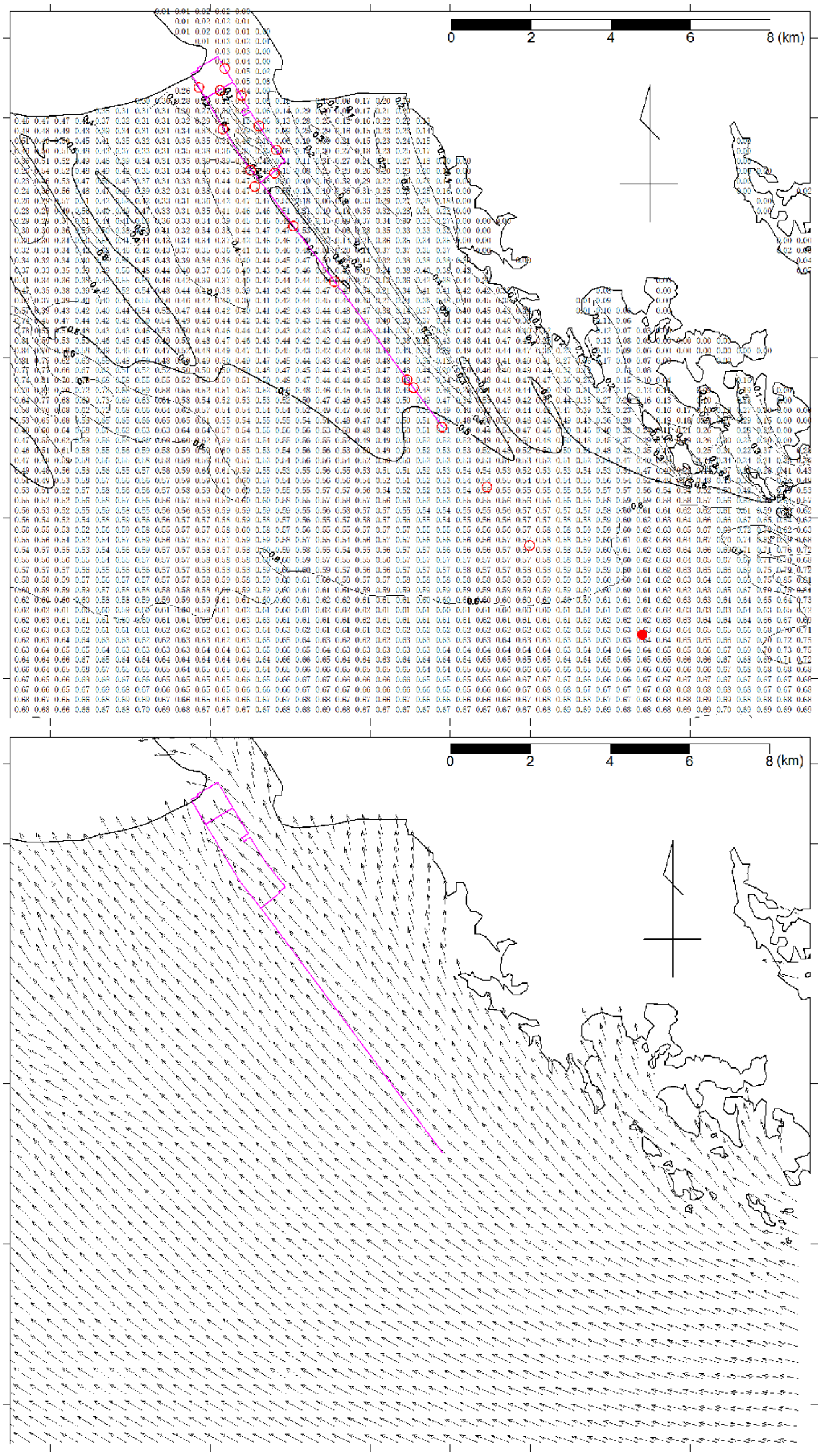


Figure 2.4.23 Distribution of Refraction/Diffraction Coefficient and wave direction (Wave with a return period of 50 years, T=13.3 sec, θ = E, W.L.=H.H.W.L., With Outer Revetment. The red blank circles are calculation points of A1 to A9, B1 to B7, and S0)

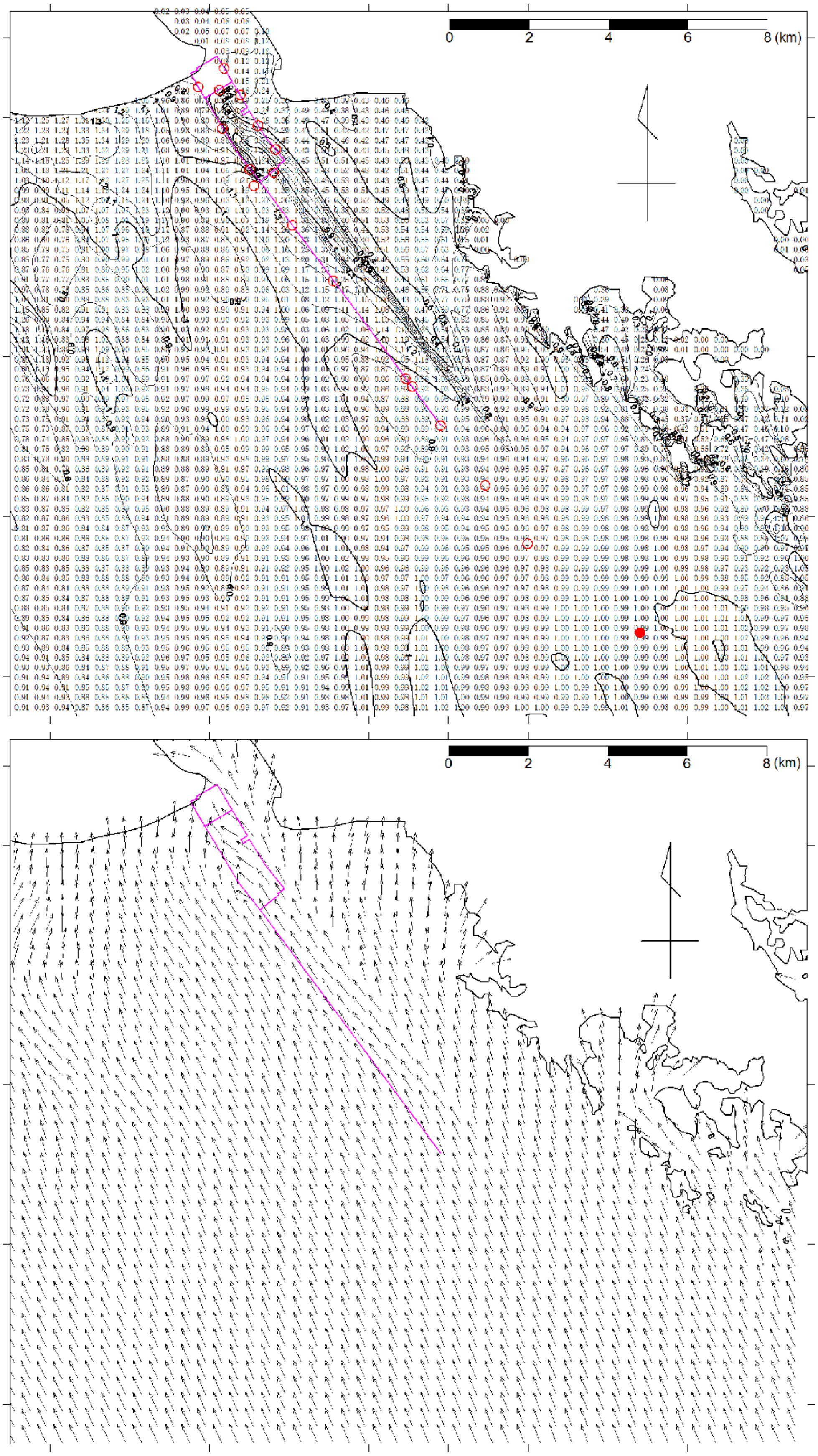


Figure 2.4.24 Distribution of Refraction/Diffraction Coefficient and wave direction (Wave with a return period of 50 years, T=13.3 sec, θ = SSE, W.L.=H.H.W.L., With Outer Revetment. The red blank circles are calculation points of A1 to A9, B1 to B7, and S0)

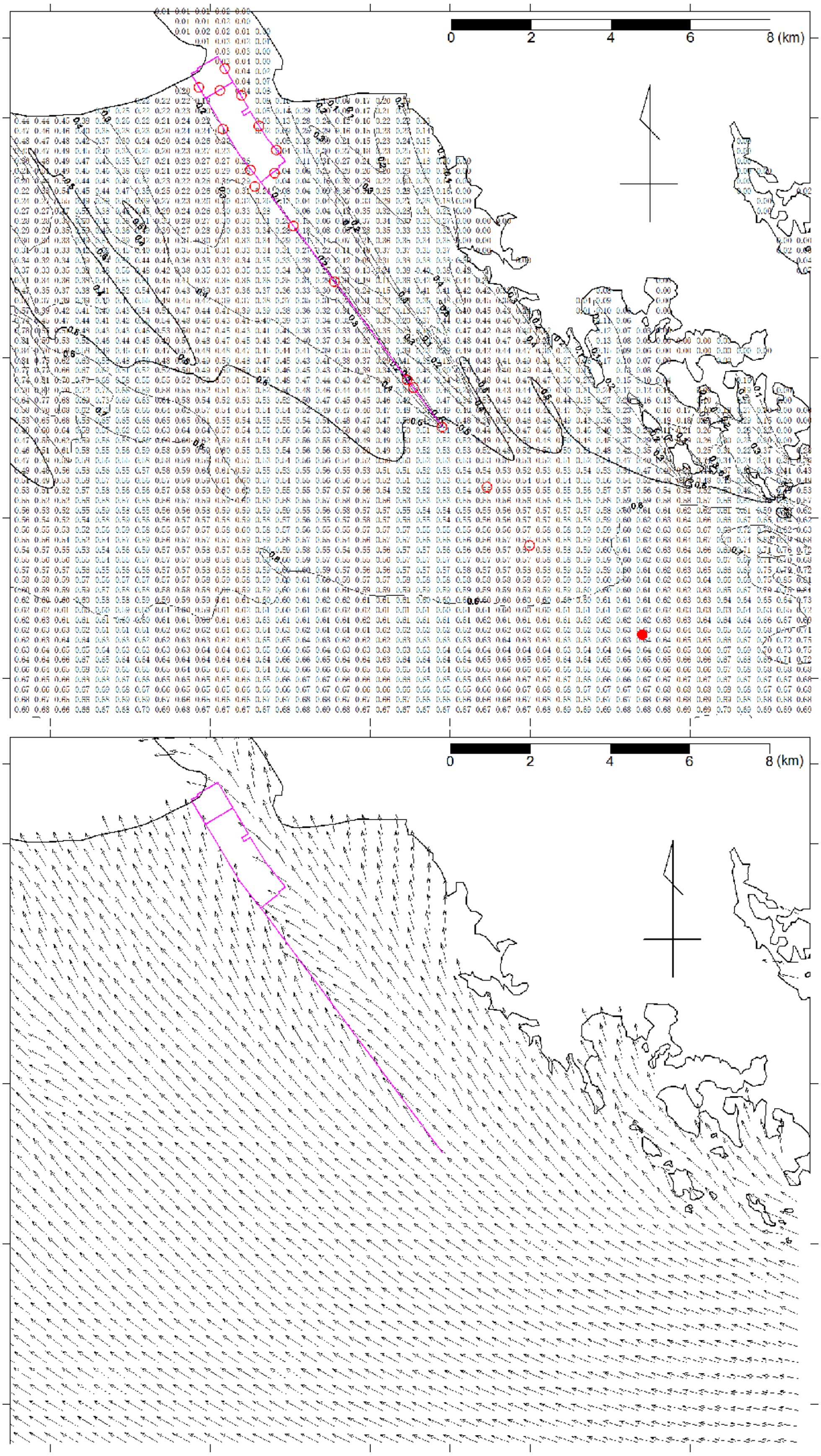
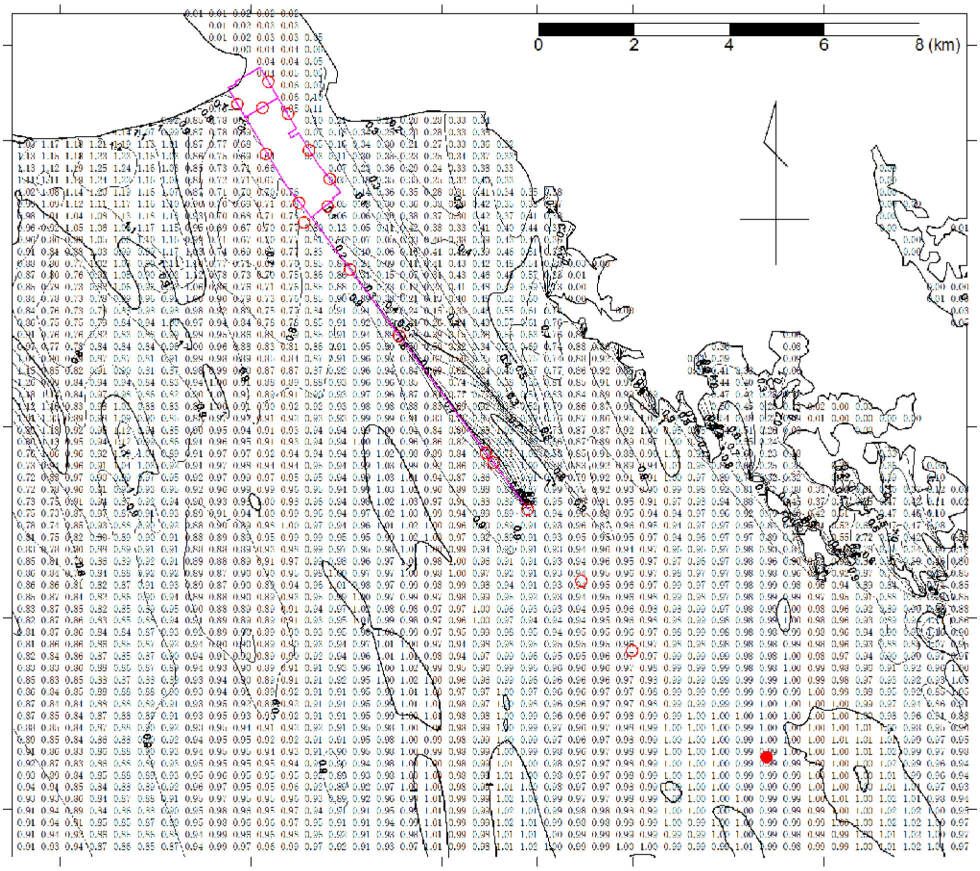


Figure 2.4.25 Distribution of Refraction/Diffraction Coefficient and wave direction
(Wave with a return period of 50 years, T=13.3 sec, θ = E, W.L.=H.H.W.L., With all structures
The red blank circles are calculation points of A1 to A9, B1 to B7, and S0)



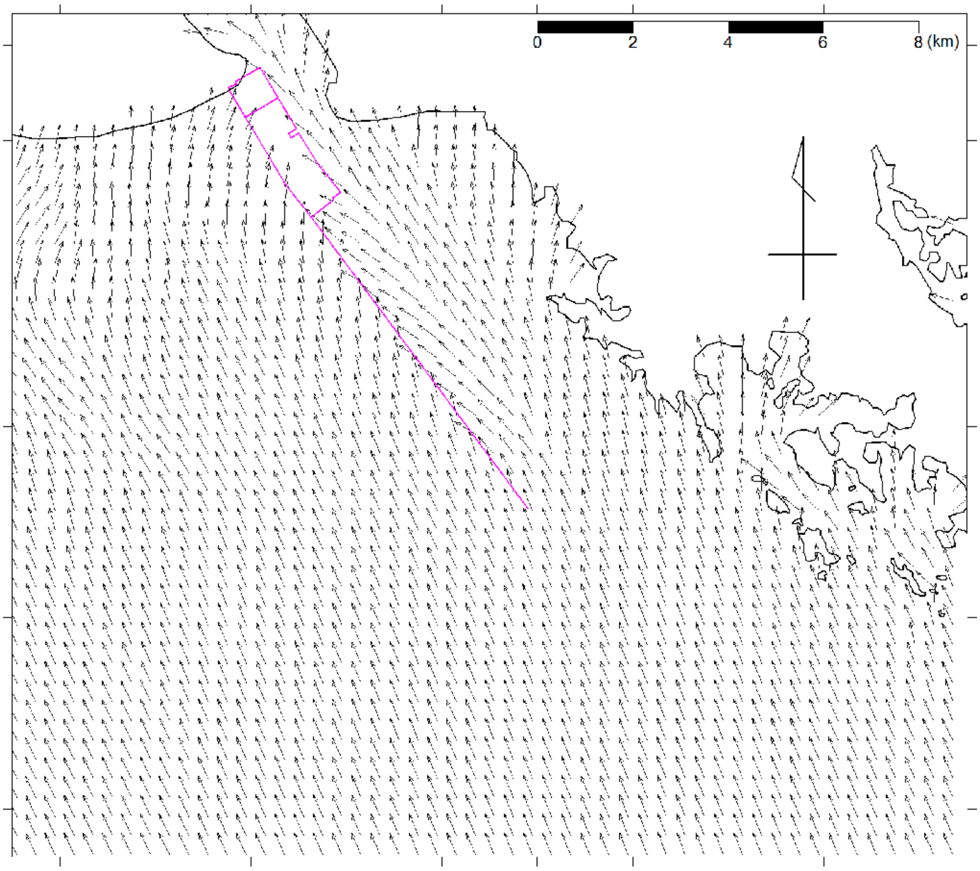


Figure 2.4.26 Distribution of Refraction/Diffraction Coefficient and wave direction (Wave with a return period of 50 years, T=13.3 sec, θ = SSE, W.L.=H.H.W.L., With all structures. The red blank circles are calculation points of A1 to A9, B1 to B7, and S0)

2.4.4 Results of design wave calculation

The design wave at the target locations have been calculated by using the 180 cases of wave transformation calculations. For each location, the significant wave height of $H_{1/3}$ is summarized in Table 2.4.9 through Table 2.4.20. For each target location, the largest wave height out of 18 cases (= 3 tide levels x 6 wave directions) or that out of 12 cases (= 2 tide levels x 6 wave directions) is extracted. The symbols used in the following tables are defined as follows;

θ	Wave direction angle (degree), defined as from N to clockwise.
K_s	Shoaling coefficient calculated by Eq. The blank means that wave is breaking.
$K_r \cdot K_d$	Refraction/Diffraction coefficient
H'_0	Equivalent offshore wave height (m)
h	Water depth (m)
h_b	$h + 5.0 \times H_{1/3} \times \tan\theta$; $\tan\theta$ is the bed slope
h / L_0	Relative water depth with respect to the offshore wave length
H'_0 / L_0	Equivalent offshore wave steepness
$H_{1/3}/H'_0$	Relative significant wave height with respect to the equivalent offshore wave height
H_{max}/H'_0	Relative maximum wave height with respect to the equivalent offshore wave height
β	Angle between the wave direction and the perpendicular line to the normal line of the structure (degree) in the range of ± 15 degrees of the wave direction.

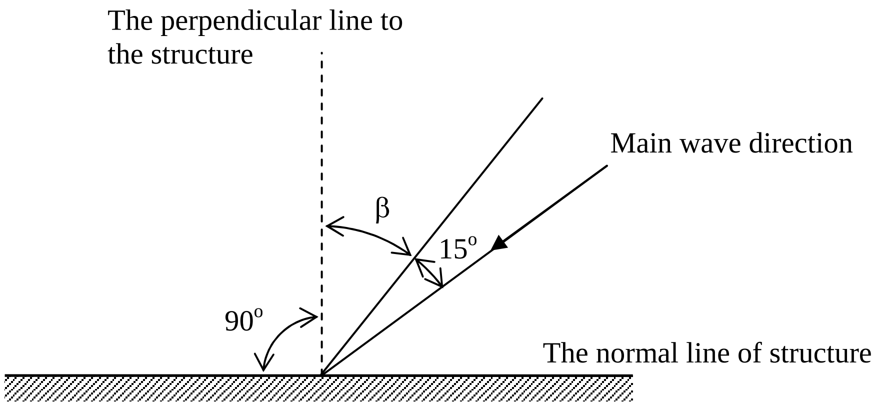


Figure 2.4.27 Definition of the angle β

The design waves listed in Table 2.4.9 through Table 2.4.20 are estimated including effect of wave breaking. In the method applied in this section, however, the effect of wave breaking is estimated by the standard method based on the wave breaking on a slope. It mainly depends on the local water depth at the estimation point and the complex wave breaking phenomena such as wave re-formation on topography with a bar is not taken into account. As Lach Huyen port is located on the shoal, it is considered that the waves acted on the port are much influenced by the complex topography. Designers of the port protection works may need to take the effect of complex topography into account in the design of structures.

1) Case without any structure

a) Wave with a return period of 50 years

Table 2.4.9 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 50 years. Without Structures

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho'	$H_{1/3}$	β
Training Dike	B1	H.H.W.L.	SSE	5.78	13.3	149.0	--	1.354	7.83	4.31	0.016	0.028	0.550	0.395	3.09	69.4
	B2	H.H.W.L.	SSE	5.78	13.3	149.1	--	1.222	7.06	5.44	0.020	0.026	0.770	0.515	3.64	69.4
	B3	H.H.W.L.	SSE	5.78	13.3	157.8	--	0.914	5.28	6.95	0.025	0.019	1.316	0.816	4.31	60.7
	B4	H.H.W.L.	SSE	5.78	13.3	157.8	--	0.904	5.23	7.43	0.027	0.019	1.422	0.873	4.56	60.7
	B5	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.911	5.27	9.46	0.034	0.019	1.797	1.013	5.33	61.0
	B6	H.H.W.L.	SSE	5.78	13.3	158.2	--	0.942	5.45	11.93	0.043	0.020	2.191	1.003	5.46	60.3
	B7	H.H.W.L.	SSE	5.78	13.3	158.3	--	0.968	5.60	14.44	0.052	0.020	2.581	0.995	5.57	60.2
	C0	H.H.W.L.	SSE	5.78	13.3	151.0	--	1.304	7.54	4.47	0.016	0.027	0.593	0.419	3.16	67.4
	C1	H.H.W.L.	SSE	5.78	13.3	149.7	--	1.338	7.73	4.50	0.016	0.028	0.582	0.412	3.18	68.8
	C2	H.H.W.L.	SSE	5.78	13.3	149.7	--	1.335	7.72	4.55	0.016	0.028	0.590	0.417	3.22	68.7
	C3	H.H.W.L.	SSE	5.78	13.3	150.0	--	1.235	7.14	5.30	0.019	0.026	0.742	0.500	3.57	68.5
	C4	H.H.W.L.	SSE	5.78	13.3	146.5	--	1.144	6.61	5.87	0.021	0.024	0.887	0.577	3.82	72.0
	C5	H.H.W.L.	SSE	5.78	13.3	145.6	--	1.078	6.23	6.36	0.023	0.023	1.021	0.649	4.05	72.8
	C6	H.H.W.L.	SSE	5.78	13.3	157.1	--	0.930	5.38	6.73	0.024	0.019	1.252	0.781	4.20	61.4
	C7	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.905	5.23	8.48	0.031	0.019	1.622	0.976	5.11	60.9
	C8	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.916	5.29	9.98	0.036	0.019	1.885	1.011	5.35	60.9
	C9	H.H.W.L.	SSE	5.78	13.3	158.1	--	0.934	5.40	11.21	0.041	0.020	2.076	1.004	5.42	60.4
	C10	H.H.W.L.	SSE	5.78	13.3	158.3	--	0.947	5.47	12.59	0.046	0.020	2.300	1.001	5.48	60.2
	C11	H.H.W.L.	SSE	5.78	13.3	158.4	--	0.962	5.56	13.93	0.050	0.020	2.505	0.997	5.54	60.0
Outer Rivetment	A1	H.H.W.L.	SSW	6.83	13.3	191.2	--	1.070	7.30	4.88	0.018	0.026	0.668	0.459	3.35	32.3
	A2	H.H.W.L.	SSW	6.83	13.3	183.1	--	1.067	7.28	3.58	0.013	0.026	0.500	0.369	2.69	41.2
	A3	H.H.W.L.	SSE	5.78	13.3	152.9	--	1.286	7.43	4.13	0.015	0.027	0.556	0.401	2.98	65.5
mooring area	A4	H.H.W.L.	SSW	6.83	13.3	199.9	--	1.151	7.86	4.08	0.015	0.028	0.519	0.378	2.97	35.0
	A5	H.H.W.L.	SSE	5.78	13.3	150.8	--	1.328	7.68	4.32	0.016	0.028	0.563	0.404	3.10	-6.0
	A6	H.H.W.L.	SSW	6.83	13.3	189.4	--	0.873	5.96	8.07	0.029	0.022	1.354	0.825	4.91	-34.5
	A7	H.W.L.	SSW	6.81	13.3	217.5	--	0.903	6.15	10.77	0.039	0.022	1.752	0.970	5.96	-6.9
	A8	H.W.L.	SSW	6.81	13.3	203.1	--	0.865	5.89	9.54	0.035	0.021	1.620	0.964	5.67	-20.5
	A9	H.W.L.	SSW	6.81	13.3	192.7	--	0.884	6.02	9.53	0.035	0.022	1.584	0.944	5.68	-24.0
Other	S0	H.H.W.L.	SSE	5.78	13.3	150.8	--	1.275	7.37	4.64	0.017	0.027	0.629	0.439	3.24	67.7

b) Wave with a return period of 30 years

Table 2.4.10 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 30 years. Without Structures

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho'	$H_{1/3}$	β
Training Dike	B1	H.H.W.L.	SSE	5.44	12.8	149.0	--	1.353	7.36	4.31	0.017	0.029	0.585	0.412	3.03	69.4
	B2	H.H.W.L.	SSE	5.44	12.8	149.1	--	1.219	6.63	5.44	0.021	0.026	0.820	0.541	3.59	69.4
	B3	H.H.W.L.	SSE	5.44	12.8	157.8	--	0.913	4.97	6.95	0.027	0.019	1.399	0.860	4.27	60.7
	B4	H.H.W.L.	SSE	5.44	12.8	157.8	--	0.903	4.91	7.43	0.029	0.019	1.512	0.920	4.52	60.7
	B5	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.911	4.96	9.46	0.037	0.019	1.909	1.008	5.00	61.0
	B6	H.H.W.L.	SSE	5.44	12.8	158.2	--	0.942	5.12	11.93	0.047	0.020	2.328	0.998	5.12	60.3
	B7	H.H.W.L.	SSE	5.44	12.8	158.3	--	0.968	5.27	14.44	0.057	0.021	2.743	0.990	5.22	60.2
	C0	H.H.W.L.	SSE	5.44	12.8	150.9	--	1.300	7.07	4.47	0.018	0.028	0.632	0.439	3.11	67.5
	C1	H.H.W.L.	SSE	5.44	12.8	149.6	--	1.334	7.26	4.50	0.018	0.028	0.620	0.431	3.13	68.8
	C2	H.H.W.L.	SSE	5.44	12.8	149.7	--	1.332	7.25	4.55	0.018	0.028	0.628	0.437	3.16	68.8
	C3	H.H.W.L.	SSE	5.44	12.8	150.0	--	1.231	6.70	5.30	0.021	0.026	0.791	0.525	3.52	68.5
	C4	H.H.W.L.	SSE	5.44	12.8	146.5	--	1.143	6.22	5.87	0.023	0.024	0.943	0.606	3.77	71.9
	C5	H.H.W.L.	SSE	5.44	12.8	145.7	--	1.076	5.85	6.36	0.025	0.023	1.087	0.683	4.00	72.7
	C6	H.H.W.L.	SSE	5.44	12.8	157.1	--	0.928	5.05	6.73	0.026	0.020	1.333	0.823	4.15	61.3
	C7	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.905	4.92	8.48	0.033	0.019	1.723	1.010	4.97	60.9
	C8	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.916	4.98	9.98	0.039	0.019	2.003	1.006	5.01	60.9
	C9	H.H.W.L.	SSE	5.44	12.8	158.0	--	0.934	5.08	11.21	0.044	0.020	2.206	1.000	5.08	60.4
	C10	H.H.W.L.	SSE	5.44	12.8	158.3	--	0.947	5.15	12.59	0.049	0.020	2.444	0.996	5.13	60.2
	C11	H.H.W.L.	SSE	5.44	12.8	158.4	--	0.963	5.24	13.93	0.054	0.020	2.658	0.992	5.20	60.1
Outer Rivetment	A1	H.H.W.L.	SSW	6.41	12.8	191.0	--	1.072	6.87	4.88	0.019	0.027	0.710	0.480	3.30	32.5
	A2	H.H.W.L.	SSW	6.41	12.8	183.0	--	1.066	6.83	3.58	0.014	0.027	0.524	0.385	2.63	41.3
	A3	H.H.W.L.	SSE	5.44	12.8	152.8	--	1.284	6.99	4.13	0.016	0.027	0.592	0.419	2.93	65.6
mooring area	A4	H.H.W.L.	SSW	6.41	12.8	199.5	--	1.149	7.36	4.08	0.016	0.029	0.554	0.396	2.91	34.7
	A5	H.H.W.L.	SSE	5.44	12.8	150.6	--	1.326	7.21	4.32	0.017	0.028	0.599	0.422	3.05	-6.1
	A6	H.H.W.L.	SSW	6.41	12.8	189.4	--	0.876	5.61	8.07	0.032	0.022	1.437	0.867	4.87	-34.5
	A7	H.W.L.	SSW	6.39	12.8	217.0	--	0.901	5.76	10.77	0.042	0.023	1.869	0.966	5.57	-7.5
	A8	H.W.L.	SSW	6.39	12.8	202.5	--	0.865	5.53	9.54	0.037	0.022	1.725	0.973	5.38	-21.0
	A9	H.W.L.	SSW	6.39	12.8	192.1	--	0.884	5.65	9.53	0.037	0.022	1.686	0.967	5.46	-24.6
Other	S0	H.H.W.L.	SSE	5.44	12.8	150.7	--	1.272	6.92	4.64	0.018	0.027	0.670	0.460	3.18	67.7

c) Wave with a return period of 10 years

Table 2.4.11 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 10 years. Without Structures

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho'	$H_{1/3}$	β
Training Dike	B1	H.W.L.	SSE	4.61	11.8	149.9	--	1.380	6.36	3.43	0.016	0.029	0.539	0.387	2.46	68.5
	B2	H.W.L.	SSE	4.61	11.8	148.9	--	1.243	5.73	4.56	0.021	0.026	0.796	0.527	3.02	69.6
	B3	H.W.L.	SSE	4.61	11.8	157.6	--	0.912	4.20	6.07	0.028	0.019	1.444	0.883	3.71	60.8
	B4	H.W.L.	SSE	4.61	11.8	157.7	--	0.899	4.14	6.55	0.030	0.019	1.581	0.956	3.96	60.7
	B5	H.W.L.	SSE	4.61	11.8	157.5	--	0.908	4.19	8.58	0.040	0.019	2.050	1.010	4.23	61.0
	B6	H.W.L.	SSE	4.61	11.8	158.2	--	0.941	4.34	11.05	0.051	0.020	2.548	0.999	4.34	60.3
	B7	H.W.L.	SSE	4.61	11.8	158.2	--	0.968	4.46	13.56	0.062	0.021	3.040	0.991	4.42	60.2
	C0	H.W.L.	SSE	4.61	11.8	154.6	--	1.347	6.21	3.59	0.017	0.029	0.579	0.410	2.54	63.8
	C1	H.W.L.	SSE	4.61	11.8	150.6	--	1.359	6.26	3.62	0.017	0.029	0.578	0.409	2.56	67.8
	C2	H.W.L.	SSE	4.61	11.8	150.7	--	1.353	6.24	3.67	0.017	0.029	0.589	0.416	2.59	67.7
	C3	H.W.L.	SSE	4.61	11.8	150.1	--	1.255	5.78	4.42	0.020	0.027	0.764	0.511	2.95	68.4
	C4	H.W.L.	SSE	4.61	11.8	146.1	--	1.154	5.32	4.99	0.023	0.024	0.937	0.602	3.20	72.4
	C5	H.W.L.	SSE	4.61	11.8	144.9	--	1.084	5.00	5.48	0.025	0.023	1.097	0.688	3.44	73.6
	C6	H.W.L.	SSE	4.61	11.8	156.8	--	0.931	4.29	5.85	0.027	0.020	1.363	0.839	3.60	61.7
	C7	H.W.L.	SSE	4.61	11.8	157.5	--	0.900	4.15	7.60	0.035	0.019	1.833	1.013	4.20	60.9
	C8	H.W.L.	SSE	4.61	11.8	157.5	--	0.913	4.21	9.10	0.042	0.019	2.163	1.008	4.24	60.9
	C9	H.W.L.	SSE	4.61	11.8	158.1	--	0.932	4.30	10.33	0.048	0.020	2.405	1.001	4.30	60.4
	C10	H.W.L.	SSE	4.61	11.8	158.3	--	0.946	4.36	11.71	0.054	0.020	2.685	0.997	4.35	60.2
	C11	H.W.L.	SSE	4.61	11.8	158.4	--	0.962	4.43	13.05	0.060	0.020	2.942	0.993	4.40	60.1
Outer Rivetment	A1	H.W.L.	SSW	5.41	11.8	201.2	--	1.174	6.35	4.00	0.018	0.029	0.630	0.435	2.76	22.4
	A2	H.W.L.	SSW	5.41	11.8	197.7	--	1.194	6.46	2.70	0.015	0.030	0.500	0.324	2.09	26.7
	A3	H.W.L.	SSW	5.41	11.8	186.6	--	1.156	6.25	3.25	0.015	0.029	0.520	0.380	2.38	31.9
mooring area	A4	H.W.L.	SSW	5.41	11.8	211.3	--	1.365	7.39	3.20	0.017	0.034	0.500	0.326	2.41	46.4
	A5	H.W.L.	SSE	4.61	11.8	154.9	--	1.374	6.33	3.44	0.016	0.029	0.544	0.391	2.48	-1.8
	A6	H.W.L.	SSW	5.41	11.8	190.7	--	0.961	5.20	7.19	0.033	0.024	1.383	0.835	4.34	-33.2
	A7	H.W.L.	SSW	5.41	11.8	216.3	--	0.908	4.91	10.77	0.050	0.023	2.192	0.965	4.74	-8.2
	A8	H.W.L.	SSW	5.41	11.8	201.9	--	0.870	4.71	9.54	0.044	0.022	2.026	0.972	4.58	-21.7
	A9	H.W.L.	SSW	5.41	11.8	191.3	--	0.888	4.80	9.53	0.044	0.022	1.983	0.967	4.64	-25.4
Other	S0	H.W.L.	SSE	4.61	11.8	154.3	--	1.310	6.04	3.76	0.017	0.028	0.622	0.434	2.62	64.2

d) Wave with a return period of 5 years

Table 2.4.12 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 5 years. Without Structures

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.W.L.	SSE	4.04	11.0	145.0	--	0.826	3.34	3.43	0.018	0.018	1.026	0.664	2.22	73.4
	B2	H.W.L.	S	4.15	11.0	170.4	--	0.886	3.67	4.56	0.024	0.019	1.242	0.775	2.85	48.1
	B3	H.W.L.	SSW	4.72	11.0	164.8	--	0.704	3.32	6.09	0.032	0.018	1.834	1.038	3.45	53.6
	B4	H.W.L.	SSW	4.72	11.0	140.5	--	0.687	3.24	6.53	0.035	0.017	2.017	1.043	3.38	-72.1
	B5	H.W.L.	SSE	4.04	11.0	157.5	--	0.910	3.68	8.59	0.046	0.019	2.336	1.007	3.70	61.0
	B6	H.W.L.	SSE	4.04	11.0	158.1	--	0.944	3.82	11.05	0.059	0.020	2.896	0.996	3.80	60.3
	B7	L.W.L.	SSE	3.97	11.0	158.5	--	0.963	3.83	10.44	0.055	0.020	2.729	0.995	3.81	59.9
	C0	H.W.L.	SSW	4.72	11.0	218.0	--	0.783	3.69	3.60	0.019	0.020	0.975	0.633	2.34	0.5
	C1	H.W.L.	SSE	4.04	11.0	137.6	--	0.798	3.23	3.61	0.019	0.017	1.120	0.714	2.30	-69.2
	C2	H.W.L.	S	4.15	11.0	168.4	--	0.829	3.44	3.70	0.020	0.018	1.078	0.694	2.38	50.1
	C3	H.W.L.	S	4.15	11.0	157.1	--	0.875	3.63	4.43	0.023	0.019	1.221	0.764	2.77	61.3
	C4	H.W.L.	SSW	4.72	11.0	133.2	--	0.764	3.60	4.99	0.026	0.019	1.384	0.846	3.05	-64.8
	C5	H.W.L.	SSW	4.72	11.0	123.8	--	0.717	3.38	5.48	0.029	0.018	1.620	0.972	3.29	-55.4
	C6	H.W.L.	SSW	4.72	11.0	131.8	--	0.691	3.26	5.84	0.031	0.017	1.791	1.040	3.39	-63.3
	C7	H.W.L.	SSW	4.72	11.0	147.3	--	0.684	3.23	7.60	0.040	0.017	2.356	1.044	3.37	71.1
	C8	H.W.L.	SSE	4.04	11.0	157.5	--	0.916	3.70	9.10	0.048	0.020	2.458	1.004	3.72	60.9
	C9	H.W.L.	SSE	4.04	11.0	158.0	--	0.935	3.78	10.33	0.055	0.020	2.733	0.997	3.77	60.4
	C10	H.W.L.	SSE	4.04	11.0	158.2	--	0.949	3.84	11.71	0.062	0.020	3.053	0.994	3.81	60.2
	C11	H.W.L.	SSE	4.04	11.0	158.3	0.973	0.965	3.90	13.05	0.069	0.021	3.345	0.973	3.80	60.2
Outer Rivetment	A1	H.W.L.	SSW	4.72	11.0	228.1	--	0.968	4.56	4.04	0.021	0.024	0.886	0.576	2.63	-4.6
	A2	H.W.L.	SSW	4.72	11.0	232.4	--	0.902	4.25	2.71	0.014	0.023	0.638	0.450	1.92	-8.1
	A3	H.W.L.	SSW	4.72	11.0	225.9	--	0.879	4.14	3.26	0.017	0.022	0.786	0.530	2.20	-7.4
mooring area	A4															
	A5	H.W.L.	ESE	5.07	11.0	136.0	1.301	0.118	0.60	3.50	0.019	0.003	5.848	1.301	0.78	-9.3
	A6	H.W.L.	SE	4.08	11.0	116.6	1.052	0.046	0.19	8.04	0.043	0.001	42.829	1.052	0.20	42.7
	A7	H.W.L.	SE	4.08	11.0	120.7	0.998	0.057	0.23	10.99	0.058	0.001	47.218	0.998	0.23	46.2
	A8	L.W.L.	E	6.48	11.0	100.7	1.087	0.041	0.27	6.75	0.036	0.001	25.429	1.087	0.29	27.1
	A9	H.W.L.	SE	4.08	11.0	120.1	1.019	0.055	0.23	9.63	0.051	0.001	42.896	1.019	0.23	53.4
Other	S0	H.W.L.	SSW	4.72	11.0	216.1	--	0.767	3.62	3.76	0.020	0.019	1.039	0.668	2.42	2.4

2) Case with Outer Revetment and without Training Dike

a) Wave with a return period of 50 years

Table 2.4.13 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 50 years. with Outer Revetment

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho'	$H_{1/3}$	β
Training Dike	B1	H.H.W.L.	SSE	5.78	13.3	149.1	--	1.354	7.83	4.31	0.016	0.028	0.550	0.395	3.09	69.4
	B2	H.H.W.L.	SSE	5.78	13.3	149.1	--	1.222	7.06	5.44	0.020	0.026	0.770	0.515	3.64	69.4
	B3	H.H.W.L.	SSE	5.78	13.3	157.7	--	0.914	5.28	6.95	0.025	0.019	1.316	0.816	4.31	60.7
	B4	H.H.W.L.	SSE	5.78	13.3	157.7	--	0.904	5.23	7.43	0.027	0.019	1.422	0.873	4.56	60.7
	B5	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.911	5.27	9.46	0.034	0.019	1.797	1.013	5.33	61.0
	B6	H.H.W.L.	SSE	5.78	13.3	158.2	--	0.942	5.45	11.93	0.043	0.020	2.191	1.003	5.46	60.3
	B7	H.H.W.L.	SSE	5.78	13.3	158.3	--	0.968	5.60	14.44	0.052	0.020	2.581	0.995	5.57	60.2
	C0	H.H.W.L.	SSE	5.78	13.3	152.3	--	1.302	7.53	4.48	0.016	0.027	0.595	0.420	3.16	66.2
	C1	H.H.W.L.	SSE	5.78	13.3	149.7	--	1.338	7.73	4.50	0.016	0.028	0.582	0.412	3.18	68.8
	C2	H.H.W.L.	SSE	5.78	13.3	149.7	--	1.335	7.72	4.56	0.017	0.028	0.591	0.418	3.22	68.7
	C3	H.H.W.L.	SSE	5.78	13.3	149.9	--	1.235	7.14	5.30	0.019	0.026	0.743	0.501	3.57	68.5
	C4	H.H.W.L.	SSE	5.78	13.3	146.5	--	1.144	6.61	5.87	0.021	0.024	0.887	0.577	3.82	72.0
	C5	H.H.W.L.	SSE	5.78	13.3	145.6	--	1.078	6.23	6.36	0.023	0.023	1.021	0.649	4.05	72.8
	C6	H.H.W.L.	SSE	5.78	13.3	157.0	--	0.930	5.38	6.73	0.024	0.019	1.252	0.781	4.20	61.4
	C7	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.905	5.23	8.49	0.031	0.019	1.622	0.976	5.11	60.9
	C8	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.916	5.29	9.98	0.036	0.019	1.885	1.011	5.35	60.9
	C9	H.H.W.L.	SSE	5.78	13.3	158.1	--	0.934	5.40	11.21	0.041	0.020	2.076	1.004	5.42	60.4
	C10	H.H.W.L.	SSE	5.78	13.3	158.3	--	0.947	5.47	12.59	0.046	0.020	2.300	1.001	5.48	60.2
	C11	H.H.W.L.	SSE	5.78	13.3	158.4	--	0.962	5.56	13.93	0.050	0.020	2.505	0.997	5.54	60.0
Outer Rivetment	A1	H.H.W.L.	SSW	6.83	13.3	219.2	--	0.870	5.94	4.92	0.018	0.022	0.829	0.552	3.28	4.4
	A2	H.H.W.L.	SSW	6.83	13.3	218.1	--	0.812	5.54	3.63	0.013	0.020	0.655	0.464	2.57	6.3
	A3	H.H.W.L.	SSE	5.78	13.3	179.2	--	0.937	5.42	4.15	0.015	0.020	0.766	0.525	2.85	39.3
mooring area	A4	H.H.W.L.	SSE	5.78	13.3	155.6	--	0.507	2.93	4.06	0.015	0.011	1.386	0.879	2.58	-9.3
	A5	H.H.W.L.	SSE	5.78	13.3	147.7	--	1.309	7.57	4.38	0.016	0.027	0.578	0.413	3.13	-9.1
	A6	H.H.W.L.	SSW	6.83	13.3	119.0	1.109	0.083	0.57	8.92	0.032	0.002	15.75	1.109	0.63	45.0
	A7	H.H.W.L.	SSW	6.83	13.3	127.0	1.055	0.152	1.04	11.59	0.042	0.004	11.17	1.055	1.09	52.6
	A8	H.H.W.L.	S	5.94	13.3	131.3	1.103	0.488	2.90	10.39	0.038	0.010	3.587	1.103	3.20	57.8
	A9	H.H.W.L.	SSW	6.83	13.3	149.5	--	0.674	4.60	10.40	0.038	0.017	2.261	1.049	4.83	-67.2
Other	S0	H.H.W.L.	SSE	5.78	13.3	150.8	--	1.275	7.37	4.64	0.017	0.027	0.629	0.439	3.24	67.7

b) Wave with a return period of 30 years

Table 2.4.14 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 30 years. with Outer Revetment

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.H.W.L.	SSE	5.44	12.8	149.0	--	1.353	7.36	4.31	0.017	0.029	0.585	0.412	3.04	69.4
	B2	H.H.W.L.	SSE	5.44	12.8	149.1	--	1.219	6.63	5.44	0.021	0.026	0.820	0.541	3.59	69.4
	B3	H.H.W.L.	SSE	5.44	12.8	157.8	--	0.913	4.97	6.95	0.027	0.019	1.400	0.860	4.27	60.7
	B4	H.H.W.L.	SSE	5.44	12.8	157.8	--	0.903	4.91	7.43	0.029	0.019	1.512	0.920	4.52	60.7
	B5	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.911	4.96	9.46	0.037	0.019	1.909	1.008	5.00	61.0
	B6	H.H.W.L.	SSE	5.44	12.8	158.2	--	0.942	5.12	11.93	0.047	0.020	2.328	0.998	5.12	60.3
	B7	H.H.W.L.	SSE	5.44	12.8	158.3	--	0.968	5.27	14.44	0.057	0.021	2.743	0.990	5.22	60.2
	C0	H.H.W.L.	SSE	5.44	12.8	152.2	--	1.299	7.07	4.48	0.018	0.028	0.633	0.440	3.11	66.2
	C1	H.H.W.L.	SSE	5.44	12.8	149.7	--	1.334	7.26	4.50	0.018	0.028	0.620	0.431	3.13	68.8
	C2	H.H.W.L.	SSE	5.44	12.8	149.7	--	1.332	7.25	4.56	0.018	0.028	0.629	0.437	3.17	68.8
	C3	H.H.W.L.	SSE	5.44	12.8	150.0	--	1.231	6.70	5.30	0.021	0.026	0.792	0.526	3.52	68.5
	C4	H.H.W.L.	SSE	5.44	12.8	146.5	--	1.143	6.22	5.87	0.023	0.024	0.944	0.606	3.77	71.9
	C5	H.H.W.L.	SSE	5.44	12.8	145.7	--	1.076	5.85	6.36	0.025	0.023	1.087	0.683	4.00	72.7
	C6	H.H.W.L.	SSE	5.44	12.8	157.1	--	0.928	5.05	6.73	0.026	0.020	1.333	0.823	4.15	61.3
	C7	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.905	4.92	8.49	0.033	0.019	1.723	1.010	4.97	60.9
	C8	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.916	4.98	9.98	0.039	0.019	2.003	1.006	5.01	60.9
	C9	H.H.W.L.	SSE	5.44	12.8	158.0	--	0.934	5.08	11.21	0.044	0.020	2.206	1.000	5.08	60.4
	C10	H.H.W.L.	SSE	5.44	12.8	158.3	--	0.947	5.15	12.59	0.049	0.020	2.444	0.996	5.13	60.2
	C11	H.H.W.L.	SSE	5.44	12.8	158.4	--	0.963	5.24	13.93	0.054	0.020	2.658	0.992	5.20	60.1
Outer Rivetment	A1	H.H.W.L.	SSW	6.41	12.8	219.0	--	0.872	5.59	4.92	0.019	0.022	0.881	0.578	3.23	4.6
	A2	H.H.W.L.	SSW	6.41	12.8	217.9	--	0.812	5.20	3.63	0.014	0.020	0.698	0.486	2.53	6.4
	A3	H.H.W.L.	SSE	5.44	12.8	179.0	--	0.936	5.09	4.15	0.016	0.020	0.814	0.550	2.80	39.4
mooring area	A4	H.H.W.L.	SSE	5.44	12.8	155.5	--	0.509	2.77	4.06	0.016	0.011	1.467	0.920	2.55	-9.3
	A5	H.H.W.L.	SSE	5.44	12.8	147.7	--	1.307	7.11	4.38	0.017	0.028	0.615	0.432	3.07	-9.0
	A6	H.H.W.L.	SSW	6.41	12.8	119.3	1.092	0.085	0.55	8.92	0.035	0.002	16.38	1.092	0.60	45.4
	A7	H.H.W.L.	SSW	6.41	12.8	127.3	1.04	0.155	0.99	11.59	0.045	0.004	11.66	1.040	1.03	52.8
	A8	H.H.W.L.	S	5.59	12.8	131.5	1.08	0.491	2.74	10.39	0.041	0.011	3.788	1.080	2.96	58.0
	A9	H.H.W.L.	SSW	6.41	12.8	149.8	--	0.678	4.35	10.40	0.041	0.017	2.394	1.043	4.53	-66.9
Other	S0	H.H.W.L.	SSE	5.44	12.8	150.7	--	1.272	6.92	4.64	0.018	0.027	0.670	0.460	3.18	67.7

c) Wave with a return period of 10 years

Table 2.4.15 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 10 years. with Outer Revetment

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.W.L.	SSE	4.61	11.8	149.9	--	1.380	6.36	3.43	0.016	0.029	0.539	0.387	2.47	68.5
	B2	H.W.L.	SSE	4.61	11.8	148.9	--	1.243	5.73	4.56	0.021	0.026	0.796	0.527	3.02	69.6
	B3	H.W.L.	SSE	4.61	11.8	157.6	--	0.912	4.20	6.07	0.028	0.019	1.444	0.883	3.71	60.8
	B4	H.W.L.	SSE	4.61	11.8	157.7	--	0.899	4.14	6.55	0.030	0.019	1.580	0.956	3.96	60.7
	B5	H.W.L.	SSE	4.61	11.8	157.5	--	0.908	4.19	8.58	0.040	0.019	2.051	1.010	4.23	61.0
	B6	H.W.L.	SSE	4.61	11.8	158.2	--	0.941	4.34	11.05	0.051	0.020	2.548	0.999	4.34	60.3
	B7	H.W.L.	SSE	4.61	11.8	158.2	--	0.968	4.46	13.56	0.062	0.021	3.040	0.991	4.42	60.2
	C0	H.W.L.	SSE	4.61	11.8	155.8	--	1.344	6.19	3.60	0.017	0.029	0.580	0.411	2.55	62.6
	C1	H.W.L.	SSE	4.61	11.8	150.6	--	1.359	6.26	3.62	0.017	0.029	0.578	0.408	2.56	67.8
	C2	H.W.L.	SSE	4.61	11.8	150.7	--	1.353	6.24	3.68	0.017	0.029	0.590	0.416	2.60	67.7
	C3	H.W.L.	SSE	4.61	11.8	150.1	--	1.255	5.78	4.42	0.020	0.027	0.764	0.511	2.95	68.4
	C4	H.W.L.	SSE	4.61	11.8	146.1	--	1.154	5.32	4.99	0.023	0.024	0.938	0.602	3.20	72.4
	C5	H.W.L.	SSE	4.61	11.8	144.9	--	1.084	5.00	5.48	0.025	0.023	1.097	0.688	3.44	73.6
	C6	H.W.L.	SSE	4.61	11.8	156.8	--	0.931	4.29	5.85	0.027	0.020	1.363	0.839	3.60	61.7
	C7	H.W.L.	SSE	4.61	11.8	157.5	--	0.900	4.15	7.61	0.035	0.019	1.833	1.013	4.20	60.9
	C8	H.W.L.	SSE	4.61	11.8	157.5	--	0.913	4.21	9.10	0.042	0.019	2.163	1.008	4.24	60.9
	C9	H.W.L.	SSE	4.61	11.8	158.1	--	0.932	4.30	10.33	0.048	0.020	2.404	1.001	4.30	60.4
	C10	H.W.L.	SSE	4.61	11.8	158.3	--	0.946	4.36	11.71	0.054	0.020	2.685	0.997	4.35	60.2
	C11	H.W.L.	SSE	4.61	11.8	158.4	--	0.962	4.43	13.05	0.060	0.020	2.942	0.993	4.40	60.1
Outer Rivetment	A1	H.W.L.	SSW	5.41	11.8	226.6	--	0.991	5.36	4.04	0.019	0.025	0.754	0.507	2.72	-3.1
	A2	H.W.L.	SSW	5.41	11.8	226.5	--	0.976	5.28	2.75	0.013	0.024	0.521	0.386	2.04	-2.2
	A3	H.W.L.	SSW	5.41	11.8	218.6	--	0.961	5.20	3.27	0.015	0.024	0.628	0.444	2.31	-0.1
mooring area	A4	H.W.L.	SSE	4.61	11.8	157.4	--	0.537	2.48	3.18	0.015	0.011	1.286	0.822	2.04	-7.5
	A5	H.W.L.	SSE	4.61	11.8	148.3	--	1.330	6.13	3.50	0.016	0.028	0.570	0.408	2.50	-8.5
	A6	H.W.L.	SSE	4.61	11.8	118.8	1.08	0.091	0.42	8.04	0.037	0.002	19.18	1.080	0.45	44.8
	A7	H.W.L.	SSW	5.41	11.8	129.0	1.025	0.138	0.75	10.71	0.049	0.003	14.34	1.025	0.77	54.6
	A8	H.W.L.	S	4.73	11.8	129.6	1.052	0.441	2.09	9.51	0.044	0.010	4.562	1.052	2.19	56.1
	A9	H.W.L.	SSW	5.41	11.8	148.9	--	0.641	3.47	9.52	0.044	0.016	2.746	1.063	3.69	-67.8
Other	S0	H.W.L.	SSE	4.61	11.8	154.3	--	1.310	6.04	3.76	0.017	0.028	0.622	0.434	2.62	64.2

d) Wave with a return period of 5 years

Table 2.4.16 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 5 years. with Outer Revetment

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.W.L.	SSE	4.04	11.0	149.8	--	1.376	5.56	3.43	0.018	0.029	0.616	0.427	2.38	68.6
	B2	H.W.L.	SSE	4.04	11.0	148.9	--	1.239	5.01	4.56	0.024	0.027	0.911	0.587	2.94	69.5
	B3	H.W.L.	SSE	4.04	11.0	157.7	--	0.912	3.69	6.07	0.032	0.020	1.647	0.989	3.65	60.7
	B4	H.W.L.	SSE	4.04	11.0	157.8	--	0.900	3.64	6.55	0.035	0.019	1.800	1.011	3.68	60.7
	B5	H.W.L.	SSE	4.04	11.0	157.5	--	0.910	3.68	8.58	0.045	0.019	2.333	1.007	3.70	60.9
	B6	H.W.L.	SSE	4.04	11.0	158.1	--	0.944	3.82	11.05	0.059	0.020	2.896	0.996	3.80	60.3
	B7	L.W.L.	SSE	3.97	11.0	158.5	--	0.963	3.83	10.44	0.055	0.020	2.729	0.995	3.81	59.9
	C0	H.W.L.	SSE	4.04	11.0	155.4	--	1.339	5.41	3.60	0.019	0.029	0.664	0.454	2.46	63.0
	C1	H.W.L.	SSE	4.04	11.0	150.5	--	1.356	5.48	3.62	0.019	0.029	0.660	0.451	2.47	67.9
	C2	H.W.L.	SSE	4.04	11.0	150.6	--	1.351	5.46	3.68	0.019	0.029	0.674	0.460	2.51	67.9
	C3	H.W.L.	SSE	4.04	11.0	150.1	--	1.251	5.06	4.42	0.023	0.027	0.874	0.568	2.87	68.4
	C4	H.W.L.	SSE	4.04	11.0	146.2	--	1.153	4.66	4.99	0.026	0.025	1.070	0.671	3.13	72.3
	C5	H.W.L.	SSE	4.04	11.0	145.1	--	1.082	4.37	5.48	0.029	0.023	1.253	0.769	3.36	73.4
	C6	H.W.L.	SSE	4.04	11.0	156.9	--	0.930	3.76	5.85	0.031	0.020	1.556	0.939	3.53	61.5
	C7	H.W.L.	SSE	4.04	11.0	157.6	--	0.902	3.65	7.61	0.040	0.019	2.086	1.009	3.68	60.9
	C8	H.W.L.	SSE	4.04	11.0	157.5	--	0.916	3.70	9.10	0.048	0.020	2.458	1.004	3.72	60.9
	C9	H.W.L.	SSE	4.04	11.0	158.0	--	0.935	3.78	10.33	0.055	0.020	2.733	0.997	3.77	60.4
	C10	H.W.L.	SSE	4.04	11.0	158.2	--	0.949	3.84	11.71	0.062	0.020	3.053	0.994	3.81	60.2
	C11	H.W.L.	SSE	4.04	11.0	158.3	0.973	0.965	3.90	13.05	0.069	0.021	3.345	0.973	3.80	60.2
Outer Rivetment	A1	H.W.L.	SSW	4.72	11.0	226.0	--	0.987	4.65	4.04	0.021	0.025	0.869	0.566	2.64	-2.4
	A2	H.W.L.	SSW	4.72	11.0	225.7	--	0.965	4.55	2.75	0.015	0.024	0.605	0.430	1.96	-1.4
	A3	H.W.L.	SSW	4.72	11.0	217.9	--	0.954	4.50	3.27	0.017	0.024	0.726	0.495	2.23	0.6
mooring area	A4	H.W.L.	SSE	4.04	11.0	157.4	--	0.542	2.19	3.18	0.017	0.012	1.453	0.908	1.99	-7.5
	A5	H.W.L.	SSE	4.04	11.0	148.3	--	1.327	5.36	3.50	0.019	0.028	0.652	0.450	2.41	-8.4
	A6	H.W.L.	S	4.15	11.0	119.8	1.052	0.092	0.38	8.04	0.043	0.002	21.09	1.052	0.40	45.9
	A7	H.W.L.	SSW	4.72	11.0	129.6	1.002	0.145	0.68	10.71	0.057	0.004	15.66	1.002	0.69	55.2
	A8	H.W.L.	S	4.15	11.0	130.2	1.022	0.449	1.86	9.51	0.050	0.010	5.110	1.022	1.90	56.6
	A9	H.W.L.	SSW	4.72	11.0	149.5	1.04	0.652	3.07	9.52	0.050	0.016	3.097	1.040	3.20	-67.2
Other	S0	H.W.L.	SSE	4.04	11.0	153.9	--	1.305	5.28	3.76	0.020	0.028	0.712	0.481	2.54	64.6

3) Case with all port facilities

a) Wave with a return period of 50 years

Table 2.4.17 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 50 years. with all port facilities

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.H.W.L.	SSE	5.78	13.3	144.5	--	0.820	4.74	4.31	0.016	0.017	0.909	0.604	2.86	74.0
	B2	H.H.W.L.	SSW	6.83	13.3	173.6	--	0.762	5.20	5.44	0.020	0.019	1.047	0.674	3.51	44.9
	B3	H.H.W.L.	SSW	6.83	13.3	164.9	--	0.696	4.75	6.97	0.025	0.017	1.467	0.900	4.28	53.6
	B4	H.H.W.L.	SSW	6.83	13.3	141.6	--	0.680	4.64	7.41	0.027	0.017	1.597	0.966	4.49	-73.1
	B5	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.911	5.27	9.47	0.034	0.019	1.799	1.013	5.33	61.0
	B6	H.H.W.L.	SSE	5.78	13.3	158.2	--	0.942	5.45	11.93	0.043	0.020	2.191	1.003	5.46	60.3
	B7	H.H.W.L.	SSE	5.78	13.3	158.3	--	0.968	5.60	14.44	0.052	0.020	2.581	0.995	5.57	60.2
	C0	H.H.W.L.	SSW	6.83	13.3	208.4	--	0.684	4.67	4.48	0.016	0.017	0.960	0.632	2.95	10.1
	C1	H.H.W.L.	SSE	5.78	13.3	136.9	--	0.797	4.61	4.49	0.016	0.017	0.975	0.640	2.95	-68.5
	C2	H.H.W.L.	S	5.94	13.3	167.2	--	0.825	4.90	4.58	0.017	0.018	0.936	0.621	3.04	51.2
	C3	H.H.W.L.	S	5.94	13.3	156.3	--	0.859	5.10	5.31	0.019	0.018	1.041	0.672	3.43	62.2
	C4	H.H.W.L.	SSW	6.83	13.3	132.9	--	0.750	5.12	5.87	0.021	0.019	1.146	0.724	3.70	-64.4
	C5	H.H.W.L.	SSW	6.83	13.3	123.7	--	0.708	4.83	6.36	0.023	0.018	1.315	0.815	3.94	-55.3
	C6	H.H.W.L.	SSW	6.83	13.3	132.5	--	0.685	4.68	6.72	0.024	0.017	1.437	0.881	4.12	-64.1
	C7	H.H.W.L.	SSW	6.83	13.3	149.0	--	0.675	4.61	8.48	0.031	0.017	1.840	1.051	4.84	69.5
	C8	H.H.W.L.	SSE	5.78	13.3	157.5	--	0.916	5.29	9.98	0.036	0.019	1.885	1.011	5.35	60.9
	C9	H.H.W.L.	SSE	5.78	13.3	158.1	--	0.934	5.40	11.21	0.041	0.020	2.076	1.004	5.42	60.4
	C10	H.H.W.L.	SSE	5.78	13.3	158.3	--	0.947	5.47	12.59	0.046	0.020	2.300	1.001	5.48	60.2
	C11	H.H.W.L.	SSE	5.78	13.3	158.4	--	0.962	5.56	13.93	0.050	0.020	2.505	0.997	5.54	60.0
Outer Rivetment	A1	H.H.W.L.	SSW	6.83	13.3	221.5	--	0.849	5.79	4.92	0.018	0.021	0.850	0.564	3.27	2.1
	A2	H.H.W.L.	SSW	6.83	13.3	224.8	--	0.753	5.14	3.59	0.013	0.019	0.699	0.491	2.52	-0.5
	A3	H.H.W.L.	SSW	6.83	13.3	215.0	--	0.725	4.95	4.14	0.015	0.018	0.836	0.566	2.80	3.4
mooring area	A4															
	A5	H.W.L.	ESE	7.29	13.3	136.7	1.621	0.116	0.85	3.50	0.013	0.003	4.131	1.621	1.37	-10.0
	A6	H.H.W.L.	SE	5.85	13.3	115.6	1.109	0.045	0.26	8.92	0.032	0.001	33.894	1.109	0.29	41.7
	A7	L.W.L.	SE	5.67	13.3	115.4	1.137	0.051	0.29	7.87	0.029	0.001	27.232	1.137	0.33	40.9
	A8	L.W.L.	E	9.56	13.3	100.1	1.174	0.039	0.37	6.75	0.024	0.001	18.107	1.174	0.44	26.6
	A9	H.H.W.L.	SE	5.85	13.3	120.0	1.074	0.054	0.32	10.51	0.038	0.001	33.274	1.074	0.34	53.3
Other	S0	H.H.W.L.	SSE	5.78	13.3	182.1	--	0.804	4.65	4.64	0.017	0.017	0.998	0.654	3.04	36.3

b) Wave with a return period of 30 years

Table 2.4.18 Result of Design Wave Calculation for $H_{1/3}$. Return Period= 30 years. with all port facilities

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.H.W.L.	SSE	5.44	12.8	144.4	--	0.817	4.44	4.31	0.017	0.017	0.969	0.635	2.82	74.0
	B2	H.H.W.L.	SSW	6.41	12.8	173.7	--	0.763	4.89	5.44	0.021	0.019	1.113	0.708	3.46	44.8
	B3	H.H.W.L.	SSW	6.41	12.8	165.1	--	0.699	4.48	6.97	0.027	0.018	1.555	0.946	4.24	53.4
	B4	H.H.W.L.	SSW	6.41	12.8	141.7	--	0.683	4.38	7.41	0.029	0.017	1.693	1.016	4.45	-73.2
	B5	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.911	4.96	9.47	0.037	0.019	1.911	1.008	5.00	61.0
	B6	H.H.W.L.	SSE	5.44	12.8	158.2	--	0.942	5.12	11.93	0.047	0.020	2.328	0.998	5.12	60.3
	B7	H.H.W.L.	SSE	5.44	12.8	158.3	--	0.968	5.27	14.44	0.057	0.021	2.743	0.990	5.22	60.2
	C0	H.H.W.L.	SSW	6.41	12.8	208.1	--	0.684	4.38	4.48	0.018	0.017	1.022	0.664	2.91	10.4
	C1	H.H.W.L.	SSE	5.44	12.8	136.9	--	0.794	4.32	4.49	0.018	0.017	1.040	0.673	2.91	-68.4
	C2	H.H.W.L.	S	5.59	12.8	167.3	--	0.824	4.60	4.58	0.018	0.018	0.996	0.651	3.00	51.2
	C3	H.H.W.L.	S	5.59	12.8	156.4	--	0.859	4.80	5.31	0.021	0.019	1.106	0.705	3.38	62.1
	C4	H.H.W.L.	SSW	6.41	12.8	132.9	--	0.751	4.81	5.87	0.023	0.019	1.219	0.761	3.66	-64.5
	C5	H.H.W.L.	SSW	6.41	12.8	123.8	--	0.711	4.56	6.36	0.025	0.018	1.395	0.855	3.90	-55.3
	C6	H.H.W.L.	SSW	6.41	12.8	132.7	--	0.687	4.40	6.72	0.026	0.017	1.525	0.927	4.08	-64.2
	C7	H.H.W.L.	SSW	6.41	12.8	148.8	--	0.679	4.35	8.48	0.033	0.017	1.948	1.045	4.55	69.7
	C8	H.H.W.L.	SSE	5.44	12.8	157.5	--	0.916	4.98	9.98	0.039	0.019	2.003	1.006	5.01	60.9
	C9	H.H.W.L.	SSE	5.44	12.8	158.0	--	0.934	5.08	11.21	0.044	0.020	2.206	1.000	5.08	60.4
	C10	H.H.W.L.	SSE	5.44	12.8	158.3	--	0.947	5.15	12.59	0.049	0.020	2.444	0.996	5.13	60.2
	C11	H.H.W.L.	SSE	5.44	12.8	158.4	--	0.963	5.24	13.93	0.054	0.020	2.658	0.992	5.20	60.1
Outer Rivetment	A1	H.H.W.L.	SSW	6.41	12.8	221.2	--	0.851	5.45	4.92	0.019	0.021	0.903	0.590	3.22	2.4
	A2	H.H.W.L.	SSW	6.41	12.8	224.5	--	0.753	4.83	3.59	0.014	0.019	0.745	0.514	2.48	-0.2
	A3	H.H.W.L.	SSW	6.41	12.8	214.7	--	0.725	4.65	4.14	0.016	0.018	0.891	0.594	2.76	3.8
mooring area	A4															
	A5	H.W.L.	ESE	6.85	12.8	136.6	1.545	0.117	0.80	3.50	0.014	0.003	4.361	1.545	1.24	-9.9
	A6	H.H.W.L.	SE	5.51	12.8	116.1	1.092	0.046	0.25	8.92	0.035	0.001	35.228	1.092	0.28	42.1
	A7	L.W.L.	SE	5.34	12.8	115.4	1.12	0.052	0.28	7.87	0.031	0.001	28.322	1.120	0.31	41.0
	A8	L.W.L.	E	8.94	12.8	100.2	1.155	0.039	0.35	6.75	0.026	0.001	19.367	1.155	0.40	26.7
	A9	H.H.W.L.	SE	5.51	12.8	120.1	1.059	0.055	0.30	10.51	0.041	0.001	34.710	1.059	0.32	53.5
Other	S0	H.H.W.L.	SSE	5.44	12.8	181.9	--	0.802	4.36	4.64	0.018	0.017	1.063	0.687	3.00	36.5

c) Wave with a return period of 10 years

Table 2.4.19 Result of Design Wave Calculation for $H_{1/3}$.
Return Period= 10 years. with all port facilities

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.W.L.	SSE	4.61	11.8	145.1	--	0.830	3.83	3.43	0.016	0.018	0.896	0.596	2.28	73.4
	B2	H.W.L.	S	4.73	11.8	170.2	--	0.884	4.18	4.56	0.021	0.019	1.092	0.697	2.91	48.2
	B3	H.W.L.	SSW	5.41	11.8	164.4	--	0.696	3.77	6.09	0.028	0.017	1.617	0.979	3.69	54.1
	B4	H.W.L.	SSW	5.41	11.8	140.2	--	0.679	3.67	6.53	0.030	0.017	1.778	1.047	3.85	-71.8
	B5	H.W.L.	SSE	4.61	11.8	157.5	--	0.907	4.18	8.59	0.040	0.019	2.055	1.010	4.22	61.0
	B6	H.W.L.	SSE	4.61	11.8	158.2	--	0.941	4.34	11.05	0.051	0.020	2.548	0.999	4.34	60.3
	B7	H.W.L.	SSE	4.61	11.8	158.2	--	0.968	4.46	13.56	0.062	0.021	3.040	0.991	4.42	60.2
	C0	H.W.L.	SSW	5.41	11.8	218.9	--	0.788	4.26	3.60	0.017	0.020	0.844	0.565	2.41	-0.4
	C1	H.W.L.	SSE	4.61	11.8	137.8	--	0.801	3.69	3.61	0.017	0.017	0.979	0.641	2.37	-69.3
	C2	H.W.L.	S	4.73	11.8	168.3	--	0.828	3.92	3.70	0.017	0.018	0.946	0.625	2.45	50.2
	C3	H.W.L.	S	4.73	11.8	157.0	--	0.873	4.13	4.43	0.020	0.019	1.073	0.687	2.84	61.4
	C4	H.W.L.	SSW	5.41	11.8	133.1	--	0.759	4.11	4.99	0.023	0.019	1.214	0.758	3.11	-64.7
	C5	H.W.L.	SSW	5.41	11.8	123.8	--	0.710	3.84	5.48	0.025	0.018	1.426	0.871	3.35	-55.4
	C6	H.W.L.	SSW	5.41	11.8	131.5	--	0.684	3.70	5.84	0.027	0.017	1.577	0.954	3.53	-63.0
	C7	H.W.L.	SSW	5.41	11.8	147.5	--	0.675	3.65	7.60	0.035	0.017	2.080	1.049	3.83	71.0
	C8	H.W.L.	SSE	4.61	11.8	157.5	--	0.913	4.21	9.10	0.042	0.019	2.163	1.008	4.24	60.9
	C9	H.W.L.	SSE	4.61	11.8	158.1	--	0.932	4.30	10.33	0.048	0.020	2.404	1.001	4.30	60.4
	C10	H.W.L.	SSE	4.61	11.8	158.3	--	0.946	4.36	11.71	0.054	0.020	2.685	0.997	4.35	60.2
	C11	H.W.L.	SSE	4.61	11.8	158.4	--	0.962	4.43	13.05	0.060	0.020	2.942	0.993	4.40	60.1
Outer Rivetment	A1	H.W.L.	SSW	5.41	11.8	228.9	--	0.971	5.25	4.04	0.019	0.024	0.770	0.516	2.71	-5.3
	A2	H.W.L.	SSW	5.41	11.8	233.2	--	0.912	4.93	2.71	0.012	0.023	0.550	0.404	1.99	-8.9
	A3	H.W.L.	SSW	5.41	11.8	226.7	--	0.885	4.79	3.26	0.015	0.022	0.681	0.474	2.27	-8.2
mooring area	A4															
	A5	H.W.L.	ESE	5.81	11.8	136.3	1.396	0.117	0.68	3.50	0.016	0.003	5.143	1.396	0.95	-9.6
	A6	H.W.L.	SE	4.66	11.8	115.2	1.08	0.044	0.21	8.04	0.037	0.001	39.223	1.080	0.22	41.3
	A7	L.W.L.	SE	4.57	11.8	115.6	1.084	0.053	0.24	7.87	0.036	0.001	32.488	1.084	0.26	41.2
	A8	L.W.L.	E	7.49	11.8	100.4	1.117	0.040	0.30	6.75	0.031	0.001	22.531	1.117	0.34	26.9
	A9	H.W.L.	SE	4.66	11.8	119.4	1.044	0.052	0.24	9.63	0.044	0.001	39.745	1.044	0.25	52.7
Other	S0	H.W.L.	SSW	5.41	11.8	217.0	--	0.771	4.17	3.76	0.017	0.019	0.901	0.596	2.48	1.5

d) Wave with a return period of 5 years

**Table 2.4.20 Result of Design Wave Calculation for $H_{1/3}$.
Return Period= 5 years. with all port facilities**

Name of Facility	Position	Tide Level	Offshore wave Condition			Condition for Design										
			DIR	Ho	To	θ	Ks	KrKd	Ho'	h	h/Lo	Ho'/Lo	h/Ho'	$H_{1/3}$/Ho	$H_{1/3}$	β
Training Dike	B1	H.W.L.	SSE	4.04	11.0	145.0	--	0.826	3.34	3.43	0.018	0.018	1.026	0.664	2.22	73.4
	B2	H.W.L.	S	4.15	11.0	170.4	--	0.886	3.67	4.56	0.024	0.019	1.242	0.775	2.85	48.1
	B3	H.W.L.	SSW	4.72	11.0	164.8	--	0.704	3.32	6.09	0.032	0.018	1.834	1.038	3.45	53.6
	B4	H.W.L.	SSW	4.72	11.0	140.5	--	0.687	3.24	6.53	0.035	0.017	2.017	1.043	3.38	-72.1
	B5	H.W.L.	SSE	4.04	11.0	157.5	--	0.910	3.68	8.59	0.046	0.019	2.336	1.007	3.70	61.0
	B6	H.W.L.	SSE	4.04	11.0	158.1	--	0.944	3.82	11.05	0.059	0.020	2.896	0.996	3.80	60.3
	B7	L.W.L.	SSE	3.97	11.0	158.5	--	0.963	3.83	10.44	0.055	0.020	2.729	0.995	3.81	59.9
	C0	H.W.L.	SSW	4.72	11.0	218.0	--	0.783	3.69	3.60	0.019	0.020	0.975	0.633	2.34	0.5
	C1	H.W.L.	SSE	4.04	11.0	137.6	--	0.798	3.23	3.61	0.019	0.017	1.120	0.714	2.30	-69.2
	C2	H.W.L.	S	4.15	11.0	168.4	--	0.829	3.44	3.70	0.020	0.018	1.078	0.694	2.38	50.1
	C3	H.W.L.	S	4.15	11.0	157.1	--	0.875	3.63	4.43	0.023	0.019	1.221	0.764	2.77	61.3
	C4	H.W.L.	SSW	4.72	11.0	133.2	--	0.764	3.60	4.99	0.026	0.019	1.384	0.846	3.05	-64.8
	C5	H.W.L.	SSW	4.72	11.0	123.8	--	0.717	3.38	5.48	0.029	0.018	1.620	0.972	3.29	-55.4
	C6	H.W.L.	SSW	4.72	11.0	131.8	--	0.691	3.26	5.84	0.031	0.017	1.791	1.040	3.39	-63.3
	C7	H.W.L.	SSW	4.72	11.0	147.3	--	0.684	3.23	7.60	0.040	0.017	2.356	1.044	3.37	71.1
	C8	H.W.L.	SSE	4.04	11.0	157.5	--	0.916	3.70	9.10	0.048	0.020	2.458	1.004	3.72	60.9
	C9	H.W.L.	SSE	4.04	11.0	158.0	--	0.935	3.78	10.33	0.055	0.020	2.733	0.997	3.77	60.4
	C10	H.W.L.	SSE	4.04	11.0	158.2	--	0.949	3.84	11.71	0.062	0.020	3.053	0.994	3.81	60.2
	C11	H.W.L.	SSE	4.04	11.0	158.3	0.973	0.965	3.90	13.05	0.069	0.021	3.345	0.973	3.80	60.2
Outer Rivetment	A1	H.W.L.	SSW	4.72	11.0	228.1	--	0.968	4.56	4.04	0.021	0.024	0.886	0.576	2.63	-4.6
	A2	H.W.L.	SSW	4.72	11.0	232.4	--	0.902	4.25	2.71	0.014	0.023	0.638	0.450	1.92	-8.1
	A3	H.W.L.	SSW	4.72	11.0	225.9	--	0.879	4.14	3.26	0.017	0.022	0.786	0.530	2.20	-7.4
mooring area	A4															
	A5	H.W.L.	ESE	5.07	11.0	136.0	1.301	0.118	0.60	3.50	0.019	0.003	5.848	1.301	0.78	-9.3
	A6	H.W.L.	SE	4.08	11.0	116.6	1.052	0.046	0.19	8.04	0.043	0.001	42.829	1.052	0.20	42.7
	A7	H.W.L.	SE	4.08	11.0	120.7	0.998	0.057	0.23	10.99	0.058	0.001	47.218	0.998	0.23	46.2
	A8	L.W.L.	E	6.48	11.0	100.7	1.087	0.041	0.27	6.75	0.036	0.001	25.429	1.087	0.29	27.1
	A9	H.W.L.	SE	4.08	11.0	120.1	1.019	0.055	0.23	9.63	0.051	0.001	42.896	1.019	0.23	53.4
Other	S0	H.W.L.	SSW	4.72	11.0	216.1	--	0.767	3.62	3.76	0.020	0.019	1.039	0.668	2.42	2.4

3. SURVEY ON ENVIRONMENTAL CONDITIONS

3.1 Review of Previous EIA

In order to confirm the compatibility of the approved Environmental Impact Assessment (EIA) for the proposed Lach Huyen gateway port (MONRE No. 2231/QD-BTNMT, 31 October, 2008) and Japan Bank for International Cooperation (JBIC) Environmental and Social Consideration, 2002[1] (The JBIC Guideline), the approved EIA and its review report (THE PREPARATORY SURVEY ON LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION IN VIET NAM, 2010) were reviewed. Reviewed documents were as follows:

Table 3.1.1 List of Reviewed Documents

Reviewed EIA Report	
Environmental Impact Assessment Report/ Lach Huyen Gateway Port Construction Project (2010-2015), October 2008 (Approved Port EIA)	Prepared by HYMENET assigned by PMU III, VINAMARINE Approved on 31 October 2008
Other reviewed reports	
The Preparatory Survey on Lach Huyen Port Infrastructure Construction in Viet Nam, July 2010 (SAPROF study 2010)	Prepared by JICA SAPROF study team assigned by JICA
Supplemental Report – Environmental Impact Assessment Report for Lach Huyen Gateway Port Construction Project (2010-2015), May 2010 (SAPROF EIA)	Prepared by JICA SAPROF study team assigned by JICA

3.1.1 Legal Framework of Environmental and Social Consideration in Vietnam

In general, Vietnam legal framework for environmental and social consideration are well developed to avoid unnecessary losses and to secure adequate compensation for the losses and assist recovery of livelihood as fair philosophy as most of developed countries. The fundamentals of the environmental and social consideration are defined by 1992 Constitution of the Socialist Republic of Vietnam amended in 2001. Under the constitution, the primary laws relevant to the environmental and social consideration are Environmental Protection Law No.52 (2005) and Land Law No.13 (2003). Due to the complexity of the issues and continuous changes in economic development, relevant regulations have been continuously issued to address the realistic issues on the ground and adapt the gaps between legislation and reality.

In April 2011, a new decree on environmental protection – "Decree No.29/2011/ND-CP dated April 18th 2011 of Provisions of the Strategic Environmental Assessment, Environmental Impact Assessment, Environmental Protection Commitment entered into force from 5th of June, 2011. For the detailed guidelines for the decree #29/2001/NDCP, Circular No. 26/2011/TT-BTNMT entered into force from September 2nd of 2011. As a result ALL new EIA application shall meet the new decree and circular respectively after the effective dates. Before the enforcement of the decree #29/2011/ND-CP, a supplemental EIA to address the change in port design and require the final approval was required by decree #21/2008/ND-CP and Circular #05/2008/TT-BTNMT respectively. However by the new regulation (decree #29/2001/NDCP and circular # 26/2011/TT-BTNMT), Lach Huyen Gateway Port are required to prepare full set of EIA documentation instead of Supplemental EIA.

Based on the Article 12, 3 (decree #29/2011/ND-CP), Lach Huyen Gateway Port project meets the

[1] Although JICA's new environment policy – "Guidelines for Environmental and Social Considerations (JICA Env. Guideline 2010)" came into force on 1st of July, 2010, for the projects whose applications have been made before the effective date (July 1st, 2010), the "JBIC Guidelines for Confirmation of Environmental and Social Considerations 2002 (JBIC Env. Guideline 2002)" will apply to Loan aid (JICA Env. Guideline 2010).

following cases for the EIA requirement: b) Failure to implement projects within thirty-six (36) months from the time of issuance of the decision approving the report on environmental impact assessment and c) Change the size, capacity or technology that increases the level of negative environmental impact or scope of those affected by this change caused.

In addition to the assessment of the port project, it is also required to consider the potential impacts of the new disposal site(s) for the channel and other required dredging for the port development within the new EIA preparation since the previously approved disposal site at the south Dinh Vu area is not suitable for both South Dinh Vu Industrial Zone development and economical port development. As of October 2011, Hai Phong People's Committee and Ministry of Transport (Decision 476 QD-BGTVT dated March 15, 2011) approved the new disposal site for the port development adjacent to the south coast of Cat Hai Island (NEAR-shore). On the contrary, JICA D/D study team has been recommending "OFF-shore" disposal to meet the very tight time frame for the port operation by 2013 and economically feasible port development as well as to minimize the impacts on natural and social environment.

For the preparation of the new EIA compatible with the new environmental regulations, environmental experts shall carefully examine the potential impacts by the port development including both port structures-operation and channel dredging-disposal and fulfill the updated requirements. In this section, the approve EIA was carefully examined with most updated legal frameworks and The JBIC Guide Line. Detailed concerned matters including updated environmental assessment, proposed mitigation measures and environmental management plans shall be addressed in Chapter 13 and 21 of this document.

1) Relevant legislation on Environmental Protection Law, 2005

Year/ Objective	**Law and Regulation**
2005/ LAW	Environmental Protection Law No.52/2005/QH11
1998/ LAW	Water Resources Law 1998, effective in January 1st 1999
2011/ pursuant to Law on Environment, Dec.#29/2011/ND-CP and replacing Circular No. 05/2008/TT-BTNMT	Circular No. 26/2011/TT-BTNMT Detailing a number of articles of Decree No. 29/2011/ND-CP April 18, 2011 the Government's regulations on environmental assessment strategic environmental impact assessment, environmental protection commitments <the decree entered into force from September 2, 2011 and all new EIA applications after the effective date are required to meet this new decree.>
2011/ pursuant to Law on Environment, Replacing some articles of Dec.#80/2006/ND-CP and Dec.#21/2008/ND-CP and amending and supplementing some articles of Dec.#80/2006/ND-CP	Decree No.29/2011/ND-CP dated April 18th 2011 of Provisions of the Strategic Environmental Assessment, Environmental Impact Assessment, Environmental Protection Commitment <the decree entered into force from June 5, 2011 and all new EIA applications after the effective date are required to meet this new decree.>
2008/ pursuant to Law on Environmental Protection, Dec.#21/2008/ND-CP, Dec.#80/2006/ND-CP	Circular No. 05/2008/TT-BTNMT guiding strategic environmental assessment, environmental impact assessment and environmental protection commitment, 08 December 2008
2008/ pursuant to Law on Environmental Protection, and amending Dec.#80/2006/ND-CP	Decree No.21/2008/ND-CP dated February 28th 2008 of the Government on amendment of some articles of Decree No.80/2006/ND-CP dated August 9th 2006 guiding the implementation of Environment Protection Law.
2008	Decision No.16/2008/QD-BTNMT dated December 18th 2006 of the Ministry of Natural Resources and Environment on obligatory application of Vietnamese standards on environment
2007/ pursuant to Law on Environmental Protection, Law on Water Resources	Decree No.88/2007/ND-CP dated May 28th 2007 of the Government on drainage for urban and industrial zones

Year/ Objective	Law and Regulation
2007	Decree No.59/2007/ND-CP dated April 9th 2007 of the Government on solid waste management
2007	Decree No.88/2007/ND-CP dated May 28th 2007 of the Government on drainage for urban and industrial zones
2006/ pursuant to Law on Environmental Protection, and amending Dec.#80/2006/ND-CP	Decree No.80/2006/ND-CP detailing and guiding the implementation of a number of articles of the Law on Environmental Protection
2006/ pursuant to Law on Environmental Protection	Decree No.80/2006/ND-CP detailing and guiding the implementation of a number of articles of the Law on Environmental Protection
2006	Decision No.22/2006/QD-BTNMT dated December 18th 2006 of the Ministry of Natural Resources and Environment on obligatory application of Vietnamese standards on environment
2006	Decision No.23/2006/QD=BTNMT dated December 26th 2006 of the Ministry of Natural Resources and Environment on list of dangerous waste
2006	Circular No.12/2006/TT-BTNMT dated December 26th 2006 of the Ministry of Natural Resources and Environment guiding the procedures for application, registration, licensing, and code issuance for managing dangerous waste.
2002	Decision No.35/2002/QD-BKHCNMT dated June 25th 2002 of the Ministry of Science, Technology, and Environment on list of obligatory application of Vietnamese environment standards

2) Relevant legislation on Land Law, 2003

Year/ Objective	Law and Regulation
2003/ LAW	Land Law No.13/2003/QH11
2010/ promulgating the unit price for compensation	Decision 2295 /2010/QĐ-UBND, dated 31/12/ 2010 Hai Phong PC promulgated the unit price for compensation of categories of land when the Government acquires land on Hai Phong territory: land price is adjusted to higher.
2010/ amending 130/2010/QĐ-UBND	Decision 1263/2010/QD-UBND dated 30/7/2010 of Hai Phong PC amending and supplementing some articles in the Decision 130/2010/QĐ-UBND dated 22/1/2010 regarding compensation, assistance and resettlement when the Government acquires land in Hai Phong territory
2010/ pursuant to Land Law, pursuant to Dec.#69/2009/ND-CP	Decision 130/2010/QĐ-UBND dated 22/1/2010 regarding compensation, assistance and resettlement when the Government acquires land in Hai Phong territory
2009/ pursuant to Land Law, pursuant to Dec.#69/2009/ND-CP, Dec.#84/2007/ND-CP	Circular No. 14/2009/TT-BTNMT detailing the compensation, support and resettlement and order of and procedures for land recovery, allocation and lease
2009/ pursuant to Land Law	Decree No.69/2009/ND-CP to amend a number of provisions on land use planning land rental rates land reclamation and resettlement and compensation
2008/ pursuant to Land Law, Dec.#84/2007/ND-CP	Circular No. 14/2008/TTLT/BTC-BTNMT Joint circular on guiding the implementation of a number of articles of the Government's Decree No.84/2007/ND-CP
2007/ pursuant to Land Law	Decree No.84/2007/ND-CP dated May 25th 2007 of the Government on granting land use right certificate, land collection, land use right, procedures for compensation, support, resettlement where the land acquired by the State and complain denunciation
2004/ pursuant to Land Law	Decree No. 197/2004/ND-CP on compensation, support and resettlement when land is recovered by the State. 03 December 2004
2004/ pursuant to Land Law	Decree No. 188/2004/ND-CP on methods of determining land prices and assorted-land price brackets. - 16 November 2004
2004/ pursuant to Land Law	Decree No. 181/2004/ND-CP on the implementation of the Land Law. - 29 October 2004

3.1.2 Compliance with the JBIC Guideline of the Proposed Port Project

In principal, JICA respects the legal framework of the borrower's environmental and social considerations. However in the case of the borrower's legal framework and common practices for such consideration are significantly different from regional practices or/and internationally acceptable level, JICA may request the responsible authorities of the ODA recipient(s) to reconsider the acceptable level of environmental and social consideration to grant the ODA. Due to the recent reorganization of the Japanese ODA agencies in 2008, specifically JICA and Japan Bank for International Cooperation (JBIC), "Guidelines for Confirmation of Environmental and Social Consideration, April 2002 by JBIC" (the JBIC Guideline) is applied for the proposed Lach Huyen Port project.

1) Principles of the JBIC Guideline and Vietnamese Requirement

Principles of the JBIC Guideline and comparison of the JBIC Guideline's and Vietnamese regulations on environmental and social consideration are shown in Appendix 3-1. By the definition of the effective law and regulations of Vietnam, coverage and requirements of the EIA meet the JBIC Guideline except the analysis of the alternatives. Although the requirement of the Vietnamese EIA does not fulfill the definition of the JBIC Guideline's alternatives, the analyses of the alternatives are certainly examined in the "Feasibility study report" of the assessed project, which is required for the appraisal of the EIA. The view point of such alternative analyses may not specifically focus on preventing or minimizing adverse impact and choosing a better project option for environmental and social considerations. Thus, additional description of studied alternatives may be added to either JICA D/D study or updated Supplemental EIA and a new EIA for dump site to fulfill the JIBC Guideline. Followings are the principles of the JBIC Guideline.

Table 3.1.2 Principles of the JBIC Guideline (Summary)

Principles	JBIC Policy
a) Examination of Measures	· Examination of multiple alternative proposals to prevent or minimize adverse impact and to choose a better project option for environmental and social considerations (Priority is the prevention of the impact, and when it's not possible, minimization and reduction are considered next. Compensation measures must be examined only when impact cannot be prevented · Preparation of appropriate follow-up plans and systems, costs of such plans and systems, and financial methods to fund such costs
b) Scope of Impact to be Examined	· Examination of environmental impact (air, water, soil, waste, accidents, water usage, ecosystems, and biota) and social concerns (involuntary resettlement, the indigenous people, cultural heritage, landscape, gender, children's rights and communicable diseases, and trans-boundary and global environmental problems)
c) Compliance with Laws, Standards and Plans	· Compliance with national and local laws, ordinances and standards relating to environmental and social considerations as well as environmental and social consideration policies and plans of the jurisdiction over the project · Principal avoidance of protected areas specifically designated by laws or ordinances of the government for the conservation of nature or cultural heritage
d) Social Acceptability and Social Impacts	· Appropriate acceptability of the project in the country and locality of the project site · Sufficient consultations with stakeholders, appropriate disclosure of project and impact information, incorporation of the outcome of such consultations into the project plan/design · Appropriate consideration for vulnerable social groups, such as women, children, the elderly, the poor, and ethnic minorities
e) Involuntary Resettlement	· Avoidance of involuntary resettlement and loss of means of livelihood, where feasible, exploration of all viable alternatives and effective measures to minimize impact and to compensate for losses, and agreeable measures for the loss · Assurance of sufficient compensation for the project affected people's losses (land and monetary compensation) and supporting the means for an alternative sustainable livelihood, and providing the expenses necessary for relocation and the re-establishment of a community at relocation sites at least as same level as pre-project condition in timely

Principles	JBIC Policy
	manner · Appropriate participation by the affected people and their communities in planning, implementation and monitoring the counter/compensation measures
f) Indigenous People	· Special safety guard for indigenous people to respect their rights in relation to land and resources in accordance with the spirit of the relevant international declarations and treaties · The consent of indigenous people
g) Monitoring	· <Desirable> by the project proponents to monitor: (i) whether any situations that were unforeseeable before the project began have arisen, (ii) the implementation situation and the effectiveness of the mitigation measures prepared in advance, and that they then take appropriate measures based on the results of such monitoring · <Desirable> making results of the monitoring process available by project proponents to project stakeholders · <Desirable> assurance of a forum for discussion and examination of countermeasures with the participation of stakeholders in the relevant project in the case of the improper care for the environmental and social considerations after the project implementation

2) Compliance of the Approved Lach Huyen Port EIA with the JBIC Guideline

Considering the compliance of the EIA report of Lach Huyen Gateway Port Construction Project (2010-2015), it principally complies with the JBIC Guideline except the 1) short of biological environmental information seasonally and geographically and 2) improper consideration for coastal fishing activities, which is beyond the Vietnamese safeguard policies due to lack of legal framework for such fishing activities at this moment.

Such issues were confirmed and recognized by Vietnamese authorities including VINAMARINE, MPMU II, commune People's Committees (PCs) on Cat Hai Islands and responsible JICA representatives during the SUPROF Study 2010. In order to fulfill the JBIC guideline, environmental experts of JICA D/D study team and local environmental experts had conducted additional environmental surveys in May 2011 and are going to conduct other environmental surveys in August/September 2011 to understand the seasonal changes. The sets of the additionally collected data shall be considered as the base line/reference data covering appropriate extent of project affected area for the future monitoring. Detailed compatibility and confirmation of the potential impacts on environment shall be addressed in the following sections and relevant sections in the detailed design report.

a) Natural Environment

In order to confirm the compliance of the Approve Port EIA and JBIC Guideline 2002, analyzed natural environmental parameters were reviewed. Though there are sufficient kinds of parameters were analyzed, but allocation of such monitored points were not appropriate. Due to the upscale change in the port design including berth and sand control dike's length and channel depth, a Supplemental EIA is required to acquire the approval of design change and final EIA approval by law on Environment. In order to adequately evaluate the potential impacts, supplement natural environmental parameters were collected in May 2011 to cover the sufficient project affected area. The collected parameters will be considered as the baseline/reference value of the monitoring program in construction and operation phase.

i) Air Quality, Sound and Vibration

Air quality, sound and vibration were measured at six (6) points (Cát Hái Town Primary School, Hoà Hy Temple, Cross-road, Next to Mr. Nguên Quang Dúc's house, Gót Ferry and Center for Culture-Science), in Approved Port EIA. As it is considered that those parameters will be affected especially in the construction phase due to activities of heavy machineries, survey point near to the construction area is desirable.

ii) Sea Water Quality and Bottom Sediment Quality

Sea water quality and bottom sediment quality were measured at five (5) points in Approved Port EIA. Those five points are located close to the shoreline of Cat Hai Island, while the influenced area by port construction is considered wider. Survey points, therefore, should be distributed widely to cover the influenced area.

b) Biological Environment

Chapters relevant to the biological environment in Approved Port EIA were reviewed, focusing particularly on the baseline condition, environmental impact assessment, mitigation measures and environmental management plan. Recommendations are also made for improvement, which could be reflected into either the supplemental EIA or new dump site EIA, whichever is appropriate.

i) Review of baseline condition (Chapter 2 of Approved Port EIA)

Approved Port EIA describes the status of the biological environment by presenting information on phytoplankton/zooplankton, benthic fauna, seaweed/sea grass, wetland flora and fish, which were collected through field and literature surveys. However, in general, the quality and quantity of the presented information is not sufficient, and some fundamental information is also lacking. Following are the main deficiencies identified through the review process:

- The locations of the field survey sites are not clearly indicated. The surveyed area is also insufficient as it does not cover all the areas that could be potentially affected by the project. For example, no field surveys were conducted along the west, south and east coasts of Cat Ba Island, which could be affected by turbid plumes generated from dredging and dumping activities. Hence additional field surveys should be conducted, covering representative sites of potentially affected areas.
- According to certain sources (e.g. UNEP/GEF South China Sea Project), coral reefs are distributed in the south and southeast of Cat Ba Island as well as in some offshore islands, which is not mentioned in Approved Port EIA. Since these coral reefs could be affected by turbid plumes generated from dredging and dumping activities, the status of these coral reefs should be surveyed at some representative sites.
- Approved Port EIA conducted field surveys only during one season (May 2006). Additional field surveys should be conducted to understand the seasonal variations in the local biological environment.
- Although ecologically valuable marine habitats such as coral reef, mangrove, seagrass/seaweed and tidal flat are known to be present in the area, Approved Port EIA does not provide any information on their spatial distribution. Such information will be important for assessing the impacts of dredging and dumping activities, and should be identified through literature and additional field surveys.
- There is a lack of quantitative information on the benthic community (e.g. species composition, biomass, presence of endangered species) at the project sites (e.g. port area, access channel, dumping site). Such information will be important to assess the impacts of construction activities on these benthic communities, and should be collected through additional field surveys.
- Approved Port EIA does not provide any information on the protected areas around the project site, such as Cat Ba National Park. The status of these protected areas should be identified through literature survey and by referring to relevant national laws/regulations.

ii) Review of environmental impact assessment (Chapter 3 of Approved Port EIA)

Construction phase

- Approved Port EIA does not assess the impacts of construction activities on the biological environment. This is a major flaw as construction activities such as dredging and dumping activities could potentially have major impacts on the local marine ecosystem, in particular for marine organisms or habitats that are sensitive to excessive turbidity and sedimentation. Therefore, a sediment dispersion simulation should be conducted to predict the extent of sediment dispersion from dredging and dumping activities, and assess their impacts on the biological environment.
- Inevitably, some marine habitats and organisms in the project sites will be lost through the construction activities. The significance of these losses should be assessed based on the results of the additional field surveys.

Operation phase

- Approved Port EIA does not assess the impacts of maintenance dredging on the biological environment. This is a major flaw as maintenance dredging will be one of the major sources of impact in the operation phase. Impacts on the biological environment should be assessed based on the results of the sediment dispersion simulation.

iii) Review of mitigation measures (Chapter 4 of Approved Port EIA)

Construction and operation phases

- Although activities such as capital and maintenance dredging are likely to have impacts on the biological environment, no mitigation measures are proposed to prevent or minimize impacts. Appropriate mitigation measures should be proposed if significant impacts are identified through the additional impact assessment.

iv) Review of environmental management plan (Chapter 6 of Approved Port EIA)

Construction and operation phases

- The EIA proposes monitoring of phytoplankton/zooplankton and benthic fauna during both the construction and operation phases. However, fundamental information is lacking such as: aim of monitoring, monitoring frequency, monitoring location and so on. A detailed monitoring plan should be proposed based on the results of the additional impact assessment.

c) Social Environment

In regard to the improper consideration for project affected fishing communities, it seems reasonable to apply the present “Involuntary resettlement policies” relevant to Law on Land although recovery of the livelihood and living standard for the costal and offshore fishermen is out of scope under the resettlement policies. Since the negative impacts on AQUACULTURE by a project shall be compensated by the involuntary resettlement policies, it shall be similar philosophy to take care of project affected coastal and offshore fishermen. However, unlike aquaculture ponds on land, it is not practical to define the “Loss of fishing area” and its value for individual fisherman because there are no specific legal rights to allocate the fishing area within the proposed port development area. In order to evaluate the present living standards for the potentially affected fishermen and consider the practical and favorable safeguard programs for such PAP, social environmental surveys focusing on potentially affected fishing communities were conducted in May 2011. Result of the survey is described in section 3.4 of this basic design document and proposed safeguard programs shall be given in the following detail design report.

Following are the summary of the compliance with the JBIC Guideline and the approved EIA and relevant documents.

Table 3.1.3 Summary of the compliance with the JBIC Guideline and the Approved Port EIA

Principles	Remarks
a) Examination of Measures	· Although the requirement of the Vietnamese EIA does not fulfill the definition of the JBIC Guideline, the analyses of the alternatives are examined in the feasibility study of Lach Huyen Gateway Port Construction Project, which is the attachment of the EIA report for the approval. · Three (3) alternative locations are comparatively evaluated from economic, environmental and social viewpoints on comprehensive manner. It is concluded that Lach Huyen as the most appropriate location. The other two alternative locations are 1) Cam Pha in Quang Ninh Province located north of Lach Huyen and 2) south of Do Son located south west of Lach Huyen, also located in Hai Phong. In environmental and social view points, Cam Pha and Do Son were not selected due to the significant impacts by the inland waterway access to the port through the world heritage-Ha Long Bay and the significant impacts on beach resort oriented eco-tourism development respectively. · In addition to the selection of the project site, selection of the port structure and facilities were technically examined. Such technical consideration does not focus on the reduction of the environmental and social impacts, but in general the economical and technical options could be considered as the favorable options environmentally and socially.
b) Scope of Impact to be Examined	· Potential impacts on natural environment are well covered though it lacks the seasonal information. The seasonal information shall be added and monitored under the responsibility of the implementation agency and operator, which will be conducted in detailed design stage and specified in environmental management plan. · Potential impacts on social environment are also covered except coastal fishing activities as mentioned above. This SAPROF study conducted two sample surveys to understand the potential impacts on the coastal fishing. · Due to the change in design to add public portion on the Cat Hai island and the reclaimed land, the impacts on the extended portion on the Cat Hai island are additionally examined in this SAPROF study.
c) Compliance with Laws, Standards and Plans	· The approved EIA is fully compatible with the effective national law, regulations and standards. The Lach Huyen port is one of the key components of the general plan on developing Hai Phong city up to 2025 and vision to 2050.
d) Social Acceptability and Social Impacts	· Throughout the public consultation required by law and additional public hearing requested by JICA and conducted by MPMU II in April 2010, it confirmed that the port development projects are fully accepted by the community. At the additional public hearing in April 2010, announcement of the concrete project schedule and consideration for the costal fishermen were requested by the representatives of the local communities. MPMU II agrees to address the mentioned opinions with the collaboration with responsible authorities.
e) Involuntary Resettlement	· Due to the offshore construction, there are minimal requirements for the involuntary resettlement except coastal fishing activities. · Though some land clearance is required for the public facilities added by the change of design, the additionally required land clearance on Cat Hai island does not require any house resettlement but some community woods, tombs and aquaculture ponds. Though the specific land acquisition plan was not completed by the end of April 2010, people's committee of the Cat Hai dist, the responsible authority for the land clearance, has already consulted with the relatives of the potentially resettled tombs and received general acceptance of the resettlement. · The additional safeguard policies for coastal fishing activities is ongoing process of development at the end of April 2010, but such policies shall adequately treat project affected people due to the MPMU II and people's committee of the Hai Phong city's proactive intentions to treat people adequately.
f) Indigenous People	· It is not applicable for the proposed project.

Principles	Remarks
g) Monitoring	· The monitoring program is strictly required by Vietnamese law and described in the EIA report, which is likely to meet the JBIC Guideline. · Reporting of the environmental monitoring and assurance of the adequate environmental management are also required by Vietnamese law and regulation, which secure the environmental and social consideration after the project implementation.

3.2 Natural Environments

Based on the review of previous EIA, following surveys were conducted in May, 2011. The purposes of the survey are:

- In order to supplement the baseline of the natural environmental condition for the SUPPLEMENTAL EIA preparation of the Lach Huyen Gateway Port, necessary Environmental Condition Survey shall be conducted. With the survey results and necessary public consultation at the project sites, the SUPPLEMENTAL EIA reports in both Vietnamese and English shall be prepared for the final approval of the Gateway Port project.
- In order to understand the baseline of the natural environmental condition for the three (3) proposed dump site for the maintenance dredging and prepare the NEW EIA report for the NEW dump site, necessary Environmental Condition Survey shall be conducted. With the survey results and necessary public consultation at the project sites, the NEW EIA reports in both Vietnamese and English shall be prepared for the approval of the NEW dump site EIA.
- In order to collect the base line environmental data for Tan Vu-Lach Huyen Highway Project.

Survey points are shown in Figure 3.2.1.

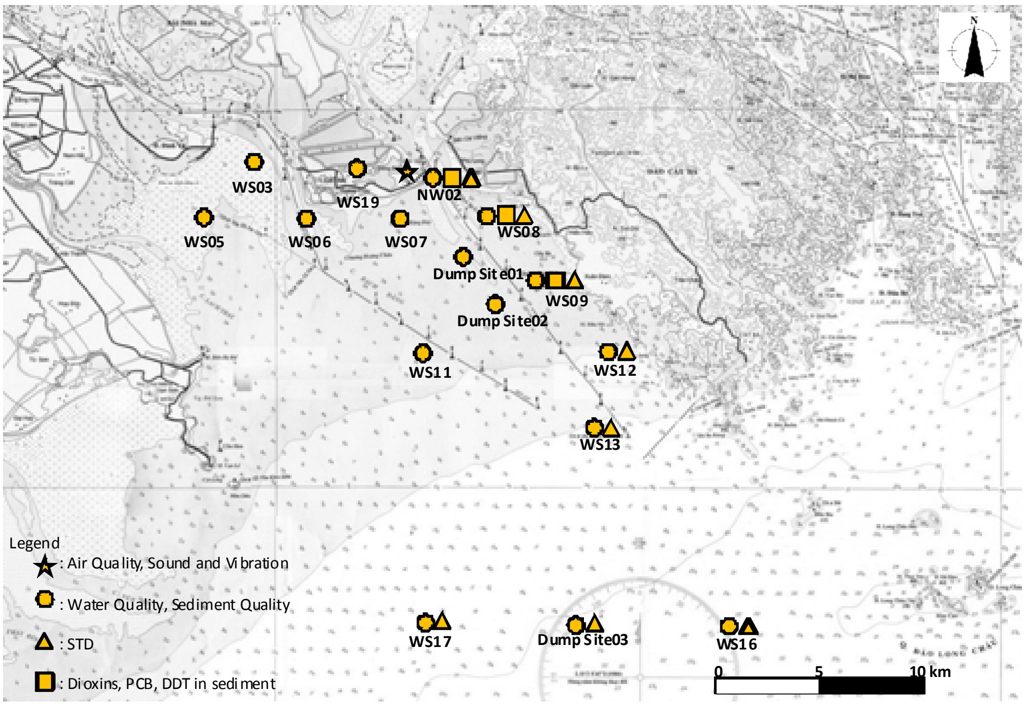


Figure 3.2.1 Survey Point for Air Quality, Sound, Vibration, Water Quality and Sediment Quality

3.2.1 Methodology

In this section, survey methodology is introduced.

Basically the Vietnamese Technical Standard (TCVN, TCQS) was referred for sampling and chemical analysis. Analytical method by USEPA[2] and the Standard method[3] are also referred if proper method in Vietnam is not applicable.

List of actual equipment, method for each survey parameter is stored in Appendix 3-2.

1) Air Quality

Survey items, locations, frequency, number of samples and method are summarized in Table 3.2.1

Table 3.2.1 Survey Summary (Air Quality)

Survey Item	Location	Frequency	Number of Samples	Method
Temperature	1 site (the nearest site to the potential NEW Dumpsite02)	One (1) time	2 (morning and afternoon)	TCVN 5949:1998
Wind speed				
Humidity				
TSP				TCVN 5067:1995
SO_2				TCVN 5971:1995
NO_2				TCVN 6137:1996
CO				TCVN 5972:1995
VOC				Gas chromatography

2) Sound and Vibration

Survey items, locations, frequency, number of samples and method are summarized in Table 3.2.2.

Table 3.2.2 Survey Summary (Sound and Vibration)

Survey Item	Location	Frequency	Number of Samples	Method
Sound Level (L_{eq}, L_5, L_{95})	1 site (the nearest site to the potential NEW Dumpsite02)	One (1) time (24hours)	3 (6-18h, 18-22h, 22-6h)	TCVN 7878-2-2010
Vibration Level (L_{eq})			Every 1 hour	Portable Vibration Meter (RION)

3) Water Quality

Survey items, locations, frequency, number of samples and method are summarized in Table 3.2.3.

Vertical profiles for Water temperature, Salinity/Conductivity and depth were obtained by equipment at several survey sites.

WS-19 is survey in order to complement information in salt field/fish pond for the road and bridge portion project.

[2] USEPA: United States Environmental Protection Agency, U.S.A
[3] SMEWW : Standard Methods for the Examination of Water and Wastewater, 20th Edition, L. S. Clesceri et Al., 1998, APHA

Table 3.2.3 Survey Summary (Water Quality)

Survey Item	Location	Frequency	Number of Samples	Method
Water Temperature	**Coastal Water:** 16 sites (NM02, WS03, WS05-09, WS11-13, WS16-17, Dump Site01-03, **Water Channel in salt field/fish pond:** 1site(WS19)	Two (2) times (High tide and Low tide) of a day	**Coastal Water:** three (3) samples (surface, middle, and bottom +0.5m) x two (2) tides (high & low) per each site in a day **Water Channel in salt field/fish pond:** 1 site (WS19): one (1) sample (surface) x two (2) tides (high & low) per each site in a day	TCVN 4457:88
Salinity				SMEWW 2520 B
pH				TCVN 6492:1999
DO (dissolved Oxygen)				TCVN 5499:1995
SS (Suspended Solid)				TCVN 6625:2000
BOD_5				TCVN 6001-1:2008
Total Nitrogen				SMEWW 4500 N.C
Total Phosphorus				TCVN 6202:2008
NH_3				SMEWW 4500 NH_3-F
Fe				TCVN 6177:1996
Cr^{3+}				SMEWW 3113 TCVN 7939:2008
Cr^{6+}				
Pb				TCVN 6193:1996
Zn				
Cd				
As				TCVN 6626-2000
Hg				TCVN 7877:2008
Mn				SMEWW 3500 MnB
Hydrocarbons / Mineral Oils				TCVN 5070:1995
Coliform				TCVN 6187-2:1996
Vertical profile of STD (Salinity, Temperature and Depth)	8 sites (NM02, WS08-09, WS12-13, WS16-17, Dump Site03	Two (2) times (High tide and Low tide) in a day	One (1) vertical data for 1 measurement	Vertical profile was obtained by equipment in the field.

Note: Sampling is based on the TCVN 5992:1995, TCVN 5993:1995 and TCVN 5998:1995

4) Sediment Quality

Survey items, locations, frequency, number of samples and method are summarized in Table 3.2.4.

Dioxins, PCB and DDT were sampled at three (3) sites (NM02, WS08 and WS09) to study the influence of hazardous substances to the environment through dredged materials on dumping.

Table 3.2.4 Survey Summary (Sediment Quality)

Survey Item	Location	Frequency	Number of Samples	Method
Fe	16 sites (NM02, WS03, WS05-09, WS11-13, WS16-17, WS19, Dump Site01-03,	One time only	One (1) sample per each site	TCVN 6649:2000 TCVN 6177:1996
Cr				TCVN 6649:2000 TCVN 6496:1999
Cu				
Pb				
Zn				
Cd				
As				TCVN 6649:2000 TCVN 6626:2000

Survey Item	Location	Frequency	Number of Samples	Method
Hg				TCVN 6649:2000 TCVN 7877:2008
Hydrocarbons / Mineral Oils				TCVN 5070:1995
Dioxins	3 sites (NM02, WS08-09)	One time only	One (1) sample per each site	TCQS 01:2010/NĐVN
PCB				EPA 617 – 1996
DDT				TCVN 7876 – 2008

3.2.2 Survey Result

1) Air Quality

Survey date and time, location and its coordinate are shown in Table 3.2.5, and survey result is shown in Table 3.2.6.

Comparing the data with the Vietnamese Standard, all parameters (CO, SO_2, NO_2 and TSP) are satisfied in both morning and evening time. VOC (Volatile Organic Compound) was not detected.

Table 3.2.5 Survey Date and Time, Location and Coordinate

Location	Sampling	Coordinate	Date and Time
In front of the house of Mr. Thao Thanh (near Cat Hai bulkheads). Don Luong Section (Near Dump site NM 02)	KK-Morning	20°47’47”N, 106°53’36”E	7:00 – 8:00, 16/5/2011
	KK-Evening		15:00 – 16:00, 16/5/2011

Table 3.2.6 Survey Result (Air Quality)

	Temperature (°C)	Humidity (%)	Wind speed (m/s)	CO (mg/m^3)	SO_2 (mg/m^3)	NO_2 (mg/m^3)	VOC	TSP (mg/m^3)
KK-Morning (1-Hour Average)	26	84	2.147	0.934	0.101	0.028	<0.005	0.11
KK-Evening (1-Hour Average)	28	80	1.934	1.583	0.116	0.063	<0.005	0.13
Vietnamese Standard (QCVN 05:2009/BTNMT) (1-Hour)	-	-	-	30	0.35	0.2	-	0.3

2) Sound and Vibration

Survey date and time, location and its coordinate are shown in Table 3.2.7, and survey result is shown in Table 3.2.8.

Sound levels (L_{eq}, L_{10} and L_{90}) are all satisfied the Vietnamese Standard in all time slots.

Vibration levels (L_{eq}) are also all satisfied the Vietnamese Standard in all time slots.

Original data is shown in Appendix 3-2.

Table 3.2.7 Survey Date and Time, Location and Coordinate

<table>
<tr><th></th><th>Location</th><th>Sampling</th><th>Coordinate</th><th>Date and Time</th></tr>
<tr><td>Sound</td><td rowspan="2">In front of the house of Mr. Thao Thanh (near Cat Hai bulkheads). Don Luong Section (Near Dump site NM02</td><td rowspan="2">24 hours</td><td rowspan="2">20°47'47"N, 106°53'36"E</td><td>From 6:00 16/5/2011 to 6:00 17/5/2011</td></tr>
<tr><td>Vibration</td><td>From 11:00 3/8/2011 to 11:00 4/8/2011</td></tr>
</table>

Survey for vibration was conducted in August due to equipment failure

Table 3.2.8 Survey Result (Sound)

<table>
<tr><th rowspan="3"></th><th rowspan="3">Period</th><th colspan="3">Results</th><th colspan="3" rowspan="2">Vietnamese Standard</th></tr>
<tr><th colspan="3">Sound (average of 8 Hour)</th></tr>
<tr><th>L_{eq}</th><th>L₁₀</th><th>L₉₀</th><th>6h – 21h</th><th>21h – 6h</th><th></th></tr>
<tr><td rowspan="3">Sound</td><td>6 h – 14 h</td><td>58.4</td><td>59.2</td><td>46.0</td><td>70</td><td>-</td><td rowspan="3">QCVN 26:2010/BTNMT</td></tr>
<tr><td>14h – 22h</td><td>59.5</td><td>59.9</td><td>48.0</td><td>70</td><td>-</td></tr>
<tr><td>22h – 6h</td><td>49.5</td><td>52.1</td><td>38.8</td><td>-</td><td>55</td></tr>
<tr><td>Vibration</td><td>11h – 11h</td><td>58 - 62</td><td>-</td><td>-</td><td colspan="2">75</td><td>QCVN 27:2010/BTNMT</td></tr>
</table>

3) Water Quality

a) General Parameters

Survey date and time, coordinate and depth are shown in Table 3.2.9, and summary of survey result is shown in Table 3.2.10. As the survey objective for WS-19 is to complement data for the report on the road and bridge potion project, the result is not included in the table.

Original data are put in Appendix 3-2.

None of unusual data was detected.

The concentration of Total Suspend Solid (TSS) at the surface is less than that at bottom layer. This suggest that 1) influence of fresh water from the river is small at this time and 2) turbid water mass exists at bottom layer in this area, which might cause negative impact on construction phase.

Concentrations of Total Phosphorous and Total Nitrogen are comparatively high. 1mg/L for Total Nitrogen and 0.09mg/L for Total Phosphorus (annual average) are applied in Japan as the Environmental Standard for Fishery class 3, industrial water and conservation of habitable environment for marine biota.

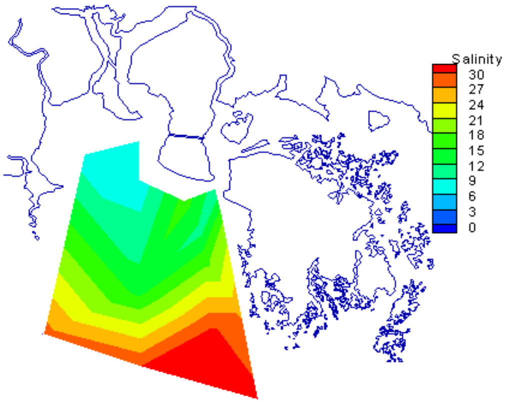
Figure 3.2.2 and Figure 3.2.3 show horizontal distribution of major parameters of water quality in low tide and high tide respectively. Concentration of each parameter tends to decrease from upper part of the figure to lower part of the figure. This suggests that influence of river flow is comparatively great in this area and it reaches to the end of the planned channel.

Table 3.2.9 Survey Date and Time, Coordinate and Depth

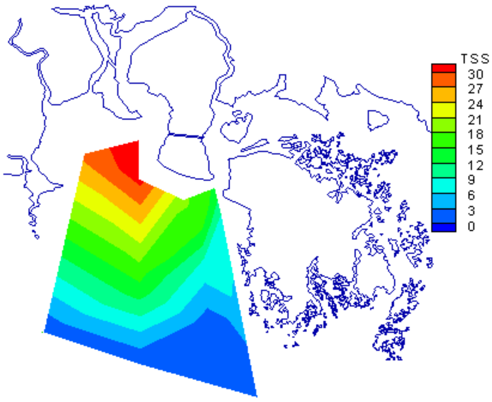
No.	Name	High tide					Low tide				
		Longitude	Latitude	Depth (m)	Sampling Time		Longitude	Latitude	Depth (m)	Sampling Time	
					Hour	Date				Hour	Date
1	NM-02	106º54'42"E	20º47'54"N	13.9	18h30	16/5/2011	106º54'41"E	20º47'54"N	11.6	4h30	18/5/2011
2	WS-03	106º49'30"E	20º48'55"N	1.6	17h00	16/5/2011	106º49'30"E	20º48'55"N	1.0	8h50	18/5/2012
3	WS-05	106º48'10"E	20º47'06"N	2.5	15h40	16/5/2011	106º48'10"E	20º47'06"N	1.6	8h00	18/5/2013
4	WS-06	106º50'50"E	20º47'06"N	6.2	16h00	16/5/2011	106º50'50"E	20º47'06"N	4.7	7h15	18/5/2014
5	WS-07	106º53'31"E	20º47'06"N	4.1	13h15	16/5/2011	106º53'31"E	20º47'06"N	2.8	6h45	18/5/2015
6	WS-08	106º56'04"E	20º47'06"N	5.2	15h00	16/5/2011	106º56'04"E	20º47'05"N	2.2	5h00	18/5/2016
7	WS-09	106º57'28"E	20º45'31"N	6.2	14h00	17/5/2011	106º57'24"E	20º45'23"N	3.5	6h45	18/5/2017
8	WS-11	106º54'16"E	20º43'49"N	7.0	15h15	17/5/2011	106º54'00"E	20º43'47"N	5.2	8h03	18/5/2018
9	WS-12	106º59'17"E	20º43'29"N	7.6	16h24	17/5/2011	106º59'10"E	20º43'21"N	5.3	5h35	18/5/2019
10	WS-13	106º58'46"E	20º40'50"N	14.7	15h00	17/5/2011	106º58'08"E	20º40'08"N	12.4	4h55	18/5/2020
11	WS-16	107º02'00"E	20º36'00"N	24.6	18h45	17/5/2011	107º02'00"E	20º36'00"N	22.7	1h00	18/5/2021
12	WS-17	106º54'00"E	20º36'00"N	21.1	16h30	17/5/2011	106º54'00"E	20º36'00"N	17.5	3h15	18/5/2022
13	Dump site 01	106º55'10"E	20º46'00"N	2.6	13h10	17/5/2011	106º54'55"E	20º45'23"N	3.5	7h20	18/5/2023
14	Dump site 02	106º56'45"E	20º45'01"N	6.3	14h26	17/5/2011	106º56'30"E	20º44'50"N	3.0	6h22	18/5/2024
15	Dump site 03	106º58'00"E	20º36'00"N	23.3	17h35	17/5/2011	106º58'00"E	20º36'00"N	20.9	2h20	18/5/2025
16	WS-19	106º52'23"E	20º48'23"N	0.8	16h00	16/5/2011	106º52'23"E	20º48'26"N	0.2	8h00	18/5/2026

Table 3.2.10 Summary of the Survey Result (Water Quality)

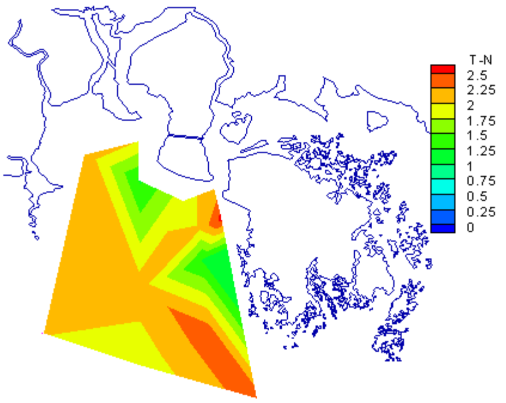
Item	Unit	High Tide									Low Tide									Vietanease Standard (QCVN 10:2008/BTNMT, Other sea area)
		Surface			Middle			Bottom			Surface			Middle			Bottom			
		Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	
Temperature	^oC	24.0	28.6	25.9	24.0	26.8	25.2	24.0	25.6	24.8	24.0	26.8	25.0	24.0	26.8	25.0	23.0	26.7	24.8	-
pH	-	7.69	8.13	7.97	7.66	8.17	7.98	7.81	8.17	8.01	7.37	8.15	7.83	7.40	8.16	7.87	7.24	8.13	7.84	6.5-8.5
Sality	%o	7.3	31.6	20.6	8.9	31.8	25.5	15.1	31.9	27.8	6.9	31.1	17.6	10.2	31.7	22.6	8.7	32.1	23.2	-
BOD_5	mg/l	0.6	2.2	1.6	0.5	2.0	1.4	0.5	1.8	1.4	0.7	2.4	1.7	0.6	2.2	1.6	0.6	2.3	1.6	-
DO	mg/l	5.25	6.46	6.04	5.10	9.95	6.05	4.62	6.51	5.48	5.06	6.59	5.90	4.98	6.19	5.51	4.27	5.76	5.16	-
TSS	mg/l	0.8	48.3	11.8	1.9	52.3	14.2	2.2	82.6	24.7	5.1	32.3	15.7	1.2	29.8	15.4	6.3	62.4	29.3	-
NH_3	mg/l	0.277	0.848	0.549	0.286	0.843	0.509	0.260	0.945	0.489	0.367	0.743	0.562	0.371	0.687	0.486	0.371	0.657	0.485	0.5
Toal Phosphorus	mg/l	1.982	2.556	2.210	1.961	2.774	2.220	1.963	2.519	2.276	1.141	2.526	2.194	1.762	2.614	2.231	1.594	2.910	2.279	-
Total Nitrogen	mg/l	1.172	3.014	1.925	1.069	2.726	1.804	1.206	2.267	1.712	1.206	2.415	1.856	1.087	2.610	1.804	1.313	2.743	1.927	-
Cr^{3+}	mg/l	0.001	0.021	0.009	0.004	0.026	0.011	0.002	0.025	0.010	0.002	0.022	0.008	0.003	0.017	0.011	0.002	0.068	0.013	0.2
Cr^{6+}	mg/l	0.003	0.024	0.011	0.002	0.021	0.011	0.004	0.016	0.008	0.002	0.013	0.007	0.002	0.016	0.007	0.002	0.016	0.008	0.05
Zn	mg/l	0.001	0.005	0.003	0.001	0.005	0.002	0.001	0.009	0.003	0.002	0.008	0.004	0.002	0.006	0.004	0.001	0.006	0.004	2.0
Cd	mg/l	3.0E-04	8.0E-04	5.3E-04	4.0E-04	7.0E-04	5.3E-04	2.0E-04	7.0E-04	4.9E-04	5.0E-04	7.0E-04	5.9E-04	5.0E-04	7.0E-04	5.7E-04	5.0E-04	7.0E-04	5.9E-04	5.0E-03
Pb	mg/l	0.001	0.003	0.002	0.001	0.004	0.002	0.001	0.004	0.002	0.001	0.003	0.002	0.001	0.005	0.002	0.001	0.004	0.002	0.1
Total-Fe	mg/l	0.465	1.995	0.965	0.535	2.170	1.118	0.478	1.990	1.128	0.379	1.881	1.115	0.420	1.770	1.030	0.389	1.960	1.081	0.3
Mn	mg/l	0.0004	0.0047	0.0021	0.0005	0.0062	0.0025	0.0012	0.0052	0.0024	0.0007	0.0062	0.0021	0.0001	0.0030	0.0017	0.0002	0.0047	0.0019	0.1
As	mg/l	0.001	0.006	0.003	0.001	0.007	0.004	0.002	0.007	0.004	0.001	0.005	0.003	0.002	0.006	0.004	0.001	0.006	0.004	0.05
Hg	mg/l	1.0E-04	9.0E-04	3.6E-04	1.0E-04	7.0E-04	3.2E-04	1.0E-04	7.0E-04	3.2E-04	1.0E-04	8.0E-04	3.1E-04	1.0E-04	4.0E-04	2.4E-04	1.0E-04	5.0E-04	1.8E-04	5.0E-03
Hydrocarbons/ mineral Oils	mg/l	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
Coliform	MPN/100ml	200	450	299	190	360	251	190	390	289	220	440	297	190	360	252	200	390	318	1000



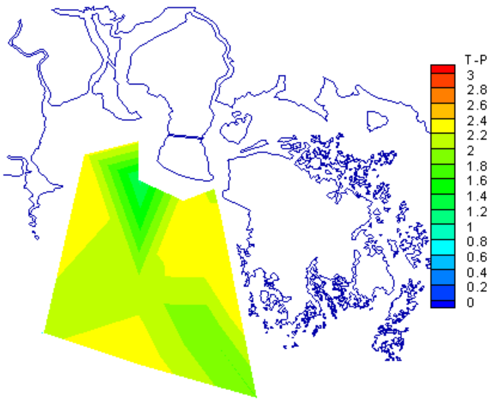
Salinity (-)



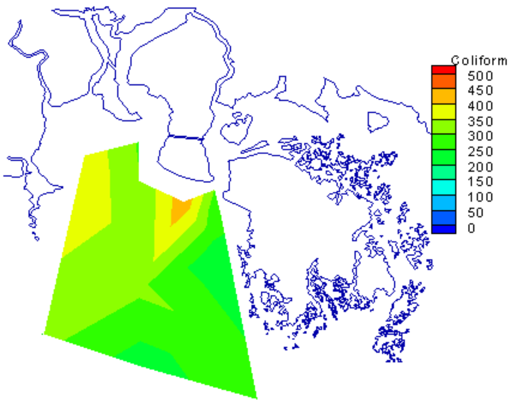
TSS (mg/L)



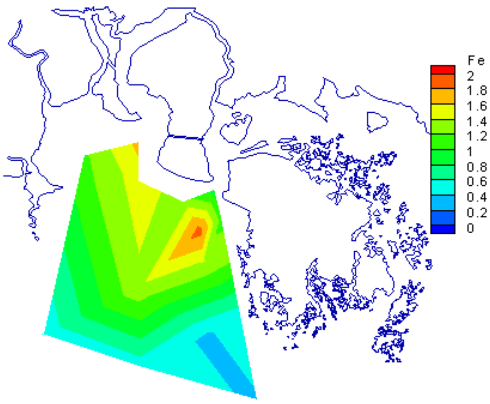
T-N (mg/L)



T-P (mg/L)



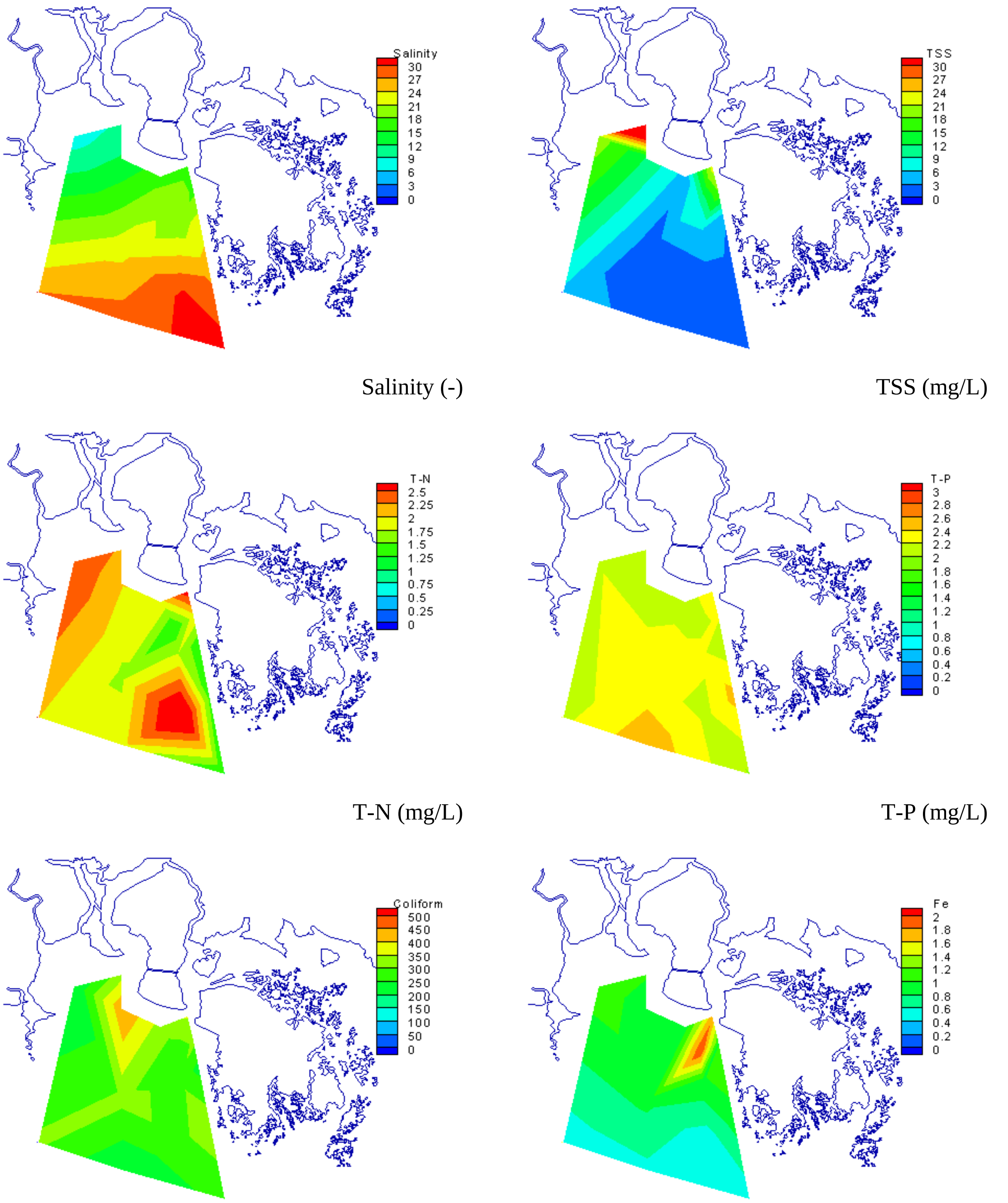
Coliform (100 individuals/100mL)



Fe (mg/L)

Date: May 18th, 2011
Major parameters are specified.

Figure 3.2.2 Horizontal Distribution of Water Quality (Low Tide)



Salinity (-)

TSS (mg/L)

T-N (mg/L)

T-P (mg/L)

Coliform (100 individuals/100mL)

Fe (mg/L)

Date: May 16th, 2011
Major parameters are specified.

Figure 3.2.3 Horizontal Distribution of Water Quality (High Tide)

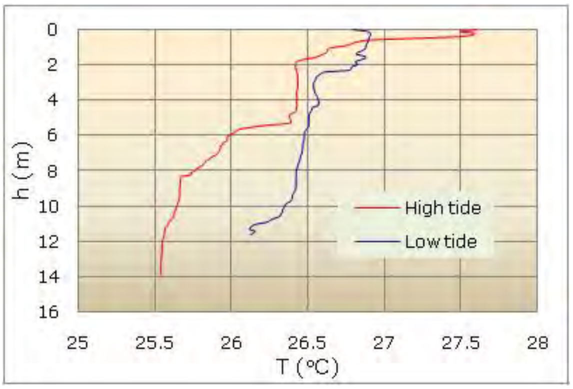
b) Vertical Profile of Water Temperature and Salinity

Survey date and time, coordinate are shown in Table 3.2.11, and vertical distributions of Water Temperature and Salinity are shown in Figure 3.2.4 and Figure 3.2.5. Original data are put in Appendix 3-2.

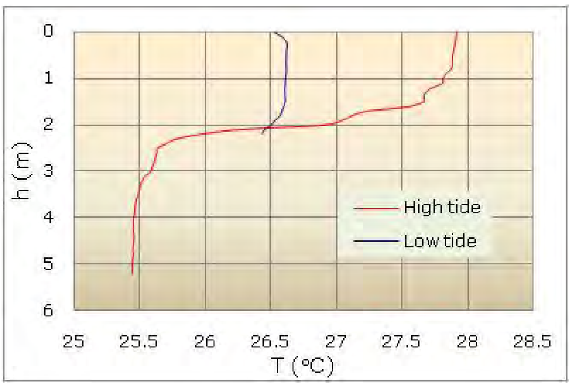
Influence of river water causing lowering of water temperature salinity at upper layer is clearly seen at the near shore points such as NM02, WS08, WS09 and WS12 in both tides.

Table 3.2.11 Survey Date and Time and Coordinate

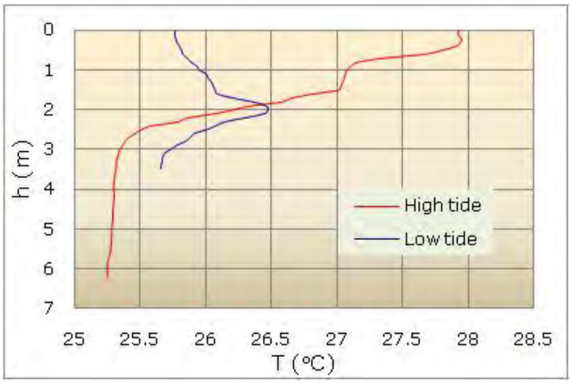
NO.	Name	Location		High Tide		Low Tide	
		Longitude	Latitude	Date	Time	Date	Time
1	NM02	106° 54’ 43’’E	20° 48’03’’N	5/17	12h36	5/18	7h05
2	WS08	106° 56’ 01’’E	20° 46’56’’N	5/17	13h09	5/18	6h38
3	WS09	106° 57’ 33’’E	20° 45’22’’N	5/17	13h42	5/18	6h11
4	WS12	106° 59’ 23’’E	20° 43’23’’N	5/17	14h18	5/18	5h34
5	WS13	106° 58’ 45’’E	20° 40’55’’N	5/17	14h54	5/18	4h50
6	WS16	107° 02’ 00’’E	20° 36’00’’N	5/17	18h48	5/18	1h01
7	WS17	106° 54’ 00’’E	20° 36’00’’N	5/17	16h28	5/18	3h18
8	Dump site 03	106° 58’ 00’’E	20° 36’00’’N	5/17	17h32	5/18	2h11



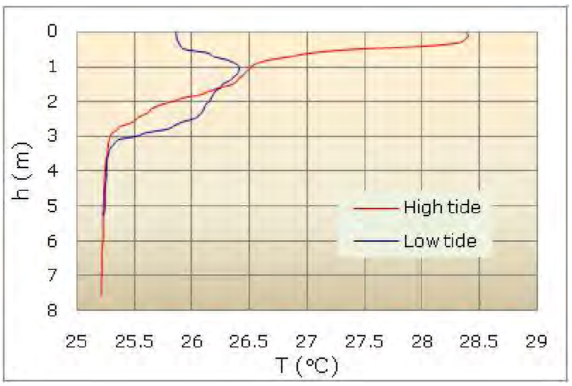
NM02



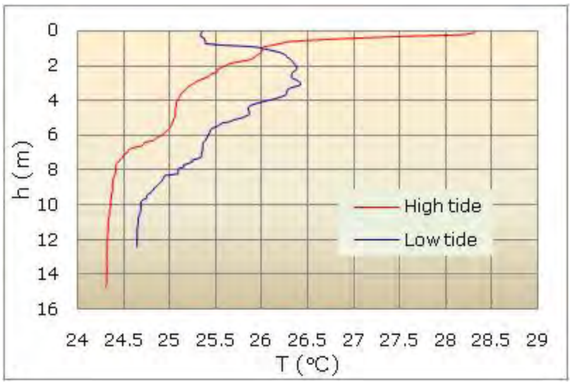
WS08



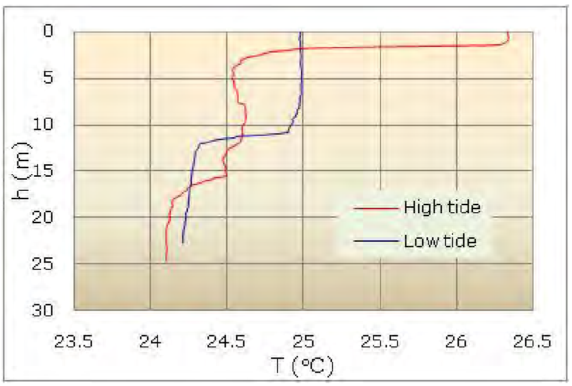
WS09



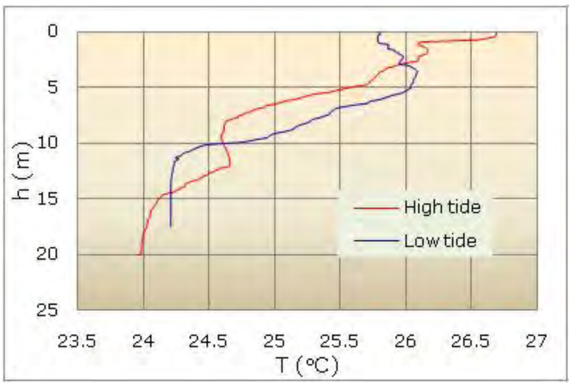
WS12



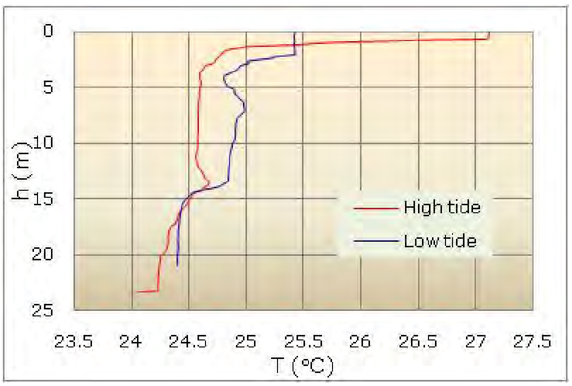
WS13



WS16

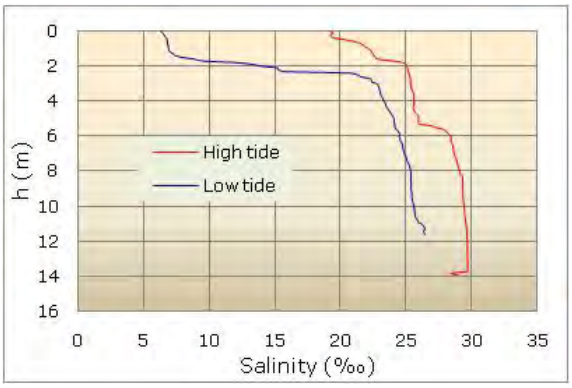


WS17

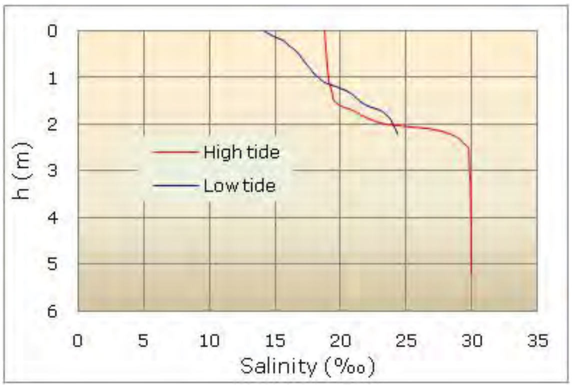


Dump site 03

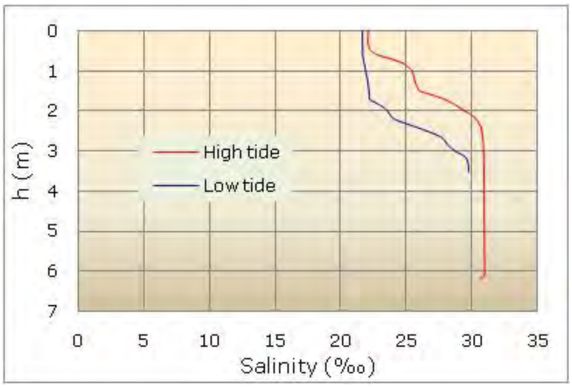
Figure 3.2.4 Vertical Distribution of Water Temperature



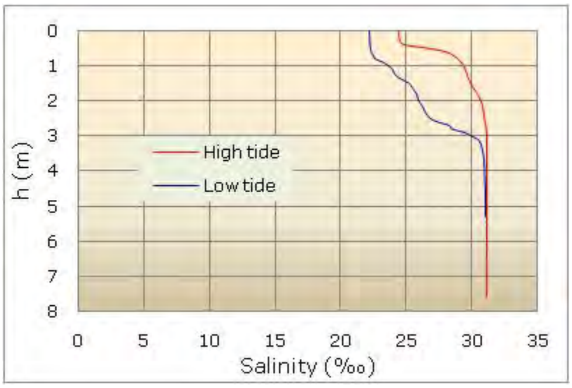
NM02



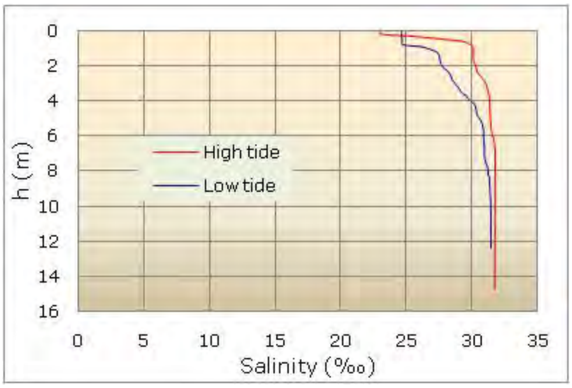
WS08



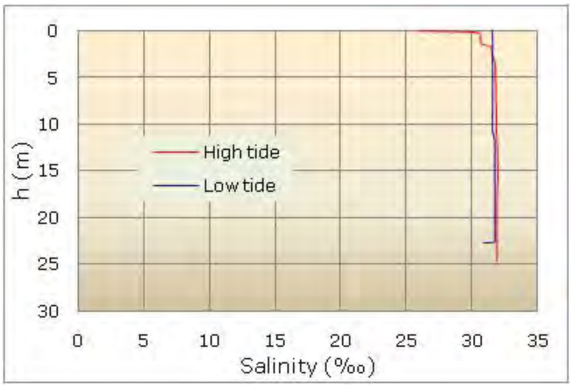
WS09



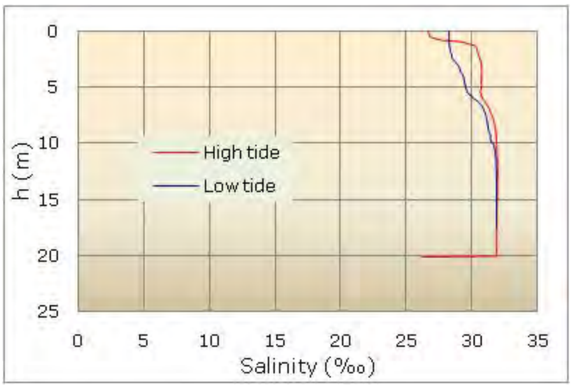
WS12



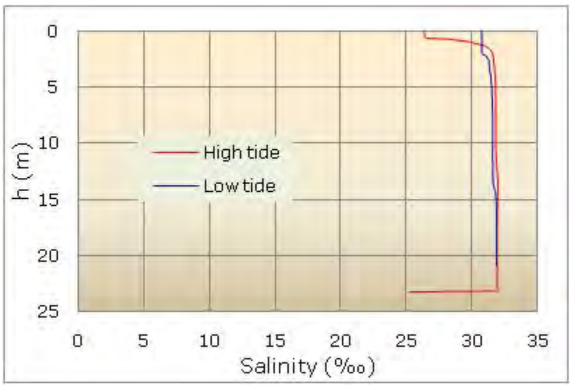
WS13



WS16



WS17



Dump site 03

Figure 3.2.5 Vertical Distribution of Salinity

4) Sediment Quality

a) General Parameters

Survey date and time, coordinate and depth are shown in Table 3.2.12, and summary of survey result is shown in Table 3.2.13. Original data are put in Appendix 3-2.

There is no technical regulation available in Vietnam regarding sea bottom sediment. Screening levels for dumping in a guideline by Australia[4] are referred to evaluate the appropriateness of the concentration. Concentrations of Cu and Pb exceed the value in some point (WS06 in Cu, WS06 and WS13 in Pb), but the exceedance is less than 2% except WS06 in Pb.

Figure 3.2.6 shows horizontal distribution of sediment quality. The distribution pattern is the same as that of water quality, higher concentration at upper part of figure and lower concentration at lower part of the figure, suggesting the influence of river flow.

Table 3.2.12 Survey Date and Time, Coordinate and Depth

No	Name	Longitude	Latitude	Depth (m)	Time		Note
					Hour	Date	
1	NM-02	106°54’42”	20°47’54”	13.9	18h35	16/5/2011	High tide
2	WS-03	106°49’30”	20°48’55”	1.6	17h10	16/5/2011	High tide
3	WS-05	106°48’10”	20°47’06”	2.5	15h50	16/5/2011	High tide
4	WS-06	106°50’50”	20°47’06”	6.2	16h00	16/5/2011	High tide
5	WS-07	106°53’31”	20°47’06”	4.1	13h35	16/5/2011	High tide
6	WS-08	106°56’04”	20°47’06”	5.2	15h10	16/5/2011	High tide
7	WS-09	106°57’28”	20°45’31”	6.2	14h05	17/5/2011	High tide
8	WS-11	106°54’16”	20°43’49”	7.0	15h20	17/5/2011	High tide
9	WS-12	106°59’17”	20°43’29”	7.6	16h30	17/5/2011	High tide
10	WS-13	106°58’46”	20°40’50”	14.7	15h00	17/5/2011	High tide
11	WS-16	107°02’00”	20°36’00”	24.6	18h45	17/5/2011	High tide
12	WS-17	106°54’00”	20°36’00”	21.1	16h35	17/5/2011	High tide
13	Dump site 01	106°54’55”	20°45’23”	3.5	7h20	18/5/2023	Low tide
14	Dump site 02	106°56’45”	20°45’01”	6.3	14h41	17/5/2011	High tide
15	Dump site 03	106°58’00”	20°36’00”	23.3	17h35	17/5/2011	High tide

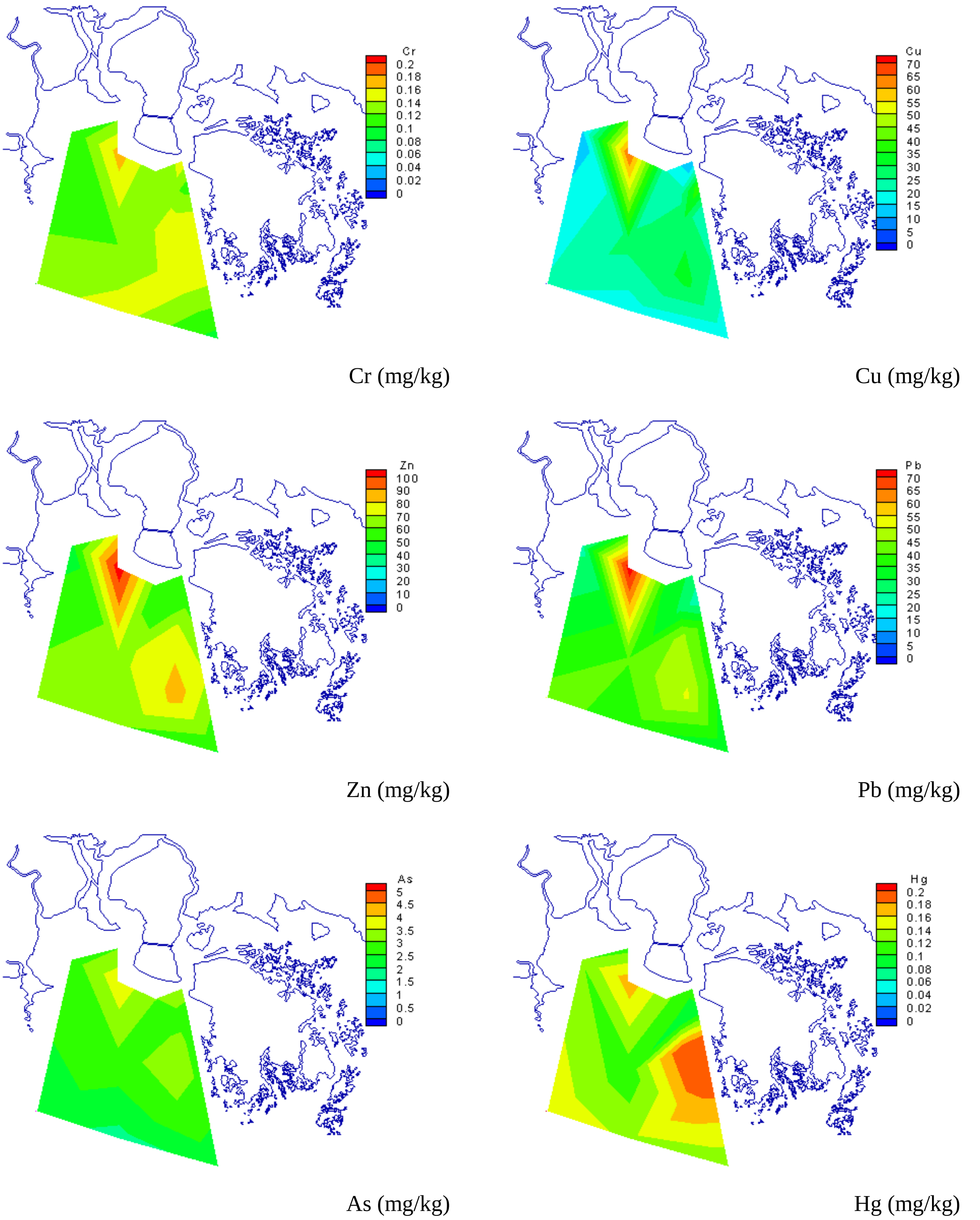
Table 3.2.13 Summary of Survey Result (Sediment Quality: General Parameters)

Unit: mg/kg

	Min.	Max.	Ave.	Guideline Value*
Cr	0.0930	0.1740	0.1319	80
Cu	10.05	65.70	26.40	65
Zn	45.95	106.81	65.58	200
Cd	0.012	0.029	0.022	1.5
Pb	20.70	73.80	37.78	50
Fe	1741	1823	1781	-
As	1.821	3.866	2.812	20
Hg	0.091	0.199	0.140	0.15
Hydrocarbons/ mineral Oils	10	40	17	550

*National Assessment Guidelines for Dredging, 2009, Australia

[4] National Assessment Guidelines for Dredging, 2009, Commonwealth of Australia



Date: May 16th, 2011
Major parameters are specified.

Figure 3.2.6 Horizontal Distribution of Sediment Quality

b) Dioxin, PCB and DDT

Survey date and time, coordinate and depth are shown in Table 3.2.14, and survey result is shown in Table 3.2.15.

PCBs and DDT were not detected, while low concentrations of Dioxin were detected.

Vietnamese National Technical Regulation (QCVN 07:2009/BTNMT, Hazardous Waste Thresholds) set the threshold value of Dioxins as 5ppm, which is much greater than the detected values.

According to the Japanese Environmental Standard, 150pg/TEQ-g is applied for water bottom sediment. This value is far greater than the one that was detected this time. As Dioxins has a lot of isomers, TEQ (Toxicity Equivalency Quantity) is used to evaluate its toxicity multiplying coefficient of toxic strength to quantity of each isomer.

Table 3.2.14 Survey Date and Time, Coordinate and Depth

Name	Longitude	Latitude	Depth (m)	Time		Note
				Hour	Date	
NM-02	106°54’42”	20°47’54”	13.9	18h35	16/5/2011	High tide
WS-13	106°58’46”	20°40’50”	14.7	15h00	17/5/2011	High tide
Dump site 02	106°56’45”	20°45’01”	6.3	14h41	17/5/2011	High tide

Table 3.2.15 Survey Result (Sediment Quality: Dioxin, PCB and DDT)

Name	PCBs (mg/Kg)	DDT (mg/Kg)	Dioxin (pg/g)
NM 02	<0.005	<0.005	1.67
WS 13	<0.005	<0.005	3.38
Dump site 02	<0.005	<0.005	2.41

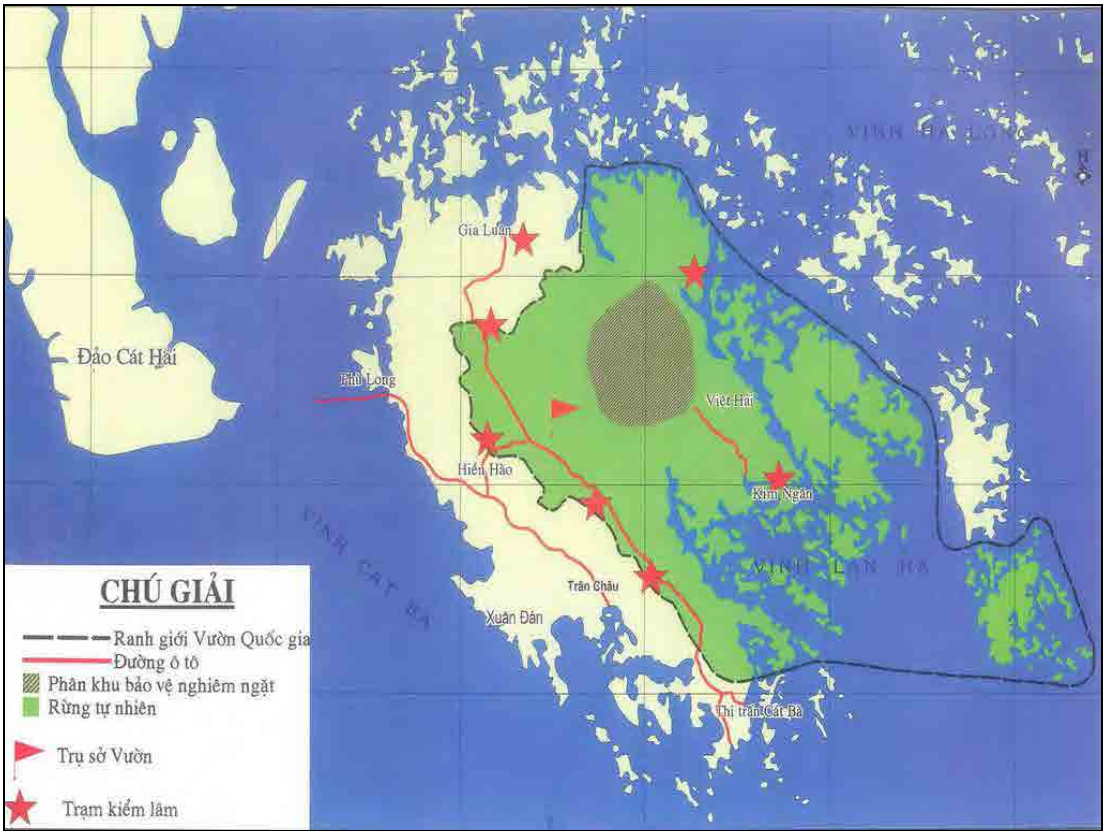
3.3 Biological Conditions

3.3.1 Protected area

A total of 15,200 ha of Cat Ba Island is designated as a national park (Cat Ba National Park) in accordance to Decision No. 79/CT of the Chairman of the Council of Ministers (dated 31 March 1986). Within the total area, 9,800 ha are terrestrial, while 5,400 ha are marine area. The national park supports a great diversity of habitats and ecosystems, including forested hills, small freshwater lakes, freshwater swamp forest, mangroves, sandy beaches and coral reefs. Figure 3.3.1 shows the boundary of Cat Ba National Park.

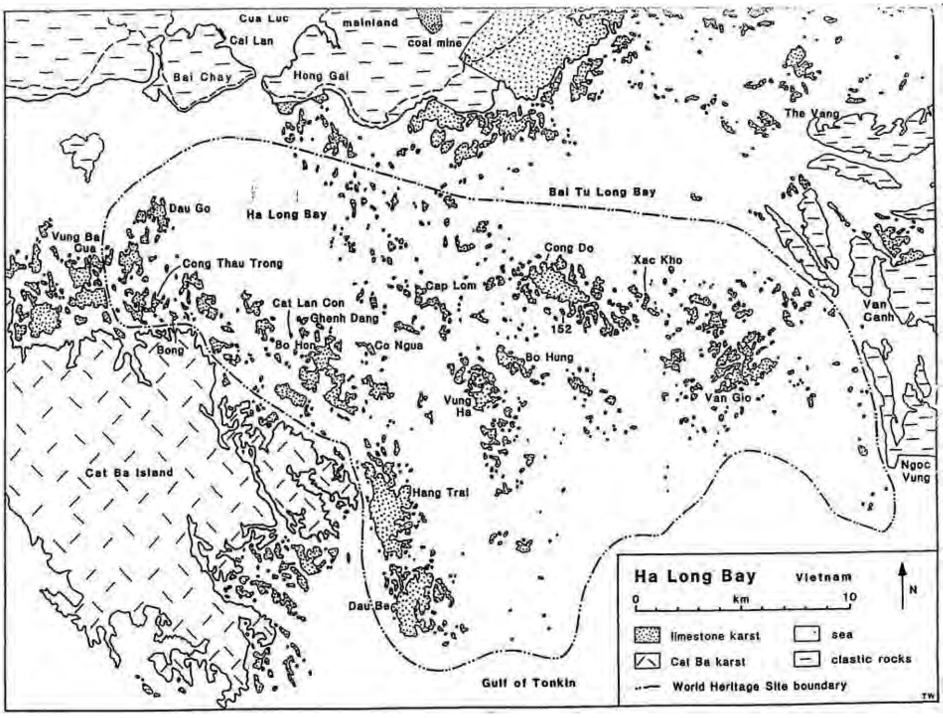
Cat Ba island is also designated as a Biosphere Reserve by UNESCO’s Man and the Biosphere (MAB) Programme since 2004. The total area is 26,241 ha, which is divided into core zone (8,500 ha (marine area: 2,000)), buffer zone (7,741 ha (marine area: 2,800)) and transition zone (10,000 ha (marine area: 4,400 ha)).

East to south of Cat Ba Island lay Halong Bay, which is designated as UNESCO’s World Heritage Site (natural site). It has an area of 150,000 ha. Figure 3.3.2 shows the boundary of the Halong Bay World Heritage Site.



Source: Vietnam National Parks and Protected Areas Association (2001)

Figure 3.3.1 Boundary (black dotted line) of Cat Ba National Park



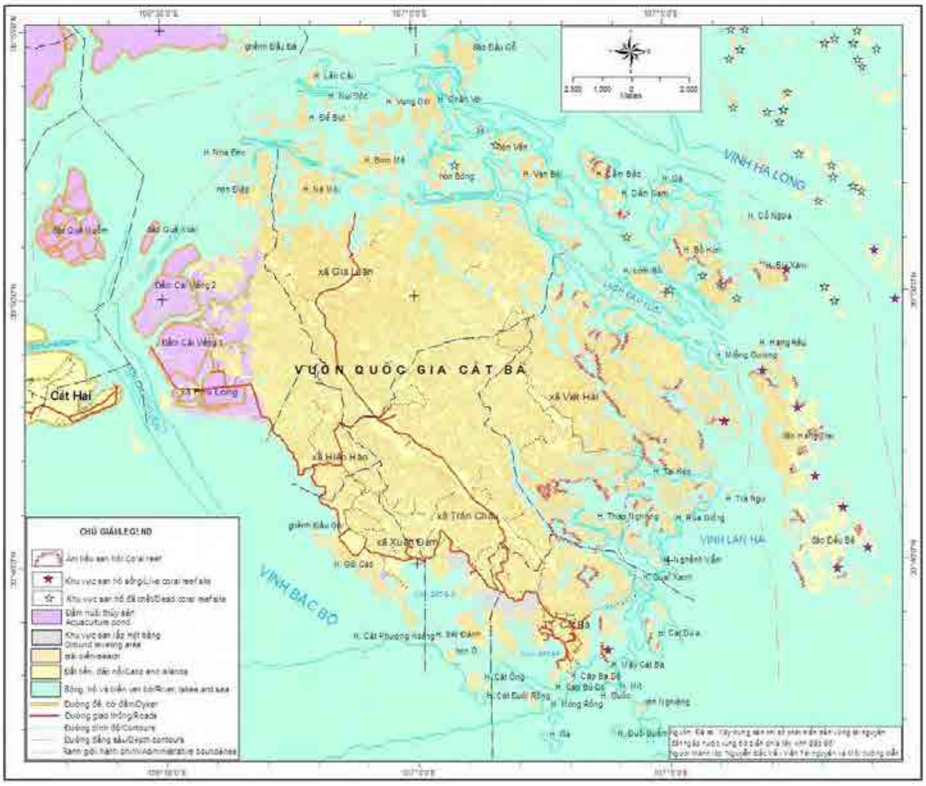
Source: UNESCO (http://whc.unesco.org/en/list/672/)

Figure 3.3.2 Boundary of Halong Bay World Heritage Site

3.3.2 Distribution of ecologically valuable marine habitats

Marine ecosystems such as coral reef, seagrass/seaweed beds and mangrove forest are considered ecologically valuable, as these areas function for example as spawning/nursery ground and habitat for various marine organisms.

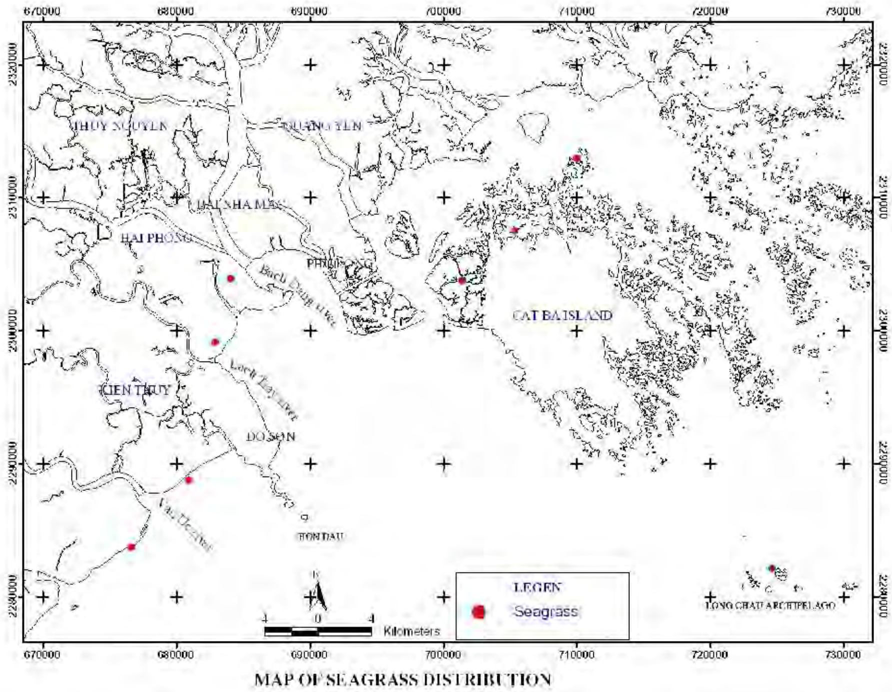
Figure 3.3.3 shows the distribution of coral reef in the Cat Ba Island, which is based on satellite image analysis and past spot-check surveys. Most of the coral reefs are fringing reefs surrounding the lime stone islands and are mainly distributed in the southeastern side of Cat Ba Island. Live coral coverage has reduced rapidly in recent years. In the past, some reefs had 50-70% live coral coverage but now most reefs have less than 40% live coral coverage. Coral reefs are also distributed in Long Chau Islands, which is located approximately 10 km south of Cat Ba Island.



Source: Nguyen Dac Ve (2010)

Figure 3.3.3 Distribution of coral reefs around Cat Ba Island

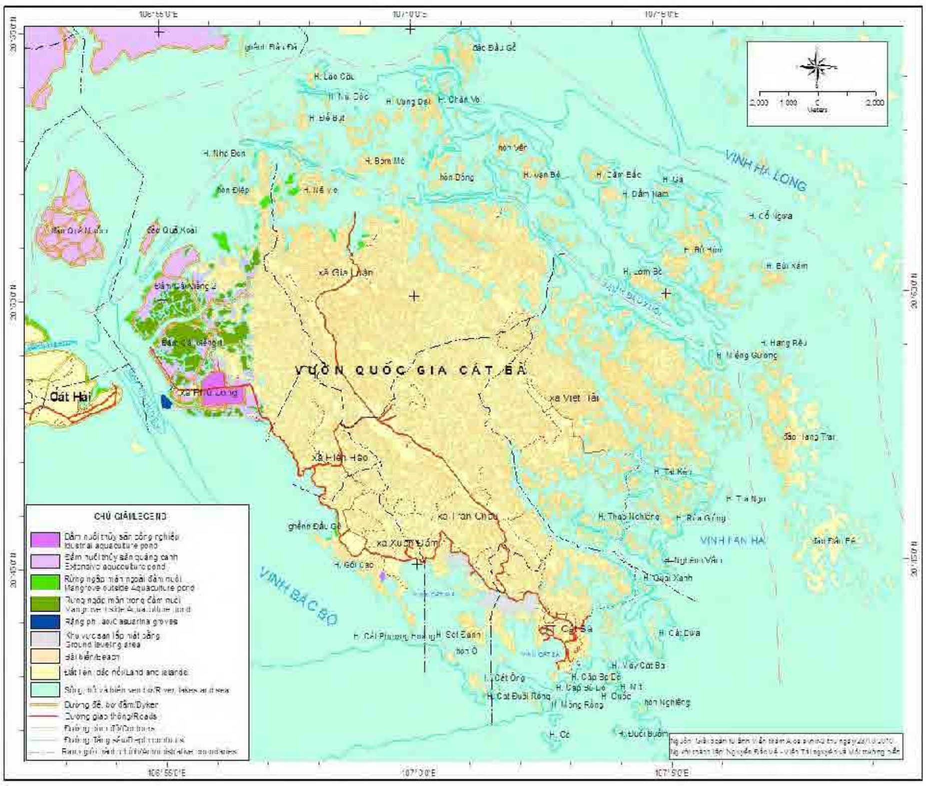
Figure 3.3.4 shows the distribution of seagrass bed around the project site which is based on past spot-check surveys. Most seagrass are distributed in small patches near mud flats and inside aquaculture ponds. Small patches of seagrass are also distributed in Long Chau Islands.



Source: Nguyen Dac Ve (2010)

Figure 3.3.4 Distribution of seagrass around the project site

Figure 3.3.5 shows the distribution of mangrove around Cat Ba Island which is based on satellite image analysis. Most of the mangroves are distributed in the Phu Long commune area. A large portion of the mangroves are distributed inland along aquaculture ponds.



Source: Nguyen Dac Ve (2010)

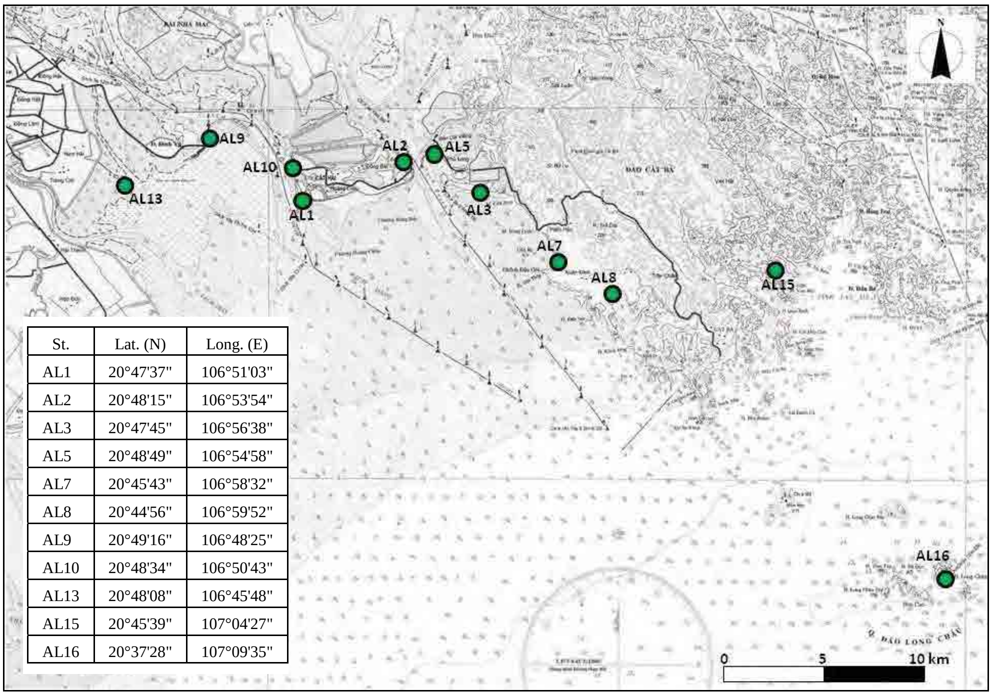
Figure 3.3.5 Distribution of mangrove forest around the project site

3.3.3 Results of field survey

In order to acquire baseline information/data on the biological conditions in and around the Lach Huyen Port project area, field surveys were conducted during May 15-19th (dry season) and August 3-4th (wet season) by subcontracting local Vietnamese consultant Technology Application and Training Center for Hydro-Meteorology and Environment (HYMETEC). Under the supervision of HYMETEC, the field surveys and laboratory analysis were conducted by Institute of Marine Environment and Resources (IMER). The field surveys covered the following items:

- Mangrove
- Seaweed/seagrass
- Coral
- Phytoplankton
- Zooplankton
- Zoobenthos
- Demersal fish/macrozoobenthos

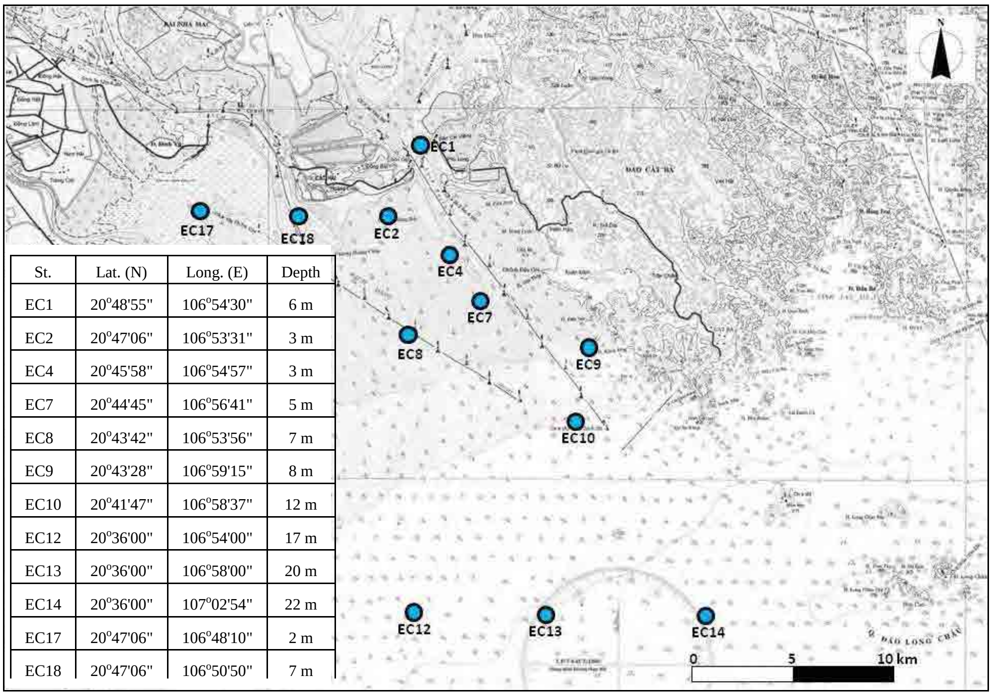
Mangrove, seaweed/seagrass and coral surveys were conducted only in the dry season survey. The location of the field survey sites is shown Figure 3.3.6 and Figure 3.3.7. The methodology and results are described in the ensuing sections.



St.	Lat. (N)	Long. (E)
AL1	20°47'37"	106°51'03"
AL2	20°48'15"	106°53'54"
AL3	20°47'45"	106°56'38"
AL5	20°48'49"	106°54'58"
AL7	20°45'43"	106°58'32"
AL8	20°44'56"	106°59'52"
AL9	20°49'16"	106°48'25"
AL10	20°48'34"	106°50'43"
AL13	20°48'08"	106°45'48"
AL15	20°45'39"	107°04'27"
AL16	20°37'28"	107°09'35"

Note 1: Coral was surveyed only at sites AL15 and AL16
Note 2: Site AL8 was not surveyed as the area was under construction activities.

Figure 3.3.6 Locations of the field survey sites (mangrove, seaweed/seagrass and coral)



St.	Lat. (N)	Long. (E)	Depth
EC1	20°48'55"	106°54'30"	6 m
EC2	20°47'06"	106°53'31"	3 m
EC4	20°45'58"	106°54'57"	3 m
EC7	20°44'45"	106°56'41"	5 m
EC8	20°43'42"	106°53'56"	7 m
EC9	20°43'28"	106°59'15"	8 m
EC10	20°41'47"	106°58'37"	12 m
EC12	20°36'00"	106°54'00"	17 m
EC13	20°36'00"	106°58'00"	20 m
EC14	20°36'00"	107°02'54"	22 m
EC17	20°47'06"	106°48'10"	2 m
EC18	20°47'06"	106°50'50"	7 m

Figure 3.3.7 Locations of the field survey sites (phytoplankton, zooplankton/larvae, zoobenthos, and demersal fish/macrozoobenthos)

1) Mangrove

a) Methodology

All mangrove species that were identified in the survey sites were recorded. Also to obtain quantitative data, a 10 m x 10 m quadrat was set at a location that was representative of the site, and the following information was recorded: species composition, canopy height (highest and lowest), stem diameter (1.3 m from ground) and density (no. of stems/100 m^2).

b) Results

Table 3.3.1 shows the mangrove species identified through the field survey. Eleven species belonging to 9 families were identified. *Rhizophora stylosa* and *Avicennia marina* were the most common species in the survey area. None of the identified species are included in the Vietnam Red Book.

Table 3.3.1 List of mangrove species identified through the field survey

	Family	Genus/species	Status in Vietnam Red Book	Identified survey sites
1	Sonneratiaceae	*Sonneratia caseolaris*	Not listed	AL9, AL10, AL13,
2	Rhizophoraceae	*Rhizophora stylosa*	Not listed	AL1, AL2, AL3, AL5, AL7
3	Rhizophoraceae	*Kandelia obovata*	Not listed	AL5, AL10, AL13
4	Rhizophoraceae	*Bruguirea gymnorrhiza*	Not listed	AL1, AL3, AL7
5	Aviceniaceae	*Avicennia marina*	Not listed	AL1, AL2, AL3, AL5, AL7
6	Myrsinaceae	*Aegiceras corniculatum*	Not listed	AL1, AL3, AL9
7	Pteridaceae	*Acrostichum aureum*h	Not listed	AL10, AL13
8	Acanthaceae	*Acanthus ilicifolius*	Not listed	AL13
9	Verbenaceae	*Cleodendrum inerme*	Not listed	AL2, AL10, AL13
10	Euphorbiaceae	*Excoecaria agallocha*	Not listed	AL3, AL5
11	Malvaceae	*Hibiscus tiliaceus*	Not listed	AL5

Source: JICA Study Team

Table 3.3.2 shows the results of the quadrat survey. In terms of canopy height and stem diameter, mangroves in AL2 and AL5 were significantly smaller compared to the other sites (see Figure 3.3.8), hence could be more vulnerable to natural and human impacts

Table 3.3.2 Results of mangrove quadrat survey

Survey site	Species composition	Max. and min. canopy height (m)	Ave. stem diameter (cm)	Density (no. of stems/100 m^2)
AL1	*Rhizophora stylosa* *Aegiceras corniculatum* *Bruguirea gymnorrhiza* *Avicennia marina*	Max.: 4.60 Min.: 1.20	4.90	41
AL2	*Avicennia marina* *Clerodendrum inerme* *Rhizophora stylosa*	Max.: 1.40 Min.: 0.80	1.20	51
AL3	*Rhizophora stylosa* *Excoecaria agallocha* *Bruguirea gymnorrhiza* *Avicennia marina* *Aegiceras corniculatum*	Max.: 2.51 Min.: 2.30	3.15	105
AL5	*Avicennia marina* *Rhizophora stylosa* *Excoecaria agallocha* *Kandelia obovata* *Hibiscus tiliaceus*	Max.: 1.50 Min.: 0.50	1.5	53
AL7	*Rhizophora stylosa* *Avicennia marina* *Bruguirea gymnorrhiza*	Max.: 3.60 Min.: 2.50	4.68	42
AL9	*Sonneratia caseolaris* *Aegiceras corniculatum*	Max.: 3.60 Min.: 2.50	8.12	38
AL10	*Sonneratia caseolaris* *Kandelia obovata* *Acrostichum aureum* *Clerodendrum inerme*	Max.: 5.00 Min.: 1.00	4.45	61
AL13	*Sonneratia caseolaris* *Kandelia obovata* *Ancanthus ebracteatus* *Clerodendrum inerme* *Acrostichum aureum*	Max.: 10.00 Min.: 1.20	10.00	42

Source: JICA Study Team

Figure 3.3.8 Mangroves at sites AL2 (left) and AL5 (right)

2) Seaweed/seagrass

a) Methodology

All seaweed/seagrass species that were identified in the survey sites were recorded. Samples were collected and preserved in a 10% formalin solution for further analysis at IMER’s laboratory. Except sites AL15 and 16, survey was conducted only along the shoreline (underwater survey was not possible due to very low water visibility). Sites AL15 and AL16 were surveyed by scuba diving.

b) Results

Table 3.3.3 shows the seaweed species identified through the field survey. Seventeen species belonging to 9 families were identified. *Chaetomorpha capillaris* and *Enteromorpha compressa* were the most common species. Some species such as *Asparagopsis taxiformis*, *Colpomenia sinuosa*, and *Cladophoropsis membrannacea* were identified at only specific sites. None of the identified species are included in the Vietnam Red Book. Some species in the *Ulvaceae* family are harvested for food stuffs in certain areas of Vietnam.

Table 3.3.3 List of seaweed species identified through the field survey

	Family	Genus/species	Status in Vietnam Red Book	Identified survey sites
1	Gracilariaceae	*Gracilaria tenuispitata*	Not listed	AL9, AL13
2	Bonnemaisoniaceae	*Asparagopsis taxiformis*	Not listed	AL16
3	Ceramiaceae	*Bostrychia binderi*	Not listed	AL3, AL5, AL7, AL10
4	Ceramiaceae	*Polysiphonia sertularioides*	Not listed	AL1, AL2, AL10
5	Delesseriaceae	*Caloglosa ogasawaraensis*	Not listed	AL2, AL3, AL7
6	Scytosiphonaceae	*Colpomenia sinuosa*	Not listed	AL16
7	Dictyotaceae	*Padina australis*	Not listed	AL15, AL16
8	Sargassaceae	*Sargassum* sp.	Not listed	AL16
9	Cladophoraceae	*Chaetomorpha capillaris*	Not listed	AL1, AL03, AL05, AL07, AL10, AL13, AL15, AL16
10	Cladophoraceae	*Ch. linum*	Not listed	AL1, AL9, AL10
11	Cladophoraceae	*Cladophora fascicularis*	Not listed	AL9
12	Cladophoraceae	*Cladophoropsis membrannacea*	Not listed	AL13
13	Ulvaceae	*Enteromorpha kylinii*	Not listed	AL13
14	Ulvaceae	*E. compressa*	Not listed	AL1, AL3, AL5, AL7, AL9, AL10, AL15, AL16
15	Ulvaceae	*E. kylinii*	Not listed	AL1, AL9, AL10
16	Ulvaceae	*E. flexuosa*	Not listed	AL1, AL9
17	Ulvaceae	*Ulva conglobata*	Not listed	AL5, AL16

Source: JICA Study Team

Table 3.3.4 shows the seagrass species identified through the field survey. Only two seagrass species *Ruppia maritima* and *Halophila beccarii* were identified, which were found at sites AL10 and AL16 respectively. *Halophila beccarii* was record for the first time in the surveyed area. Although both species are not included in the Vietnam Red Book, *Halophila beccarii* is classified as “Vulnerable” in IUCN Red List.

Table 3.3.4 List of seagrass species identified through the field survey

	Family	Genus/species	Status in Vietnam Red Book	Identified survey sites
1	Ruppiaceae	*Ruppia maritima*	Not listed	AL10
2	Hydrocharitaceae	*Halophila beccarii*	Not listed	AL16

Source: JICA Study Team

3) Coral

a) Methodology

Coral survey was conducted by scuba diving at sites AL15 and AL16. Species composition and live coral coverage were recorded at 5 m interval along a 100 m line transect.

b) Results

Table 3.3.5 shows the hard coral species identified through the field survey. Twenty-eight species and 58 species were identified at sites AL15 and AL16 respectively (see Figure 3.3.9). The diversity at site AL15 was lower probably due to relatively turbid conditions. However, live coral coverage was higher at AL15 (approx. 40%) compared to AL16 (approx. 30%). Within the identified species, 4 species are listed in the Vietnam Red Book namely: *Porites lobata*, *Acropora aspera*, *Acropora formosa* and *Acropora nobilis*; which are all classified as "Vulnerable". *Porites lobata* was found at AL15 and all 4 species were found at AL16.

Table 3.3.5 List of hard coral species identified through the field survey

	Survey site	Family	Genus/species	Status in Vietnam Red Book
1	AL15	Acroporidae	*Acropora pulchra*	Not listed
2		Poritidae	*Porites lobata*	**Vulnerable**
3			*Porites lutea*	Not listed
4			*Goniopora columna*	Not listed
5			*Goniopora lobata*	Not listed
6		Agariciidae	*Pavona decussata*	Not listed
7		Oculinidae	*Galaxea astreata*	Not listed
8			*Galaxea fascicularis*	Not listed
9		Pectiniidae	*Pectinia lactuca*	Not listed
10			*Echinophyllia aspera*	Not listed
11			*Mycedium elephantotus*	Not listed
12		Fungiidae	*Lithophyllon undulatum*	Not listed
13			*Sandalolitha robusta*	Not listed
14		Mussidae	*Lobophyllia hattaii*	Not listed
15			*Lobophyllia hemprichii*	Not listed
16			*Symphyllia. agaricia*	Not listed
17		Merulinidae	*Merulina ampliata*	Not listed
18		Faviidae	*Favia maritime*	Not listed
19			*Favia matthaii*	Not listed
20			*Favia lizardensis*	Not listed
21			*Favia maxima*	Not listed
22			*Favites abdita*	Not listed
23			*Goniastrea pectinata*	Not listed
24			*Goniastrea favulus*	Not listed
25			*Cyphastrea serailia*	Not listed
26			*Echinopora lamellose*	Not listed
27			*Platygyra daelalea*	Not listed
28		Dendrophylliidae	*Turbinaria peltata*	Not listed
1	AL16	Acroporidae	*Montipora tuberculosa*	Not listed
2			*Montipora crassituberculata*	Not listed
3			*Montipora undata*	Not listed
4			*Acropora humilis*	Not listed
5			*Acropora gemmifera*	Not listed
6			*Acropora aspera*	**Vulnerable**
7			*Acropora formosa*	**Vulnerable**

Survey site	Family	Genus/species	Status in Vietnam Red Book
8		*Acropora glauca*	Not listed
9		*Acropora nobilis*	**Vulnerable**
10		*Acropora tumida*	Not listed
11		*Acropora microphthalma*	Not listed
12		*Acropora pulchra*	Not listed
13		*Acropora cytherea*	Not listed
14		*Acropora hyacinthus*	Not listed
15		*Astreopora myriophthalma*	Not listed
16	Poritidae	*Porites solida*	Not listed
17		*Porites lobata*	**Vulnerable**
18		*Porites australiensis*	Not listed
19		*Porites lutea*	Not listed
20		*Goniopora stokesi*	Not listed
21		*Goniopora djiboutiensis*	Not listed
22		*Goniopora lobata*	Not listed
23		*Goniopora columa*	Not listed
24		*Goniopora stuchburyi*	Not listed
25	Siderastreidae	*Pseudosiderastrea tayamai*	Not listed
26	Agariciidae	*Pavona decussata*	Not listed
27		*Pavona explanulata*	Not listed
28	Fungiidae	*Sandalolitha robusta*	Not listed
29	Oculinidae	*Galaxea fascicularis*	Not listed
30	Pectiniidae	*Mycedium elephantotus*	Not listed
31	Merulinidae	*Merulina ampliata*	Not listed
32		*Hydnophora exesa*	Not listed
33	Mussidae	*Acanthastrea hillae*	Not listed
34		*Lobophyllia hemprichii*	Not listed
35		*Lobophyllia robusta*	Not listed
36		*Symphyllia recta*	Not listed
37		*Symphyllia radians*	Not listed
38		*Symphyllia agaricia*	Not listed
39	Faviidae	*Favia favus*	Not listed
40		*Favia mathaii*	Not listed
41		*Favia lizardensis*	Not listed
42		*Favia speciosa*	Not listed
43		*Favia halicora*	Not listed
44		*Favites complanata*	Not listed
45		*Favites pentagona*	Not listed
46		*Goniastrea retiformis*	Not listed
47		*Goniastrea aspera*	Not listed
48		*Goniastrea favulus*	Not listed
49		*Goniastrea australensis*	Not listed
50		*Platygyra daedalea*	Not listed
51		*Platygyra pini*	Not listed
52		*Montastrea curta*	Not listed
53		*Leptastrea purpurea*	Not listed
54		*Leptastrea pruinosa*	Not listed
55		*Echinopora lamellosa*	Not listed
56	Dendrophylliidae	*Turbinaria peltata*	Not listed
57		*Turbinaria mesenterina*	Not listed
58		*Turbinaria reniformis*	Not listed

Source: JICA Study Team

Figure 3.3.9 Hard coral species at sites AL15 (left) and AL16 (right)

4) Phytoplankton

a) Methodology

Phytoplankton samples were collected by towing a plankton net (mesh size: 20 µm, diameter: 20 cm) several times in the vertical direction. Phytoplankton samples were also collected from the surface by collecting 1 L of surface water. All samples were preserved in 3 ml Lugol solution for further analysis at IMER's laboratory.

b) Results

Table 3.3.6 shows the phytoplankton species identified through the dry and wet season surveys. A total of 134 and 136 species were identified in the dry and wet season surveys respectively. Chaetoceros spp. were found in many survey sites in both seasons, which play an important role as food sources for fish and other marine species, in particular at the early stages of their life cycle. Some of the identified dinoflagellate species such as *Ceratium fusus*, *Prorocentrum micans* and *Dinophysis* caudate are known to cause red tide and harmful algae bloom when at high density.

Table 3.3.6 List of phytoplankton species identified through the field survey

Dry season			Wet season		
No.	Scientific name	No. of identified survey sites	No.	Scientific name	No. of identified survey sites
	Diatoms			**Diatoms**	
1	*Paralia sulcata*	1	1	*Paralia sulcata*	2
2	*Hyalodiscus stelliger*	1	2	*Melosira granulata*	2
3	*Cyclotella striata*	3	3	*Melosira granulata v. angustissima*	6
4	*Cyclotella comta*	6	4	*Cyclotella comta*	11
5	*Cyclotella* sp.	1	5	*Coscinodiscus asteromphalus*	11
6	*Coscinodiscus asteromphalus*	12	6	*Coscinodiscus oculus-iridis*	4
7	*Coscinodiscus oculus-iridis*	6	7	*Coscinodiscus jonesianus*	1
8	*Coscinodiscus radiatus*	1	8	*Coscinodiscus jonesianus v. commutata*	12
9	*Coscinodiscus granii*	1	9	*Coscinodiscus marginatus*	1
10	*Coscinodiscus cf. subtilis*	3	10	*Coscinodiscus cf. subtilis*	1
11	*Coscinodiscus* sp.	1	11	*Asteromphalus cleveanus*	1
12	*Lauderia borealis*	5	12	*Thalassiosira eccentrica*	3
13	*Skeletonema costatum*	8	13	*Thalassiosira lineata*	12
14	*Leptocylindrus danicus*	3	14	*Thalassiosira* sp.	2
15	*Guinardia flaccida*	8	15	*Lauderia borealis*	11
16	*Guinardia striata*	12	16	*Skeletonema costatum*	11

Dry season			Wet season		
No.	**Scientific name**	**No. of identified survey sites**	**No.**	**Scientific name**	**No. of identified survey sites**
17	*Bacteriastrum varians*	5	17	*Guinardia flaccida*	5
18	*Bacteriastrum hyalinum*	5	18	*Guinardia striata*	2
19	*Thalassiosira eccentrica*	2	19	*Dactyliosolen mediterraneus*	2
20	*Thalassiosira lineata*	6	20	*Bacteriastrum varians*	8
21	*Thalassiosira* sp.	2	21	*Bacteriastrum hyalinum*	1
22	*Arthrospira platensis*	2	22	*Pseudosolenia calcar-avis*	3
23	*Rhizosolenia robusta*	3	23	*Rhizosolenia cylindrus*	1
24	*Rhizosolenia setigera*	2	24	*Rhizosolenia robusta*	1
25	*Rhizosolenia hyalina*	4	25	*Chaetoceros affinis*	8
26	*Proboscia alata*	9	26	*Chaetoceros abnormis*	5
27	*Proboscia alata f. indica*	1	27	*Chaetoceros curvisetus*	10
28	*Proboscia alata f. gracillima*	1	28	*Chaetoceros coarctatus*	2
29	*Proboscia alata f. genuina*	1	29	*Chaetoceros compressus*	3
30	*Chaetoceros affinis*	12	30	*Chaetoceros constrictus*	2
31	*Chaetoceros affinis v. willei*	1	31	*Chaetoceros crinitus*	1
32	*Chaetoceros abnormis*	5	32	*Chaetoceros diversus*	3
33	*Chaetoceros curvisetus*	4	33	*Chaetoceros distans*	1
34	*Chaetoceros compactus*	3	34	*Chaetoceros lorenzianus*	7
35	*Chaetoceros compressus*	7	35	*Chaetoceros subtilis*	9
36	*Chaetoceros constrictus*	12	36	*Biddulphia regia*	11
37	*Chaetoceros decipiens*	1	37	*Biddulphia dubia*	1
38	*Chaetoceros denticulatus*	3	38	*Biddulphia reticulum*	1
39	*Chaetoceros distans*	2	39	*Odontella mobiliensis*	4
40	*Chaetoceros dydimus*	1	40	*Bellerochea horologicalis*	1
41	*Chaetoceros lauderii*	1	41	*Hemiaulus sinensis*	3
42	*Chaetoceros lorenzianus*	11	42	*Hemiaulus indicus*	1
43	*Chaetoceros paradoxus*	3	43	*Cerataulina bergonii*	1
44	*Chaetoceros rostratus*	9	44	*Cerataulina compacta*	1
45	*Chaetoceros subtilis*	3	45	*Ditylum sol*	11
46	*Biddulphia regia*	2	46	*Eucampia cornuta*	1
47	*Biddulphia reticulum*	3	47	*Eucampia zoodiacus*	2
48	*Odontella mobiliensis*	1	48	*Climacodium biconcavum*	1
49	*Hemiaulus sinensis*	1	49	*Palmeria hardmaniana*	4
50	*Cerataulina bergonii*	1	50	*Thalassionema nitzschioides*	5
51	*Cerataulina compacta*	1	51	*Thalassionema frauenfeldii*	11
52	*Ditylum brightwellii*	1	52	*Pleurosigma affine*	2
53	*Eucampia zoodiacus*	6	53	*Pleurosigma* sp.	2
54	*Climacodium biconcavum*	3	54	*Pleurosigma* sp.1	1
55	*Palmeria hardmaniana*	5	55	*Nitzschia lorenziana*	3
56	*Thalassionema frauenfeldii*	12	56	*Nitzschia longissima*	1
57	*Navicula membranacea*	7	57	*Pseudo-nitzschia* sp.1	3
58	*Navicula cancellata*	2	58	*Campylodiscus echeneis*	1
59	*Tropidoneis lepidoptera*	1		**Dinoflagellates**	
60	*Pleurosigma affine*	4	59	*Ceratium breve*	2
61	*Pleurosigma angulatum*	1	60	*Ceratium deflexum*	1
62	*Pleurosigma* sp.1	7	61	*Ceratium extensum*	1
63	*Pleurosigma* sp.2	1	62	*Ceratium falcatum*	1
64	*Pleurosigma naviculaceum*	4	63	*Ceratium furca*	11
65	*Pleurosigma pelagicum*	4	64	*Ceratium fusus*	4
66	*Amphiprora alata*	1	65	*Ceratium trichoceros*	6
67	*Nitzschia lorenziana*	6	66	*Ceratium massiliense*	1
68	*Nitzschia longissima*	2	67	*Ceratium tripos*	3
69	*Nitzschia longissima v. reversa*	1	68	*Ceratium* sp.	1
70	*Nitzschia sigma*	4	69	*Dinophysis miles*	3
71	*Nitzschia sigma v.*	1	70	*Dinophysis caudata*	11

Dry season			Wet season		
No.	**Scientific name**	**No. of identified survey sites**	**No.**	**Scientific name**	**No. of identified survey sites**
	intercedens				
72	*Pseudonitzschia* sp.1	8	71	*Dinophysis hastata*	1
73	*Pseudonitzschia* sp.2	2	72	*Dinophysis doryphorum*	1
74	*Surirella ovalis*	5	73	*Dinophysis* sp.	1
75	*Surirella gemma*	2	74	*Ornithocercus magnificus*	1
76	*Campylodiscus echeneis*	3	75	*Histioneis costata*	1
77	*Campylodiscus undulatus*	1	76	*Amphisolenia bidentata*	3
	Phylum - Dinophyceae		77	*Gymnodinium sanguineum*	1
78	*Ceratium breve*	3	78	*Gonyaulax sp.*	3
79	*Ceratium furca*	11	79	*Gonyaulax polygramma*	3
80	*Ceratium deflexum*	2	80	*Gonyaulax rotundata*	5
81	*Ceratium fusus*	11	81	*Protoperidinium abei*	1
82	*Ceratium trichoceros*	10	82	*Protoperidinium cf. brochii*	3
83	*Ceratium macroceros*	4	83	*Protoperidinium conicum*	11
84	*Ceratium massiliense*	4	84	*Protoperidinium claudicans*	4
85	*Ceratium asymmetricum*	2	85	*Protoperidinium crassipes*	3
86	*Ceratium tripos*	3	86	*Protoperidinium divergens*	1
87	*Prorocentrum micans*	10	87	*Protoperidinium elegans*	1
88	*Prorocentrum rhathymum*	1	88	*Protoperidinium oceanicum*	6
89	*Prorocentrum* sp.	2	89	*Protoperidinium ovum*	1
90	*Dinophysis caudata*	10	90	*Protoperidinium thorianum*	1
91	*Dinophysis mitra*	1	91	*Protoperidinium pellucidum*	6
92	*Dinophysis cf. rotundata*	1	92	*Protoperidinium pentagonum*	2
93	*Noctiluca scintillans*	4	93	*Protoperidinium punctulatum*	1
94	*Gonyaulax* sp.	4	94	*Protoperidinium spinulosum*	6
95	*Gonyaulax polygramma*	9	95	*Protoperidinium sphaeroides*	1
96	*Gonyaulax spinifera*	1	96	*Protoperidinium* sp.	1
97	*Gonyaulax scrippsae*	2	97	*Protoperidinium* sp.1	2
98	*Gonyaulax verior*	1	98	*Peridinium* sp.	1
99	*Gonyaulax rotundata*	2	99	*Alexandrium* sp.	1
100	*Gonyaulax diegiensis*	4	100	*Goniodoma polyedricum*	1
101	*Protoperidinium steinii*	5	101	*Lingulodinium polyedra*	5
102	*Protoperidinium conicum*	10	102	*Diplopsalis* sp.	2
103	*Protoperidinium crassipes*	8	103	*Diplopsalopsis* sp.	2
104	*Protoperidinium divergens*	6	104	*Zygabikodinium* sp.	1
105	*Protoperidinium depressum*	1	105	*Pyrophacus horologium*	1
106	*Protoperidinium elegans*	3	106	*Pyrophacus* sp.	7
107	*Protoperidinium oceanicum*	3	107	*Podolampas bipes*	1
108	*Protoperidinium ovum*	9		**Cyanobacteria**	
109	*Protoperidinium pellucidum*	11	108	*Trichodesmium erythraeum*	2
110	*Protoperidinium pentagonum*	1	109	*Oscillatoria limosa*	3
111	*Protoperidinium leonis*	2	110	*Oscillatoria raciborskii*	3
112	*Protoperidinium spinulosum*	1	111	*Oscillatoria* sp.1	6
113	*Protoperidinium sphaeroides*	6	112	*Oscillatoria* sp.2	2
114	*Protoperidinium* sp.	8	113	*Oscillatori princeps*	2
115	*Peridinium quinquecorne*	2	114	*Lyngbya* sp.	1
116	*Scrippsiella* sp.	1	115	*Arthrospira platensis*	9
117	*Alexandrium* sp.	2	116	*Anabaena* sp.	4
118	*Alexandrium pseudogonyaulax*	4	117	*Anabaena cf. viguieri*	1
119	*Goniodoma polyedricum*	5	118	*Microcystis cf. wesenbergii*	7
120	*Diplopsalis* sp.	5	119	*Microcystis* sp.	7
121	*Diplopsalopsis* sp.	2		**Chlorophyte**	
122	*Zygabikodinium* sp.	1	120	*Pediastrum simplex v. simplex*	9
123	*Oblea* sp.	2	121	*Pediastrum boryanum*	1
124	*Pyrophacus horologicum*	7	122	*Pediastrum duplex*	8

Dry season			Wet season		
No.	**Scientific name**	**No. of identified survey sites**	**No.**	**Scientific name**	**No. of identified survey sites**
	Phylum - Dictyochophyceae		123	*Pediastrum* sp.	3
125	*Dictyocha fibula*	1	124	*Pediastrum tetras*	4
126	*Dictyocha speculum*	3	125	*Scenedesmus* sp.	3
	Cyanobacteria		126	*Scenedesmus quadricauda*	6
127	*Trichodesmium erythraeum*	5	127	*Scenedesmus carinatus*	1
128	*Oscillatoria* sp.	2	128	*Scenedesmus acuminatus*	1
	Chlorophyte		129	*Scenedesmus javanensis*	2
129	*Pediastrum simplex v. simplex*	4	130	*Staurastrum* sp.	8
130	*Pediastrum duplex v. duplex*	2	131	*Palmella* sp.	1
131	*Pediastrum* sp.	1	132	*Eudorina elegans*	1
132	*Scenedesmus* sp.	1	133	*Eudorina* sp.	4
133	*Scenedesmus quadricauda*	1		**Euglenoids**	
134	*Staurastrum* sp.	1	134	*Euglena* sp.	1
			135	*Phacus cf. longicauda*	1
			136	*Phacus* sp.1	1
			137	*Phacus* sp.2	1

Source: JICA Study Team

Table 3.3.7 shows the number of phytoplankton species and cell density at each survey site. For the dry season, the number of species ranged between 32 and 57 species. While there was no clear spatial trend in the cell density, relatively high levels were recorded at EC4, EC8 and EC12. For the wet season, the number of species ranged between 30 and 60 species. Cell density was generally lower compared to the dry season.

Table 3.3.7 Number of phytoplankton species and cell density at each survey site

Survey site	Dry season		Wet season	
	No. of species	**Density (cells/litre)**	**No. of species**	**Density (cells/litre)**
EC1	40	15,720	37	9,540
EC2	40	4,640	34	2,480
EC4	55	148,400	31	3,340
EC7	53	74,840	44	3,780
EC8	49	158,240	42	2,500
EC9	55	20,320	32	19,040
EC10	57	29,500	30	5,080
EC12	44	137,340	53	13,400
EC13	42	28,760	46	41,000
EC14	54	36,900	60	12,540
EC17	32	35,320	35	7,900
EC18	48	5,380	36	4,180

Source: JICA Study Team

5) Zooplankton

a) Methodology

Zooplankton samples were collected by towing a plankton net (mesh size: 200 µm, diameter: 60 cm) several times in the horizontal direction. Zooplankton samples were also collected from the surface by filtering 100 L of surface water through the plankton net. All samples were preserved in 4% formalin solution for further analysis at IMER’s laboratory.

b) Results

Table 3.3.8 shows the zooplankton/larvae species identified through the field survey. A total of 35 and 41 zooplankton species were identified in the dry and wet seasons respectively. During the dry season survey, five fish larvae species were also identified in the coastal survey sites. No fish larvae were found in the offshore sites (i.e. EC12, 13 and 14). Table 3.3.9 shows the number of zooplanktons species and density recorded at each survey site. While there was no specific trend, zooplanktons density was particularly high at sites EC4, EC7 and EC8 in the dry season. Zooplankton density was in general lower in the wet season.

Table 3.3.8 List of zooplanktons indentified through the field survey

No.	Scientific name	EC 1	EC 2	EC 4	EC 7	EC 8	EC 9	EC 10	EC 12	EC 13	EC 14	EC 17	EC 18
Dry season													
Phylum: Cnidaria													
1	Scyphozoa sp.	*											
Phylum: Chaetognatha													
Family: Sagittidae													
2	*Sagitta delicate*		*	*	*	*	*	*	*	*	*		
3	*Sagitta crassa*		*										
4	*Sagitta enflata*				*	*				*	*	*	
Phylum: Arthropoda													
Family: Halocypridae													
5	*Conchocia imbricata*	*	*										
Family: Cypridinidae													
6	*Cypridina noctiluca*				*			*					
Family: Polyhemidae													
7	*Evadne nordmani*	*	*										
8	*Evadne tergestina*			*	*	*	*	*	*	*	*	*	*
Family: Sididae													
9	*Penilia schmackeri*		*	*	*	*		*	*	*	*	*	*
Subclass: Copepoda													
10	Copepoda larvae	*										*	
Family: Calanidae													
11	*Canthocalanus tenuiremis*		*										
12	*Canthocalanus pauper*									*			
Family: Paracalanidae													
13	*Paracalanus aculeatus*						*		*				
14	*Paracalanus parvus*	*	*	*	*	*	*	*	*	*	*	*	*
Family: Temoridae													
15	*Temora turbinata*				*	*				*			
Family: Centropagidae													
16	*Centropages tenuiremis*						*		*	*			
17	*Centropages orsini*			*	*	*		*		*	*		
Family: Pseudiaptomidae													
18	*Pseudodiaptomus incisus*											*	
Family: Pontellidae													
19	*Labidocera minuta*					*	*	*					
Family: Acartidae													
20	*Acartia hudsomani*									*			
21	*Acartia pacifica*	*	*	*	*	*	*	*	*	*		*	*
22	*Acartiella sinensis*	*	*										

No.	Scientific name	EC 1	EC 2	EC 4	EC 7	EC 8	EC 9	EC 10	EC 12	EC 13	EC 14	EC 17	EC 18
	Family: Oithonidae												
23	*Oithona nana*	*					*			*			
24	*Oithona similis*	*	*				*		*	*	*		
	Family: Corycaeidae												
25	*Corycaeus andrewsi*					*					*		
26	*Corycaeus dahli*							*		*	*		*
	Family: Tachidiidae												
27	*Microsetella norvegica*						*						
	Family: Luciferidae												
28	*Lucifer hanenssi*								*			*	
	Infraorder: Caridea												
29	Caridea larvae					*		*					
30	Alpheidae larvae									*			*
	Infraorder: Thalassinidea												
31	*Anomura* larvae							*					
	Infraorder: Brachyura												
32	Brachyura larvae	*	*			*					*	*	*
	Subclass: Stomatopoda												
33	*Squilla* sp.							*					
Phylum: Protochordata													
	Family: Oikopleuridae												
34	*Oikopleura dioica*		*		*					*	*		
	Family: Doliolidae												
35	*Doliolum* sp.										*		
Others (fish larvae)													
36	Engraulidae larvae	*		*	*		*	*					
37	Gobiidae larvae	*			*								
38	Ambassidae larvae		*			*							
39	Sciaenidae larvae			*				*					
40	Ophiuroidae larvae					*							
						Wet season							
Phylum: Coelenterata													
1	**Class: Hydrozoa**						*						
Phylum: Ctenophora													
	Family: Pleurobrachiidae												
2	*Hormiphora* sp.						*						
Phylum: Chaetognatha													
	Family: Sagittidae												
3	*Sagitta delicata*	*					*	*	*	*			
4	*Sagitta crassa*						*				*		
5	*Sagitta enflata*							*	*				
Phylum: Arthropoda													
	Family Cypridinidae												
6	*Cypridina noctiluca*							*					
	Family: Sididae												
7	*Diaphanosoma sarsi*												*
8	*Penilia schmackeri*										*		
	Subclass: Copepoda												
9	*Copepoda* larvae	*	*	*	*	*	*	*					
	Family: Eucalanidae												
10	*Eucalanus crassus*							*	*				
	Family: Paracalanidae												
11	*Paracalanus parvus*	*	*	*	*	*	*	*	*	*	*	*	*

No.	Scientific name	EC 1	EC 2	EC 4	EC 7	EC 8	EC 9	EC 10	EC 12	EC 13	EC 14	EC 17	EC 18
Family: Temoridae													
12	*Temora turbinata*								*				
13	*Temora discaudata*										*		
Family: Pseudiaptomidae													
14	*Pseudodiaptomus* sp.							*					
15	*Pseudodiaptomus incisus*	*				*						*	*
16	*Pseudodiaptomus marinus*						*						
Family: Pontellidae													
17	*Calanopia thompsoni*					*	*						
Family: Acartidae													
18	*Acartia hudsomani*		*	*				*	*			*	*
19	*Acartia pacifica*	*	*		*	*	*	*	*	*	*	*	
20	*Acartiella sinensis*	*	*			*						*	*
Family: Tortanidae													
21	*Tortanus derjugini*				*				*				
22	*Tortanus dextrilobatus*											*	
Family: Oithonidae													
23	*Oithona plumifera*									*			
24	*Oithona nana*				*								
25	*Oithona fallax*									*			
26	*Oithona similis*			*	*	*	*	*		*	*		
Family: Oncaeidae													
27	*Oncaea conifera*								*				
28	*Oncaea venusta*									*	*		
Family: Corycaeidae													
29	*Corycaeus andrewsi*										*		
30	*Corycaeus dahli*									*	*		
Family: Cyclopidae													
31	*Thermocyclops hyalinus*												*
Family: Tachidiidae													
32	*Euterpina acutifrons*							*	*	*	*		
Family: Clytemnestridae													
33	*Clytemnestra scutellata*						*						
Family: Penaeidae													
34	*Penaeidae* larvae						*		*				
Family: Sergestidae													
35	*Acetes* sp.					*	*						
Family: Luciferidae													
36	*Lucifer* larvae	*							*				
37	*Lucifer hanenssi*					*	*	*	*	*	*		
Infraorder: Caridea													
38	*Caridea* larvae										*		
Infraorder: Brachyura													
39	*Brachyura* larvae				*				*				
Phylum: Protochordata													
Family: Oikopleuridae													
40	*Oikopleura dioica*										*		
Others													
41	*Ophiuroidae* sp.									*			

*: Indicate identified sites
Source: JICA Study Team

Table 3.3.9 Number of zooplankton species and density at each survey site

Survey site	Dry season		Wet season	
	No. of species	Density (individual/m^3)	No. of species	Density (individual/m^3)
EC1	12	720	7	150
EC2	13	610	6	532.5
EC4	8	24,800	4	41
EC7	12	10,700	7	130
EC8	14	7,700	9	320
EC9	11	540	14	170
EC10	13	230	12	340
EC12	9	420	14	280
EC13	16	330	11	310
EC14	12	400	13	140
EC17	9	380	6	200
EC18	7	3,220	6	290

Source: JICA Study Team

6) Zoobenthos

a) Methodology

Zoobenthos samples were collected with a grab sampler (size: 0.25 m^2), which was deployed twice per site. To extract the zoobenthos from the collected bottom sediment, samples were filtered with metallic sieves of 3 different mesh sizes. The extracted zoobenthos were then preserved in a 70% ethanol solution for further analysis at IMER’s laboratory.

b) Results

Table 3.3.10 shows the zoobenthos species identified through the field survey and associated data. Species diversity ranged between 3-8 and 1-8 species in the dry and wet seasons respectively. Species abundance was significantly higher in the dry season (range of 15-95 individuals) compared to the wet season (range of 1-30 individuals). In the dry season, species abundance was particularly high at sites EC2, EC9 and EC17, which are all located in relatively shallow waters. In the wet season, species abundance was high at sites EC1, EC9 and EC10, which are also located in relatively shallow waters.

Table 3.3.10 Results of zoobenthos survey

Survey site	Family	Genus/species	No. of individuals	Wet weight (mg)	
				Total	Average
Dry season					
EC1	Nephtyidae	*Nephtys (A) inermis*	5	17.1	3.42
		Nephtys (A) dibranchis	5	154.1	30.82
	Spionidae	*Scolelespis* sp.	5	41.6	8.32
	Arenicolidae	*Branchiomaldane* sp.	5	196.3	39.26
	Mellanellidae	*Melanella* sp.	5	133	26.6
	Psamobidae	*Sanguinolaria (soletellina) diphos*	16	800	50
		Sanguinolaria polanulata	5	267	53.4
	Leucosiidae	*Philyra* sp.	5	79.9	15.98
EC2	Amphinomidae	*Pontogenia nuda*	5	381.9	76.38
	Maldanidae	*Maldane* sp.	5	115.2	23.04
	Spionidae	*Scolelespis* sp.	5	227.7	45.5
	Naticidae	*Natica* sp.	5	187	37.4
	Turridae	*Turriculla javana*	5	2,587	517.4
	Cultellidae	*Siliqua radiata Linnaeus*	5	1,707	341.4
	Amphiuridae	*Amphiophus koechii*	53	2,053	410.6

Survey site	Family	Genus/species	No. of individuals	Wet weight (mg)	
				Total	Average
Dry season					
EC4	Naticidae	*Natica* sp.	5	53	10.6
	Nassaridae	*Nassarius comptus*	5	133	26.6
	Cultellidae	*Siliqua radiata Linnaeus*	5	107	21.4
EC7	Nephtyidae	*Nephtys (A) dibranchis*	5	12.1	2.42
	Turritellidae	*Turritella terebra*	5	5,733	1,146.6
	Terebridae	*Terebra dussamieri*	5	240	48
	Nassaridae	*Nassarius camptus*	5	267	53.4
	Ostridae	*Ostrea (lopha) sinensis*	11	38,666	3,515
EC8	Amphinomidae	*Chloeia flava*	11	181.3	16.5
	Glyceridae	*Glycera longipinis*	5	1,438.9	287.8
	Naticidae	*Natica* sp.	5	53	10.6
	Cultellidae	*Siliqua allida*	5	5,227	1,045.4
	Ophiuridae	Ophiuridae sp.	11	133	12.1
	Phronimidae	*Phronima* sp.	5	27.5	5.5
EC9	Nephtyidae	*Nephtys (A) inemis*	5	154.7	30.9
	Glyceridae	*Glycera longipinis*	5	777.1	155.4
	Pinnotheridae	*Xenophlalnus pinnotheroides*	5	1,003	200.6
		Tritodynamia sp.	11	773	70.3
	Ophiomyxidae	*Ophiomyxa australis*	69	6,400	92.7
EC10	Sabellidae	*Jasmineira* sp.	5	4,611.7	922.34
	Trochidae	*Minolia chinensis Sowerby*	5	Data unavailable	Data unavailable
	Nuculanidae	*Nuculana illepida*	5	107	21.4
	Thraciidae	*Thracia adenensis*	5	507	101.4
		Carcinoplax vestitus	5	7,812.8	1,562.56
		Ophiupholis kochii	36	6,426.3	178.51
EC12	Nephtyidae	*Nephtys (A) dibranchis*	16	21.7	1.356
		Echinoderm sp.1	5	987	197.4
		Echinoderm sp.2	11	160	14.545
		Penaeus monodon	11	133	12.091
	Amphiuroidae	*Amphiophus praestaus*	1	997	997
EC13	Eunicidae	*Eunice* sp.	5	252.3	50.46
	Veneridae	*Chione (claursinella) calophylla*	5	8,427	1,685.4
		Paphia textile	5	2,053	410.6
	Goneplacidae	*Xenoplitralmodes moebii*	11	10,325	938.64
	Amphiuroidae	*Aphipholin kochii*	5	160	32
EC14	Nephtyidae	*Nephtys (A) inermis*	5	187.2	37.44
		Nephtys (A) disbranchis	5	41.6	8.32
	Cirratulidae	*Cirratulus cirratulus*	5	93.3	18.66
	Tellinidae	*Tellina remies*	5	1,493	298.6
EC17	Veneridae	*Paphia* sp.	5	267	53.4
		Scylla serrata	5	960	192
	Goneplacidae	*Typhlocarcium villosus*	32	4,187	837.4
	Sergestidae	*Acetes* sp.	5	27	5.4
	Atyidae	*Caridina* sp.	11	933	84.82
	Pinnotheridae	*Xenophthalmus pinnotheroides*	5	719.5	143.9
EC18	Eunicidae	*Eunice* sp.	11	4,555.7	414.15
	Capitellidae	*Notomatus* sp.	5	1,715.7	343.14
	Amphinomidae	*Chloeia flava*	5	105.1	21.02
	Corbulidae	*Corbula erythroda*	11	293	26.64

Survey site	Family	Genus/species	No. of individuals	Wet weight (mg)	
				Total	Average
Dry season					
		Scylla serrata	5	10,160	2,032
	Goneplacidae	*Typhlocarcium villosus*	5	10,000	2,000
Wet season					
EC1	Corbulidae	*Corbula laevis*	1	50	50
		Corbula erythroden	7	145	20.71
	Goneplacidae	*Typhylocarcinus nudus*	6	387	64.5
	Sergestidae	*Acetes indicus*	2	55	27.5
	Ophioconidae	*Ophiarthrum elegans*	1	75	75
EC2	Capitellidae	*Dasybranchus sp*	1	5.9	5.9
EC4	Nassaridae	*Nassarius comptus*	1	65	65
	Veneridae	*Chione impricata*	1	60	60
	Mactridae	*Mactra grandis*	1	280	280
EC7	Nassaridae	*Nassarius camptus*	1	55	55
	Nucularisdae	*Nuculana taphria*	3	105	35
	Veneridae	*Chione imbricata*	3	187	62.3
	Corbulidae	*Corbula erythroden*	1	215	215
	Solenidae	*Siliqua albida*	1	120	120
	Glyceridae	*Glycera* sp.	2	23.1	11.6
EC8	Data not available				
EC9	Solenidae	*Silliqua allida*	3	280	93.3
	Sternaspidae	*Sternaspis scutata*	2	38.5	18.3
	Spionidae	*Scolelepis* sp.	13	212.9	16.4
	Capitellidae	*Notomastus* sp.	11	177.4	16.1
	Nephtyidae	*Nephtys (A) dibranchis*	1	39.1	39.1
EC10	Nassaridae	*Nassarius olivaceus*	1	80	80
	Veneridae	*Paphia textile*	1	960	960
	Solenidae	*Siliqua albida*	1	880	880
		Solen sloanii	1	155	155
	Tellinidae	*Tellina joliacea*	1	4.195	4.195
	Nephtyidae	*Nephtys (A) dibranchis*	1	99	99
	Goneplacidae	*Xenophthalnoides mocbii Richters*	1	190	190
	Amphiuroidae	*Amphipholis kochii*	12	1773	147.8
EC12	Arenicollidae	*Brachiomaldane vicenti*	4	28.9	7.22
	Nephtyidae	*Nephtys (A) dibranchis*	1	4.3	4.3
	Spionidae	*Scolelepis* sp.	1	22	4.3
EC13	Dentalidae	*Dentalium aprinum*	2	25	12.5
	Atyidae	*Atys cylindnicus*	1	7	7
	Nephtyidae	*Nephtys (A) dibranchis*	1	5.2	5.2
	Capitellidae	*Notomastus* sp.	2	13.9	7.9
EC14	Nephtyidae	*Nephtys (A) gravieri*	1	19.7	19.7
		Nephtys (A) dibranchis	2	27.5	13.75
	Capitellidae	*Notomastus* sp.	1	9.4	9.4
	Pinnotheridae	*Xenophthaenus pinnotheroides*	1	29.5	29.5
EC17	Data not available				
EC18	Capitellidae	*Notomastus sp*	1	9.4	9.4
	Pinnotheridae	*Xenophthaenus pinnotheroides*	1	29.5	29.5
	Buccinidae	*Ptychosalpinx golobulus*	2	510	255
	Corbulidae	*Corbula laevis*	3	946	315.3

Source: JICA Study Team

7) Demersal fish/macrozoobenthos

a) Methodology

Demersal fish and macrozoobenthos were collected with a trawling net (mesh size: #15, width: 5 m). Each trawl was conducted for 15-20 minutes at a speed of 1.5-2 miles/hour. All collected species were measured (total length) and weighted, then preserved in 10% formalin solution for further analysis at IMER's laboratory.

b) Results

Table 3.3.11 shows the demersal fish species identified through the field survey. In general, fish diversity and abundance tended to be higher in the coastal survey sites compared to the offshore survey sites (e.g. EC12, EC13, and EC14). Within the identified species, two species are listed in Vietnam Red Book namely, *Bostrichthys sinensis* and *Anodontostoma chacunda,* which were found in the shallow coastal survey sites EC1 and EC2 respectively during both seasons. *Bostrichthys sinensis* and *Anodontostoma chacunda* are classified as "Critical" and "Vulnerable" respectively.

Table 3.3.11 Results of demersal fish survey

Survey site	Family	Genus/species	No. of individuals	Total and ave. wet weight (g)	Ave. length (cm)	Status in Vietnam Red Book
Dry season						
EC1	Sparidae	*Sparus latus*	1	6	6.5	Not listed
	Taenioididae	*Trypauchen vagina*	2	Total: 12.97 Ave. : 6.5	9	Not listed
	Eleotridae	*Bostrichthys sinensis*	1	23	13	**Critical**
	Sillaginidae	*Sillago sihama*	1	15.4	12.5	Not listed
	Eleotridae	*Butis butis*	1	4.5	5	Not listed
	Platycephalidae	*Rogadus asper*	1	12.5	11	Not listed
	Platycephalidae	*Cociella crocodila*	1	5	5.5	Not listed
	Cynoglossidae	*Symphurus orientalis*	1	4.5	3.5	Not listed
EC2	Cynoglossidae	*Symphurus orientalis*	1	11	9.5	Not listed
	Soleidae	*Heteromycterus japonica*	1	13	8	Not listed
	Sillaginidae	*Sillago sihama*	1	12.5	14.9	Not listed
	Clupeidae	*Anodontostoma chacunda*	5	Total: 60 Ave: 12	15.3	**Vulnerable**
	Sciaenidae	*Nibea albiflora*	1	26	23.5	Not listed
EC4	Synodontidae	*Saurida tumbil*	3	Total: 36.4 Ave: 12.2	15.4	Not listed
	Leiognathidae	*Leiognathus equulus*	24	Total: 50 Ave: 2.1	6.5	Not listed
	Clupeidae	*Escualosa thoracata*	2	Total: 4 Ave: 2	5.3	Not listed
	Taeniodidae	*Trypauchen vagina*	6	Total: 37 Ave: 6.6	11.2	Not listed
	Mugilidae	*Mugil cephalus*	1	14	16	Not listed
	Platycephalidae	*Cociella crocodila*	3	Total: 16.3 Ave: 5.4	5.2	Not listed
EC7	Leiognathidae	*Leiognathus equulus*	16	Total: 35 Ave: 2.2	5.8	Not listed
	Carangidae	*Parastromateus niger*	1	35	12	Not listed
	Ephippidae	*Drepane punctata*	1	28	13	Not listed
	Mugilidae	*Mugil cephalus*	1	16	18	Not listed
	Sillaginidae	*Sillago sihama*	1	12	13.8	Not listed
	Terapontidae	*Terapon jarbua*	1	21	12	Not listed

Survey site	**Family**	**Genus/species**	**No. of individuals**	**Total and ave. wet weight (g)**	**Ave. length (cm)**	**Status in Vietnam Red Book**
	Carangidae	*Selaroides leptolepis*	5	Total: 75 Ave: 15	14.9	Not listed
	Sciaenidae	*Nibea soldado*	1	28	26	Not listed
EC8	Cynoglossidae	*Cynoglossus abbreviatus*	1	15.5	8	Not listed
EC9	Cynoglossidae	*Cynoglossus abbreviatus*	3	Total: 29.05 Ave: 9.7	7.9	Not listed
EC10	Eleotridae	*Butis butis*	1	5.3	6.4	Not listed
EC12	Cynoglossidae	*Cynoglossus bbreviatus*	1	14	7.7	Not listed
	Platycephalidae	*Rogadus asper*	1	14	13.1	Not listed
	Taeniodidae	*Trypauchen vagina*	1	5.3	10.7	Not listed
EC13	Bothidae	*Arnoglossus tenuis*	1	83	24	Not listed
	Cynoglossidae	*Cynoglossus robustus*	1	50.1	15.3	Not listed
EC14	Cynoglossidae	*Symphurus orientalis*	1	5.2	6.1	Not listed
EC17	Cynoglossidae	*Cynoglossus bbreviatus*	5	Total: 53.8 Ave: 10.76	12.5	Not listed
EC18	Cynoglossidae	*Cynoglossus abbreviatus*	1	11	14	Not listed
	Taenioididae	*Trypauchen vagina*	1	5	10	Not listed
			Wet season			
EC1	Muraenesocidae	*Muraenesox cinereus*	1	36	25	Not listed
	Taenioididae	*Trypauchen vagina*	2	Total: 25.4 Ave. : 12.7	13	Not listed
	Eleotridae	*Bostrichthys sinensis*	1	Total: 42 Ave: 14	12.5	**Critical**
	Sciaenidae	*Nibea soldado*	26	Total: 93.37 Ave: 3.59	7.2	Not listed
	Siganidae	*Siganus fuscescens*	1	7.5	8	Not listed
EC2	Bagridae	*Cranoglanis sinensis*	9	Total: 400 Ave: 44.4	22.3	Not listed
	Bothidae	*Arnoglossus tenuis*	3	Total: 3.13 Ave: 1.04	5	Not listed
	Clupeidae	*Anodontostoma chacunda*	2	Total: 30 Ave: 15	16.7	**Vulnerable**
	Sciaenidae	*Nibea albiflora*	3	Total: 17.04 Ave: 5.68	3.5	Not listed
EC4	Dasyatidae	*Dasyatis zugei*	1	400	22.5	Not listed
	Sciaenidae	*Otolithes ruber*	1	20.24	14.7	Not listed
	Cynoglossidae	*Symphurus orientalis*	3	Total: 19.84 Ave: 6.6	7.1	Not listed
EC7	Siganidae	*Siganus fuscescens*	5	Total: 37.55 Ave: 7.51	10	Not listed
	Sciaenidae	*Dendrophysa* sp.	1	3.71	5	Not listed
EC8	Platycephalidae	Rogadus asper	1	13.81	14	Not listed
	Cynoglossidae	*Cynoglossus abbreviatus*	9	Total: 92.93 Ave: 10.32	11	Not listed
	Sciaenidae	*Nibea soldado*	9	Total: 48.86 Ave: 5.38	6	Not listed
	Siganidae	*Siganus fuscescens*	3	Total: 24.02 Ave: 8	8	Not listed
	Taenioididae	*Trypauchen vagina*	6	Total: 34.21 Ave: 5.7	3.7	Not listed
	Clupeidae	*Escualosa thoracata*	5	Total: 12.13 Ave: 2.42	5.3	Not listed
EC9	Dasyatidae	*Dasyatis zugei*	2	Total: 400 Ave: 200	21	Not listed

Survey site	Family	Genus/species	No. of individuals	Total and ave. wet weight (g)	Ave. length (cm)	Status in Vietnam Red Book
	Cynoglossidae	*Cynoglossus abbreviatus*	2	Total: 21 Ave: 10.5	22.5	Not listed
	Ephippidae	*Drupane punctata*	1	6.27	6	Not listed
	Sillaginidae	*Sillago sihama*	1	23.63	13	Not listed
	Sciaenidae	*Dendrophysa russelli*	17	Total: 100 Ave: 5.9	9.1	Not listed
	Engraulidae	*Coilia nasus*	1	13.96	16	Not listed
	Taenioididae	*Trypauchen vagina*	1	4.26	10	Not listed
	Siganidae	*Siganus fuscescens*	4	Total: 28.59 Ave: 7.15	7.6	Not listed
	Terapontidae	*Terapon jarbua*	5	Total: 24 Ave: 4.8	4.3	Not listed
EC10	Cynoglossidae	*Cynoglossus abbreviatus*	2	Total: 20.8 Ave: 10.4	17	Not listed
		Symphurus orientalis	3	Total: 121.2 Ave: 40.4	19.3	Not listed
	Sciaenidae	*Pennahia pawak*	4	Total: 14.77 Ave: 4	8.4	Not listed
	Platycephalidae	*Rogadus asper*	2	Total: 12.83 Ave: 6.41	8.5	Not listed
	Gerreidae	*Gerres oyena*	1	9.53	8.5	Not listed
	Bothidae	*Arnoglossus tenuis*	1	2.52	5.5	Not listed
EC12	Platycephalidae	*Cociella crocodila*	1	250	21	Not listed
	Cynoglossidae	*Cynoglossus abbreviatus*	1	21.39	13	Not listed
	Taenioididae	*Trypauchen vagina*	1	7.88	12.5	Not listed
EC13	Data not available*					
EC14	Sciaenidae	*Pennahia pawak*	1	0.98	2.5	Not listed
	Engraulidae	*Coilia nasus*	3	Total: 26.4 Ave: 13.2	15.4	Not listed
EC17	Sparidae	*Sparus latus*	1`	59.43	14	Not listed
	Bothidae	*Arnoglossus tenuis*	1	1.73	3.45	Not listed
	Cynoglossidae	*Symphurus orientalis*	1	18	10	Not listed
EC18	Sciaenidae	*Dendrophysa russelii*	13	Total: 20.85 Ave: 1.6	8.4	Not listed
	Cynoglossidae	*Cynoglossus abbreviatus*	1	11.3	20	Not listed
		Symphurus orientalis	1	8.82	9.5	Not listed
	Gobiidae	*Acentrogobius*	1	5.13	8	Not listed
	Engraulidae	*Coilia nasus*	1	9.71	5.5	Not listed

*: Wet season survey at EC13 was not possible due to presence of fishing vessels.
Source: JICA Study Team

Table 3.3.12 shows the macrozoobenthos species identified through the field survey. Many species are caught commercially which include: clams (*Anadara antiquate, Chloromytilus viridis, Portunus pelagicus, Siliqua ablida*), sea snails (*Cymio lacera, Natica tigrina*), swimming crabs (*Charybdis anisodon*), shrimp/prawns (*Metapenaeus spp., Parapenaeopsis spp., Palaemonetes sinensis, Penaeus merguiensis*), mantis shrimps (*Oratosquilla oratoria*) and octopuses (*Octopus dollfusi*).

Diversity and abundance of macrozoobenthos were generally higher in the coastal survey sites compared to the offshore sites (e.g. EC12, EC13, and EC14) for both seasons. No species are listed under Vietnam Red Book.

Table 3.3.12 Results of macrozoobenthos survey

Survey site	Family	Genus/species	No. of individuals	Total and ave. wet weight (g)	Status in Vietnam Red Book
Dry season					
EC1	Naticidae	*Natica tigrina*	16	Total: 151.8 Ave: 9.49	Not listed
	Squillidae	*Oratosquilla oratoria*	11	Total: 111.76 Ave: 10.16	Not listed
	Penaeidae	*Metapenaeus ensis*	11	Total: 49.8 Ave: 4.52	Not listed
	Palaemonidae	*Palaemonetes sinensis1*	3	Total: 21 Ave: 7	Not listed
EC2	Penaeidae	*Penaeus monodon*	1	4.43	Not listed
	Portunidae	*Portunus pelagicus*	3	Total: 118 Ave: 3.93	Not listed
	Turritellidae	*Turitella terebra*	4	Total: 44.56 Ave: 11.14	Not listed
	Arcidae	*Anadara antiquate*	9	Total: 57.48 Ave: 6.39	Not listed
	Solenidae	*Siliqua ablida*	12	Total: 6.93 Ave: 0.58	Not listed
EC4	Penaeidae	*Parapenaeopsis hungerfordi*	2	Total: 6.19 Ave: 3.1	Not listed
		Metapenaeus intermedius	3	Total: 3.18 Ave: 1.06	Not listed
		Penaeus merguiensis	1	16.88	Not listed
	Palaemonidae	*Palaemonetes sinensis*	54	Total: 480 Ave: 240	Not listed
EC7	Octopodidae	*Octopus dollfusi*	1	Total: 34.21	Not listed
EC8	Penaeidae	*Metapenaeus intermedius*	52	Total: 120 Ave: 2.3	Not listed
		Parapenaeopsis hungerfordi	28	Total: 80 Ave: 2.85	Not listed
	Portunidae	*Portunus pelagicus*	3	Total: 46 Ave: 15.33	Not listed
	Arcidae	*Anadara antiquate*	5	Total: 47 Ave: 9.4	Not listed
EC9	Turritellidae	*Turitella terebra*	70	Total: 147 Ave: 2.1	Not listed
	Leucosidae	*Pseudophilyra olivace*	4	Total: 26.2 Ave: 6.55	Not listed
EC12	Penaeidae	*Parapenaeopsis tenella*	2	Total: 32.3 Ave: 16.15	Not listed
EC13	Palaemonidae	*Palaemonetes sinensis*	6	Total: 26.2 Ave: 4.34	Not listed
EC14	Muricidae	*Cymio lacera*	2	Total: 3.4 Ave: 1.7	Not listed
EC17	Turritellidae	*Turitella terebra*	23	Total: 93.8 Ave: 4.07	Not listed
EC18	Veneridae	*Paphia textile*	2	Total: 25 Ave: 12.5	Not listed
	Portunidae	*Charybdis anisodon*	3	Total: 11.63 Ave: 3.88	Not listed
	Naticidae	*Natica tigrina*	38	Total: 120 Ave: 3.16	Not listed

Survey site	Family	Genus/species	No. of individuals	Total and ave. wet weight (g)	Status in Vietnam Red Book
		Wet season			
EC1	Naticidae	*Natica tigrina*	11	Total: 106.7 Ave: 9.7	Not listed
	Muricidae	*Cymio lacera*	9	Total: 145.56 Ave: 16.17	Not listed
	Mytilidae	*Chloromytilus viridis*	2	Total: 106.7 Ave: 53.35	Not listed
	Squillidae	*Oratosquilla oratoria*	7	Total: 65.4 Ave: 9.34	Not listed
	Penaeidae	*Parapenaeopsis tenella*	82	Total: 230 Ave: 2.8	Not listed
		Metapenaeus ensis	3	Total: 14.72 Ave: 4.9	Not listed
	Palaemonidae	*Palaemonetes sinensis*	110	Total: 210 Ave: 1.9	Not listed
EC2	Penaeidae	*Metapenaeus ensis*	1	4.92	Not listed
	Naticidae	*Natica tigrina*	30	Total: 118 Ave: 3.93	Not listed
	Turritellidae	*Turitella terebra*	4	Total: 44.56 Ave: 11.14	Not listed
	Arcidae	*Anadara antiquate*	9	Total: 57.48 Ave: 6.39	Not listed
	Solenidae (juveline)	*Siliqua ablida*	12	Total: 6.93 Ave: 0.58	Not listed
EC4	Penaeidae	*Parapenaeopsis hungerfordi*	2	Total: 6.19 Ave: 3.1	Not listed
		Metapenaeus intermedius	3	Total: 3.18 Ave: 1.06	Not listed
		Penaeus merguiensis	1	16.88	Not listed
	Palaemonidae	*Palaemonetes sinensis*	54	Total: 480 Ave: 240	Not listed
EC7	Octopodidae	*Octopus dollfusi*	1	Total: 34.21	Not listed
EC8	Penaeidae	*Metapenaeus intermedius*	52	Total: 120 Ave: 2.3	Not listed
		Parapenaeopsis hungerfordi	28	Total: 80 Ave: 2.85	Not listed
	Portunidae	*Portunus pelagicus*	2	Total: 92.12 Ave: 46.06	Not listed
		Charybdis anisodon	1	8.12	Not listed
	Arcidae	*Anadara antiquate*	1	17.13	Not listed
	Muricidae	*Cymio lacera*	1	8.19	Not listed
	Squillidae	*Oratosquilla oratoria*	2	Total: 5.25 Ave: 2.62	Not listed
	Octopodidae	*Octopus dollfusi*	2	Total: 46.72 Ave: 23.36	Not listed
EC9	Portunidae	*Portunus pelagicus*	2	Total: 63.24 Ave: 31.62	Not listed
		Charybdis anisodon	5	Total: 28.11 Ave: 5.62	Not listed
	Squillidae	*Oratosquilla oratoria*	2	Total: 7.2 Ave: 3.6	Not listed
	Penaeiddae	*Metapenaeus intermedius*	4	Total: 15.3 Ave: 3.82	Not listed

Survey site	Family	Genus/species	No. of individuals	Total and ave. wet weight (g)	Status in Vietnam Red Book
		Metapenaeus ensis	48	Total: 110 Ave: 2.29	Not listed
		Metapenaeus joyneri	5	Total: 14.28 Ave: 2.86	Not listed
	Naticidae	*Natica tigrina*	4	Total: 14.34 Ave: 3.59	Not listed
	Arcidae	*Anadara antiquate*	2	Total: 4.34 Ave: 2.17	Not listed
EC10	Squillidae	*Oratosquilla oratoria*	1	29.17	Not listed
	Goneplacidae	*Typhylocarcinus nudus*	1	18.69	Not listed
	Penaeidae	*Parapenaeopsis tenella*	5	Total: 14.45 Ave: 2.89	Not listed
EC12	Squillidae	*Oratosquilla oratoria*	4	Total: 100 Ave: 25	Not listed
	Portunidae	*Portunus pelagicus*	1	60	Not listed
		Portunus sangunolentus	1	29	Not listed
	Penaeidae	*Metapenaeus ensis*	1	6.99	Not listed
EC13	Data not available*				
EC14	Veneridae	*Paphia textile*	1	9.6	Not listed
EC17	Arcidae	*Anadara antiquate*	5	Total: 42.5 Ave: 8.5	Not listed
	Squillidae	*Oratosquilla oratoria*	2	Total: 9.5 Ave: 4.75	Not listed
	Penaeidae	*Metapenaeus ensis*	1	4.76	Not listed
	Palaemonidae	*Palaemonetes sinensis*	32	Total: 62.13 Ave: 31.06	Not listed
	Naticidae	*Natica tigrina*	1	4.95	Not listed
	Muricidae	*Cymio lacera*	1	11.96	Not listed
EC18	Palaemonidae	*Palaemonetes sinensis*	189	Total: 380 Ave: 2.01	Not listed
	Squillidae	*Oratosquilla oratoria*	2	Total: 9.64 Ave: 4.82	Not listed
	Naticidae	*Natica tigrina*	1	7.82	Not listed

*: Wet season survey at EC13 was not possible due to presence of fishing vessels.
Source: JICA Study Team

3.4 Environmental Socio-Economic Conditions

Within SAPROF study 2010 prepared by JICA SAPROF study team, JICA environmental experts recognized the significant impacts on fishing communities in and around the proposed Lach Huyen Gateway Port despite little consideration for such project affected people in Approved PORT EIA (MONRE No. 2231/QD-BTNMT, 31 October, 2010). A “QUALITATIVE” social environmental survey was conducted to evaluate the potential impacts on such fishing communities in and around the proposed port development area during SAPROF study in 2009 and 2010. Based on the survey, considerable impacts on fulltime and seasonal fishing households were confirmed. Based on SAPROF Study 2010, Vietnamese authorities including VINAMARINE and HPPC and responsible JICA officials recognized the potential impacts on such fishing communities (Annex III A, Minutes of Discussions on Lach Huyen Port Infrastructure Construction Project between JICA and the Government of Vietnam dated 18th June, 2010).

There are few applicable safeguard policies for COASTAL/OFFSHORE fishing although considerable impacts on fishing communities were recognized and appropriate mitigation measures are necessary such as recovery of livelihood or support for vocational training for expected new job opportunities related to the proposed port development projects. On the contrary, safeguard policies for AQUACULTURE or other fishery activities "On LAND" are well developed and practically enforced by law on land and relevant legislation.

Unlike compensation policy for aquaculture on land (land for land or land for cash with recovery of livelihood and living standard), it is not practical for fishermen to compensate with neither "Fishing area for fishing area" nor "fishing area for cash". Because there is no allocated/specified OFFSHORE or COASTAL fishing area in project area except traditional fishing net, it is hardly to define the appropriate compensation for the loss of fishing area under present circumstances and legal frameworks. However, it is also true that compensation or assistance for recovery of livelihood and living standard is necessary for those who are not compensated by any safeguard polities, especially coastal fishermen, who loose primary fishing area and may not be able to recover such loss in other fishing area.

In order to QUANTITATIVELY evaluate the potential impacts on fishing communities, identify the needs for assistance or solutions, and consider recommendable safeguard programs, environmental experts of the JICA D/D study and qualified local environmental experts have conducted social environmental surveys. The result of the survey also covers the potential impacts by land clearance on Cat Hai Island for "Public administration area (Component A[5])" for the proposed Lach Huyen Gateway Port.

3.4.1 Methodologies of Social Environmental Survey

1) Survey Area

Survey area was carefully considered throughout the review of past studies and discussion with local experts and decided to cover the potential DIRECT impact area on local economies including land based activities and coastal and offshore fishing activities (Figure 3.4.1 and Table 3.4.1).

Figure 3.4.1 Social Environmental Survey Area

[5] Component A (including vessel channel, turning basin, breakwater, sand dyke, port service road): VINAMARINE, implementing agency: MPMU II; Component B (wharf, internal road, common port facilities, and so on): Joint venture between VINALINES and Japanese partners introduced by Japanese government. (Decision 476 QD-BGTVT dated 15 March, 2011 by MOT)

Table 3.4.1 List of Surveyed Communes and an Immigrant Fishing Community

Communes		
1	Hoan Chau, Cat Hai Island	Southwest end of the Cat Hai Island with limited road accesses
2	Nghia Lo, Cat Hai Island	West-end gate community of the Cat Hai Island with ferry port and expected joining point of Tan Vu-Lach Huyen Highway Bridge
3	Van Phong, Cat Hai Island	Physically central community with south coastline
4	Dong Bai, Cat Hai Island	Northeast-end community of the Cat Hai Island with limited road access and expected right of way - Tan Vu-Lach Huyen Highway
5	Cat Hai TT, Cat Hai Island	East end of the Cat Hai Island and economically central community with the east gate - Ben Pha Got Harbor
7	Phu Long, Cat Ba Island	West-end gate community of the Cat Ba Island with ferry port
Immigrant Fishing Community		
6	Immigrant Fishermen in Ben Pha Got Harbor	Fishermen living on the fishing boats and coming from other provinces

2) Survey Period

In order to appropriately cover the potentially affected people by the social environmental survey, the surveys were conducted including preliminary survey for survey design as follow.

Table 3.4.2 List of Surveys and Location

25/April	Preliminary survey for social environmental design with local authorities	MPMU II, DONRE/HPPC, Cat Hai Town PC
9-11/May	Preliminary survey for social environmental design with local authorities	DONRE/HPPC, Cat Hai PC (relevant departments), Commune PC (Hoan Chau, Nghia Lo, Van Phong, Dong Bai, Cat Hai TT, Phu Long)
17-31/May	Social environmental survey	Communes (Hoan Chau, Nghia Lo, Van Phong, Dong Bai, Cat Hai TT, Phu Long) and the Immigrant Fishermen in Ben Pha Got Harbor

3) Survey Items and Methods

For the purpose of the QUANTITATIVE evaluation and consistency of the Vietnamese safeguard policy under the law on land, survey items were selected with commonly used survey methods for preparation of “Resettlement action plans or land acquisition”.

Table 3.4.3 Survey Items and Methods

Survey Item	Remarks
Safeguard policies	Confirmation and updates of National and HPPC’s policies on involuntary resettlement and land acquisition including HPPC’s regulation on compensation and unit price for compensation in 2011
Socio-economic profile	Updated information from local authorities commonly by each commune’s reports on social-economic implementation plan
Confirmation of land use and estimation of compensation costs	Based on the land acquisition plan prepared by MPMU II in April 2011, confirmation of actual activities, classification of land, and estimation of land acquisition by field survey
Directly affected household survey for public administration area (component A) and port portion (component B)	Collection of project affected house hold information by interview commonly used for Resettlement Action Plan preparation to evaluate the losses, estimate compensation, share the information on the project, exploration of preferable and feasible compensation measures, and opinion for the projects

Survey Item	Remarks
Value of assets in component A and B	Evaluation of assets including residential and public building, trees, cemetery, public infrastructures, etc.
Directly affected fishing household survey	Collection of project affected fishing house hold (fulltime and seasonal) information by representative* interview commonly used for Resettlement Action Plan preparation to evaluate the losses in fishing activities, estimate compensation value, share the information on the project, exploration of preferable and feasible compensation measures, and opinion for the projects * Since the fishing household survey ONLY focuses on livelihood/income restoration rather than assets' compensation, simplified interview was conducted for financial (income and expenditure), household structure, education level, willingness and potentiality to change the occupation, and opinions for the projects. Unlike asset evaluation, there is good similarity among fishing households' occupation and financial situation in the same community. With assistance by commune PC or representatives of the fishing communities, representative households were selected and interviewed.
Selective consumer price index	Collection of key commodity prices such as rice and fish to understand the present local economy and to be considered as the baseline status of the pre-construction and essential reference for the safeguard programs' monitoring during construction and operation phases

4) Survey Samples

In order to address the potential impacts on those who might not be covered by the existing Vietnamese legal framework, JICA environmental experts have conducted preliminary consultation with representatives of the all commune PCs to identify those potentially impacted groups and effective sampling measures to gather the REPRESENTATIVE and QUANTITATIVE results. For the purpose of the survey's quality control and reference, JICA experts also collected numbers from those who are legally eligible for compensation under legal framework (salt production and aquaculture on land) and have been surveyed by Tan VU – Lach Huyen Highway project. With the JICA experts (Japanese and Vietnamese)' experiences and commune PCs' suggestions, JICA experts have conducted social environmental surveys with the following number of samples.

Table 3.4.4 Number of Social Environmental Survey Samples

Commune/Communities	Total # of HH*	Potentially Affected Coastal/Offshore Fishing HH*		Potentially Affected Salt Production & Aquaculture HH*	
	HH*	Total** HH*	Interviewed HH*	Total** HH*	Interviewed HH*
Hoang Chau	346	186	60 (32%)	55	9 (16%)
Nghia Lo	639	37	15 (45%)	585	18 (3%)
Van Phong	560	50	20 (40%)	510	24 (5%)
Dong Bai	298	76	25 (31%)	369	10 (3%)
Cat Hai town	1,668	253	120 (40%)	295	5 (2%)
Phu Long	520	180	50 (31%)	150	17 (11%)
Total	**4,031**	**782**	**290 (37%)**	**1,964**	**83** (4%)
Immigrant Fishermen in Ben Pha Got Harbor	N/A	N/A	6***	0	0

* HH: house hold, **: Total number was confirmed by each commune representatives in September 2011
*** reference purpose only, 6 HH/Fishing Boats (17 labors out of 27 people) were found and interviewed on the date of social environmental survey, but total number of immigrant HH is not known. All immigrants fishing HH live on the boat and go fishing around port development area or further offshore.
Source: Social environmental survey by JICA D/D Study team

3.4.2 Socio-Economic Condition of the Potentially Affected Communities

1) Population and Labor

Estimated population of the six potentially project affected communes (PACs) is 15,993 (4,045 households) out of 29,797 - population of Cat Hai District (2010). Poverty rate in the 6 communes ranges from 7.4% (Phu-Long Commune) to 10% (Cat Hai town).

Table 3.4.5 Population and Labors in Project Affected Area

Items	Unit	Hoang Chau	Nghia Lo	Van Phong	Dong Bai	Cat Hai town	Phu Long	Total
Total population	Pers.	1,378	2,385	2,300	1,332	6,538	2,060	**15,993**
Male	Pers.	675	1,158	1,104	598	3,101	991	**7,627**
Female	Pers.	703	1,227	1,196	734	3,437	1,069	**8,366**
Total households	HH	364	639	556	298	1,668	520	**4,045**
Average person per household	Per./ HH	3.8	3.7	4.1	4.5	3.9	4.0	**4.0**
Total labors	Pers.	N/A	N/A	556	610	3,495	N/A	**N/A**
Agric. production	HH	N/A	N/A	400	125	N/A	190	**N/A**
Fishing households	HH	186	37	50	76	253	180	**782**
Service & others activities	HH	N/A	N/A	106	98	N/A	181	**N/A**
Rate of poor households	%	8.6	9.7	8.4	7.7	10	7.4	**-**

N/A: Data is Not Available, -: Not Applicable
Source: Social-economic Plan Implementation Reports each commune PC and JICA D/D study team's hearing data at each commune with estimated value by JICA experts

2) Economic Activities in the Project Affected Communes

Primary income source of the PACs are salt production, aquaculture, and fishing. Gradual reduction of salt production was reported among all salt producers due to the gradual increment of rainy days, which has led unfavorable household economies due to continuous increment of costs of living. Limited crop farming and livestock feeding can be seen among the communities, but such products are mainly consumed by the producers' themselves. It is also clear that almost all primary economic activities highly depend on natural environment and vulnerable to environmental changes such as climate, large scale construction work, or large scale industrial activities.

Table 3.4.6 Primary Economical Activities by Sectors in PACs

Items	Unit	Hoang Chau	Nghia Lo	Van Phong	Dong Bai	Cat Hai town	Phu Long
Salt	t/y	N/A	2,560	2,278	2,540	N/A	0
Fishing	t/y	N/A	N/A	52	155	1,040	671
Aquaculture	t/y	N/A	140	N/A	1,800	120	1,268
Livestock	Head in all kind	N/A	8,600	N/A	910 (mill. VND)	2,929	6,605
Agricultural Products	t/y	N/A	58	N/A	N/A	12	42
Fish source production	Litter/y	N/A	N/A	N/A	N/A	10,500	N/A
Service sectors	-	N/A	N/A	9 billion VND	N/A	N/A	700 tourists

Source: Social-economic Plan Implementation Reports each commune PC and JICA D/D study team's hearing data at each commune

3) Land Use

Primary income source of the PACs are salt production, aquaculture, and fishing. Gradual reduction of salt production was reported among all salt producers due to the gradual increment of rainy days, which has led unfavorable household economies due to continuous increment of costs of living. Limited crop farming and livestock feeding can be seen among the communities, but such products are mainly consumed by the producers' themselves. It is also clear that almost all primary economic activities highly depend on natural environment and vulnerable to environmental changes such as climate, large scale construction work, or large scale industrial activities.

Table 3.4.7 Land Use in PACs

Type of land	Hoang Chau	Nghia Lo	Van Phong	Dong Bai	Cat Hai town	Phu Long
Total land area	133.96	N/A	250.28	802.08	172.26	4,408.98
1. Agricultural land	30.82	N/A	181.39	28.62	23.31	N/A
2. Aquaculture land	11.75	254.46	85.42	159.02	110.31	1,184.44
3. Forest land	N/A	10.64	11.01	N/A	3.00	2,675.2
4. Residential	16.34	N/A	18.34	8.44	28.32	21.5
5. Specific use	11.65	N/A	19.71	109.08	N/A	39.92
6. Unused	N/A	N/A	15.67	248.7	5.66	4.31
7. Waters - river, stream, pond	63.24	N/A	N/A	246.77	N/A	N/A
8. Others	N/A	N/A	N/A	1.43	N/A	N/A

Source: Social-economic Plan Implementation Reports by each commune PC and JICA D/D study team's hearing data at each commune

4) Basic Infrastructure

Except tap water supply, basic social infrastructure is well developed in the PACs. Relatively well maintained and developed road networks and frequent ferry and speed boat services allow all PCAs' residents access to necessary social services and business actives. Based on the stakeholders meetings among PACs, the tap water supply from Hai Phong city through the Tan Vu-Lach Huyen Bridge is one of the most eager demands raised by Cat Hai residents.

Table 3.4.8 Basic Social Infrastructures in PACs

Type of Infrastructure		Hoang Chau	Nghia Lo	Van Phong	Dong Bai	Cat Hai town	Phu Long
1. School							
- Kindergarten	Number	1	1	2	1	1	1
- Primary school	Number	1	1		1	1	1
- Secondary sch.	Number	1	1	1	1	1	1
- High school	Number			1			
- Vocational Training Center	Number					1	
2. Hospital							
- Hospital, healthcare station	Number	1	1	1	1	1	1
- Doctors	Pers.	5	N/A	4	2	N/A	1
- Patient beds	Bed	6	N/A	3	12	N/A	10
3. Electricity							
- Households with electricity	%	100	100	100	100	100	100
4. Clean water							
- Tap water	%						13
Well/underground water	%	100	100	100	100	100	87

Type of Infrastructure		Hoang Chau	Nghia Lo	Van Phong	Dong Bai	Cat Hai town	Phu Long
5. Tele- communication							
- Household with telephone	%	96	95	100	52	100	100

Source: Social-economic Plan Implementation Reports each commune PC and JICA D/D study team's hearing data at each commune

5) Occupation and Labors' Age Structure of Interviewed/Focused Project Affected People

Most of interviewed PAP finished primary school or secondary school, which might be led by limited occupational opportunities and few needs for the higher education in the past. The labor groups between 23-40 and 41-55 account for 86% of the interviewed PAPs, which would be the primary target groups requiring appropriate livelihood recovery or/and income restoration programs. Especially, age between 41-55 accounts for 57.5% and may face difficulties to recover the income level with occupational change without proper vocational training.

Table 3.4.9 Age Structure of the Interviewed PAPs

Ages	Male headed household (Number)	Female headed households (Number)	Total (Number)	Percentage (%)
23-40	93	9	102	28.7
41 to 55	179	25	204	57.5
56 to 60	24	3	27	7.6
Above 60	17	5	22	6.2
Total	313	42	355	100
Percentage (%)	88	12	100	

Source: JICA D/D study team's interview at PACs

Table 3.4.10 Occupation (primary income source) of the Interviewed PAPs

Primary Income Source	Unit	Hoang Chau	Nghia Lo	Van Phong	Dong Bai	Cat Hai town	Phu Long
Salt Production	%	4.6	*	65.0	34.3	0.8	0.0
Coastal Fishing	%	81.5	*	22.5	20.0	97.6	90.0
Aquaculture	%	13.8	*	12.5	42.9	1.6	10.0
Government Employee	%	0.0	*	0.0	2.9	0.0	0.0

* Will be updated in DRAFT FINAL report
Source: JICA D/D study team's interview at PACs

6) Income and Expenditure of Interviewed/Focused Project Affected People

Based on the HPPC's most updated resettlement policy, "Decision No. 09/2011/QĐ-TTg issued on 30/01/2011 promulgating the poverty lines for the poor and the poor threshold applicable in the period 2011 – 2015", roughly one forth (1/4) of the interviewed coastal fishermen, salt producer, and aquaculture fishermen could be categorized as equal or under poverty line (VND 400,000/person-month). With the consideration of Occupation type (Table 3.4.10) and Net income level (3.4.10), lower income/poverty line households tend to be higher in coastal fishing communities (Hoang Chau and Cat Hai town except Phu Long) while higher income households tend to be higher in Aquaculture communities (Dong Bai). Based on the interviews, many fishermen in Phu Long commune tend to go fishing not only coastal area around the port development site but also offshore area such as # zero buoy, which is roughly 30km from the Phu Long commune. On the contrarily, due to the limitation of the equipment, fishermen in Cat Hai islands tend to fish only around very near shore, which area would be highly affected by the proposed port construction work. Safeguard programs for such vulnerable occupational group shall be carefully considered in the detail design.

Table 3.4.11 Net Income Level of the Interviewed PAPs

Unit: Household (%)

Commune	Net Income by month (1,000 VND)					
	<2000	**2000 - <3000**	**3,000 - <4,000**	**4,000 - 6,000**	**>6,000**	**Total**
Hòang Châu	5 (7.7)	15 (23.1)	**25 (38.5)**	17 (26.2)	3 (4.6)	65 (100)
Nghĩa Lộ	**10 (33.3)**	7 (23.3)	4 (13.3)	4 (13.3)	5 (16.7)	30 (100)
Văn Phong	**17 (42.5)**	2 (5.0)	10 (25.0)	3 (7.5)	8 (20.0)	40 (100)
Đồng Bài	7 (20.0)	3 (8.6)	1 (2.9)	1 (2.9)	**23 (65.7)**	35 (100)
TT Cát Hải	**43 (34.4)**	24 (19.2)	25 (20.0)	24 (19.2)	9 (7.2)	125 (100)
Phù Long	4 (6.7)	12 (20.0)	9 (15.0)	**18 (30.0)**	17 (28.3)	60 (100)
Total	86 (24.2)	63 (17.7)	74 (20.8)	67 (18.9)	65 (18.3)	355 (100)
Immigrant Fishermen in Ben Pha Got Harbor	0 (0.0)	0 (0.0)	0 (0.0)	2 (33.3)	4 (66.7)	6 (100)

Source: JICA D/D study team's interview at PACs

Table 3.4.12 Expenditure Level of the Interviewed PAPs

Unit: Household (%)

Commune	Expenditure by month (1,000 VND)					
	<2000	**2000 - <3000**	**3,000 - <4,000**	**4,000 - 6,000**	**>6,000**	**Total**
Hòang Châu	1 (1.5)	2 (3.1)	30 (46.2)	28 (43.1)	4 (6.2)	65 (100)
Nghĩa Lộ	0 (0.0)	2 (6.7)	6 (20.0)	19 (63.3)	3 (10.0)	30 (100)
Văn Phong	4 (10.0)	11 (27.5)	14 (35.0)	9 (22.5)	2 (5.0)	40 (100)
Đồng Bài	1 (2.9)	4 (11.4)	6 (17.1)	15 (42.9)	9 (25.7)	35 (100)
TT Cát Hải	1 (0.8)	18 (14.4)	30 (24.0)	68 (54.4)	8 (6.4)	125 (100)
Phù Long	0 (0.0)	10 (16.7)	12 (20.0)	23 (38.3)	15 (25.0)	60 (100)
Total	7 (2.0)	47 (13.2)	98 (27.6)	162 (45.6)	41 (11.5)	355 (100)
Immigrant Fishermen in Ben Pha Got Harbor	0 (0.0)	1 (16.7)	1 (16.7)	4 (66.7)	0 (0.0)	6 (100)

Source: JICA D/D study team's interview at PACs

3.4.3 Status of the Land Clearance for the Lach Huyen Gateway Port Project

Based on the Decision 476 QD-BGTVT dated 15 March, 2011 on approval for adjustment of Hai Phong international gateway port construction investment project- Starting stage, project owner and responsibilities of;

Component A (including vessel channel, turning basin, breakwater, sand dyke, port service road) is VINAMARINE and implementing agency is MPMU II,

While project owner and responsibilities of;

Component B (wharf, internal road, common port facilities, and so on) is joint venture (JV) between VINALINES and Japanese partners introduced by Japanese government.

1) Description of Component A

Requirement for the land acquisition would be 23ha including one of major cemeteries on Cat Hai island, salt pan, abandoned aquaculture pond, pine forest, residential and public service office area, road, and sea dyke. Based on the baseline survey by MPMU II's assigned surveyor in May, number of project affected people for 1) salt production, 2) residential land and 3) residential houses are 49 (persons), 7 (households) and 2 (households) respectively (Table 3.4.13). Since two households are required to relocate fully, a resettlement action plan (RAP) is required to prepare and acquire the approval of the land clearance. However, the requirement area for the two households is allocated for a railway infrastructure in the future, it is not urgent to acquire the approval of the RAP at this moment. Though the aquaculture ponds are observed, presently no leasing contract for such aquaculture pond is made. Thus, there is no need for restoration programs for Aquaculture for component A.

Table 3.4.13 Present Use of Component A Area and Affected Infrastructure

Items	Unit	Quantity	No. of PAPs
I. Affected land	m^2	214,000	
1. Cemetery area	m^2	34,320	
- Unused area	m^2	11,820	
- Grave	tomb	1,000	
2. Salt production area	m^2	33,100	49
3. Aquaculture pond	m^2	98,730	
4. Community forest area	m^2	25,250	
5. Residential area	HH	2	
- Land	m^2	200	2
- Houses	m^2	150	2
II. Affected infrastructure			
6. Electric line 10KVA	m	1140	
7. Electric line 0.4 KVA	m	1140	
8. Telecommunication cable	m	1140	
9 Sea dyke	m	240	
10 Primary road to Ben Got Harbor	m	700	
III. Water surface	ha	824.2	

Source: Land Acquisition Plan - Adjustment on LH Port Construction Investment Project - Land Clearance - Component A, 2011/April (MPMU II)

Table 3.4.14 Estimated Compensation Cost for Component A

Items	Unit	Quantity	Cost (mill. VND)
I. Detailed Land Survey			**300**
II. Affected land	m^2	**214,000**	**25,797**
1. Cemetery area	m^2	34,320	
- Unused area	m^2	11,820	284
- Grave	tomb	1,000	8,580
- Relocation site construction	m^2	22,500	1,350
2. Salt production area*	m^2	33,100	2,277
3. Aquaculture pond*	m^2	98,730	3,199
4. Community forest area	m^2	25,250	364
5. Residential area	HH	2	
- Land	m^2	200	330
- Houses*	m^2	150	164
6. Electric line 10KVA	m	1140	79.8
7. Electric line 0.4 KVA	m	1140	34.2
8. Telecommunication cable	m	1140	68.4
9 Sea dyke	m^3	1,920	632
10 Primary road to Ben Got Harbor	m	700	8,435
III. Water surface	m^2	**8,242,000**	**9,890**
11 Supporting expenditure (estimate)	m^2	8,242,000	9,890
IV. Implementation cost		**2.8% of Sub-Total**	**7,120**
Compensation Sub-Total			36,707
Contingency		10%	3,671
			40,377.634

* including the income restoration support for the affected labors
Source: Land Acquisition Plan - Adjustment on LH Port Construction Investment Project - Land Clearance - Component A, 2011/April (MPMU II)

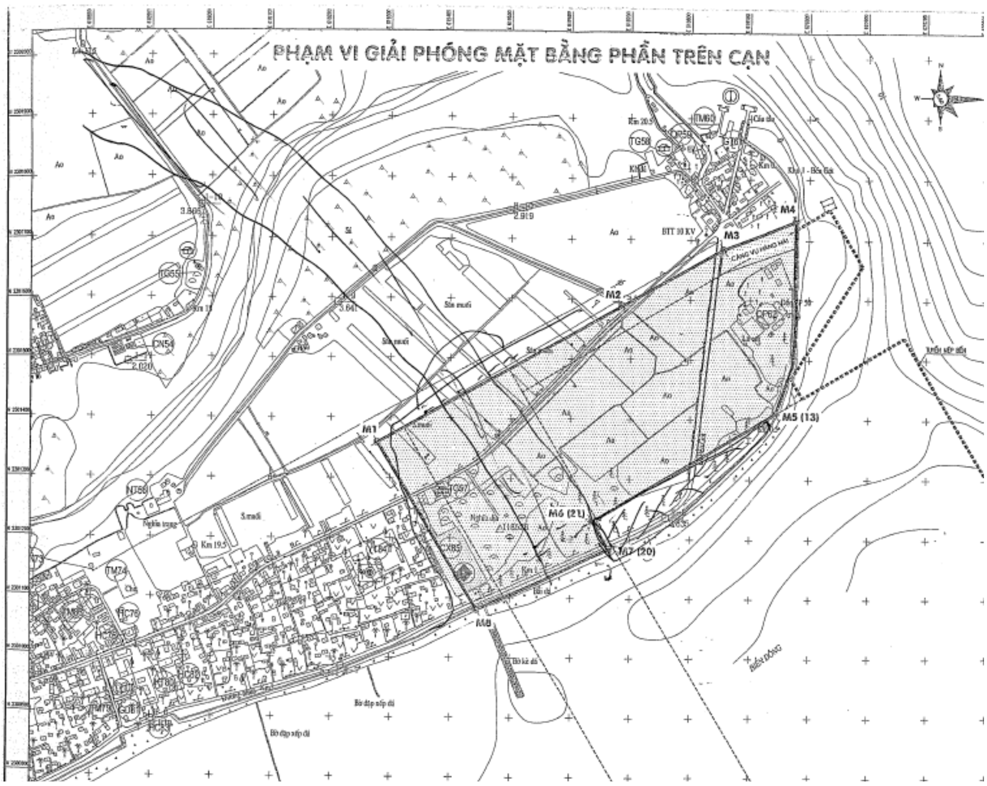


Figure 3.4.2 Component A - Adjustment on LH Port Construction Investment Project

2) Description of Component B

Requirement for the land acquisition would be 1.57ha including abandoned aquaculture pond, pine forest, road, and sea dyke. Based on the baseline survey by VINALINE's assigned surveyor in May, there would be no requirement for involuntary resettlement including residential relocation and active productive land acquisition. As a result, it is very simple procedures to acquire the final approval by the authority (Cat Hai District PC given the full authorization for land clearance matter by HPPC).

Table 3.4.15 Estimated Compensation Cost for Component B

Items	Unit	Quantity	Cost (mill. VND)
1. Woods forest	Tree	989	36.73
2. Coconuts	Tree	15	4.5
3. Graves with owner	Tomb	39	114.1
4. Graves with unknown owner	Tomb	12	142.0
5. Aquaculture pond (commune)	m^2	1,194.6	8.66
6. Aquaculture pond (military)	m^2	571.7	13.76
7. Paved embankment	m^3	21	6.33
8. Water level gage	Gage	1	180
9. Primary road to Ben Got Harbor	m	254	3,073
10a. Cat Hai sea dyke repair	m	391	3,000
10b. Cat Hai sea dyke relocation – volume	m^3	393.6	866
11. Electric line and cable	Poles	5	45
Compensation Sub-Total			7,489.873
Implementation cost		2% of Sub-Total	149.797
Contingency		10%	736,967
Total cost			8,404,000

Source: General Land Acquisition Plan for Hai Phong International Gateway Port Project - Component B, 2011/June (VINALINE)

3) Required Land Acquisition and Number of PAP or PAHs for Component A

In order to evaluate the accuracy of the land acquisition plan and resettlement action plan prepared by MPMU II, following data was collected by field observation and interviews with PAP: size of affected salt pan area, number of affected household, their socio-economic condition, living standards, livelihood, occupational activities, preference for livelihood/living standard restoration program, and opinion for the project in May and June 2011. Number of PAP and affected structures are summarized below. The preference and opinions given by the PAP/PAHs are described in chapter 21.

Table 3.4.16 Permanently Acquired Land Area for Component A

Village	Total households	Residential land		Salt production land	
		HHs	Area (m^2)	HHs	Area (m^2)
Total	55	7	804	49	48,634
Don Luong	36	7	804	30	28,512
Hoa Hy	15			15	16,561
Luc Do	4			4	3,561

Table 3.4.17 Affected Structures in Component A

Village	Structures on residential land					Structures on salt production land				
	Total of HHs	House category IV(m^2)	Auxiliary constructions (m^2)	Water tank (m^3)	Cement yard (m^2)	Total of HHS	Salt storage (m^2)	Yards (m^2)	Ditch (unit)	Salt tank (m^3)
Don Luong	2	115	35	3	23.5	34	94	3760	89	110
Hoa Hy						11	86	2385	59	66
Luc Do						4	25	855	22	28
Total	2	115	35	3	23.5	49	205	7145	173	204

4) Progress of the Land Clearance for Component A

Cat Hai District PC issued the final approval of the land acquisition plan of component A on 2nd of December 2011 (Decision No. 2160/QD-UBND). Following table shows the key steps/achievements toward the land clearance for component A.

Table 3.4.18 Progress of Land Clearance Procedures for Component A

Progress	Remarks
Establishment of Cat Hai Compensation, Assistance, and Resettlement Board (CARB)	The Land Resource Development Center (LDC) of Cat Hai District PC is functioned for land acquisition and resettlement in the district, so it has availably been on duty of land acquisition and resettlement of the Port project
HPPC decision on land acquisition, compensation, and clearance for the Component A	Hai Phong PC/ issue the Decision No.2907/UBND_GT dated 27/5/2011 regarding land acquisition, compensation, and clearance for the Component A
Submission of MPMU II's Study on Land Acquisition Plan - Adjustment on LH Port Construction Investment Project - Component A,	MPMU II has handed over related documents in April 2011 to Cat Hai District PC/ Cat Hai LDC for requesting land clearance. MPMU II has closely cooperated with the Cat Hai LDC officials for land acquisition and clearance implementation for the Component A
Two public consultations	2 meetings were organized by the LDC for information disclosures (notification of project and Government /project resettlement policy.
Final approval of Land Acquisition Plan of Component A	Cat Hai District PC issued the final approval of the land acquisition plan of component A on 02/Dec./2011 (Decision No. 2160/QD-UBND).

5) Time Frame of the Land Clearance for Component A

Based on the communication with Cat Hai district officials in May 2011, followings are expected time frame of land acquisition, resettlement and land clearance for the Component A. Actual land acquisition shall be started after approval of updated RAP and construction will be started after completing payment of compensation and assistance and resettlement. Due to the delay of final approval of the Master Plan of Dinh Vu - Cat Hải Economic Zone, expected time frame was modified to adjust such delay.

Table 3.4.19 Expected Time Frame of Land Clearance for Component A

Activities	Time frame
Public consultation, SES, and information disclosure	May - June, 2011
EOL and RAP formulation, submission, and approval	May - August, 2011
- Fixation of Land acquisition stakes:	October - November, 2011
- Updated RAP formulation: DMS, valuation, and option valuation	December, 2011
Public consultation, SES, and information disclosure Community need assessment for income restoration activities	January - February, 2012
Submission of Updated RAP to Donor for approval	February - March, 2012
Compensation payment	March - April, 2012
Land clearance	March - April, 2012
Internal and External Monitoring	February - March, 2012 on ward
Earliest possible starting month of construction	May, 2012, 2012
Initial post resettlement assessment	May, 2012, 2012 (preferably same month of commencement month)

6) Progress of the Land Clearance for Component B

Cat Hai District PC has issued the final approval of the land acquisition plan of component B on 15th of August, 2011 (Decision No. 1544/QD-UBND). Since the Cat Hai District PC is also the implementation agency of the land clearance, the actual activities shown in Table 3.4.19 shall be taken in accordance with Component A adjacent to Component B.

DIVISION – I

REVIEW OF PREVIOUS FS STUDY

4. REVIEW OF CARGO DEMAND

4.1 Socio-Economic Back Ground Information

4.1.1 Population

According to the 2010 Statistical handbook, the population of Vietnam is estimated as 86,927 thousand. Vietnam is divided into 58 provinces and there are also 5 centrally-controlled municipalities existing at the same level as provinces. Ho Chi Minh City is the biggest municipality with population of 7,396,500 and followed by Hanoi (6,561,900) as shown in Table 4.1.1.

Table 4.1.1 Average Population by Region and Province

Region	Provinces	Population (2010)	Region	Provinces	Population (2010)
Whole Vietnam		**86,927,700**	Central Highlands 5,214,200	Daklak	1,754,400
Red River Delta 18,610,500	Bắc Ninh	1,034,200		Dak Nông	510,600
	Hà Nam	786,300		Gia Lai	1,300,900
	Hải Dương	1,712,800		Kontum	443,400
	Hưng Yên	1,132,300		Lâm Đồng	1,204,900
	Nam Định	1,830,000	South Central Coast 7,095,600	Bình Định	1,489,700
	Ninh Bình	900,600		Khánh Hòa	1,167,700
	Thái Bình	1,786,300		Phú Yên	868,500
	Vĩnh Phúc	1,008,300		Quảng Nam	1,425,100
	Hà Nội *	6,561,900		Quảng Ngãi	1,218,600
	Hải Phòng *	1,857,800		Đà Nẵng *	926,000
North Central Coast 10,092,900	Hà Tĩnh	1,228,000	Southeast 16,313,500	Bà Rịa-Vũng Tàu	1,012,000
	Nghệ An	2,917,400		Bình Dương	1,619,900
	Quảng Bình	849,300		Bình Phước	893,400
	Quảng Trị	600,500		Bình Thuận	1,176,900
	Thanh Hoá	3,406,800		Đồng Nai	2,569,400
	Thừa Thiên-Huế	1,090,900		Ninh Thuận	570,100
Northeast 9,555,700	Bắc Giang	1,560,300		Tây Ninh	1,075,300
	Bắc Kạn	296,500		Hồ Chí Minh City *	7,396,500
	Cao Bằng	513,100	Mekong River Delta 17,272,200	An Giang	2,149,500
	Hà Giang	735,800		Bạc Liêu	867,800
	Lạng Sơn	735,600		Bến Tre	1,256,700
	Lào Cai	626,200		Cà Mau	1,212,100
	Phú Thọ	1,322,100		Đồng Tháp	1,670,500
	Quảng Ninh	1,159,500		Hậu Giang	758,600
	Thái Nguyên	1,131,300		Kiên Giang	1,703,500
	Tuyên Quang	728,900		Long An	1,446,200
	Yên Bái	746,400		Sóc Trăng	1,300,800
Northwest 2,773,100	Điện Biên	504,500		Tiền Giang	1,677,000
	Hoà Bình	793,500		Trà Vinh	1,005,900
	Lai Châu	382,400		Vĩnh Long	1,026,500
	Sơn La	1,092,700		Cần Thơ *	1,197,100

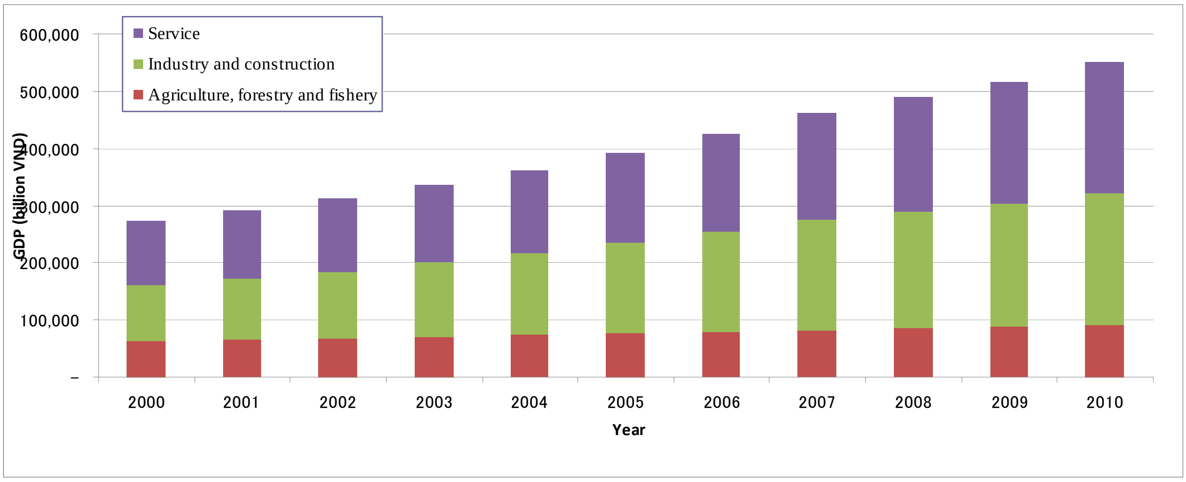
Source: 2010 Statistical Hnadbook
Note: *: municipality

The Vietnam categorizes the various provinces into eight regions. The Red River Delta comprising of 10 provinces is the most populated region (18,610,500), followed by Mekong River Delta (17,272,200). The Red River Delta and the Mekong River Delta are the regions containing the deltas of the two large rivers, where fertile land and favorable conditions for agricultural cultivation are located. These two regions share 41.3% of the country’s population.

4.1.2 Economic Indices

The GDP of Viet Nam at constant 1994 prices is summarized in the following table. In addition, GDP by sector is also indicated in the table.

Table 4.1.2 GDP Growth Rate of Viet Nam, Asian Countries/USA by Year



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GDP	273,666	292,535	313,247	336,242	362,435	393,031	425,373	461,344	489,833	516,568	551,600
Agriculture, forestry and fishery	63,717	65,618	68,352	70,827	73,917	76,888	79,723	82,717	86,082	88,168	90,600
Industry and construction	96,913	106,986	117,125	129,399	142,621	157,867	174,259	192,065	203,791	214,799	231,300
Service	113,036	119,931	127,770	136,016	145,897	158,276	171,392	186,562	199,960	213,601	229,700

(in billion VND)

Source: 2010 Statistical Handbook

From 2004 to 2007, annual GDP growth rate in Viet Nam rose to over 8%, and then slowed down to 6.3% in 2008 and 5.3% in 2009. The impact of global financial crisis on each country's GDP in the years of 2008 and 2009. But 2010 Statistical handbook indicates that GDP growth rate in 2010 is 6.8% as a preliminary data. Therefore, it is expected that Viet Nam economy is recovering from the impact.

After 2009, the GDPs growth rates are estimated to recover from the year 2010. Following table indicates the GDP's forecast by IMF, ADB and the Ministry of Planning and Investment (MPI). Ministry of Planning and Investment (MPI) in Viet Nam is assumed for GDP growth rate in 2010-2020 as 6.5% for sustainable growth of GDP and 7.5% for high level of GDP.

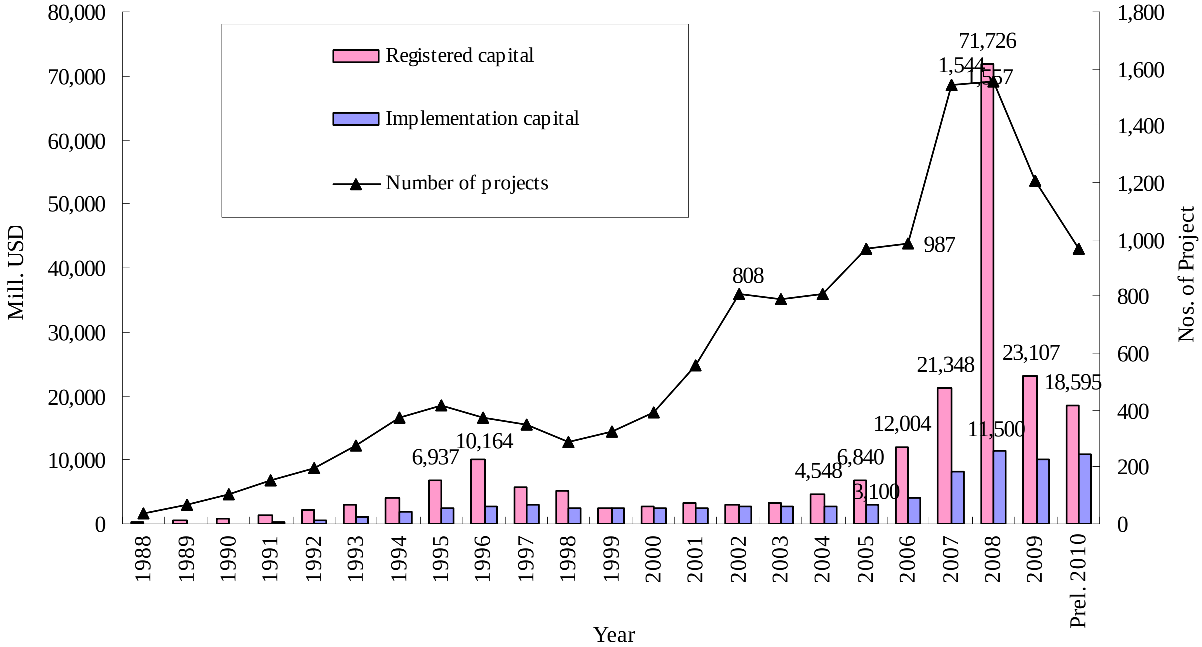
Table 4.1.3 GDP Growth Rate of Viet Nam, Asian Countries/USA by Year

Country \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Forecast by	2011	2012	2013	2014	2015	2016
Vietnam	6.8	6.9	7.1	7.3	7.8	8.4	8.2	8.5	6.3	5.3	6.8	IMF	6.3	6.8	7.2	7.4	7.5	7.5
												ADB	6.1	6.7				
												MPI	6.5% for 2010-2020					
China	8.4	8.3	9.1	10.0	10.1	10.4	11.6	13.0	9.0	9.0	9.0	IMF	9.6	9.5	9.5	9.5	9.5	9.5
												ADB	8.2	8.9				
Hong Kong	8.0	0.5	1.8	3.0	8.5	7.1	7.0	6.4	2.3	-2.7	6.8	IMF	5.4	4.2	4.2	4.2	4.3	4.3
												ADB	5.0	4.7				
India	5.7	3.9	4.6	6.9	7.9	9.2	9.7	9.2	6.7	8.0	8.6	IMF	8.2	7.8	8.2	8.1	8.1	8.1
												ADB	8.2	8.8				
Indonesia	5.4	3.6	4.5	4.8	5.0	5.7	5.5	6.3	6.0	4.6	6.1	IMF	6.2	6.5	6.7	7.0	7.0	7.0
												ADB	6.4	6.7				
Japan	2.9	0.2	0.3	1.4	2.7	1.9	2.0	2.3	-0.7			IMF	1.4	2.1	1.7	1.5	1.3	1.2
Korea	8.5	4.0	7.2	2.8	4.6	4.0	5.2	5.1	2.3	0.2	6.1	IMF	4.5	4.2	4.2	4.0	4.0	4.1
												ADB	4.6	4.6				
Malaysia	8.7	0.5	5.4	5.8	6.8	5.3	5.8	6.5	4.7	-1.7	7.2	IMF	5.5	5.2	5.1	5.1	5.0	5.0
												ADB	5.3	5.3				
Philippines	6.0	1.8	4.4	4.9	6.4	5.0	5.3	7.1	3.7	1.1	7.3	IMF	5.0	5.0	5.0	5.0	5.0	5.0
												ADB	5.0	5.3				
Singapore	10.1	-2.4	4.1	3.8	9.3	7.3	8.6	8.8	1.5	-0.8	14.5	IMF	5.2	4.4	4.3	4.2	4.1	4.0
												ADB	5.5	4.8				
Taiwan	5.8	-2.2	4.6	3.5	6.2	4.2	5.4	6.0	0.7	-1.9	10.8	IMF	5.4	5.2	5.1	5.0	4.9	4.9
												ADB	4.8	5.0				
Thailand	4.8	2.2	5.3	7.1	6.3	4.6	5.1	5.0	2.5	-2.3	7.8	IMF	4.0	4.5	4.7	4.8	4.9	5.0
												ADB	4.5	4.8				
United States	4.1	1.1	1.8	2.5	3.6	3.1	2.7	2.1	0.4			IMF	2.8	2.9	2.7	2.7	2.7	2.7

Source: IMF (International Monetary Fund), World Economic Outlook Database, April 2011
ADB (Asia Development Bank), Asian Development Outlook 2009 Update, Sep 2011
MPI (Ministry of Planning and Investment) , 2009 GDP forecast was announced by 7th plenary session of National Assembly's Economic Committee, May 2009

4.1.3 Foreign Direct Investment (FDI)

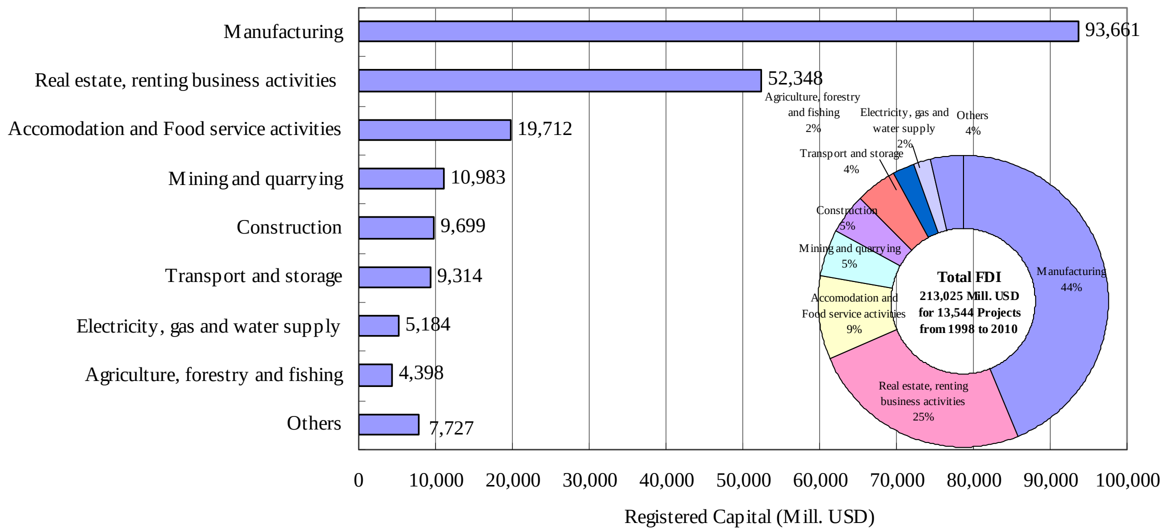
After 20 years of economic reform, Vietnamese economic growth is driven by the strong FDI inflows. Especially, the past three years, since 2006, FDI inflows sharply increased, thanks to the favorable FDI promotion policies after the accession WTO. In 2006, registered FDI recorded 12 billion USD; then, in 2007 reached 21.3 billion USD; in 2008 increased 71.7 billion USD. But, the influence from global financial crisis caused the slowdown in FDI in Vietnam, and FDI has not recovered from the influence until 2010 (Figure 4.1.1).



Source: GSO

Figure 4.1.1 FDI Inflows

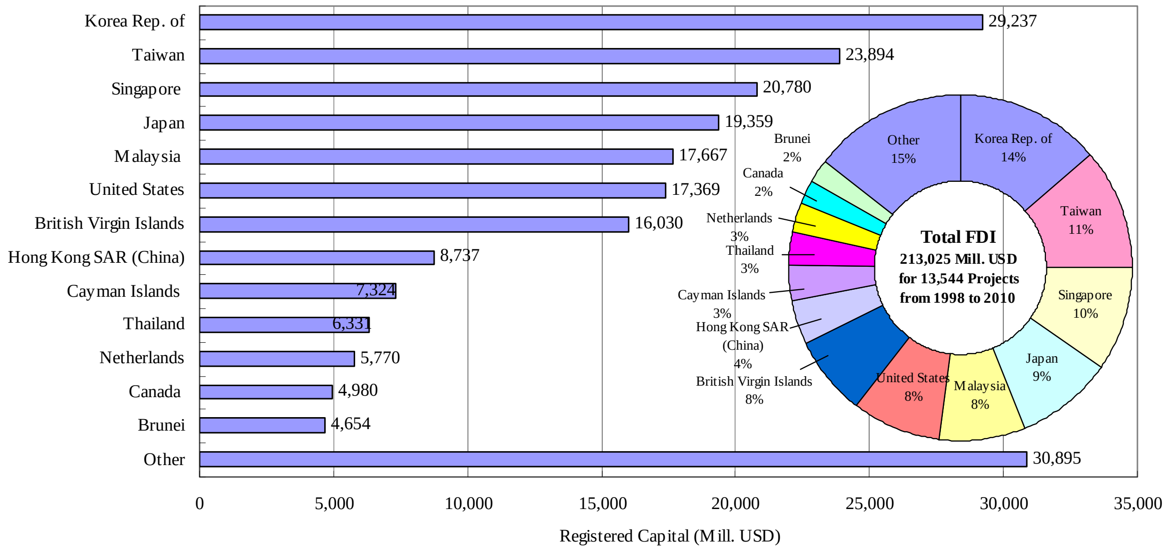
From 1988 to 2010, FDI inflows have been focused especially on manufacturing sector with 93.7 billion USD (44% of total) and followed by real estate, renting business activities sector with 52.3 billion USD (25% of total), both sectors have high proportion in the FDI inflow (Figure 4.1.2).



Source: GSO

Figure 4.1.2 FDI Inflows from 1988 to 2010 by Sector

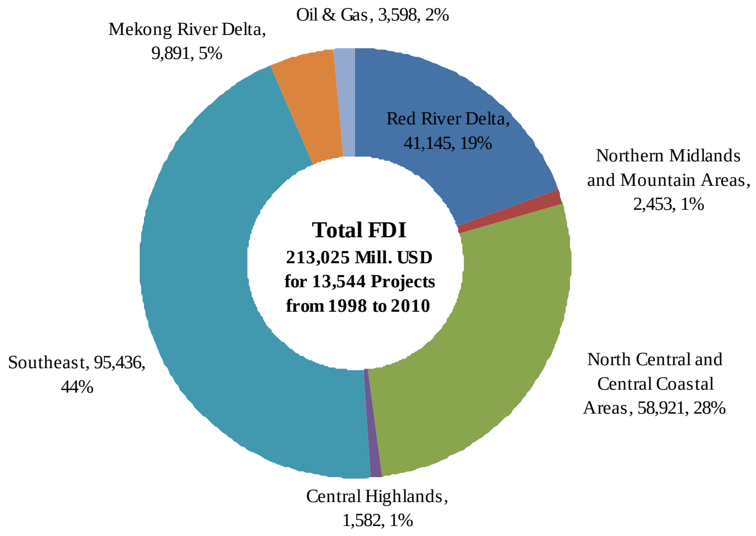
From 1988 to 2010, top 10 countries and territories having invested into Vietnam are Korea, Taiwan, Singapore, Japan, Malaysia, United States, British Virgin Islands, Hong Kong, Cayman Island and Thailand, accounting for 78.3% of registered capital of total FDI inflows as shown in Figure 4.1.3.



Source: GSO

Figure 4.1.3 FDI Inflows from 1988 to 2010 by Countries

From 1988 to 2010, registered capital of FDI Inflows in the Southeast region hit the highest 95.4 billion USD accounting for 45% of total and followed by North Central and Central Coastal Area 58.9 billion USD (28% of total). Figure 4.1.4 shows registered capital in FDI inflows (1998-2010) by regions.



Source: GSO

Note: Including supplementary capital to licensed projects in previous years, including Oil & Gas

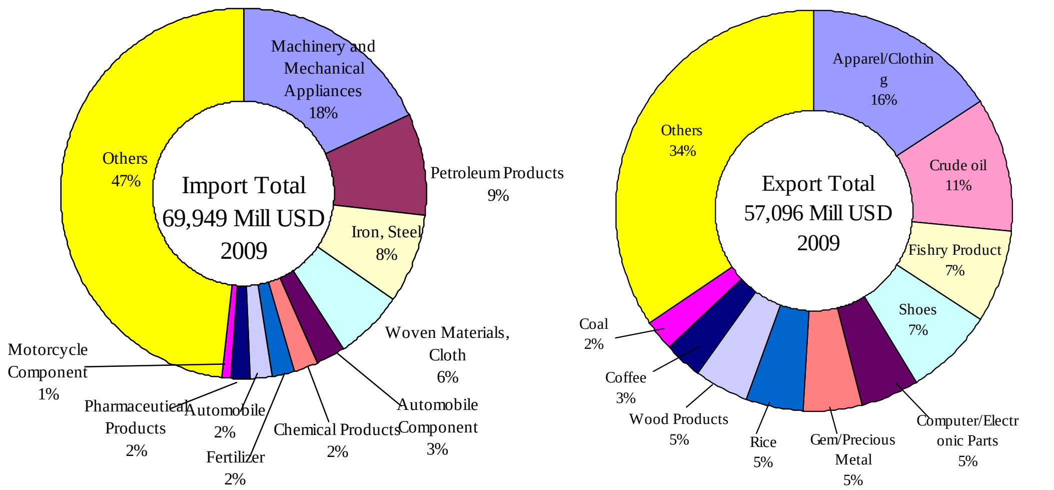
Figure 4.1.4 Registered Capital of FDI Inflows from 1988 to 2010 by Regions

4.1.4 Distribution of Goods and Ocean Shipping

1) Distribution of Goods

a) Trade in Viet Nam

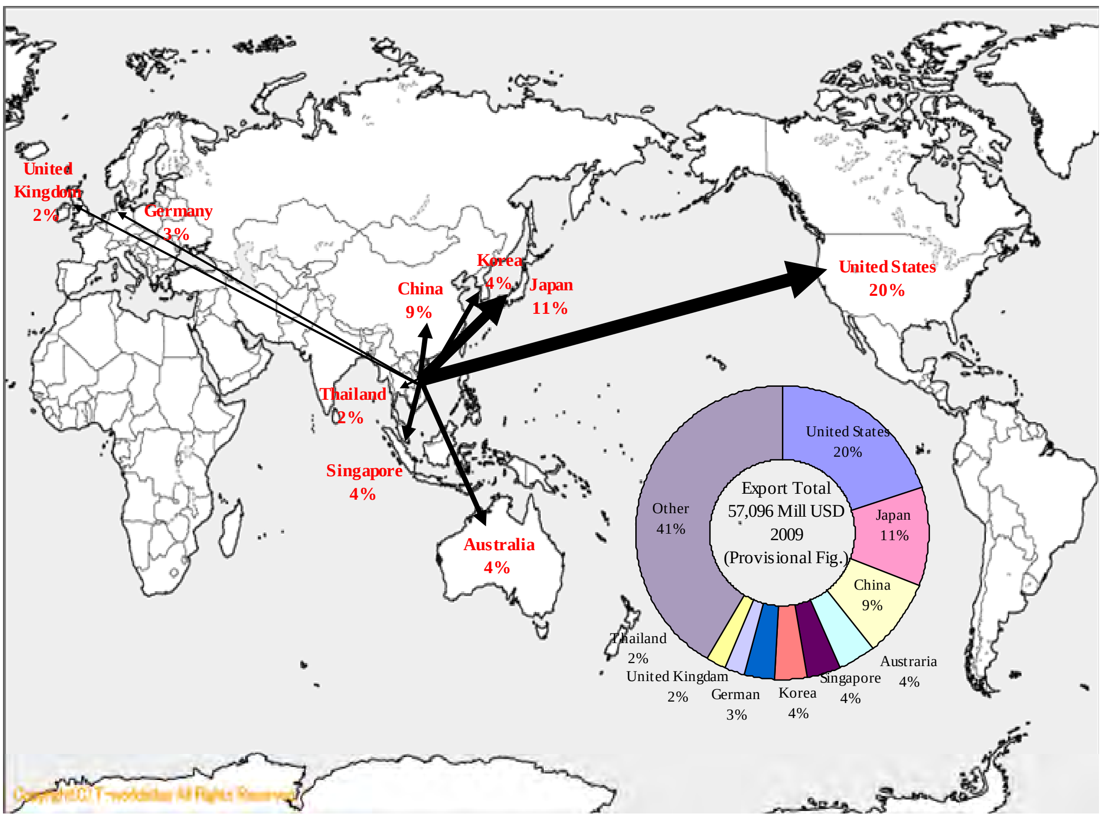
Vietnam has demonstrated its strong commitment to trade liberalization in recent years. It has joined the WTO in 2007 and signed Free Trade Agreements (FTAs) with ASEAN countries and the USA. Vietnam also has a cooperation agreement with the EU. In 2009, exports are mainly made up of apparel/clothing, crude oil, and fishery products, whereas imports are mainly made up of machinery, petroleum products and steel (Figure 4.1.5).



Source: JETRO

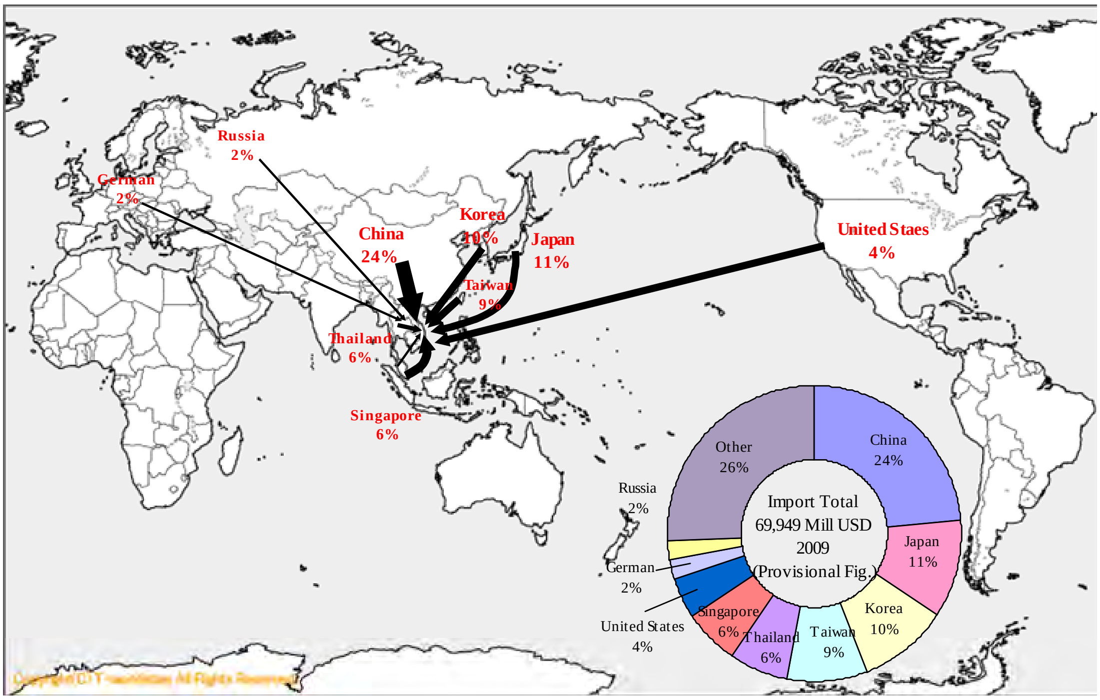
Figure 4.1.5 Main Commodity of Import and Export

The main export customers of Vietnam are the USA, Japan, China and Australia. For imports, the country's main partners are China, Japan, South Korea, Taiwan and Singapore. (See Figure 4.1.6 and Figure 4.1.7 Trade Partner Country of Import and Export in 2009)



Source: JETRO

Figure 4.1.6 Trade Partner Country of Export in 2009

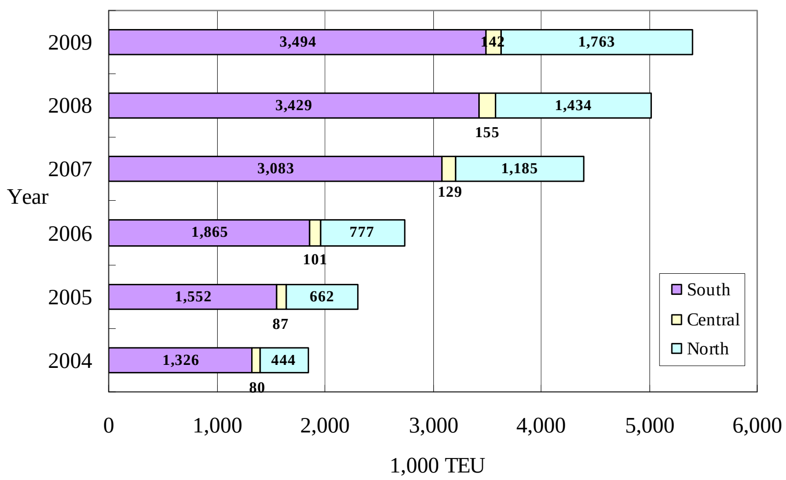


Source: JETRO

Figure 4.1.7 Trade Partner Country of Import in 2009

b) Rapid Growth of Container Movement in Viet Nam's Sea Ports

In 2008, Viet Nam's seaport handled 5,018,000 TEU, 2.7 times of 1,851,000 TEU in 2004. Especially, Northern Vet Nam's sea ports handled 1,434,000 TEU, 3.2 times of 444,000 TEU in 2004 (Figure 4.1.8).



Source: Vietnam Seaport Association and VINAMARINE

Figure 4.1.8 Rapid Growth of Container Movement in Viet Nam's Sea Ports

c) Nationwide Cargo Throughputs in the Seaports

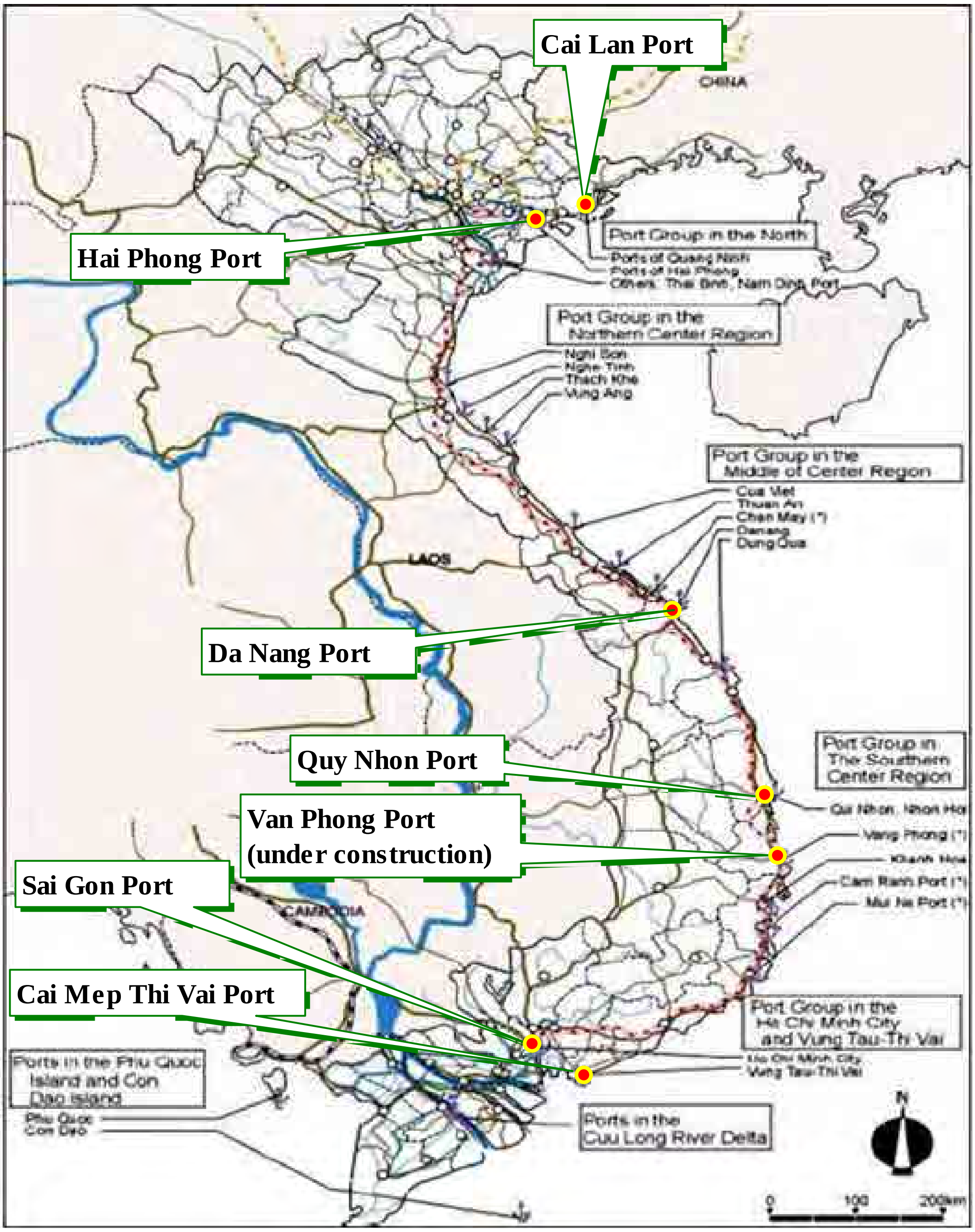
In 2009, Viet Nam's seaport handled 172,128,000 tons, comprising 47,118,000 tons of import, 80,984,000 tons of export and 44,026,000 tons of domestic transport. On the other hand, total vessel calls were 32,021 in the Vietnam's Seaports, consisting of 10,089 calls in North Vietnam, 8,804 calls in Central Vietnam and 13,128 in South Vietnam (Table 4.1.4).

Table 4.1.4 Cargo Throughputs in Vietnam Sea Port

2009							
No.	**Ports'name**	**Vessels**	**Cargo throughput (x 1,000 MT)**				**TEUs**
		Calls	***Tons***	***Import***	***Export***	***Domestic***	
NORTH		**10,089**	**63,752**	**17,126**	**29,129**	**17,394**	**1,762,627**
1	Quang Ninh	464	4,736	1,633	1,674	1,430	185,235
2	Cam Pha	2,543	25,700		22,550	3,150	
3	Cang dau B12	325	7,862	4,000		3,862	
4	Hai Phong	4,779	14,730	8,226	2,376	3,768	816,000
5	Doan Xa	256	4,300	704	640	2,956	250,000
6	Vat Cach	708	1,323	62	3	1,258	
7	Cua cam	400	530	120		410	
8	Transvina	212	1,676	473	1,203		152,392
9	Dinh Vu	402	3,254	1,909	683	663	359,000
CENTRAL		**8,804**	**14,994**	**1,183**	**6,583**	**7,228**	**142,229**
1	Thanh Hoa	443	282	20	5	257	
2	Nghe Tinh	934	1,249	95	605	549	3,918
3	Ha Tinh	245	786	11	661	114	
4	Quang Binh	128	88			88	
5	Vinashin-Cua Viet	172	84	44	18	23	
6	Thuan An	136	120		20	100	
7	Chan May	233	1,003	18	590	395	
8	Da Nang	1,800	3,132	63	1,352	1,717	69,720
9	9 Song Han						
10	Hai Son	214	214			214	
11	Nguyen Van Troi	216	166			166	
12	Ky Ha	434	300		155	145	
13	Ky Ha – Quang Nam	200	40			40	10,000
14	Quy Nhon	1,510	3,856	836	2,016	1,004	54,649
15	Thi Nai	542	644	3	113	528	
16	Nha Trang	688	1,334	30	395	909	3,942
17	Cam Ranh	518	1,257	63	622	571	
18	V4ng Ro	391	438		30	408	
SOUTH		**13,128**	**93,382**	**28,809**	**45,272**	**19,301**	**3,494,246**
1	Ben Dam – Con Dao VT	350	265			265	
2	Thuong Cang Vung Tau	478	578	25	127	427	
3	Interflour Cai Mep	25	272	254		18	
4	SP-PSA	68	1,056	1,056			96,000
5	Phu My	412	3,133	2,559	68	506	
6	Dong Nai	741	2,366	792	530	1,044	
7	Binh Duong	600	600	3	3	594	60,000
8	Xang Dau Cat Lai	71	1,971	990		981	
9	Saigon Petro	134	983	983			
10	Tan Cang Sai Gon	2,319	33,000	13,073	19,927		2,460,000
11	Sai Gon	1,721	14,008	4,375	4,615	5,019	378,226
12	Tan Thuan Dong	176	696	693		3	
13	Ben Nghe	870	4,354	1,948	455	1,951	140,922
14	VICT	672	3,300	1,500	1,800		300,000
15	Rau Qua	136	299			299	295
16	Lotus	411	1,127	13	1,100	14	23,896
17	SPCT	30	88	50	38		8,000
18	Nha Be Oil	244	4,700			4,700	
19	My Tho	177	210	31	17	162	
20	Dong Thap	40	242	20	17	222	
21	Vinh Long	67	255	4	2	249	
22	Binh Minh	15	250			250	
23	Can Tho	1,713	7,532	191	6,798	544	8,052
24	Tra Noc – Can Tho	549	4,409		3,552	857	
25	Cai Cui	494	4,340		4,266	74	
26	Cty CP-VT Thuy Can Tho	130	72			72	
27	My Thoi	485	3,275	249	1,974	1,051	18,855
TOTAL		**32,021**	**172,128**	**47,118**	**80,984**	**44,026**	**5,399,102**

Source: Vietnam Seaport Association and Port operator data by VINAMARINE

Viet Nam has 80 seaports in 8 categorized seaport groups. The major seaports in Viet Nam are illustrated in Figure 4.1.9. In 2009, the construction of Van Phong Port started aiming for deep-sea transshipment hub port.

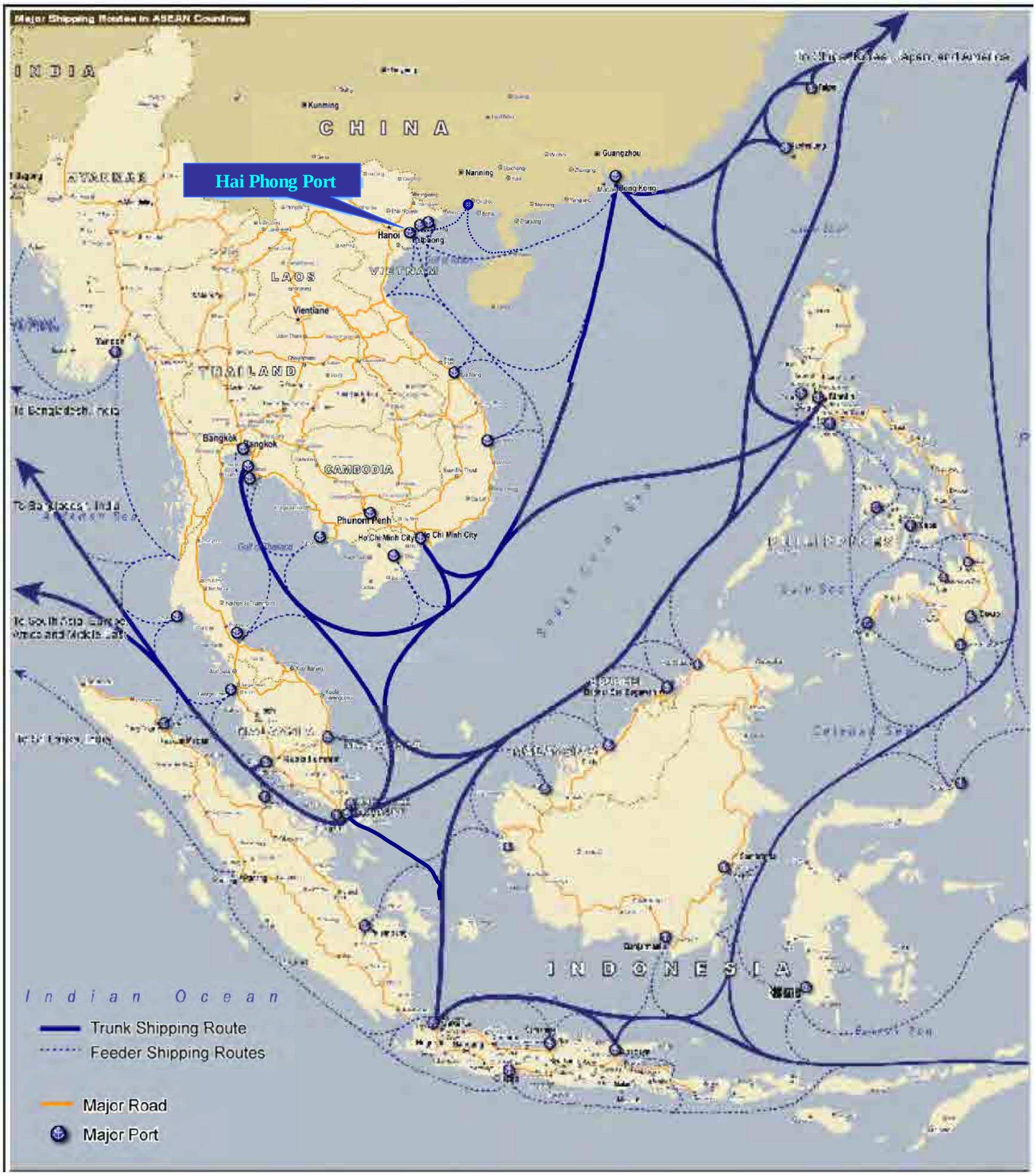


Source: VINAMARINE and Study Team

Figure 4.1.9 Major Seaports in Viet Nam

d) Shipping Route and Line in the Northern Seaports

In 2008, the Northern Seaports in Viet Nam acted as only feeder ports, no deep-sea ports for trunk line vessels. Therefore, most of the Vietnamese export or import cargoes without deep-sea port in Southern Vietnam were transported to the neighboring hub ports where the vessels sailing on trunk line could call, such as ports of Hong Kong and Singapore, and then transshipped to the mother vessels and transported to the destination ports (Figure 4.1.10).



Source: ASEAN Logistics Network Map, 2nd Edition 2008, JETRO, Arrangement by JICA Study Team

Figure 4.1.10 Trunk and Feeder Shipping Routes of Viet Nam's Seaports

In 2009, the shipping schedule of Hai Phong Port has 43 liner service routes, 22 routes via Hong Kong port and 7 routes via Singapore Port. The maximum onboard capacity is 3,252 TEUs (Table 4.1.5).

Table 4.1.5 Liner Service in Hai Phong Port (as of November 2009)

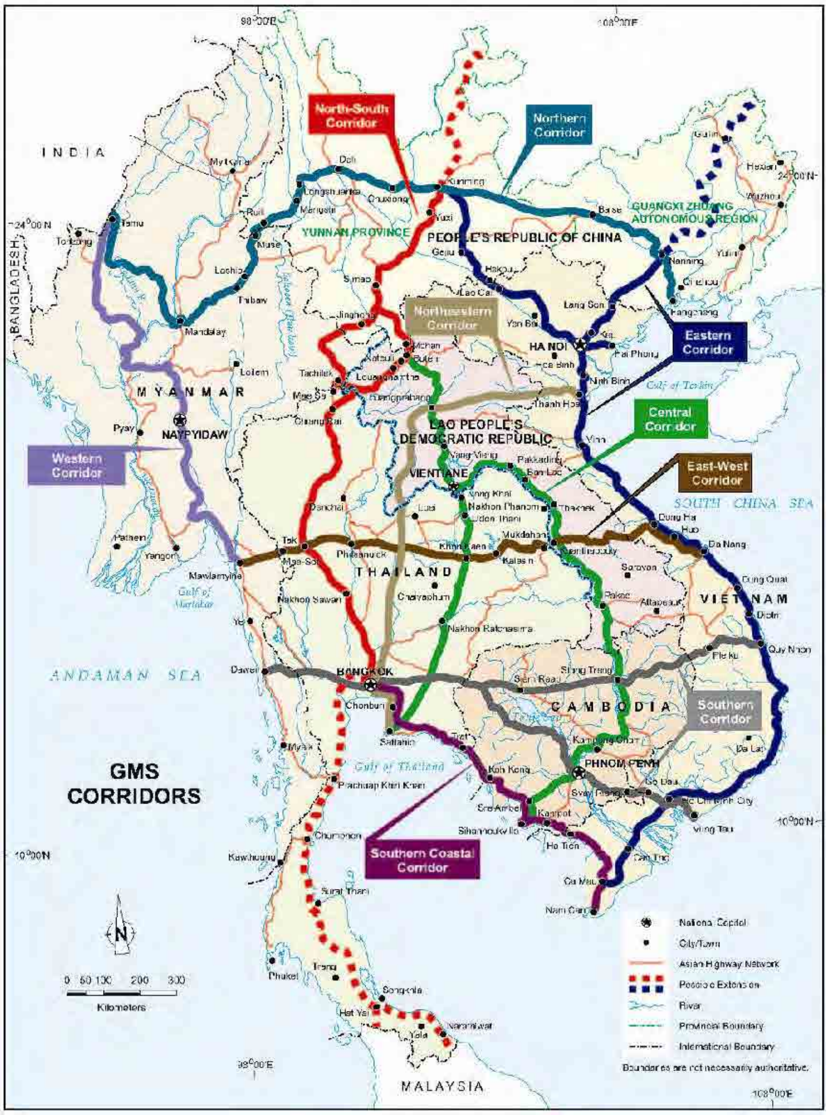
No.	Shipping Line	Service Code	Type of Service	Frequency	Fixed Day Service	Total Vessels	Shipboard Capacity	Service Partners	Shipping Route	Days of Round Trip
1	Advance Container Lines (Pte) Ltd	North Vietnam Exp	Feeder service	2 sailings a week	Yes	1	938 TEU	Advance Container Lines (Pte) Ltd Samudera Shipping Line Ltd	Singapore(PSA)-Haiphong-Danang-Qui Nhon-Singapore(PSA)	14
2	Bien Dong Shipping Co	Vietnam-Singapore	Feeder service	1 sailing a week	No	4	3,252 TEU	Bien Dong Shipping Co Mitsui OSK Lines Ltd	Haiphong-HCM-Singapore (PSA)-HCM-Haiphong	14
3		Vietnam-Hong Kong	Feeder service	3 sailings a week	Yes	3	1,285 TEU	Bien Dong Shipping Co Slot-charter Mitsui OSK Lines Ltd	Haiphong-Hong Kong- Haiphong	7
4		Vietnam-Thailand	Feeder service	1 sailing a week	Yes	2	1,154 TEU	Bien Dong Shipping Co Slot-charter Mitsui OSK Lines Ltd	Haiphong-HCM-Bangkok-Laem Chabang-HCM-Haiphong	14
5		Vietnam-Korea	Mainline service	1 sailing a week	Yes				Haiphong-Busan-Haiphong	14
6	Cosco Container Lines Ltd	HPP	Mainline service	1 sailing a week	Yes	1	422 TEU		Hong Kong-Haiphong-Fangcheng-Hong Kong	7
7	China Shipping Container Lines Co Ltd	Chiwan-HK-Haiphong	Mainline service	1 sailing a week	Yes	1	170 TEU		Chiwan-Hong Kong-Haiphong-Chiwan	7
8	CT Navigation SA	Vietnam	Mainline service	1 sailing a week	Yes	1	556 TEU		Kaohsiung-Haiphong-Danang-Kaohsiung	7
9	China United Lines Ltd	SVG	Feeder service	1 sailing a week	Yes	1	525 TEU		Shekou-Hong Kong-Haiphong-Fangcheng-Shekou	7
10	Evergreen Line	KHP	Mainline service	1 sailing a week	Yes	1	629 TEU		Kaohsiung-Haiphong-Kaohsiung	7
11	Gold Star Line Ltd	HHS	Feeder service	1 sailing a week	Yes			Slot-charter Gold Star Line Ltd Sinokor Merchant Marine Co Ltd	Haiphong-Hong Kong-Haiphong	7
12		HSX	Mainline service	1 sailing a week	Yes			Slot-charter Gold Star Line Ltd Perkapalan Dai Zhun Sdn Bhd (PDZ)	Hong Kong-Haiphong-Fangcheng-Hong Kong	7
13	Hanjin Shipping Co Ltd	HES	Mainline service	1 sailing a week	Yes				Haiphong-Shanghai-Busan-Shanghai-Haiphong	14
14	Heung-A Shipping Co Ltd	HPS1	Mainline service	1 sailing a week	Yes	2	1,306 TEU		Gwangyang-Busan-Hong Kong-Haiphong-Fangcheng-Hong Kong-Gwangyang	14
15		HPS2	Mainline service	1 sailing a week	Yes				Haiphong-Fangcheng-Shekou-Hong Kong- Ulsan-Busan-Hong Kong-Haiphong	14
16	Hub Shipping Sdn Bhd	Pkg-Hph-Hcm-Pkg	Feeder service	1 sailing a week	Yes	1	700 TEU	CNC Line Co Ltd Gemartrans (Vietnam) Co Ltd Hub Shipping Sdn Bhd	Port Klang-Haiphong-HCM-Port Klang	14
17	Kawasaki Kisend Kaisha Ltd	GEMCO-2	Feeder service	1 sailing a week	Yes			Gemadept Logistics Co Ltd Slot-charter Kawasaki Kisen Kaisha Ltd	Haiphong-Hong Kong-Haiphong	7
18		GEMCO-3	Feeder service	1 sailing a week	Yes			Gemadept Corp Slot-charter Kawasaki Kisen Kaisha Ltd	Haiphong-Kaohsiung-Haiphong	7
19	MCC Transport Pte Ltd	NVN2	Feeder service	1 sailing a week	Yes	2	1,775 TEU	Evergreen Line MCC Transport Pte Ltd	Tanjung Pelepas-Singapore (PSA)-Taijung Pelepas-Haiphong-Danang-Nhatrang-Tanjung Pelepas	14
20		NVN4	Feeder service	1 sailing a week	Yes	1	1,128 TEU	Evergreen Line MCC Transport Pte Ltd	Singapore (PSA)-Quy Nhon-Haiphong-Quy Nhon-Nha Trang-Tanjung Pelepas-Singapore (PSA)	14
21	Mariana Express Lines Ltd	KHX	Feeder service	2 sailings a week	Yes	2	1,404 TEU	Mariana Express Lines Ltd Slot-charter Yang Ming Marine Transport Corp	Kaohsiung-Haiphong-Kaohsiung	7
22	Mitsui OSK Lines Ltd	TVS	Mainline service	1 sailing a week	Yes			Bien Dong Shipping Co Slot-charter Mitsui OSK Lines Ltd	Haiphong-HCM-Bangkok-Laem Chabang-HCM-Haiphong	14
23		VH2	Feeder service	1 sailing a week	Yes			Bien Dong Shipping Co Slot-charter Mitsui OSK Lines Ltd	Hong Kong-Haiphong-Hong Kong	7
24		VSS	Feeder service	1 sailing a week	Yes			Bien Dong Shipping Co Mitsui OSK Lines Ltd	Haiphong-HCM-Singapore (PSA)-HCM-Haiphong	14
25		VH3	Feeder service	1 sailing a week	Yes			Bien Dong Shipping Co Slot-charter Mitsui OSK Lines Ltd	Haiphong-Shekou-Hong Kong-Haiphong	7
26		VH4	Feeder service	1 sailing a week	Yes			Bien Dong Shipping Co Slot-charter Mitsui OSK Lines Ltd	Haiphong-Hong Kong-Haiphong	7
27	Mediterranean Shipping Co SA	Tongking Express	Feeder service	1 sailing a week	Yes	1	2,157 TEU		Hong Kong-Haiphong-Shantou-Hong Kong	7
28	Namsung Shipping Co Ltd	Vietnam Haiphong	Mainline service	1 sailing a week	Yes	2	684 TEU		Incheon-Gwangyang-Busan-Hong Kong-Haiphong-Shekou-Incheon	14
29	Orient Oversea Container Line Ltd	HPH	Feeder service	1 sailing a week	Yes				Haiphong-Kaohsiung-Haiphong	7
30	STX Pan Ocean Co Ltd	KHX	Feeder service	1 sailing a week	Yes	1	1,049 TEU	Korea Marine Transport Co Ltd STX Pan Ocean Co Ltd	Shanghai-Busan-Gwangyang-Haiphong-Xiamen-Shanghai	14
31		KVX	Feeder service	1 sailing a week	Yes	1	1,118 TEU	Korea Marine Transport Co Ltd STX Pan Ocean Co Ltd	Incheon-Busan-Hong Kong-Haiphong-Hong Kong-Shekou-Incheon	14
32	PDZ Lines	HSX	Feeder service	1 sailing a week	Yes	1	384 TEU	Slot-charter Gold Star Line Ltd PDZ Lines Slot-charter Zim Intergrated Shipping Services Ltd	Hong Kong-Haiphong-Fangcheng-Hong Kong	7
33		HEX	Feeder service	1 sailing a week	Yes				Singapore (PSA)-Haiphong-Singapre (SPA)	7
34	Regional Container Lines Public Co Ltd	RHP	Mainline service	1 sailing a week	Yes			Slot-charter Regional Container Lines Public Co Ltd Steamers Feederships (99) Pte Ltd	Singapore (PSA)-Haiphong-Singapre (SPA)	14
35		RSK	Mainline service	1 sailing a week	Yes	3	1,884 TEU		Songkhla-Hong Kong-Haiphong-Hong Kong-Keelung-Taichung-Hong Kong-Sihanoukville-Songkhla	21
36		RSX	Mainline service	1 sailing a week	Yes	2	2,228 TEU		Shekou-Singapore (PSA)-Haiphong-Hong Kong-Xiamen-Hong Kong-Shekou	14
37	Russo-Orient Shipping Line Co Ltd	Russo-Orient Exp	Mainline service	2 sailings a week	No				Vostochniy-Vladivostok-Hong Kong-Singapore (PSA)-HCM-Haiphong-Hong Kong-Vostochniy	
38	Samudera Shipping Line Ltd	NVX	Feeder service	1 sailing a week	Yes	1	1,054 TEU	Advance Container Lines (Pte) Ltd Samudera Shipping Line Ltd	Singapore (PSA)-Haiphong-Danang-Quy Nhon-Singapore (PSA)	14
39	Sinokor Merchant Marine Co Ltd	HHS	Mainline service	weekly	No	1	300 TEU		Hong Kong-Haiphong-Hong Kong	
40	SITC Container Lines Co Ltd	CJV	Mainline service	1 sailing a week	No				Tokyo-Yokkaichi-Nagoya-Shanghai- Hong Kong-HCM-Haiphong-Tokyo	
41	Steamers Feederships (99) Pte Ltd	Sing-Haiphong	Mainline service	2 sailings a week	Yes			Gemartrans (Vietnam) Co Ltd Slot-charter Regional Container Lines Public Co Ltd Sea Consortium Pte Ltd Slot-charter Steamers Feederships (99) Pte Ltd	Singapore (PSA)-Haiphong-Singapore (PSA)	14
42	Vinalines Shipping Co	HCM-HPH	Feeder service	5 sailings a week	No	5	2,275 TEU		HCM-Haiphong-HCM	6
43	Wan Hai Lines Ltd	HPH/HP2	Mainline service	2 sailings a week	Yes	2	1,282 TEU		Haiphong-Kaohsiung-Haiphong	7

Source: Web Sites of Shipping Lines

e) Vietnam-China Boarder Transport in the Northern Vietnam

Vietnam-China border regions have effectively cooperated in transport, tourism, culture and education. In 2003, the Greater Mekong Subregion (GMS) Cross-Border Transport Agreement (CBTA) entered into force for a multilateral legal instrument among GMS countries (Cambodia, People's Republic of China [PRC], Lao People's Democratic Republic [Lao PDR], Myanmar, Thailand and Vietnam). The major actions related to the transport between Vietnam and China are as follows:

- A new highway connecting Nanning National Route 1 in Vietnam was opened. (2005)
- The regular scheduled road transport service from Hanoi to China has begun and then, using the return transport, the consolidation service for multi customers also started. (2007)
- Vietnam and China signed MOU to include the Nanning-Hanoi corridor and the Youyiguan-Huu Nghi Border Crossing Point under the umbrella of the GMS Cross-Border Transport Agreement. (2008)
- For facilitation of the movement of Chinese goods, Vietnam Government has the planning of six-lane expressway from Hanoi to Lang Son to connect with Guangxi. (2008)



Source: GMS Transport Strategy 2006-2015, ADB

Figure 4.1.11 New GMS Corridors

Figure 4.1.12 shows the present condition of sea and land transport of Hanoi-Guangzhou. After opening Nanning - Youyiguan expressway in the end of 2005 and opening Nanning – Zhanjiang - Guangzhou around the same time, the sea transport cost of Hanoi-Guangzhou is half price of the land transport cost, but the sea transport days are 1.5 times longer than land transport days.

Source: JETRO

Figure 4.1.12 Sea and Land Transport from Hanoi to Guangzhou Area

Fangcheng Port in Guangxi province is one of major 24 ports in China. Fangcheng port has 36 berths including 21 deep-sea berths of more than 10,000 ton vessel accommodation and maximum berth capacity with 200,000 ton vessel accommodation. 11 deep-sea berths for 50,000 to 200,000 ton vessel accommodation is under-construction now. Target capacity of Fangcheng Port North International port group (Fangcheng Port, Qin Zhou port and BeiHai port) is 100 million ton in 2010 and 300 million ton in 2020.

In the TEU-ranking of the container ports in 2010, Hong Kong is No. 3 (23.5 million TEU), Shenzhen is No.4 (22.5 million TEU) with 22.3% growth rate in 1998-2010 and Guangzhou is No. 7 (12.6million TEU) with 25.8% growth rate in 1998-2010 (Table 4.1.6).

Table 4.1.6 TEU-ranking of the top 10 world container ports in 2010

TEU-Ranking		Port (Country)	Mill TEU			TEU% Growth	
2010	(1998)		1998	2009	2010	2009-2010	1998-2010
1	(10)	Shanghai (China, PR of)	3.1	25.0	29.1	16.4%	20.5%
2	(1)	Singapore (Singapore)	15.1	25.9	28.4	9.7%	5.4%
3	(2)	Hong Kong (China, PR of)	14.6	21.0	23.5	11.9%	4.0%
4	(18)	Shenzhen (China, PR of)	2.0	18.3	22.5	23.0%	22.3%
5	(5)	Busan (Korea, Rep of)	5.2	12.0	14.2	18.3%	8.7%
6	(64)	Ningbo (China, PR of)	0.4	10.5	13.1	24.8%	33.7%
7	(52)	Guangzhou (China, PR of)	0.8	11.2	12.6	12.5%	25.8%
8	(35)	Qingdao (China, PR of)	1.2	10.3	12.0	16.5%	21.2%
9	(11)	Dubai (UAE)	2.8	11.1	11.6	4.5%	12.6%
10	(4)	Rotterdam (Netherlands)	6.0	9.7	11.1	14.4%	5.3%

Source: ISL Port Data Base 2009, and Containerisation International

Moreover, 3 major ports (Guangzhou, Shenzhen and Xiamen) in Pearl River Delta have planning huge development in the future. Table 4.1.7 shows actual volume of cargo and container cargo and future development plan in Chinese major ports.

Table 4.1.7 Chinese Port Development Plan

Chinese Port	Actual Data		Development Plan					Remarks
			2010		2020		2030	
	Cargo Volume (mil. ton)	Container Cargo (mil. TEU)	Cargo Volume (mil. ton)	Container Cargo (mil. TEU)	Cargo Volume (mil. ton)	Container Cargo (mil. TEU)	Cargo Volume (mil. ton)	
Guangzhou	Year 2008							
	347	11.0		14.0				
Shenzhen	Year 2008							
	211	21.4	280	28.0	440		480	
Shekou	Year 2007							Shenzhen Area
	54.3	5.0						
Yantian	Year 2007							Shenzhen Area
	54.3	10.0						
Xiamen	2007	2008			*Future Volume*			
	81.2	5.0	120	10.0	*260-290 ton*	*17 - 19*		
Qingdao	Year 2008							
	300	10.0	320	12.0	450	22		
Tianjin (Tientsin)	Year 2008							
	356	8.5						
Shanghai	Year 2008							
	508	28.0						
Nantong	Year 2007							
	120	0.43	200	1.5				
Lianyungang	Year 2008							
	101	3.0	120	3.4	190	8.0		
Ningbo	Year 2008							
	520	10.9		11.0				
Yantai	Year 2008							
	111	1.5	200	2.5 - 3.0				
Dailian	Year 2008							
	246	4.5	250	8.0				

Source: KWE Kintesu World Express, Inc.

4.2 Present Situation of Northern Sea Ports

Until now the sea ports in Vietnam were divided into eight (8) groups, however, by the new Master Plan for Vietnam Seaport System Development till 2020 orientation to 2030, they are re-grouped into six (6). The ports concerning this SAPROF study belong to the Group 1: North.

There are two big port groups in the Group 1, namely Hai Phong and Quang Ninh with national general ports of Hai Phong and Cai Lan and many local ports and dedicated ports. Total throughput in Hai Phong and Cai Lan ports in 2000 was 9.2 million tons and had strongly grown every year and reached to 29.8 million tons in 2008. However, seaport sales have not been facilitated because Hai Phong Port is located deep inside riverbank with a limited channel depth to the ports, and the industrial zone development and logistic facilities have not been developed yet synchronously in Cai Lan Port. There is no international gateway seaport in the region and big vessels are obliged to reduce load and transfer a part of cargo by barges before entering into the port.

4.2.1 Quang Ninh Port Zone

1) Quang Ninh Zone Ports

- Two (2) dedicated ports for coal of Cua Ong and Hon Gai servicing the whole nation's demand and export.
- Petroleum Port (B12) servicing northern regions.
- General Ports: Quang Ninh Floating Berth and Cai Lan Port.

2) Cai Lan Port

Present condition of Cai Lan Port is summarized as shown in Table 4.2.1.

Table 4.2.1 Facility and Equipment of Cai Lan Port

Berth	Length	Depth	Cargo	Yard	Warehouse	Equipment
No.1 No.5 No.6 No.7	166m 220m 220m 220m	-9.0m -12.0m -12.0m -13.0m	Bulk/G.C. Bulk/G.C. Bulk/G.C. Container	14.2 ha	1.54 ha	Mobile Crane: 1x64t, 1x104t, RTG: 4x40t, 1x50t Rubber Tyre Crane 3x14t, 1x25t Ev Crane: 1x50t, Forklift: 2x7t, 3x8t 13 Chassis

Cai Lan Port was developed in Bai Chay Bay by dredging up to -9.0m to -13.0m. Berth No.5 to Berth No.7 were constructed by the Japan's ODA fund in 2004 and started container handling. However, during the past few years, throughput of container in Cai Lan Port had been decreased drastically because of damage of quay gantry container cranes by typhoon in 2006, but it has been recovering very quickly.

Cai Lan Port shall be accessed through about 33km long approach channel of -10m deep in Ha Long Bay from the ocean and further deepening of the approach channel cannot be expected from an environmental point of view.

Cai Lan Port is managed and operated by the Quang Ninh Port Company under the JV of Quang Ninh Province and VINALINES. Cai Lan Port has decided to develop No.2 to No.4 container berths by 2012 by the private fund of American developer. Throughput of Cai Lan Port during 2002 to 2009 is presented in Table 4.2.2.

Table 4.2.2 Throughput of Cai Lan Port

TT	Criteria	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	11 months 2009
I	**Bulk cargo capacity**	**Ton**	**1,533,130**	**1,525,911**	**1,563,232**	**1,623,215**	**2,335,059**	**3,177,937**	**3,738,540**	**2,967,566**	**3,339,818**	**4,686,722**
II	**Total passing cargo capacity**	**Ton**	**1,513,261**	**1,513,573**	**1,559,076**	**1,748,406**	**2,475,597**	**3,185,136**	**3,498,824**	**2,805,408**	**3,022,618**	**4,289,116**
	Export	Ton	284,773	284,858	368,338	491,366	980,710	974,717	1,157,528	1,562,421	1,664,397	1,365,110
	Import	Ton	419,824	638,312	924,795	1,025,686	828,242	1,059,104	883,548	831,760	856,349	1,512,346
	Domestic	Ton	808,664	590,403	265,943	231,354	666,645	1,151,315	1,457,748	411,227	501,872	1,411,660
*	**Container**	**teus**	**2,182**	**662**	**244**	**2,289**	**121,252**	**211,788**	**245,923**	**66,701**	**63,367**	**301,299**
	Cargo container	**Ton**	**0**	**0**	**0**	**1,121**	**55,320**	**93,151**	**113,360**	**32,220**	**30,147**	**129,882**
	Export	Ton					11,673	14,359	18,869	10,752	11,259	21,868
	Import	Ton					15,477	39,558	30,166	15,724	17,310	51,257
	Domestic	Ton				1,121	28,170	39,234	64,325	5,744	1,578	56,757
	Non-bulk cargo container	**Ton**	**2,182**	**662**	**244**	**47**	**10,612**	**25,486**	**19,203**	**2,261**	**3,073**	**41,535**
	Export	Ton					1,568	6,547	2,388	176	2,278	17,755
	Import	Ton					354	1,047	2,930	84	122	1,529
	Domestic	Ton	2,182	662	244	47	8,690	17,892	13,885	2,001	673	22,251
*	**Details of passing capacity**	Ton	1,513,261	1,513,573	1,559,076	1,748,406	2,475,597	3,185,136	3,498,824	2,805,408	3,022,618	4,289,116
1	**Export**	**Ton**	**284,773**	**284,858**	**368,338**	**491,366**	**980,710**	**974,717**	**1,157,528**	**1,562,421**	**1,664,397**	**1,365,110**
	Cargo container	Ton					114,820	216,166	263,748	150,542	225,180	306,152
	Non-bulk cargo container	Ton						43,340	6,045	440	5,695	248,570
	Oil	Ton	3,757	5,077	9,460	7,500	3,460	4,067	7,684	2,950	4,696	8,618
	Wood chip	Ton	16,771	7,516			9,621	251,204	374,688	493,617	416,996	285,851
	Wood	Ton							10,050	6,448	1,604	
	Stone (Tan Mai, Banpu)	Ton	51,103	75,436	73,040	90,014	73,127	72,160				
	Fertilizer	Ton								114,511	203,967	4,926
	Ore	Ton									291,025	126,729
	Steel	Ton									25,060	127
	Coal	Ton	213,142	170,359	285,838	387,728	779,620	378,266	450,223	781,655	457,664	370,313
	Clinker	Ton										
	Equipment	Ton									2,040	1,324
	Cement	Ton										12,500
	Contruction material	Ton							39,182	9,146	29,968	
	Others	Ton		26,470		6,124	62	9,514	5,908	3,112	502	
2	**Import**	**Ton**	**419,824**	**638,312**	**924,795**	**1,025,686**	**828,242**	**1,059,104**	**883,548**	**831,760**	**856,349**	**1,394,354**
	Cargo container	Ton					228,500	614,205	347,785	220,289	346,200	717,598
	Non-bulk cargo container	Ton						8,230	7,325	210	305	21,406
	Oil	Ton			128,122	113,276	132,564	149,148	144,854	144,625	121,554	162,404
	Chemical	Ton							15,800	22,269	8,576	5,010
	Gypsum	Ton	6,311	48,134	40,401	137,393	40,637	6,100				
	Klinker	Ton		38,600	329,147	390,812	156,848					
	Wheat	Ton							176,137	168,893	32,987	
	Wheat flour	Ton									400	
	Barley corn	Ton		38,720	146,984	124,987	150,248	117,506				148,259
	Fertilizer	Ton		56,378	247,896	180,498	81,568	96,886	62,644	121,461	124,684	92,961
	Fertilizer in bags	Ton	290,477	425,384		12,025	3,838	21,837	15,466	100,172	75,018	
	Feedstuffs	Ton	61,828					15,041	75,785	17,576	57,098	185,205
	Equipment	Ton	6,118			43,678	13,858	10,426	27,145	21,085	3,327	5,269
	Scrap bundle	Ton					2,487	10,006		656	61,563	118
	Asphalt	Ton					7,760	9,540	7,498	14,524	17,448	
	Others	Ton	55,090	31,096	32,245	23,017	9,934	179	3,109		7,189	56,124
3	**Domestic**	**Ton**	**808,664**	**590,403**	**265,943**	**231,354**	**666,645**	**1,151,315**	**1,457,698**	**411,227**	**501,845**	**1,411,660**
*	*Domestic export*	*Ton*	*726,905*	*558,937*	*260,888*	*221,840*	*371,269*	*778,496*	*774,177*	*322,399*	*200,986*	*796,117*
	Cargo container	Ton					209,411	433,019	524,343	60,448	1,040	596,834
	Non-bulk cargo container	Ton						75,573	27,637	4,225	1,483	31,220
	Wheat	Ton	33,071	52,159	42,569	20,528	18,992	20,789	30,703	16,615	8,935	9,339
	Container	Ton										8,652
	Wood	Ton										3,228
	Oil	Ton							5,532	3,212	3,299	17,057
	Klinker	Ton	376,294	221,061	12,783	9,748	12,000	176,738	142,308	201,021	158,521	100,545
	Fertilizer	Ton								20,577	16,811	15,991
	Chemical	Ton								7,756		505
	Ore	Ton								3,130	5,269	
	Coal	Ton	107,412	115,875	35,000	26,767	20,885	38,938	9,416	140	1,000	
	Cement	Ton										4,779
	Steel	Ton										2,633
	Equipment	Ton								419	2,814	5,334
	Others	Ton	210,128	169,842	170,536	164,797	109,981	33,439	34,238	4,856	1,814	
*	*Domestic import*	*Ton*	*81,759*	*31,466*	*5,055*	*9,514*	*295,376*	*372,819*	*683,521*	*88,828*	*300,859*	*615,543*
	Cargo container	Ton	55,981	15,058	4,870		240,130	211,509	564,005	31,456	27,720	197,764
	Non-bulk cargo container	Ton						27,787	7,075	778	100	280,294
	Wheat	Ton									2,501	
	Oil	Ton						1,597		9,750	2,573	9,550
	Container	Ton										1,960
	Wood	Ton	24,723	3,807	185		30,666	106,031	97,582	33,434	25,039	12,685
	Barley corn	Ton					12,661		9,508	11,831	23,265	12,444
	Klinker	Ton								826		
	Ore	Ton									199,269	90,005
	Steel	Ton										795
	Equipment	Ton								658	3,169	7,396
	Construction material	Ton					11,919	25,895	5,351		17,223	
	Others	Ton	1,055	12,601						95		2,650
	Loading rate		1,01	1,01	1,00	0,93	0,94	1,00	1,07	1,06	1,10	1,09
III	**Cargo Volume by transport line, including:**											
1	By sea transport							2,707,366	2,974,000	2,384,597		
2	By road transport							477,770	524,824	420,811		
IV	**Vessel quantity:**											
1	*By type*								*479*	*493*	*516*	*416*
	Passenger ship								17	42	59	10
	Bulk cargo ship								292	323	347	255
	Container vessel								170	128	110	151
2	*By capacity*								*0*	*493*	*516*	
	Under 10.000T									250	333	198
	From 10.000 to under 20.000									148	97	82
	From 20.000 to under 30.000									63	59	80
	Above 30.000									32	27	56

4.2.2 Hai Phong Port Zone

Currently, seaport network in Hai Phong Port Zone located mainly along Cam Riverbank with about 17 major ports stretching on 7.8km bank. Total throughput of this port group in 2004 was about 13 million tons/year, mainly handled in Hai Phong Port (80% - 90%), and in 2008, within 4 years, it reached to 27 million tons/year.

Hai Phong Port is the largest international commercial port in Northern Vietnam and handling the second largest throughput in Vietnam following Saigon Port. Hai Phong Port includes four (4) loading zones which are planned for development as follows:

- Vat Cach Zone will be upgraded for a 650m berth, which can receive ship under 3,000DWT. This port will be domestic operation and act as a cargo transfer facility in Hai Phong Port.
- Hoang Dieu Zone with a 1,718m berth will be upgraded, which functions as a general port (general cargo and container zone incorporated with one international passenger wharf).
- Doan Xa Zone (with a 200m pier) will be repaired to maintain the function for general cargo. This zone can receive 5,000DWT vessels.
- Chua Ve Zone was developed for the first dedicated modern container port in the region. Rehabilitation of No.1 and No.2 berths and construction of No.3 berth were implemented by Japan's ODA fund as Hai Phong Port Rehabilitation Project Phase I during 1997 to 2001. Additional two (2) berths were also constructed by the Japan's ODA fund as Hai Phong Port Rehabilitation Project Phase II during 2001 to 2005.

Dinh Vu Zone will be developed for general cargo and container. The two (2) berths of Dinh Vu General Cargo Port are under operation. The first two container berths in Dinh Vu New Port were developed by private entity and under operation using tower cranes and the other 3 container berths are now under construction by Hai Phong Port.

Present situation of Hai Phong Zone Ports are summarized as shown in Table 4.2.3.

Table 4.2.3 Facility and Equipment of Hai Phong Ports

<table>
<tr><th>Berth</th><th>Length</th><th>Depth</th><th>Cargo</th><th>Yard</th><th>Warehouse</th><th>Equipment</th></tr>
<tr><td colspan="7">Main Port (Hoan Dieu)</td></tr>
<tr><td>1,2,3</td><td>413m</td><td rowspan="2">-8.7m</td><td>Container</td><td rowspan="2">29.63ha</td><td rowspan="2">3.01ha</td><td rowspan="2">Tower Crane: 26x5t-40t,
Floating Crane: 2x10t-85t,
RTG: 6x 25t-50t
Forklift: 36x3t-45t
Tug/Service Boat: 8x305CV-3,200CV,
Weighbridge: 4x80t
Automatic Filling Line 8x3,500t/day/ship</td></tr>
<tr><td>4 - 11</td><td>1,304m</td><td>G.C</td></tr>
<tr><td colspan="7">Chua Ve Container Terminal</td></tr>
<tr><td>1-5</td><td>848m</td><td>-8.4m</td><td>Container</td><td>18.87ha</td><td>0.6ha</td><td>QGC: 6x35.6t
Tower Crane: 5x5t-40t
RTG: 12x35.6t,
Rubber Tyre Crane: 2x25t-50t
Forklift: 22x3t-45t
Weighbridge: 1x80t</td></tr>
<tr><td colspan="7">Doan Xa Port</td></tr>
<tr><td>1</td><td>220m</td><td>-7.8m</td><td>Container</td><td>6.5ha</td><td>0.12ha</td><td>Tower Crane 2x40t, 1X10t, Forklift Truck 3x5t, 1x10t, 4x45t, Crane 1x16t</td></tr>
</table>

Berth	**Length**	**Depth**	**Cargo**	**Yard**	**Warehouse**	**Equipment**
Dinh Vu General Port						
1	237m	-9.3m	G.C.	23.64ha	0.36ha	Tower Crane: 3x40t Top Lifter: 3x45t Rubber Tyre Crane: 1x25t
2	188m	-9.3m	G.C.			
Dinh Vu New Port						
1	200m	-10.2m	Container	56.9ha	0.1ha	Tower Crane: 2x5t-40t
2	200m	-10.2m	Container			
3-5	200m	-10.2m	Container			*Under Construction /2010
Vat Cach Port						
1-6	485m	-4.0m/-4.7m	G.C.	21ha	0.72ha	Shore Crane: 11x5t-36t Forklift: 4x4t-7t Truck: 9x5t-16t Excavator: 1
Cua Cam Port						
1-4	350m	-2.5m/-7.0m	G.C.	2.7ha	1.17ha	Shore Crane: 4x7.5t-16t Rubber Tyre Crane: 4x16t-36t Crawler Crane: 1x25t
Transvina Port						
1	165m	-7.8m	Container	5.1ha	0.12ha	Harbour Mobile Crane: 1x100t Tower Crane: 1x40t Forklift 3x45t, 1x5t Lift Truck: 6x3t-10t Container Truck: 15x10t-30t Tug Boat 1x800HP, 1x1600HP
Green Port						
2	320m	-8.0m	Container	4.73ha		Slewing Gantry Crane: 2x40t Mobile Crane: 2x40t Straddle Carrier: 4x40t Tug Boat: 1x70t
Le Chan Port						
1	144m		Container	6.65ha		2 Jib Cranes

Hai Phong ports are located along the maritime access channel of 42.8km from Buoy No. Zero and its depth are kept to -7.3m up to Dinh Vu Port and to -5.5m up to central terminal. The average tidal difference is 2.5m. The limited depth of access channel is the biggest problem for Hai Phong Ports. However, Hai Phong Port has a long history for operation and not only accumulation of port facilities but also supporting functional facilities and infrastructures and many peoples living with port business. Therefore, it is very important to use Hai Phong ports effectively.

Hai Phon Port is managed and operated by Haiphong Port Holding Limited Liability Co. under VINALINES. VINALINES is operating not only Hai Phong Port but also other main Vietnamese ports, such as Saigon Port, Da Nang Port, Can Tho Port and Cai Lan Port through its subsidiary companies.

Throughput of Hai Phong Port during 2002 to 2009 is presented in Table 4.2.4.

Table 4.2.4 Throughput of Hai Phong Port

	2002	2003	2004	2005	2006	2007	2008	2009 until Oct
1. Export	**1,365,476**	**1,757,845**	**1,792,445**	**2,349,120**	**2,825,099**	**2,684,001**	**3,243,855**	**1,977,551**
Sugar								
Apatit		1,750	2,029		45,790	75,824	261,446	60,592
General	3,947	2,035	500	1,750	504	33,177		
Container	1,193,139	1,650,877	1,650,945	1,827,447	2,193,578	2,117,574	2,190,655	1,649,867
Timber	65,886	28,800	68,388	109,131	103,836	82,533	54,800	45,567
Logistic cargo								
Chemical			287				2,922	
Metal	6,998	1,250	2,002	2,712	409	13,041	204,558	18,205
Klinker			2,100		54,311	51,662	154,439	21,146
Forest and native products								
Foodstuff	10,000							
Miscellaneous								
Equipment	11,055	2,477	5,944	10,151	10,317	14,735	18,092	21,768
Asphalt			1,399					
Fertilizer			212	5,679		27,784	110,504	31,568
Metalic ore	50,379	29,656	11,376	17,149	25,044	28,455	43,924	10,069
Food and vegitable								
Jute carpet								
Gypsum			60					
Coal				331,492	306,938	4,991	18,985	5,716
Construction Material	24,072	41,000	14,798	38,051	67,962	230,109	149,024	94,581
Cement			32,405	5,558	16,410	4,100	27,312	18,470
Oil						16	5,703	
2. Import	**5,286,584**	**5,401,816**	**5,368,625**	**5,196,931**	**5,198,668**	**6,218,248**	**7,634,025**	**7,103,342**
Sugar			2,199		5,893			2,000
Apatit			49	83	2,100	40	57	133
General	121,105	31,386	16,527	6,353	5,516	10,459	17,438	11, 226
Cotton								
Container	1,652,471	1,974,339	1,792,646	2,035,552	2,237,235	3,285,283	3,990,268	3,007,776
Timber	36,357	46,783	72,101	21,307	41,699	13,059	13,669	38,217
Logistic cargo								
Chemical	43,192	38,267	40,078	56,655	47,060	64,945	46,404	16,982
Metal	1,974,411	1,535,265	1,607,142	1,426,176	1,220,232	1,409,737	1,791,699	1,990,958
Klinker	133,229	279,003	286,376	154,056	146,148	26,149	30,832	3,000
Forest and native products	5,382		21,635	3,738				
Foodstuff	118,852	6,546	823	3,933	160			
Miscellaneous		2,911		796				
Equipment	145,641	105,523	137,863	111,199	88,789	249,282	325,785	259,687
Salt	52,152	1,132					22,921	61,961
Asphalt	12,057							
Fertilizer	589,320	552,182	446,514	259,515	101,807	54,593	18,922	99,305
Sulfur				58,073	96,701	95,251	73,443	143,246
Metalic ore	75,373	77,695	133,623	113		49,358	60,907	32,786
Food and vegitable			50	209	219	38,241		72,135
Foodstuff for cattle	218,398	698,176	399,636	513,652	762,977	833,030	608,688	869,331
Gypsum	106,744	52,322	118,958	121,709	17,608	22,603	10,340	
Coal			42,849	26,671	23,466		13,582	23,586
Construction Material	1,900	1	27,115	6,501	550	245	39,964	1,688
Cement					400,508			
Oil		285	222,441	390,640				467,076
3. Domestic	**3,669,293**	**3,358,601**	**3,325,436**	**2,966,007**	**3,127,601**	**3,398,319**	**3,091,106**	**2,982,229**
Sugar	14,324	502	4,874	8,743	4,958	240		11,444
Apatit	53,354	89,637	98,620	114,231	114,293	109,283	135,624	98,368
General	268,717	65,323	60,980	55,649	39,891	55,397	57,224	67,449
Cotton	0	0	0	0	0			
Container	1,183,766	1,303,783	1,466,208	1,379,057	1,146,160	1,168,873	1,552,846	1,683,740
Timber	2,120	13,349	28,996	51,052	33,407	18,696	12,666	1,865
Logistic cargo	0	0	0	0	0			
Chemical	18,768	7,420	12,387	15,998	3,433	4,260	4,583	7,497
Metal	240,395	269,411	285,358	243,201	160,302	157,437	203,633	261,517
Klinker	41,387	34,189	48,565	140,275	460,925	509,190	182,741	289,464
Forest and native products	7,369	14,571	10,436	7,917	0		1,413	1,955
Foodstuff	571,881	199,198	249,819	60,718	50,082			
Miscellaneous	0	46	45	0	0			14,570
Salt	46,750	21,796	15,302	6,504	1,719		1,638	1,014
Equipment	8,801	13,042	13,867	16,374	19,194	47,391	18,237	12,665
Asphalt	821	1,390	130	61	0			
Fertilizer	252,149	300,599	161,187	192,722	120,171	278,589	276,357	110,994
Sulfur	0	0	61,686	2,654	0	2,114	8,132	
Metalic ore	27,034	39,362	51,348	54,236	50,960	42,380	78,161	7,871
Food and vegitable	6,146	12,393	18,116	13,490	17,614	62,784	63,126	46,673
Foodstuff for cattle	73,001	283,258	219,382	288,871	279,437	147,489	134,275	123,211
Gypsum	0	6,119	11,909	0	0		6,119	2,350
Coal	0	773	149,658	52,660	40,642	27,819	21,739	46,264
Construction Material	185,410	237,612	142,447	116,463	100,664	114,322	42,378	49,310
Cement	667,100	444,682	213,815	144,619	475,446	652,050	275,958	133,998
Oil	0	146	301	512	58	5	14,256	10,010
Sulfur					8,245			

4.3 Review of Cargo Demand Forecast

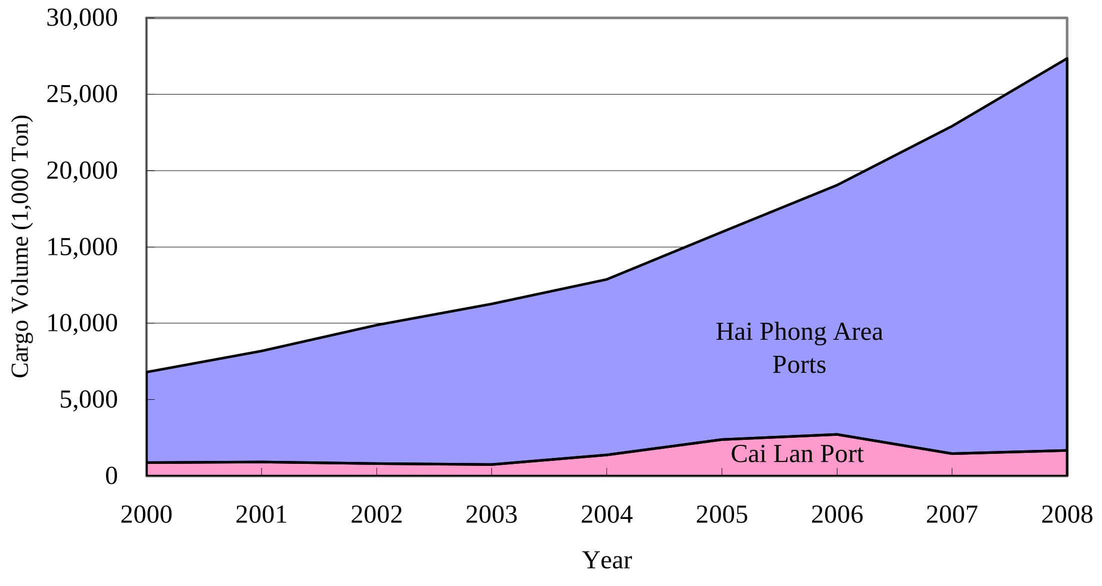
4.3.1 General

In this chapter, the method of the demand forecast is conducted by Micro forecast for commodity-wise cargo in the Northern Vietnam Ports. The method follows the method which utilized in "Preparatory Survey on Lach Huyen Port Infrastructure Construction in Viet Nam". In this study, JICA Study Team confirms the latest situation regarding to the cargo of Northern Vietnam Ports, and revises the results of the demand forecast, utilizing the updated information. In the method, cargo demand Lach Huyen port is analyzed as overflowed cargo based on the cargo handling capacity of Northern Vietnam Ports including their future expansion. Consequently, detail container cargo volume is analyzed in order to estimate the cargo traffic in terms of TEUs.

4.3.2 Cargo Throughputs of the Northern Ports in Vietnam

Northern Ports (without oil products, cement and fertilizer) in Vietnam are divided into 2 areas such as Hai Phong Area Port and Cai Lan Port. In 2008, total cargo throughputs of Northern Ports amounted to approximately 25 million ton as shown in Figure 4.3.1.

Total cargo throughput in 2008, 25,340 thousand ton is almost 3.9 times of volume (6,494 thousand ton) in 2000 with yearly average growth rate 19% from 2000.



Unit: 1,000 ton

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Hai Phong Area Ports	5,606	7,006	8,920	9,775	10,527	11,176	13,087	19,836	23,777
Cai Lan Port	888	927	812	756	1,193	2,108	2,854	1,450	1,563
Total Cargo Throughput	**6,494**	**7,933**	**9,732**	**10,531**	**11,720**	**13,284**	**15,941**	**21,286**	**25,340**
Growth Rate		22.2%	22.7%	8.2%	11.3%	13.3%	20.0%	33.5%	19.0%

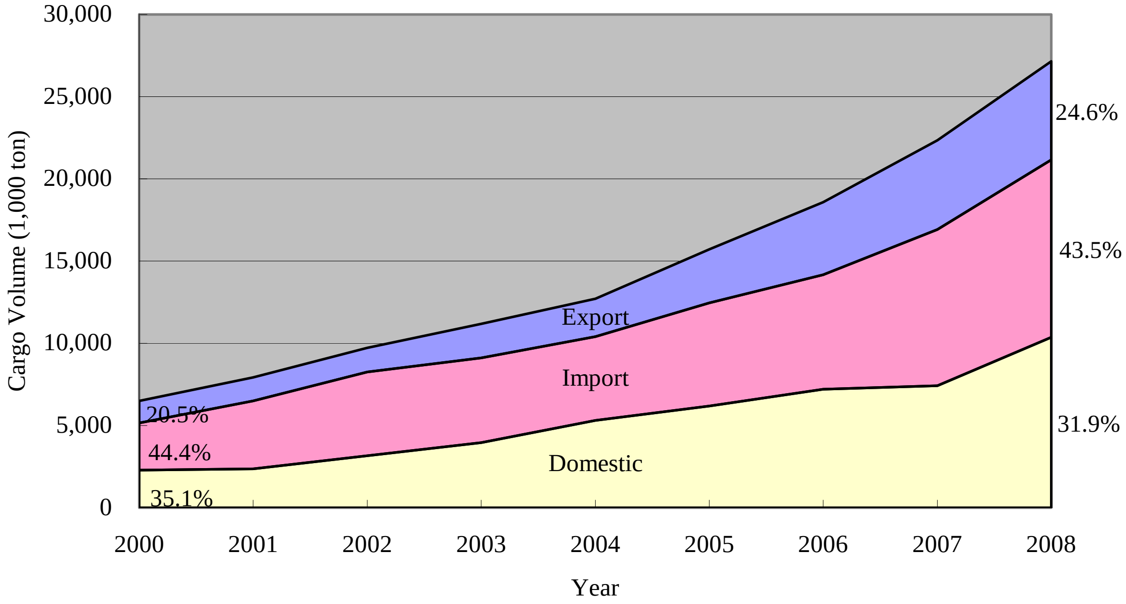
Note: Cargo Throughputs Volume is not including oil products, cement and fertilizer

Source: Original data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), and container data (2003-2008) by VINAMARINE

Figure 4.3.1 Total Cargo Throughputs in the Northern Ports in Viet Nam

4.3.3 Export, Import and Domestic Cargo Volume Share

In 2008, cargo volume share of Export, Import and Domestic in the Northern Ports were 24.6%, 43.5% and 31.9%, respectively. The share of Export gradually went up from 20.5% in 2000 to 24.6% in 2008 but the Import share marginally went down from 44.4% to 43.5%. The Domestic share went down from 35.1% 2000 in to 31.9% in 2008.



Unit: 1,000 ton

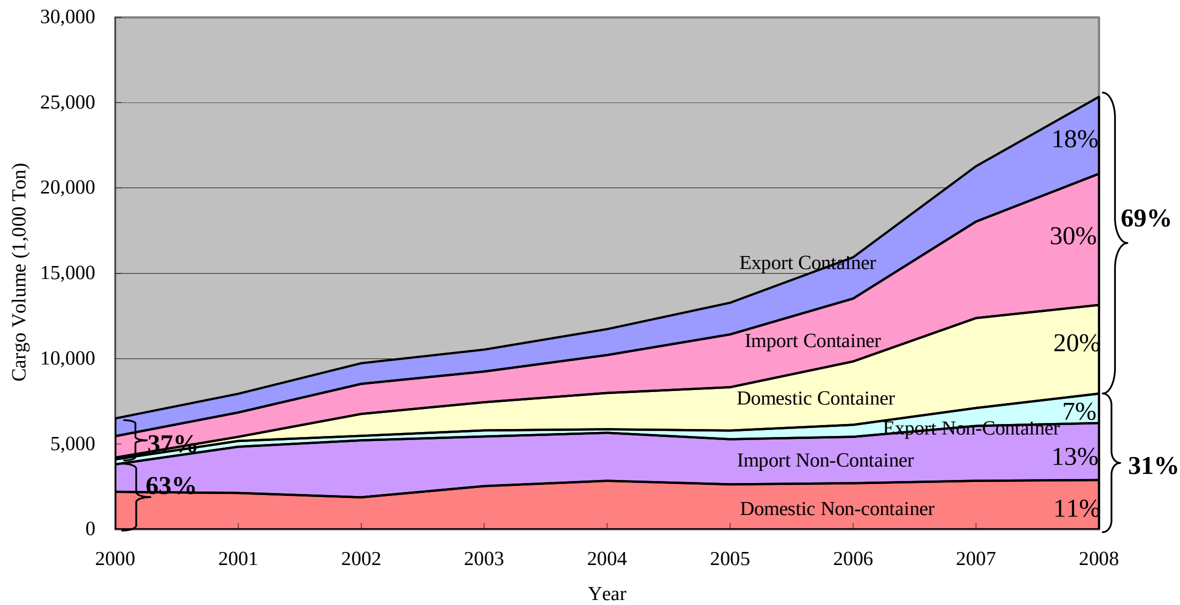
	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export	**Volume**	1,334	1,438	1,470	1,656	1,708	2,381	3,117	4,307	6,233
	Share	20.5%	18.1%	15.1%	15.7%	14.6%	17.9%	19.6%	20.2%	24.6%
Import	**Volume**	2,883	4,126	5,103	4,693	5,042	5,727	6,405	8,855	11,024
	Share	44.4%	52.0%	52.4%	44.6%	43.0%	43.1%	40.2%	41.6%	43.5%
Domestic	**Volume**	2,278	2,370	3,159	4,182	4,970	5,176	6,419	8,124	8,083
	Share	35.1%	29.9%	32.5%	39.7%	42.4%	39.0%	40.3%	38.2%	31.9%
Total		6,494	7,933	9,732	10,531	11,720	13,284	15,941	21,286	25,340

Note: Cargo Throughputs Volume is not including oil products, cement and fertilizer
Source: Original data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), and container data (2003-2008) by VINAMARINE

Figure 4.3.2 Export, Import and Domestic Cargo in the Northern Ports in Viet Nam

4.3.4 Container and Non-container Cargo

In 2008, container cargo volume share in the Northern Ports are dramatically changed from 37% in 2000 to 69%, while on the other hand, non-container cargo share drop from 63% in 2000 to 31% in 2008. Another way of saying, container cargo volume is sharply increased from 2,387 thousand ton in 2000 to 17,382 thousand ton in 2008 with yearly average growth rate 29%, and non-container gradually increased from 4,105 thousand ton in 2000 to 7,958 thousand ton in 2008 with yearly average growth rate 9% (Figure 4.3.3).



	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Container	1,037	1,087	1,201	1,294	1,510	1,865	2,421	3,253	4,504
Import Container	1,263	1,420	1,773	1,790	2,228	3,092	3,683	5,652	7,688
Domestic Container	88	244	1,285	1,653	2,127	2,539	3,719	5,276	5,190
Export Non-Container	297	350	269	362	199	516	697	1,054	1,729
Import Non-Container	1,621	2,705	3,330	2,903	2,814	2,635	2,722	3,203	3,336
Domestic Non-container	2,190	2,126	1,874	2,529	2,842	2,636	2,700	2,848	2,893
Total Container	2,387	2,752	4,259	4,737	5,865	7,496	9,822	14,181	17,382
	37%	*35%*	*44%*	*45%*	*50%*	*56%*	*62%*	*67%*	*69%*
Total Non-Container	4,107	5,182	5,473	5,795	5,855	5,787	6,119	7,105	7,958
	63%	*65%*	*56%*	*55%*	*50%*	*44%*	*38%*	*33%*	*31%*
Total	6,494	7,933	9,732	10,531	11,720	13,284	15,941	21,286	25,340

Figure 4.3.3 Container and Non-container Cargo in the Northern Ports in Viet Nam

4.3.5 Updated Information for Demand Forecast

In general, cargo volume of international ports and GDP are close relationship, especially, in Viet Nam, import and export values are largely influenced to GDP. In 2008, based on GSO's preliminary figures, import values (goods and services) are comparable to 94.7% of National Amount (GDP), and export values are 78.2% of GDP. On the other hand, nowadays, hinterland of the Northern Ports is not only the Northern region of Viet Nam, but also all over the Viet Nam, because of closely-linked to central and southern regional connection by domestic sea transport. The relationship between cargo volume of international ports and GDP was proved in the preparatory survey.

In this study, demand forecasted is revised along the method utilized in the preparatory survey. As the method utilizes GDP data in Vietnam, the following tables shows the comparison of GDP data utilized in the preparatory survey to the latest GDP information, which will be used in this study.

Table 4.3.1 Comparison of GDP Growth Rate

	2008	2009	2010	2011-
Preparatory Survey	6.18% (A)	5.32% (A)	6.50% (F)	6.50% (F)
This Study	6.18% (A)	5.46% (A)	6.78% (A)	6.50% (F)

Note (A): Actual, (F): Forecasted

Table 4.3.2 Comparison of GDP Growth Rate by Sector

		2008	2009	2010	2011-
Preparatory Survey	Agriculture, forestry and fishery	4.07% (A)	3.00% (A)	3.40% (F)	3.40% (F)
	Industry and construction	6.11% (A)	7.00% (A)	7.10% (F)	7.10% (F)
	Service	7.18% (A)	6.60% (A)	6.80% (F)	6.80% (F)
This Study	Agriculture, forestry and fishery	4.07% (A)	2.42% (A)	2.76% (A)	3.21% (F)
	Industry and construction	6.11% (A)	5.40% (A)	7.68% (A)	7.25% (F)
	Service	7.18% (A)	6.82% (A)	7.54% (A)	6.84% (F)

Note (A): Actual, (F): Forecasted

Based on the updated information regarding GDP, this study revises the demand forecast.

4.3.6 Revised Demand Forecast

Before revising the demand forecast, following table shows a comparison of results of demand forecast for northern ports in Viet Nam, including preparatory survey.

Table 4.3.3 Comparison of Forecasted Throughput of Northern Ports

	2015	2020	2030
TEDI FS in 2007			
Low growth rate alternative	43.0	72.0	
High growth rate alternative	46.0	88.0	
JICA Preparatory Survey in 2010			
Low growth rate alternative	47.3	62.5	
Middle growth rate alternative	52.8	71.8	
High growth rate alternative	58.3	81.1	
VITRANSS 2 in 2009		78.9	140.0
Nippon Koei in 2009			
Low growth rate alternative		58.0	109.9
Middle growth rate alternative		69.5	134.4
High growth rate alternative		85.6	168.5
Port System Master Plan			
Low growth rate alternative	56.1	73.3	119.0
Middle growth rate alternative	59.7	84.0	164.0
High growth rate alternative	63.9	98.2	233.2

(in million tons)

Source: "Report on Adjustment of Investment Project -Haiphong International Gateway Port", Transport Engineering Design Incorporated

In the methodology for demand forecast, the methodology established in the preparatory survey, commodity-wise cargoes is firstly grouping by each sector, and secondly analyzing with correlation between grouping cargo volume and GDP or GDP by sector. Thirdly, containerization should be considered with compatibility of characteristic products.

Table 4.3.4 Commodity-wise Cargoes Grouping for Micro Forecast

Cargo Commodity \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	Micro Forecast Consideration
1. Export	**1,334**	**1,438**	**1,470**	**1,656**	**1,708**	**2,381**	**3,117**	**4,307**	**6,233**	
Container	1,037	1,087	1,201	1,294	1,510	1,865	2,421	3,253	4,504	Correlation of GDP
General	50	16	5	152	1	12	11	43	30	Correlation of GDP (convert to Container Cargo)
Timber	83	97	66	29	78	360	489	583	477	Correlation of Primary Sector GDP as Agriculture or Forestry Product
Food and vegetable	10	7	9	7	3	4	8	3	5	
Industrial Product	-	1	-	-	0	-	-	-	-	Correlation of Secondary Sector GDP as Industrial Product or Construction material (40% of forcast cargo convert to Container Cargo in 2020)
Equipment	8	7	11	2	6	10	10	18	46	
Construction Material	95	141	101	127	89	110	107	230	156	
Metal	3	2	7	1	2	3	0	13	331	
Foodstuff	25	28	20	12	6	-	1	60	80	
Apatite	2	-	-	2	2	-	46	76	261	Correlation of Secondary Sector GDP as Mining Product
Metallic ore	20	50	50	30	11	17	25	28	343	
2. Import	**2,883**	**4,126**	**5,103**	**4,693**	**5,042**	**5,727**	**6,405**	**8,855**	**11,024**	
Container	1,263	1,420	1,773	1,790	2,228	3,092	3,683	5,652	7,688	Correlation of GDP
General	98	86	290	45	20	6	6	9	10	Correlation of GDP (convert to Container Cargo)
Miscellaneous	-	-	-	3	-	1	3	17	24	Correlation of GDP (convert to Container Cargo)
Timber	14	42	36	47	72	21	42	13	19	Correlation of Primary Sector GDP as Agriculture or Forestry Product
Forest and native products	-	-	5	-	22	4	-	1	-	
Food and vegetable	13	317	227	114	135	149	145	145	-	
Foodstuff for cattle	42	185	273	763	445	664	872	937	832	
Cotton	129	-	-	-	-	-	-	-	-	Correlation of Secondary Sector GDP as Industrial Product or Construction material (40% of forcast cargo convert to Container Cargo in 2020)
Chemical	75	67	43	38	40	57	63	87	51	
Metal	1,018	1,620	1,974	1,535	1,607	1,426	1,220	1,410	1,819	
Construction Material	37	32	14	0	35	17	10	-	-	
Equipment	111	169	146	150	154	111	89	271	391	
Foodstuff	24	94	246	131	151	121	176	169	33	
Sulfur	-	-	-	-	-	58	97	95	96	Correlation of Secondary Sector GDP as Mining Product
Metallic ore	59	95	75	78	134	0	-	49	61	
3. Domestic	**2,278**	**2,370**	**3,159**	**4,182**	**4,970**	**5,176**	**6,419**	**8,124**	**8,083**	
Container	88	244	1,285	1,653	2,127	2,539	3,719	5,276	5,190	Correlation of GDP
General	1,006	834	511	271	207	86	50	60	75	Correlation of GDP (convert to Container Cargo)
Food and vegetable	44	77	67	35	38	31	21	16	7	Correlation of Primary Sector GDP as Agriculture or Forestry Product (40% of forcast cargo convert to Container Cargo in 2020)
Foodstuff for cattle	81	79	73	283	219	289	279	147	158	
Forest and native products	6	3	7	15	10	8	59	7	1	
Wheat	-	-	-	-	-	21	40	12	26	
Timber	28	25	8	80	90	189	168	98	84	
Flour	-	-	-	-	-	-	-	16	11	
Chemical	30	21	19	7	12	16	3	12	5	Correlation of Secondary Sector GDP as Industrial Product or Construction material
Metal	243	233	240	269	285	243	160	157	227	
Construction Material	305	341	198	251	154	143	106	114	48	
Foodstuff	278	340	572	199	250	61	-	53	20	
Equipment	42	27	98	989	1,364	1,379	1,640	2,000	1,841	
Apatit	68	62	53	90	99	114	114	109	136	Correlation of Secondary Sector GDP as Mining Product
Sulfur	-	-	-	-	62	3	8	2	6	
Metallic ore	60	84	27	39	51	54	51	45	248	

Source: Original data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), and container data (2003-2008) by VINMARINE

In the above table, containerization was considered from conventional cargo such as general cargo, miscellaneous cargo and 40% of industrial and construction material of Import and Export cargo.

4.3.7 Results of Revised Forecast

In the forecast, commodity-wise cargoes is firstly grouping by each sector, and secondly, analyzing with correlation between grouping cargo volume and GDP or GDP by sector. Thirdly, containerization should be considered with compatibility of characteristic products.

The national goal in Viet Nam is to become an industrial country by 2020, therefore, the component rate of GDP by sector in 2020 adapted to same target of Red River Delta component rate in 2010 estimated by Central Economic Institute such as 12% for Agriculture Sector, 45% for Industry & Construction sector and 43% for Service sector.

The GDP by Sector in 2000, 2010 and 2020 summarized as follows. In the forecast, GDP growth rate in 2010-2020 adapt to 6.5% of sustainable growth planning by MPI.

Table 4.3.5 Results of GDP by Sector in 2000, 2010 and 2020

GDP by Sector	2000	2010	2020	Remarks
Agriculture, forestry and fishery	63,717	90,600	124,251	Target Rate by MPI in 2010
Component Rate	*23%*	*16%*	*12%*	15-16%
Industry and construction	96,913	231,300	465,943	Target Rate by MPI in 2010
Component Rate	*35%*	*42%*	*45%*	43-44%
Service	113,036	229,700	445,234	Target Rate by MPI in 2010
Component Rate	*41%*	*42%*	*43%*	40-41%
GDP	273,666	551,600	1,035,429	

The results of forecast of 3 alternative scenarios shows in Table 4.3.6, Table 4.3.7 and Table 4.3.8. The high growth case estimated 1.2 times of increased volume of middle growth case and the low growth case 0.8 times of increased volume of middle growth case based on the results of Micro Forecast.

Table 4.3.6 Results of Micro Forecast (Middle Growth Case)

Category of Cargo	Type of Cargo	Unit	2008	2015	2020
1. Export			**6,233**	**14,196**	**19,380**
Container and Containerized Cargo	Container Cargo	1,000 ton	4,534	11,583	15,757
Agriculture, forestry Product	General Cargo	1,000 ton	482	1,050	1,502
Industry and construction material	General Cargo	1,000 ton	613	561	679
Mining Products	Dry Bulk Cargo	1,000 ton	604	1,002	1,443
2. Import			**11,024**	**18,847**	**27,992**
Container and Containerized Cargo	Container Cargo	1,000 ton	7,722	15,149	23,834
Agriculture, forestry Product	General Cargo	1,000 ton	851	1,775	2,367
Industry and construction material	General Cargo	1,000 ton	2,294	1,695	1,467
Mining Products	Dry Bulk Cargo	1,000 ton	157	228	324
3. Domestic			**8,083**	**15,978**	**24,032**
Container and Containerized Cargo	Container Cargo	1,000 ton	5,265	11,819	19,081
Agriculture, forestry Product	General Cargo	1,000 ton	287	652	835
Industry and construction material	General Cargo	1,000 ton	2,141	3,040	3,428
Mining Products	Dry Bulk Cargo	1,000 ton	390	467	688
Cargo Volume by Cargo Type					
Total Cargo Volume		1,000 ton	**25,340**	**49,022**	**71,404**
Container and Containerized Cargo		1,000 ton	17,521	38,552	58,672
		1,000TEU	1,434	3,323	5,058
General Cargo		1,000 ton	6,668	8,773	10,277
Dry Bulk Cargo		1,000 ton	1,151	1,698	2,455

Table 4.3.7 Results of Micro Forecast (Low Growth Case)

Category of Cargo	Type of Cargo	Unit	2008	2015	2020
1. Export			**6,233**	**12,603**	**16,751**
Container and Containerized Cargo	Container Cargo	1,000 ton	4,534	10,173	13,513
Agriculture, forestry Product	General Cargo	1,000 ton	482	936	1,298
Industry and construction material	General Cargo	1,000 ton	613	572	666
Mining Products	Dry Bulk Cargo	1,000 ton	604	922	1,275
2. Import			**11,024**	**17,283**	**24,599**
Container and Containerized Cargo	Container Cargo	1,000 ton	7,722	13,664	20,612
Agriculture, forestry Product	General Cargo	1,000 ton	851	1,590	2,064
Industry and construction material	General Cargo	1,000 ton	2,294	1,815	1,632
Mining Products	Dry Bulk Cargo	1,000 ton	157	214	291
3. Domestic			**8,083**	**14,399**	**20,842**
Container and Containerized Cargo	Container Cargo	1,000 ton	5,265	10,509	16,318
Agriculture, forestry Product	General Cargo	1,000 ton	287	579	725
Industry and construction material	General Cargo	1,000 ton	2,141	2,860	3,171
Mining Products	Dry Bulk Cargo	1,000 ton	390	452	628
Cargo Volume by Cargo Type					
Total Cargo Volume		1,000 ton	**25,340**	**44,285**	**62,191**
Container and Containerized Cargo		1,000 ton	17,521	34,345	50,442
		1,000TEU	1,434	2,961	4,348
General Cargo		1,000 ton	6,668	8,352	9,555
Dry Bulk Cargo		1,000 ton	1,151	1,588	2,194

Table 4.3.8 Results of Micro Forecast (High Growth Case)

Category of Cargo	Type of Cargo	Unit	2008	2015	2020
1. Export			**6,233**	**15,789**	**22,010**
Container and Containerized Cargo	Container Cargo	1,000 ton	4,534	12,993	18,002
Agriculture, forestry Product	General Cargo	1,000 ton	482	1,163	1,706
Industry and construction material	General Cargo	1,000 ton	613	551	692
Mining Products	Dry Bulk Cargo	1,000 ton	604	1,082	1,610
2. Import			**11,024**	**20,412**	**31,386**
Container and Containerized Cargo	Container Cargo	1,000 ton	7,722	16,635	27,056
Agriculture, forestry Product	General Cargo	1,000 ton	851	1,960	2,670
Industry and construction material	General Cargo	1,000 ton	2,294	1,575	1,301
Mining Products	Dry Bulk Cargo	1,000 ton	157	242	358
3. Domestic			**8,083**	**17,557**	**27,221**
Container and Containerized Cargo	Container Cargo	1,000 ton	5,265	13,130	21,844
Agriculture, forestry Product	General Cargo	1,000 ton	287	724	944
Industry and construction material	General Cargo	1,000 ton	2,141	3,220	3,686
Mining Products	Dry Bulk Cargo	1,000 ton	390	483	747
Cargo Volume by Cargo Type					
Total Cargo Volume		1,000 ton	**25,340**	**53,758**	**80,617**
Container and Containerized Cargo		1,000 ton	17,521	42,758	66,903
		1,000TEU	1,434	3,686	5,767
General Cargo		1,000 ton	6,668	9,194	10,999
Dry Bulk Cargo		1,000 ton	1,151	1,807	2,715

4.3.8 Cargo Volume of Lach Huyen Port

1) Demand Forecast of Lach Huyen Port

Firstly, cargo demand of Lach Huyen port can be considered overflowed cargo more than cargo handling capacity volume of Northern ports in the Viet Nam. Moreover, the following items are the role of Lach Huyen Port in Vietnam Sea Port System for demand forecast.

(1) Lach Huyen Port will be a general port group used for handling of general cargoes, container cargoes, bulk cargoes and liquid cargoes (Petrol)

(2) Lach Huyen port will not be used for handling of specialized cargoes such as: coal (to be handled at Cam Pha), and military cargoes (a military port will be formed at South Do Son)

(3) Lach Huyen port belongs to the Northern sea port group (group 1) and play role as a key international gateway port of the North (Port of class I, to be ranked in accordance with Marine Law). Lach Huyen port is a main junction for cargo exchange of northern provinces to the countries in the region.

(4) In the future (after 2020) Lach Huyen port will likely to play more role of container transshipment for the northern area (together with Van Phong port in the Central, Cai Mep-Thi Vai or Ben Dinh-Sao Mai port in the South).

Addition to above items, depend on the present circumstance of cargo handling system in the northern Vietnam, cargoes of cement and fertilizer handled in their own private port like DAP Fertilizer Jetty, Ching Fong Haiphong Cement Plant Jetty or Cam Pha port

The capacities of existing ports are estimated based on the existing port facilities and equipment for Haiphong ports group and Cai Lan port, and for Dinh Vu port additional container berths under construction are considered and for Cai Lan port 3 additional container berths which are decided to be constructed within a few years are also considered.

The cargo handling capacity volume of Northern ports in Viet Nam is estimated in the following Table 4.3.9. In 2012, the capacity of the existing Northern ports is estimated 3,470 thousand TEU of container cargo and 12,600 thousand tons of conventional cargo.

Table 4.3.9 Cargo Handling Capacity Volume of Northern ports in the Viet Nam

	Actual 2008		Existing Berth Capacity			Expansion Berth Capacity (2010)			Expansion Berth Capacity (2011)			Expansion Berth Capacity (2012-2020)		
	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU
Container Handling Volume														
Chua Ve	7,731	729,978	848	8,210	707,786	848	8,210	707,786	848	8,210	707,786	848	8,210	707,786
Hoan Dieu			413	4,014	346,029	413	4,014	346,029	413	4,014	346,029	413	4,014	346,029
Dinh Vu (New)	2,715	218,269	400	2,635	227,191	600	5,271	454,381	800	7,906	681,572	1,002	10,542	908,762
Doan Xa	2,232	156,314	220	2,265	195,244	220	2,265	195,244	220	2,265	195,244	220	2,265	195,244
Transvina	1,371	115,771	165	1,642	141,557	165	1,642	141,557	165	1,642	141,557	165	1,642	141,557
Green	2,150	191,584	320	2,281	196,607	320	2,281	196,607	320	2,281	196,607	320	2,281	196,607
Le Chan	N.A	N.A	144	1,368	117,964	144	1,368	117,964	144	1,368	117,964	144	1,368	117,964
Cai Lan	425	35,028	200	2,373	244,667	200	2,373	244,667	596	7,906	681,572	794	9,933	856,334
Sub-Total	16,624	1,446,944	2,710	24,789	2,177,045	2,910	27,424	2,404,236	3,506	35,593	3,068,331	3,906	40,255	3,470,284
Conventional Cargo Handling Volume														
Hoan Dieu	6,238		1,304	6,408		1,304	6,408		1,304	6,408		1,304	6,408	
Cua Cam	566		220	577		220	577		220	577		220	577	
Vat Cach	1,501		485	1,887		485	1,887		485	1,887		485	1,887	
Dinh Vu (Gen)			525	1,165		525	1,165		525	1,165		525	1,165	
Cai Lan	2,289		646	2,563		646	2,563		646	2,563		646	2,563	
Sub-Total	10,594		3,180	12,600		3,180	12,600		3,180	12,600		3,180	12,600	
Total	**27,218**	**1,446,944**		**37,389**	**2,177,045**		**40,025**	**2,404,236**		**48,193**	**3,068,331**		**52,856**	**3,470,284**

Source: Original cargo data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), Vietnam Ports Association (VPA), Port operator data by VINAMARINE

2) Allocation of Cargo among Ports in the Area

The basic considerations of allocation of cargo among Haiphong port, Cai Lan port and Lach Huyen port are as follows:

(1) All container terminals in the existing ports are still very new constructed only 7 to 8 years ago and new four (4) container berths in Dinh Vu port will open soon and No.2 to No.4 container berths in Cai Lan port are determined to be completed within a few years. From national economic view point these facilities should be utilized effectively as much as possible.

(2) This Hai Phong International Gateway Port Development Project is planned to be implemented by Public Private Partnership (PPP). In PPP the public sector should provide incentives to private sector and should not interfere in business activities of private sector as much as possible. Therefore, actual cargo volume to be handled at each port should be left for their free marketing efforts.

(3) When Lach Huyen port is opened and left for free competition among three ports, it will be highly provable that most cargoes will shift from the existing ports to Lach Huyen port, since all kind of vessels from small size to large size can enter at any tidal conditions with shortest distance from ocean route.

From above considerations, JICA Study Team proposes to allocate to Lach Huyen port the cargo which exceed the capacity of existing ports and the cargo equivalent to 10% of the existing ports capacity which will shift from the existing ports at 2015 and it will increase up to 20% by 2020 for development planning of Lach Huyen port, with consideration as actualization of container cargo handling for South East Asia/USA Trunk Line in Lach Huyen port.

Consequently, the allocation of cargo volumes among the three (3) ports will become as follows:

Table 4.3.10 Allocation of Cargo among Three Ports

Cargo Type	Unit	Haiphong Port		Cai Lan Port		Lach Huyen Port	
		2015	**2020**	**2015**	**2020**	**2015**	**2020**
High Growth Case							
Container	000 ton	27,290	24,258	8,940	7,946	9,888	34,699
	000TEU	2,353	2,091	771	685	852	2,991
GC +Bulk	000 ton	9,033	8,030	2,307	2,050	0	3,634
Total	000 ton	**36,323**	**32,287**	**11,246**	**9,997**	**9,888**	**38,333**
Middle Growth Case							
Container	000 ton	27,290	24,258	8,940	7,946	5,122	26,468
	000TEU	2,353	2,091	771	685	442	2,282
GC +Bulk	000 ton	8,840	8,030	2,257	2,050	0	2,652
Total	000 ton	**36,130**	**32,287**	**11,197**	**9,997**	**5,122**	**29,120**
Low Growth Case							
Container	000 ton	24,801	24,258	8,125	7,946	3,659	18,238
	000TEU	2,138	2,091	701	685	315	1,572
GC +Bulk	000 ton	8,318	8,030	2,124	2,050	0	1,669
Total	000 ton	**33,119**	**32,287**	**10,249**	**9,997**	**3,659**	**19,907**

In November 2009, 43 liner services in Hai Phong Port consist of Hong Kong route (47%), Singapore (21%), Busan route (9%), Kaohsiung route (14%) and other routes (9%). There is high possible that 70 % (Hong Kong, Busan and Kaohsiung route) in total liner services is gradually converted to South East Asia/USA Trunk Line through Lach Huyen Port from 2015 to 2020. (See Figure 4.3.4)

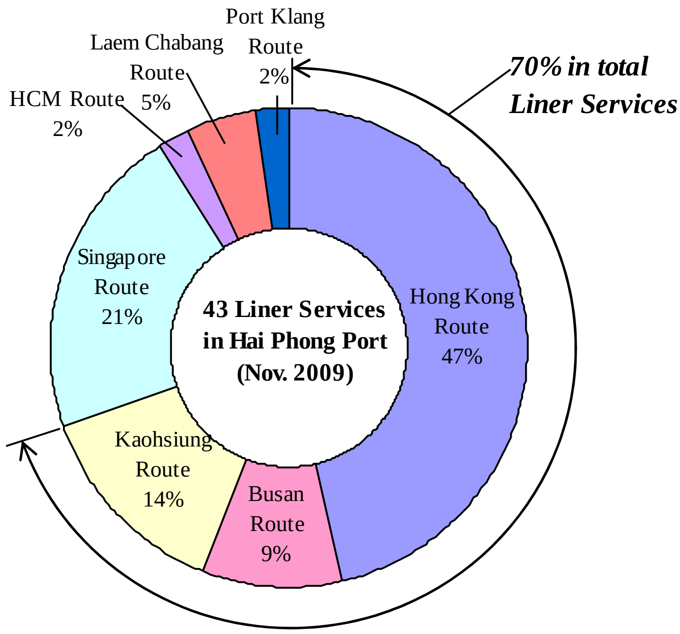


Figure 4.3.4 Liner Services in Hai Phong Port (Nov. 2009)

The demand forecast of Northern Ports, cargo handling capacities of Hai Phong and Cai Lan Port and required of cargo handling capacity of Lach Huyen Port are described in Figure 4.3.5.

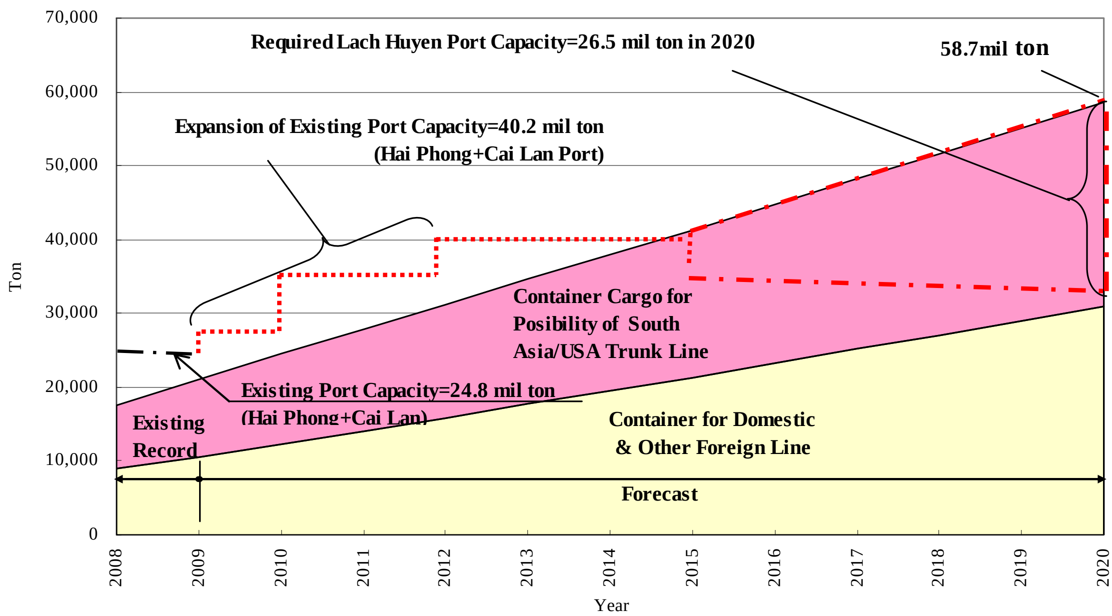


Figure 4.3.5 Container Demand Forecast of Northern ports in the Viet Nam and Lach Huyen Port (Middle Growth Case)

3) Cargo Volume of Lach Huyen Port

Yearly cargo volume of Lach Huyen port is forecast as shown in Table 4.3.11.

Table 4.3.11 Forecast Cargo Volume of Lach Huyen Port

Cargo Type	Unit	2015	2016	2017	2018	2019	2020
High Growth Case							
Container	1,000 ton	9,888	14,793	19,727	24,690	29,680	34,699
	1,000TEU	852	1,275	1,701	2,128	2,559	2,991
GC +Bulk	1,000 ton	413	1,114	1,786	2,431	3,047	3,634
Total	1,000 ton	**10,300**	**15,907**	**21,514**	**27,120**	**32,727**	**38,333**
Middle Growth Case							
Container	1,000 ton	5,122	9,344	13,590	17,859	22,152	26,468
	1,000TEU	442	806	1,172	1,540	1,910	2,282
GC +Bulk	1,000 ton	-	383	986	1,565	2,120	2,652
Total	1,000 ton	**5,122**	**9,727**	**14,575**	**19,424**	**24,272**	**29,120**
Low Growth Case							
Container	1,000 ton	3,659	3,894	7,452	11,029	14,624	18,238
	1,000TEU	315	336	642	951	1,261	1,572
GC +Bulk	1,000 ton	-	-	185	699	1,193	1,669
Total	1,000 ton	**3,659**	**3,894**	**7,637**	**11,727**	**15,817**	**19,907**

Consequently, cargo volume of Middle Growth case of Lach Huyen Port is estimated 2,282,000 TEU for container and 2,652,000 tons for general cargo and bulk cargo in 2020

The details of container forecast for Northern Viet Nam Ports and Lach Huyen Port are estimated in Table 4.3.12. In this estimation, TEU/Box ratio and empty container ratio are adapted with Hai Phong Port data. And Export and Import container is estimated to totally balance.

Table 4.3.12 Details of Container Forecast for Northern Viet Nam Ports and Lach Huyen Port

	Unit	Northern Viet Nam Port			Lach Huyen Port	Remarks
		2008	2015	2020	2020	
1. Export						
Container	1,000 ton	4,534	11,583	15,757	9,672	
Container	1,000TEU	504	999	1,572	1,085	Export and Import container volume was estimated to totally balance.
Loaded	1,000TEU	281	724	985	593	
Empty	1,000TEU	224	275	587	491	
40'	No.	168	333	524	362	TEU/Box ratio was estimated 1.5 based on latest 3 years of Hai Phong Port Data
20'	No.	168	333	524	362	
Box No.	No.	336	666	1,048	724	
2. Import						
Container	1,000 ton	7,722	15,149	23,834	15,727	
Container	1,000TEU	504	999	1,572	1,085	Export and Import container volume was estimated to totally balance.
Loaded	1,000TEU	478	947	1,490	965	
Empty	1,000TEU	26	52	82	120	Empty container ratio was for import container estimated 5.5% for import container based on latest 3 years of Hai Phong Data
40'	No.	168	333	524	362	TEU/Box ratio was estimated 1.5 based on latest 3 years of Hai Phong Port Data
20'	No.	168	333	524	362	
Box No.	No.	336	666	1,048	724	
3. Domestic						
Container	1,000 ton	7,722	15,149	23,834	1,094	
Container	1,000TEU	640	1,613	2,325	114	
Loaded	1,000TEU	478	947	1,490	67	
Empty	1,000TEU	162	218	343	47	
40'	No.	213	388	611	38	TEU/Box ratio was estimated 1.5 based on latest 3 years of Hai Phong Port Data
20'	No.	213	388	611	38	
Box No.	No.	426	776	1,222	76	
Total	1,000 ton	**19,977**	**41,881**	**63,425**	**26,493**	
Container	1,000TEU	**1,434**	**3,610**	**5,468**	**2,284**	Ton/TEU was estimated based 11.6 ton in 2009 based on VINAMARINE data

Note: Based on container data (year 2000 to Oct. 2009) of Hai Phong Port and VINAMARINE data, the Study Team estimated.

4.4 Cargo Volume in 2030

Since the Preparatory Study Team did not conduct a forecast for 2020-2030, the DD team estimated the cargo volume in 2030.

4.4.1 Methodology

Vietnam has entered a period of economic growth. It is currently in the initial stage and will continue to grow until it reaches a mature stage. Accordingly, a "Growth Curve" may be applied to the forecast of GDP. In fact, the growth of GDP has been remarkable in the past 10 years. And this growth is expected to continue until it reaches maturity. The growth of GDP in Vietnam may be illustrated as the line-A in Figure 4.4.1. If the government maintains its policy to promote industrialization and expansion of trade, the growth of the freight will also continue. The growth of freight of northern ports has also been remarkable in the past 10 years. It will last for a certain period until it reaches maturity.

Curve B represents the image of the growth of cargo throughput in Vietnam.

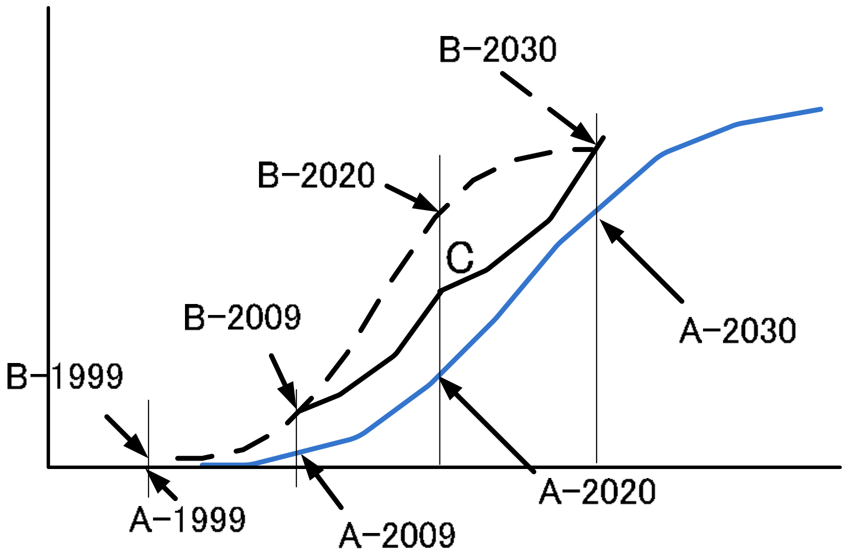


Figure 4.4.1 Growth Curve

However, higher wages, lack of land for industry, or limited resources, etc. may retard industrial development. Taking this into consideration, a moderate growth rate is normally applied for forecasting cargo. The curve C in the Figure 4.4.1 represents the forecast cargo in the case of using the moderate growth rate.

The cargo forecast for 2020-2030 is conducted here, assuming the moderate growth rate, since it has fewer risks than assuming a "growth curve".

4.4.2 Forecast

Taking the past performance and the cargo volume forecast by the Preparatory Study Team for 2008-2020 into consideration, the DD team assumed the growth rates for 2020-2030: 9.8% for containers, 3.0% for general cargo and 4.5% for dry bulk (The growth rate became 8.9% as a whole).

The cargo throughput forecast by the DD team for northern ports in the year 2030 is indicated in the Table 4.4.1.

Table 4.4.1 Cargo Forecast for Northern Ports 2020- 2030 (unit: 000ton, 000teu)

Year	2020	2030
Total Cargo	71,404	167,060
Container	58,672	149,436
(TEU)	(5,058)	(13,585)
GC	10,277	13,811
Dry Bulk	2,455	3,813

The northern ports consist of Haiphong Port, Dinh Vu Port, Lach Huyen Port, and Cai Lan Port. The future volume of cargo in each port is as follows.

1) Hai Phong & Dinh Vu Area

Presently Hai Phong and Dinh Vu Area have 24 berths. The total berth length is 9,200m. The breakdown of those berths is shown in the Table 4.4.2.

Table 4.4.2 Existing Berths in Hai Phong and Dinh Vu area

12 general terminals, L=3,665m, 2,000-40,000dwt	Vat Cach, Nam Ninh, Cuyunh Cu, Song Da 12.4, Duy Linh, Hai Phong, Ha Long Fish Port, Cua Cam, Thuy San2, Nang Luong, Don Hai, 128 Port
9 container terminals, 2,666m, 7,000-20,000dwt	Nam Hai, Doan Xa, Transvina, Green Port, Chua Ve, Dinh Vu, Dinh Vu New Port, PSTC Dinh Vu, Hai Phong Port
12 liquid and dedicated terminals, 1,855m, 1,000-10,000dwt	Thang Long Gas, Yhuonh Ly, Gas Dai Hai, Shell Gas, Total Gas, K99, Petec, 19-9, XD Dinh Vu, Caltex, DAP, electro thermal HP
08 maintenance and ship building terminals	Lilama, Bach Dang, Co Khi Ha Long, Nam Thieu, Pha Rung, Dong Do, XD Hong Bang, CK Marine Products
05 calm buoys and transshipment areas	Bach Dang, Ninh Tiep, Ben Got, Lan Ha, Ha Long

Since Haiphong Port has no room for expansion, the capacity will remain as it is.

Table 4.4.3 Capacity of Hai Phong Port

	2015	2020	2030
Container (000 ton)	14,850	14,850	14,850
(000 TEU)	(1,350)	(1,350)	(1,350)
GC & Dry Bulk (000 ton)	3,665	3,665	3,665
Total (000 ton)	18,515	18,515	18,515

Dinh Vu Area and Lach Huyen Area will be developed to meet the demand. The Dinh Vu Area has the following expansion plan.

Table 4.4.4 Expansion Plan of Dinh Vu Area

Dinh Vu	Terminal type	Year 2015	2020	2030
I	Container terminal			
	Number of berths	2	4	5
	Total length	440	880	1100
	Vessel size	20,000 DWT	←	←
II	General terminal			
	Number of berths	2	3	3
	Total length	440	660	660
	Vessel size	20,000 DWT	←	←
III	Petrol terminal			
	Number of berths	1	6	6
	Total length			
	Vessel size	20,000 DWT	←	←
IV	Internal construction terminal			
	Number of berths	1	5	5
	Total length			
	Vessel size	20,000 DWT	←	←

Construction of two container berths and two general cargo berths have almost been completed in Dinh Vu Area.

Assuming capacity of 200,000 TEUs per berth, Dinh Vu area will be able to handle 400,000TEUs in 2015, 800,000TEUs in 2020, and 1.0 million TEUs in 2030.

Assuming handling capacity of 400,000 tons per berth for general cargo, Dinh Vu area will have the capacity to handle general cargo up to 800,000tons in 2015, and 1.2 million tons in 2020 and in 2030.

As a result, the handling capacity at Dinh Vu area is summarized as Table 4.4.5.

Table 4.4.5 Cargo Handling Capacity at Dinh Vu Area (excluding Liquid Bulk)

	2015	2020	2030
Container (000 ton)	4,400	8,800	11,000
(000 TEU)	(400)	(800)	(1,000)
GC & Dry Bulk (000 ton)	800	1,200	1,200
Total (000 ton)	4,800	10,000	12,200

2) Cai Lan Port

Cai Lan Port presently has the berths (-11 x 460m), and there is an expansion plan up to -12 x 1,870m. The productivity of the port is presently at half capacity. If berths are extended to 1,870m (3 times of present facilities), the capacity to handle cargo will reach 6 times the present volume.

However, volume of cargo in Cai Lan Port will not reach the limit before 2030.

Based on the above assumptions, cargoes for each port are estimated and shown in Table 4.4.6.

Table 4.4.6 Cargo Handling Volume Among Northern Ports, Year 2030

YEAR 2030	Northern Total	Cai Lan	Haiphong	Dinh Vu	Lach Huyen
Container (000 ton)	149,436	20,238	14,850	11,000	103,347
(000 TEU)	(13,585)	(1,745)	(1,350)	(1,000)	(9,490)
GC+Bulk (000 ton)	17,624	3,451	3,665	1,200	9,308
Total (000 ton)	167,060	23,690	18,515	12,200	112,655

The forecast cargo above is almost the same as the latest study conducted by VINAMARINE, which is shown in Table 4.4.7.

Table 4.4.7 Forecast Cargo for Lach Huyen Port by VINAMARINE

YEAR	2015	2020	2030
Container (000 ton)	12.1	24.2	100
GC+BULK (000 ton)	-	4	15
TOTAL (000 ton)	12.1	28.2	115

It will be necessary to construct 27 highly efficient container terminals by 2030, assuming one terminal is capable of handling 400,000TEUs/Year.

In other words, total required berth length is 9,450m, while 567ha will be required for container terminals, assuming that each berth is 350m and each terminal has an area of 21ha.

4.5 Vessel Calls

Vietnam has 126 ports along their 3,260 km coast line, and 24 ports of them are opened for international trade. Shipping lines have liner services only in six ports out of the 24 ports, namely, Ho Chi Minh, Vung tau, Hai Phong, Cai Lan, Quy Nhon, and Danang.

There are three trunk lines in the world shipping industry. They are Far East - Southeast Asia - Europe, Southeast Asia - Far East - USA West coast, and USA East coast - Europe routes. Vietnamese ports are geographically included in the above former two trunk routes covering Asia. Despite their geographical locations, no Vietnamese ports are listed in the published shipping schedule as calling ports by the shipping lines operating Asia/USA and Asia/Europe direct services at the moment. Vietnamese cargos from / to the origins / destinations on the above trunk routes are still transshipped at the hub ports where the trunk line vessels call.

The reason of this situation is that Vietnamese ports are too shallow and small to receive large container vessels, and container volumes handled in the ports did not satisfy the space of large vessels at one calling until a few years ago. However, recently Vietnam has grown to become the “world’s factory” after BRICs countries, therefore, cargo volume jumped up by development of manufacturing and consuming power.

Ho Chi Minh area had been an only surpassing big location in Vietnam until several years ago. Hai Phong and Cai Lan ports appeared recently on the stage as the 2nd key port in this country, which is regarded as a gate for not only North Vietnam but also northern part of Indo-China countries like as North Thailand and Laos, and the border area of China. Both ports, however, are not incorporated in the trunk lines, neither in Asia/USA nor Asia/Europe route yet.

Since 2004, the container throughput in Hai Phong and Cai Lan have increased average 38% every year until 2008, and still continues to grow.

The deployed vessels are greater than 1,000 TEU and applicable for feeding the panamax/post panamax container vessels. They are also servicing markets and area where the demand for large container vessels is too low. Such size are deployed into near seas navigation route around South East Asia, as panamax/post panamax size vessels are not into South East Asia/ USA route including Hai Phong. Propulsion trends in container vessels are prevailing due to high fuel oil price and the following cost to vessel operation and port charges increase.

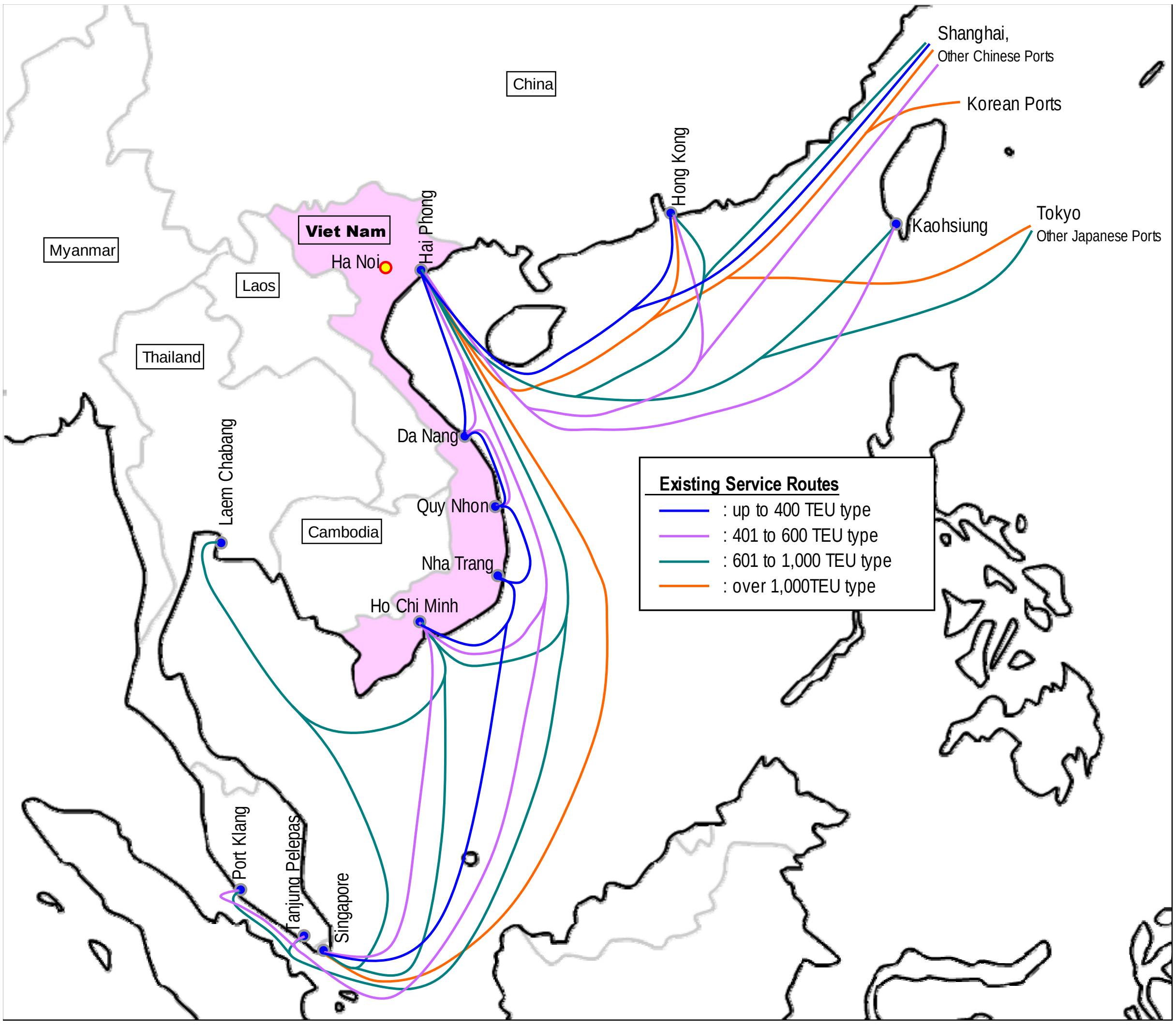
The size of feeder vessels are getting larger, as the feeder transportation demand from hub to feeder ports increases. This is because post panamax / panamax size vessels currently appeared on most main route in Asia

The existing routes served by the shipping companies calling at Hai Phong / Cai Lan and the vessel size are shown on the following map (Figure 4.5.1) with colored line in respective vessels' container loading capacity. This map was organized from the following table (Table 4.5.1), which shows the service nets and details of the deployed vessels.

It is shown that most vessels in this route are 500/600 TEU type, and basically serving weekly. It can be found that the world major shipping companies have slot charter contract with regional feeder shipping companies, or have joint service as a partner.

Slot charter is to buy partial space from an owner, and partner is to throw their own vessels together into a group to maintain a round service.

It also shows that they connect the neighboring and closed ports/countries each other by deploying small size of container vessels, and containers are relayed from/to the trunk service at the hub ports, where are Kaohsiung, Chinese ports and Singapore. There is currently no direct service between India, Europe and USA, and Hai Phong/Cai Lan. A few direct services are towards Far eastern countries, Japan and Korea.



Source: JICA Study Team

Figure 4.5.1 Existing Service Route

Table 4.5.1 Service Type and Vessels calling at Haiphong

Shipping Cos. In Service	Route	Vessels Name	Loading Capacity	Frequency	P: Partners SC: Slot Charter
APL	SP/HCM/SP	"Cape Arago" "Westerhever	FC 1,066 TEU FC 1,572 TEU	2 /Week	P: ACL
China Shipping	Chiwan/HK/HP/Chiwan	"Su Peng"	MP 170 TEU	Weekly	
COSCO	HK/HP/Zhanjing HP/Danang/QuiNhon/SP HP/HK/HP	"Bei Hai"	MP 602 TEU	Weekly Weekly	P: Sinotrans SC : Gold Star SC: COSCON P: Sinocor
Evergreen	Kaohsiung/HP/Kaohsiung	"Da Ping" "Dong Du"	MP 602 TEU FC 566 TEU	Weekly	
Gemartrans	HP/Kaohsiung/HK/HP HP/HK/HP HP/QuiNhon/HCM/SP/HCM/HP HP/Danang/QuiNhon/SP/HP	"Vinalines Pioneer" "Matura ll"	FC 588 TEU FC 534 TEU	Weekly Weekly 2/Week	SC: K P: K, TS,SC:Cosco P: Cosco, etc. SC:Coscon

Shipping Cos. In Service	Route	Vessels Name	Loading Capacity	Frequency	P: Partners SC: Slot Charter
Hanjin	Busan/HK/HP/ Busan			Weekly	SC: Hanjin, MOL
Heung A	Gwanyang/Busan/HK/HP/ Fangcheng/HK. HP/Fengchang/ Shekou	"Heung A Bangkok" "Heung A Singapore" "Heung A Hong Kong" "El Bravo"	FC 653 TEU FC 653 TEU FC 650 TEU FC 1,118 TEU	Weekly	
Hub Shipping	PKelang/HCM/HP/PKelang	"Hub Enzo"	FC 818 TEU	Weekly	P: CNC, Gemartrans
K Line	Kaohsiung/HP, HP/HK, HP/Kaohsiung/HCM/HP	"Vinalines Pioneer"	FC 588 TEU	2/Week Weekly	P: Wan Hai SC: Gemartrans P: Gemartrans
MCC Transport	SP/HP/T Pelepas, TPelepas/SP/HP/ Danang/NhaChang/TPelepas,/ HP/HK/Kaohsiung/HP TPelepas/SP/HP/ Qui Nhon/SP	"Fesco Ayon" "MCC Confidence" "MCC Proteus"	FC 1,102 TEU FC 543 TEU FC 653 TEU	Weekly Weekly Weekly Weekly	 P: Evergreen P: Evergreen P: Evergreen
MSC	HK/HP/Shantou/HK	"MSC Wellington"	FC 1,271 TEU	Weekly	
MOL	HK/HP/Chiwang/HK, HP/HK/HP			Weekly Weekly	SC: Bien Dong
Bien Dong	HP/HCM/SP/HCM/HP,/HCM HP/Fengchang/HK/HP, HP/HCM/BKK/LC/HCM/HP	"VinashinFreighter" "Vinashin Trader" "Van Hung" "Van Ly" "Bien Dons Star" "Van Phuc"	FC 610 TEU FC 610 TEU FC 420 TEU FC 357 TEU FC 750 TEU FC 404 TEU	Weekly 2/Week Weekly	P: MOL SC: MOL
Nam Sung	Korean Ports/HK/HP/ Shekou/Xiamen/Inchon	"Bonny Star" "Happy Star"	FC 342 TEU FC 342 TEU	Weekly	
OOCL	HP/Kaohsiung/HP	"Grand Ocean"	FC 560TEU	Weekly	
RCL	SP/HP/SP			Weekly	
RSK	Shekou/SP/HP/ HK/Xiamen	"Ocean Bhum" "Resourceful"	FC 1,114 TEU FC 1,114 TEU	Weekly	
Samdera/ Advance CL	SP/HP/Danang/QuiNhon/SP HP/Chiwan/HK HK/HCM/HK	"Sinar Padang" "Kota Ria" "Kota Rakyat"	FC 400 TEU FC 938 TEU FC 938 TEU	Weekly	 P: MOL
Sinocor Merchant Marine	HK/HP/HK	"Hua Sha"	MP 300TEU	Weekly	
SITC CL	Japanese Ports / Shanghai/HK/HCM/ HP/Tokyo	"Josco Lily" "SITC Tokyo" "Trinity"	FC 1,049 TEU 847 TEU 907 TEU	Weekly	
NYK RCL	Guangzhou/Cai Lan/HCM HCM/Cai Lan/HK/Japan. ports Songkhla/HK/HP/HK	"ACX Lilly" "Asian Gyro" "Pira Bhum" "Ratha Bhum" "Supa Bhum"	1,404 TEU 1,032 TEU FC 628 TEU FC 628 TEU FC 628 TEU	Weekly Weekly	P: Tokyo Senpaku P: Tokyo Senpaku
TS Lines	Shekou/HK/Fangcheng /HP/Fangcheng, Fangcheng/HP/Chiwan			2/week	P: CU Lines
Vinalines	HCM/HP	Various	MP/FC 215/556 TEU	5/week	

Shipping Cos. In Service	Route	Vessels Name	Loading Capacity	Frequency	P: Partners SC: Slot Charter
Vinashin Ocean Shipping	?	"Vinashin Express 1"	MP 567 TEU	?	
Wan Hai	HP/Kaohsiung/HP	"Venus C" "Tai Ping"	FC 816 TEU ? TEU	Weekly	P: K Line, SC: Coscon, Evergreen, MOL

Source: Containerization International Year Book 2009 and International Transportation Handbook 2009
HP : Hai Phong, HCM: Ho Chi Minh, SP: Singapore, HK: Hong Kong, LC: Laem Chabang, BKK: Bangkok
SC: Slots Charter, P: Partners, FC: Full Container Ship, MP: Multi-purpose Ship

From the above table (Table 4.5.1), the actual substance of the service around Hai Phong area and the connecting transportation would be cleared. Only Tokyo Senpaku, under the name of NYK launched service on calling at Cai Lan since 2004 and has twice a week service with middle size container vessels, and MSC did in 2009. The containers of these lines are transported between Hai Phong and Cai Lan by motor barges and other provinces by trucks.

Now the cargo movement Asia/Europe is growing more than Asia/USA in percentages, it is said, and some Chinese shipping line swapped the fleet of post panamax size deployed in USA route for Europe route.

But there is little possibility for Far East Asia/Europe line vessels to call directly at Hai Phong due to several days' deviation from the usual navigation route at moment. Cargo transportation pattern between Vietnam/Europe will be transshipped at the hub ports like as Singapore for another several years, too, unless the new line which is originated from Hai Phong.

For eastbound cargo, there is possibility that panamax or post panamax size of container vessels will extend her service route to Lach Huyen from China and Taiwan area, especially on completion of expansion of width in Panama Canal which is to be completed in 2014, since many shipping lines maintain South China/USA west coast service by such size of vessels now.

The following table (Table 4.5.2) shows the respective operation group and their vessels of container loading capacity at present. Some vessels out of the fleet will be feasible to call at Lach Huyen on opening of the new modern container terminal. The service between Asia and US East coast via Suez Canal is excluded from this list. Such westbound routes have recently commenced due to avoiding heavy congestion of Panama Canal and escalation of Canal toll, of which amount is appropriated for the construction of new canal.

The existing calling situations of the shipping service in Hai Phong and Cai Lan are as follows:

(1) Water depth in Hai Phong Channel is 7.8m, which can accommodate approximate 10,000 DWT container vessels to be equivalent to 500/600 TEU with full load condition in spite of tidal condition, and moreover, there is no big container terminal here which has capacity to handle huge volume of containers quickly at present. In so way, the smaller type of vessels, therefore, are deployed, or around 1,000 TEU type vessels come on berth Hai Phong in not full load, with empty containers/vacant space. The channel through Cai Lan is deeper than to Hai Phong, 12m in depth, but small volume of cargo is concentrated.

(2) There have been not enough containers accumulated to handle the large size vessels in a short stay on the berth in one calling. The smaller sizes and frequency services have compensated for the above situation.

(3) The terminal is indispensable to make the shipping lines learn container productivity at quay side for keeping their service schedule as their planning. But they will not be able to catch operative condition at the existing port. Only modern equipment and facilities can perform

the steady and expeditious container handling with skillful operation.

(4) Approximately there are several days' deviations from the regular course on Kaohsiung or Shanghai/Singapore/Europe to the location of Hai Phong port. The shipping companies cannot deserve this extra navigable time and expenses for their accounts and Asia/Europe clients. Connecting feeder vessels can compensate heir loss time with transshipment at neighboring hub ports from Hai Phong.

All the other items but No. 4 out of the above descriptions can be solved on construction of the new container terminal in Hai Phong area and how to operate it to fascinate and to induce the users are essential for port of Lach Huyen.

Table 4.5.2 Existing PRC (Asia) /USA Service

Group Name	Organized Members	Capacity of Deployed vessels	Typical Vessels' names Deployed	
TNWA	MOL, APL, Hyundai	2,996 - 6,479 TEU	MOL Miracle	2,996 TEU
			APL England	5,508 TEU
			Hyundai Dominion	6,479 TEU
Grand Alliance	NYK, Hapag-Lloyd, OOCL	2,893 - 8,060 TEU	NYK Springitde	2,893 TEU
			Dresden Express	4,639 TEU
			OOCL Hamburg	8,063 TEU
CKYH	Coscon, K Line, Yang Ming, Hanjin	2,702-5,576 TEU	COSCO Panama	2,702 TEU
			Chicago Bridge	5,576 TEU
			YM Prosperity	3,266 TEU
			Hanjin Osaka	4,024 TEU
Maersk	Maersk	1,129 – 6,600 TEU	Astor	1,129 TEU
			Albert Maersk	6,600 TEU
Evergreen	Evergreen	2,728 – 7,024 TEU	Ever Gifted	2,728 TEU
			Ever Shine	7,024 TEU
CMA CGM	CMA CGM	4,298 – 8,600 TEU	CMA CGM Galaxy	4,298 TEU
			CMA CGA Courage	8,600 TEU
China Shipping	China Shipping	4,250 – 5,688 TEU	Xin Dan Dong	4,250 TEU
			Xin Yan Tai	5,688 TEU
MSC	MSC	873 – 8,034 TEU	MSC Immacorata	873 TEU
			MSC Beijing	8,034 TEU
CTP	Wan Hai, PIL	2,495 – 4,250 TEU	Wan Hai 302	2,495 TEU
			Wan Hai 509	4,250 TEU
China Express	China Express, Matson	1,970 – 2,524 TEU	R J Pfeiffer	1,970 TEU
			Manukai	2,524 TEU

Source: MOL's data & Containerization International Year Book 2009

Northern Vietnamese ports, comparing to the southern ports, the service frequency had been poor till the several years ago. Naturally, it is not always dominant in physical and geographical location, and the trade container volume. However the service numbers of the shipping companies to Hai Phong/Cai Lan are increasing due to the recent jumping up of container volume. The following table shows the new joiners and the increase of frequency in services 2006 vs. 2010.

Table 4.5.3 Service Variation of Type and Vessels calling at Hai Phong/Cai Lan in 2010 & 2006

	2010				2006			
Shipping Lines In Service	**Route**	**Frequency**	**Partners**	**Vessels in Service**	**Route**	**Frequency**	**Partners**	**Vessels in Service**
ACL	SP/HP/Danang/Quinhon/ SP	Weekly		Kota Machan 606 TEU Kota Ria 938 TEU	Same as 2010	Weekly		Jatianom 459TEU Kota Bintang 476 TEU
APL	Feeder from Kao, HK, SP, or Chiwan	Weekly		Nil	Nil	Nil	Nil	Sinar Padang 495 TEU Cape Arago 1066 TEU Nil
Biendong	SP/HCM/HP/HCM/SP HP/HK/HP	Weekly Weekly	SC:MOL SC:MOL	Vinashin Mariner Vinashin Navigator 1016 TEU	Nil	Nil	Nil	Nil
Chien Lie (CMA CGM)	Kao/HP/Kao Kao/HP/Kao	Weekly Weekly	SC: Y.Ming SC: TS Lines Wan Hai	Mell Senang 698 TEU Mell Seraya 704 TEU Kuo Chang, Kuo Chia, Kuo Fu, Kuo Yu 1295 TEU	Nil	Nil	Nil	Nil
ECL	Yoko/Nya/Kobe/HP/HC M	1-2/month			Same as 2010	1-2/month		
Evergreen	Kao/HK/HP/Kao	Weekly	SC: Wan Hai	Rio Lawrence 1155 TEU	Nil	Nil	Nil	Nil
Gold Star	Shekou/HK/HP/Shekou	Weekly		Xiao Yun 300TEU	Nil			
Hanjin/ Sinotrans	Busan/Shai/HP/Shai/ Busan/	Weekly		Appen Charlotte 1043 TEU Sinar Bintan 1060 TEU	Nil			
Heung-A	KwangYang/Busan/HK/ HP/Shekou/HK/KwangY	Weekly		DS Ability 1118 TEU Heung A Bangkok 650 TEU	Same as 2010	Weekly		Hueng-A Bangkok Hueng-A Hong Kong 650 TEU
Hyungdai/ Spic/TSK	Feeder service from HCM				Nil			
Kambara Kisen	Feeder service from Shanghai	Weekly			Nil			
KL/Wan Hai/ GEMCO	HK/HP/HK Another feeder service From HK	Weekly		Vinalines Pioneer 588 TEU	Kao/HP/Danang/ HC Another feeder service fm HK	Weekly	GEMCO Loop 1	Gematrans Pioneer Van Phong 585/563 TEU
KMTC/STX Pan Ocean	Busan/KwangYang/HP/ Xiamen/Shai/Busan	Weekly		Lantau Breeze 1049 TEU MareAdriaticum 1054 TEU	Nil			

Maersk	Feeder service from Kao	Weekly			Feeder service from HK or Kao			
Marui (Ro/Ro)		6-8/month			Nil			
MOL	Feeder service from HK				Feeder service from HK			
Nam Sun	Inchon/Busan/HK/HP/ HK/Shekou/Xiamen/ Inchon			Bohai Star 706 TEU Liberty Star 706 TEU	Nil			
OOCL	Kao/HP/Kao	Weekly			Nil			
PIL	Feeder service from Shanghai			Kota Tegue 700 TEU Kota Terau 720 TEU	Feeder service from SP			
RCL	SP/HP/HK/Fencheng/ SP	Weekly		Methi Bhum 926 TEU Nethi Bhum 928 TEU	Nil			
SITC	HP/HK/Xiamen/Shai Shi/Japanese Ports/ Busan/ Shai/Keelung/HP Incheon/Pyongtaek/Shai/ HK/HP/Xiamen/Incheon			Josco Star 1043 TEU Josco View 1049 TEU Sunrise Express 1049 TEU SITC Express 917 TEU SITC Quingdao 787 TEU	Nil			
TS Lines	Feeder from Kao by Chien Lie Line				Nil			
Toko	Yoko/Kobe/HP/HCM	2-3/month			Japanese ports/HP/HCM	2-3/month		
TSK	Feeder from Kao Japanese ports/Nansha/ Cailan/HCM/SP/Jakarta/ HCM/Cailan/HK/Tokyo	2/week		ACX Cosmos 1241 TEU ACX Lilly 1182 TEU Asian Gyro 1098 TEU Asian Zehhyr 1098 TEU	Japanese ports/ Shai/HK/Huangpu/ Cai Lan/HCM/ Shekou/HK/Tokyo	Weekly		ACX Cherry ACX Cosmos 1241 TEU Sunrise 1181 TEU
Wan Hai	Kao/HP/Kao	2/week		An Chun 642 TEU Shin Chung 640 TEU	Same as 2010	Weekly		Padma 734 TEU
Dongnama					Feeder from HK	Weekly		
Hapag					Feeder from SP			

Source: International Transportation Handbook 2010 & 2006
HP: Hai Phong, HCM: Ho Chi Minh, SP: Singapore, HK: Hong Kong, Kao: Kaohsiung, Shai: Shanghai, SC: Slot Charter, P: Partner

4.6 Access Road Traffic Demand

Volume of container is forecasted as 2,282,000TEU in 2020. It will be transported through a road, a railroad, or the other modes such as small ships.

Assuming 80% of containers will be transported through the road, the port road should transport 1,826,000 TEU/Year. Since 40’ trailer will be mainly used for transportation, 912,800 cars per year will pass the road in both directions because import or export needs the same number of empty containers.

As for the general cargo, assuming an allotment by transportation mode like Table 4.6.1 and assuming that 10-ton trucks will be used for road transportation, 198,900 cars per year will use the road. Therefore, the large-sized vehicle will pass 1,111,700 times per year in total.

Assuming that these cars will be distributed evenly in 10 working hours per day, the traffic volume is estimated as 309 cars/hr.

The above is mainly the large freight car. Ancillary vehicles will be generated by the port activity. Assuming these additional cars as 15%, total number of cars to pass the port road is forecast as 355 cars.

Table 4.6.1 Estimation of car traffic on the port road

Item	Year	
	2020	2030
Container (000TEU)	2,282	9,490
Road (80%)	1,826	7,592
Rail (15%)	342	1,424
Other (5%)	114	475
General Cargo(000ton)	2,652	9,308
Road (75%)	1,989	7,446
Rail (15%)	398	1,396
Other (10%)	265	465
Number of Vehicles per year		
Container Trailer (40')	912,800	3,796,000
Truck (10ton)	198,900	744,640
Large Vehicle Total	1,111,700	4,540,640
Working Hour/Year	3,600	3,600
Large Vehicle/hr	309	1,261
Additional Vehicle (15%)	46	189
Total Vehicle/Hr	355	1,450
Design Capacity per lane	500	500
Required Number of Lanes	0.7	2.9

The design capacity of the port road is normally 500 /Lane/hr.

On the other hand, the port road which is adjacent to the container terminal shall have a minimum of 2 lanes; one lane is a slow speed lane and the other lane is a normal speed lane. In addition to above passing lanes, 2 lanes of parking should be secured along the terminal fence.

The freight in 2030 is 9,490,000TEUs. Three lanes in each direction will be required for the port road connecting to the large container terminal area.

That means 4 lanes are needed as a whole for one direction, because 1 lane is basically needed for slow speed lane.

A green belt which has 20m -30m in width is normally needed between the two different direction lanes to allow very large vehicles to turn without inconveniencing other cars.

Although the project starts from two berths, the road in front of this terminal will be most heavily utilized in the future.

The road area should be reserved based upon 2030 demand.

5. CHANNEL SEDIMENT ANALYSIS

5.1 Initial Sedimentation Regime Analysis

5.1.1 General

The review work for this project and methodology were as follows:

(1) Review previous modeling;

(2) Review and analyze the recent bathymetric data collected since the last capital dredging;

(3) The preliminary findings related to the proposed Deep Water Port at Lach Huyen were summarized.

The aspects to be covered include the following:

The channel sedimentation assessment takes into consideration the apparent infill rates which are determined from the repeated bathymetric surveys, together with other information derived from the previous studies. It should be noted that this is an initial desk assessment, and that more detailed studies will be required to both improve the estimate and to assess the effectiveness of each of the schemes (e.g. sand protection dyke), which may help reduce sedimentation.

For interpretation of the actual infill volume, it was noted that maintenance dredging in Lach Huyen Channel had not been carried out until the present. For Ha Nam reach, small maintenance dredging of 300,000 m^3 each had been carried out for both ends of Bach Dang and Lach Huyen sides in 2008 and 2009. Moreover, a total of 200,000 m^3 maintenance dredging had been conducted in the turning basin of Cam Channel.

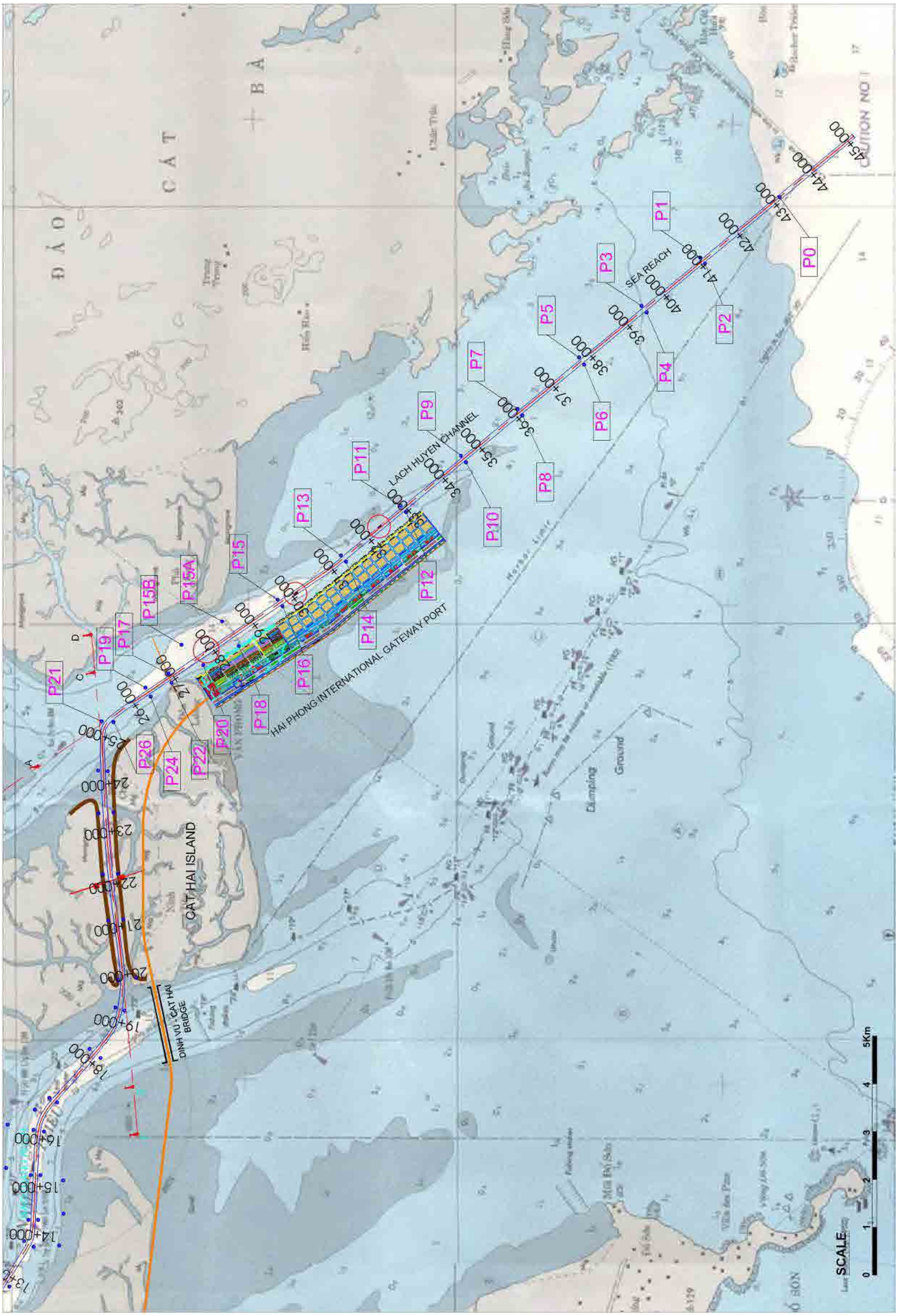


Figure 5.1.1 Location Map of Buoys and Mileage of Access Channel

5.1.2 Previous Modeling

1) Hai Phong II Project

a) Assessment of Sedimentation around Lach Huyen Channel

Generally, water arriving in Lach Huyen from Chanh River has few sediments. A few spot measurements of concentrations in the upper and lower parts of the water column show surface concentrations less than 28 mg/L and bed concentrations less than 37 mg/L for all samples taken from the west of Hon Gai and Cai Lan access channel.

The more obvious thing was that measurements showed lower concentrations in Lach Huyen than in Bach Dang and Nam Rivers, and the highest concentrations were obtained on the dry season spring tide measurement.

The HAECON study included the dredging of a trial pit in October 1995 for the purpose of monitoring infill in an area that will be most critical for the proposed future channel, namely the seaward bar of Lach Huyen. The bottom of the pit was 160 m by 20 m with approximately the same alignment as that of the proposed channel, and side slopes of 1 in 10 over its landward half and 1 in 20 over its seaward half. Centered at where natural depths were about 2.5 m below Chart Datum, the pit was dredged to a depth of 2.0 to 2.5 m in the fine sands of the bar. The trial pit and adjacent banks were surveyed and the infill sediment was sampled over 15 months. The infill of the trial pit proved to be much reduced by more than 1 meter depth than in the Nam Trieu sea channel in January 1997. The series of cross sections surveyed trace the infill amounting to 0.07 m per month in the dry season, while infill rates rose to about 0.25 m per month in the wet season.

The results of seabed samplings are summarized and illustrated in Figure 5.1.14. A detailed explanation is discussed in Section 5.1.9 “Distribution of Seabed Materials”. The used particles are as follows:

- For sand infill 0.15 mm and 0.10 mm
- For mud infill

Season	**HW Concentration (mg/L)**		**LW Concentration (mg/L)**	
	Bach Dang	Ha Nam	Bach Dang	Ha Nam
Dry spring	225	100	100	100
Dry neap	125	100	30	30
Wet spring (low flows)	40	50	125	30
Wet neap (low flows)	125	50	125	100
Wet spring (high flows)	50	300	300	100
Wet neap (high flows)	50	300	200	300

For Lach Huyen Channel, the results of HAECON’s test pits were applied.
Sand infill of 0.25 mm per month, and mud infill of 0.07 m per month

b) Numerical Simulation

i) General

The processes of infill by sand and mud are quite different and consequently, these aspects are dealt with separately. The upriver reaches of Ha Nam Channel, and Bach Dang and Cam Rivers are only affected by mud transport processes, whereas the sea channel across the outer bar and into naturally deep water will attract both mud and sand infill.

ii) Methodology

In this study, sand infill was predicted by waves and tidal and fluvial currents, while mud infill was predicted by tidal and fluvial currents only.

1. Wave transformation model

Wave transformation is determined through the energy balance equation together with the wave diffraction and dissipation for wave deformation.

2. Current model

The current model is composed of three dimensional (3D) modeling within a larger two dimensional (2D) modeling. The flow model was based on TELEMAC, which was developed by EDF-LNHE Paris.

iii) Model setup

1. Computation domain

Along the length of Cam, Nam and Chanh Rivers, the mesh has a node spacing of 200 m and has five elements across the width. The node spacing in Bach Dang River is 200 m. The element size increases to 700 m at the southern boundary of the model. A structured region corresponding to the location of the proposed dredged channel has a 20 m node spacing across its width.

2. Incident wave

For this study it was proposed that an offshore wave climate is to be established using VOS data (voluntary observations of weather from ships) combined with a wind wave generation model of the Gulf of Tonkin. VOS data was obtained from the UK Meteorological Office for the area enclosed by 18-20^{o}N and 106-108^{o}E. Wind data recorded at Phu Lien as well as wind data in the Gulf of Tonkin from the UK Meteorological Office Global Wave Model were also obtained from the UK Meteorological Office. In addition to this, wave data recorded at Bach Long Vi Island and Hon Dau were considered.

iv) Estimated infill

Table 5.1.1 Estimated Range of Infill Rates for Various Channel Reaches

Reach	Infill Rate (m^3/year)						Mean
	Dry Season		Wet Season		Total		
	from	to	from	to	from	to	
Sea Reach (Outer) Km. 38+000~42+000	50,000	800,000	140,000	250,000	190,000	330,000	260,000
Sea Reach (Inner) Km. 31+000~38+000	200,000	600,000	350,000	1,400,000	550,000	2,000,000	1,275,000
Lach Huyen Km. 25+500~31+000	0	0	0	0	0	0	0
Total	**250,000**	**1,400,000**	**490,000**	**1,650,000**	**740,000**	**2,330,000**	**1,535,000**

Table 5.1.2 Actual Infill Rates for Various Channel Reaches
[First Year] from 01 October 2005 to 16 November 2006

Reach	Infill Rate (m^3/ year)		
	Dry Season	Wet Season	Total
Sea Reach (Outer) Km. 38+000~42+000	196,203	302,000	498,203
Sea Reach (Inner) Km. 31+000~38+000	857,505	425,875	1,283,380
Lach Huyen Km. 25+500~31+000	57,743	365,375	423,118
Total	**1,111,450**	**1,093,250**	**2,204,700**

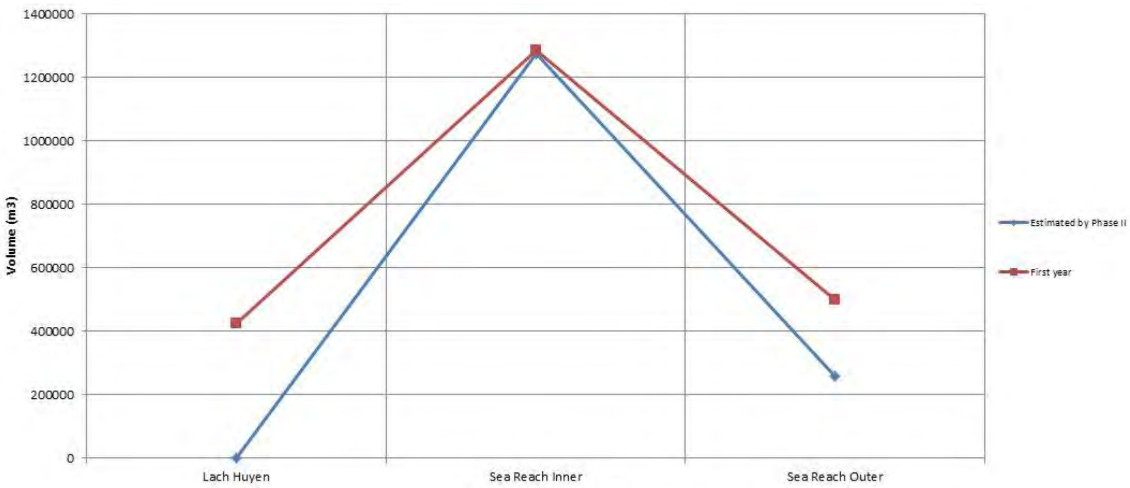


Figure 5.1.2 Infill Rate Comparisons

The previous studies carried out in 2000-2001 considered channel design, navigability, and sedimentation analysis. The sedimentation assessment considered all reaches of the channel from the present port out to the channel fairway buoy, and assessed the infill due to both sand and mud, and the seasonal distribution of this infill in terms of the contribution during the wet and dry seasons. However after initial dredging, based on the actual seabed bottom sampling, it was found out that the sand movement could not be recognized.

2) JICA Preparatory Study No. 2

a) Assessment of Sedimentation around Lach Huyen Channel

In general, the depth difference between the two frequencies indicates the thickness of the fluid mud. The fluid mud thickness is characterized as follows:

- Along the channel, the depth difference between high and low frequencies is approximately 0.1-0.2 m at Km. 26+000-36+000, 0.2-0.4 m at Km. 36+000-39+000, and 0.3 m at Km. 40+000 to offshore; and
- The depth difference is relatively larger in the center of the channel compared to the outside of the channel.

These were the results of sediment sampling that has been carried out at 80 points in November 2009. Most of the sediments on the center of the channel are silt and clay, in which the average grain size is 22 μm. It was also seen that the grain size is getting smaller and the mud content is getting higher in the offshore area. These tendencies indicate that quite fine sediment is deposited on the channel bottom, particularly the offshore part of the channel.

b) Numerical Simulation

i) General

In order to predict the sedimentation in Lach Huyen Channel, numerical simulations have been carried out. As seen in the results of sediment sampling, very fine materials of silt and clay are deposited in the bottom of the channel. Therefore, the sedimentation in Lach Huyen Channel is supposed to be induced by siltation. Siltation is a phenomenon in which the cohesive sediment such as silt and clay is moved up from the seabed by waves and currents, and then flows into the channel bottom. As the cohesive sediment is typically transported as a suspended load, the advection-diffusion sediment transport model is applied to simulate the sedimentation.

ii) Methodology

In this study, mud transport due to waves and currents has been calculated in order to estimate the sedimentation of the channel. Waves, currents, and sediment transport were calculated by using the following numerical models. The outlines of these models are summarized below.

1. Wave transformation model

For numerical analysis of wave transformation, the energy balance equation with addition of the wave diffraction term and the energy dissipation term by breaking is employed.

2. Current model

The numerical model for the current simulation is based on a finite difference numerical representation of the 2D depth-integrated continuity and momentum equations of water motion. Cells are defined on a staggered and rectilinear grid. Momentum equations are solved in a time-stepping manner first, followed by solution of the continuity equation, in which the updated velocities calculated by the momentum equations are applied.

3. Sediment transport and morphology change

Mud transport is usually treated as a suspended load. Its basic equation is the advection-diffusion equation of sediment concentration.

iii) Model setup

1. Computational domain

For numerical simulations of wave, current, and topography change, a computational domain was prepared based on the chart data of Hai Phong and bathymetric survey data around the channel. Two computational domains were prepared. The larger domain consists of 500 m by 500 m cells, while the smaller one consists of 50 m by 50 m cells.

2. Computational conditions

-Water surface elevation

In order to compute for tidal currents, the time series of water surface elevation is needed for the boundary condition. In this study, the water surface elevation for the boundary condition was calculated by the NAO.99b tidal prediction system developed by Matsumoto et al.

-Incident wave

In order to compute for wave transformation, the properties of offshore such as wave height, period, and direction are needed. In this study, the energy averaged wave was used for the representative wave. The dominant wave direction is from east to south, but it seems that the high waves more often prevail from the southeast and south directions. Since Lach Huyen Channel is sheltered by Cat Ba Island against waves from the east direction, the wave from the south direction is considered as the representative wave that affects sedimentation in the channel. The probability of non-exceedance for the energy averaged wave is approximately 70%.

-Sediment property

Most of the sediments around Lach Huyen Channel are of silt and clay. For sedimentation simulation, sediments with 22 μm particle size and 2680 kg/m^3 density are used as the representative sediment. According to the Stokes Formula, the settling velocity of the particle is 0.39 mm/s in 20° of water temperature.

-Sedimentation process

For the present situation of Lach Huyen Channel, sedimentation due to tidal current alone and that due to wave plus tidal current were calculated to examine each of their effects on the sedimentation. Both calculations were conducted for 15 days sedimentation including neap and spring tide. Also, for the case of wave plus tidal current, the energy averaged wave of 0.95 m in height, 5.4 s in period, and south in wave direction was given with the variation of tide level.

iv) Numerical prediction of future sedimentation

In Lach Huyen Channel, channel deepening and widening were planned with the development of new port facilities. In general, channel deepening will induce further sedimentation and affect smooth port operation. According to the feasibility study (FS) report by TEDI, the sand protection dike which is 7,000 m along the channel was proposed to reduce sedimentation. Therefore in this study, numerical simulations of future sedimentation have been carried out to predict the volume of sedimentation, and to examine the reasonable position and length of the sand protection dike.

Table 5.1.3 List of Prediction Cases

Case	Channel depth	Forcing Condition	Realization Duration	Port Facility / Protection Measures
1	7.5 m	Tide alone	15 days	None / None, present situation
		Tide + Wave	15 days	
2	8.0 m	Tide alone	15 days	None / None, the smoothed channel bottom with 8 m depth.
		Tide + Wave	15 days	
3	14.0 m	Tide alone	15 days	None / None
		Tide + Wave	15 days	
4	14.0 m	Tide alone	15 days	Port / None
		Tide + Wave	15 days	
5	14.0 m	Tide alone	15 days	Port / Dike 1
		Tide + Wave	15 days	
6	14.0 m	Tide alone	15 days	Port / Dike 2
		Tide + Wave	15 days	
7	14.0 m	Tide alone	15 days	Port / Dike 3
		Tide + Wave	15 days	
7b	14.0 m	Tide alone	15 days	Port / Dike 3 with the crown height of + 2.0 m CD
		Tide + Wave	15 days	

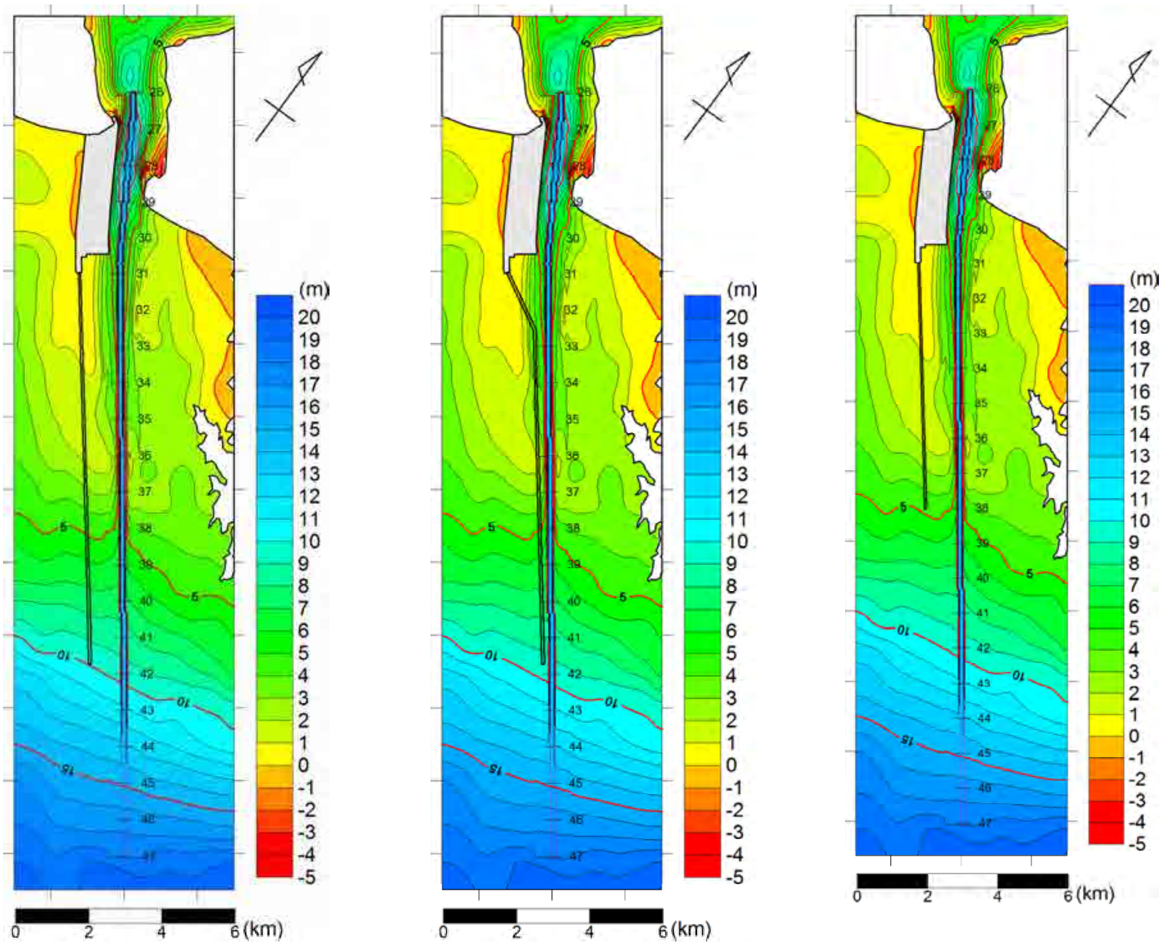


Figure 5.1.3 Positions of the Sand Protection Dike

v) Simulation results

Case 7b is the case in which the crown height of the dike is set as same with the mean water level (MWL) (=+2.0 m, CD) and allows wave, current, and sediment transport to pass over the dike when the water level is higher than the MWL. Comparing sedimentation volume between Cases 7 and 7b, the volume of Case 7b is slightly larger than that of Case 7.

Table 5.1.4 Summary of Sedimentation

Case	Description	First Year (m^3/y)	After Second Year (m^3/y)
1 and 2	Approximately 8 m in depth as of the present situation	1,200,000*	260,000
3	14 m without any structures	6,873,000	1,491,000
4	14 m with port facilities	6,712,000	1,456,000
5	14 m with port and dike of 10,000 m, 1.5 km apart from the channel	1,678,000	364,000
6	14 m with port and dike of 11,000 m, close to the channel	1,107,000	240,000
7	14 m with port and dike of 7,000 m	2,829,000	614,000
7b	14 m with port and dike of 7,000 m (hc = +2 m, CD)	3,442,000	747,000

* Estimated by analyzing bathymetric survey data.

c) Comments

- There is no clear justification for the sedimentation volume after the second year, which is 21.7% of its first year.
- According to Figure 5.1.8, the actual sedimentation volume of the second year was assessed at 0.5 million m3 instead of 0.26 million m^3.
- Even though there is a larger grain size for about a 2-km belt along the channel, the representative grain size is still applied at 22 μm.
- Comparing Cases 7b and 4, the effectiveness of the sand dike can be said to have about 50% decrease of sedimentation along the channel. It shall be assessed whether investment on the sand dike is economically viable.

5.1.3 Post-Deepening Bathymetric Surveys Analysis

Numerical models in the Hai Phong Phase 2 project study are only as good as data that is used to run the model, and these data are insufficient. In most cases, there tend to be a lack of good quality data relating to the processes of sedimentation, whereas at this site, it is only bathymetry which has been routinely measured. The data sets obtained provide an excellent record of the response of the channel since its deepening in 2005.

Capital dredging of the main sea reach area was undertaken in the first half of 2005 with a ten day campaign at the end of January, followed by a more concerted campaign from the end of February to the start of May (this information was derived from the offshore disposal logs). There was also a short period of dredging along a short section of the outer bar at the end of 2004.

Capital volumes removed from Lach Huyen area were quoted as being 4.85 million m^3, although this figure was based on the most complete post-dredge survey of October 2005 (some five months after the end of the dredging period and following the wet season). There is evidence to show that the bed levels rose significantly in some parts of the channel during this period.

In late September 2005, a large typhoon hit Hai Phong Bay only months after the completion of the capital dredging. There was also a partial survey just before this typhoon event (and after the main wet season), and another partial survey in October 2005 which was after the typhoon (Figure 5.1.13).

Figure 5.1.4 shows the bed level in the center of the channel as a function of distance (landward) from the offshore P0 buoy. Some points to note from this data set are as follows:

(1) Those areas over the bar (Km. 35+000-38+000) experienced very rapid infill after the initial dredge;

(2) There is some indication that the infill rate over the bar area has slowed as the bed level has risen;

(3) In the northern part of the channel, near Km. 30+000, bed levels have deepened/eroded, suggesting a degree of increased flow/velocity through the channel;

(4) Bed levels around Km. 30+000 have deepened since dredging, and at around 31+000 to 32+000, they have remained to be near stable;

(5) Over the bar area (Km. 35+000-38+000), the most rapid infill occurred in the period just after dredging;

(6) In the outer area (Km. 39+000-41+000), the infill rate has been more steady to almost constant;

(7) The seabed peak has existed near Km. 36+000 after the sand bar before the initial dredging. However after dredging, this seabed peak moves toward the offshore for about 2 km. This is evidence that after dredging, flow velocity increases, and at Km. 43+000 the bed level has remained stable.

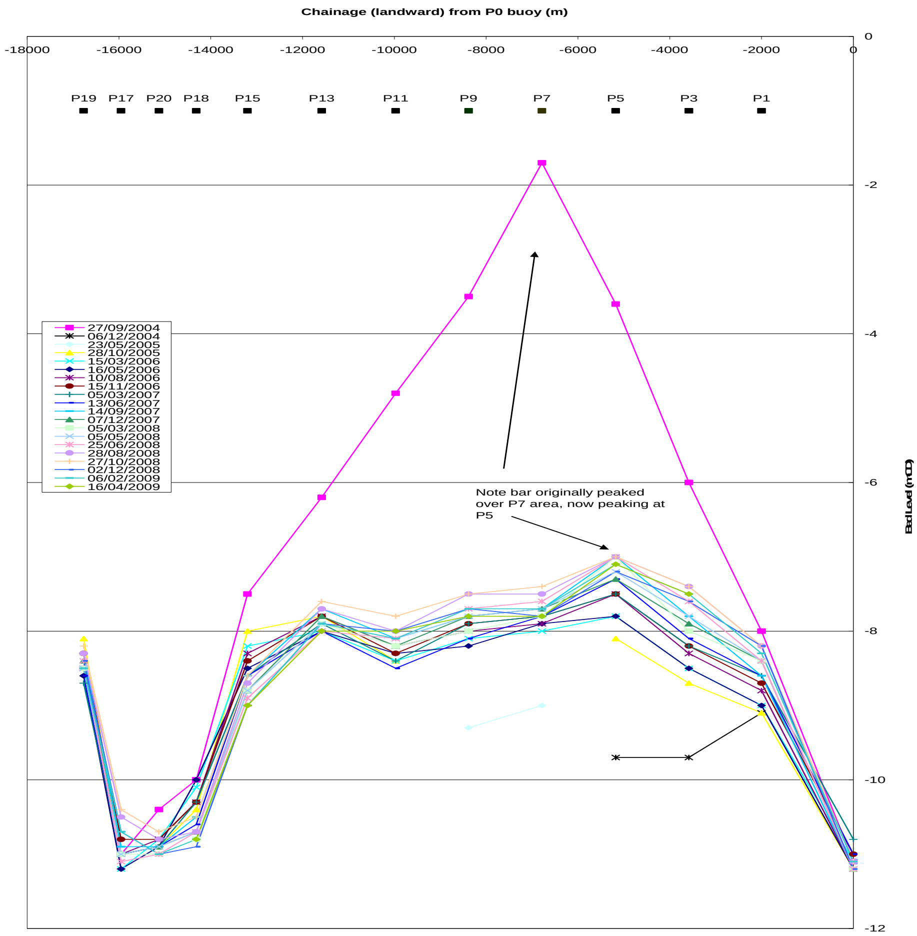


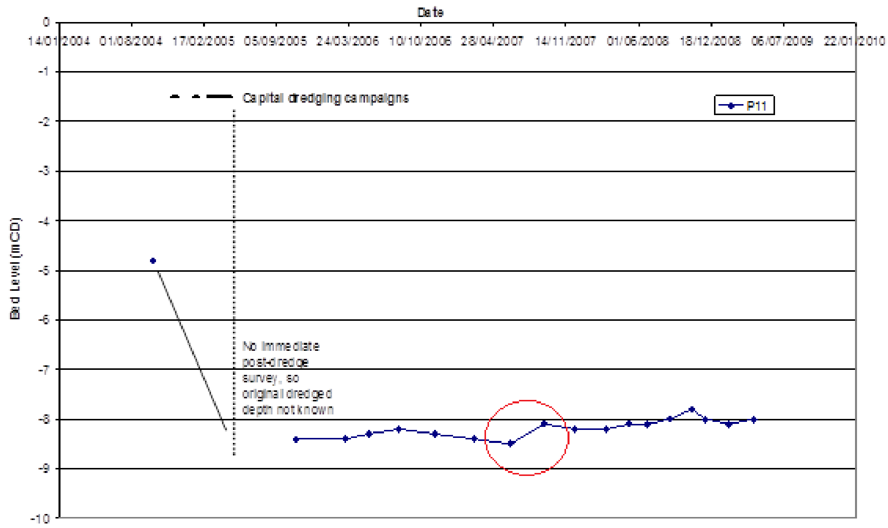
Figure 5.1.4 Accumulated Sedimentation Volumes by Each Survey

(8) There are some evidences to suggest that the greatest infill occurs during the course of the wet season (from June to September). Figure 5.1.5 showing the channel near Km. 33+000, gives the clearest response with apparent shoaling of the channel during the wet season. A similar though weaker seasonal signal is seen at locations Km. 38+000 and Km. 39+000. Using wave data observed in Hon Dao Station, the wave energy ratio was computed, as shown in Table 5.1.5. Its ratio is 60:40.

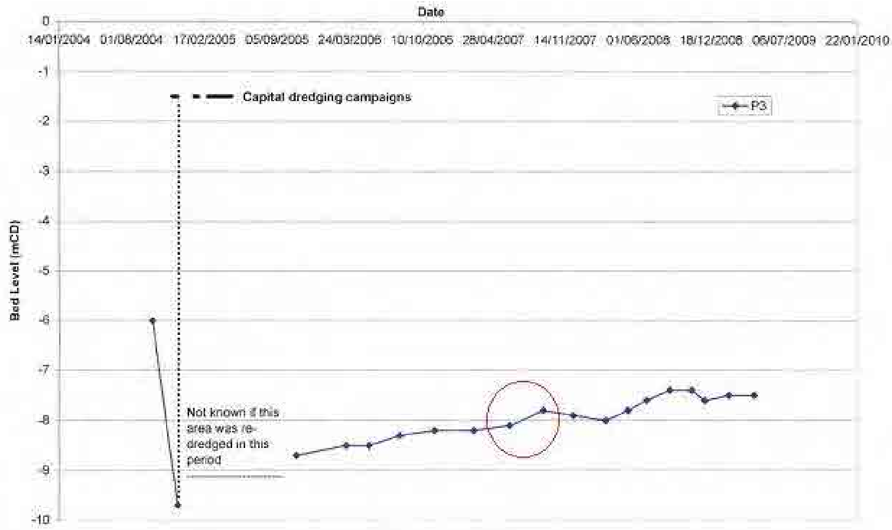
Table 5.1.5 Wave Energy Ratio of Seasons

Seasons	2006	2007	2008	Average
Wet (June-October)	58	60	70	63
Dry (November-May)	42	40	30	37

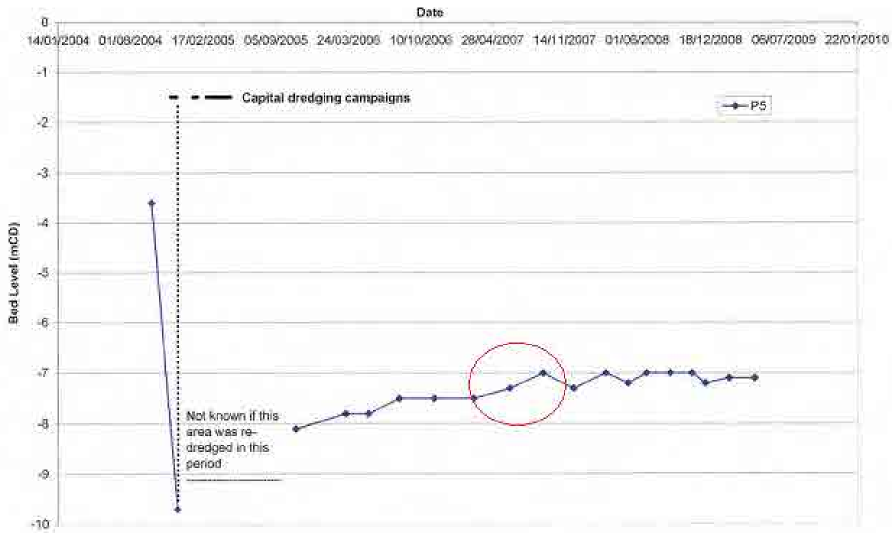
(9) By interpolating cross-sectional information along the channel, the volume of infill was calculated, as shown in Figure 5.1.6, in terms of the total volume of infill relative to the bed levels as measured during post-dredging (assumed in October 2005). This indicates that in six months there was over 1.0 million m^3 of infill in the channel. Just over the bar, the area between Km. 36+000 and Km. 38+000 has high sedimentation. This is evidence that the existing bar has a training wall to induce high velocity, but after the bar, sedimentation is induced due to the decrease in flow velocity. This fact shall be incorporated into a training wall alignment.



Km. 33+000



Km. 39+500



Km. 38+000

Figure 5.1.5 Time History of Bed Levels in the Channel Center

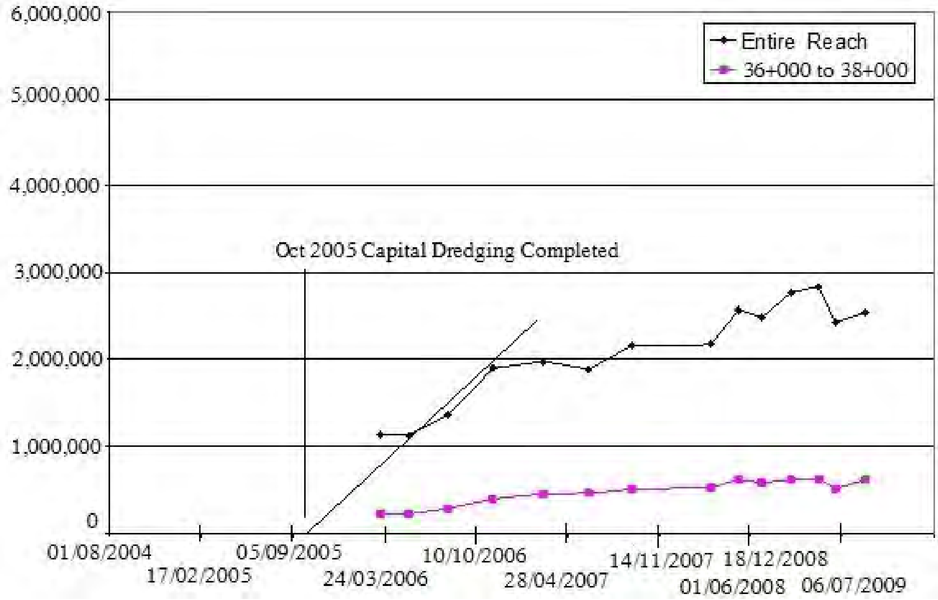


Figure 5.1.6 Channel Infill Volume Calculations based on Cross-sections

5.1.4 Overview of Sedimentation in the Location

Figure 5.1.7 shows sedimentation volume in the intervals of maintenance of the bathymetric survey. Obviously from the point near the end of sandpit to the sea reach an enormous sedimentation occurred. And the sediment volume in the survey intervals is summarized in Table 5.1.6.

Table 5.1.6 Sediment Volume of Each Survey

	From 1 October 2005 to 15 March 2006 (6 months)	From 15 March to 19 May 2006 (2 months)	From 19 May to 17 August 2006 (3 months)	From 17 August to 16 November 2006 (3 months)
a. Entire Reach Sediment Volume	952,350	1,111,450	1,668,075	2,204,700
b. Volume from Km. 33+500 to Sea	912,853	991,603	1,266,603	1,663,978
c. Increased Volume in Survey Intervals	912,853	159,100	556,625	536,625
% (b) of (a)	96	89	76	75

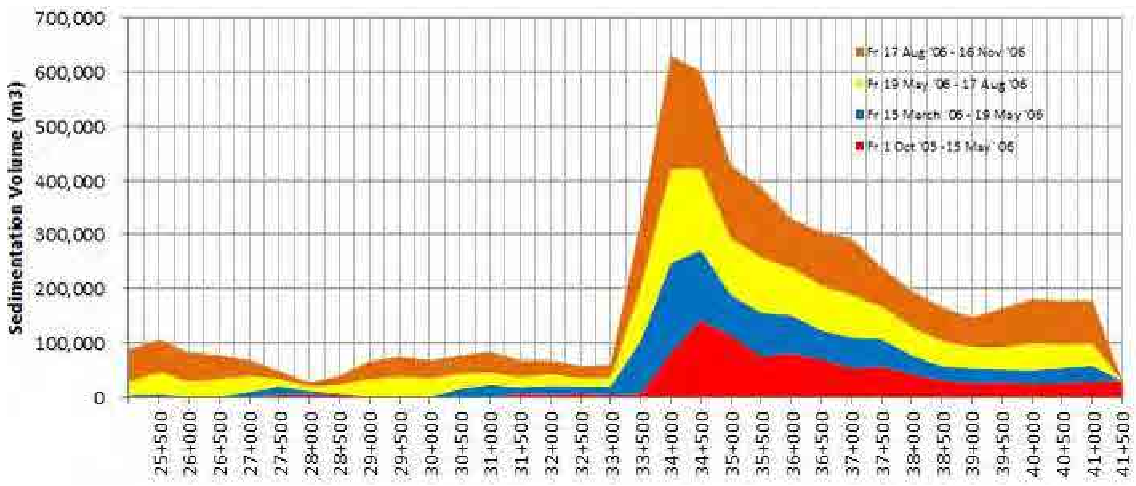


Figure 5.1.7 Accumulated Sediment Volume in Each Survey

5.1.5 Sedimentation Speed in Deepened Initial Dredging Area

During the initial dredging works, some area had been dredged rather than the designed level by 1.0 to 1.5 m. They are located between Km. 34+500~36+800 (inner area) and Km. 39+500~41+00 (outer area). The time series changing are shown in Figure 5.1.8 and Figure 5.1.9.

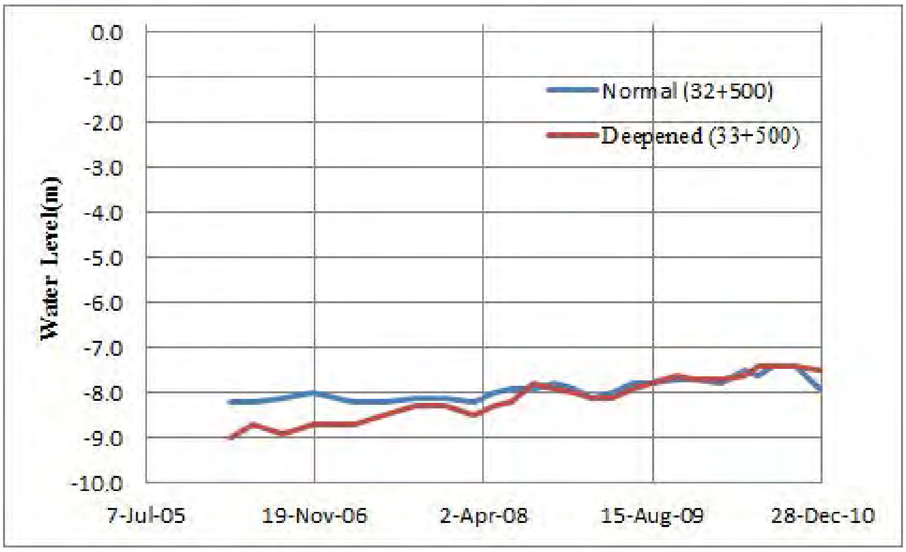


Figure 5.1.8 Sedimentation Speed in Deepening Initial Dredging Area

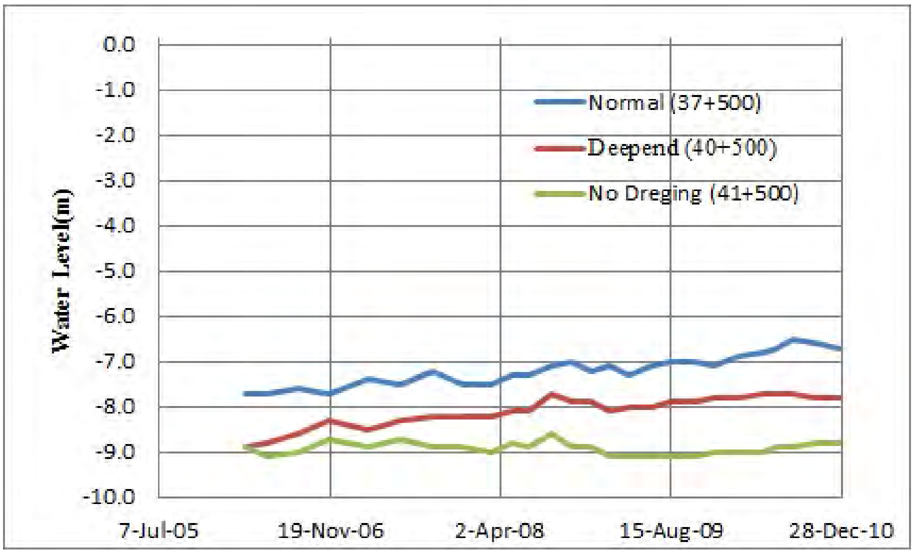


Figure 5.1.9 Sedimentation Speed in Deepening Initial Dredging Area

In the area of Km. 34+500~36+800, the sedimentation speed is at 1.0 m for every two years. On the other hand, there is no such evidence that any radical rapid infill occurred in outer area of Km. 39+500~41+00. Based on Figure 5.1.10 that the sedimentation speed in terms of depth is shown, the sedimentation speed is roughly presumed in Table 5.1.7. Deepened areas were rapidly filled by sediments to about 50%.

Table 5.1.7 Comparison of Sedimentation Speed (Unit: m)

Location	Sedimentation Speed		
	Per day	Per month	Per six months
Deepened	0.0009~0.0005	0.027~0.015	0.162~0.09
Normal	0.0006~0.0004	0.018~0.012	0.108~0.072

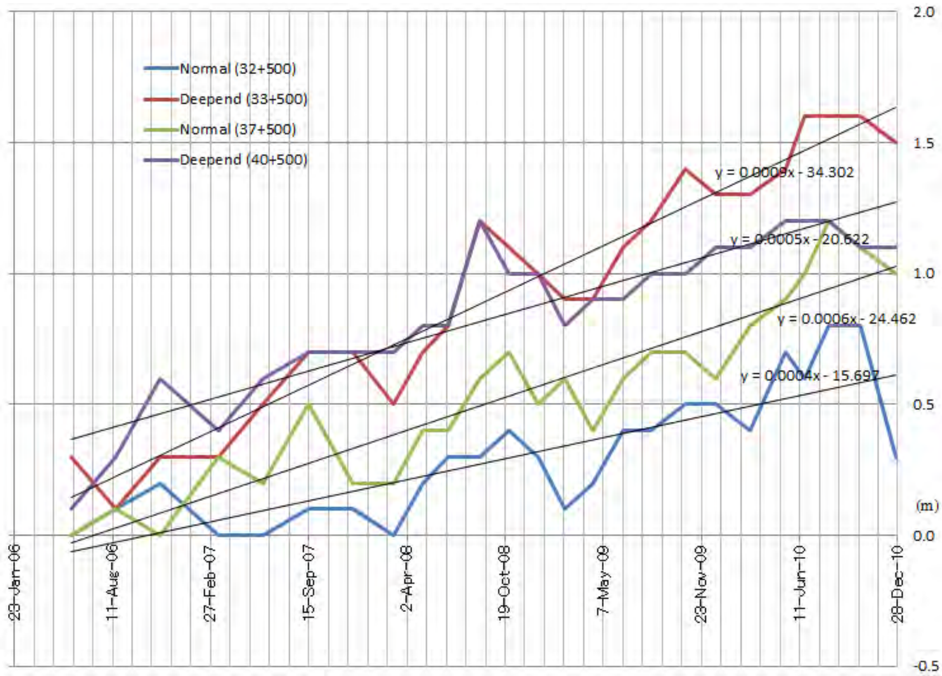


Figure 5.1.10 Sedimentation Speed in Terms of Water Depth

5.1.6 Comparison of Infill among Channel Bottoms

Two sections are selected for the investigation of infill conditions in the center channel, and the left (Cat Ba side) and right (Cat Hai side) sides of the channel. These are shown in Figure 5.1.11 and Figure 5.1.12.

From these graphs, basically the infill speed of both sides of the channel has similar conditions. As also seen in the graph, the center is rather deeper compared to the sides. This might be due to the sweeping effect of passing vessels. There is no evidence that flow sedimentation from the Cat Hai side is larger during the wet seasons.

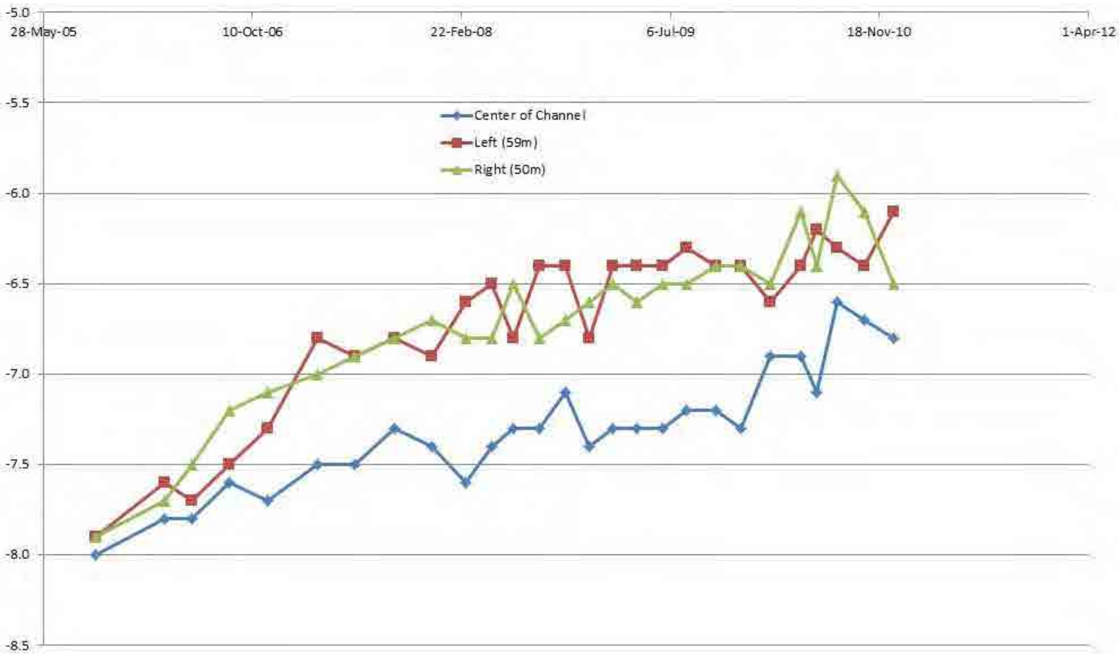


Figure 5.1.11 Changing Infill of Section Km. 37+000

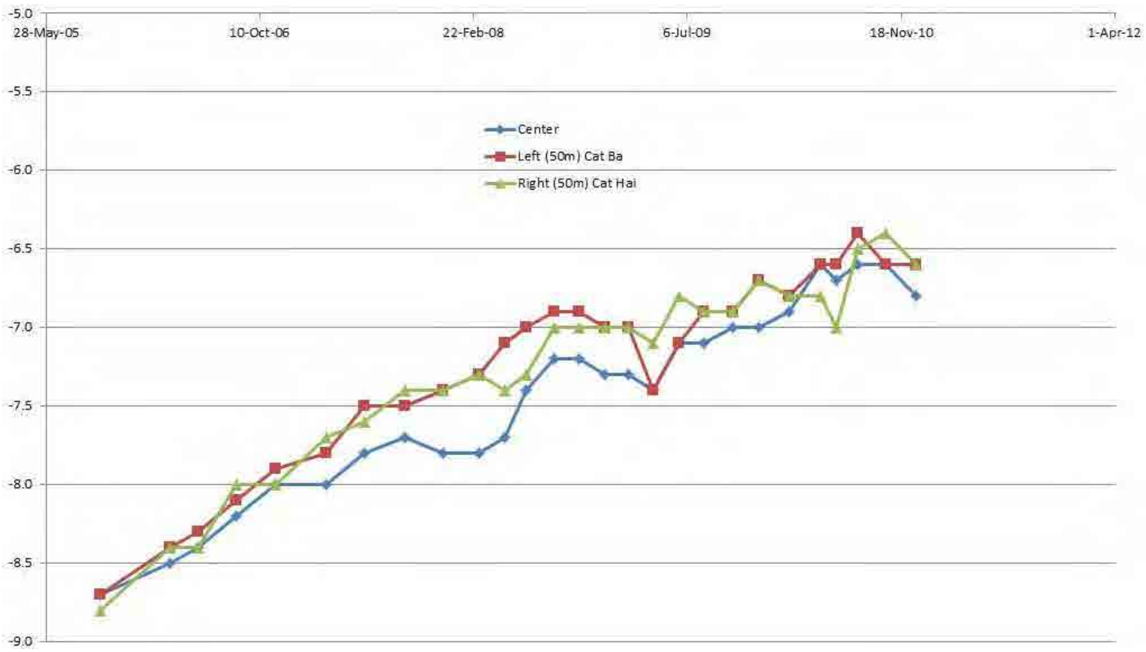


Figure 5.1.12 Changing Infill of Section Km. 39+000

5.1.7 Slope Failure of Channel

Slope failure at the top and slopes of the channel was calculated, as shown in Table 5.1.8. Its volume is quite negligible. The applied slope of 1:15 deems to be adequate in the inner reach. There is also no evidence that the sea reach slope collapses greater.

Table 5.1.8 Annual Slope Collapse Volume of Lach Huyen Channel

Lach Huyen	Oct. 2005 ~ Mar. 2006	Mar. 2006 ~ Feb. 2007	Mar. 2007 ~ Feb. 2008	Mar. 2008 ~ Feb. 2009	Mar. 2009 ~ Feb. 2010	**Total**
Left (Cat Ba Side)	32,405	80,508	133,730	13,625	14,260	**274,528**
Right (Cat Hai Side)	57,968	68,995	94,140	69,758	6,175	**297,035**
Total (m3)	**90,373**	**149,503**	**227,870**	**83,383**	**20,435**	**571,563**

5.1.8 Appraisal of the Risk of Infill under Extreme Events

Extreme infill events are most likely due to typhoon conditions. Even though the site is generally protected from typhoons from the east due to the presence of Cat Ba Island, this does not preclude the risk of severe wave activities in the access channel area.

In the previous modeling study, the sensitivity to the infill rate due to typhoons was addressed. It was concluded that it would not be unreasonable to experience 0.5 m of infill under such brief conditions, and possibly higher for more extreme typhoons. With reference to the above cases, this would equate to 1.0-2.0 million m^3.

From actual experiences of typhoon no. 7 on 27 September 2005, as shown in Figure 5.1.13, the average sedimentation is 0.3-0.4 m.

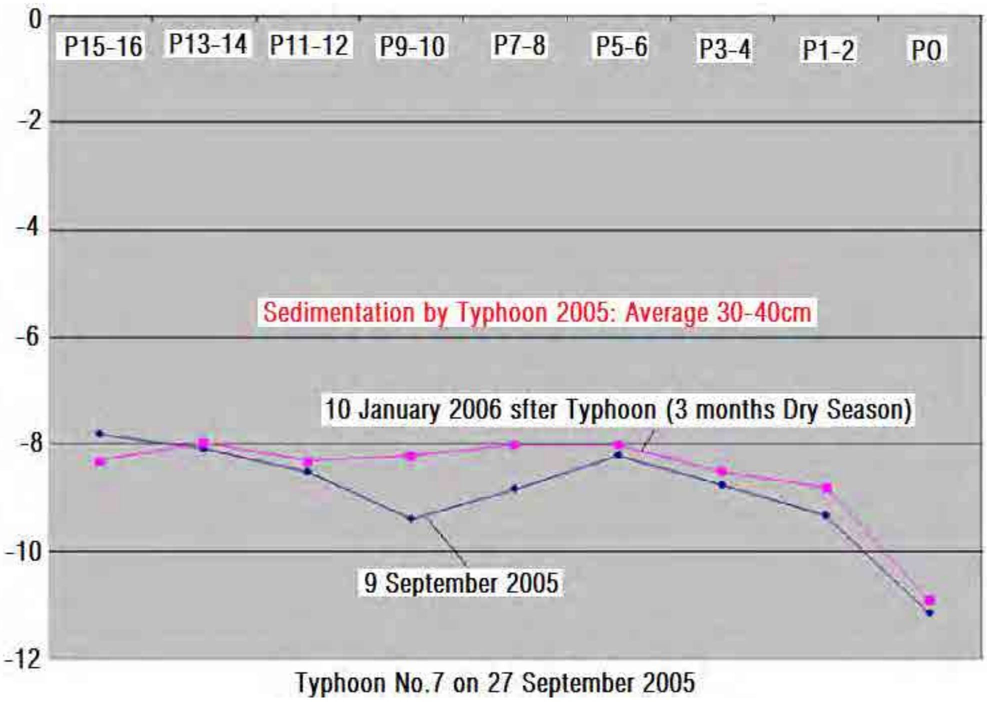


Figure 5.1.13 Infill under Extreme Events

5.1.9 Distribution of Seabed Materials

Sampling of seabed sediment has been carried out on several occasions from the 1990s up to the present so that considerable information exists regarding the seabed composition of Hai Phong Bay.

A compilation of the particle size gratings, in terms of the percentage of silt/clay (<63 microns BS), making up the seabed sediments is given in Figure 5.1.14, in 2000. In the area of Lach Huyen Channel, this distribution shows the condition before the construction of Lach Huyen Channel in order to show the original sand spit shape. Based on seabed sampling carried out in September and November of 2009 of JICA Preparatory Survey Nos. 1 and 2, the distribution map is shown in Figure 5.1.15 and Figure 5.1.16. The distribution maps of water contents are also illustrated in Figure 5.1.17 through Figure 5.1.20.

Hai Phong Bay and the major rivers into it are covered almost exclusively by clay, silt and fine sand deposits. Sediments with particle diameters in excess of 250 microns are a rarity.

The most unique aspect of the sediment distribution is the sandpits that lie on the sides of the channels of Lach Huyen and Nam Trieu. These are particularly prominent on their western sides, leading out from the mainland towards the southeast, which is some 8 km before bending to the east into the path of the channels. In the case of Lach Huyen, the east-trending termination of the spit results in a 2 km wide band of fine sand that stretches as a bar across the channel's axis, probably as far as the coast of Cat Ba Island. The Nam Trieu spit is remarkably similar.

Based on seabed material sampling in the Nam Trieu area just at the river mouth of Cam River, high concentration of mud, <63 microns, is distributed dominantly. Figure 5.1.21 shows the results of sieve analysis in this area. On the other side in Lach Huyen area, the results of sieve analysis are shown in Figure 5.1.22. D50 is about 0.01 mm, which is bigger than that of the Nam Trieu area.

In JICA Preparatory Survey No. 2, the dual frequency bathymetric survey was carried out in November 2009. Figure 5.1.23 shows the reflection lines of 30 kHz and 200 kHz. The 200 kHz line reflects the line between seawater and floated mud, while the 30 kHz line reflects the line between sediment mud and the seabed. Then the difference between the 200 and 30 kHz lines lies between floated and sediment mud. The thickness is 20 cm in average and 40 cm in the thicker area, which is located after the sand spit (Km. 36+500~38+500).

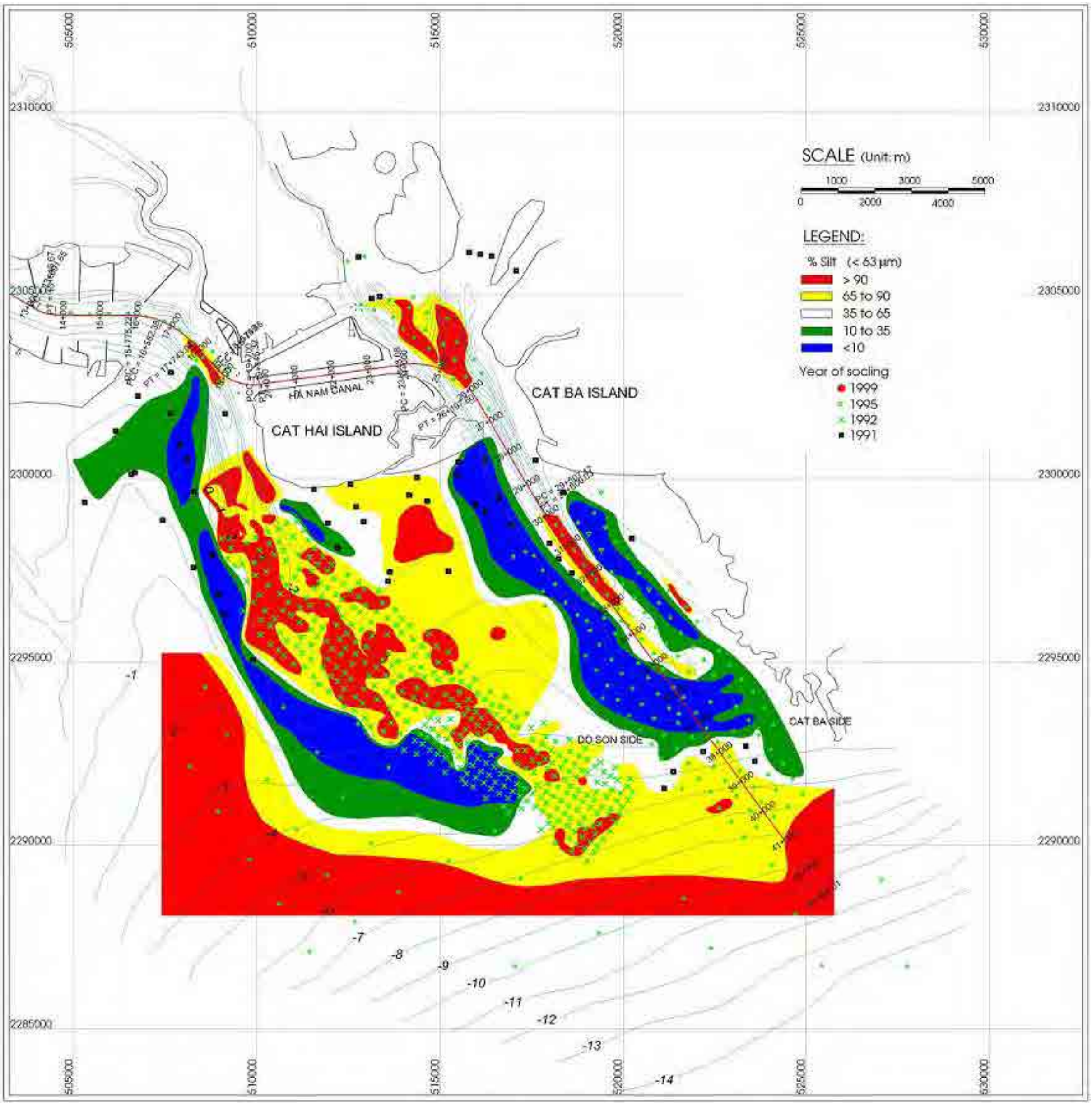


Figure 5.1.14 Distribution of Seabed Sedimentation in the Hai Phong 2 Project

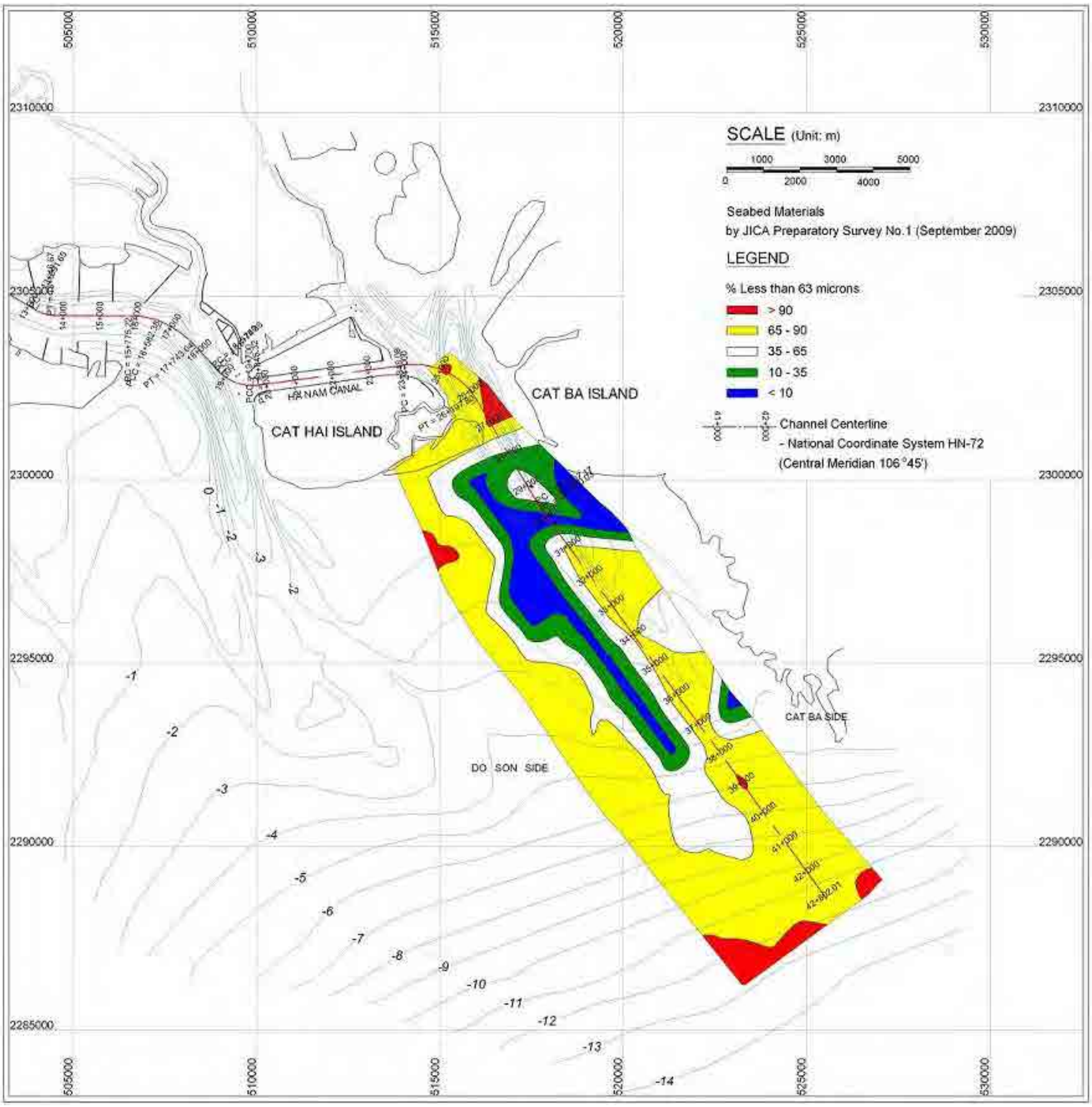


Figure 5.1.15 Distribution of Seabed Sedimentation by JICA Preparatory Survey No. 1

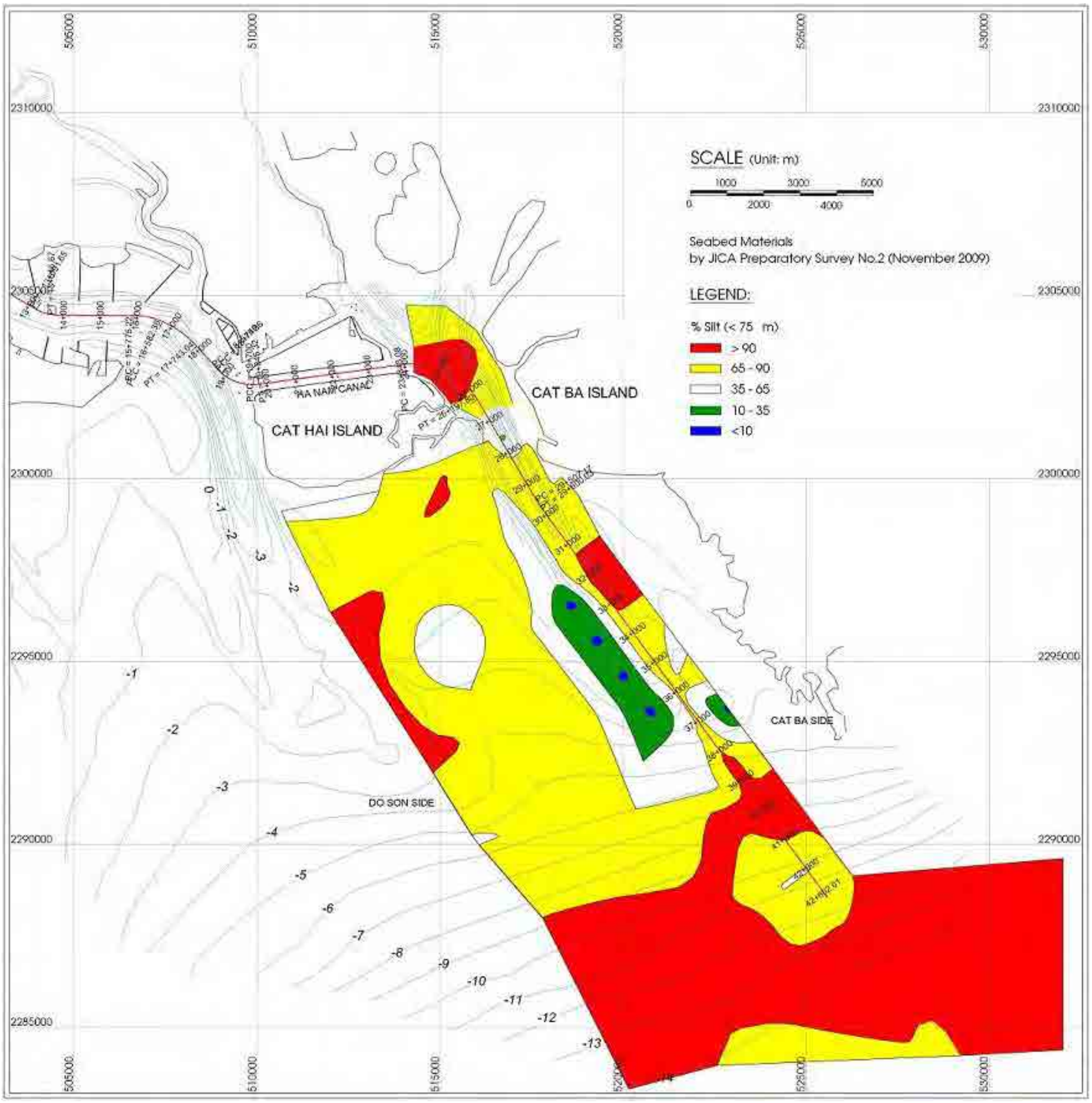


Figure 5.1.16 Distribution of Seabed Sedimentation by JICA Preparatory Survey No. 2

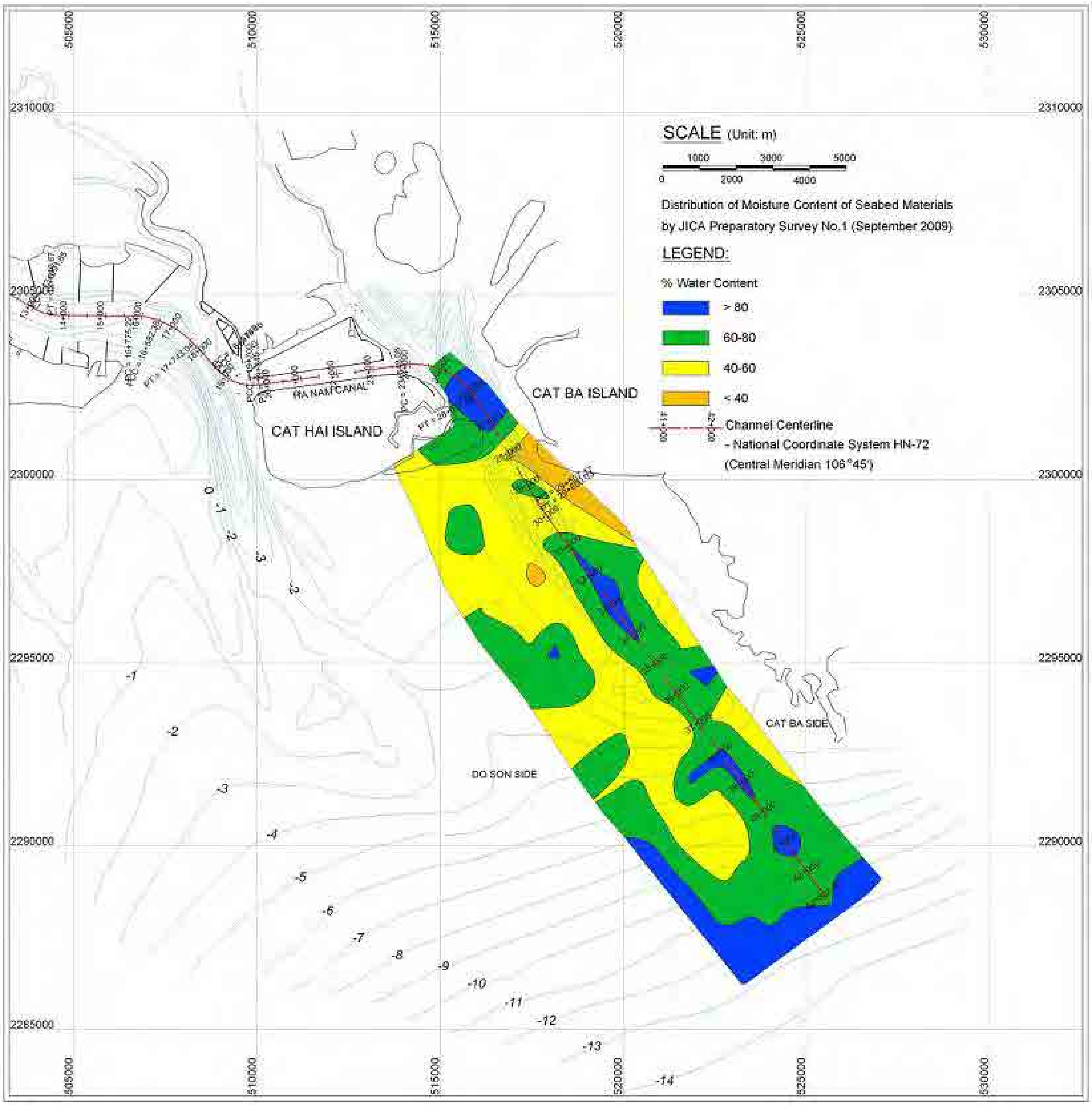


Figure 5.1.17 Distribution of Water Content Ratio of Seabed Sedimentation by JICA Preparatory Survey No. 1

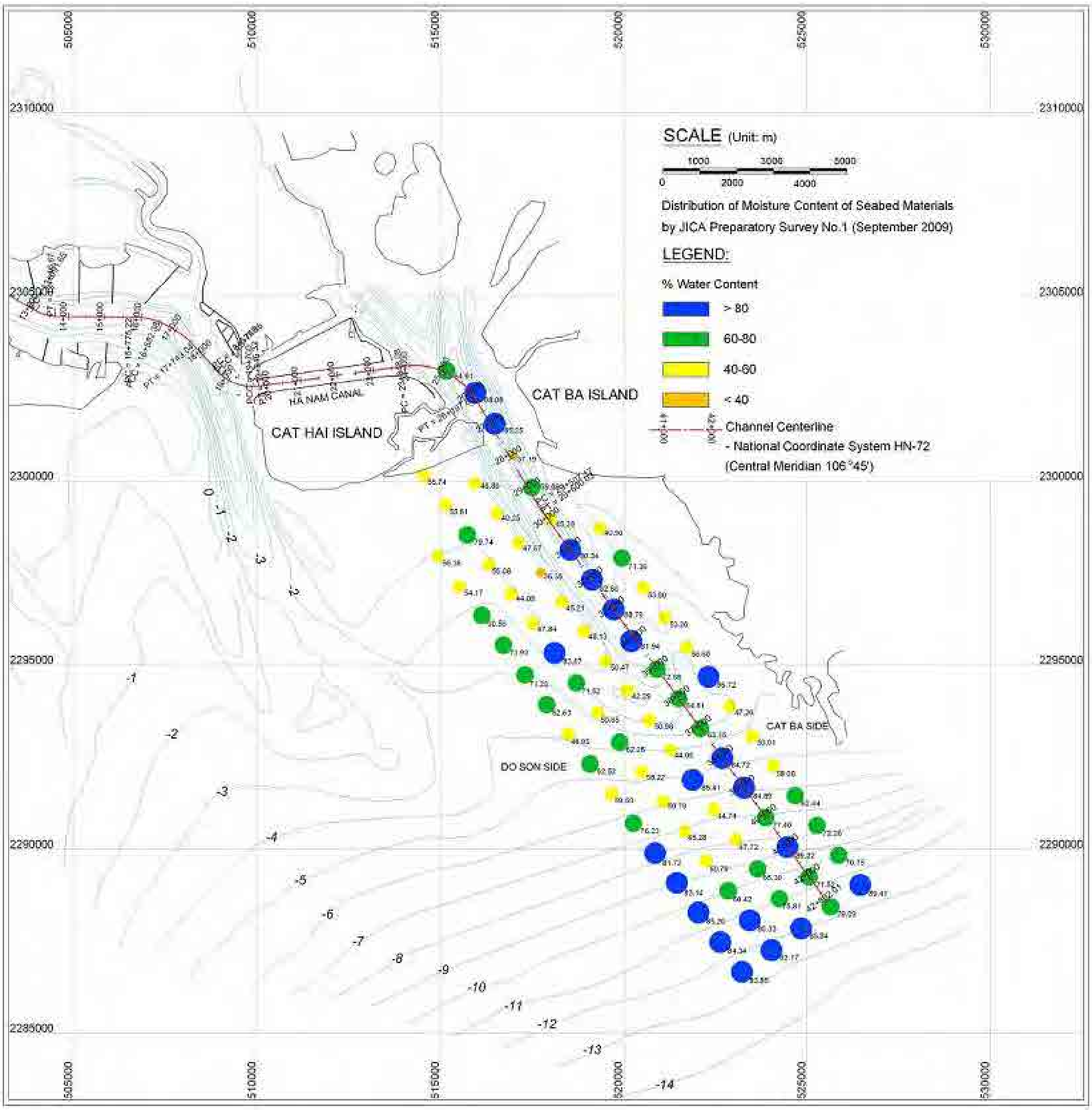


Figure 5.1.18 Distribution of Water Content Ratio of Seabed Sedimentation by JICA Preparatory Survey No. 1

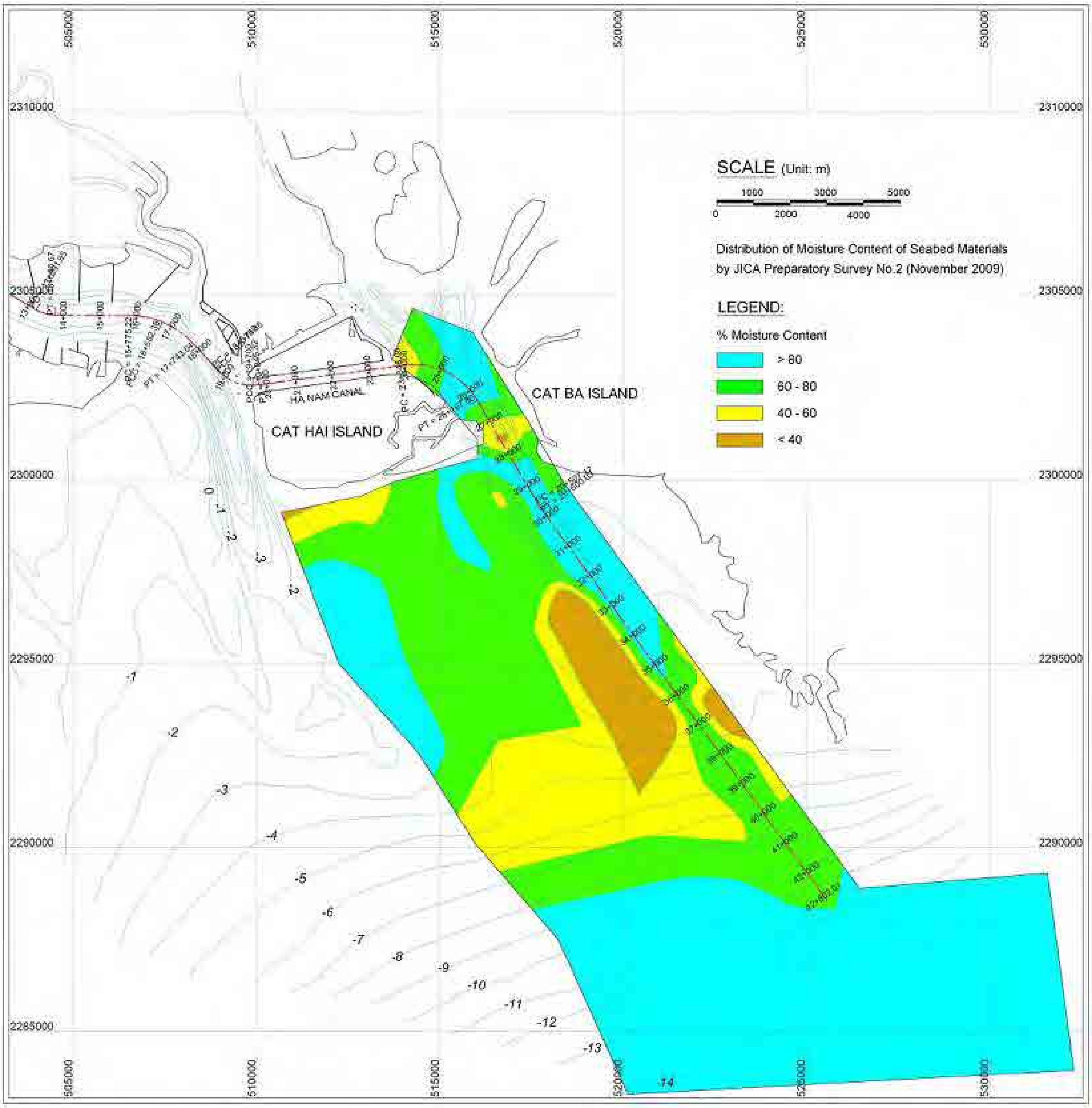


Figure 5.1.19 Distribution of Water Content Ratio of Seabed Sedimentation by JICA Preparatory Survey No. 2

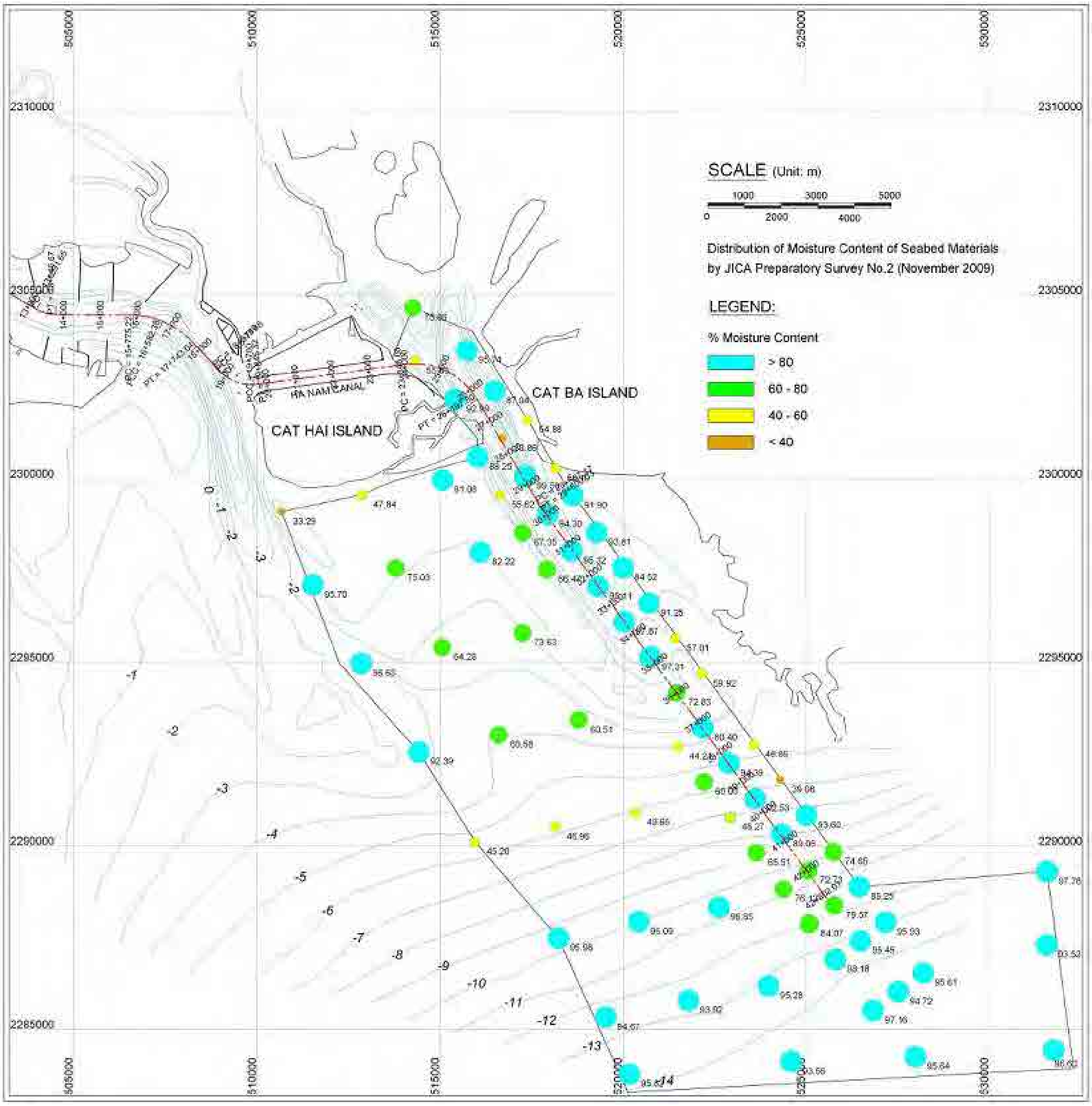


Figure 5.1.20 Distribution of Water Content Ratio of Seabed Sedimentation by JICA Preparatory Survey No. 2

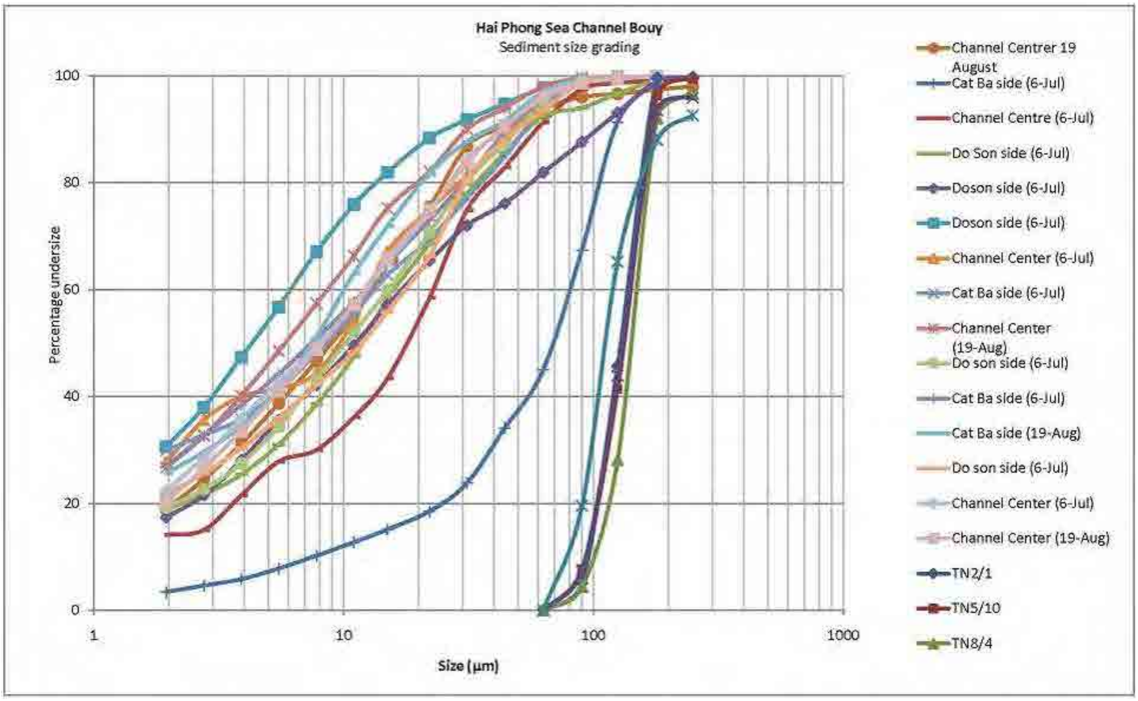


Figure 5.1.21 Sieve Analysis of Seabed Sampling in Nam Trieu

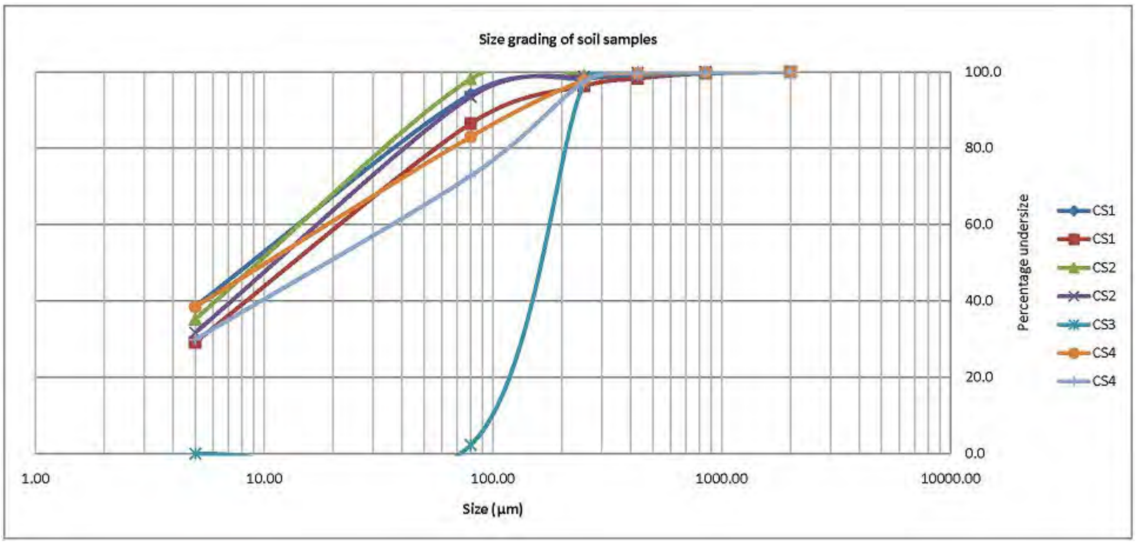


Figure 5.1.22 Sieve Analysis of Seabed Sampling in Lach Huyen

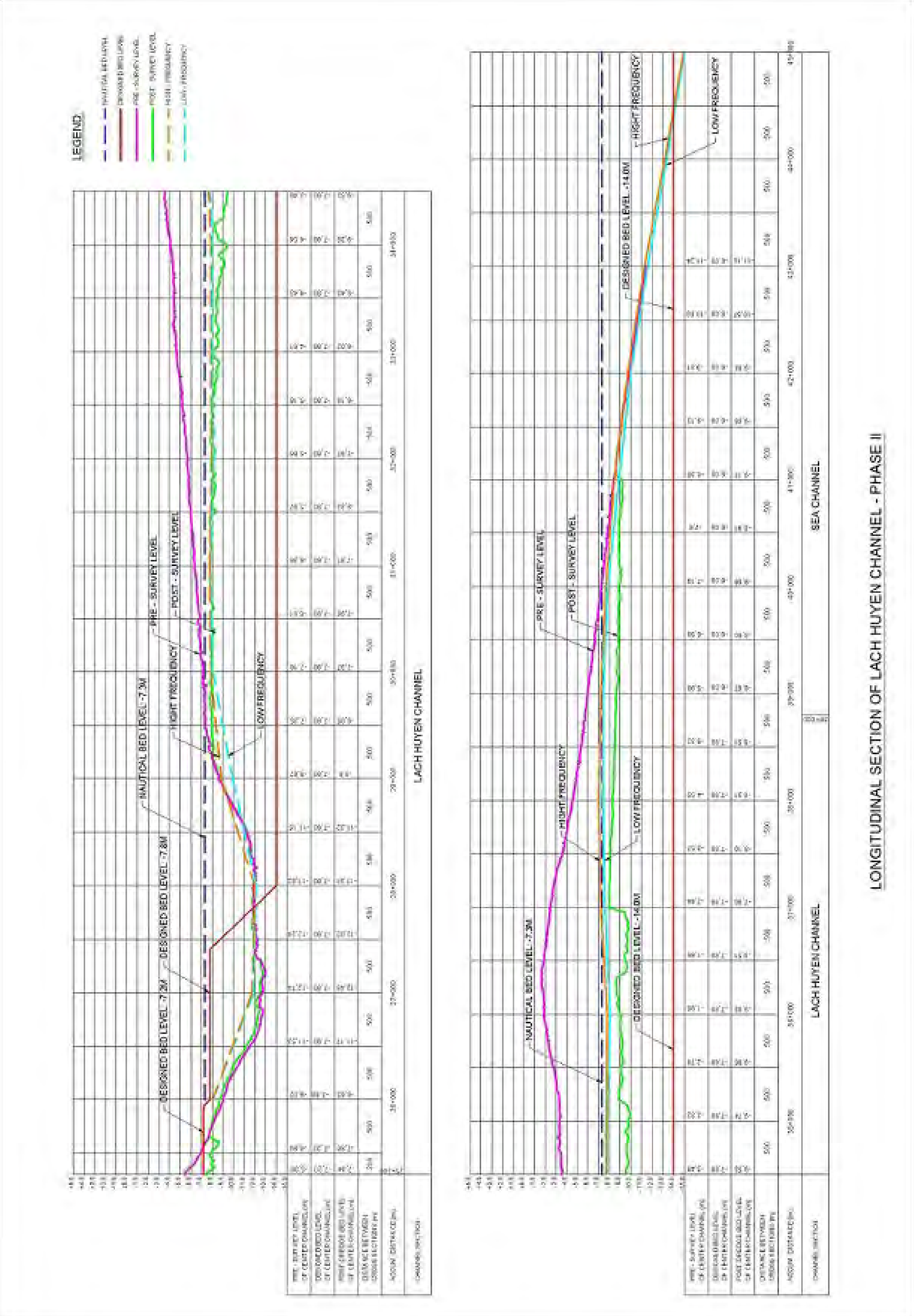


Figure 5.1.23 Dual Frequency Bathymetric Survey in Lach Huyen Area

5.1.10 Seabed Configuration

In Figure 5.1.24 and Figure 5.1.25, the seabed configuration of Hai Phong Bay is illustrated. It is noticeable that from Ben Got to about Km. 37+500, the sandpit is extended and its elevation is higher than of the west area. The seabed gradient is rather small in which until -10.0 m the gradient is 1/1,500 and from -10.0 m it is 1/600. There is possibility that this offshore gradient might be a barrier such that the sediment with high concentration of mud stays offshore. However, in case the channel depth is deepened to -14.0m, this sediment with high concentration of mud would penetrate into the channel. These things shall be incorporated into the numerical sedimentation simulation.

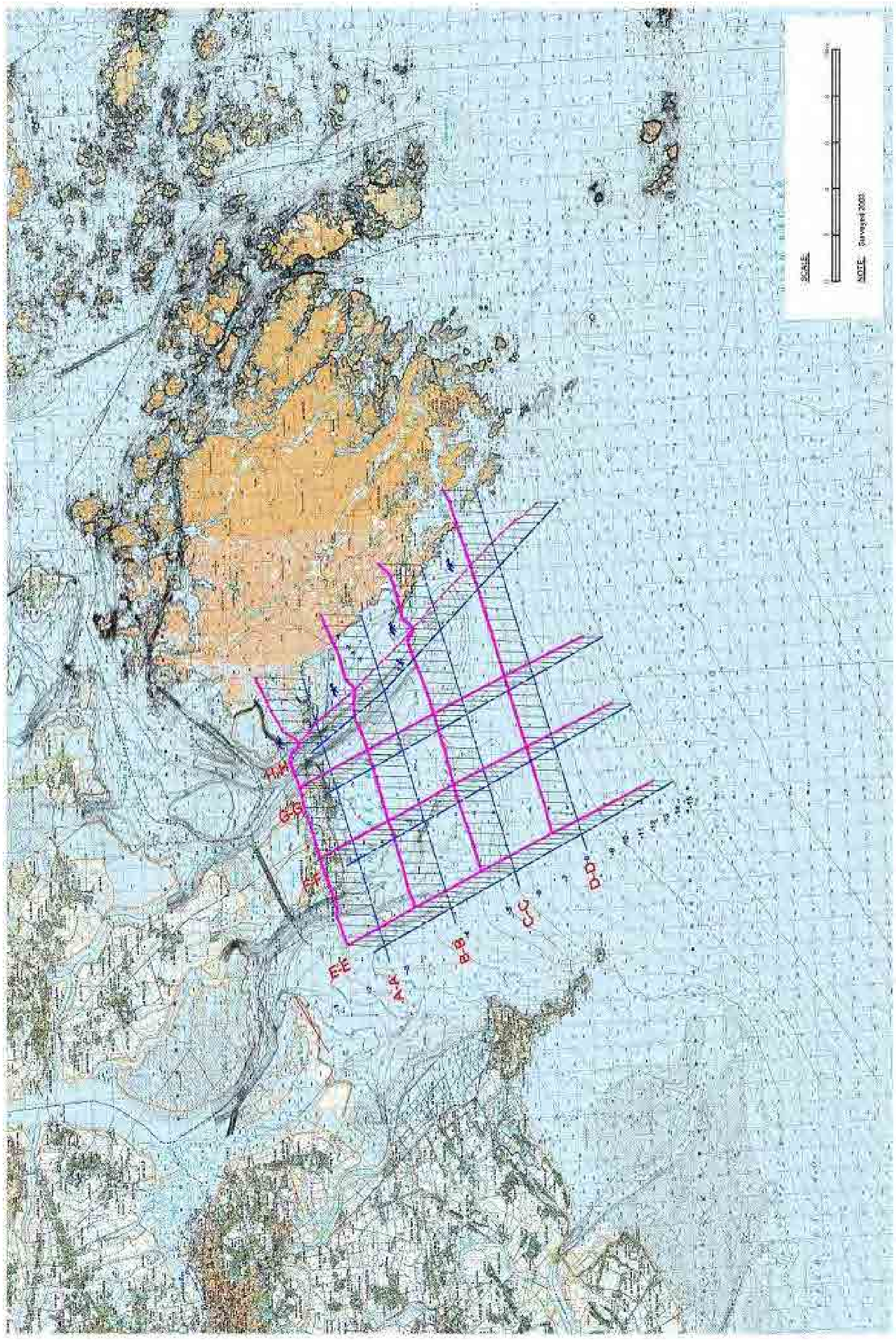


Figure 5.1.24 Sea Chart and Seabed Cross Sections

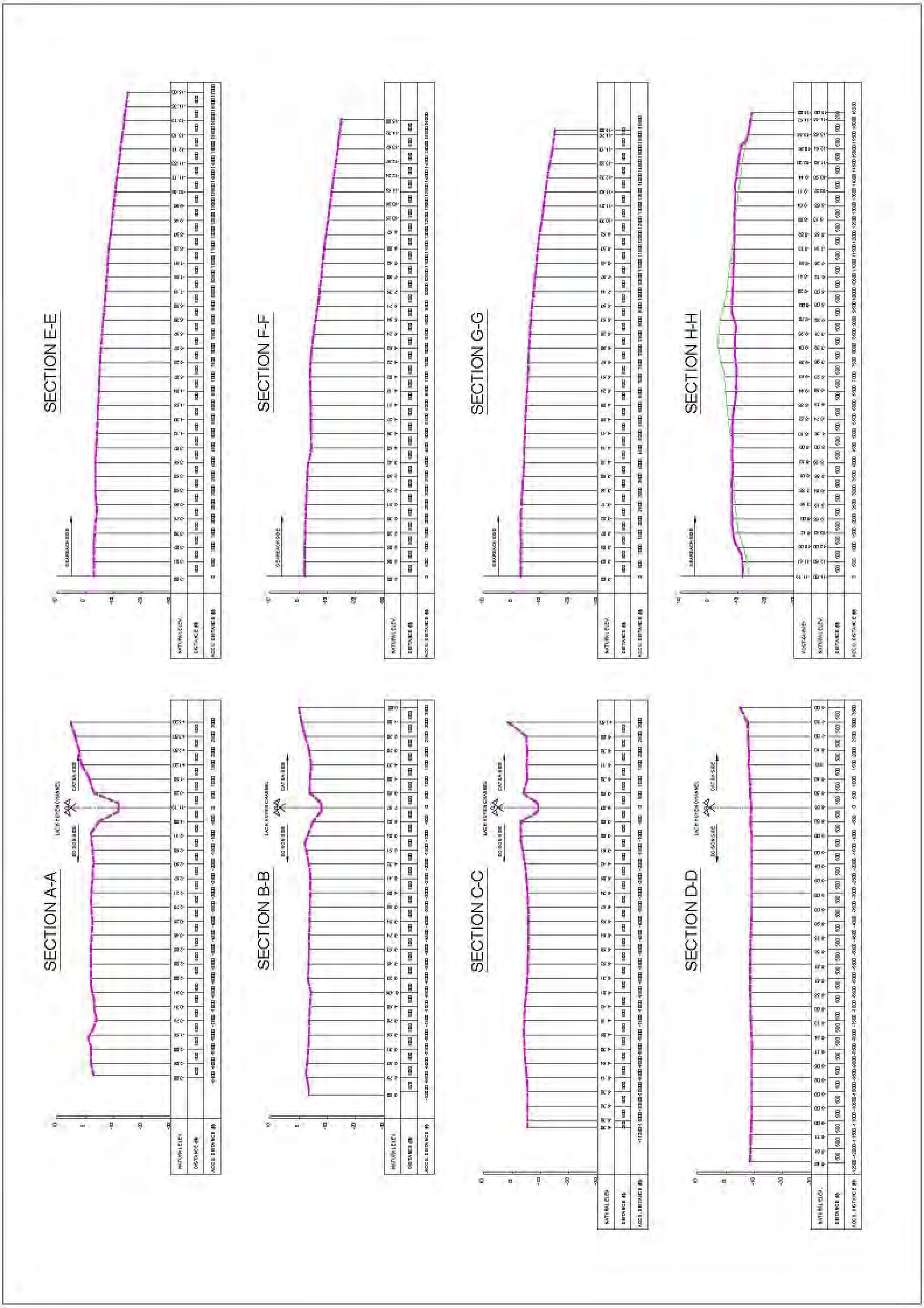


Figure 5.1.25 Sea Chart and Seabed Cross Sections

5.1.11 Water Level of Red River

In Figure 5.1.26 and Figure 5.1.27, the changing water level of Red River, which is observed at four gauge stations, that is the upper stream of Cam River is shown. The water level has drastically lowered from 2000 to the present at about 1.0 m. The cause is due to dam constructions in China as well as multipurpose intake constructions in Vietnam. However, this phenomenon could not directly affect the sedimentation regime in Hai Phong Bay immediately. In the long-term, it will affect the supply of sedimentation materials.

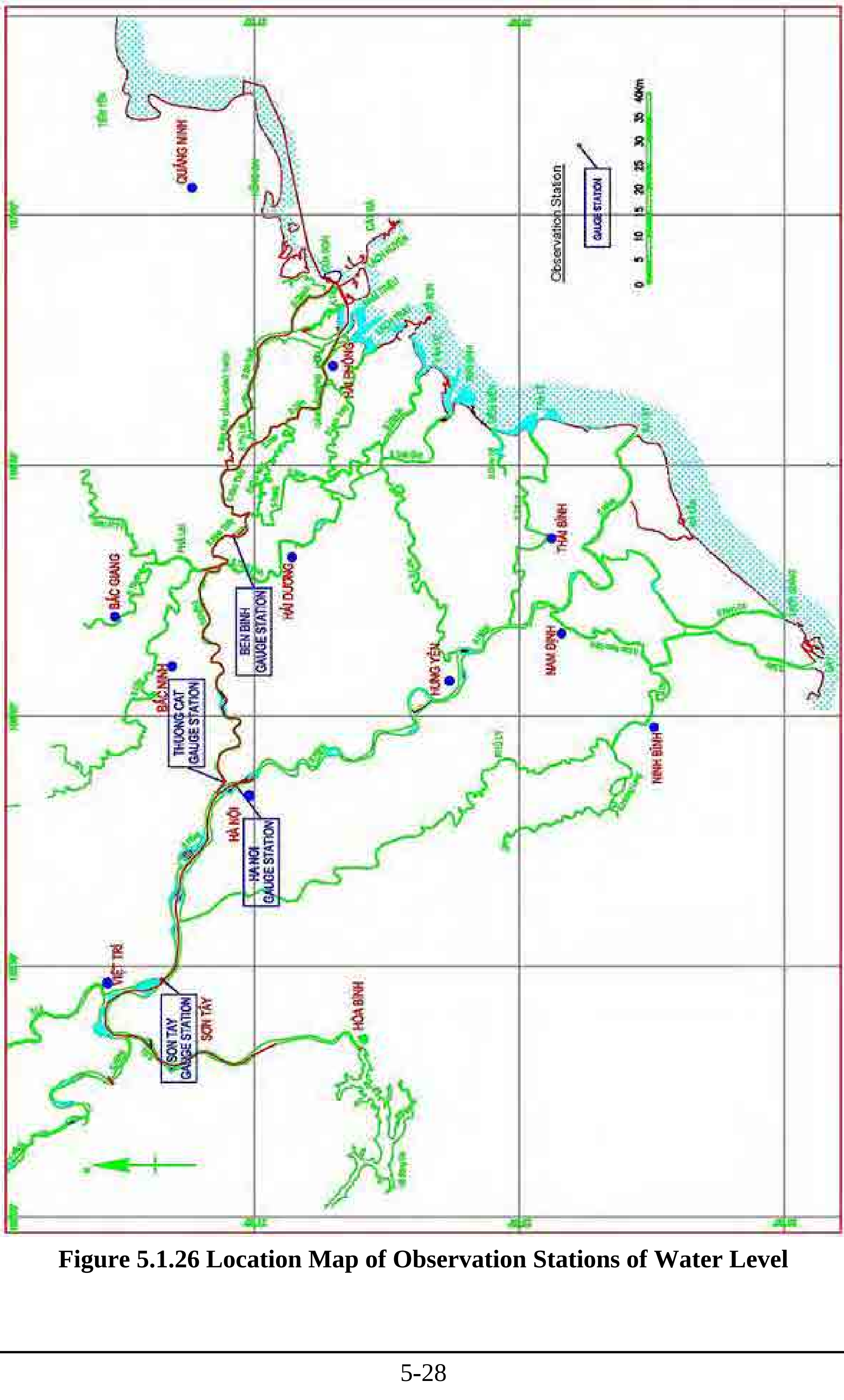
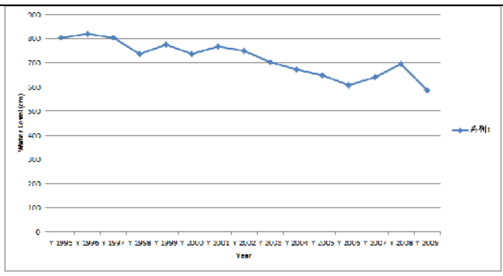
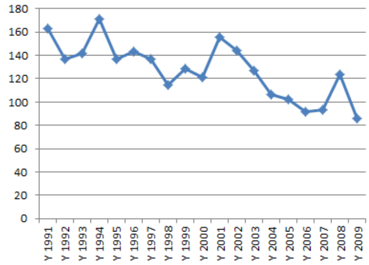
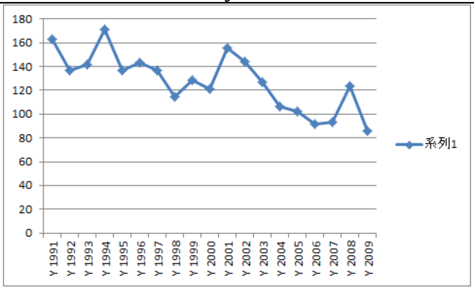


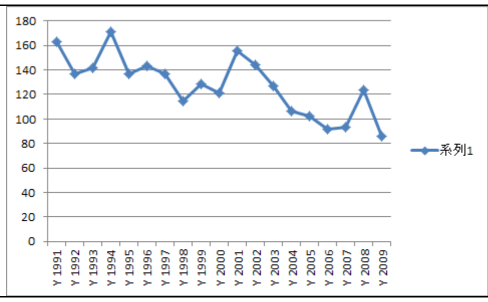
Figure 5.1.26 Location Map of Observation Stations of Water Level





Sin Tay Station	Ha Noi Station





Thuong Cat	Ben Binh

Figure 5.1.27 Historical Change of the Average Water Level per Year

5.1.12 Estimate of Channel Infill

This is only trial estimation with the following assumptions:

<u>Case 1</u>

- Channel configuration
  Depth of -13 m CD, width of 160 m, and side slopes of 1:15
- Average length of side slope is 165 m
- Applying infill rate at depend to at station Km. 36+500 as 1.0 m in the wet season

The channel extends to approximately 44.5 km chainage from the main port. Assuming infill occurs from the 30 km chainage point seaward at a rate of 1 m every six months (during the wet season), which is likely to be the time of the most rapid infill, a channel base width of 160 m gives the infill of the order of 2.36 million m^3 over the wet season [= 14,500 x (160 + 165) x 0.5]. It was considered prudent at this stage to assume an additional 40% of the above wet season infill estimate occurring during the remainder of the year, representing another 0.94 million m^3 of infill. Based on this, the total (annual) volume of dredging was estimated to be 3.30 million m^3.

<u>Case 2</u>

- Channel configuration
  Depth of -14 m CD, width of 160 m, and side slopes of 1:15
- Average length of side slope is 180 m
- Applying infill rate at depend to at station Km. 36+500 as 1.5 m in the wet season

The channel extends to approximately 45.2 km chainage from the main port. Assuming infill occurs from the 30 km chainage point seaward at a rate of 1.5 m every six months (during the wet season), which is likely to be the time of the most rapid infill, a channel base width of 160 m gives the infill of the order of 3.88 million m^3 over the wet season [= 15,200 x (160 + 180) x 0.75]. It was considered prudent at this stage to assume an additional 40% of the above wet season infill estimate occurring during the remainder of the year, representing another 1.55 million m^3 of infill. Based on this, the total (annual) volume of dredging was estimated to be 5.42 million m^3. In the case of a deeper channel, its outer part is protruded towards the seabed of fluid mud. Therefore, the total volume of dredging might be larger.

A training wall will have some effect in preventing infill into the channel. However, in order to be effective in the parts of the channel that were considered most likely to experience rapid infill, the training wall would have to extend a considerable distance towards increasing water depths. The cost-effectiveness of the optimal training wall length would need careful assessment. In the 30 km chainage, the practical extension of the training wall will be up to about -5.0 m depth. In terms of its length in the entire reach of the channel, the training wall effectiveness might be smaller. In consideration with the sedimentation regime shown in Figure 5.1.17, the training wall will be constructed coinciding with the location where high sedimentation occurs. However, the point is that there would be high possibility that the location where there is high sedimentation just moves towards the sea reach in order to mitigate the flow velocity just after the training wall.

5.1.13 Conclusions and Recommendations

Conclusions and recommendations arising from this study are as follows:

(1) The infill volume was calculated based on the periodical bathymetric survey at 1.8 million m^3 in the first year.

(2) For the second year, the infill volume is down to a level of 0.5 million m^3.

(3) After the sandpit at around Km. 37+000, sedimentation occurs greater than at other areas due to the training effect of the sandpit. By reducing the flow velocity after the sandpit, sedimentation is encouraged.

(4) From Km. 33+500 to Km. 35+500, over-dredging happened at a depth of about 1-1.5 m and width of 160 m. In this area, sedimentation response is greater than in other areas.

(5) In Lach Huyen's natural depth, there is noticed erosion due to the increasing flow speed induced by the deepening of the channel.

(6) There are seasonal changes in infill between the dry and wet seasons. These changes could be derived by the difference of wave energy generated in the bay.

(7) In terms of the section of the channel, both sides of the channel edge have similar sedimentation character. In areas with larger infill, there are evidences of seeping due to the passing vessels.

(8) By trial estimation of infill volume, this rate equates to 3.3 million m^3 of infill during the wet season for Layout 1 (160 m, -13 m CD) channel, or 5.4 million m^3 for Layout 2 (160 m, -14 m CD) channel. Infill over the dry season was estimated to be 40-50% of these wet season predictions. However, by numerical simulation, this order of infill shall be verified.

(9) It was of concern that because the starting container berth is allocated at the inner part and in a narrow area, it might erode on the channel slope surface and make additional channel sedimentation due to waves induced by ships.

5.1.14 Proposed Numerical Modeling of Channel Sedimentation

In consideration of the previous study and site sedimentation regime, the proposed numerical modeling is presented in Table 5.1.9. It was also proposed in order to simulate an influence of the existing sand spit and wave agitations of seabed, with high concentration of materials in the shallow area in front of and offshore Cat Hai Island. Considering high flow velocity in the channel reach and low velocity near the seabed, the multilayer level model shall be applied in composition with the advection diffusion model; which is now called the composition model. In the study on the effectiveness of the training wall, the flux of high concentration materials shall be analyzed prior to the formulation of study cases.

The TOR of "Hydrodynamic and Sediment Transport Modeling Studies" is in Section 5.1.15.

Table 5.1.9 NUMERICAL MODELING ON CHANNEL SEDIMENTATION OF LACH HUYEN

	JICA Preparatory Study No. 2	JOPCA Discussion	Proposed Modeling for JICA Detailed Design Study
Minimum Mesh	50 m	100 m	50m
External Conditions	Current and (Current +Waves)	Current＋Waves	Current +Waves
Wave Prediction	Energy Equilibrium Equations considering diffraction and attenuation	SWAN(Wind data considered By WRF) ※) Wind waves and wave deformation in shallow area were considered simultaneously.	SWAN or Energy Equilibrium Equations considering diffraction and attenuation
Representative Wave Conditions	Energy average wave (Wave direction: S)	Typhoon : 1 Case (Actual wave profile (10 July - 20 July 2006)	Normal condition: Wave profile(3Wave directions) Typhoon : 1 Case
Current Model	Single layer model	Multilayer model (10 layers)	Composite Multilayer (10 layers)
Tidal Current Prediction Model	NAO.99b	NAO.99b (16 components)	NAO.99b(16 components)
River Flow	Not considered	Not considered	Not considered
Wind Drive Current	Not considered	Not considered	Not considered
Seabed Material Conditions	Clay/Silt :1grain size	Clay/Silt :1grain size	Clay/Silt: 1-2 grain sizes to be discussed.
Settling velocity	Stokes Equation	・(Size of flocs of suspended sediments) Function of SS density ・Considered settling probability	・Function of SS density ・Considered settling probability
Sedimentation Model	Advection diffusion model of suspended materials	Advection Diffusion model of suspended materials (multilayer level model) and Density flow of high concentrate settled materials	Advection Diffusion model of suspended materials (multilayer level model) and Density flow of high concentrate settled mud layer
Reproduction of Model	By an average sedimentation rate of second year after channel construction (October 2005-November 2009)	By an average sedimentation rate between 19 May 2006 to 14 September 2007	Considering the periodical bathymetric survey from 2005 to 2011, a preproduction factor will be decided.
Study Cases	Case / Water depth of Channel / External Conditions / Computation period / Facility: Port / Protection 1 / 7.5 m / Current only; Current + Waves / 15 days / X / X 2 / 8.0 m / Current only; Current + Waves / 15 days / X / X 3 / 14.0 m / Current only; Current + Waves / 15 days / X / X 4 / 14.0 m / Current only; Current + Waves / 15 days / O / X 5 / 14.0 m / Current only; Current + Waves / 15 days / O / Dike 1 6 / 14.0 m / Current only; Current + Waves / 15 days / O / Dike 2 7 / 14.0 m / Current only; Current + Waves / 15 days / O / Dike 3 7b / 14.0 m / Current only; Current + Waves / 15 days / O / Dike 4	・Submerged breakwater Location: West and east of channel Height: GL +2 m Length: 13 km	Step-3 TRAINING/SAND DYKE CONSTRUCTION SCALE(6 Cases) 3.1 Channel depth with full draft 3.2 Number of cases is six, basically as follows: a. without training/sand dyke-1 case; b. with training/sand dyke-3 cases; c. with offshore submerged breakwater and training/sand dyke-2 cases In the case requested by the Engineer, a few cases will be added Step-4 CHANNEL WATER DEPTH(2 Cases) Simulation of dredged scenarios: with reduced draft and tidal operation with partial deepened area

5.1.15 The TOR of "Hydrodynamic and Sediment Transport Modeling Studies"

<u>TECHNICAL SPECIFICATION</u>

1) GENERAL

The specification shall be applied to the works for Hydrodynamic and Sediment Transport Modeling Studies on the assessment of the channel sedimentation and potential impact of maintenance dredging, hereafter says as "Sedimentation Studies" to be carried out by the Contractor under the Contract for the Detailed Design on Lach Huyen Port Infrastructure Construction Project in the northern Vietnam.

2) SITE DESCRIPTION

Lach Huyen Port Infrastructure Construction Project is a major port development planned to meet the future long term needs of the Northern Vietnam during a period of sustained growth. The port location has been selected in the location closed to open sea and deep water lies on the route of the recently realigned channel serving the existing ports of Haiphong. It has natural shelter on three sides by Cat Ba Island to the east, Cat Hai to the North and Kien Thuy to the west. In the west side, an undeveloped area is available with shallow water depths, which are suitable for reclamation and for harbor and related development foreseeable needs.

The existing access channel to Hai Phong Port area is composed of Cam River, Bach Dang River, Ha Nam Canal, Lach Huyen Reach and Sea Reach. Most of sedimentation source flows into Hai Phong Bay from Cam River through the old access channel, Nam Trieu. In this area, a sedimentation speed is enormous as much as about 2m per annual based on the periodical bathymetric survey. By this reason, the new access channel has been rerouted to Lach Huyen area so as to keep distance from a sedimentation source, fluid mud. Furthermore, in Lach Huyen, there is available the periodical bathymetric survey for several years. From these data, the sedimentation rate is about 0.8m in 2 and half years.

A major deficiency is that the site lacks land access for road and rail. The new road and rail links proposed from the west past the Dinh Vu Industrial area across the Dinh vu-Cat Hai Bridge and from the North Quang Ninh Road are major undertakings.

3) STUDY AREA

The area for simulation studies is shown in a map of STUDY AREA.

4) SCOPE OF WORK

A simulation study on channel sedimentation will be conducted in order to predict a magnitude of sedimentation rate in the dredged channel and turning basin. The Contractor shall carry out an assessment of the sensitivity of the sedimentation in a lower and high case considering spring and neap conditions.

The Works will be divided into three steps as follows:

a) Step-1 Preparatory works

To visit the site at project start, to meet with project team and confirm scope, clarify on any matters, discuss project and collect data and information pertinent to the project. And the following items shall be established in coordination with the estuary/channel sedimentation Engineer of the Study Team, hereafter says as "the Engineer".

1. Confirmation on sources of sedimentation materials
2. Collection of data on natural conditions, channel and turning basin configurations, sedimentation materials from the Study Team
3. Selection of numerical simulation model on sedimentation
4. In Bach Dang River and the old channel, the sediment material seems is fluid mud. This thing will be discussed and confirmed its influence to Lach Huyen area.
5. Confirmation of boundary conditions for reproduction and calibration of model and validation of model.

b) Step-2 Reproduction and calibration of Model

All things discussed and collected Step-1 shall be incorporated into setting up model. The process of trial and validation shall be reported in writing.

The Contractor shall be well-placed to carry out these studies, having established numerical simulation models of the entire area extending from the Sea Reach as far as the Port of Hai Phong or the mouth of Cam River, and modeling capability shall be covered the entire project area around Cat Ba Island. The numerical modeling applying for this sedimentation simulation shall be “Multi layers model” in considering the project site conditions.

c) Step-3 Training /Sand Dyke construction scale

To be assessed as part of the channel depth hydraulic studies. The scope of work involved in this element is to assess the effectiveness of a training wall or sand/rock bund in reducing channel sedimentation and consequent maintenance dredging. Sedimentation sources to include fluxes along the channel as well as across the channel. In particular the studies shall investigate the proportion of training versus benefit in reducing sedimentation. As engineering schemes, a detached offshore submerged breakwater as well as a connected training wall will be considered.

d) Step-4 Channel water depth

To investigate the appropriate channel water depth, two additional scenarios shall be carried out in conjunction with Step-3 studies:

a) Considering tidal operations (access to berths) with shallower channel and hence smaller maintenance dredging-1 case;
b) Part way solution between options a) and b) for example with some parts shallower and others deeper-1 case

5) METHODOLOGY

The methodology described in the following sections is aimed at meeting the requirements of the technical specification in full. The scope of work includes numerical modeling of tidal, fluvial currents and waves.

Prior to the commencement of the Works, the Contractor shall prepare and submit to the Engineer for his approval a proposal showing methodology and type and numerical simulation models based on Step-1 work Step

Step-1 SITE VISIT
Objective One visit to project office and site by the Contractor Engineer.
Scope Site visit at project start, to meet with project team and confirm scope, clarify on any matters, discuss project and collect data and information pertinent to the project.
Estimated Duration 0.5 Man Months Senior Scientist

Step-2 REPRODUCTION AND CALIBRATION OF MODEL	
Objective To be carried out reproduction and calibration of model To validate model	
Scope Review the data to be provided by JICA Study Team in respect of the periodical surveys. Review nature of the channel infill (muddy and/or sandy) in order to try and establish the source (marine or river). Mesh model for resolution in required areas. Determine rates of sedimentation and calibrate model on the above data Simulation and calibration of sedimentation model for present conditions. Based on information provided to date, indicating predominantly fine silt/clay infill from tidal and fluvial currents alone will be simulated, including wave effects.	
Input data -Bathymetric survey information -River flow and SS -Tidal current	 -waves -Particle size analysis of infill material. -Any dredging data
Estimated Duration 0.5 Man Months Senior Scientist and Senior Modeler 1.5 Man Months Scientist	
Deliverables A preliminary report including: -boundary conditions for model; -process reproductions and calibrations; -validation considering present conditions and actual sedimentation data	

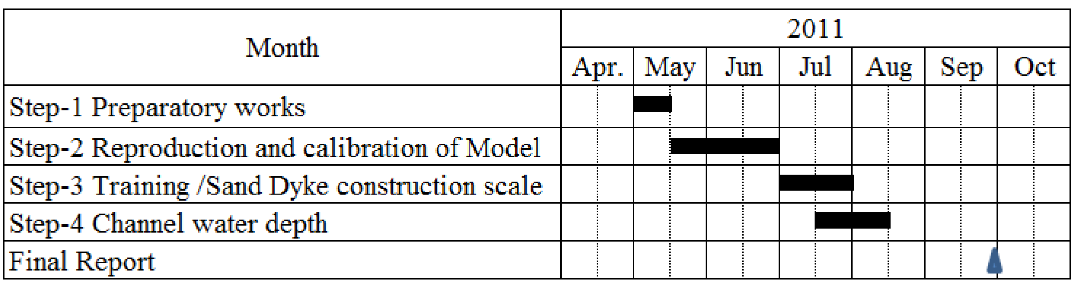
Step-3 TRAINING/SAND DYKE CONSTRUCTION SCALE
Objective To investigate and optimize the effectiveness of a dyke to train the flow, wave effects and prevent infill. Infill to be interpreted in order to ascertain whether the infill is due to a long-channel or a cross-channel sediment transport.
Scope Ideal scenario is for the channel to be dredged to full depth, with acceptable sedimentation rates. If this is not achievable then the options are to consider reduced depth and/or dyke/ offshore submerged breakwater to reduce infill. Tests will be carried out with tidal and fluvial flow modeling, including wave effects. The representative waves shall be sorted out in order to match for the natural conditions. First, simulations of this Step will be performed without dyke for case with full depth. And following tests will be carried out with full depth channel and for various length training walls, in order to survey the effectiveness of training wall and its scales. These results will be used to assess the benefits of the dyke for alternative channel depths, with confirmation simulations carried out for optimized channel depth with optimal length of dyke. The following conditions and study cases shall be considered: 3.1 Channel depth with full draft 3.2 Number of cases is 6 cases basically as follows: a. without training/sand dyke-1 case; b. with training/sand dyke-3 cases; c. with offshore submerged breakwater and training/sand dyke-2 cases

Step-3 TRAINING/SAND DYKE CONSTRUCTION SCALE
In the case requested by the Engineer, a few cases will be added. The model will represent the dyke as a solid structure.
Input data Step-2 data requirements plus: -Initial full-length training dyke characteristics (to be discussed with the JICA Study Team based on the results of the initial simulations). -Infill data. These are presently in chart form. The digitized form will be available as required. -Any information on dredging. -Particle size analysis of the infill.
Estimated Duration 0.5 Man Months Senior Scientist and Senior Modeler 1.5 Man Month Scientist
Deliverables Sedimentation rates for full-length and optimized-length training dyke with narrative engineering explanation. The sedimentation rates shall be presented in very meshes.

Step-4 CHANNEL WATER DEPTH	
Objective To assess the sedimentation speed versus the channel depth. The following two scenarios are studied in this Step.	
Scope Simulation of dredged scenarios: with reduced draft and tidal operation with partial deepened area In Step-1, the characteristic of draft/water depth will be discussed whether are including a vessel keel clearance and sedimentation buffer depth. Based on the above two scenarios providing sedimentation rates, information shall be given on timing to JICA Study Team for input to traffic/economic assessment in order to achieve optimum channel design.	
Input data -Bathymetric survey information -River flow and SS -Tidal current -waves	-Particle size analysis of infill material. -Any dredging data -Full draft channel specifications -Data and output relating to Step-3
Estimated Duration 0.5 Man Months Senior Scientist and Senior Modeler 1.5 Man Months Scientist	
Deliverables Preliminary report on sedimentation rates for two dredged scenarios for feeding into tidal operations assessment to achieve optimum channel design. Final Report after the approval of the Team Leader	

6) WORKING PERIOD

Working period will be discussed and finalized in Step-1 between JICA Study Team and the Contractor. The tentative working schedule is as follows.



7) REPORTING

Three draft copies of a report are to be submitted by the Contractor to the Engineer for approval. The draft report shall include full methodology and clear conclusions from the results of the numerical modeling. After incorporating any revisions suggested by the Engineer, the Contractor is to provide six copies of the final report to the Engineer.

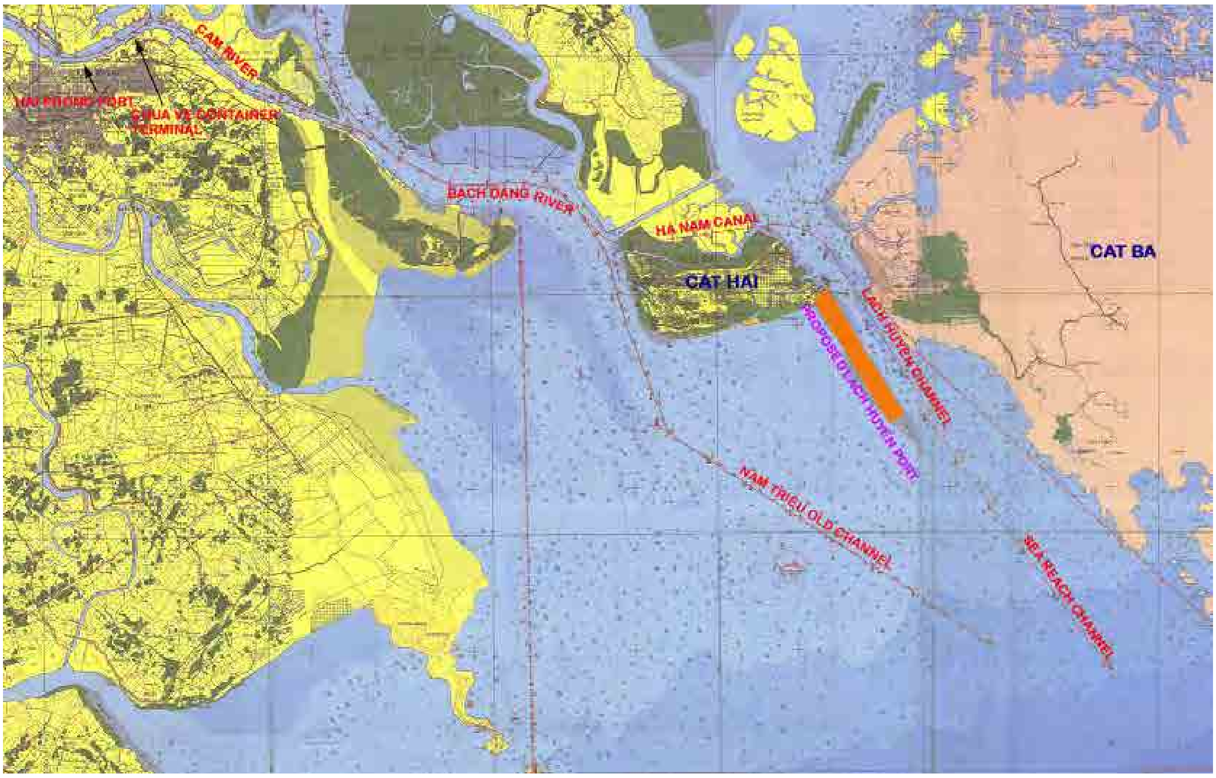
BILL OF QUANTITIES
ON
HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING STUDIES

on the assessment of the channel sedimentation and potential impact of maintenance dredging to be carried out by the Contractor under the Contract for the Detailed Design on Lach Huyen Port Infrastructure Construction Project in the northern Vietnam.

Item	Description	Q'ty	Unit	Unit Price	Amount
I. Step-1	**Site Visit**				
1-1	Senior Scientist	0.5	M/M	–	
1-2	Accommodation	1	L.S.	–	
1-3	Per diem allowance	1	L.S.		
1-4	Airfare	1	L.S.	–	
	Sub-total				
II. Step-2	**Reproduction and calibration of Model**				
2-1	Senior Scientist and Senior Modeler	0.5	M/M	–	
2-2	Scientists	1.5	M/M	–	
	Sub-total				
III. Step-3	**Training Wall**				
3-1	Senior Scientist and Senior Modeler	0.5	M/M	–	
3-2	Senior Scientists	1.5	M/M	–	
	Sub-total				
IV. Step-4	**Channel Depth**				
4-1	Principal Scientist	0.5	M/M	–	
4-2	Senior Scientists	1.5	M/M	–	
	Sub-total				
V.	**Others**	1	L.S.		
	Reporting/Printing				
	Computer charge,etc.				
	Total Amount				

STUDY AREA
FOR
HYDRODYNAMIC AND SEDIMENT TRANSPORT MODELING STUDIES

on the assessment of the channel sedimentation and potential impact of maintenance dredging to be carried out by the Contractor under the Contract for the Detailed Design on Lach Huyen Port Infrastructure Construction Project in the northern Vietnam.



5.2 Existing Situation of Oceanographer and Sedimentation Regime

5.2.1 Present Situation of Lach Huyen Access Channel

Until 2005, the Nam Trieu channel has been utilized to access to Hai Phong Port. Due to the difficulty to maintain the channel that is suffered from the huge sedimentation by the fluid mud from the Cam River, this access channel had been decided to re-aligned to the Lach Huyen area to sea by excavating Ha Nam Canal through Cat Hai Island in order to accommodate the larger size of vessels and to reduce maintenance budgetary burden.

This channel improvement had been carried out under Hai Phong Port Rehabilitation Project and completed in October 2005, and the existing access channel was opened in the early in 2006.

The present situation of the existing Lach Huyen Channel and the Nam Trieu Channel are summarized as follows.

- In the existing Lach Huyen channel, until the middle of 2011 from opening channel, there was no longer any maintenance dredging.
- The Nam Trieu channel at present is utilized for only smaller vessels than 1,000 D.W.T. Also from 2004 any maintenance dredging was not carried out.
- Only the maintenance dredging in the Hai Phong Port area is continuing every year.

Considering the natural existing conditions, the sediment process on the development of access channel is forecast for selecting the optimum channel configurations. And some countermeasures are proposed in order to decrease sedimentation into the channel.

5.2.2 Study Area

The study area is illustrated in Figure 5.2.1.

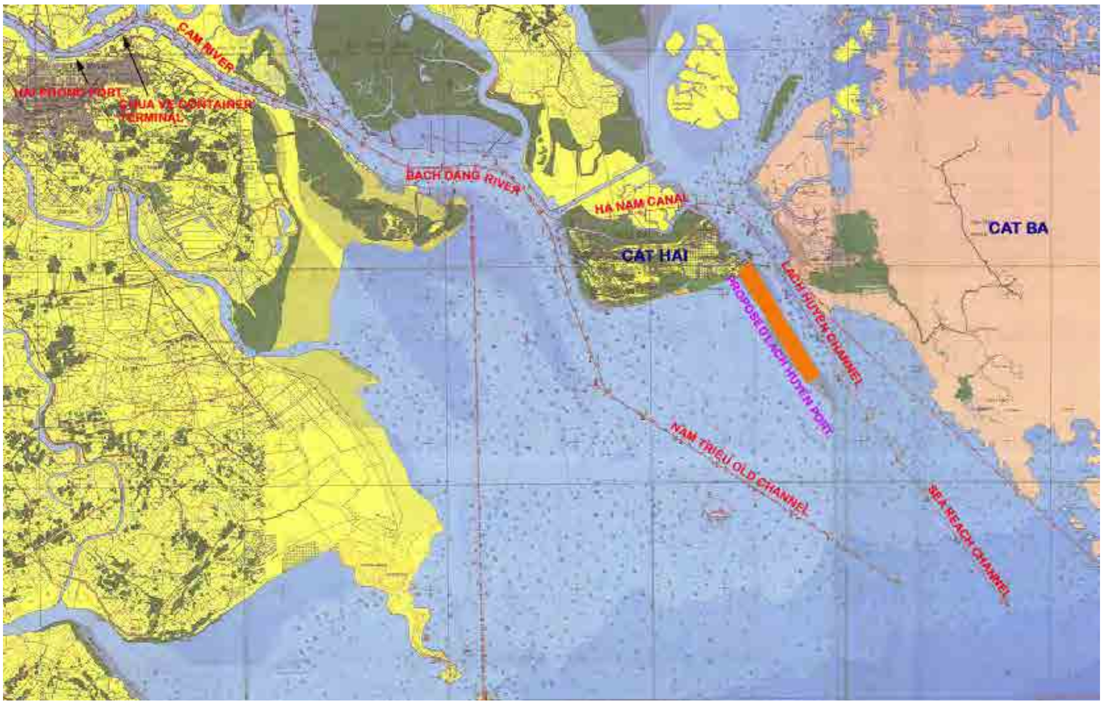


Figure 5.2.1 Study area and Project Site

5.2.3 Methodology

The methodology on the data collection related to the sediment modeling is shown in study flow in Figure 5.2.2.

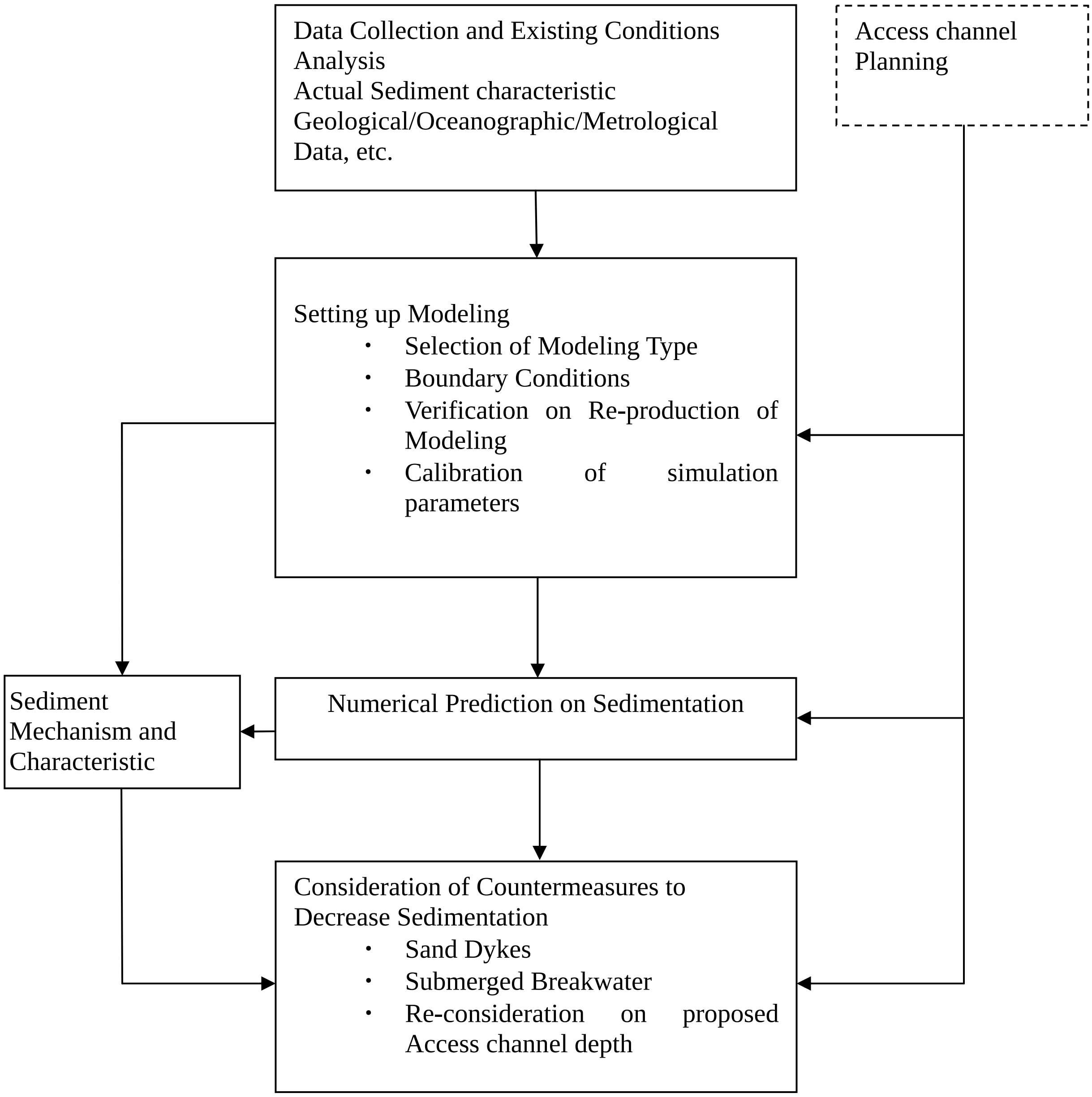


Figure 5.2.2 Flow of Channel Sediment Modeling

5.2.4 Existing Conditions

1) Geological Conditions

a) Location

The Project of Lach Huyen port development is located in the northeast inner area in Gulf of Tonkin that exposes to the southeast as shown in Figure 5.2.3.

The Lach Huyen access channel is situated in the narrow area between Cat Ba and Cat Hai Island as shown in Figure 5.2.4 and connected to Hai Phong Port through Ha Nam canal and Bach Dang River.

Figure 5.2.3 Hai Phong City and South China Sea

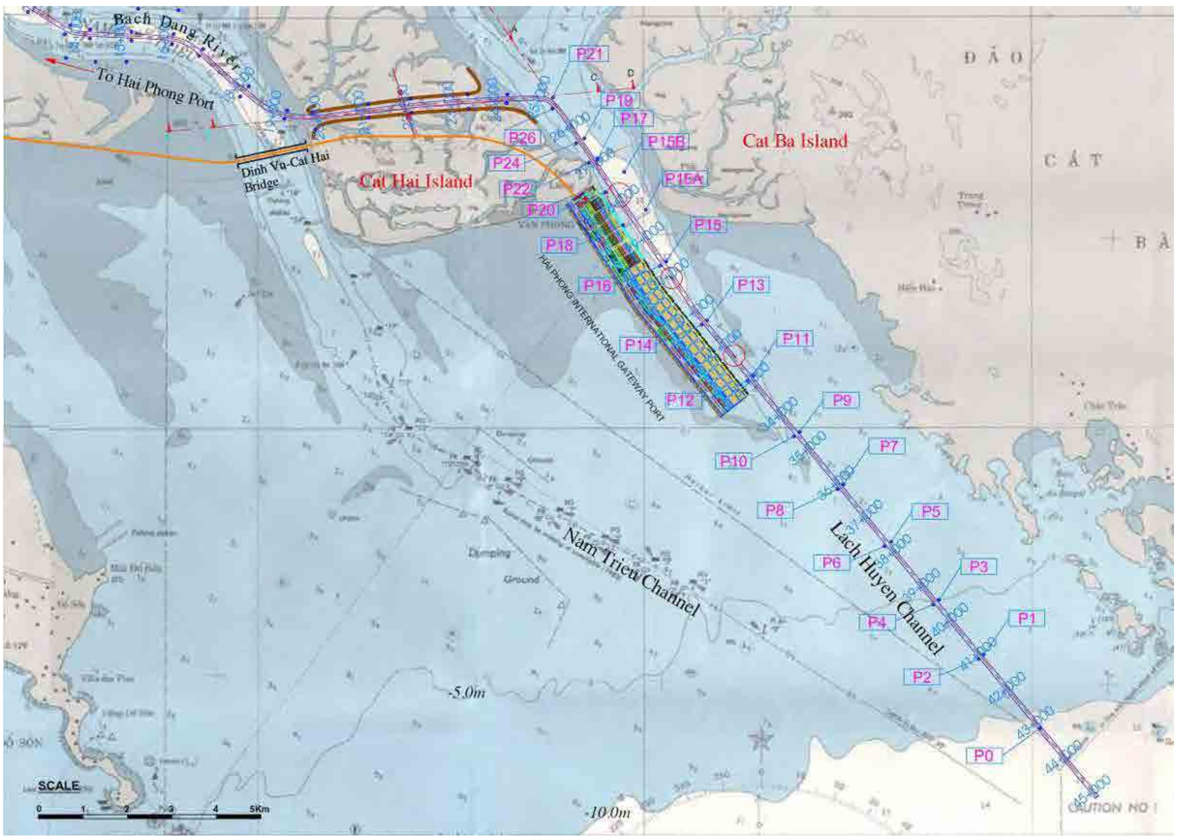


Figure 5.2.4 Map of Project Area

b) Seabed Materials

The conditions of seabed materials are summarized in Section 5.1.9.

2) External Conditions

a) Tide

In Hon Dau Observation Station (Figure 5.2.11) reckoning tide level is as follows.

H.W.L.=C.D.+3.55m、M.W.L=C.D.+1.95m、L.W.L.=C.D.+0.43m (C.D.L: Chart Datum Level)

b) Current

The measured current data are tabulated in Table 5.2.1 and Table 5.2.2. The observation location is indicated in Figure 5.2.5 through Figure 5.2.8. Based on the observation results, the current is dominated its flow in the north northwest on a flood tides and south southeast on ebbing tides along the existing channel. The calculated constituent factors are eminent in diurnal factor such as K1, O1. The current velocity in the narrow area between Cat Hai Island and Cat Ba Island, St.CM1 and St.V1 are the highest on where the surface is 1.3-1.5m/s in maximum. It becomes lower gradually toward offshore, and in the south side of Cat Ba Island is 0.5m/s (St.CM3, St.V3). Also the residual velocity is almost same levels in the Rainy and Dry season that is 0.1m/s on the surface and lower than 0.05m/s in bottom and generally southeast direction.

i) September 2009 (Rainy Season)[1]

Table 5.2.1 Maximum Current Velocity (Upper Layer)

Flood/Ebb Tide / Station	Flood Tide		Ebb Tide	
	Speed(cm/sec)	Direction	Speed(cm/sec)	Direction
CM-1 Observed	132.8	331	155.1	149
CM-2 Observed	51.5	347	101.3	146
CM-3 Observed	54.3	318	66.8	154

Table 5.2.2 Residual Current Velocity (Upper Layer)

Flood/Ebb Tide / Station	Speed(cm/sec)	Direction
CM-1 Observed	8.6	122
CM-2 Observed	13.5	140
CM-3 Observed	3.9	137

ii) November 2009 (Dry Season)[2]

Table 5.2.3 Residual Current Velocity

Vertical	V1		V2		V3		V4	
Surface Currents (cm/s & °)	8.9	123°	9.0	141°	2.9	142°	6.5	249°
Mid-Depth Current (cm/s & °)	1.7	4.3°	4.5	135°	4.7	77°	4.0	50°
Bottom Current (cm/s & °)	1.5	3.3°	1.3	181°	3.8	40°	3.8	46°

[1] NIPPON KOEI CO.,LTD.& ASSOCIATES: Report of Tidal Current Observation At LACH HUYEN-HAI PHONG, Socialist republic of Vietnam ministry of transport Hai Phong Port Rehabilitation Phase 2 Project, October 2009

[2] Oriental consultants co,. ltd: THE PREPARATORY SURVEY ON LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION IN VIET NAM REPORT ON CURRENT SURVEY, Volume i: CURRENT OBSERVATION at the project SITE, January 2010

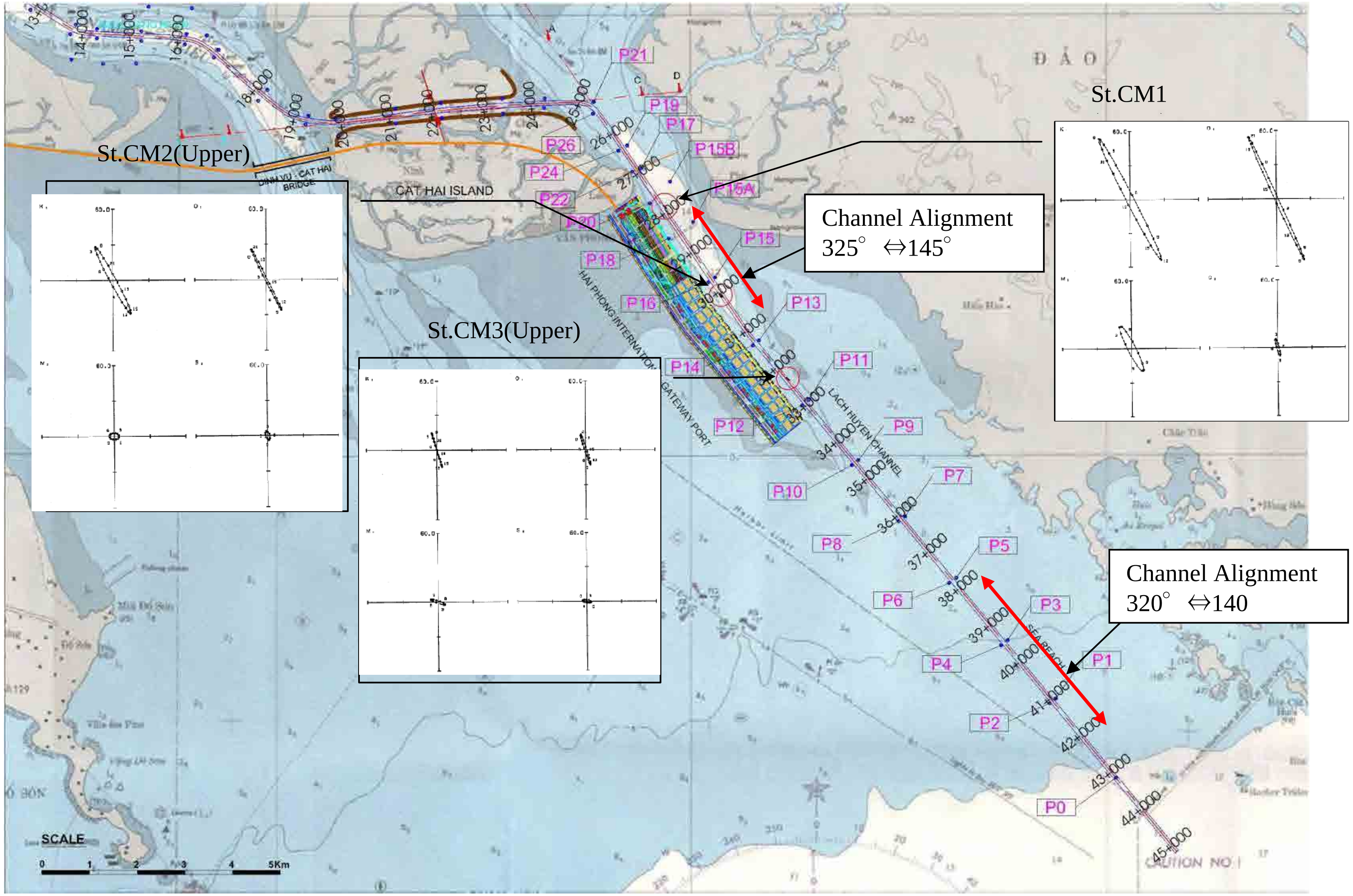


Figure 5.2.5 Tidal Ellipses at Surface In Existing Channel (September 2009) (1)

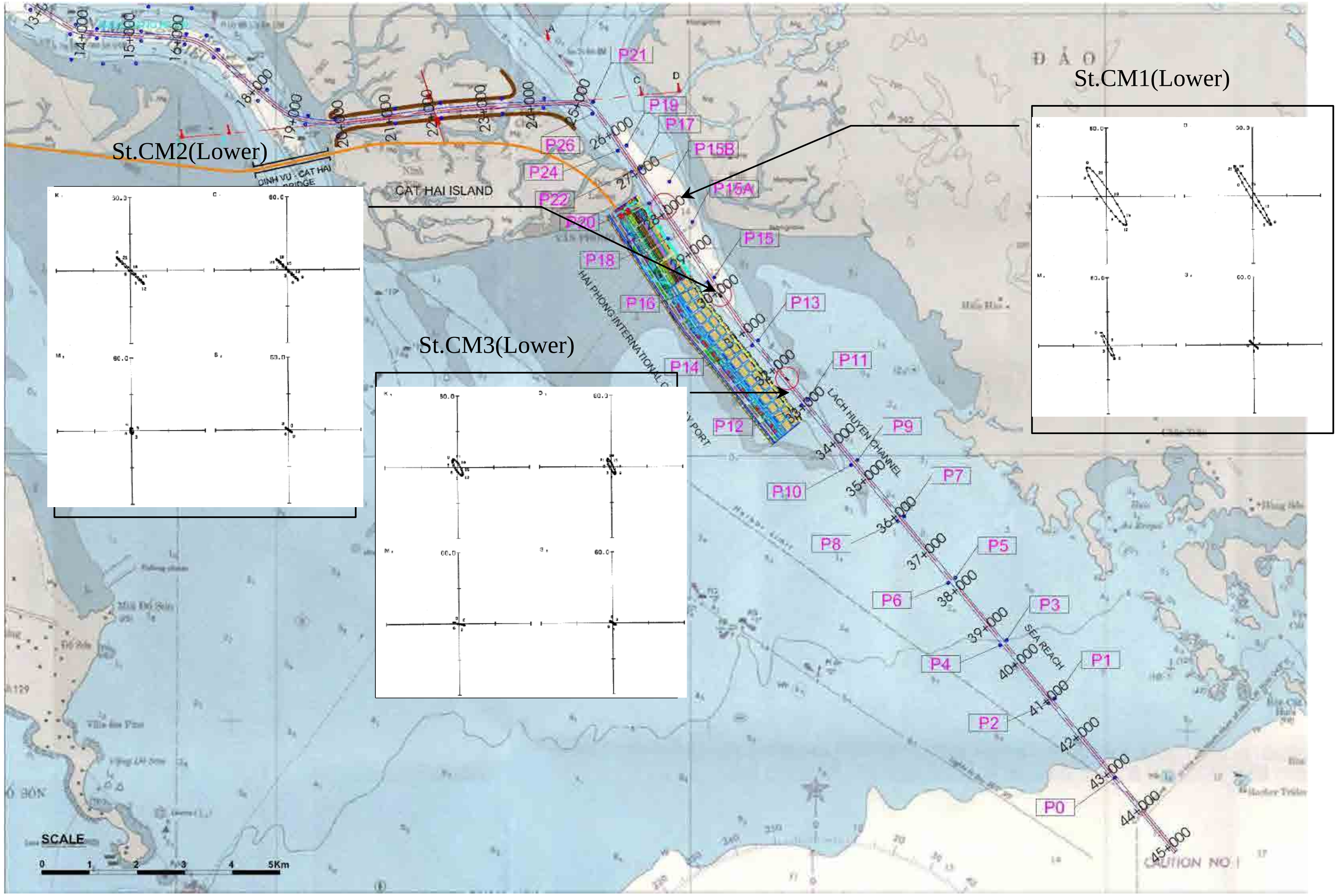


Figure 5.2.6 Tidal Ellipses at Bottom In Existing Channel (September 2009) (2)

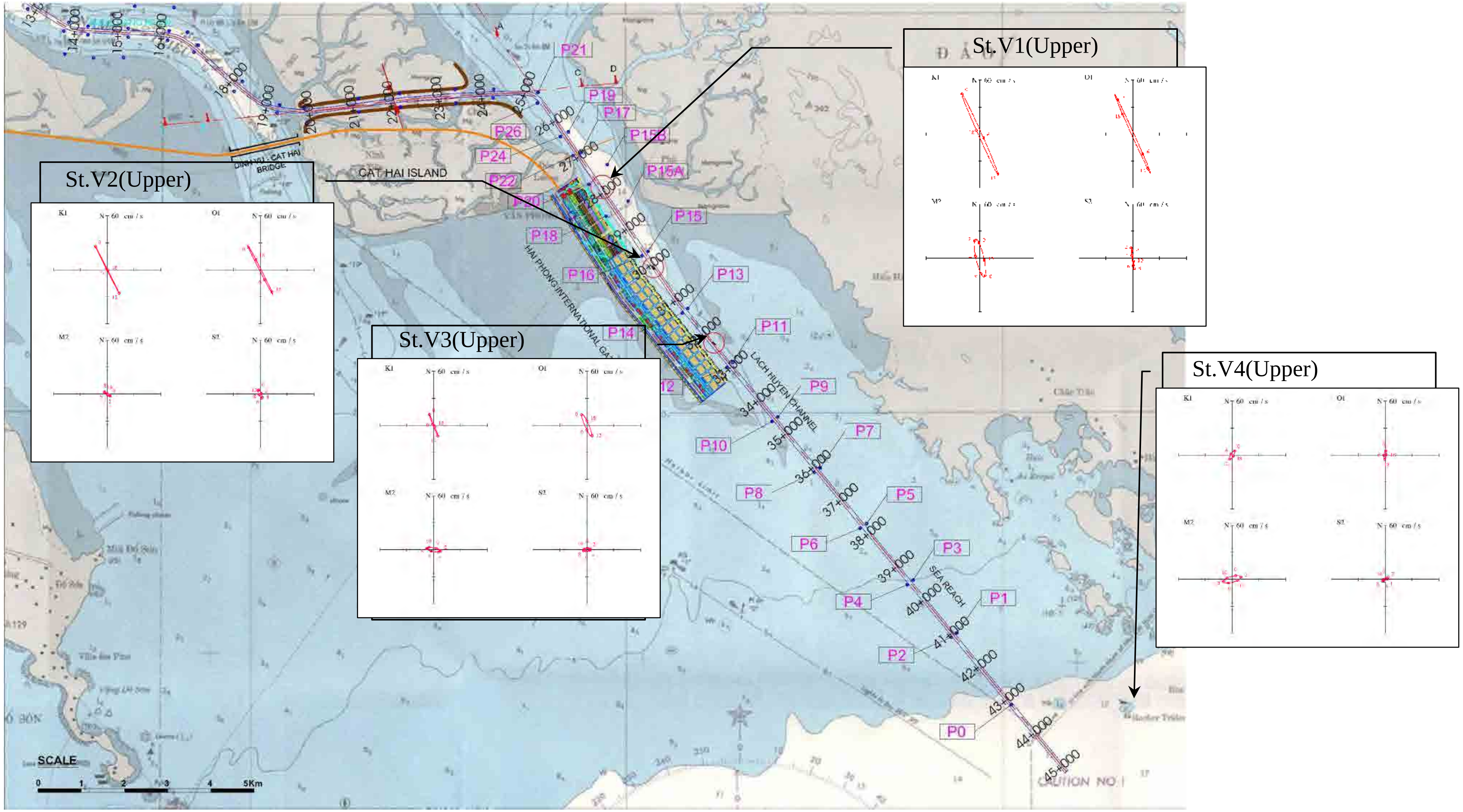


Figure 5.2.7 Tidal Ellipses at Surface In Existing Channel (November 2009) (1)

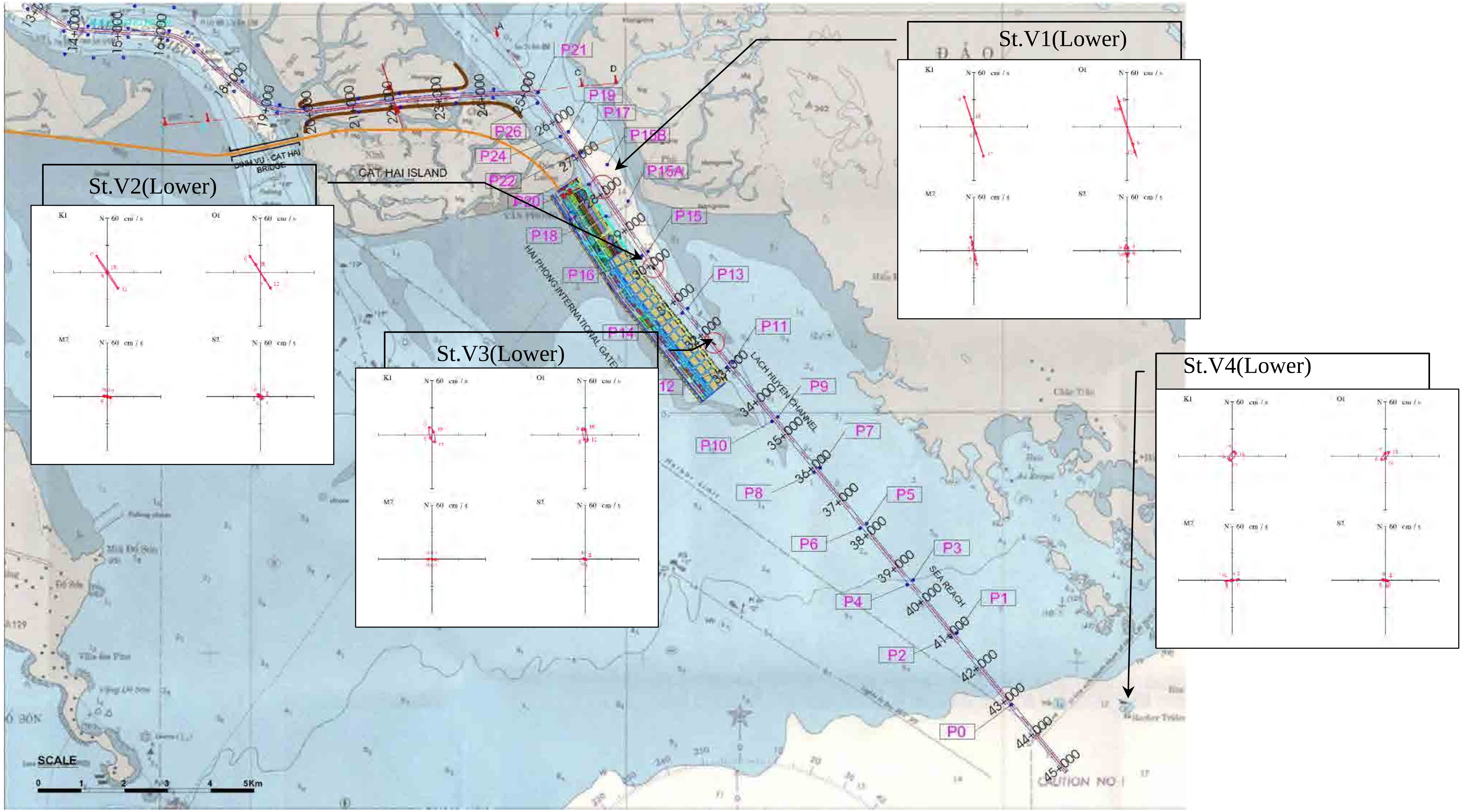
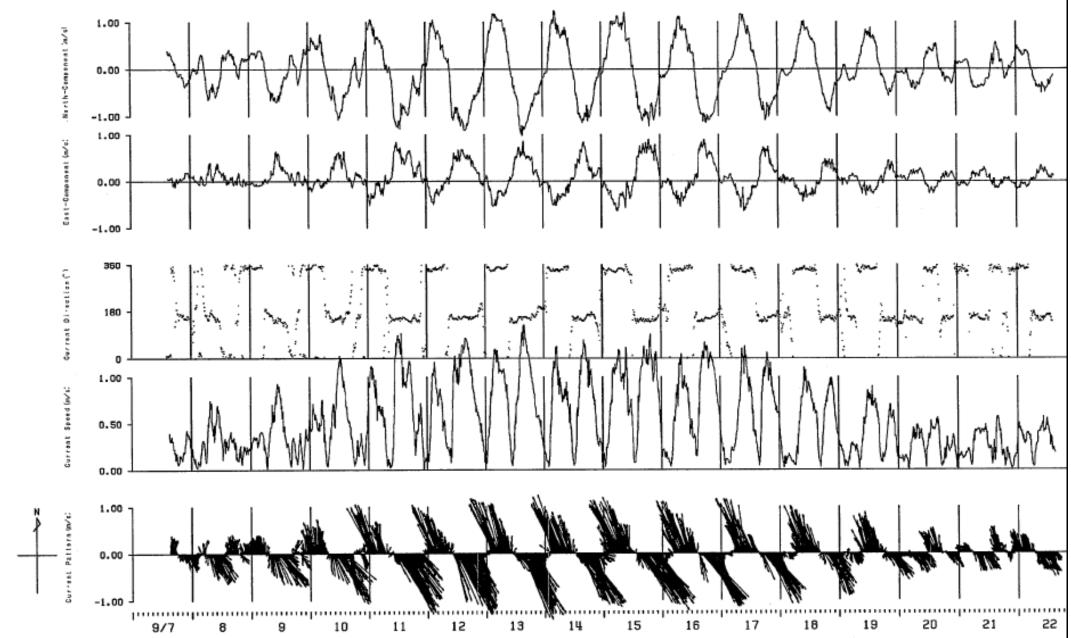
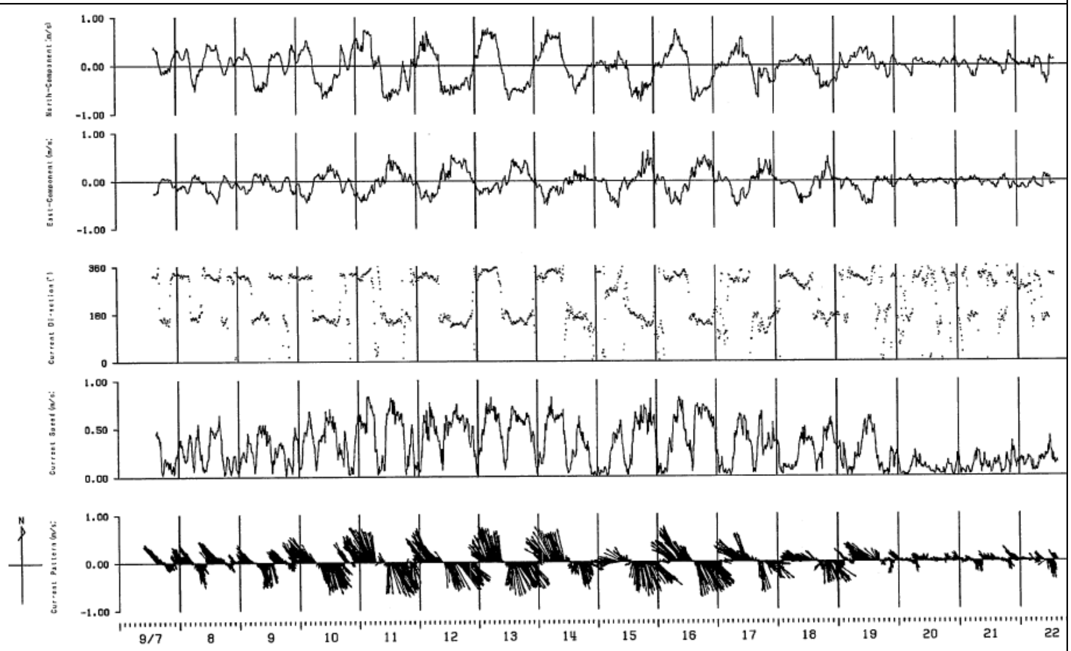


Figure 5.2.8 Tidal Ellipses at Bottom In Existing Channel (November 2009) (2)

Upper	
Lower	

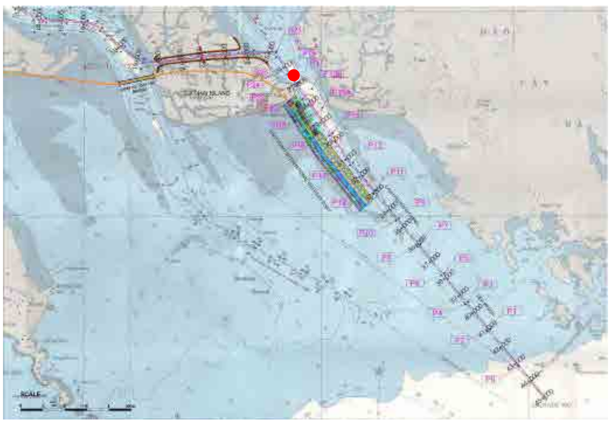
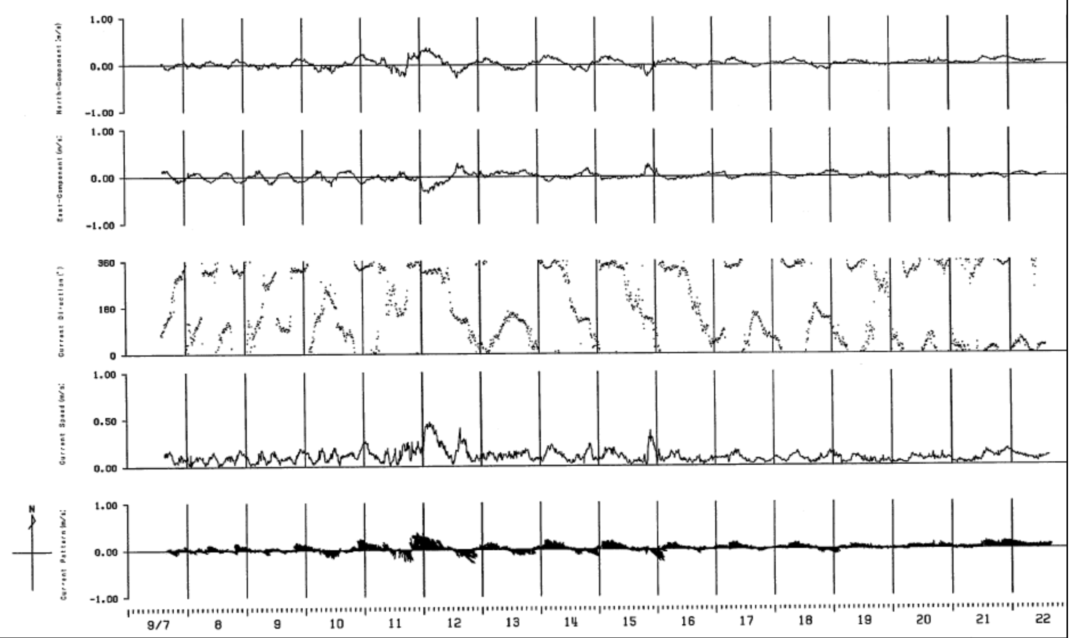
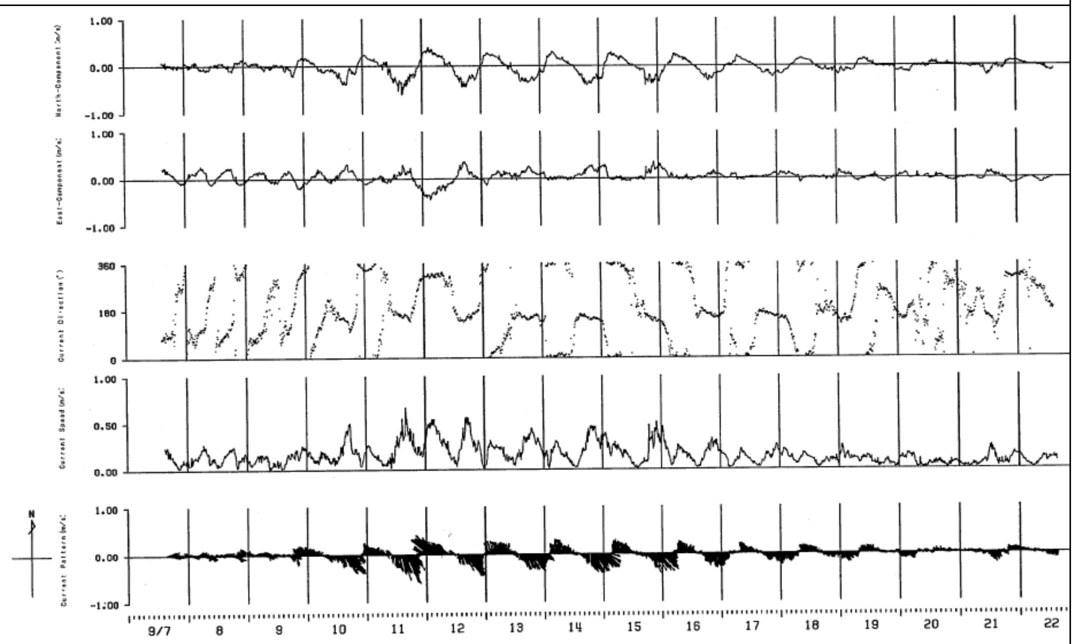


Figure 5.2.9 Charts of Current Pattern (September 2009, St.CM1) (1)

Upper	
Lower	

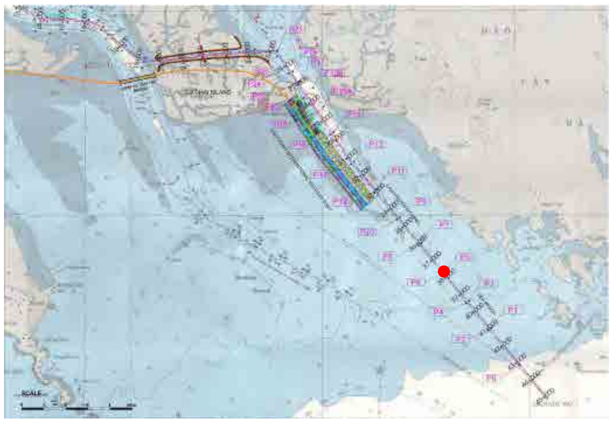


Figure 5.2.10 Charts of Current Pattern (September 2009, St.CM3)

c) Wave Conditions

i) Hon Dau National Hydrographic Station

By Hon Dau Station (Figure 5.2.11), wave observation is carried out 3times a day by an eye measurement using IVALOB H10. In Table 5.2.4, the observation data from 2005 to 2009 is tabulated in terms of occurrence frequency of wave directions and height. The occurrence frequency of wave direction is shown in Figure 5.2.12.

Figure 5.2.11 Location of Hon Dau Station

Table 5.2.4 Wave Occurrence Probability in Wave height and direction (Hon Dau: 2005-2009)

Each Colum: Occurrence/Probability (%)

Dir. / Height(m)	N	NE	E	SE	S	SW	W	NW	CALM	SUM	Probability of non-exceedance
0.00-0.25									2043	2043	2043
									37.4	37.4	37.4
0.25-0.50	5	2	237	51	8					303	2346
	0.1	0.0	4.3	0.9	0.1					5.5	42.9
0.50-0.75	51	43	1037	452	98	3	1	12		1697	4043
	0.9	0.8	19.0	8.3	1.8	0.1	0.0	0.2		31.0	73.9
0.75-1.00	24	28	360	297	118	26		3		856	4899
	0.4	0.5	6.6	5.4	2.2	0.5		0.1		15.7	89.6
1.00-1.50	9	24	131	199	107	17		1		488	5387
	0.2	0.4	2.4	3.6	2.0	0.3		0.0		8.9	98.5
1.50-2.00	2	1	19	32	15	1				70	5457
	0.0	0.0	0.3	0.6	0.3	0.0				1.3	99.8
2.00-2.50			1	1						2	5459
			0.0	0.0						0.0	99.8
2.50-3.00			3	1						4	5463
			0.1	0.0						0.1	99.9
3.00-3.50			2							2	5465
			0.0							0.0	99.9
3.50-4.00			3							3	5468
			0.1							0.1	100.0
4.00m-										0	5468
										0.0	100.0
SUM	91	98	1793	1033	346	47	1	16	2043	5468	
	1.7	1.8	32.8	18.9	6.3	0.9	0.0	0.3	37.4	100.0	

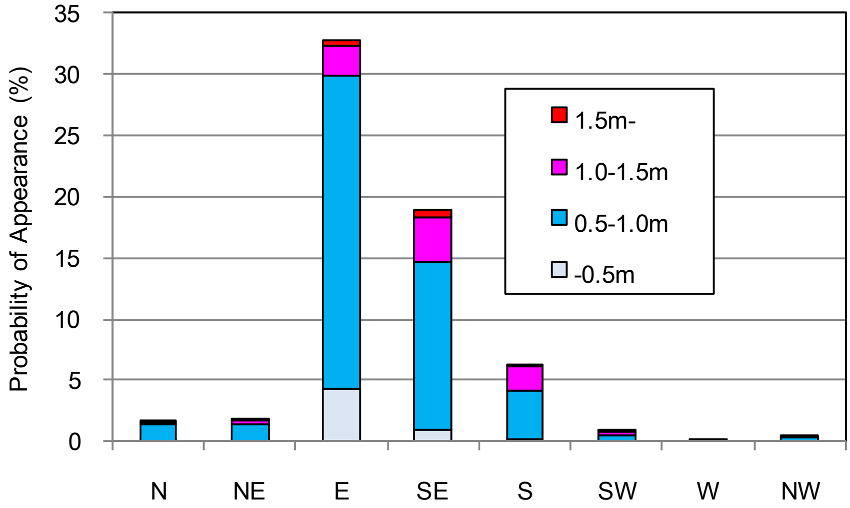


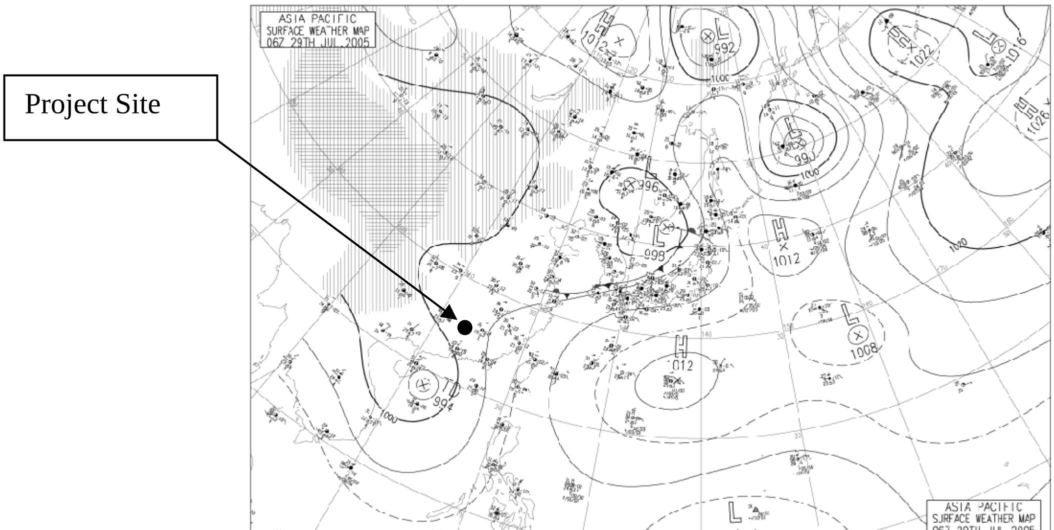
Figure 5.2.12 Probability of Wave Direction Occurrence (2005-2009 Hon Dau Data)

Table 5.2.5 Maximum Wave Height In Hon Dau (2005-2009)

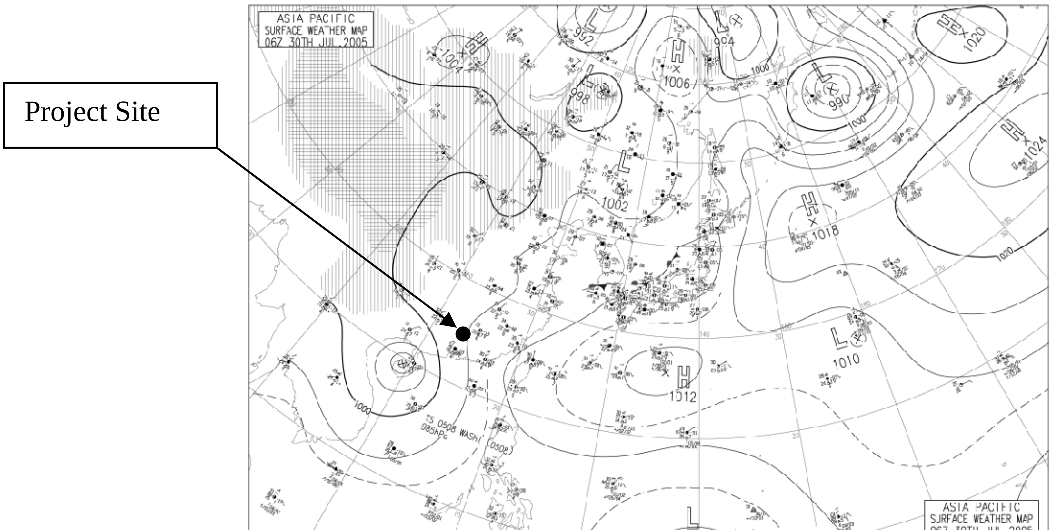
Year	Month	day	hour	Direction	Wave Height (m)	Wave Period (sec)	Notes
2005	7	31	13	E	3.69	8.7	
2006	7	18	13	SE	1.89	5.4	
2007	10	4	13	E	3.15	6.1	
2008	9	26	7	S	1.71	5.7	Lowest in five years
2009	9	12	7	SE	2.43	5.6	

Table 5.2.6 Larger Waves Higher than 1.7m In Hon Dau

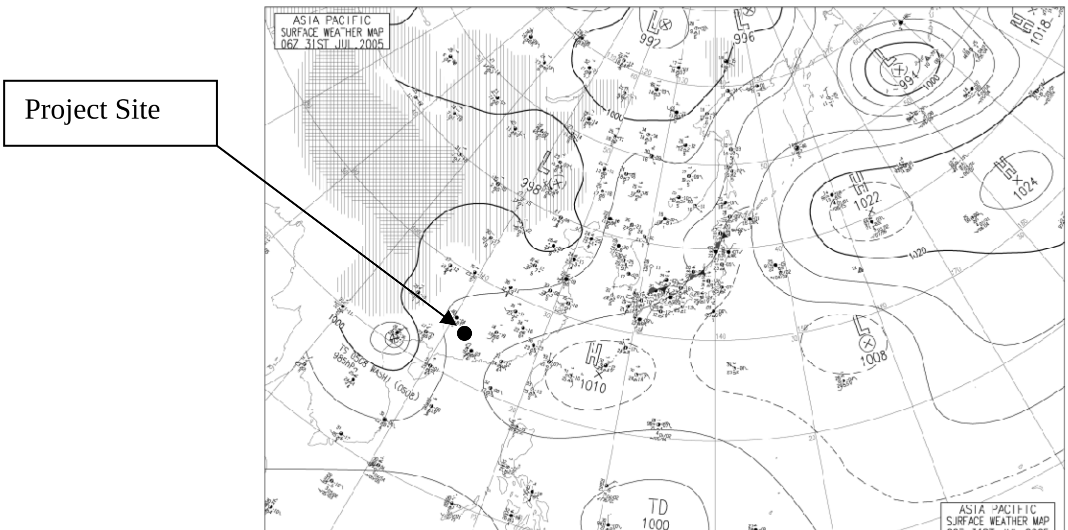
No.	Year	Month	day	hour	Direction	Wave Height (m)	Wave Period (sec)
1	2005	2	17	19	E	1.80	6.8
2	2005	4	9	19	SE	1.80	6.6
3	2005	5	13	19	E	1.80	4.8
4	2005	7	31	13	E→SE	3.69	8.7
5	2005	8	11	19	E→SE	2.16	6.3
6	2005	9	18	19	E→SE	3.60	8.2
7	2005	9	27	13	E→SE	3.60	9.5
8	2006	4	12	7	SE	1.80	6.6
9	2006	7	18	13	SE	1.89	5.4
10	2007	7	5	19	SW	1.98	7.0
11	2007	7	21	13	SE	1.81	4.4
12	2007	10	4	13	E	3.15	6.1
13	2008	9	26	7	S	1.71	5.7
14	2009	9	12	7	SE	2.43	5.6
15	2009	10	14	13	E/N	1.98	6.2



(1)2005/07/29 06UTC

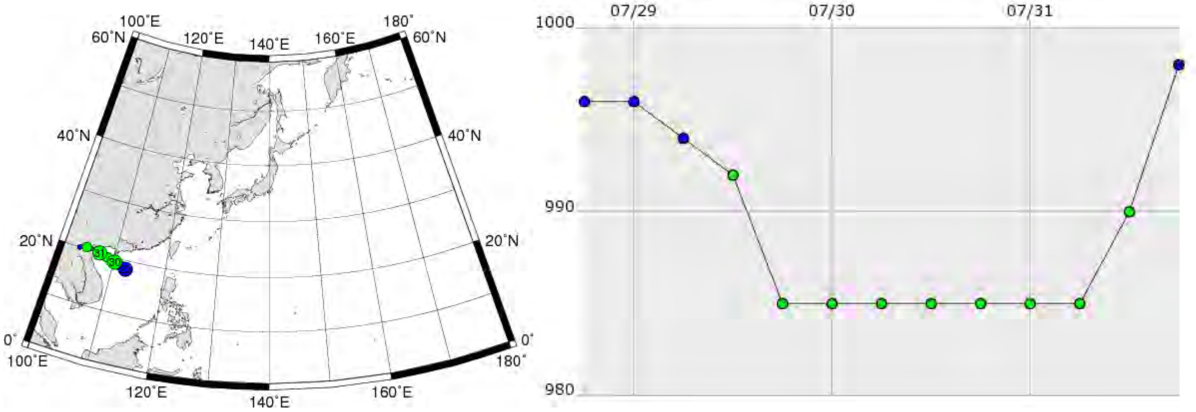


(2)2005/07/30 06UTC

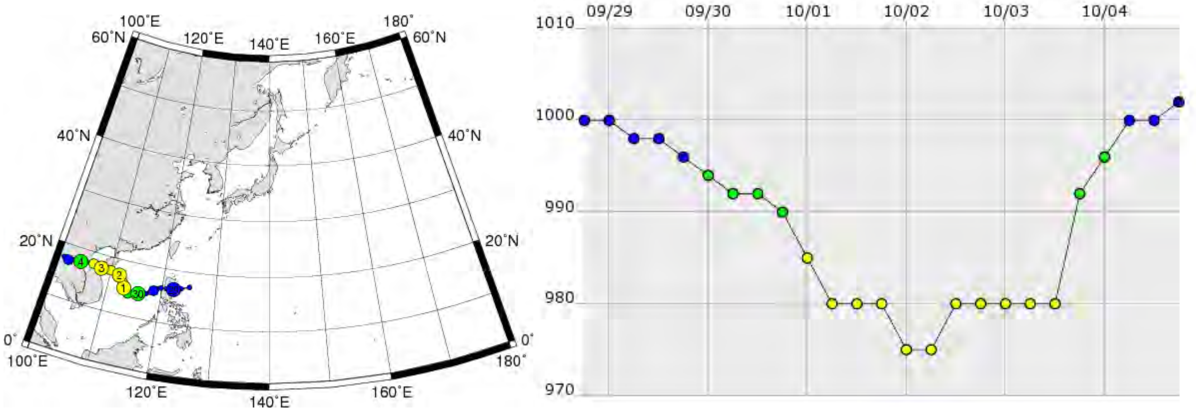


(3)2005/07/31 06UTC

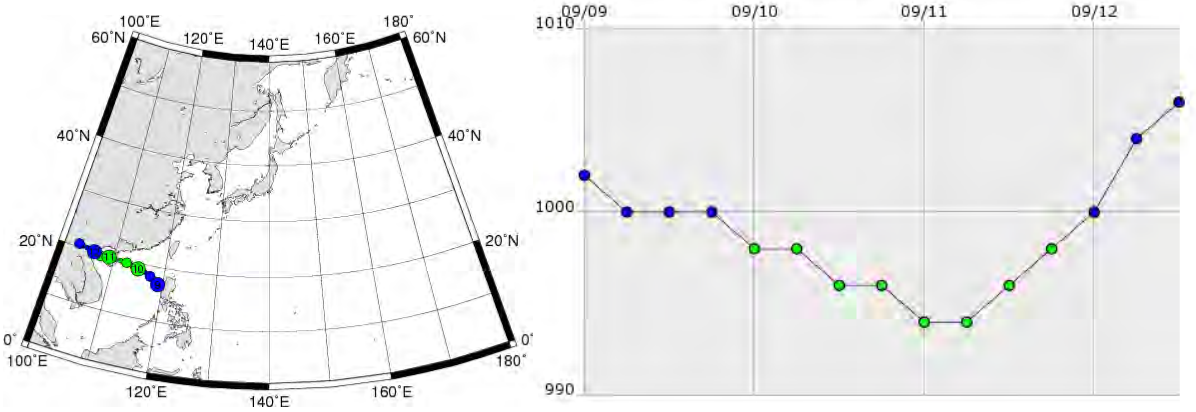
Figure 5.2.13 Weather Map of Near Project Site in Typhoon (2005/07/29-31)



(1)2005/07/29-31



(2)2007/09/29-10/4



(3)2009/09/09-12

[Typhoon Route and atmospheric pressure]

Figure 5.2.14 Typhoon Route Track attach to project site

ii) Wave Data by Wave Recorder

1. Data

By TEDI-PORT, the observed data is available from July 2005 to August 2006 at Lach Huyen channel offshore. This data is analyzed as the significant waves. And in Table 5.2.13, the wave data during the typhoon on 9 September 2005 is tabulated.

Location of the wave recorder: at Lach Huyen Channel offshore: Water depth 15.0m (C.D.L) near Buy-0.

2. Analyzed wave data

Table 5.2.7 Occurrence Frequency of Wave Height and Period

Observation period: 12 July 2005 - 14 August 2006
Location: OFFSHORE-15M

Missing data number 2825
Recorded Number 2553
Record Number 272-(9.6%)

Period / Wave height	0.0~3.0	3.0~4.0	4.0~5.0	5.0~6.0	6.0~7.0	7.0~8.0	8.0~9.0	9.0~10	10~11	11~12	Above 12.0	Total	Acoum - nlated
0.00~0.25	40 1.6	213 8.3	122 4.8	32 1.3	8 0.3	2 0.1			1 0.0			418 16.4	418 16.4
0.25~0.50	36 1.4	286 11.2	415 16.3	114 4.5	9 0.4	3 0.1	1 0.0	1 0.0		1 0.0		866 33.9	1284 50.3
0.50~1.00		42 1.6	440 17.2	421 16.5	26 1.0		1 0.0					930 36.4	2214 86.7
1.00~1.50			39 15.0	201 7.9	38 1.5	3 0.1	1 0.0					282 11.0	2496 97.8
1.50~2.00				21 0.8	24 0.9	2 0.1	1 0.0					48 1.9	2544 99.6
2.00~2.50				1 0.0	3 0.1	2 0.1						6 0.2	2550 99.9
2.50~3.00							1 0.0					1 0.0	2551 99.9
3.00~3.50							2 0.1					2 0.1	2553 100.0
3.50~4.00												0 0.0	2553 100.0
4.00m												0 0.0	2553 100.0
Total	76 3.0	541 21.2	1016 39.8	790 30.9	108 4.2	12 0.5	7 0.3	1 0.0	1 0.0	1 0.0	0 0.0	2553 100.0	
Acoumnlated	76 3.0	617 24.2	1633 64.0	2423 94.9	2531 99.1	2543 99.6	2550 99.9	2551 99.9	2552 100.0	2553 100.0	2553 100.0		

Upper: Occurrence Number
Lower: Occurrence %

Table 5.2.8 Occurrence Frequency of Wave Period and Direction

Obsenvation period: 12 July 2005 - 14 August 2006
Location: OFFSHORE-15M

Missing data number: 2825
Recorded Number: 2420
Record Number: 399-(14.1%)

Period / Wave height	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoum nlated
0.00~0.25		1 0.0	15 0.6	11 0.5	4 1.7	88 3.6	66 2.7	49 2.0	12 0.5	4 0.2	2 0.1		1 0.0	6 0.2		18 0.7		313 12.9	313 12.9
0.25~0.50	9 0.4	8 0.3	18 0.7	58 2.4	146 6.0	278 11.5	220 9.1	59 2.4	11 0.5	4 0.2	2 0.1		1 0.0	2 0.1	3 0.1	20 0.8		839 34.7	1152 47.6
0.50~1.00	2 0.1		10 0.4	117 4.8	224 9.3	295 12.2	207 8.6	50 2.1	5 0.2	9 0.4	4 0.2	1 0.0		1 0.0		3 0.1		928 38.3	2080 86.0
1.00~1.50			4 0.2	6 0.2	37 1.5	116 4.8	96 4.0	13 0.5	5 0.2	6 0.2								283 11.7	2363 97.6
1.50~2.00				1 0.0	1 0.0	12 0.5	26 1.1	5 0.2	1 0.0	1 0.0	1 0.0							48 2.0	2411 99.6
2.00~2.50				1 0.0			2 0.1	3 0.1										6 0.2	2417 99.9
2.50~3.00					1 0.0													1 0.0	2418 99.9
3.00~3.50					1 0.0	1 0.0												2 0.1	2420 100.0
3.50~4.00																		0 0.0	2420 100.0
4.00m																		0 0.0	2420 100.0
Total	11 0.5	9 0.4	47 1.9	194 8.0	450 18.6	790 32.6	617 25.5	179 7.4	34 1.4	24 1.0	9 0.4	1 0.0	2 0.1	9 0.4	3 0.1	41 1.7	0 0.0	2420 100.0	

Upper: Occurrence Number
Lower: Occurrence %

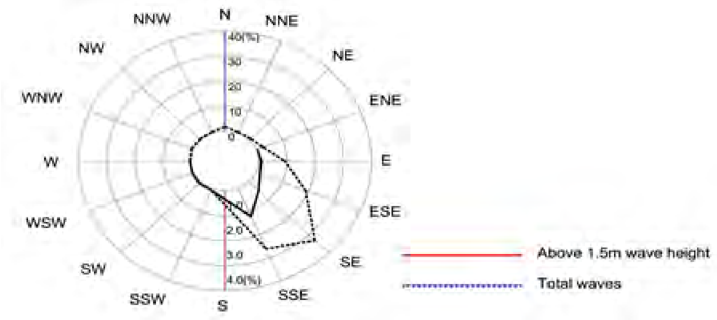


Figure 5.2.15 Occurrence Frequency of Wave Period and Direction

Table 5.2.9 Occurrence Frequency of Wave Period and Direction

Missing data number: 2825
Observation period: 12 July 2005 - 14 August 2006
Recorded Number: 2420
Location: OFFSHORE-15M
Record Number: 399-(14.1%)

Period / Wave height	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumulated
0.00~3.00			1 0.0		5 0.2	13 0.5	12 0.5	11 0.5	1 0.0					2 0.1		1 0.0		46 1.9	46 1.9
3.00~4.00	3 0.1	4 0.2	15 0.6	27 1.1	78 3.2	143 5.9	107 4.4	42 1.7	11 0.5	4 0.2	3 0.1		2 0.1	3 0.1	3 0.1	15 0.6		460 19.0	506 20.9
4.0~5.0	8 0.3	3 0.1	24 1.0	108 4.5	203 8.4	311 12.9	246 10.2	58 2.4	13 0.5	4 0.2	1 0.0	1 0.0		3 0.1		16 0.7		999 41.3	1505 62.2
5.0~6.0		2 0.1	6 0.2	55 2.3	149 6.2	286 11.8	204 8.4	55 2.3	4 0.2	13 0.5	2 0.1			1 0.0		8 0.3		785 32.5	2290 94.7
6.0~7.0			1 0.0	3 0.1	12 0.5	27 1.1	40 1.7	12 0.5	5 0.2	3 0.1	3 0.1					1 0.0		107 4.4	2397 99.1
7.0~8.0				1 0.0	1 0.0	3 0.1	6 0.2	1 0.0										12 0.5	2409 99.6
8.0~9.0					2 0.1	4 0.2	1 0.0											7 0.3	2416 99.9
9.0~10.0						1 0.0												1 0.0	2417 99.9
10.0~11						1 0.0												1 0.0	2418 100
11~12							1 0.0											1 0.0	2419 100
Above 12.0																		0.0 0.0	2419 100
Total	11 0.5	9 0.4	47 1.9	194 8.0	450 18.6	789 32.6	617 25.5	179 7.4	34 1.4	24 1.0	9 0.4	1 0.0	2 0.1	9 0.4	3 0.1	41 1.7	0 0.0	2419 100	

Upper: Occurrence Number
Lower: Occurrence %

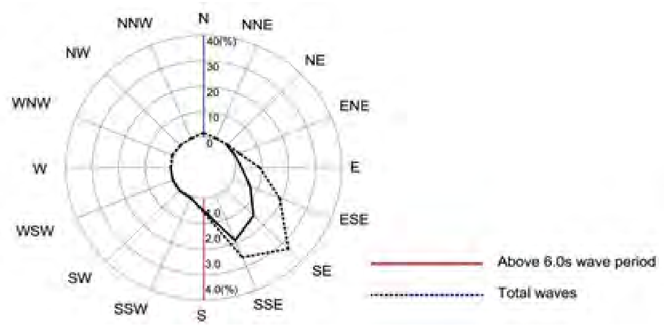


Figure 5.2.16 Occurrence Frequency of Wave Period and Direction

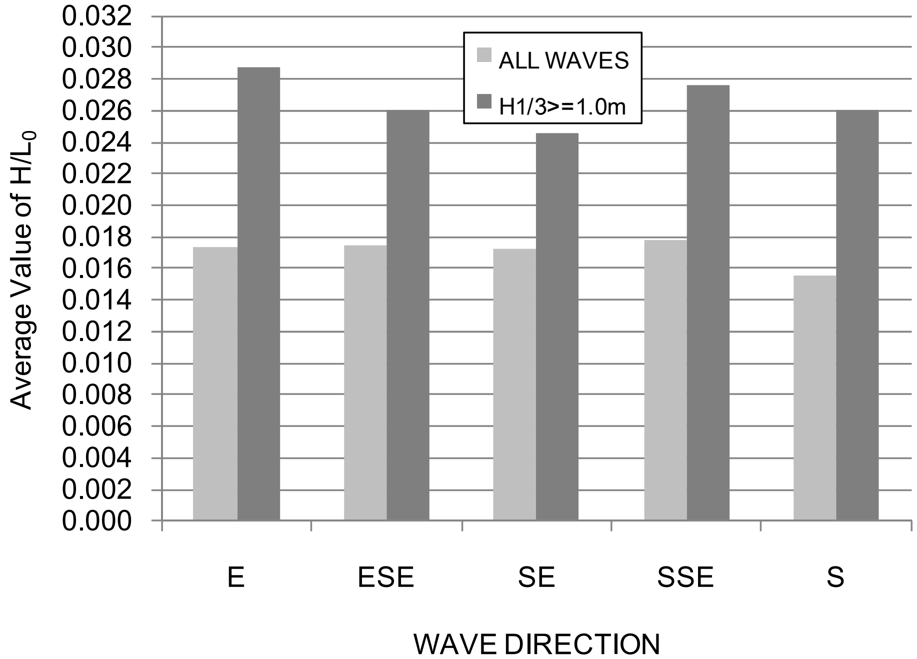


Figure 5.2.17 Average Wave Steepness and Direction

3. Average Wave Steepness in Seasons

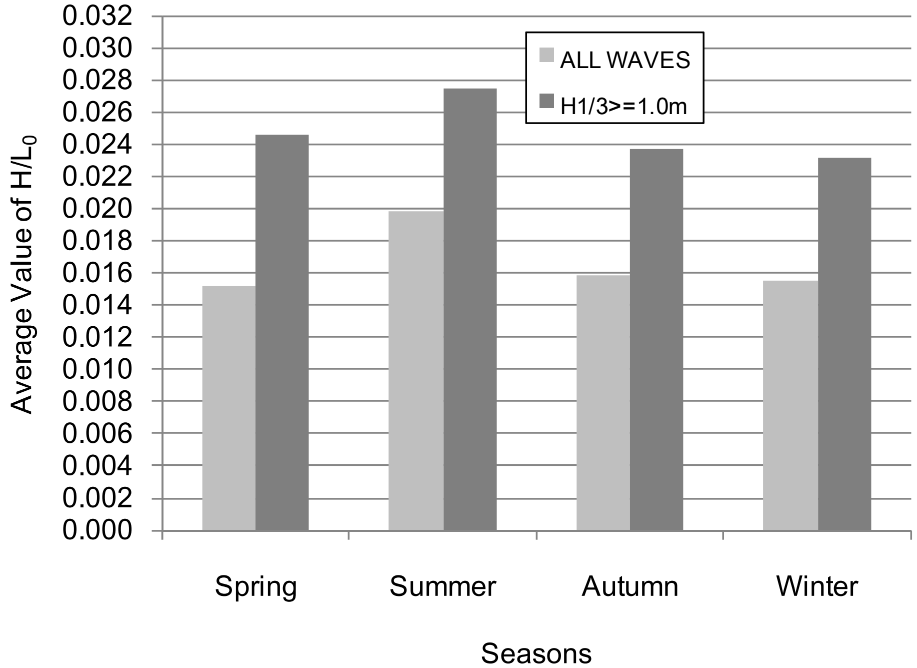


Figure 5.2.18 Average Wave Steepness in Seasons

Table 5.2.10 Seasonal Occurrence Frequency of Waves Height (Offshore -15.0m 12 July 2005-14 August 200)

Upper: Occurrence Number
Lower: Occurrence %

March - May

Period / Wave height	0.0~3.0	3.0~4.0	4.0~5.0	5.0~6.0	6.0~7.0	7.0~8.0	8.0~9.0	9.0~10	10~11	11~12	Above 12.0	Total	Acoumn lated
0.00~0.25	16 2.3	101 14.2	59 8.3	19 2.7	7 1.0	1 0.1			1 0.1			204 28.7	204 28.7
0.25~0.50	8 1.1	70 9.8	91 12.8	17 2.4	3 0.4	3 0.4	1 0.1	1 0.1		1 0.1		195 27.4	399 56.1
0.50~1.00		11 1.5	76 10.7	129 18.1	7 1.0							223 31.4	622 87.5
1.00~1.50			1 0.1	72 10.1	8 1.1							81 11.4	703 98.9
1.50~2.00				3 0.4	5 0.7							8 1.1	711 100.0
2.00~2.50												0 0.0	711 100.0
2.50~3.00												0 0.0	711 100.0
3.00~3.50												0 0.0	711 100.0
3.50~4.00												0 0.0	711 100.0
4.00m												0 0.0	711 100.0
Total	24 3.4	182 25.6	227 31.9	240 33.8	30 4.2	4 0.6	1 0.1	1 0.1	1 0.1	1 0.1	0 0.0	711 100.0	
Acoumnlated	24 3.4	206 29.0	433 60.9	673 94.7	703 98.9	707 99.4	708 99.6	709 99.7	710 99.9	711 100.0	711 100.0		

June - August

Period / Wave height	0.0~3.0	3.0~4.0	4.0~5.0	5.0~6.0	6.0~7.0	7.0~8.0	8.0~9.0	9.0~10	10~11	11~12	Above 12.0	Total	Acoumn lated
0.00~0.25	5 0.6	35 4.4	10 1.3	3 0.4								53 6.6	53 6.6
0.25~0.50	9 1.1	67 8.4	77 9.7	4 5.5	2 0.3							199 25.0	252 31.6
0.50~1.00		5 0.6	162 20.3	164 20.6	11 1.4							342 42.9	594 74.5
1.00~1.50			33 4.1	115 14.4	16 2.0	1 0.1						165 20.7	759 95.2
1.50~2.00				18 2.3	16 2.0							34 4.3	793 99.5
2.00~2.50				1 0.1	3 0.4							4 0.5	797 100.0
2.50~3.00												0 0.0	797 100.0
3.00~3.50												0 0.0	797 100.0
3.50~4.00												0 0.0	797 100.0
4.00m												0 0.0	797 100.0
Total	14 1.8	107 13.4	282 35.4	345 43.3	48 0.6	1 0.1	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	797 100.0	
Acoumnlated	14 1.8	121 15.2	403 50.6	748 93.9	796 99.9	797 100.0	797 100.0	797 100.0	797 100.0	797 100.0	797 100.0		

September - November

Period / Wave height	0.0~3.0	3.0~4.0	4.0~5.0	5.0~6.0	6.0~7.0	7.0~8.0	8.0~9.0	9.0~10	10~11	11~12	Above 12.0	Total	Acoumn lated
0.00~0.25	7 1.7	43 10.5	28 6.8	6 1.5	1 0.2							85 20.8	85 20.8
0.25~0.50	13 3.2	67 16.4	77 18.8	16 3.9	1 0.2							174 42.5	259 63.3
0.50~1.00		9 2.2	73 17.8	35 8.6	4 1.0		1 0.2					122 29.8	381 93.2
1.00~1.50			1 0.2	10 2.4	4 1.0	2 0.5	1 0.2					18 4.4	399 97.6
1.50~2.00					2 0.5	2 0.5	1 0.2					5 1.2	404 98.8
2.00~2.50						2 0.5						2 0.5	406 99.3
2.50~3.00							1 0.2					1 0.2	407 99.5
3.00~3.50							2 0.5					2 0.5	409 100.0
3.50~4.00												0 0.0	409 100.0
4.00m												0 0.0	409 100.0
Total	20 4.9	119 29.1	179 43.8	67 16.4	12 2.9	6 1.5	6 1.5	0 0.0	0 0.0	0 0.0	0 0.0	409 100.0	
Acoumnlated	20 4.9	139 34.0	318 77.8	385 94.1	397 97.1	403 98.5	409 100.0	409 100.0	409 100.0	409 100.0	409 100.0		

December-February

Period / Wave height	0.0~3.0	3.0~4.0	4.0~5.0	5.0~6.0	6.0~7.0	7.0~8.0	8.0~9.0	9.0~10	10~11	11~12	Above 12.0	Total	Acoumn lated
0.00~0.25	12 1.9	34 5.3	25 3.9	4 0.6		1 0.2						76 11.9	76 11.9
0.25~0.50	6 0.9	82 12.9	170 26.7	37 5.8	3 0.5							298 46.9	374 58.8
0.50~1.00		17 2.7	129 20.3	93 14.6	4 0.6							243 38.2	617 97.0
1.00~1.50			4 0.6	4 0.6	10 1.6							18 2.8	635 99.8
1.50~2.00					1 0.2							1 0.2	636 100.0
2.00~2.50												0 0.0	636 100.0
2.50~3.00												0 0.0	636 100.0
3.00~3.50												0 0.0	636 100.0
3.50~4.00												0 0.0	636 100.0
4.00m												0 0.0	636 100.0
Total	18 2.8	133 20.9	328 21.7	138 21.7	18 2.8	1 0.2	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	636 100.0	
Acoumnlated	18 2.8	151 23.7	617 97.0	617 97.0	635 99.8	636 100.0	636 100.0	636 100.0	636 100.0	636 100.0	636 100.0		

Table 5.2.11 Seasonal Occurrence Frequency of Wave Direction with Wave Height (Offshore -15.0m 12 July 2005 – 14 August 2006)

Upper: Occurrence Number
Lower: Occurrence %

March - May

Direction / Wave height	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~0.25		1 0.2	8 1.3	3 0.5	16 2.6	27 4.4	24 3.9	28 4.5	6 1.0	2 0.3	2 0.3		1 0.2	3.0		2 0.3		123 19.8	123 19.8
0.25~0.50	9 1.5	6 1.0	8 1.3	14 23.0	26 4.2	45 7.3	33 5.3	27 4.4	3 0.5	2 0.3	1 0.2		1 0.2	0.5	2 0.3	10 1.6		187 30.2	310 50.0
0.50~1.00	1 0.2		5 0.8	25 4.0	49 7.9	74 11.9	45 7.3	21 3.4			3 0.5					1 0.2		221 35.6	531 85.6
1.00~1.50				2 0.3	6 1.0	60 9.7	13 2.1											81 13.1	612 98.7
1.50~2.00						3 0.5	5 0.8											8 1.3	620 100.0
2.00~2.50																		0 0.0	620 100.0
2.50~3.00																		0 0.0	620 100.0
3.00~3.50																		0 0.0	620 100.0
3.50~4.00																		0 0.0	620 100.0
4.00m																		0 0.0	620 100.0
Total	10 1.6	7 1.1	21 3.4	44 7.1	97 15.6	209 33.7	120 19.4	76 12.3	9 1.5	4 0.6	3 0.5	0 0.0	2 0.3	3 0.5	2 0.3	13 2.1	0 0.0	620 100.0	

June - August

Direction / Wave height	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~0.25			4 0.5	5 0.6	6 0.8	4 0.5	5 0.6	4 0.5	1 0.1	1 0.1						15 1.9		45 5.8	45 5.8
0.25~0.50		2 0.3	5 0.6	10 1.3	28 3.6	50 6.4	64 8.2	10 1.3	5 0.6	2 0.3	1 0.1			2 0.3	1 0.1	10 1.3		190 24.3	235 30.1
0.50~1.00	1 0.1		2 0.3	24 3.1	42 5.4	110 14.1	114 14.6	27 3.5	5 0.6	9 1.2	4 0.5	1 0.1		1 0.1		2 0.3		342 43.8	577 73.9
1.00~1.50			3 0.4	3 0.4	19 2.4	43 5.5	74 9.5	13 1.7	5 0.6	6 0.8								166 21.3	743 95.1
1.50~2.00						8 1.0	18 2.3	5 0.6	1 0.1	1 0.1	1 0.1							34 4.4	777 99.5
2.00~2.50							1 0.1	1 0.1										4 0.5	781 100.0
2.50~3.00																		0 0.0	781 100.0
3.00~3.50																		0 0.0	781 100.0
3.50~4.00																		0 0.0	781 100.0
4.00m																		0 0.0	781 100.0
Total	1 0.1	2 0.3	42 5.4	42 5.4	95 12.2	215 27.5	276 35.3	62 7.9	17 2.2	19 2.4	6 0.8	1 0.1	0 0.0	3 0.4	1 0.1	27 3.5	0 0.0	781 100.0	

September - November

Direction / Wave height	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~0.25			1 0.3	1 0.3	7 1.8	25 6.5	22 5.7	9 2.3	3 0.8	1 0.3						1 0.3		70 18.1	70 18.1
0.25~0.50			2 0.5	12 3.1	40 10.4	70 18.1	35 9.1	5 1.3	2 0.5									166 43.0	236 61.1
0.50~1.00			3 0.8	32 8.3	41 10.6	33 8.5	13 3.4											122 31.6	358 92.7
1.00~1.50					7 1.8	10 2.6	1 0.3											18 4.7	376 97.4
1.50~2.00				1 0.3	1 0.3	1 0.3	2 0.5											5 1.3	381 98.7
2.00~2.50				1 0.3			1 0.3											2 0.5	383 99.2
2.50~3.00					1 0.3													1 0.3	384 99.5
3.00~3.50					1 0.3	1 0.3												2 0.5	386 100.0
3.50~4.00																		0 0.0	386 100.0
4.00m																		0 0.0	386 100.0
Total	0 0.0	0 0.0	6 1.6	47 12.2	98 25.4	140 36.3	74 19.2	14 3.6	5 1.3	1 0.3	0 0.0	0 0.0	0 0.0	0 0.0	0 0.0	1 0.3	0 0.0	386 100.0	

December-February

Direction / Wave height	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~0.25			2 0.3	2 0.3	11 1.7	32 5.1	15 2.4	8 1.3	2 0.3					3 0.5				75 11.8	75 11.8
0.25~0.50			3 0.5	22 3.5	52 8.2	113 17.9	88 13.9	17 2.7	1 0.2									296 46.8	371 58.6
0.50~1.00				36 5.7	92 14.5	78 12.3	35 5.5	2 0.3										243 38.4	614 97.0
1.00~1.50			1 0.2	1 0.2	5 0.8	3 0.5	8 1.3											18 2.8	632 99.8
1.50~2.00							1 0.2											1 0.2	633 100.0
2.00~2.50																		0 0.0	633 100.0
2.50~3.00																		0 0.0	633 100.0
3.00~3.50																		0 0.0	633 100.0
3.50~4.00																		0 0.0	633 100.0
4.00m																		0 0.0	633 100.0
Total	0 0.0	0 0.0	6 0.9	61 9.6	160 25.3	226 35.7	147 23.2	27 4.3	3 0.5	0 0.0	0 0.0	0 0.0	0 0.0	3 0.5	0 0.0	0 0.0	0 0.0	633 100.0	

Table 5.2.12 Seasonal Occurrence Frequency of Wave Direction with Wave Period (Offshore -15.0m 12 July 2005 – 14 August 2006)

Upper: Occurrence Number
Lower: Occurrence %

March - May

Direction / Period (s)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~3.00					2			7										9	9
					0.3			1.1										1.5	1.5
3.00~4.00	3	2	6	10	20	30	18	18	4	3	2		2	2	2	6		128	137
	0.5	0.3	1.0	1.6	3.2	4.8	2.9	2.9	0.6	0.5	0.3		0.3	0.3	0.3	1.0		20.6	22.1
4.0~5.0	7	3	11	18	35	54	41	27	5	1	1			1		7		211	348
	1.1	0.5	1.8	2.9	5.6	8.7	6.6	4.4	0.8	0.2	0.2			0.2		1.1		34.0	56.1
5.0~6.0		2	3	15	37	114	42	22										235	583
		0.3	0.5	2.4	6.0	18.4	6.8	3.5										37.9	94.0
6.0~7.0			1	1	3	9	13	2										29	612
			0.2	0.2	0.5	1.5	2.1	0.3										4.7	98.7
7.0~8.0							4											4	616
							0.6											0.6	99.4
8.0~9.0							1											1	617
							0.2											0.2	99.5
9.0~10.0						1												1	618
						0.2												0.2	99.7
10.0~11						1												1	619
						0.2												0.2	99.8
11~12							1											1	620
							0.2											0.2	100.0
Above 12.0																		0.0	620.0
																		0.0	100.0
Total	10	7	21	44	97	209	120	76	9	4	3	0	2	3	2	13	0	620	
	1.6	1.1	3.4	7.1	15.6	33.7	19.4	12.3	1.5	0.6	0.5	0.0	0.3	0.5	0.3	2.1	0.0	100.0	

June - August

Direction / Period (s)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~3.00			1	7	2	22	2	1								1		7	7
			0.1	0.9	0.3	2.8	0.3	0.1								0.1		0.9	0.9
3.00~4.00		2	3	23	13	81	30	7	2		1				1	9		97	104
		0.3	0.4	2.9	1.7	10.4	3.8	0.9	0.3		0.1				0.1	1.2		12.4	13.3
4.0~5.0	1		7	12	29	104	108	13	6	3		1		2		8		282	386
	0.1		0.9	1.5	3.7	13.3	13.8	1.7	0.8	0.4		0.1		0.3		1.0		36.2	49.5
5.0~6.0			3		46	7	122	30	4	13	2			1		8		345	731
			0.4		5.9	0.9	15.6	3.8	0.5	1.7	0.3			0.1		1.0		44.2	93.7
6.0~7.0					5		14	10	5	3	3					1		48	779
					0.6		1.8	1.3	0.6	0.4	0.4					0.1		6.2	99.9
7.0~8.0								1										1	780
								0.1										0.1	100.0
8.0~9.0																		0	780
																		0.0	100.0
9.0~10.0																		0	780
																		0.0	100.0
10.0~11																		0	780
																		0.0	100.0
11~12																		0	780
																		0.0	100.0
Above 12.0																		0.0	780
																		0.0	100.0
Total	1	2	14	42	95	214	276	62	17	19	6	1	0	3	1	27	0	780	
	0.1	0.3	1.8	5.4	12.2	27.4	35.4	7.9	2.2	2.4	0.8	0.1	0.0	0.4	0.1	3.5	0.0	100.0	

September - November

Direction / Period (s)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~3.00						7	4	3										14	14
						1.8	1.0	0.8										3.6	3.6
3.00~4.00			2	6	24	35	26	6	3	1								103	117
			0.5	1.6	6.2	9.1	6.7	1.6	0.8	0.3								26.7	30.3
4.0~5.0			4	26	54	60	27	4	2							1		178	295
			1.0	6.7	14.0	15.5	7.0	1.0	0.5							0.3		46.1	76.4
5.0~6.0				12	15	25	14	1										67	362
				3.1	3.9	6.5	3.6	0.3										17.4	93.8
6.0~7.0				2	2	7	1											12	375
				0.5	0.5	1.8	0.3											3.1	96.9
7.0~8.0				1	1	2	2											6	380
				0.3	0.3	0.5	0.5											1.6	98.4
8.0~9.0					2	4												6	386
					0.5	1.0												1.6	100.0
9.0~10.0																		0	386
																		0.0	100.0
10.0~11																		0	386
																		0.0	100.0
11~12																		0	386
																		0.0	100.0
Above 12.0																		0.0	386.0
																		0.0	100.0
Total	0	0	6	47	98	140	74	14	5	1	0	0	0	0	0	1	0	386	
	0.0	0.0	1.6	12.2	25.4	36.3	19.2	3.6	1.3	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	100.0	

December-February

Direction / Period (s)	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	CALM	Total	Acoumnlated
0.00~3.00					1	6	6		1					2				16	16
					0.2	0.9	0.9		0.2					0.3				2.5	2.5
3.00~4.00			4	4	21	56	33	11	2					1				132	148
			0.6	0.6	3.3	8.8	5.2	1.7	0.3					0.2				20.9	23.4
4.0~5.0			2	41	85	116	70	14										328	476
			0.3	6.5	13.4	18.3	11.1	2.2										51.8	75.2
5.0~6.0				16	51	43	26	2										138	614
				2.5	8.1	6.8	4.1	0.3										21.8	97.0
6.0~7.0					2	4	12											18	632
					0.3	0.6	1.9											2.8	99.8
7.0~8.0						1												1	633
						0.2												0.2	100.0
8.0~9.0																		0	633
																		0.0	100.0
9.0~10.0																		0	633
																		0.0	100.0
10.0~11																		0	633
																		0.0	100.0
11~12																		0	633
																		0.0	100.0
Above 12.0																		0.0	633
																		0.0	100.0
Total	0	0	6	61	160	226	147	27	3	0	0	0	0	3	0	0	0	633	
	0.0	0.0	0.9	9.6	25.3	35.7	23.2	4.3	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	100.0	

Table 5.2.13 Wave Recording Data on 9 September 2005, Offshore -15.0m

Year/Month	Day	Hour	$H_{1/3}$(m)	$T_{1/3}$(s)	Dir(°N)
2005/09	17	3	0.26	3.9	136
2005/09	17	6	0.22	5.1	139
2005/09	17	9	0.21	4.9	143
2005/09	17	12	0.26	4.0	119
2005/09	17	15	0.27	4.4	152
2005/09	17	18	0.26	4.2	116
2005/09	17	21	0.32	3.5	126
2005/09	18	0	0.65	4.0	126
2005/09	18	3	1.20	5.6	105
2005/09	18	6	1.02	5.5	104
2005/09	18	9	1.43	5.9	104
2005/09	18	12	1.97	6.2	98
2005/09	18	15	3.07	8.1	105
2005/09	18	18	2.47	7.1	94
2005/09	18	21	3.04	8.0	133
2005/09	19	0	2.27	7.5	153
2005/09	19	3	1.82	7.3	152
2005/09	19	6	1.50	6.1	154
2005/09	19	9	1.00	5.4	146
2005/09	19	12	1.02	5.2	148
2005/09	19	15	0.82	5.2	141
2005/09	19	18	0.83	5.5	137
2005/09	19	21	0.81	5.4	129
2005/09	20	0	0.75	4.2	132
200509	20	3	0.75	4.7	128

4. Considerations on wave characteristic

Based on about one-year data by TEDI-PORT from July 2005 to August 2006, generally in rainy season high waves are occurred than dry season comparatively.

The statistic data of wave heights and directions show that SE wave direction is dominant. In the case of high waves, SSE direction is dominant. As to wave period, SSE wave has the longer period, however, the wave steepness, Figure 5.1.14 and Figure 5.1.15, show there is no any significant deference in terms of wave directions.

Therefore, it is concluded that there is no much seasonal variation in wave magnitude. And against SSE wave, it is seems that there is no influence from sea swell propagating from Gulf of Tonkin.

5.2.5 Results of Field Investigation on 2011

1) Location Map of Field Investigation

Figure 5.2.19 Location Map of Field Investigation in 2011

Table 5.2.14 List of Investigation Point and Detailed Information

No	Name of Point	VN2000 COORDINATE SYSTEM NORTHING (m)	VN2000 COORDINATE SYSTEM EASTING (m)	Depth (m)	Kind of Survey	Name of Equipment
1	C1TT	2295548.662	624436.365	-5.982	Current & turbidity	Sontek Argonaut & OBS3A
2	C2TT	2294265.467	625343.405	-5.44	Current & turbidity	Sontek triton & OBS3A
3	C3TT	2292895.849	626343.043	-7.015	Current & turbidity	Sontek Argonaut & OBS3A
4	C4TT	2288882.907	629799.401	-13.462	Current & turbidity	Sontek Argonaut & OBS3A
5	C5TT	2294010.968	618766.255	-4.738	Current & turbidity	Sontek Argonaut & OBS3A
6	C6TT	2284517.418	632738.151	-20.899	Wave and Current	Nortek AWAC-AST
7	R1TT	2304983.077	607339.253	-4.6	SS survey	Flow Quest
8	R2TT	2303188.453	616302.881	-5.3	SS survey	Flow Quest
9	R3TT	2306197.804	616875.901	-9.5	SS survey	Flow Quest
10	R4TT	2305305.463	619523.751	-3.14	SS survey	Flow Quest
11	R5TT	2301800.554	620578.435	-3.64	SS survey	Flow Quest

2) Waves and Period

Wave and Period (C1 to C5)

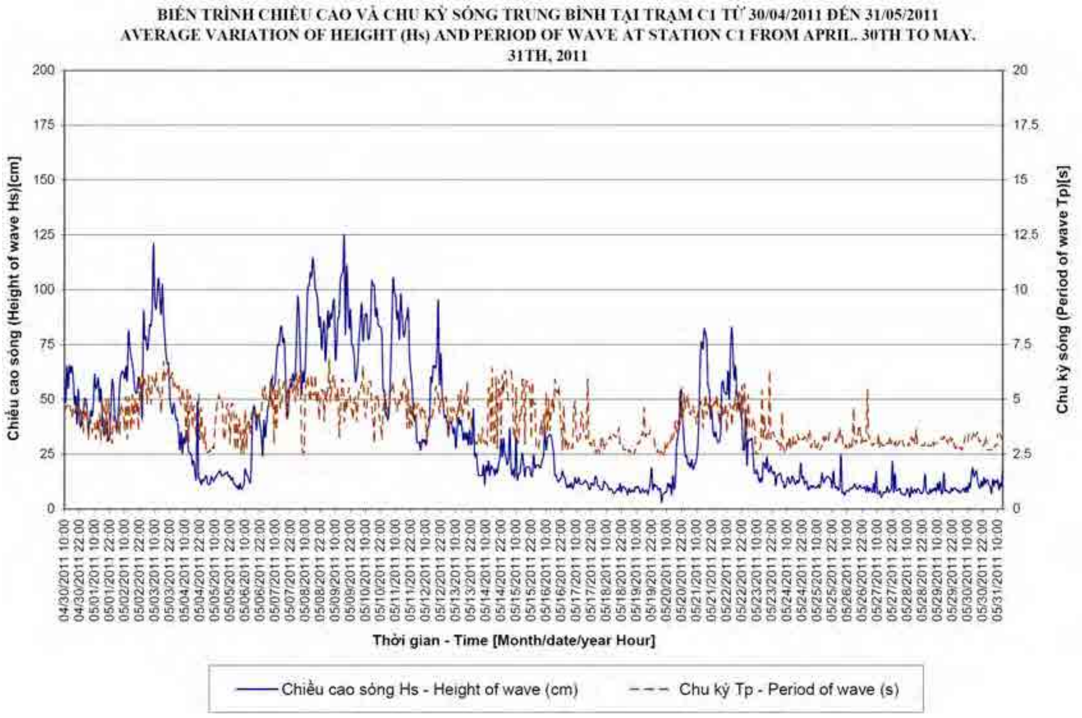


Figure 5.2.20 Raw Data of wave observation (1) (C1)

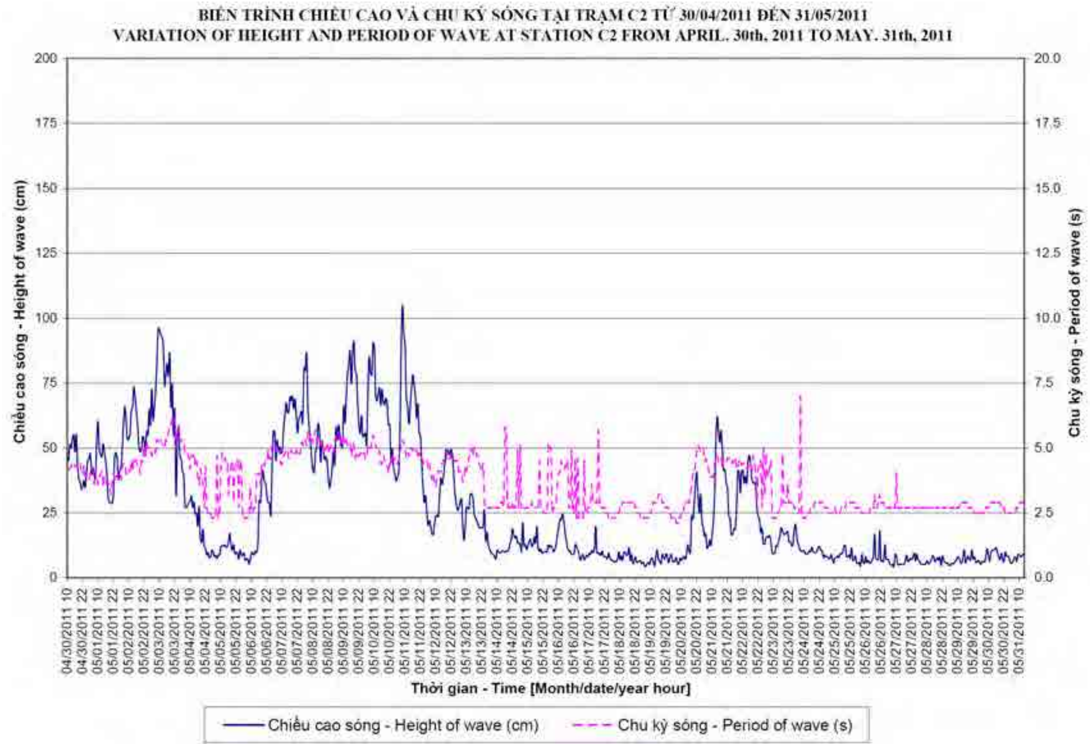


Figure 5.2.21 Raw Data of waves observation (2) (C2)

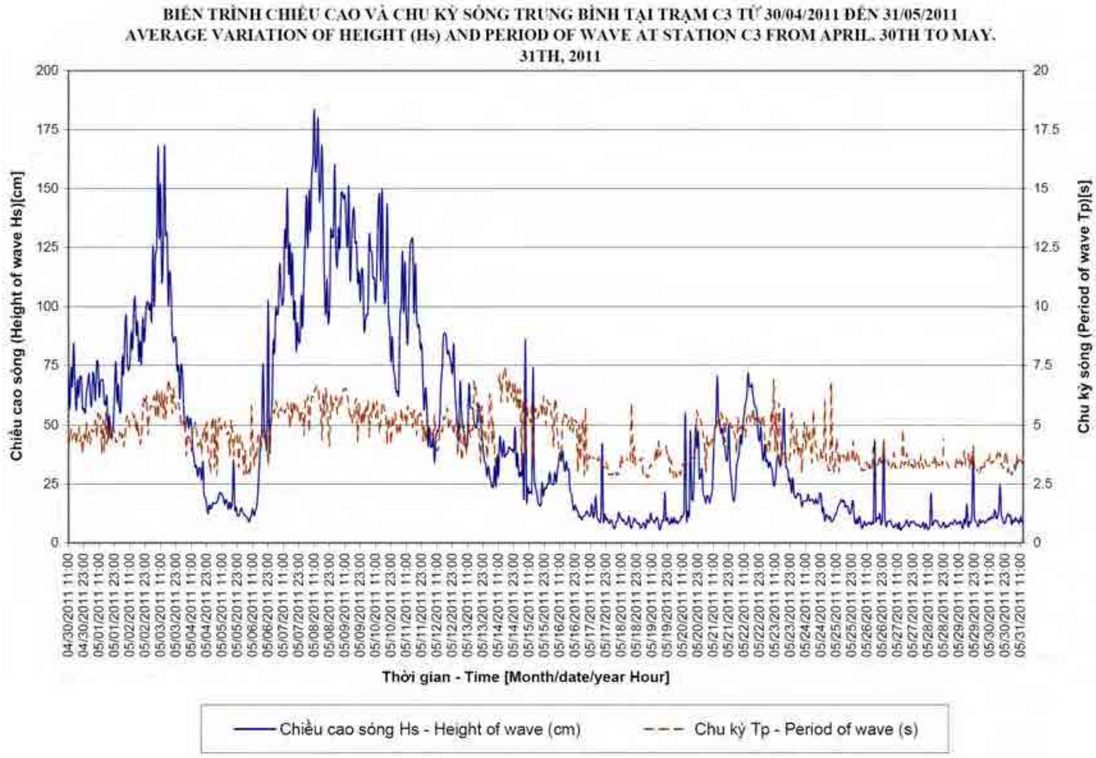


Figure 5.2.22 Raw Data of waves observation (3) (C3)

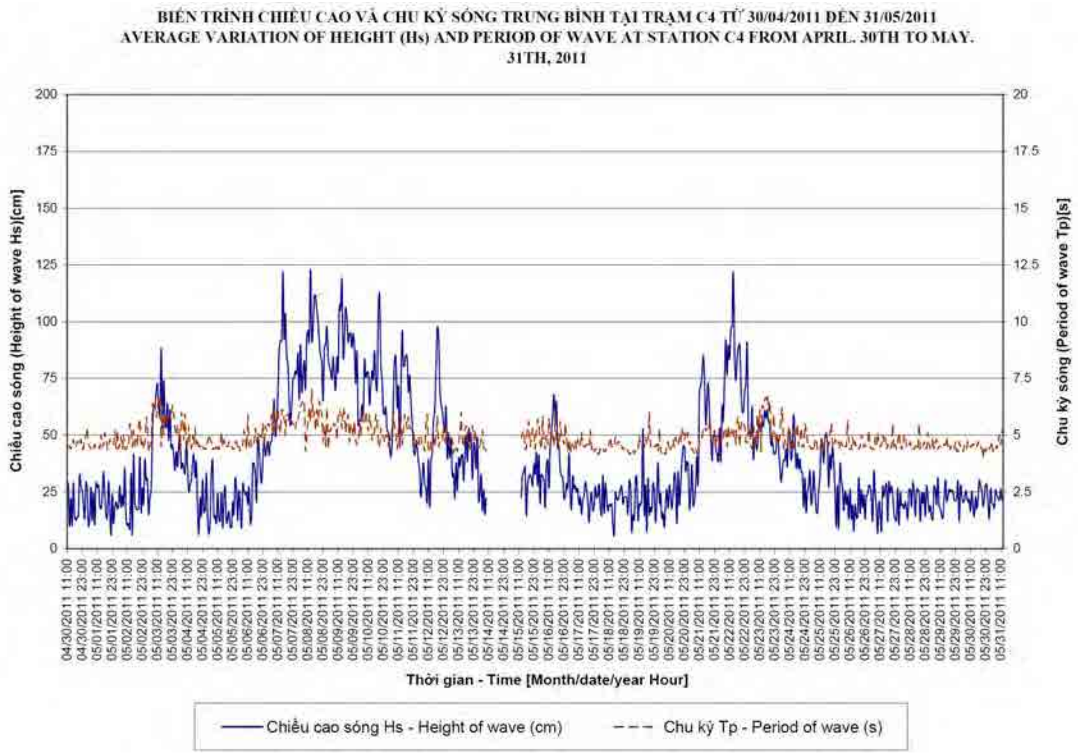


Figure 5.2.23 Raw Data of waves observation (4) (C4)

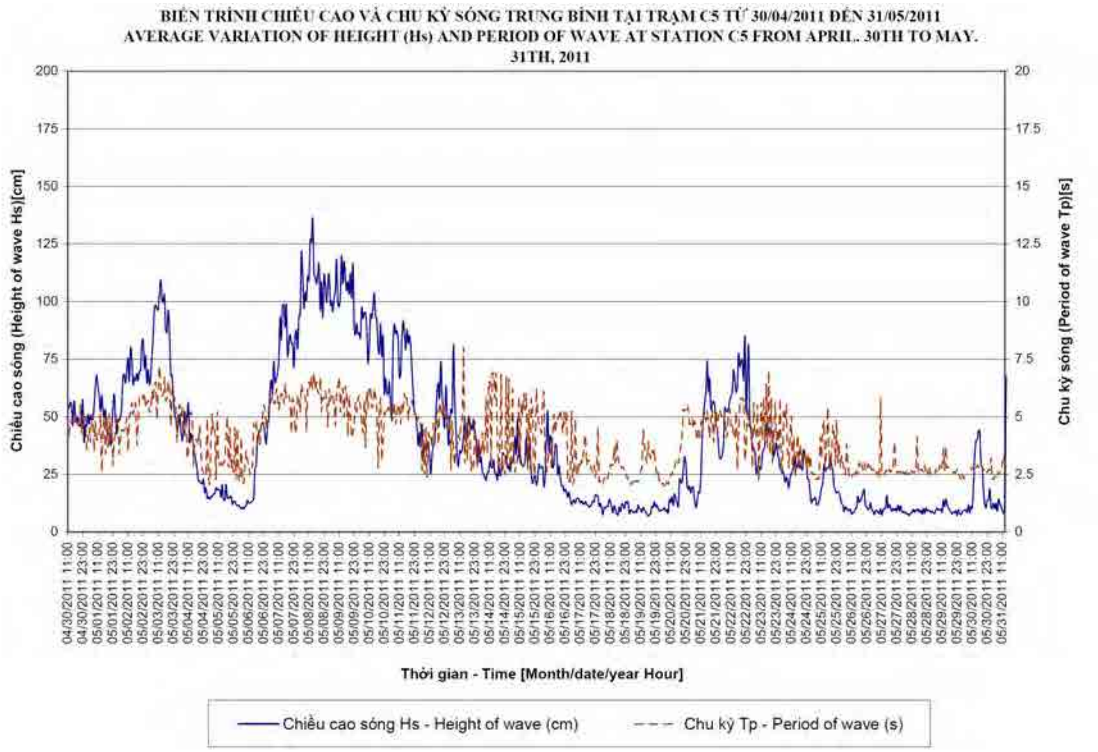


Figure 5.2.24 Raw Data of waves observation (5) (C5)

3) Suspended Solid

C1-C5

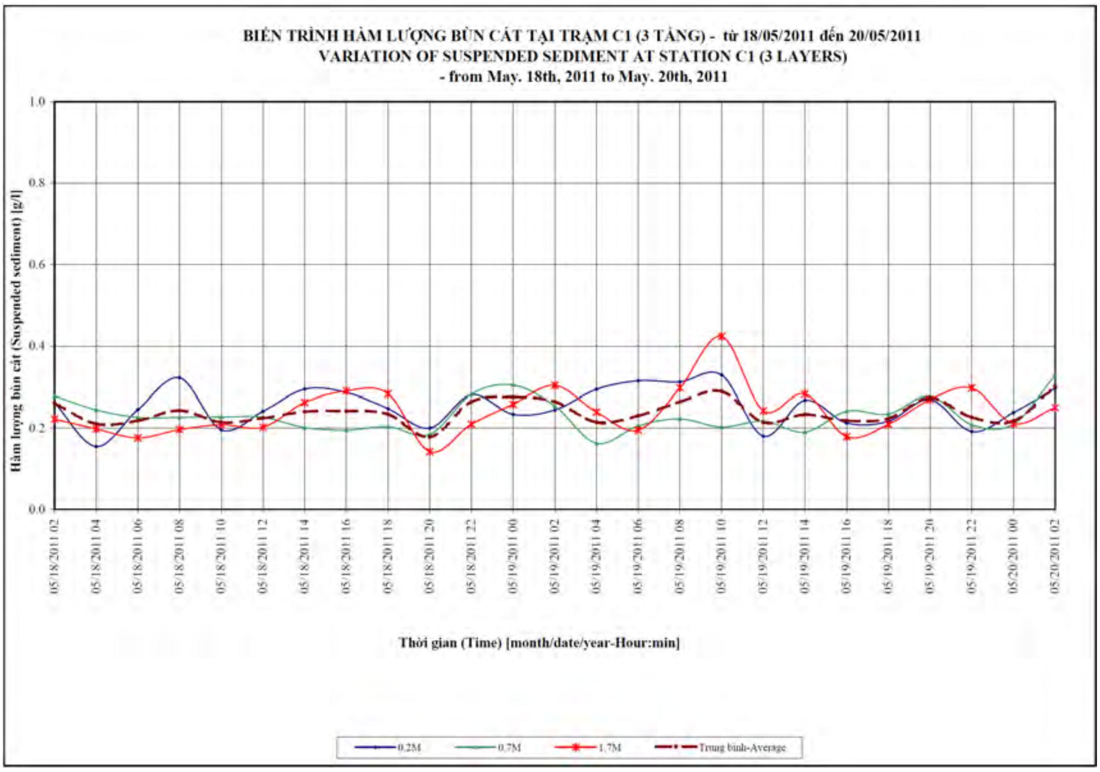


Figure 5.2.25 Raw Data of SS (1) (C1)

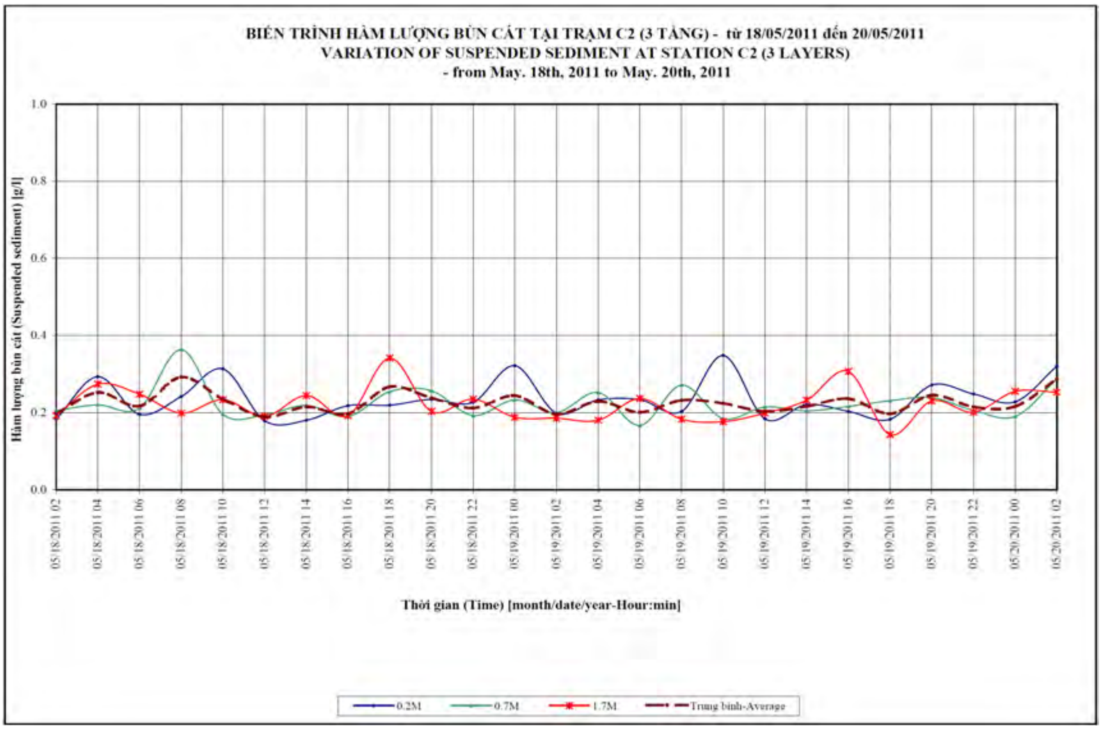


Figure 5.2.26 Raw Data of SS (2) (C2)

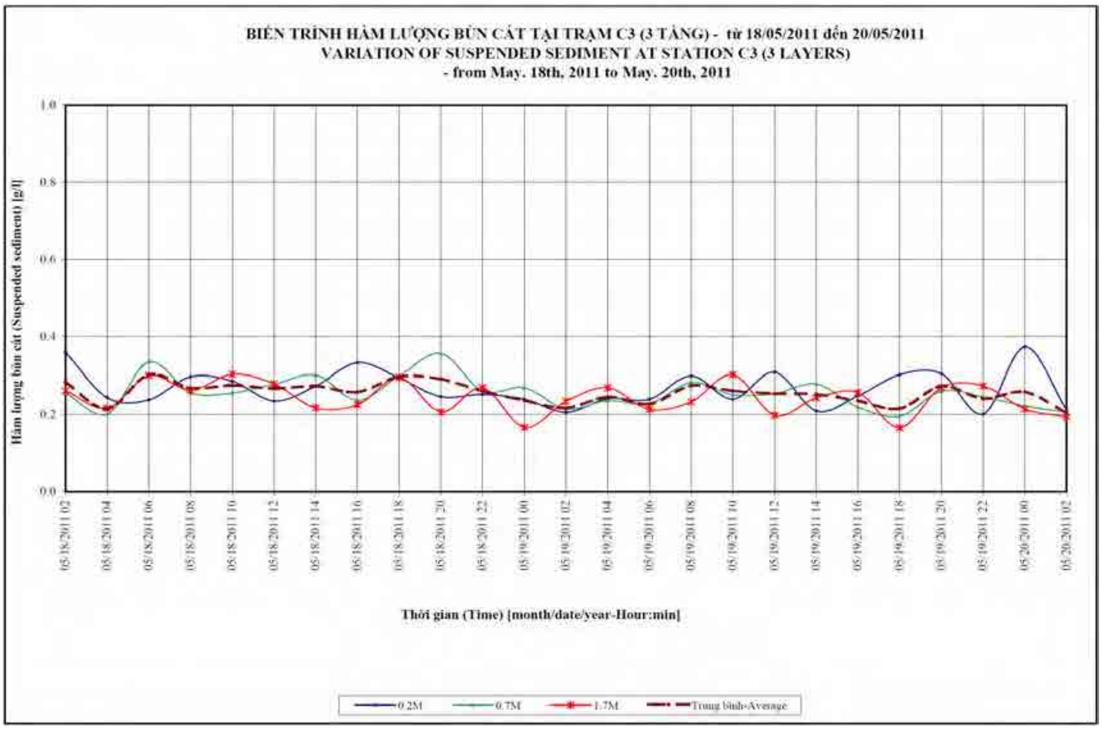


Figure 5.2.27 Raw Data of SS (3) (C3)

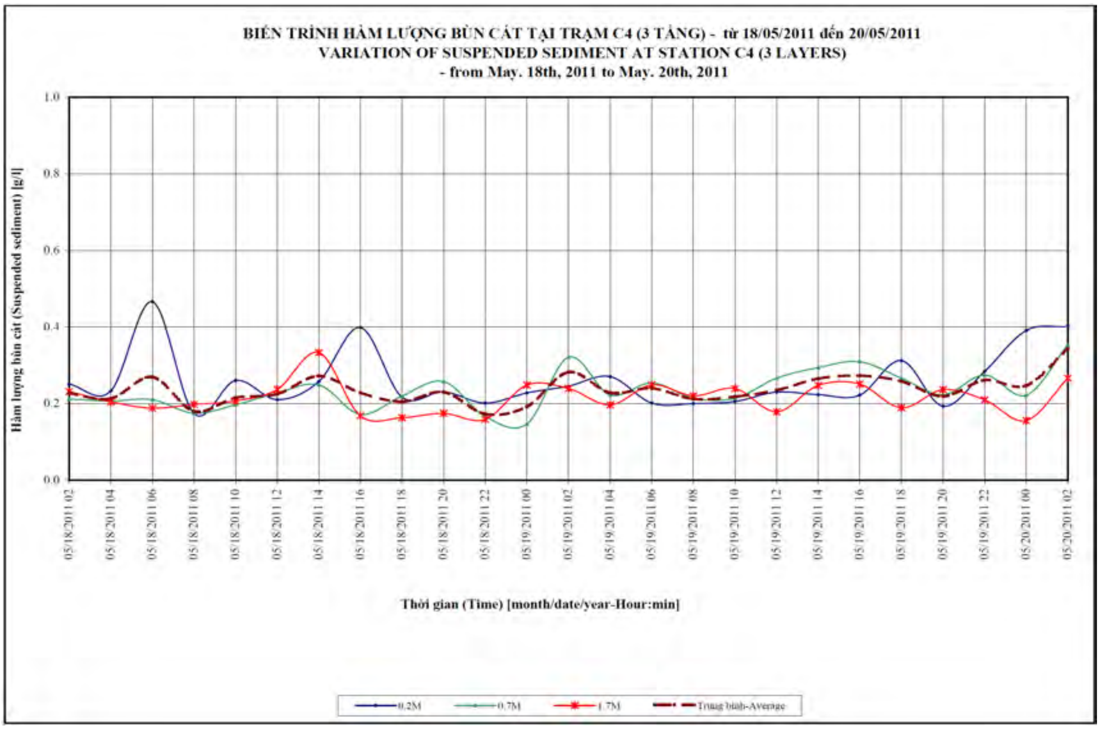


Figure 5.2.28 Raw Data of SS (4) (C4)

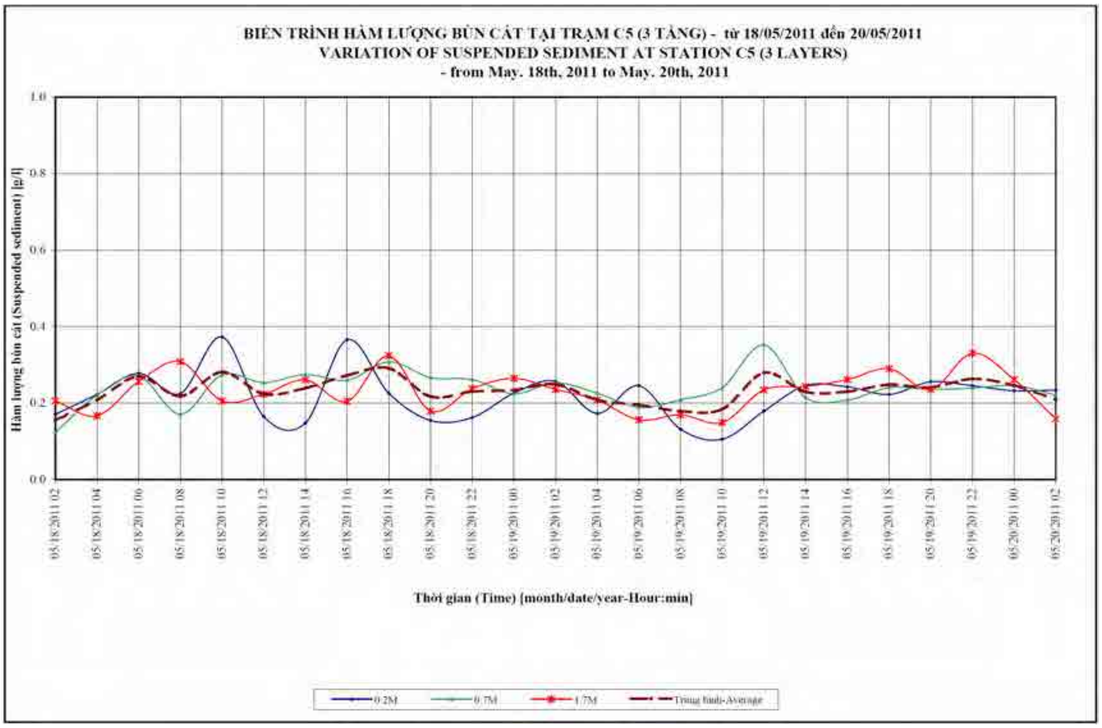


Figure 5.2.29 Raw Data of SS (5) (C5)

4) Discharge from Rivers

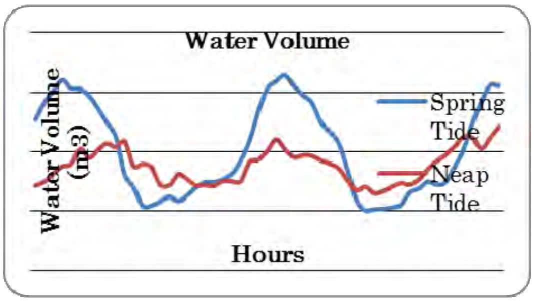
Total Discharge and SS Volume is calculated in Table 5.2.15.

Table 5.2.15 Measured daily discharge of Suspended Soil

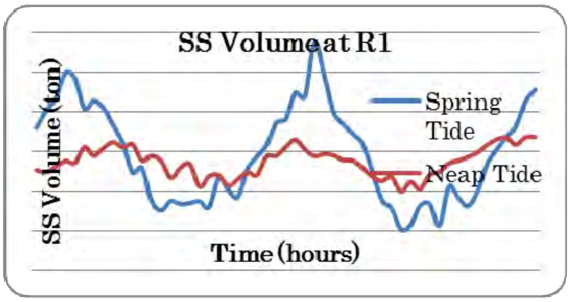
Date	Period (Hours)	Discharge of Suspended Soil (ton per day)		
		Bach Dang River (R1)	Ha Nam Canal (R2)	Lach Huyen (R5)
Neap Tide				
From 10:00 27 May 2011 to 14:00 29 May 2011	52	2,790	-42	25,372
Spring Tide				
From 10:00 2 June 2011 to 14:00 4 June 2011	52	12,466	1,063	2,155

* Based on TEDI Survey in 1992 at the point near R1, discharge of suspended soil is measured 2,300 ton per day in August 1990.

R1 station

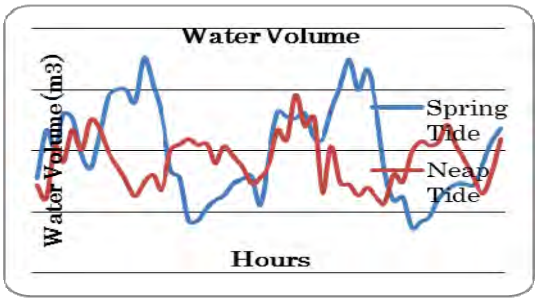


Water discharge

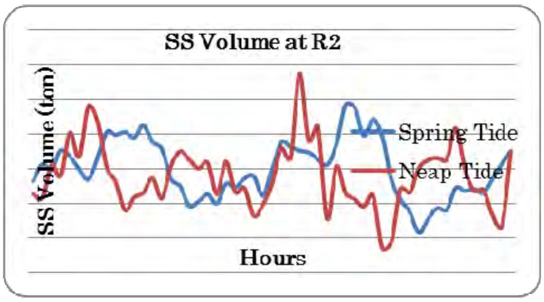


SS Volume

R2 Station

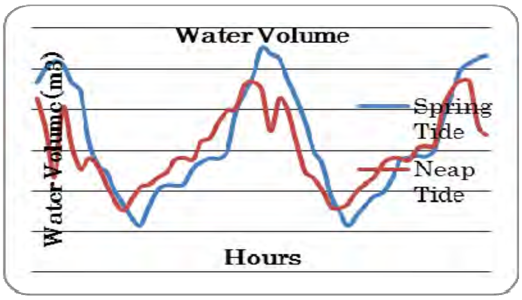


Water Volume



SS Volume

R5 Station



Water Volume

SS Volume

Figure 5.2.30 SS and Water Discharge of R1, R2 and R5

5.2.6 Detailed Analysis of Existing Sedimentation on Existing Lach Huyen Access Channel

1) Post-Deepening Bathymetric Surveys

Table 5.2.16 List of Post-Deepening Bathymetry Survey

No.	Date of Survey	JOPCA	SAPROF	D/D	Note
1	2005.10	○	○	○	
2	2006.3			○	
3	2006.5	○		○	
4	2006.8	○		○	
5	2006.11	○	○	○	
6	2007.3			○	
7	2007.6	○	○	○	
8	2007.9	○		○	
9	2007.12		○	○	
10	2008.3			○	
11	2008.5			○	
12	2008.6		○	○	
13	2008.8			○	
14	2008.10			○	
15	2008.12		○	○	
16	2009.2			○	
17	2009.4			○	
18	2009.6			○	
19	2009.8			○	
20	2009.10			○	
21	2009.11(SAPROF,30kHz and 200kHz)		○	○	By dual frequency echo sunder
22	2010.3			○	
23	2010.5			○	
24	2010.6			○	
25	2010.8			○	
26	2010.10			○	
27	2010.12			○	
28	2011.5(D/D,30kHz and 200kHz)			○	By dual frequency echo sunder

JOPCA: Japan Overseas Ports Cooperation Association: TECHNICAL GUIDE BOOK FOR THE DEVELOPMENT OF ESTUARINE NAVIGATION CHANNELS
SAPROF: The Preparatory Survey on Lach Huyen Port Infrastructure Construction In Vietnam July 2010, JICA
D/D: The Detailed Design Study Of Lach Huyen Port Project, JICA

2) Analysis of the existing Data of Sedimentation

a) Longitudinal Section of Existing Channel Center

In Figure 5.2.31 the changing of water depth from the seabed line of October 2005 after completion of the existing channel dredging is shown based on the post survey. The top blue line indicates the original seabed elevation before the Hai Phong Port channel construction.

- The reach that was over dredged is from 34km - 37km.
- It seems that in this reach a rapid sedimentation occurred in a half year.
- In the outer channel from 34km to 41km+500, there was huge sedimentation.
- In the inner channel from 34km, less sedimentation was occurred comparing with the outer channel. Also In this reach, sedimentation and erosion are repeated.

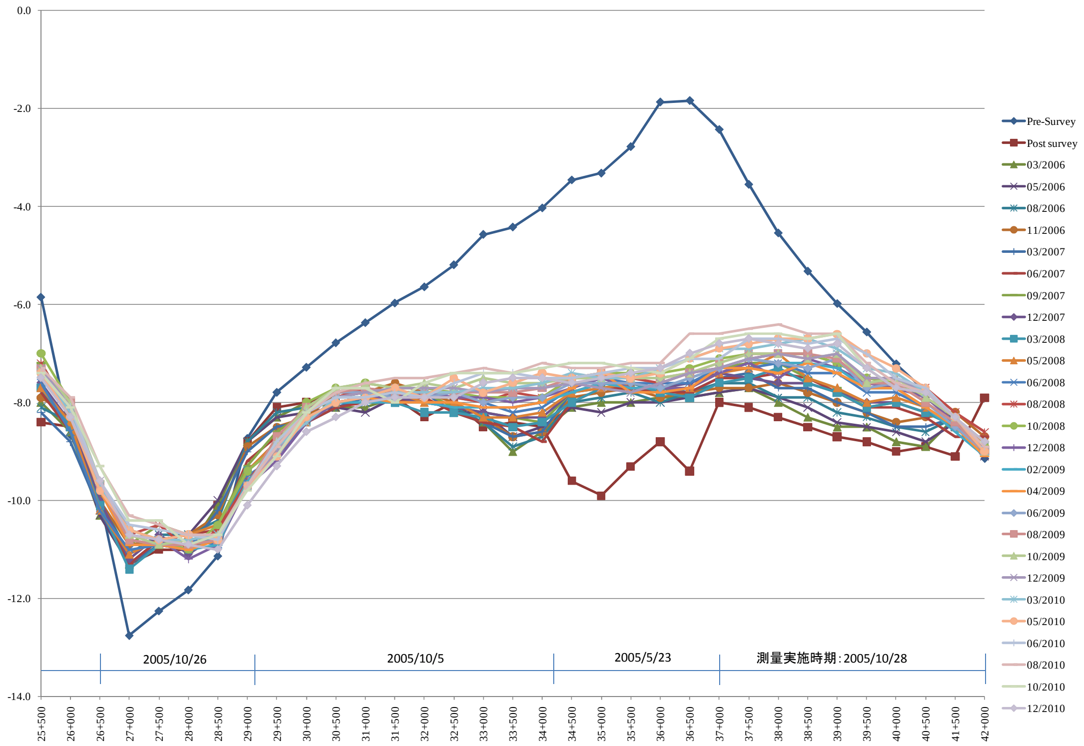


Figure 5.2.31 Longitudinal Section of Existing Channel Center in time sequence

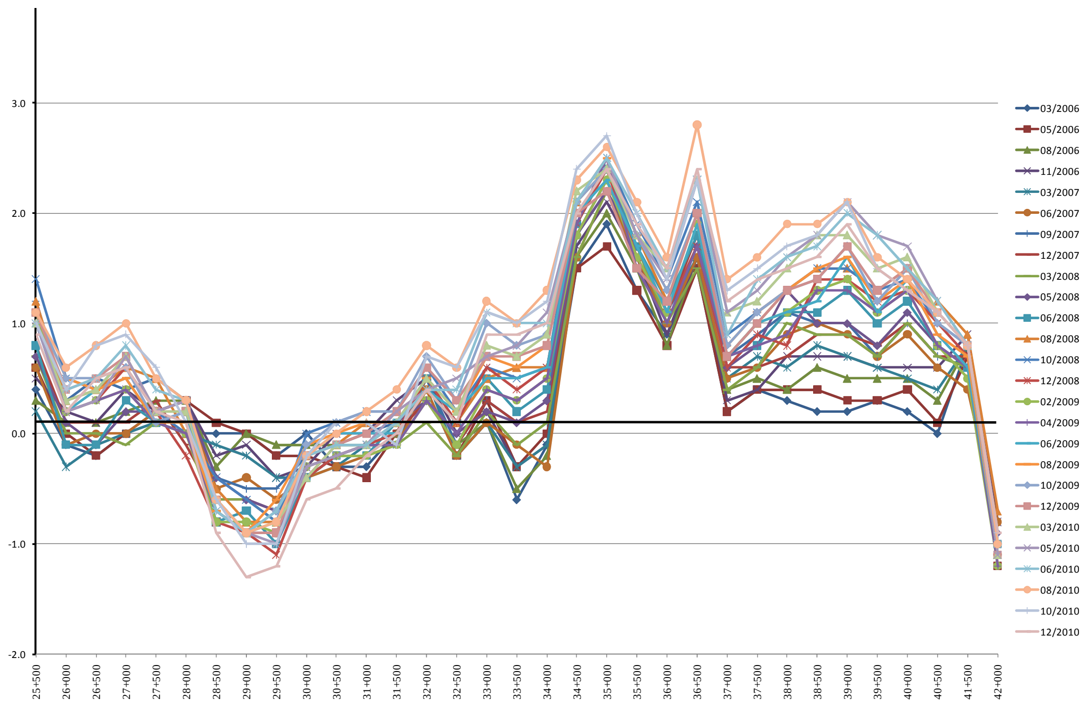


Figure 5.2.32 Changing of Water Depth in the Existing Channel Center from the Post Survey Depth (October 2005)

b) Characteristic of Sedimentation

Figure 5.2.33 shows the accumulated sediment volume in the interval of 500m from October 2005 of Post survey that the construction has been completed. The post survey in the reach from 34km to 37km was carried out in May 2005. This volume calculation is based by the area of 150m both sides from the center line of Channel. And this volume excludes the volume of slope collapse.

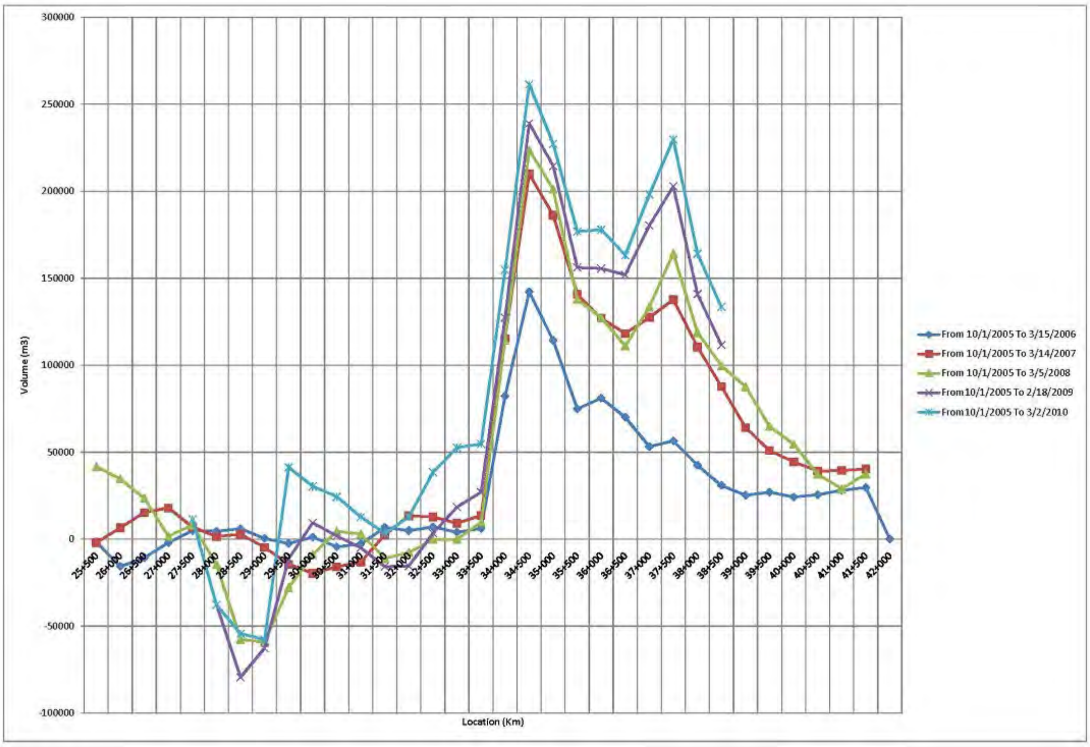


Figure 5.2.33 Accumulated Sedimentation Volume from October 2005 (After completion of Channel Dredging Construction)

Figure 5.2.34 shows the accumulated sediment volume in the whole channel in five years from October 2005. In the graph, two regression lines are shown with a straight line and a quadrant line. Clearly in the first year the enormous sedimentation occurs.

The gradient of this line is equivalent to a sediment rate. By the straight line, the average sedimentation rate in the five years is estimated at 40,000-50,000 m^3 per year and by the quadrant line, the average sediment rate in the first year is 1,200,000-1,5000,000 m^3 per year.

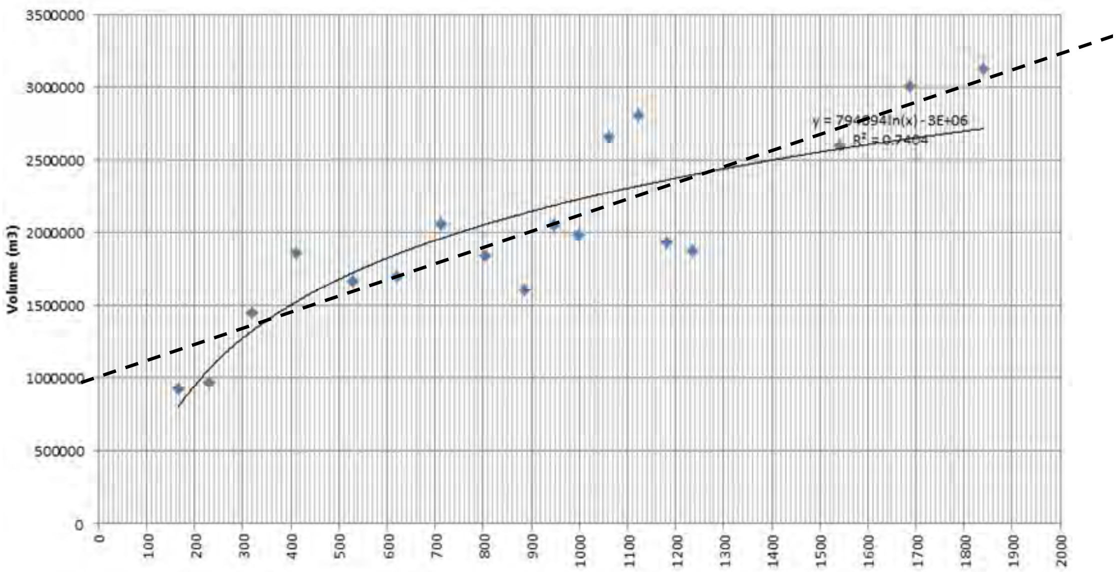


Figure 5.2.34 Accumulated Sedimentation Volume in whole Channel in Five Years

Figure 5.2.35 shows the sediment volume by each Post-Deepening Bathymetry Survey. This estimated volume is a sediment volume in the time elapse between each post-deepening bathymetry survey.

And Figure 5.2.36 shows the sediment volume together with wave energy by Hon Dau. Generally, there is the tendency that in wet season with rough wave, sedimentation is larger and in dry season under calm condition, sedimentation is smaller.

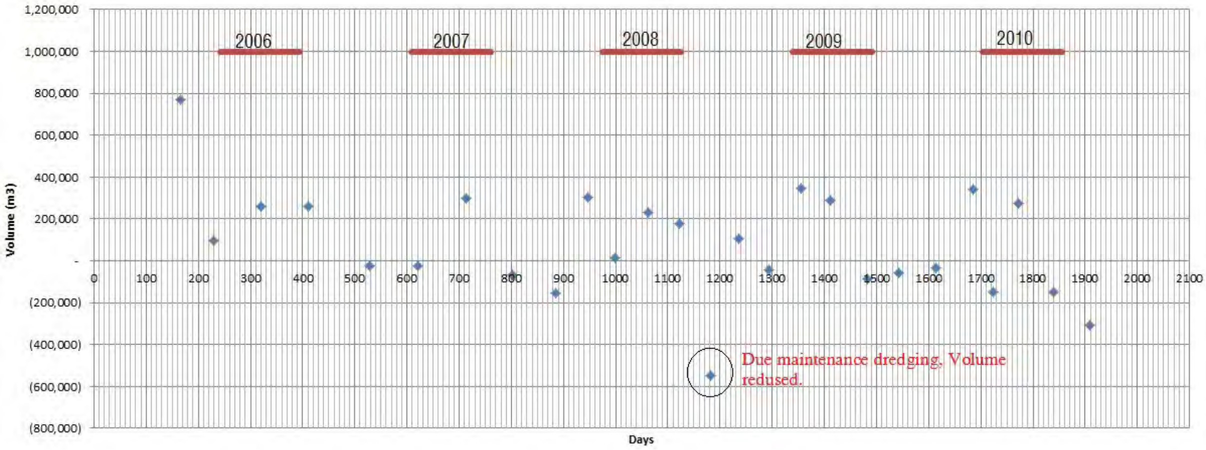


Figure 5.2.35 Sedimentation Volume by each Post-Deepening Bathymetry Survey

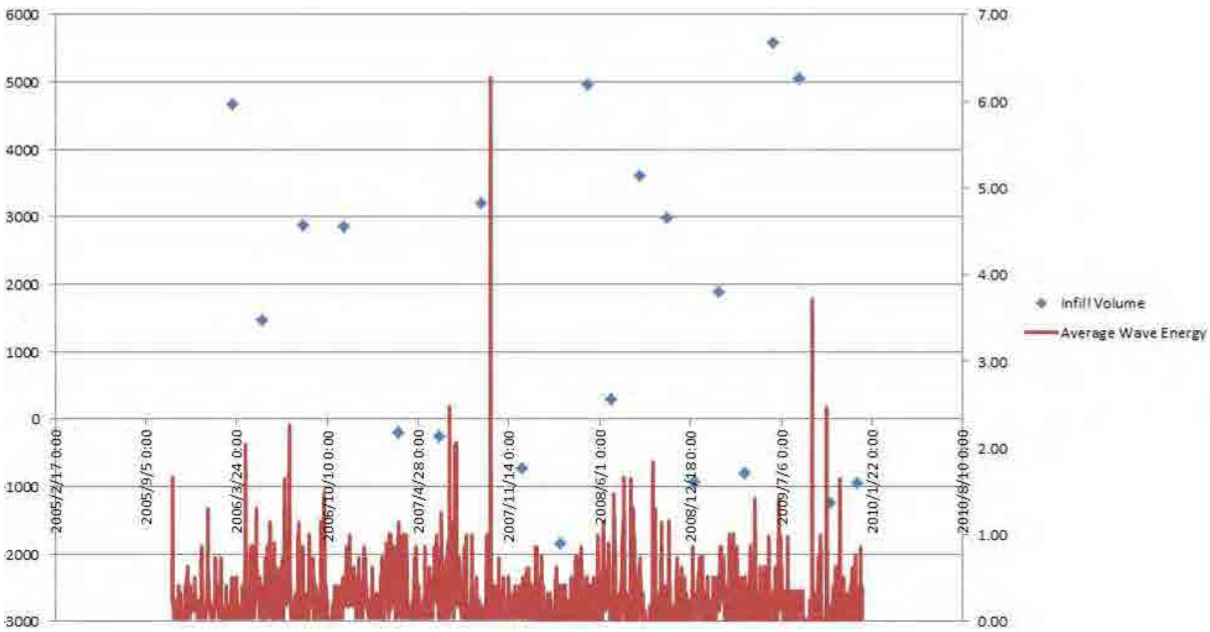


Figure 5.2.36 Relationship of Wave Energy and Sedimentation

c) Slope Collapse

The volume of slope collapse is calculated in Table 5.2.17.

Table 5.2.17 Volume of Slope Collapse

	Volume (m3)					
Lach Huyen	Post vs 1st(2006)	1st(2006) vs 1st(2007)	1st(2007) vs 1st(2008)	1st(2008) vs 1st(2009)	1st(2009) vs 1st(2010)	Total
Left	32,405.0	80,507.5	133,730.0	13,625.0	14,260.0	**274,527.5**
Right	57,967.5	68,995.0	94,140.0	69,757.5	6,175.0	**297,035.0**
Total (m3)	**90,372.5**	**149,502.5**	**227,870.0**	**83,382.5**	**20,435.0**	**571,562.5**

It seems about 200,000 m^3 is in-filled per year in the first three years. And after the first three years, suddenly this volume is decreased, drastically.

d) Bathymetry by dual frequency echo sounder

Figure 5.2.37 shows the bathymetry by dual frequency echo sounder (200 kHz and 30 kHz).

The difference of bathymetry between 200 kHz and 30 kHz is generally 10cm and 20cm in maximum.

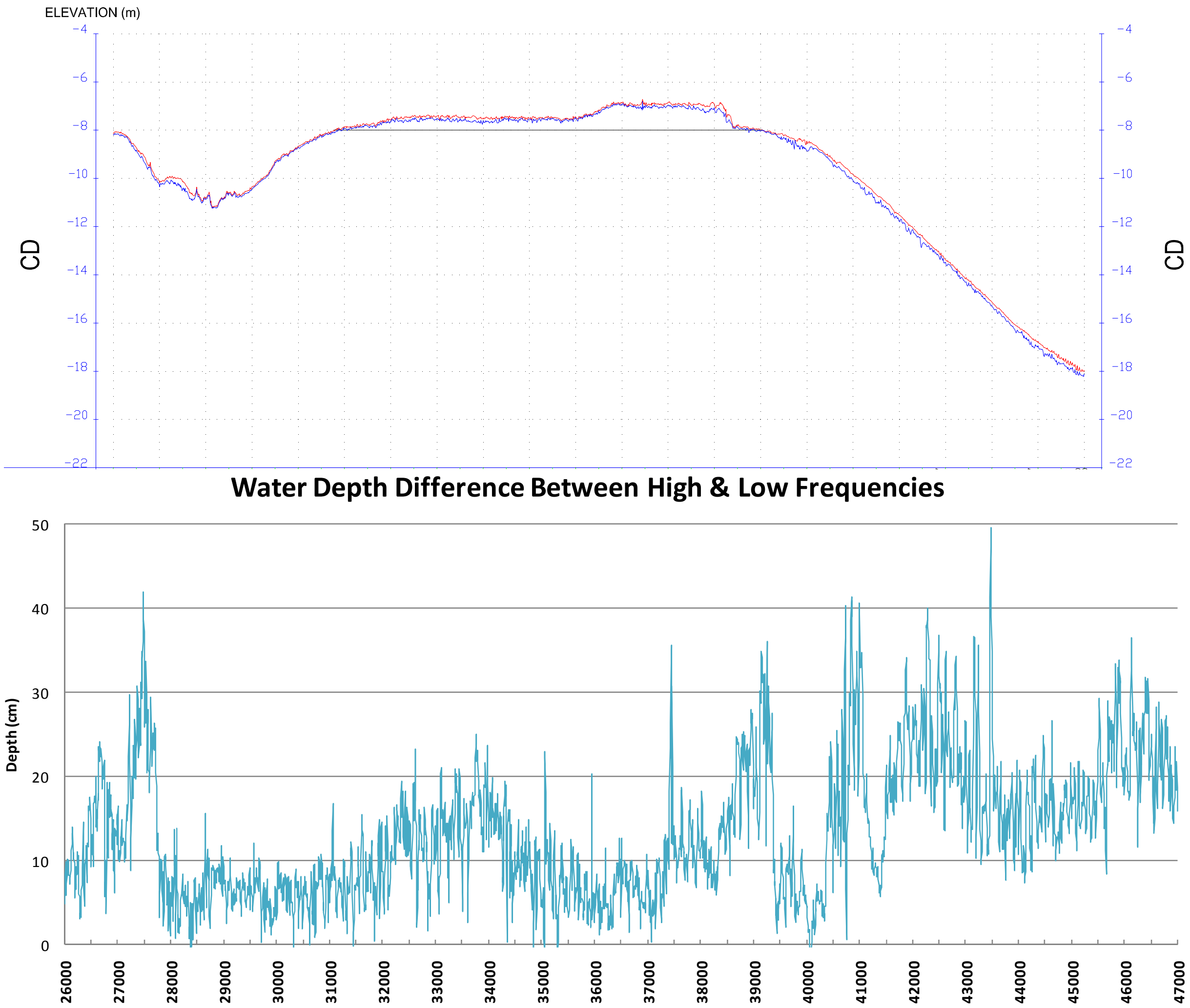


Figure 5.2.37 Difference of Bathymetry between 200 kHz and 30kHz (May 2011)

e) Changing Bathymetry of Existing Channel Cross Section

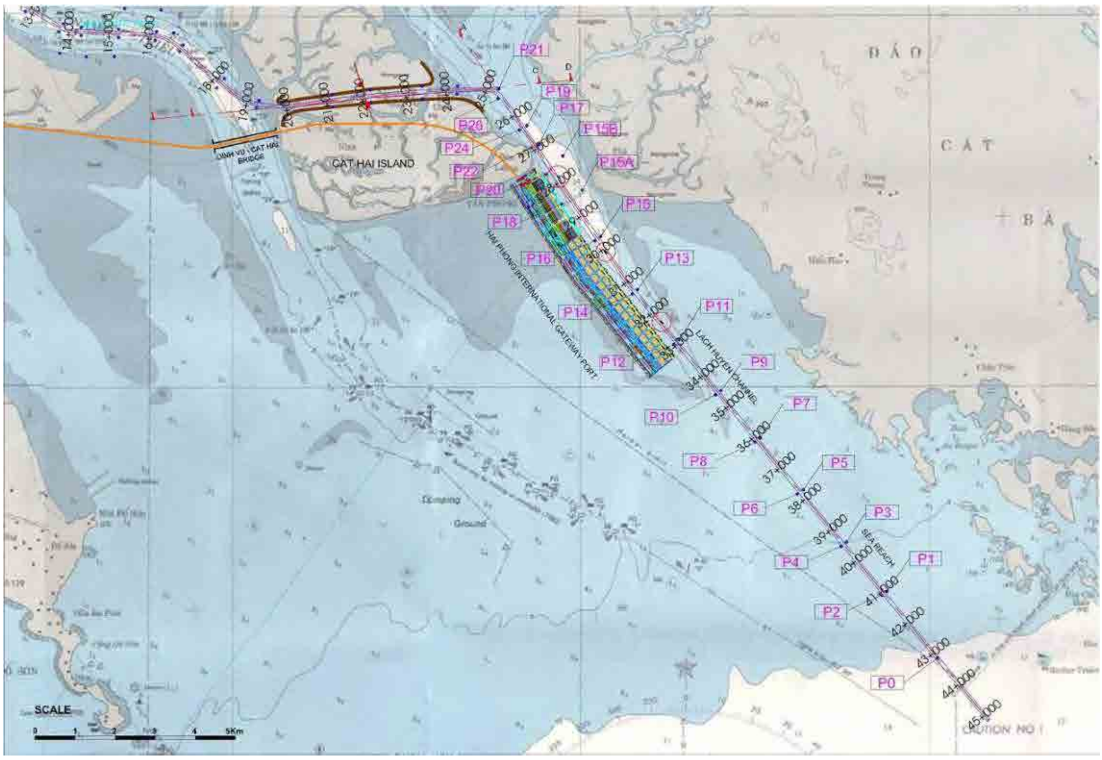


Figure 5.2.38 Location Map of cross Sections

The sections from 26km to 42km are shown in Appendix 5-1 to present the changing of channel water by sedimentation in time sequence.

5.3 Sediment Transport Modeling

5.3.1 Selection of Modeling

Modeling is selected in consideration with the following factors.

Considering the major sediment materials into the existing channel is silt and clay and high concentration mud, the proposed modeling shall functions to simulate rolling up, drifting and settling down the seabed material as well as to simulate the movement of high concentration mud. Then a model applied for the project is **"Advection Diffusion of suspended materials" and "Density flow of high concentrate settled mud layer model"**.

The study is included to propose the countermeasures to reduce sedimentation. The optimum top elevation of the countermeasures is required to study and verify by the sediment transport modeling. In order to simulate the effectiveness of the alternative height of countermeasure, **"multi-layer model"** shall be incorporated.

By these two points, the composite modeling is applied as "Multi-layer diffusion suspended and Density flow of high concentrate settled mud layer modeling".

5.3.2 Composite Model

The modeling employed in the study is the Composite Model with "Advection Diffusion model of suspended materials by multi-layers level modeling" and "Density flow of high concentration settled mud layer modeling". It is important that the modeling has several functions to reproduce the behaviors of material particles under the external forces by current forces and wave agitations.

And the periodical bathymetric data by maintenance surveys is available for five years from May 2005 to June 2011. Basically, the suspended material is supply from the Bach Dang River through Cam River and sediment in Nam Trieu channel area. It is noticed there is "Fluid-Mud" in this area and this fluid-mud might be diffused into the deeper area of Hai Phong Bay. However, Nam Trieu area is far distance from Lach Huyen area so that the influence by the fluid-mud will be minor. In order to verify the influence of the sediment fluid-mud in offshore of the Lach Huyen channel, it is also convenient to apply the Composite Modeling

1) Behavior Pattern of Seabed Mud

Mud is suspended from the seabed and/ or fluid mud layers.

Lifted suspended soil is transported and diffused by current, and then the concentration of suspended soil keeps changing.

Suspended soil is sunken into the seabed (Ds) and forms fluid mud layer on the seabed.

In the case that no fluid mud layer is settled on the seabed, mud is lifted up and/or eroded from the seabed, and in the case that fluid mud layers is settled on the seabed, mud is lifted and/or eroded from fluid mud layer by bed shear stress. It is assumed that the relation between the suspended and the seabed shear stress is to be equal in the seabed layer and fluid mud layer.

The movement of fluid mud layer obeys the model of Odd and Cooper (1989).

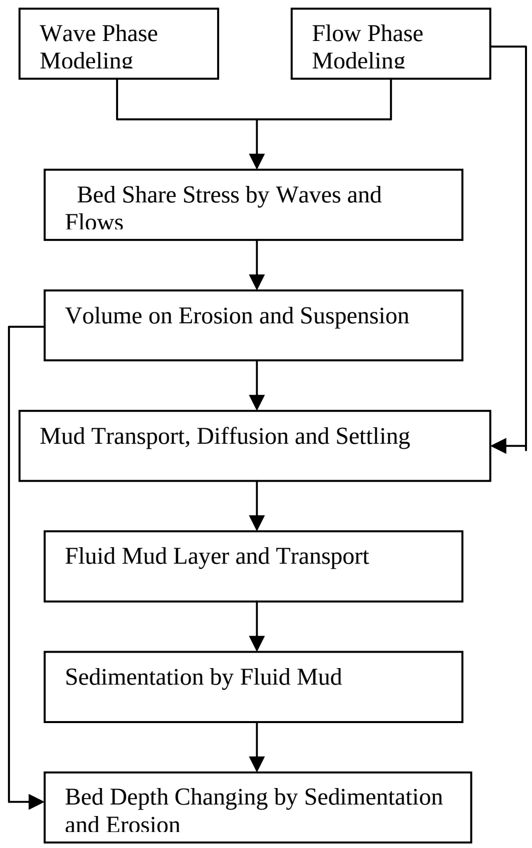
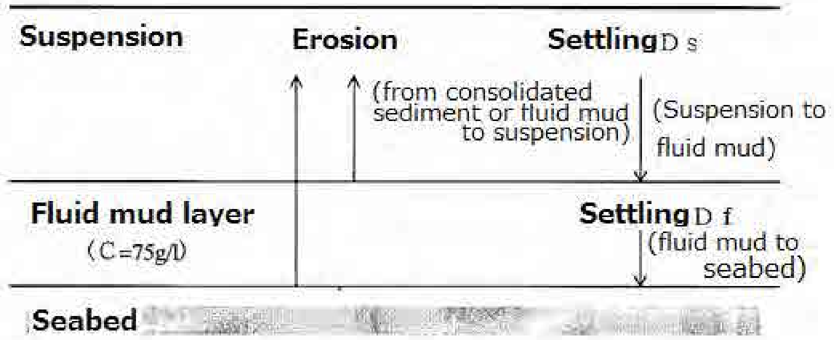


Figure 5.3.1 Flow by Composite Modeling



Source: The ministry of transport of Japan, the forth harbor construction bureau, A society of Mitigation measure for sedimentation, Text book of sedimentation mitigation measure, 1999 May, in Japan

Figure 5.3.2 Pattern of Fluid Mud Movement in Composite Model

5.3.3 External Forces

1) Waves Phase Modeling

For the numerical analysis of wave transformation, SWAN[3] is employed that the wave generation and deformation by geological conditions can assess simultaneously. SWAN is based by Wave Action Balance Equation, and the relationship between wave action (N) and energy spectrum (E) is given as follows.

$$N(\sigma,\theta)=\frac{E(\sigma,\theta)}{\sigma}$$

Where, σ :Relative angular frequency against current (Angular with frame of reference that moves according current) $\sigma = \omega - \vec{k}\vec{U}$ ω : Absolute angular frequency against current, $\vec{k}$: Wave number-frequency spectrum、$\vec{U}$: Current spectrum

Equation of SWAN is shown as follows.

Wave action balance equation

$$\frac{\partial}{\partial t}N+\frac{\partial}{\partial x}(C_x\cdot N)+\frac{\partial}{\partial y}(C_y\cdot N)+\frac{\partial}{\partial \sigma}(C_\sigma\cdot N)+\frac{\partial}{\partial \theta}(C_\theta\cdot N)=\frac{S}{\sigma}$$

Where, C_x, C_y , C_θ, C_σ are propagating velocity and given by the following equations.

$$C_x = C_g\cdot\cos\theta+U$$
$$C_y = C_g\cdot\sin\theta+V$$
$$C_\theta=\frac{\sigma}{\sinh 2kh}\left(\sin\theta\frac{\partial h}{\partial x}-\cos\theta\frac{\partial h}{\partial y}\right)$$
$$+\cos\theta\cdot\sin\theta\frac{\partial U}{\partial x}-\cos^2\theta\cdot\frac{\partial U}{\partial y}+\sin^2\theta\cdot\frac{\partial V}{\partial x}-\sin\theta\cdot\cos\theta\frac{\partial V}{\partial y}$$

Where, C_g :Group velocity U ,V : Component velocity

And the right side of the basic equation S_{in} is shown as follows.

[3] http://www.swan.tudelft.nl/

$$S = S_{in} + S_{ds} + S_{bf} + S_{br} + S_{nl3} + S_{nl4}$$

Where, S_{in} :Energy transfer from winds to waves S_{ds} : Energy disperse by wind chop crested waves

S_{bf} :Energy disperse by bottom friction coefficient (in this study this factor is neglected)

S_{br} : Energy disperse by orography breaking waves, S_{nl3} : Energy transport by 3 waves non-linear interaction, S_{nl4} : Energy transport by 4 waves non-linear interaction

By SWAN, energy disperses by orography breaking waves are computed by the Bore Model with Battjes and Janssen (1978).

$$S_{br} = D_{tot} \frac{E(\sigma,\theta)}{E_{tot}}$$

Where,

$$E_{tot} = \int_0^{2\pi} \int_0^{\infty} E(\sigma,\theta) d\sigma d\theta$$
$$D_{tot} = -\frac{1}{4} \alpha_{BJ} Q_b \left(\frac{\bar{\sigma}}{2\pi} \right) H_m^2$$

Q_b : Probability of occurrence of breaking waves, H_m: Limiting wave height

$\bar{\sigma}$: Mean wave frequency, d : water depth

Where, probability of occurrence of breaking waves (Q_b) and limiting wave height are shown as follows.

$$\frac{1-Q_b}{\ln Q_b} = -8 \frac{E_{tot}}{H_m^2}$$
$$H_m = \gamma d$$

Parameter of α_{BJ} and γ are α_{BJ}=1, γ=0.73, respectively.

And directional function of multi-directional waves is type of $\cos^n\theta$. n=2 (S_{max}=10) is applied based on the wave conditions employed to numerical simulation.

2) Current Phase Modeling

Current phase modeling is computed by continuity equation and momentum equation of fluid using finite difference method. Equation is shown as follows.

a) Continuity equation

[Total layers]

$$\frac{\partial \eta}{\partial t} + \frac{\partial}{\partial x}\left(\sum_{k=1}^{k=k\max} M_k \right) + \frac{\partial}{\partial y}\left(\sum_{k=1}^{k\max} N_k \right) = 0 \quad , \quad M = uh 、 N = vh$$

[Each layer]

$$w_{k-1/2} + \frac{\partial}{\partial x} M_k + \frac{\partial}{\partial y} N_k = w_{k+1/2}$$

Where, η: water surface elevation u and v: Horizontal mean velocities

w: Vertical mean velocities, h: Thickness of layers, $k_{\max}$:Number of layers Subscript k denotes the k layer

b) Momentum equation

[x direction]

$$\frac{\partial M_k}{\partial t} + \frac{\partial M u_k}{\partial x} + \frac{\partial M v_k}{\partial y} + \frac{(wM)_{k-1/2} - (wM)_{k+1/2}}{h_k}$$
$$= fN_k - \frac{h_k \partial p_k}{\rho_k \partial x} + A_x \frac{\partial^2 M_k}{\partial x^2} + A_y \frac{\partial^2 M_k}{\partial y^2}$$
$$+ h_k \left[\frac{\gamma^2 (u_{k-1} - u_k) \Delta V_{k-1/2}}{h_{k-1/2}} - \frac{\gamma^2 (u_k - u_{k+1}) \Delta V_{k+1/2}}{h_{k+1/2}} \right]$$

【y direction】

$$\frac{\partial N_k}{\partial t} + \frac{\partial N u_k}{\partial x} + \frac{\partial N v_k}{\partial y} + \frac{(wN)_{k-1/2} - (wN)_{k+1/2}}{h_k}$$
$$= fM_k - \frac{h_k \partial p_k}{\rho_k \partial y} + A_x \frac{\partial^2 N_k}{\partial x^2} + A_y \frac{\partial^2 N_k}{\partial y^2}$$
$$+ h_k \left[\frac{\gamma^2 (v_{k-1} - v_k) \Delta V_{k-1/2}}{h_{k-1/2}} - \frac{\gamma^2 (v_k - v_{k+1}) \Delta V_{k+1/2}}{h_{k+1/2}} \right]$$

$$\Delta V_{k-1/2} = \sqrt{(u_{k-1} - u_k)^2 + (v_{k-1} - v_k)^2} \quad \Delta V_{k+1/2} = \sqrt{(u_k - u_{k+1})^2 + (v_k - v_{k+1})^2}$$
$$\frac{1}{\rho} \frac{\partial p}{\partial x} = g \frac{\partial \eta}{\partial x} + \frac{g}{\rho} \int_z^\eta \frac{\partial p}{\partial x} dz \quad \frac{1}{\rho} \frac{\partial p}{\partial y} = g \frac{\partial \eta}{\partial y} + \frac{g}{\rho} \int_z^\eta \frac{\partial p}{\partial y} dz$$

Where, ρ: Density that is function of salinity, f: Coriolis parameter, p:Pressure

A_x and A_y:Horizontal eddy viscosities in x and y directions, respectively, g:Acceleration of gravity, γ^2: Friction coefficient $\gamma^2_{k\max} = gn^2 / h^{1/6}$ for bottom layer, $\gamma^2_k = const.$ for middle layer, n: Manning's roughness coefficient

3) Mass Conservation equations for SS

a) Advection-diffusion of SS

SS advection-diffusion is computed by finite difference equation using current that is simulated in current phase modeling.

Equation is shown as follows.

$$\frac{\partial(C_k h_k)}{\partial t} = -\frac{\partial}{\partial x}(M_k C_k) - \frac{\partial}{\partial y}(N_k C_k) - ((w + w_s)C)_{k-1/2} + ((w + w_s)C)_{k+1/2}$$
$$+\frac{\partial}{\partial x}\left(K_x h_k \frac{\partial C_k}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y h_y \frac{\partial C_k}{\partial y}\right) + \left(K_z \frac{\partial C}{\partial z}\right)_{k-1/2} - \left(K_z \frac{\partial C}{\partial z}\right)_{k+1/2}$$

Where, C: Mean concentration, K_x, K_y, K_z:Horizontal and vertical diffusion coefficients w_s: settling velocity of mud particles

b) Erosion

In the modeling, bottom materials are separately dealt as mud and sand.

Equation formulated by Partheniades (1965) is shown as follows.

$$E = P_m M \left(\frac{\tau_b}{\tau_e} - 1\right)^n$$

Where, E: Rate of erosion from seabed, P_m:Mud ratio of bed materials, M:Erosion rate coefficient, τ_b:Shear stress at bottom, τ_e:Critical shear stress for erosion, *n*: Constant

c) Deposition

Deposition rate is estimated by a similar consideration by Sheng and Lick (1979).

Equation is shown as follows.

$$D = w_s C_{bed}, \quad C_{bed} = \beta C_{k\max}$$

Where, D: settling velocity, C_{bed}:concentration of mud at seabed, β:Correction factor to estimate, C_{bed} from mean concentration of bottom layer, $C_{k\max}$:mean concentration at seabed

And settling velocity is given as follows. (Refer to Figure 5.3.18)

$$w_s = aC^b, \quad (C \le C_h)$$
$$w_s = aC_h^b, \quad (C > C_h)$$

Where, a, b, C_h: empirical constants

4) Fluid mud

In consideration that fluid mud is assumed as Bingham Plastic, which begins to flow under certain share stress, the simulation model for fluid mud is simulated by continuity equation and momentum equation using finite difference method.

a) Continuity equation

Continuity equation for fluid mud is shown as follows.

$$\frac{\partial d_m}{\partial t} + \frac{\partial u_m d_m}{\partial x} + \frac{\partial v_m d_m}{\partial y} - \frac{1}{C_0}\frac{dm}{dt} = 0$$

Where, d_m: Thickness of fluid mud, u_m, v_m:Horizontal velocity, C_0: Concentration of SS (Concentration is constant in fluid mud layer), dm/dt: Changing net mass

dm/dt increases settling from seawater and decreases by erosion and settling into seabed.

b) Momentum equation

Momentum equation is shown as follows.

[x direction]

$$\frac{\partial u_m}{\partial t} + g\frac{\partial \eta}{\partial x} + \frac{g\Delta\rho}{(\rho_0 + \Delta\rho)}\left(\frac{\partial \eta_m}{\partial x} - \frac{\partial \eta}{\partial x}\right) + \frac{1}{d_m(\rho_0 + \Delta\rho)}\left(\tau_0 + \tau_B\frac{u_m}{u_m{}^2 + v_m{}^2} - \tau_i\right) = 0$$

[y direction]

$$\frac{\partial v_m}{\partial t} + g\frac{\partial \eta}{\partial y} + \frac{g\Delta\rho}{(\rho_0 + \Delta\rho)}\left(\frac{\partial \eta_m}{\partial y} - \frac{\partial \eta}{\partial y}\right) + \frac{1}{d_m(\rho_0 + \Delta\rho)}\left(\tau_0 + \tau_B\frac{v_m}{u_m{}^2 + v_m{}^2} - \tau_i\right) = 0$$

Where, $\tau_0 = \rho_m f_m u_m (u_m{}^2 + v_m{}^2)^{1/2}$ $\tau_i = \rho_m f_m \Delta u(\Delta u^2 + \Delta v^2)^{1/2}$ $\Delta u = u - u_m$ $\Delta v = v - v_m$, f_m: friction coefficient, η: Height of water surface from reference level

η_m: Height of fluid mud layer from reference level, τ_B: Yield value of Bingham Plastic , $\rho_m = \rho_0 + \Delta\rho$: Density of mixture with fluid mud and water

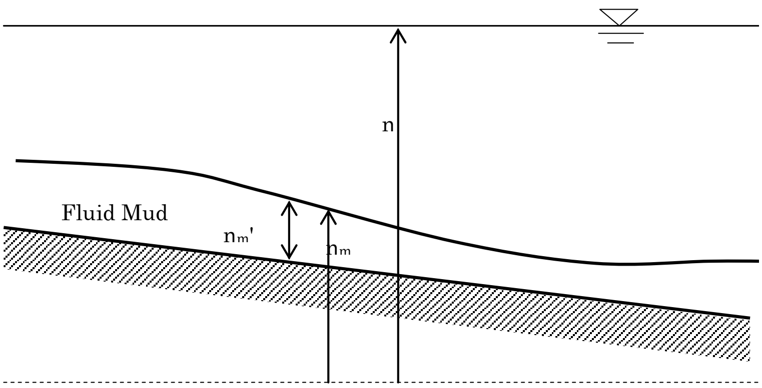


Figure 5.3.3 Fluid mud and computation parameter

c) Erosion from fluid mud layer to seawater

Erosion volume from fluid mud layer to seawater is computed by applying the same equation for erosion volume computation from seabed to seawater.

d) Settling of fluid mud to seabed

Settling volume of fluid mud to seabed is computed by following equations.

$$D_f = W_s(1 - \tau_b / \tau_d)C_0$$

$$\tau_b = \tau_0, \quad (\eta_m' \geq 30cm)$$

$$\tau_b = \tau_{cw} - \frac{\eta_m'}{30}(\tau_{cw} - \tau_0) \quad , \quad (0 \le \eta_m' < 30cm)$$

Where, D_f: Settling volume of fluid mud to seabed, W_s: Settling velocity in fluid mud layer, τ_b: Settling bottom share stress, τ_d :Critical settling share stress, τ_0: Seabed share stress by current, τ_{cw}: Bottom share stress in coexistence of waves and current, η_m': Thickness of fluid mud layer

5) Conversion Equation of Sediment Material

The sediment material by modeling is calculated by weight. However, the level sediment degree is discussed by its thickness and volume. Then the weight of sedimentation shall be converted to thickness and volume. The conversion equations are summarized as follows.

Sediment Weight: $G\left[\frac{kg}{m^2}\right]$

Wet Density: $\rho_m\left[\frac{kg}{m^3}\right] = \frac{\rho_w V_w + \rho_s V_s}{V_w + V_s}$

Sediment Thickness: $D = G/\rho_m \left[\frac{kg}{m^2}\right]\left[\frac{m^3}{kg}\right] = [m]$

Where, ρ_w: Seawater Density (=1.025), ρ_s: Mud Density (=2.65), V_w: Volume of Seawater, V_s: Volume of Mud

Water Content Ratio: $W(\%) = \frac{W_w}{W_s} = \frac{\rho_w V_w}{\rho_s V_s}$, $V_w = W \frac{\rho_s V_s}{\rho_w}$

Wet Density: $\rho_m = \dfrac{\rho_w W \frac{\rho_s V_s}{\rho_w} + \rho_s V_s}{W \frac{\rho_s V_s}{\rho_w} + V_s} = \dfrac{W + 1}{\frac{W}{\rho_w} + \frac{1}{\rho_s}}$

By seawater density ρ_w, dry density of mud ρ_s and water content ratio W, wet density is given. Then sediment weight is converted into sediment thickness. In the Study, based on SAPROF investigation, November 2009, the water content ratio of seabed materials is fixed at 89% in average. If required, the sedimentation volume is given by multiplying a thickness and certain area.

5.3.4 Modeling Conditions

1) Modeling domain and Mesh Division

The modeling domain is shown in Figure 5.3.4 that covers the area of the river mouth of Cam River, Bach Dang River and Cat Ba Island, and Long Chau Island in south offshore.

The calculation meshes are divided into three zones. The minimum mesh is 50m to present the existing and planned channel width. Using the NESTING method, the size of mesh is wider toward the outside area and the maximum size is set at 450m as indicated in Figure 5.3.4.

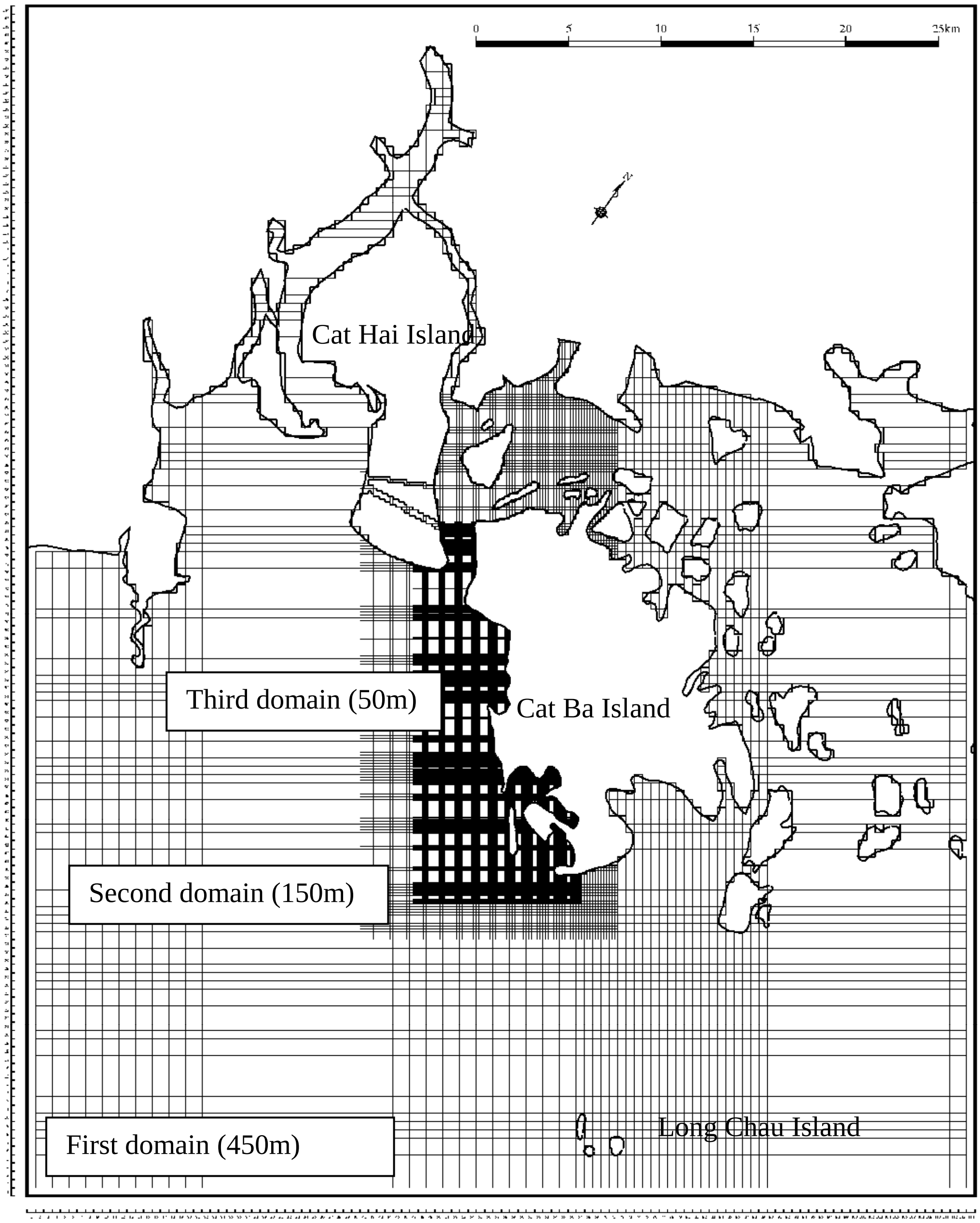


Figure 5.3.4 Model Domain and Mesh Division

2) Vertical Layer Division

In consideration that tidal range is 3-4m and the existing channel water depth is C.D.L from -7.0m to -8.0m, -14m in the development plan respectively, the layer is divided into 7 layers by 2m unit as follows.

Table 5.3.1 Calculation Layer Division

Layer	From	To
First	Seawater surface	2.0m
Second	2.0	4.0
Third	4.0	6.0
Fourth	6.0	8.0
Fifth	8.0	10.0
Sixth	10.0	15.0
Seventh	15.0	Deeper than 15.0

3) Modeling Bathymetry

The bathymetry for modeling is formulated based on the sea chart and bathymetry survey charts, and shown in Figure 5.3.5 and Figure 5.3.6. The bathymetry, October 2005 and November 2009[4] is used for the purpose of re-production of the sediment regime. And the difference of the channel area between 2005 and 2009 bathymetry is illustrated in Figure 5.3.7. In the bathymetry of 2009, the shallow area is noticed in the channel due to sedimentation from the 2005.

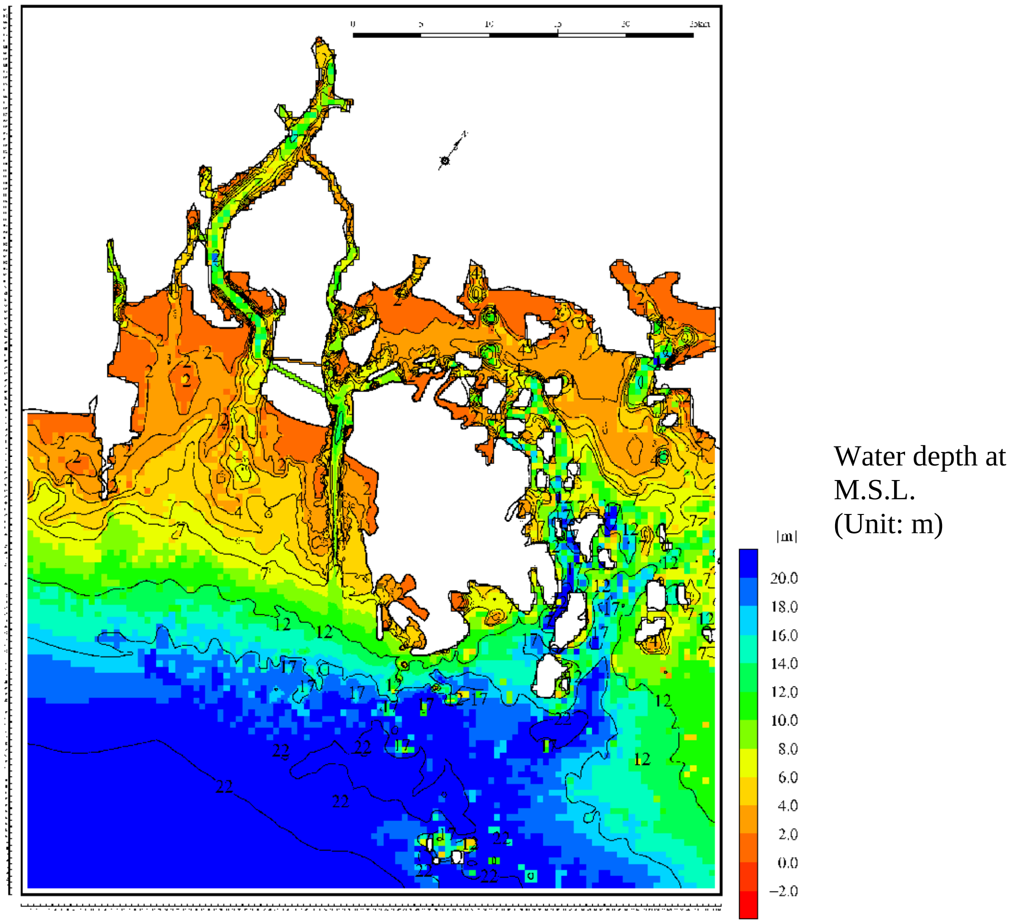


Figure 5.3.5 Bathymetry for Large Domain (450m, 150m, 50m Mesh as of 2009)

[4] ORIENTAL CONSULTANST CO., LTD (2009.12):THE PREPARATORY SURVEY ON LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION IN VIET NAM REPORT ON HYDROGRAPHIC SURVEY VOLUME I: BATHYMETRIC SURVEY

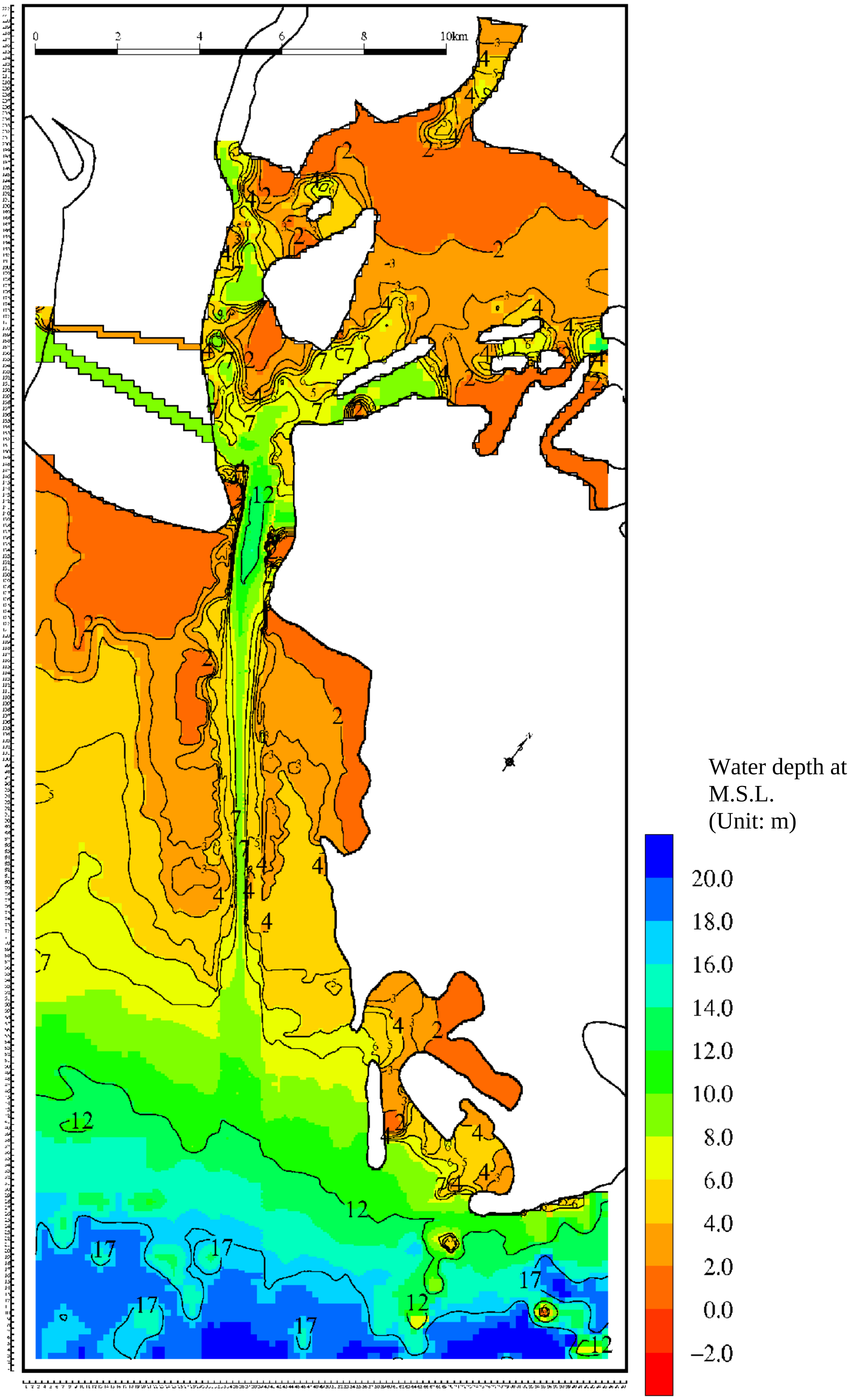


Figure 5.3.6 Bathymetry Medium – Narrow Domain (150m, 50m Mesh as of 2009)

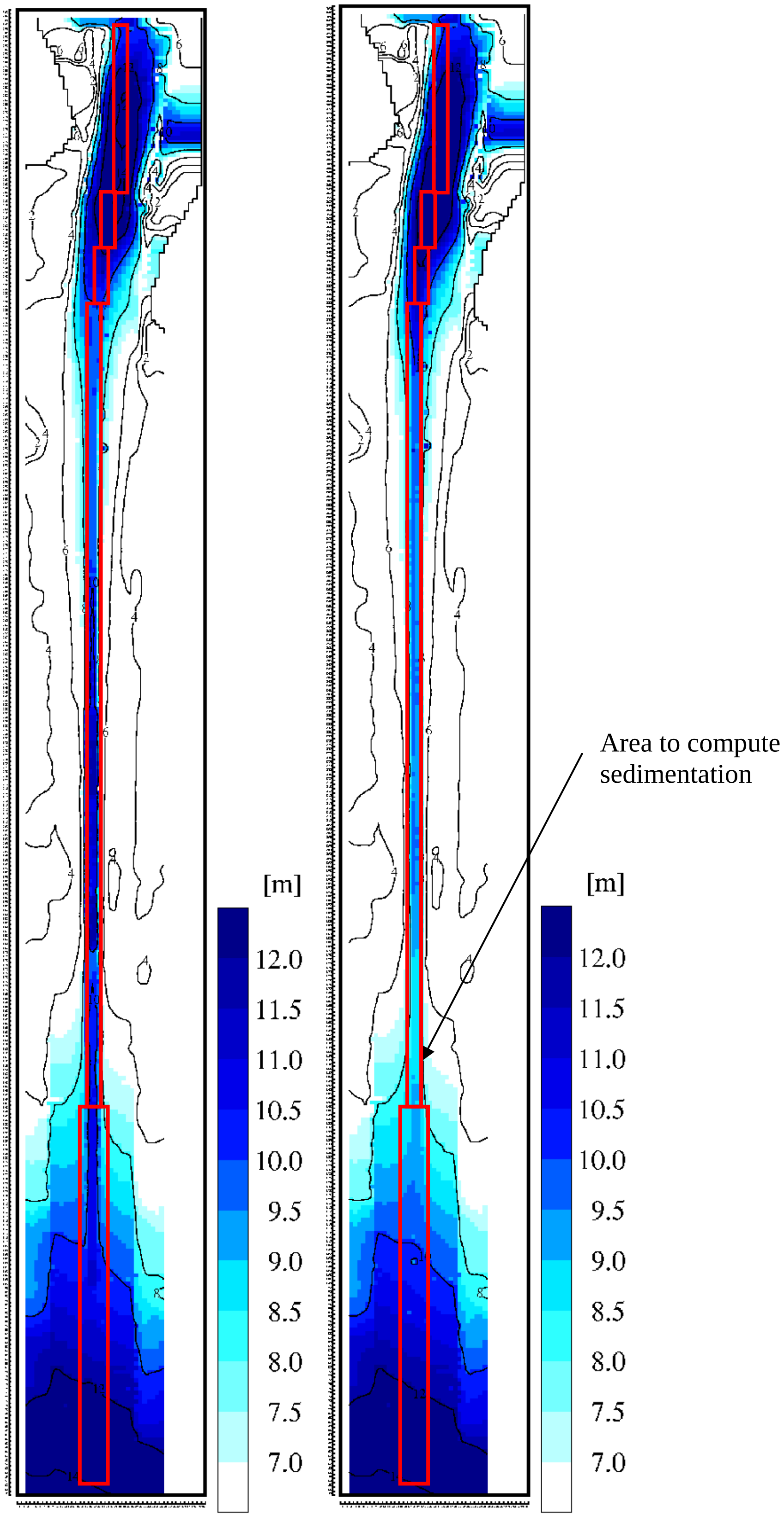


Figure 5.3.7 Difference between 2005 and 2009 bathymetry (Enlargement of Third domain 50m mesh below M.S.L.)

4) Distribution of Seabed Material

In the broad area, the seabed material conditions are analyzed based on Figure 5.1.14 as of 1999 that the original condition before construction of the existing Lach Huyen Channel is presented. In the channel area, seabed material conditions are analyzed based on Figure 5.1.15, September 2009 investigation. These data are combined and are shown in Figure 5.3.8 with water content ratio of silt/clay of seabed materials.

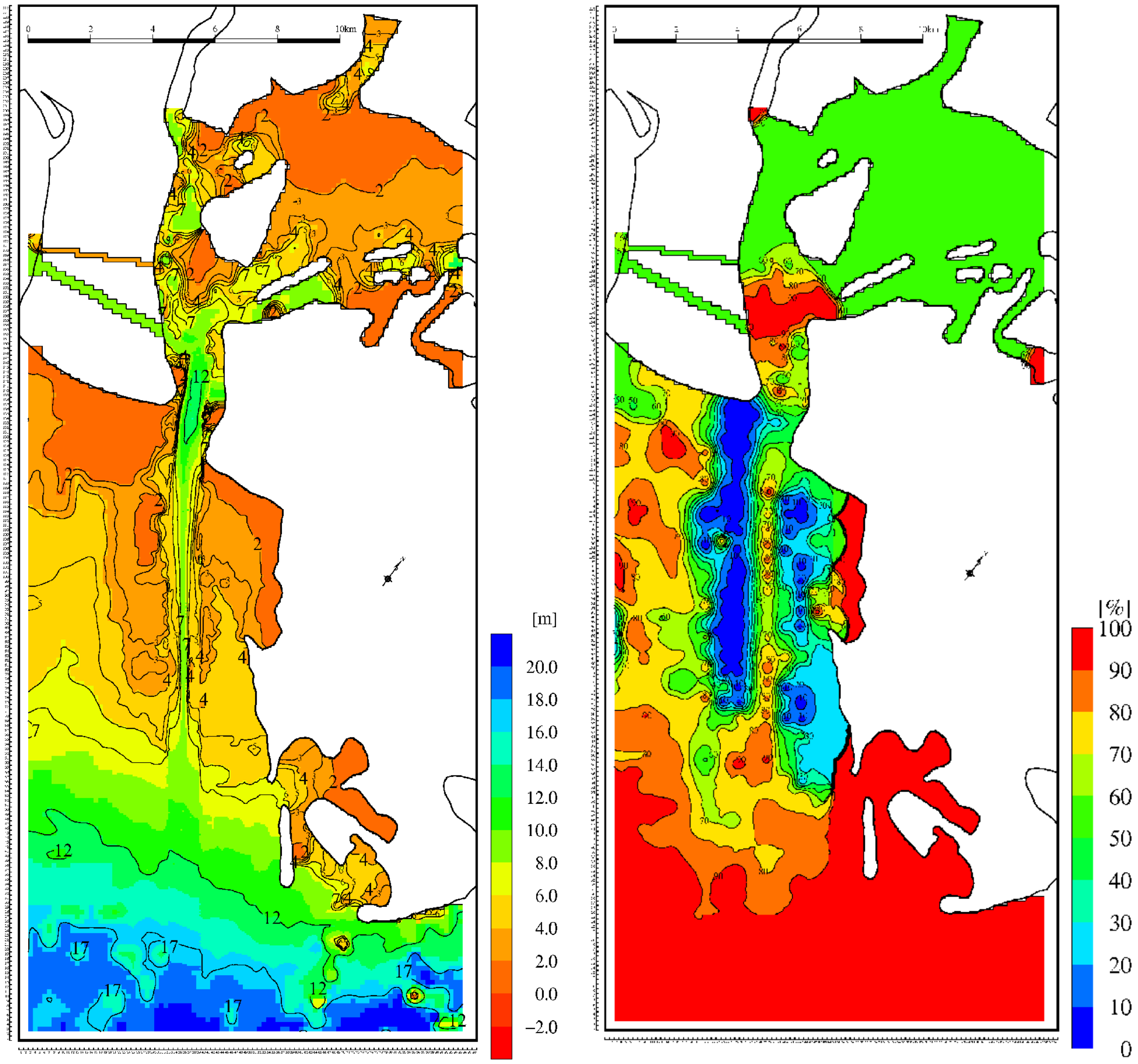


Figure 5.3.8 Bathymetry (below M.S.L., left side) and Distribution of water content ratio of silt/clay (Second-third domain, 150-50m mesh)

In Figure 5.3.9, the longitudinal distribution of seabed materials is presented in the water content ratio, the content ratio of less than 75 μm and the wet density, respectively.

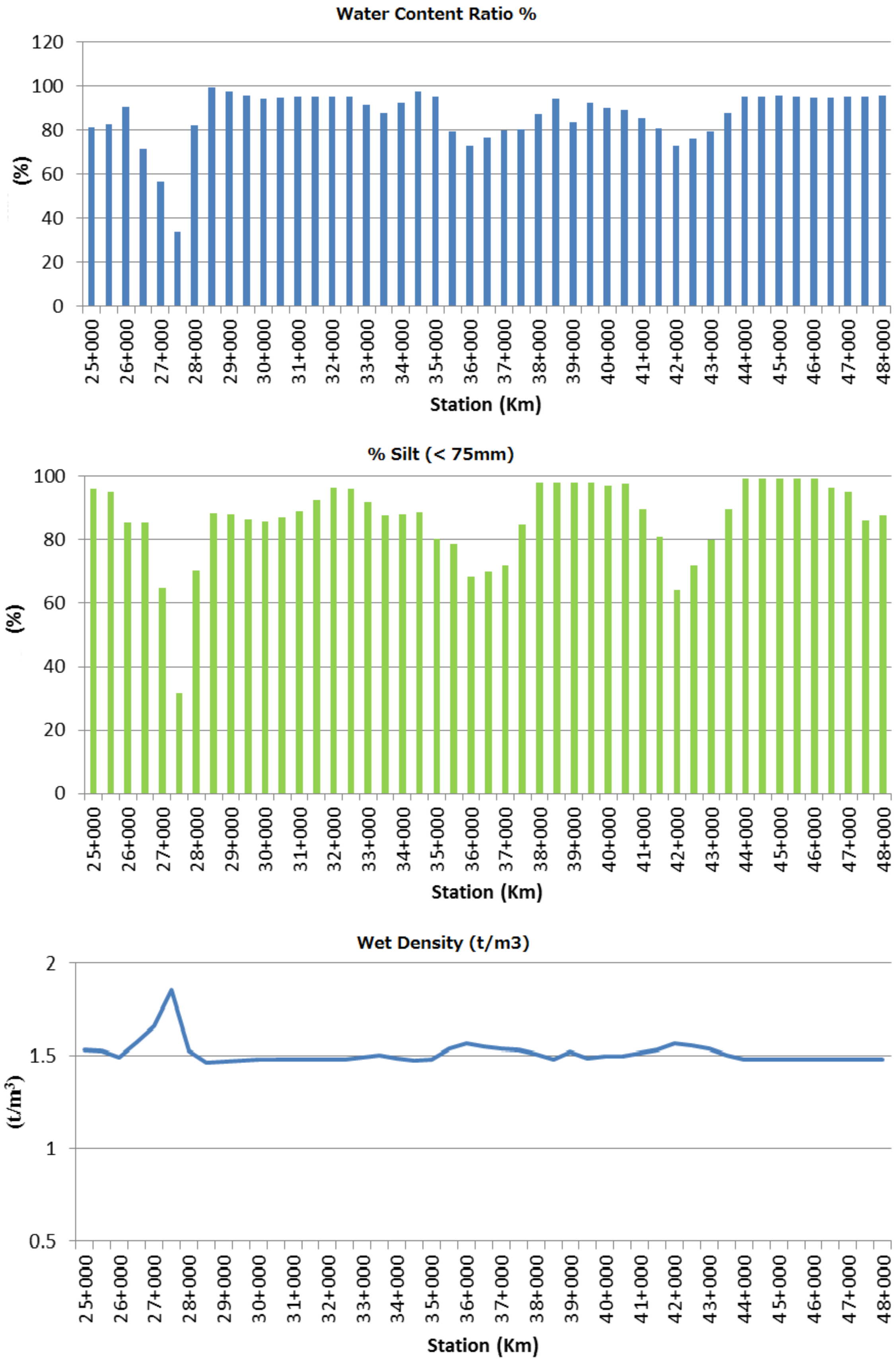


Figure 5.3.9 Results of Soil Test: SAPROF 2009

5) External Force Applied for Modeling

The external forces are derived from tidal current and waves propagated offshore. As discussed in SAPROF study[5], because the discharge materials from rivers that flows into Hai Phong Bay doesn't influence directly in the Lach Huyen area, so the input SS from rivers is not considered in the modeling.

a) Tidal Current

On the computation boundary, the water fluctuation is given by tidal movement to generate current in the computation domain. As tabulated in Table 5.3.2, eight tidal constituents that are of larger amplitude in the project area are considered among 16 constituents of the short period and 0.5 degree resolution by the Global Model of Matsumoto et al.(2000)[6].

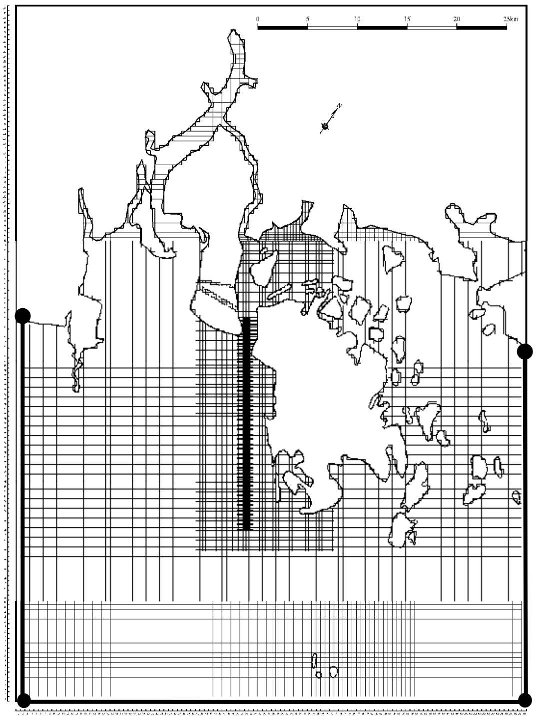


Figure 5.3.10 Setting of computation Boundary

Table 5.3.2 Selected 16 constituents

constituents	Boundary(A,B)		Boundary(C,D)	
	Amp(cm)	Phase(deg)	Amp(cm)	Phase(deg)
K1	65.8	85.2	75.1	84.3
O1	74.0	30.1	82.7	29.0
P1	21.9	78.7	25.5	77.9
Q1	16.4	7.2	18.8	4.4
M2	14.2	265.5	8.7	23.8
S2	8.2	316.3	2.3	340.4
N2	4.6	259.6	2.6	314.5
K2	2.5	311.0	0.7	302.4

[5] SUPPLEMENTAL REPORT, Environmental Impact Assesment,5/2010

[6] Matsumoto, K., T. Takanezawa, and M. Ooe (2000) : Ocean Tide Models Developed by Assimilating TOPEX/POSEIDON Altimeter Data into Hydro dynamical Model: A Global Model and a Regional Model Around Japan, Journal of Oceanography, 56, 567-581.

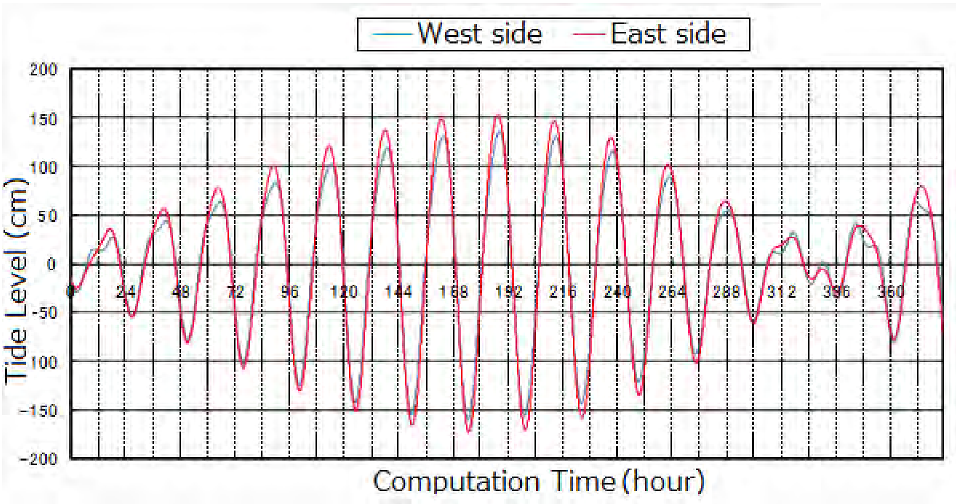


Figure 5.3.11 Tide Amplitude on the Computation Boundary

b) Waves

Based on the observation data in Hon Dau Station (Figure 5.2.12) that is summarized in Table 5.2.4 to Table 5.2.6, energy averaged wave height is analyzed for the normal conditions. And the high wave conditions are selected as follows.

Applied wave conditions are:

Case-1: Normal condition wave: Energy averaged wave
Case-2: Two high wave conditions
2-1: Average maximum waves (2005-2009, Table 5.4.2)
2-2: Highest wave in 2005 (Table 5.4.3)

Due to Hon Dau data is observed by an eye measurement, there are some errors. Then this data is corrected using the data observed by wave gauge by TEDI Port (From July 2005 to August 2006) at the offshore Lach Huyen -15.0m depth of near Buoy-0.

- Energy averaged wave (2005 – 2009 in Dau data)
  H_e=0.88 m (at Hon Dau)
  T_e=4.8 sec. (corrected by Figure 5.3.15)
  Wave direction: SE (High frequency wave direction of waves)

- High Wave Conditions (Case-1)
  : Average maximum wave in 2005 – 2009 (Average of 15 waves in five years as shown in Table 5.4.2)
  H_m=2.58 m (at Hon Dau)
  T_m=7.0 sec.
  Wave direction: SSE (High frequency wave direction of higher waves)

- High Wave Conditions (Case-2)
  : Highest waves observed at Lach Huyen offshore -15.0m (Table 5.4.3)
  H_m=3.07m
  T_m=8.1 sec.
  Wave direction: SSE (High frequency wave direction of higher waves)

The wave period is selected, considering the characteristic that the bed share stress becomes bigger under a longer wave period.

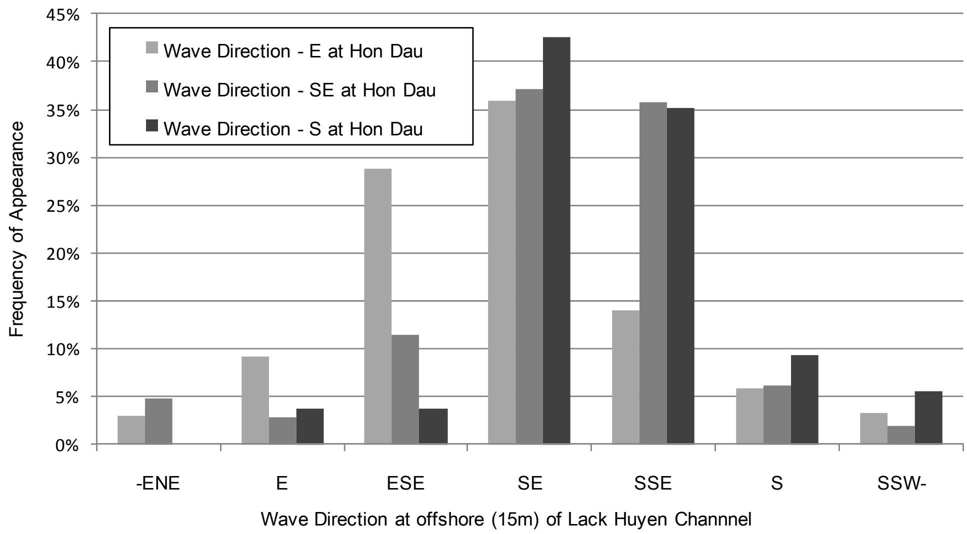
c) Comments on Wave Direction

The comparison is made between Hon Dau data, and the data observed by the instrument at Lach Huyen channel offshore. By Hon Dau data, the predominant wave direction is east, but by the offshore -15.0m depth data southeast waves are prevailing as shown in Table 5.3.3 and Figure 5.3.12.

Based on the occurrence frequency of offshore wave direction by Figure 5.3.12, the occurrence frequency of wave direction in Hon Dau for long-term observation is adjusted as Figure 5.3.13 by Σ(Occurrence Rate **A**× Occurrence Rate **B**)$_{E,SE,S}$.

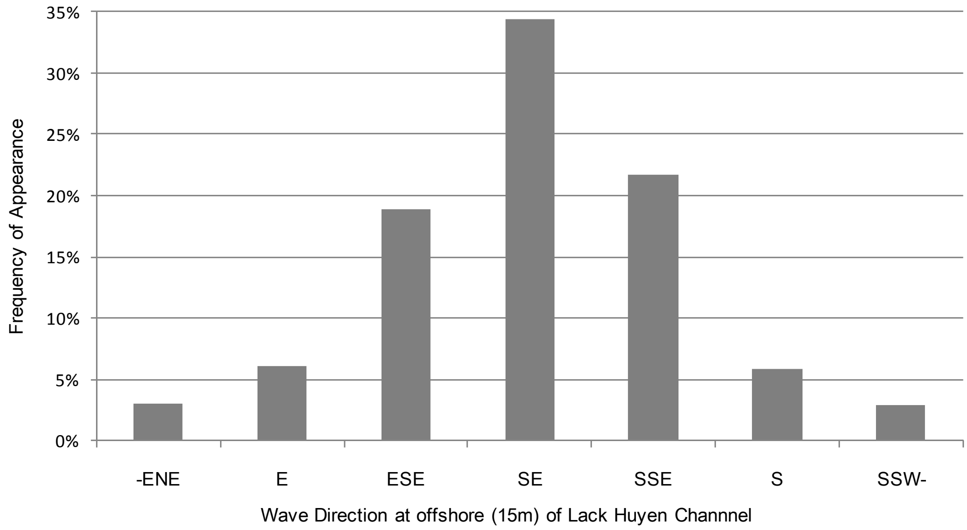
Table 5.3.3 Occurrence Ratio of Wave Direction in Hon Dau

Wave Direction in Hon Dau	Occurrence Ratio (A)	Occurrence Rate with offshore Lach Huyen -15m (B)						
		ENE	E	ESE	SE	SSE	S	SSW-
E	52.4%	2.9%	9.2%	28.8%	35.9%	14.1%	5.9%	3.3%
SE	30.2%	4.8%	2.9%	11.4%	37.1%	35.7%	6.2%	1.9%
S	10.1%	0.0%	3.7%	3.7%	42.6%	35.2%	9.3%	5.6%



(July 2005 – August 2006)

Figure 5.3.12 Occurrence Frequency of Wave Direction with Hon Dau and Lach Huyen Offshore -15m (Buoy-0)



(2005 – 2009)

Figure 5.3.13 Corrected Occurrence Frequency by Data in Lach Huyen Channel Offshore -15.0m

d) Offshore Waves

The data of Hon Dau has errors due to the eye measurements and doesn't clear whether its definition of wave height is, $H_{1/3}$, H_{max} or $H_{average}$. Furthermore, considering the location of Hon Dau Station, the data observed might be affected by the geological condition.

In Figure 5.3.13, offshore data in Lach Huyen, Significant wave height (H_{obs-A}) and Hon Dau data (Hobs-B) is plotted in accordance with the coincident observation time. And using deformation of waves to the period 4.8 and 6.1 sec., the wave height ratios are computed at both points (H_{cal-B}/H_{cal-A}=Y) and plotted in Figure 5.3.17 and Table 5.3.5. The wave ratio in Hon Dau is 0.72-0.75, but as indicated in Figure 5.3.18, even though in shallow depth this shows the wave height in Hon Dau is larger than Lach Huyen, where is deeper. Because this is theoretically contradicted, the data of Hon Dau shall be corrected by the following way.

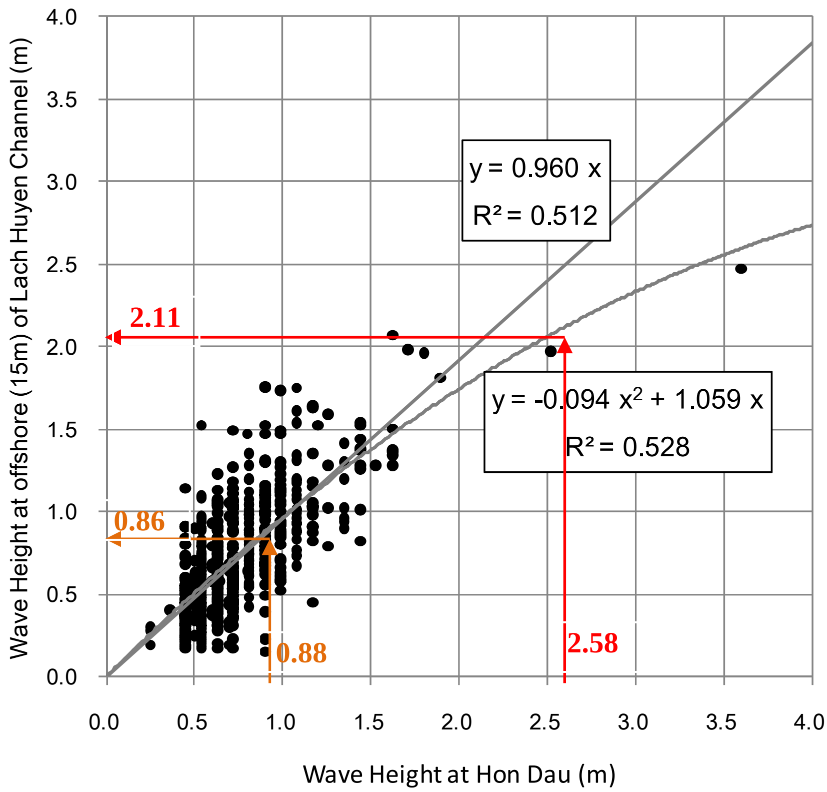
The observation data in Hon Dau is corrected as follows to the significant wave H_B.

$H_{obs-B}/H_{obs-A}=X$
$H_{cal-B}/H_{cal-A}=Y$
$H_B=H_{obs-A}*Y=H_{obs-B}/X*Y$

And using the results of wave deformation, offshore wave H_0 is given by the offshore wave ratio of Hon Dau data as follows.

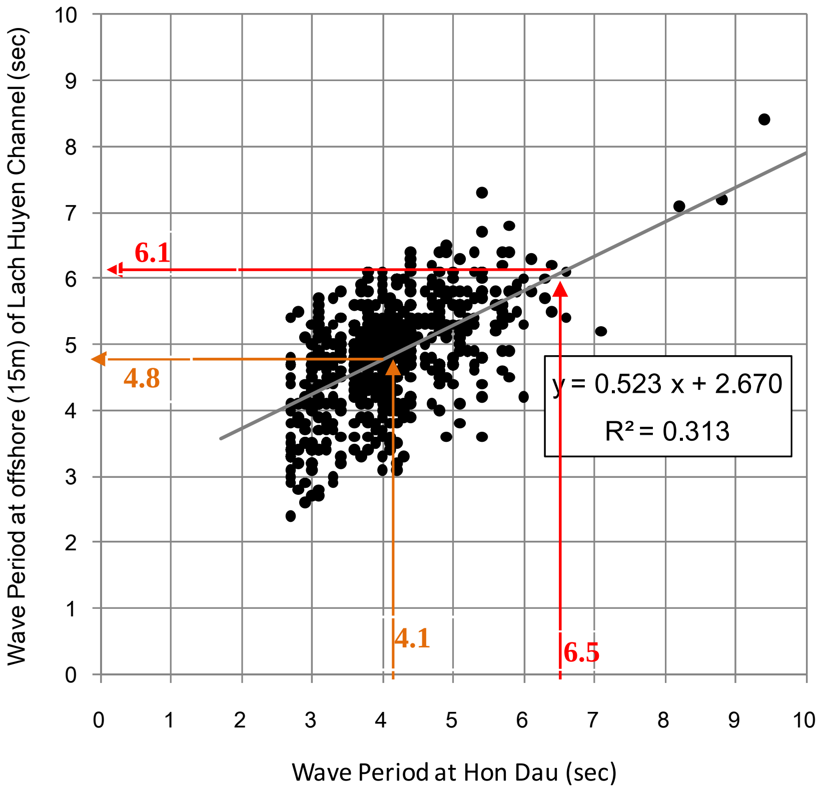
$H_0=H_B/Z$

The correction results are summarized in Table 5.3.6 and Table 5.3.7 using a quadratic equation of Figure 5.3.14 to correct Hon Dau data.



(July 2005 – August 2009)

Figure 5.3.14 Relationship between Hon Dau Waves and Lach Huyen Offshore Waves -15.0m (Buoy-0)



(July 2005 – August 2006)

Figure 5.3.15 Relationship of wave Period between Hon Dau Wave and Lach Huyen Offshore -15.0m (Buoy-0)

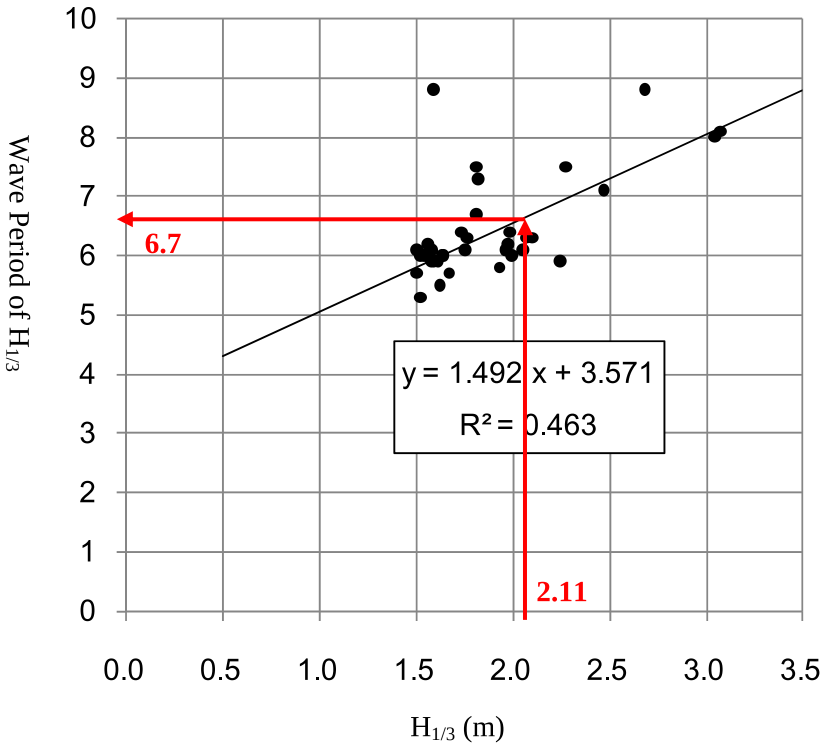


Figure 5.3.16 Interrelation between Significant Wave and Period of Lach Huyen Offshore -15.0m

Table 5.3.4 Occurrence Frequency of Significant Wave Height and Period in Offshore -15.0m

Observation period: 12 July 2005 - 14 August 2006
Location: OFFSHORE-15M

Missing data number 2825
Recorded Number 2553
Record Number 272-(9.6%)

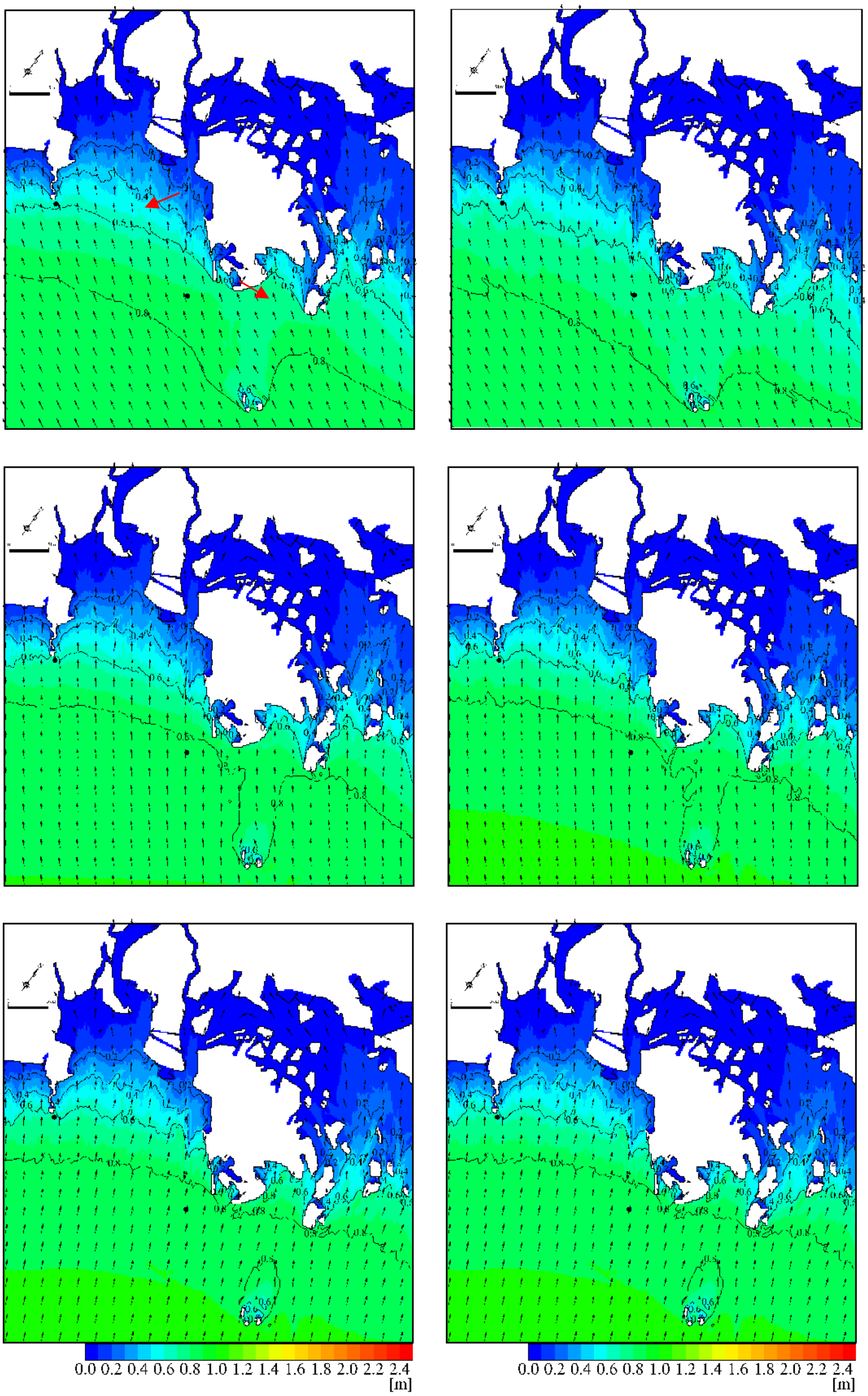
Period / Wave height	0.0~3.0	3.0~4.0	4.0~5.0	5.0~6.0	6.0~7.0	7.0~8.0	8.0~9.0	9.0~10	10~11	11~12	Above 12.0	Total	Acoum - nlated
0.00~0.25	40 1.6	213 8.3	122 4.8	32 1.3	8 0.3	2 0.1			1 0.0			418 16.4	418 16.4
0.25~0.50	36 1.4	286 11.2	415 16.3	114 4.5	9 0.4	3 0.1	1 0.0	1 0.0		1 0.0		866 33.9	1284 50.3
0.50~1.00		42 1.6	440 17.2	421 16.5	26 1.0		1 0.0					930 36.4	2214 86.7
1.00~1.50			39 15.0	201 7.9	38 1.5	3 0.1	1 0.0					282 11.0	2496 97.8
1.50~2.00				21 0.8	24 0.9	2 0.1	1 0.0					48 1.9	2544 99.6
2.00~2.50				1 0.0	3 0.1	2 0.1						6 0.2	2550 99.9
2.50~3.00							1 0.0					1 0.0	2551 99.9
3.00~3.50							2 0.1					2 0.1	2553 100.0
3.50~4.00												0 0.0	2553 100.0
4.00m												0 0.0	2553 100.0
Total	76 3.0	541 21.2	1016 39.8	790 30.9	108 4.2	12 0.5	7 0.3	1 0.0	1 0.0	1 0.0	0 0.0	2553 100.0	
Acoumnlated	76 3.0	617 24.2	1633 64.0	2423 94.9	2531 99.1	2543 99.6	2550 99.9	2551 99.9	2552 100.0	2553 100.0	2553 100.0		

Upper: Occurrence Number
Lower: Occurrence %

ESE

SE

SSE



(Period 4.8 *sec.*) (Period 7.0 *sec.*)

Figure 5.3.17 Distribution of Wave Height Ratio to Offshore Wave Height (Computation condition in Table 5.3.8)

Table 5.3.5 Wave Height Ratio by Wave Deformation

Wave Height Ratio against Offshore Wave	Wave Observation Points	ESE		SE		SSE	
		4.8s	7.0s	4.8s	7.0s	4.8s	7.0s
	-15.0m Offshore of Lach Huyen (A)	0.76	0.71	0.83	0.80	0.85	0.84
	Hon Dau (B)	0.57	0.52	0.63	0.59	0.64	0.61
(B) / (A)		0.75	0.73	0.76	0.74	0.75	0.73

Table 5.3.6 Corrected Offshore Wave Height of Energy Averaged Wave

Wave Direction	ESE	SE	SSE
Wave Period (sec.)	4.8	4.8	4.8
Wave Height at Hon Dau (m)	0.88	0.88	0.88
Wave Ration at Hon Dau (X) with raw data against -15m offshore data	1.02	1.02	1.02
Corrected wave ration against -15m offshore data (Y)	0.75	0.76	0.75
Estimated Significant Wave Ratio at Hon Dau H_B(m)	0.64	0.65	0.64
Corrected wave ration against -15m offshore	0.57	0.63	0.64
Corrected Offshore Wave Height H_0(m)	1.13	1.04	1.01

Table 5.3.7 Corrected Offshore Wave Height of Storm Condition Wave Height

Wave Direction	ESE	SE	SSE
Wave Period (sec.)	7.0	7.0	7.0
Wave Height at Hon Dau (m)	2.58	2.58	2.58
Wave Ration at Hon Dau (X) with raw data against -15m offshore data	1.22	1.22	1.22
Corrected wave ration against -15m offshore data (Y)	0.73	0.74	0.73
Estimated Significant Wave Ratio at Hon Dau H_B(m)	1.54	1.56	1.54
Corrected wave ration against -15m offshore	0.52	0.59	0.61
Corrected Offshore Wave Height H_0(m)	2.96	2.64	2.52

e) Computation Condition of Wave Deformation

The conditions of wave deformation are summarized in Table 5.3.8.

Table 5.3.8 Computation Conditions of Wave Deformation

Items	Conditions	Notes
Computation Domain	Domain is shown in Figure 5.3.4 Dummy domain: Horizontally 96km and vertically 75km included computation domain	A dummy domain is set up to get boundary conditions.
Pitch of Mesh	Computation domain: Whole area 150m :dummy Area 1,500m	In calculation domain, the mesh is the same as Composition Model.
Directional Spectrum	0～360°	
Direction Division	101	3.6° in interval
Frequency Spectrum	0.04～1.0Hz (1～25sec)	
Frequency Division	22	
Winds	Not considered	By a trial study, the influence of wind is found out minor.
Computation Tide Level	Mean Water Level	

f) Seabed Material

According to SAPROF Study, the sediment material in channel area mainly composed of particles of 75μm or less in median grain size. Hence, the sediment material is dealt as the mud of clay and silt and is explained in SS. And as there is the sand spit that contains 0.1mm median grain size in the inner along the channel, the distributions of mud content ratios of seabed materials area by area are considered in order to present the variation of seabed materials in the computation domain.

g) Computation parameters for Sediment Transport

The computation parameters are summarized in Table 5.3.9. These parameters are formulated based on the experiences of detailed studies and field investigations such as Kumamoto Port, Nakatu Port, and the study on Lach Huyen by Japan Overseas Ports Cooperation Association.

Table 5.3.9 Computation Parameters for Sedimentation Simulation

Tidal Current	Horizontal eddy viscosity coefficient: A(cm^2/s)		
	First Domain: 500,000 Second Domain: 100,000 Third Domain: 50,000		
	Vertcal viscosity coefficient $K_M=A_{VK2}\|U\|\delta$		
	A_{VK2} = 5.0×10^{-2}		
	Friction coefficient		
	γi^2 (middle layer)	γb^2 (bottom layer)	
	0.001	Gn^2/h$^{1/3}$	
	Manning roughness coefficient n (M.K.S.System of Units)		
	0.025		
SS Diffusion	Hirizontal diffusion coefficient : K(cm^2/s)		
	First Domain:1000,000 Second Domain:1000,000 Third Domain: 500,000		
	Vertical diffusion coefficien : K_Z(cm^2/s)		
	1.0		
	Settling velocity of particles $W_S=A_I C^{BI}$ (Solid line Figure 5.2.20 - Figure 5.2.24)		
	Function of density A_I = 0.6×10^{-3}m^4/kg s B_I = 1 CH = 4.3kg/m Above CH W_s = 2.6×10^{-1}cm/s		
	Erosion constant: $E=M(\tau e/\tau-1)^n$		
	M(kg/m^2/min)	τe(Pa)	n
	0.001	0.1	1.9
Fluid mud	・Density of Fluid mud: 75000g/m^3=mg/L ・Yield value of Bingham Plastic: τ_b = 0.1N/m^2 ・Settling velocity: W_f = 0.001cm/s ・Critical share stress for settling: τ_d = 0.5N/m^2 ・Critical thickness that begins to flow: 3cm		

The concentration density increasing, a probability of collision between mud particles and the settling velocity increases. This relationship is given in Figure 5.3.18. The solid line is applied for the study.

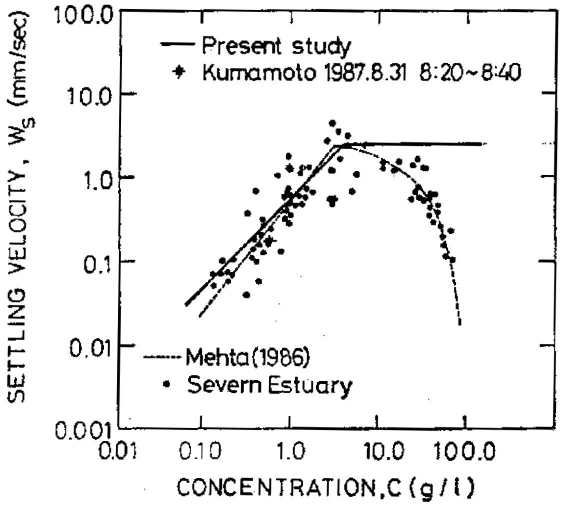


Figure 5.3.18 Relation between Settling Velocity and Concentration of Mud (Hiroichi TSURUYA , Kazuo MURAKAMI, Isao TRIE1989)

5.4 Reproduction Procedure of Channel Sedimentation

5.4.1 Existing Situation of Sedimentation and Target Period of Sediment Reproduction

1) Existing Situation

The existing Lach Huyen Channel, firstly, had been depended from the original seabed to 7.8-8.0m under Hai Phong Port Rehabilitation Project 2 in order to reroute from Nam Trieu to improve the access channel of Hai Phong Port. The channel dredging has been completed in the end of 2005. Based on the periodical bathymetric survey data for five years from the completion of the project, the progress of sedimentation is shown in Figure 5.4.1. This graph shows that in the inner part, the sedimentation is moderated, but in the reach between 36km - 42km the localized sedimentation occurred, where the sand spit along the channel is interrupted.

And Figure 5.4.2 shows the accumulated sedimentation volume in five years. Obviously, the sedimentation volume in the first year is greater than the second and later years. Figure 5.4.3 shows the periodical changing of the longitudinal profile in the channel center. Based on this figure, clearly in the reach between 33km to 41km the over-dredging were made 1-2m from the design depth.

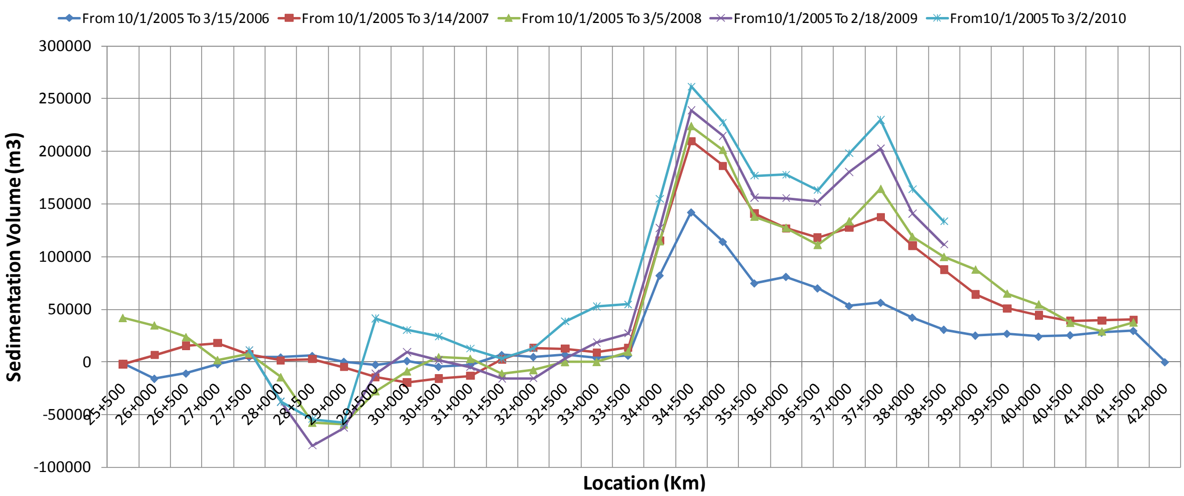


Figure 5.4.1 Accumulated sedimentation volume per year in each location of Channel

2) Target Period of Reproduction

In consideration of the actual sediment progress and over-dredging reach during construction as illustrated in Figure 5.4.3, the following two Phases are discussed in order to make well reproduction of the existing conditions and to verify an influence due to the over dredging sections against sediment speed.

Phase1: (Bathymetry with over dredging after construction) + (First year sedimentation)
(Figure 5.4.3: Black line bathymetry) (Figure 5.4.2: 1.2 -1.49million m^3/year)

Phase2: (Bathymetry after second year) + (Third Year sedimentation)
(Figure 5.4.3: Yellow line bathymetry) (Figure 5.4.2: 0.4 - 0.5million m^3/year)

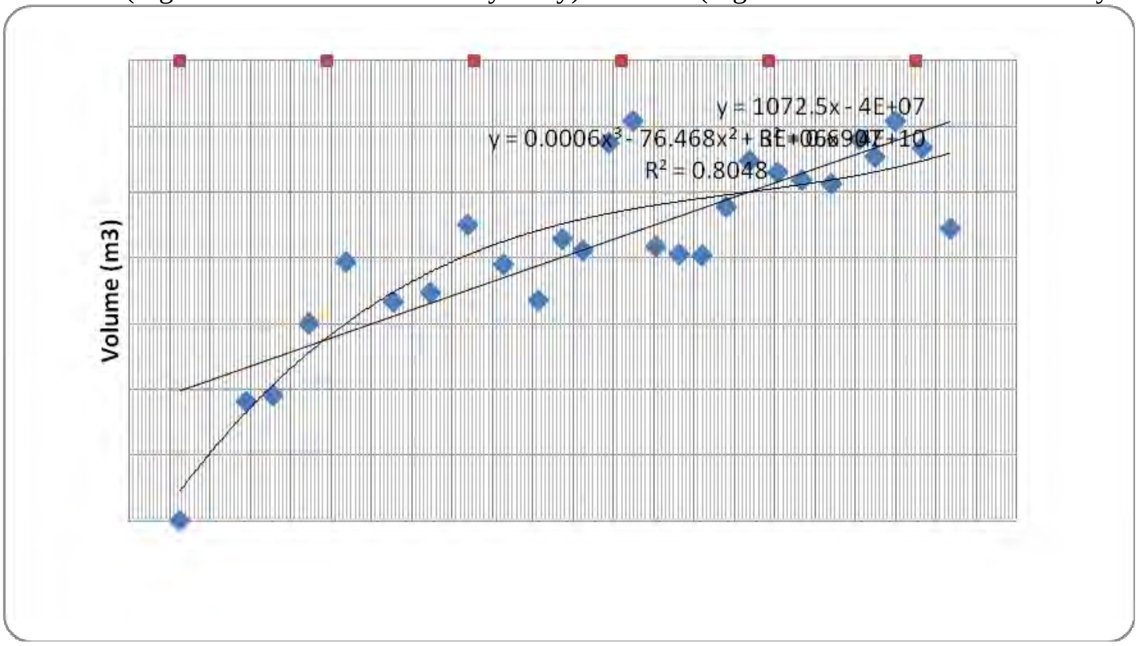


Figure 5.4.2 Reproduction Phases and Accumulated Channel Sedimentation Volume in five years

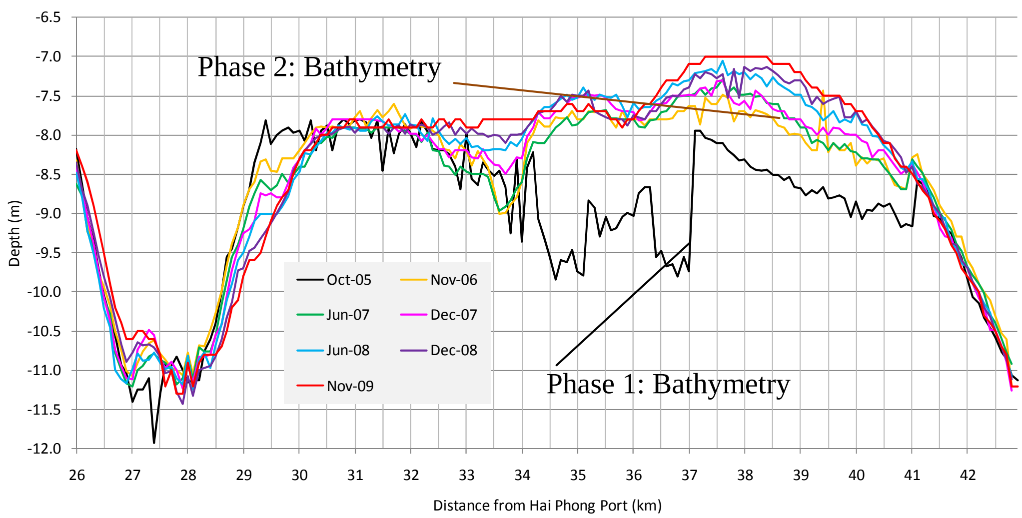


Figure 5.4.3 Bathymetry Changing in Longitudinal Channel Center

5.4.2 Parameters and Data for Verification on Reproduction

The data for verification on reproduction of sedimentation regime are:

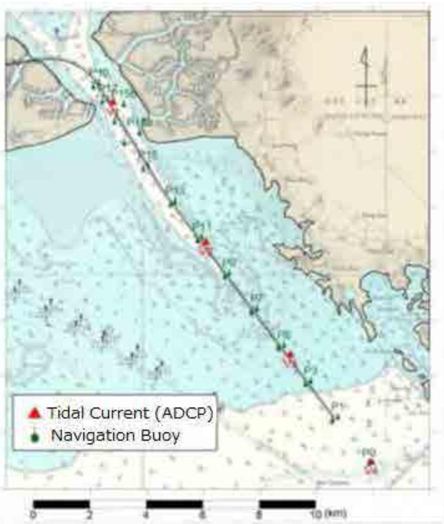
- Periodical bathymetry from October 2005
- Result and analysis of field investigations carried out in May 2011 summarized in Table 5.4.1.
- Results of tidal current observation in November - December 2009 by SAPROF

Table 5.4.1 List of Field Investigation carried out in May 2011 under the Study

Investigations	Period	Locations	Notes
Current	1month , at ocean station	C1 - C5	Doppler VHF Current Meter
Turbidity	-ditto-	C1 - C5	Turbidity meter 3 layers
Waves	-ditto-	C6 / C2	VHF Wave Gage/Pressure type wave Gage
SS	2days	C1 - C5	Water Samplings

Source: Field Investigations Report under the Study

Figure 5.4.4 Location Map of Field Investigation (May 2011)



Coordinate System : VN2000-105° 45'

Eastwest	Southnorth	Location	Depth (CD,m)
620585	2301881	V1	-9.77 m CD
623743	2297059	V2	-3.83 m CD
626820	2292833	V3	-4.56 m CD
629550	2288929	V4	-10.66 m CD

Source: SAPROF 2009

Figure 5.4.5 Information on Tidal Current Observation (November - December 2009)

5.4.3 Representative Wave and Annual Sediment Volume

The actual run-time of modeling is not time of a year. From the limitation of the computer capacity and avoiding useless computation time, the analyses of sediment simulation are carried out for the period from several days to 15 days and nights. And the annual sediment volumes are computed by combining the conditions explained as follows. An actual computation time is decided based on one cycle of tidal current as 15 days and nights for energy averaged wave and about 6 days for high waves, respectively. In the case of high waves, its action on sediment transport continues from the time of wave surging-up to the time until sediment transport becoming ease.

Considering this thing, the representative phenomena of sediment transport according to the wave conditions are sorted out as follows. And the sediment modeling carried out on these two representatives. In order to get the annual sediment volumes, the results of sediment modeling for these representatives are combined using the accumulated energy ratio of the study cases.

Representative-1: [15 days and nights of tidal current] + [15 days and nights of energy averaged wave or five year average wave]
Representative-2: [about 6 days of Tidal Current] + [about 6 days of Highest Wave]

1) Phase1 (2005 - 2006)

Normal Condition + 4 Times of Highest Wave = Prpresentative-1 multiplying A
+ Prpresentative-2 multiplying B

A: Accumulated Factor A= $E_{\_year}$ (Energy Averaged Wave per year)/ $E_{\_15days}$ (15 days and nights)=13.3
B: Accumulated Factor B= $E_{\_wave.total}$ (Highest wave condition: four times higher waves in Table-5.4.2/ $E_{\_wave.no6}$(No.6 wave) =107.653/23.2616＝4.63
Where, E: accumulated energy of waves in the selected period
This is noted that No.6 wave means the sixth wave of Table 5.4.2, but for sediment modeling, the waves of the recording data offshore in Table-5.4.3 on the same period of No.6 wave.

2) Phase2 (2006 - 2010)

Five year average wave = Prpresentative-1 multiplying A

A: Accumulated Factor A= $E_{\_year}$ (Five years average)/ $E_{\_15days}$(15 days and nights)=11.1
Where, E: accumulated energy of waves in the selected period

As shown in Table 5.4.2, during Phase2 there was a higher wave at 2007/10/4. However, considering the actual progress of sedimentation shown in Figure-5.4.3 is not so enormous, then for Phase 2 the energy averaged waves in five years only is interpolated.

Table 5.4.2 High Waves Observed in Hon Dau Station in2005-2009 (Above 1.7m)

No.	Year	Month	day	hour	Direction	Wave Height(m)	Wave Condition for Simulation	Notes
1	2005	2	17	19	E	1.80		
2	2005	4	9	19	SE	1.80		
3	2005	5	13	19	E	1.80		
4	2005	7	31	13	E→SE	3.69		Typhoon WASHI
5	2005	8	11	19	E→SE	2.16		
6	2005	9	18	19	E→SE	3.60	O	
7	2005	9	27	13	E→SE	3.60		Typhoon DAMREY
8	2006	4	12	7	SE	1.80		
9	2006	7	18	13	SE	1.89		
10	2007	7	5	19	SW	1.98		
11	2007	7	21	13	SE	1.81		
12	2007	10	4	13	E	3.15		
13	2008	9	26	7	S	1.71		
14	2009	9	12	7	SE	2.43		
15	2009	10	14	13	E/N	1.98		

Note: The water depth in Hon Dau Station is C.D.L-6.0m

Table 5.4.3 Wave Recording Data on 9 September 2005 Offshore -15.0m

Year/Month	Day	Hour	$H_{1/3}$(m)	$T_{1/3}$(s)	Dir(°N)
2005/09	17	3	0.26	3.9	136
2005/09	17	6	0.22	5.1	139
2005/09	17	9	0.21	4.9	143
2005/09	17	12	0.26	4.0	119
2005/09	17	15	0.27	4.4	152
2005/09	17	18	0.26	4.2	116
2005/09	17	21	0.32	3.5	126
2005/09	18	0	0.65	4.0	126
2005/09	18	3	1.20	5.6	105
2005/09	18	6	1.02	5.5	104
2005/09	18	9	1.43	5.9	104
2005/09	18	12	1.97	6.2	98
2005/09	18	15	3.07	8.1	105
2005/09	18	18	2.47	7.1	94
2005/09	18	21	3.04	8.0	133
2005/09	19	0	2.27	7.5	153
2005/09	19	3	1.82	7.3	152
2005/09	19	6	1.50	6.1	154
2005/09	19	9	1.00	5.4	146
2005/09	19	12	1.02	5.2	148
2005/09	19	15	0.82	5.2	141
2005/09	19	18	0.83	5.5	137
2005/09	19	21	0.81	5.4	129
2005/09	20	0	0.75	4.2	132
200509	20	3	0.75	4.7	128

5.4.4 Verification on Modeling Parameters

1) Tidal Current

The tidal harmonic constants between the field observation and the results of modeling are shown in Figure 5.4.6. Although M_2 and S_2 have comparatively large difference, K_1 and O_1 that govern the tidal movement have quite good consistency.

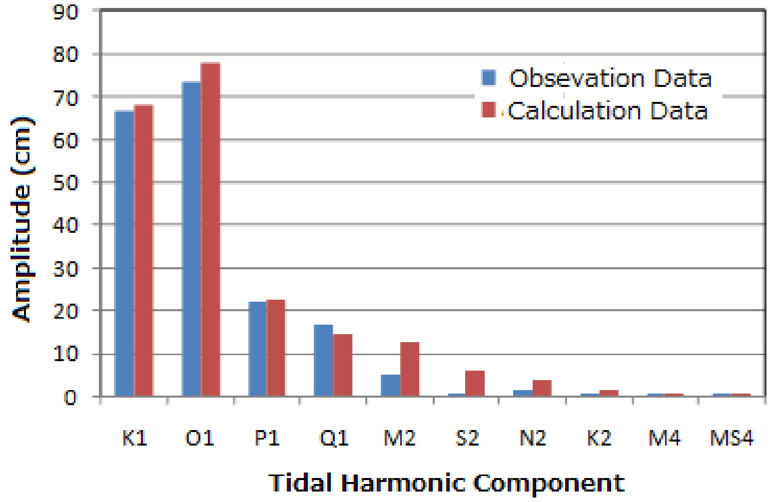
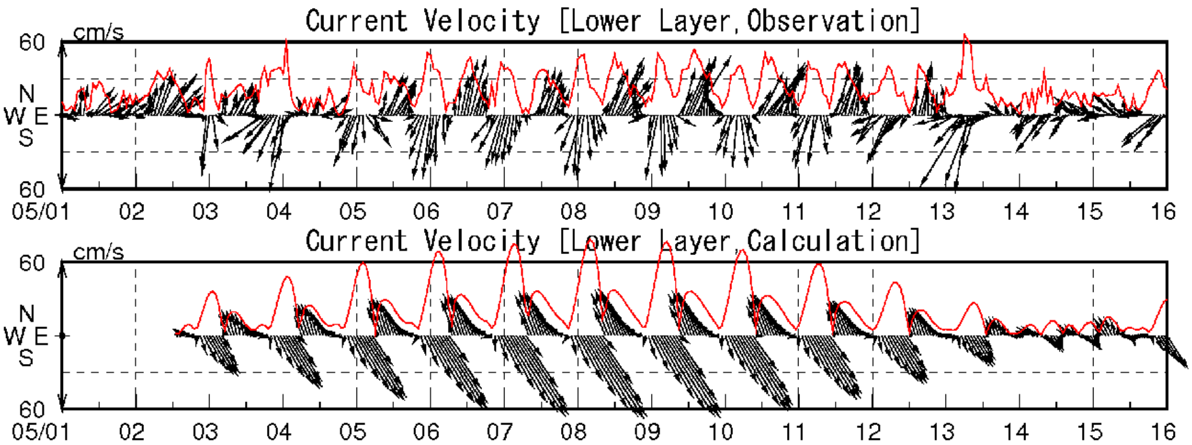


Figure 5.4.6 Comparison of Tidal Harmonic Constant between the field Observation and Simulation (V4 Location 2009)

2) Current

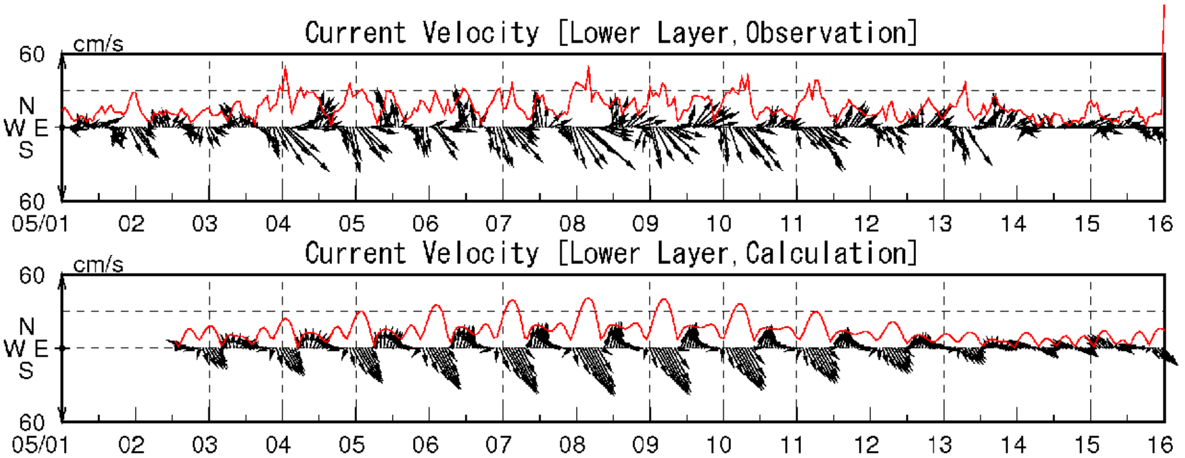
The simulated current, absolute value, is shown in Figure 5.4.7 to Figure 5.4.10 together with the observation results, flow vector of May 2011. At location of C_1 (34km) and C6 (Offshore at -20 m location), the degree of current and its direction have a difference. However, at C_3 (36km) and C_4 (38km), there is a good consistency in dual current, spring tide, neap tide.

In Figure 5.4.11 and Figure 5.4.12, based on observation in November 2009, comparisons of the tidal current ellipse are shown. The distribution of residual current is shown in Figure 5.4.13. At St.V1, the current ellipse of K_1 and O_1 at the surface is rather smaller in simulation. However, at bottom their magnitudes have a good consistency which is important to estimate the bottom material transportation. Regarding the residual current, at bottom the weak residual current has some difference, but the singularity in the residual current of the surface and middle where between Cat Hai and Cat Ba Island has good consistencies.



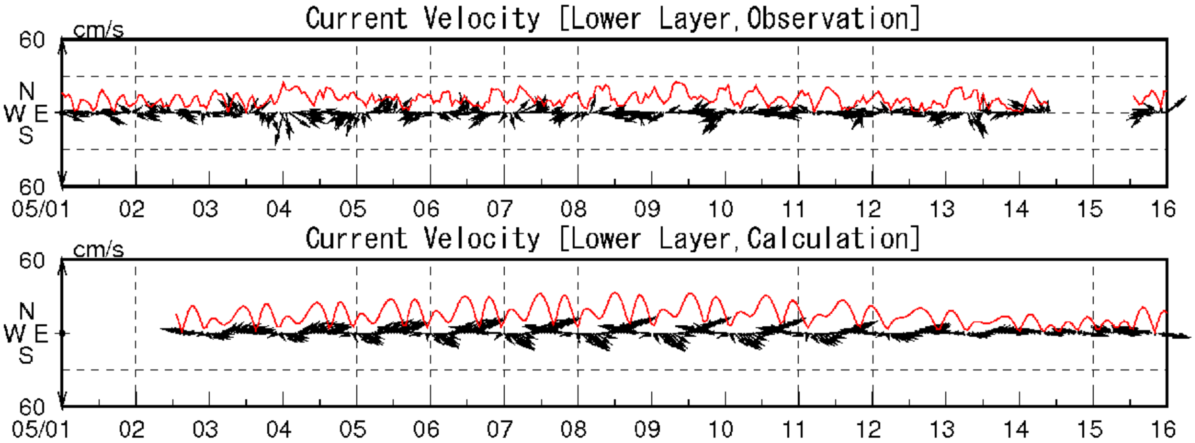
—: Absolute current value →: Flow vector

Figure 5.4.7 Reproducibility on Current based on Observation May 2011 at C1 location



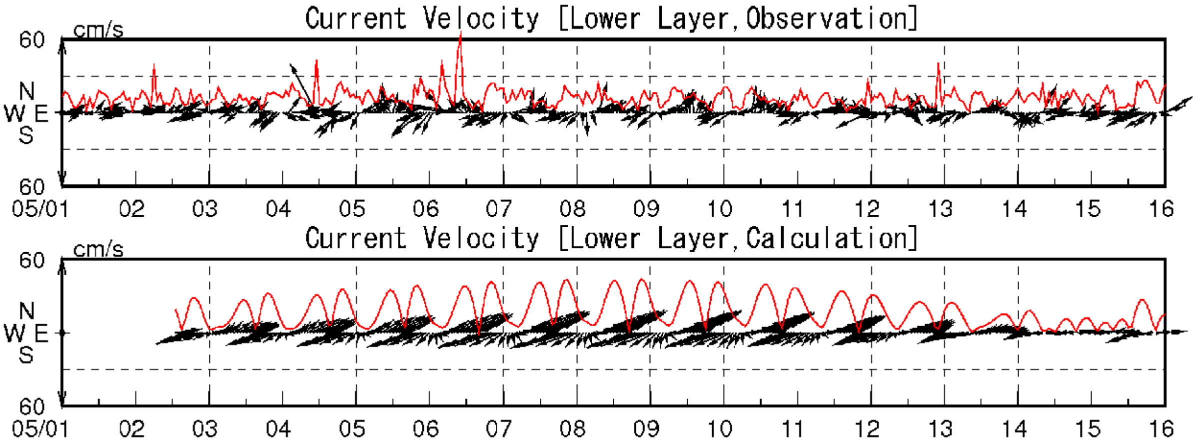
—: Absolute current value →: Flow vector

Figure 5.4.8 Reproducibility on Current based on Observation May 2011 at C3 location



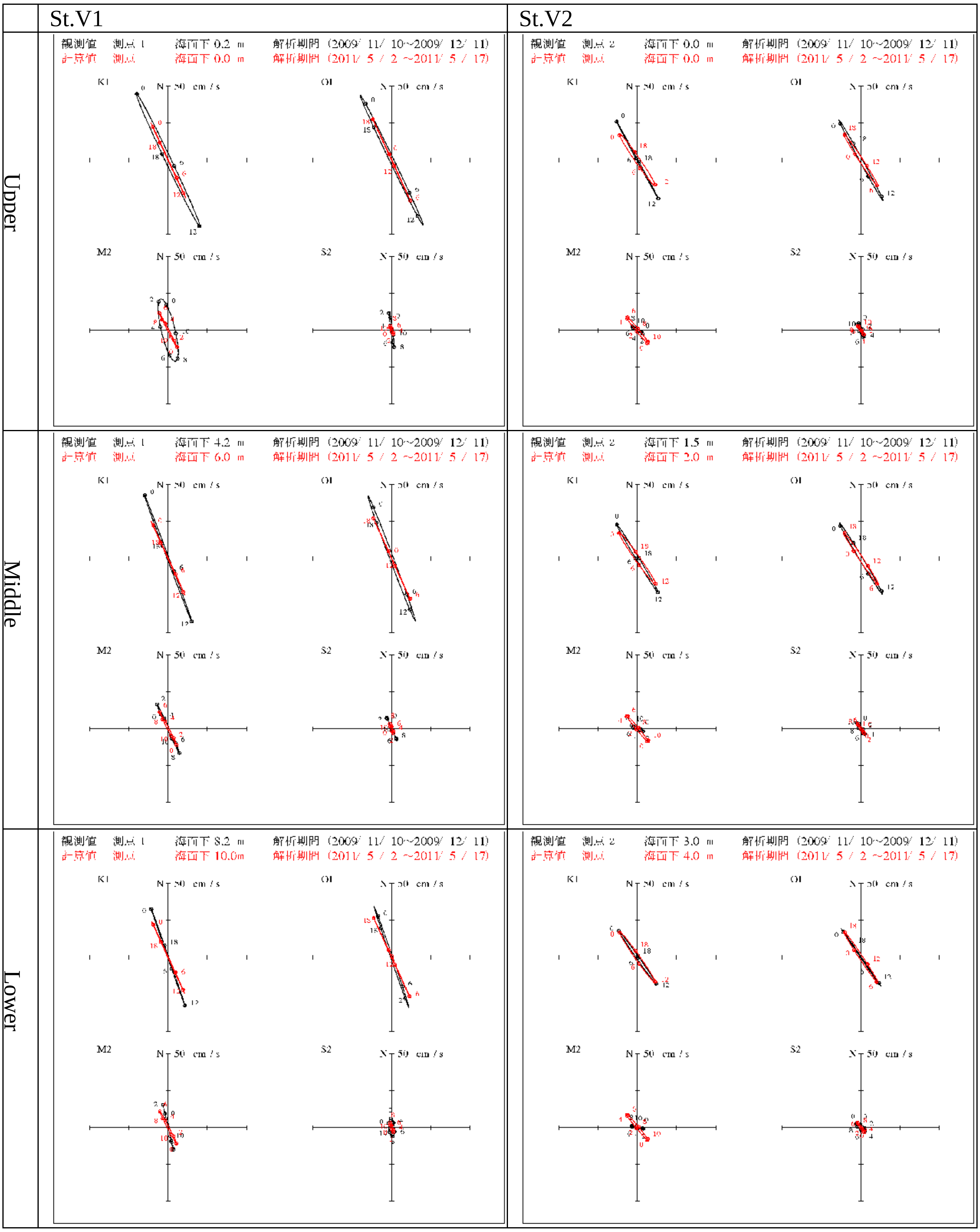
—: Absolute current value →: Flow vector

Figure 5.4.9 Reproducibility on Current based on Observation May 2011 at C4 location



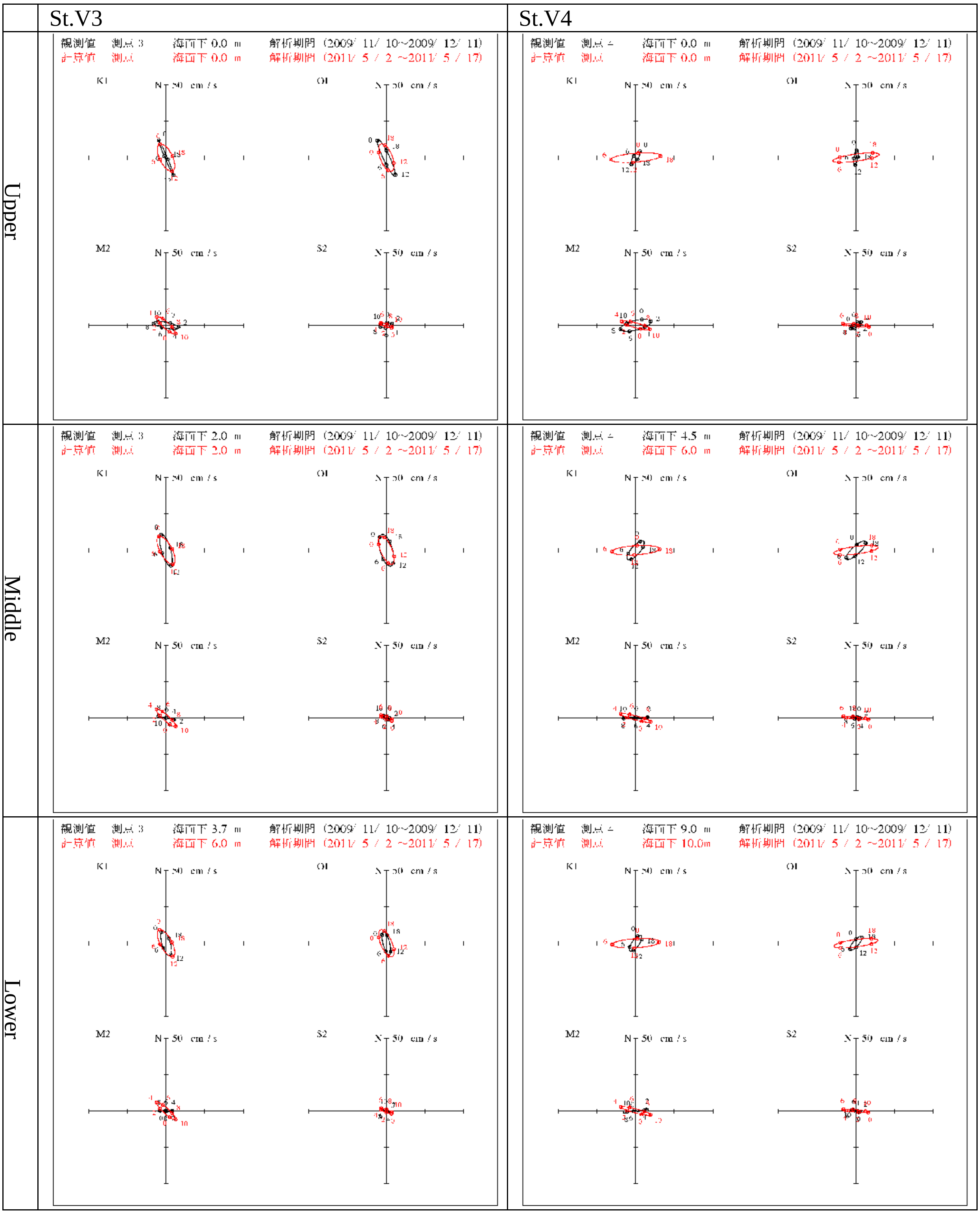
—: Absolute current value →: Flow vector

Figure 5.4.10 Reproducibility on Current based on Observation May 2011 at C6 location



—: observation, —: calculation

Figure 5.4.11 Reproducibility on Current Ellipse (Observation in November 2009)



—: observation, —: calculation

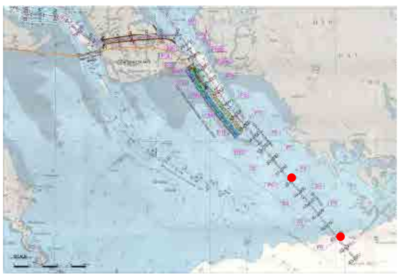
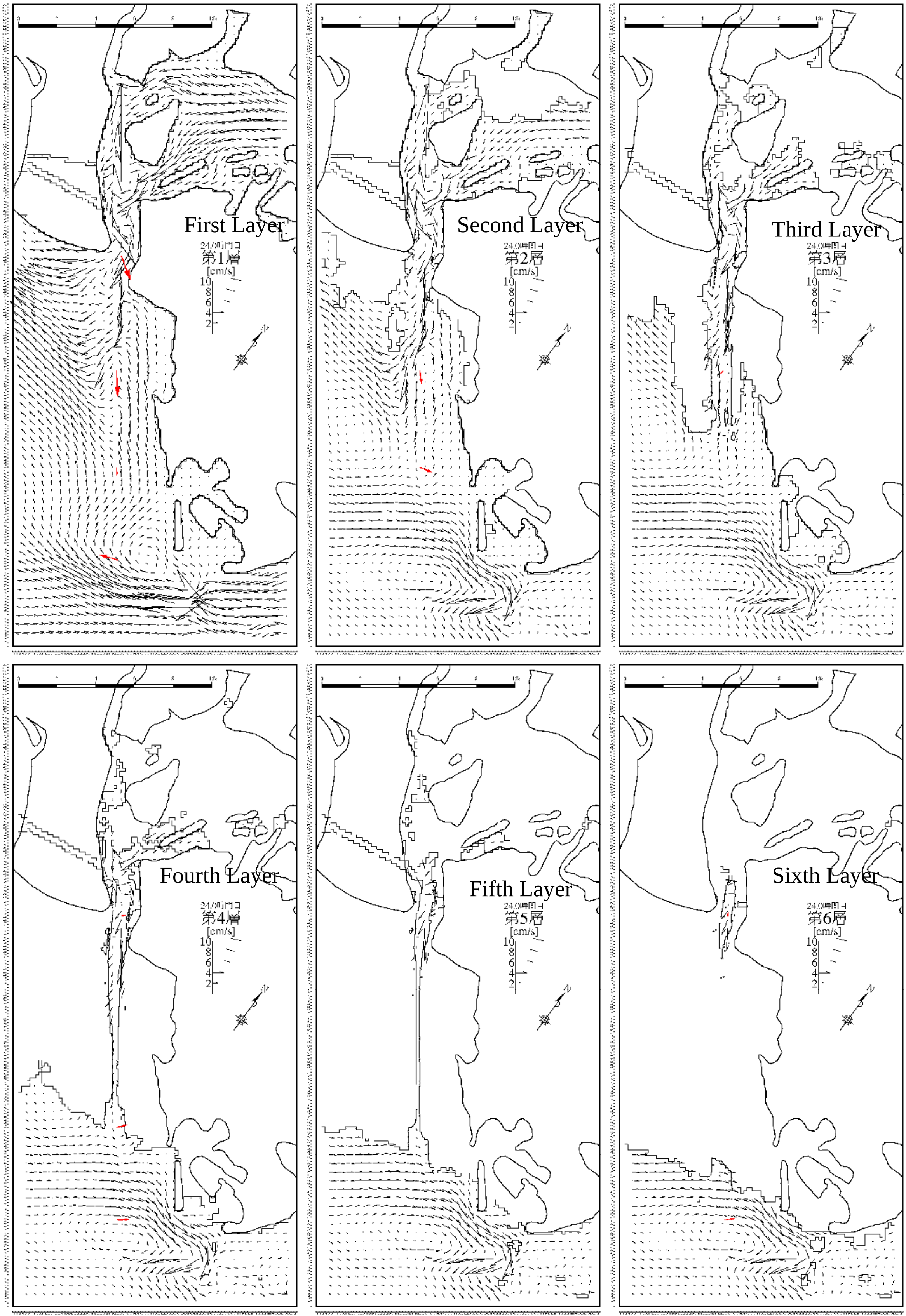


Figure 5.4.12 Reproducibility on Current Ellipse (Observation in November 2009)



→: observation, →: calculation

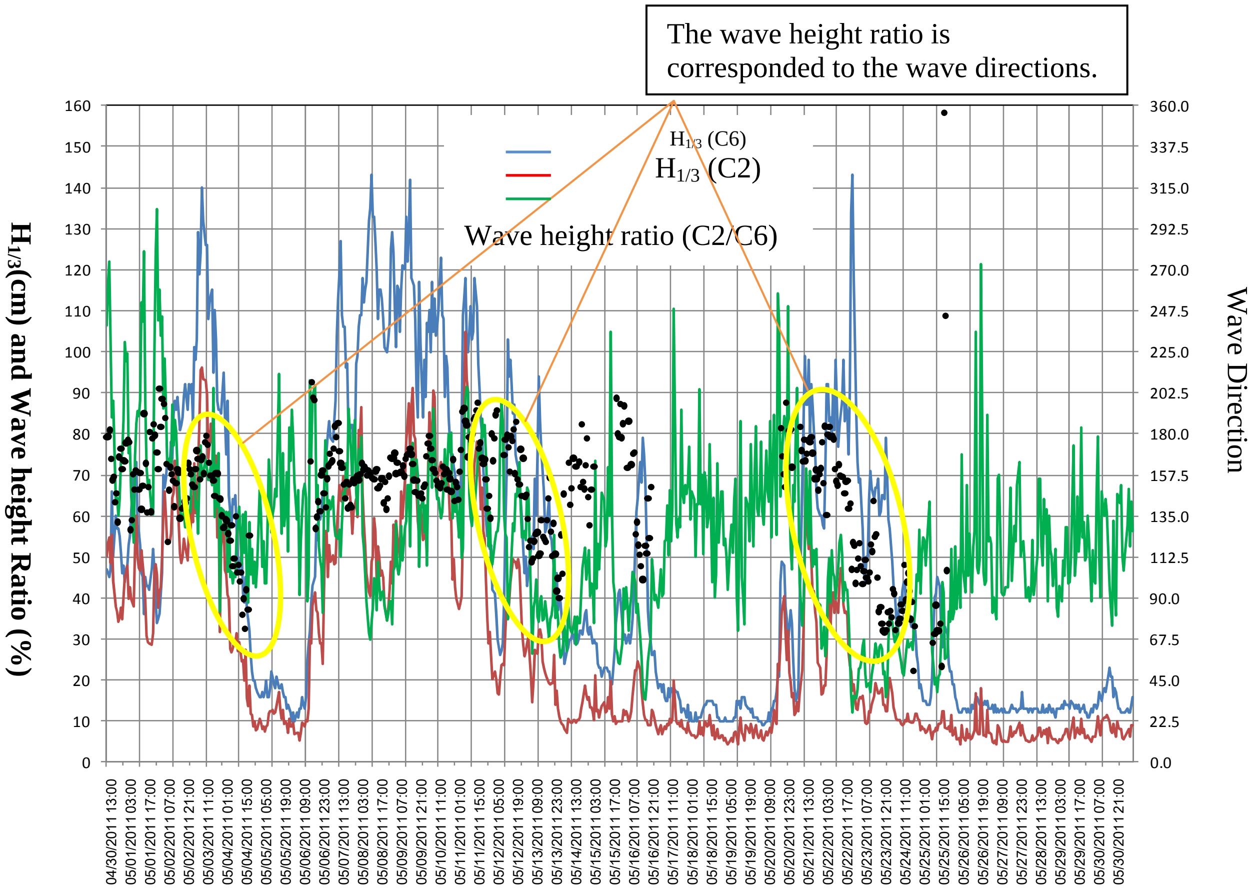
Figure 5.4.13 Reproducibility on Residual Current (November 2011)

3) Waves

The comparison of wave height and direction in time sequence between field observation and calculation at C6 and C2 (Offshore at -20m depth) is shown in Figure 5.4.14. And the wave heights observed and the simulated at the same time are plotted in Figure 5.4.15. The waves discussed are energy averaged wave and forecast higher wave with wave direction of ESE, SE and EES.

Based on Figure 5.4.14, there is a tendency to which have wave height ratio becomes smaller while changing wave direction SSE (157.5°N) to E (90°N). The reason is that the waves from E are sheltered by Cat Ba Island.

Based on Figure 5.4.15, the calculation results fall within a range of observation data. And the propagating waves offshore have a consistency with the forecast waves considering wave deformation under geological conditions such as shallow coefficient, refraction, sheltering effect by Cat Ba Island.



Note: Wave height less than 30 cm – Wave direction is indefinite
(Direction 900:N→E, 135°N→SE, 180°N→S)

Figure 5.4.14 Observation Wave Height H1/3 in time sequence (C6:-20mDepth and C2:36km)

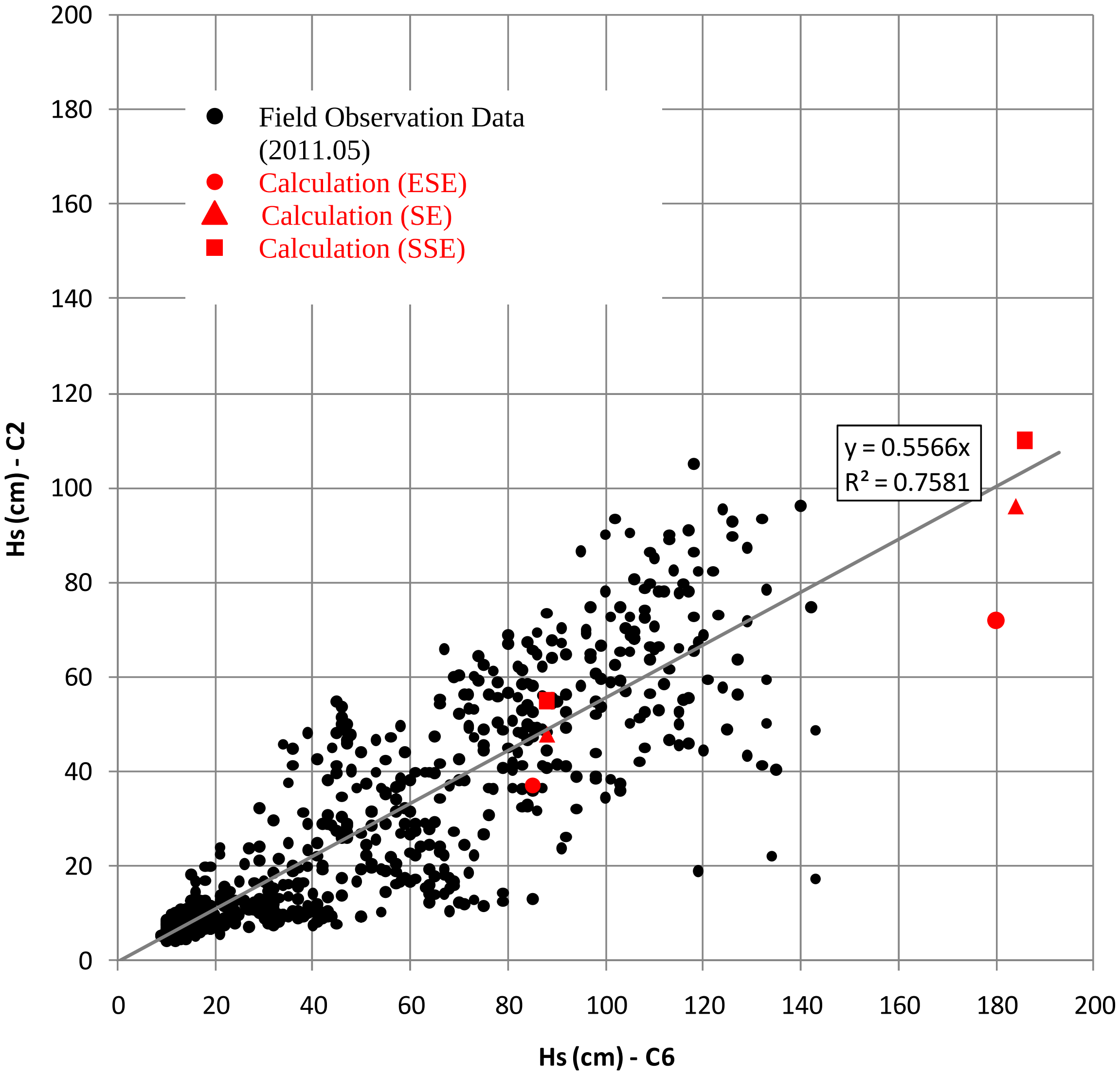
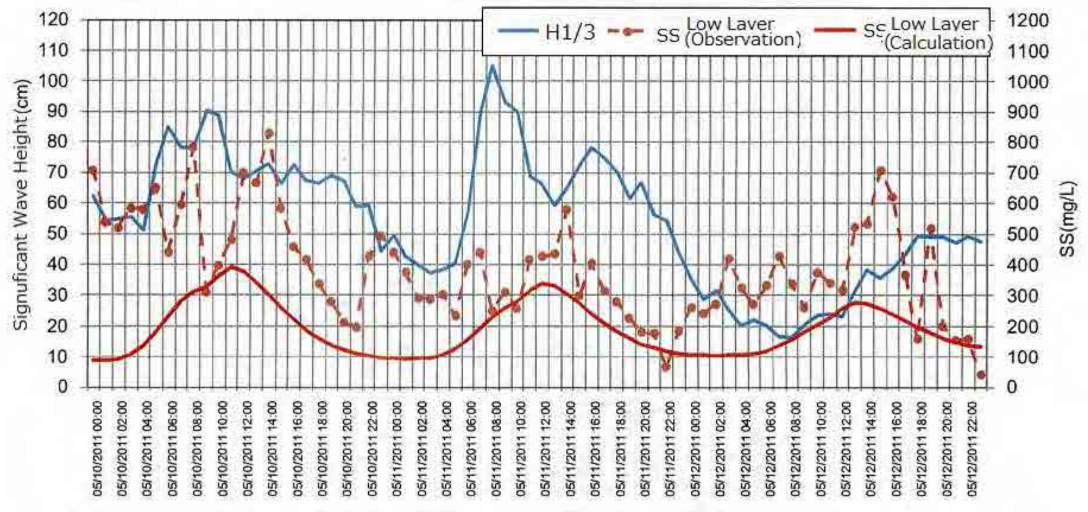


Figure 5.4.15 Relationship of observation wave heights at the same time at two locations

4) SS

The field investigation is carried out for one month from 30 April to 30 May 2011. From this investigation data, SS behavior of 10 May to 12 May is selected that is under circumstance of energy averaged waves. And Figure-5.4.12 shows the comparison between observation and simulation.



Water Sampling at the lowest layer
Calculation SS: Calculated average SS in 2m bottom Layer

Figure 5.4.16 SS behavior under observation waves and Calculated SS in time sequence (C2: 10 May – 12 May 2011)

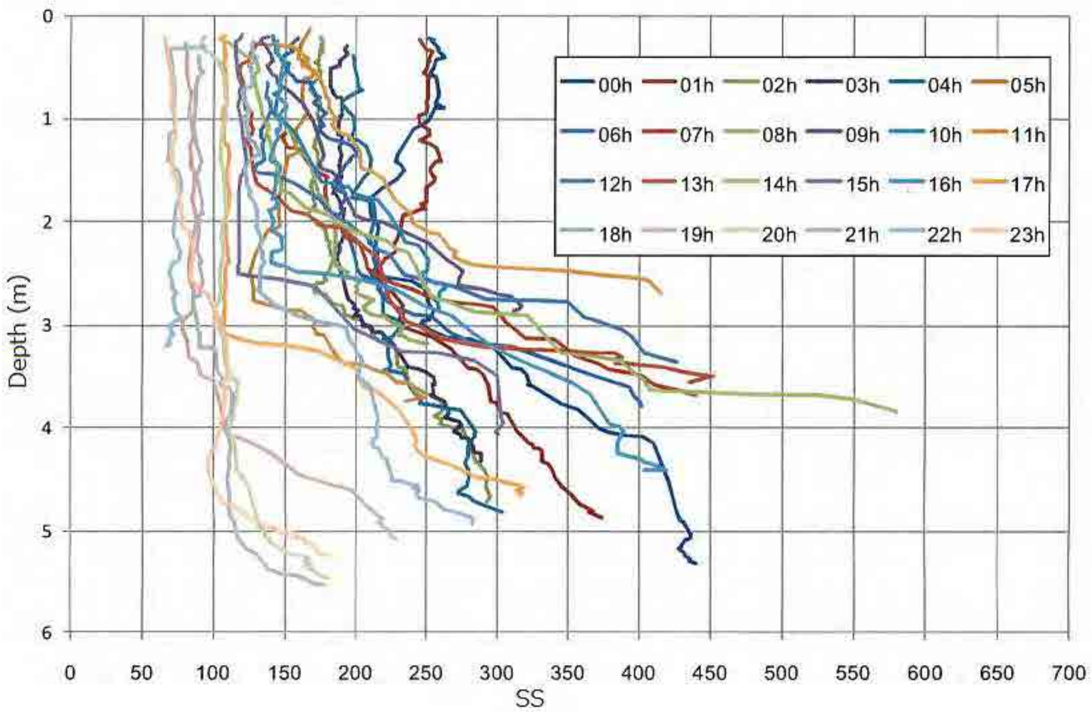


Figure 5.4.17 SS Vertical Distribution at Every Hour at C2 Location

5.4.5 Verification on Reproduction of Channel Sedimentation

The comparison between the actual sedimentation patterns and simulated patterns are shown in Figure 5.4.18 and Figure 5.4.19, for Phase 1 (2005-2006), Phase 2 (2006-2010), respectively. The total sediment volumes are summarized in Table 5.4.4 and Table 5.4.5. And the verification on reproducibility of sedimentation is discussed as follows.

1) Phase 1 (2005-2006)

There is some discrepancy in the density of sedimentation in 34-37km, where has the experience of high waves, but the sum volume of this reach has a consistency as 660,000 m^3 in simulation against 620,000-650,000m^3 in the actual sediment volume. On the other side, in offshore reach from 37km the simulation of 380,000 m^3 is smaller than the actual sediment of 470,000-510,000 m^3, but their sum volume is almost corresponded to each other.

The sediment volume in the whole channel is 1,210,000-1,490,000 m^3 of the actual sedimentation volume to 1,220,000 m^3 of simulated volume. And the sediment characteristic that in the inner part, the sedimentation is moderated and contrarily from 34km offshore the sediment volume is huge is properly reproduced.

2) Phase 2 (2006-2010)

For Phase2 (2006-2010), the simulated volume is 790,000 m^3 that is rather bigger than the actual volume of 430,000 m^3. However, also the sediment pattern is represented clearly.

In conclusion, the established sediment modeling that incorporates several external forces, characteristic of seabed material and its behaviors and geological conditions fairly represent the existing sediment mechanism, even if, in Phase 2, the estimated sediment volume is rather larger in some extent.

a) Phase1 (2005～2006)

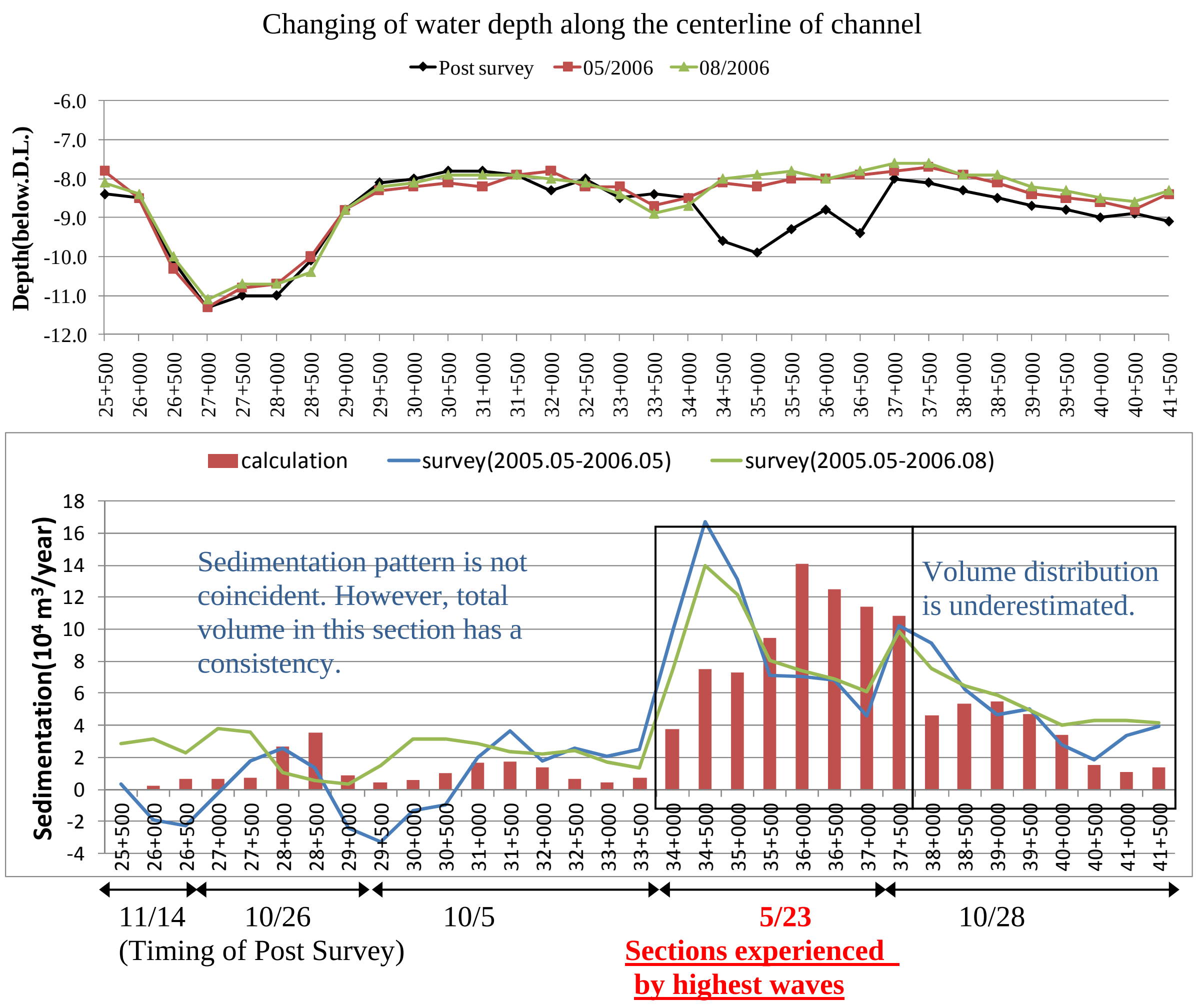


Figure 5.4.18 Phase 1: Sedimentation Volume and Pattern between Actual and Calculation

Table 5.4.4 Results of simulated sediment Volume (Phase 1) Unit: m^3

Area	Survey (Post Survey-2006/05)	Survey (Post Survey-2006/08)	Calculation
29km-33km+500	70,000	210,000	90,000
34km-37km	650,000	620,000	660,000
37km+500-41km+500	470,000	510,000	380,000
26km-41km+500	1,210,000	1,490,000	1,220,000

The actual sediment volume in each section is computed based on the bathymetric survey, considering the timing of survey date carried out and converted to the annual volume by expanding time ratio. The converted volumes are shown in Figure 5.4.18 by two straight lines. The seabed material is represented at 89% water content ratio of fluid mud. The sediment volume is converted using (Weight of sedimentation) / (Wet density of sedimentation). Only the sections of 34km to 37.5km had been experienced 4 times of high wave indicated in Table 5.4.2 in 2005. Then these sections are considered with the influence of highest wave for reproduction.

b) Phase2 (2006～2010)

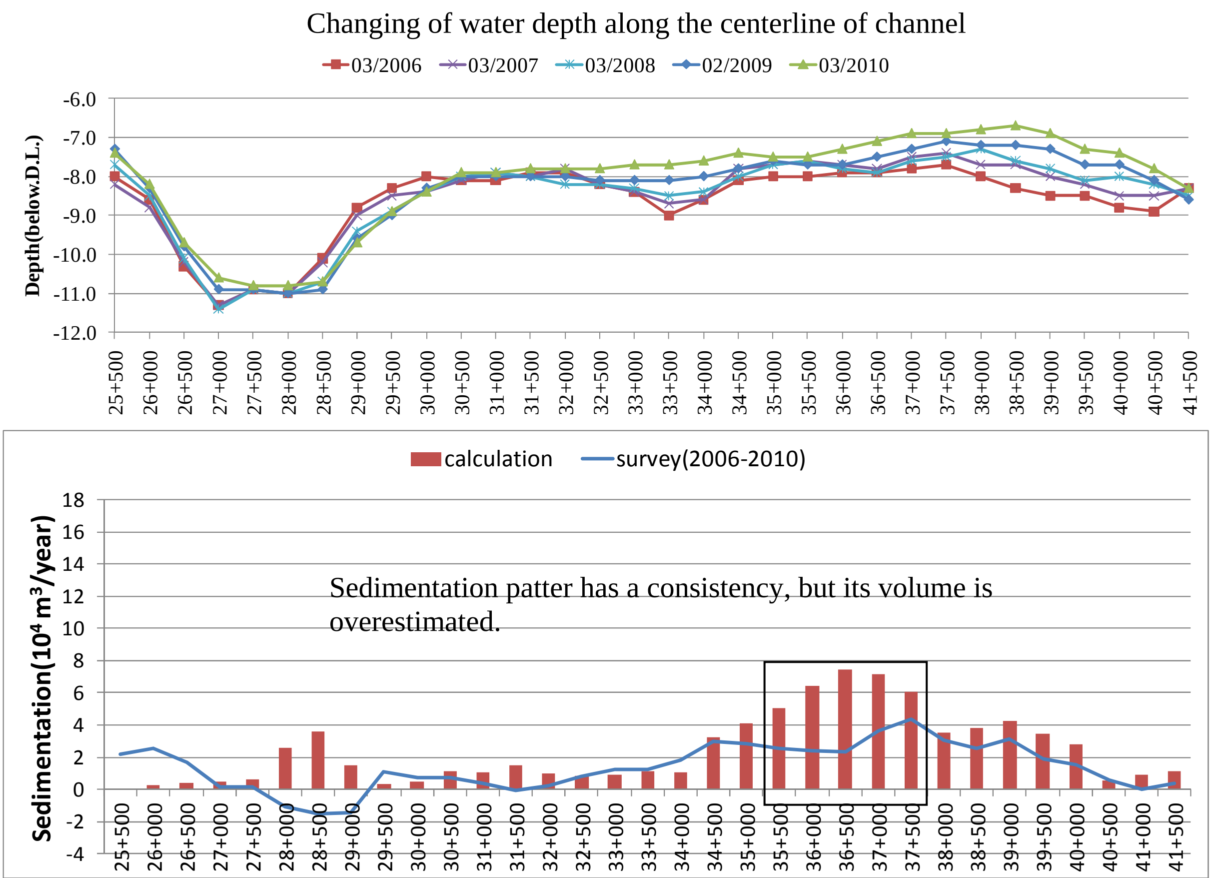


Figure 5.4.19 Phase 2: Sedimentation Volume and Pattern between Actual and Simulation

Table 5.4.5 Results of Simulated sediment Volume (Phase 2) Unit: thousand m3

Area	Survey (2006-2010)	Calculation
26km-35km	14	26
35km+500-37km+500	15	32
38km-41km+500	13	22
26km-41km+500	43	79

c) Phase1: Sedimentation volume effect by Highest waves and Energy Averaged Waves

In Phase 1, the sediment volume simulated by highest wave shown in the upper bars in Figure 5.4.20 and the lower bars show the volume for energy averaged wave. The annual sediment volume is 890,000 m^3 by the energy averaged wave and 920,000 m^3 by the highest wave, respectively. It is concluded that the effect for sedimentation by both conditions is in the same level.

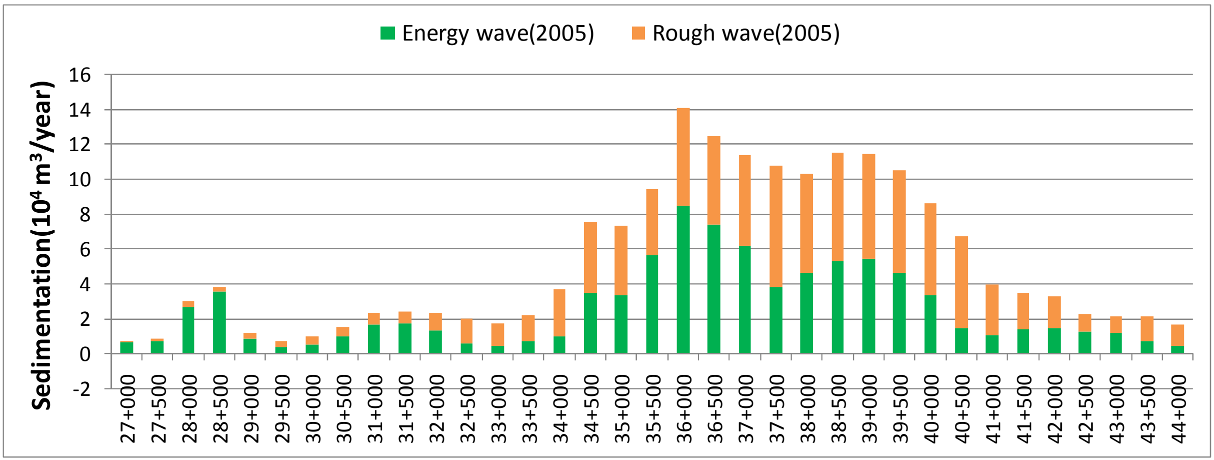
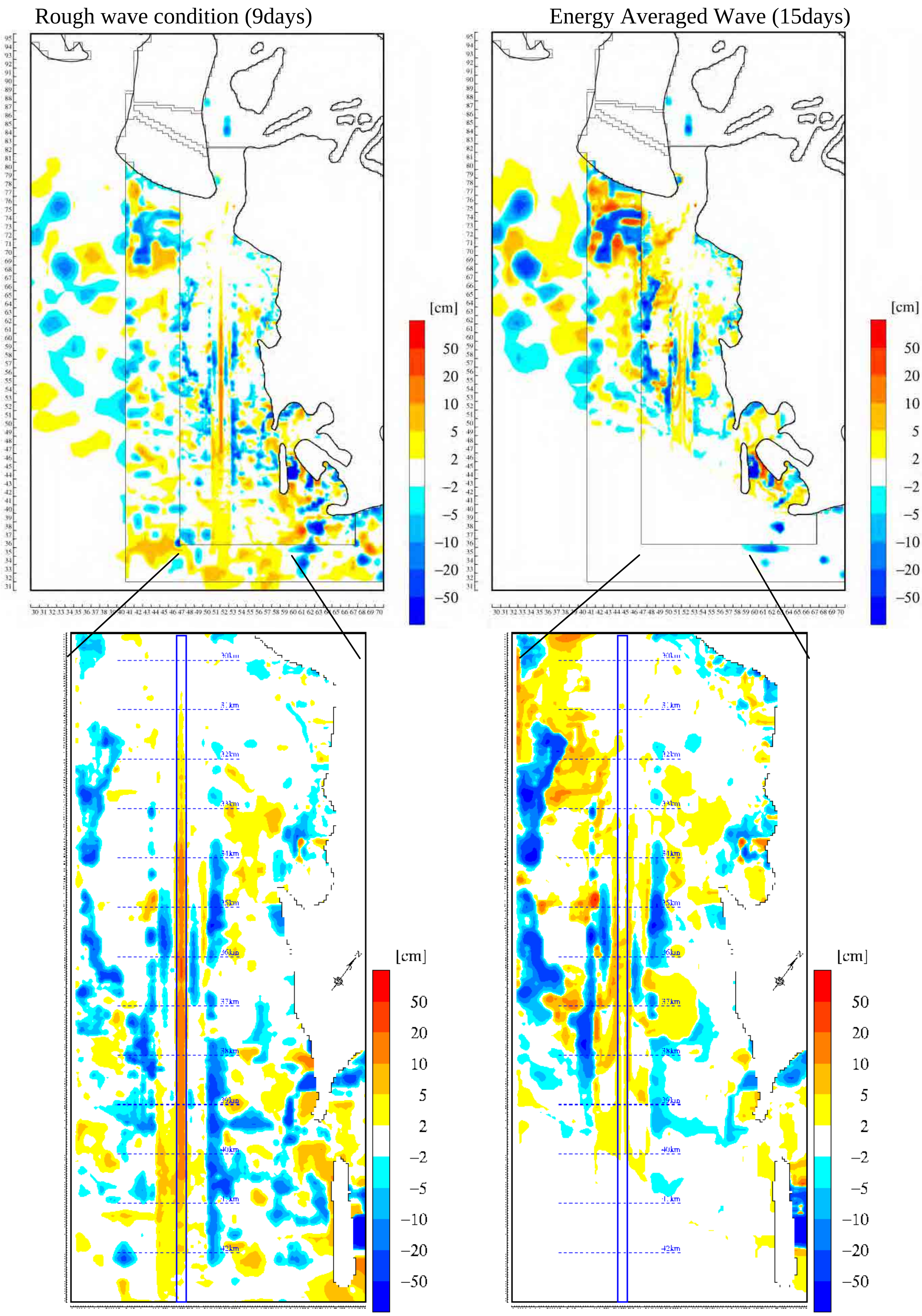


Figure 5.4.20 Phase 1: Sedimentation Volume by Energy Averaged Wave and 4 times Highest Waves

d) Changing Water Depth by Sedimentation and Erosion

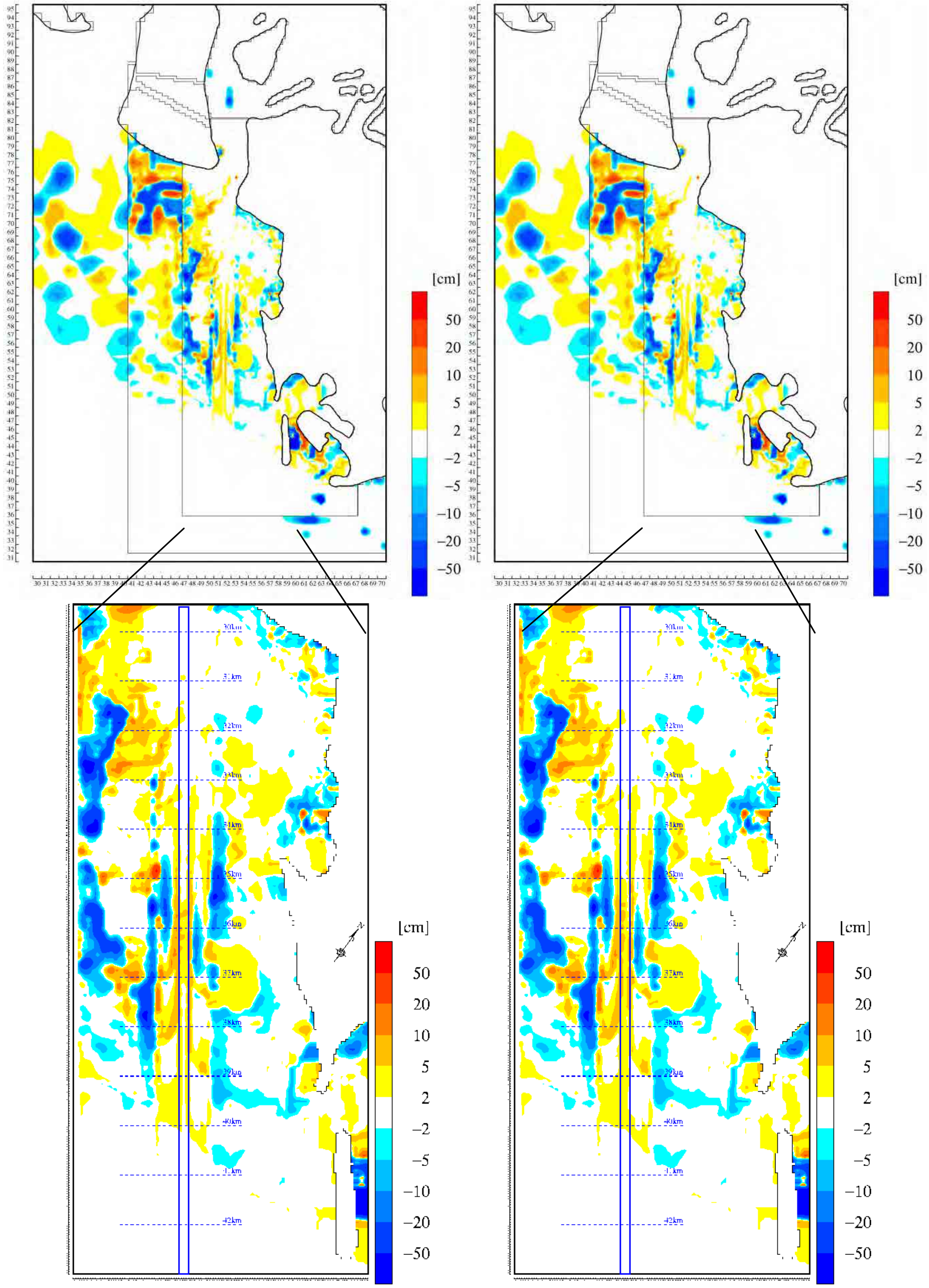
The changing water depth by the highest and energy averaged waves are shown in Figure 5.4.21 and Figure 5.4.22.



(Upper: Second Domain, Lower: Third Domain)

Figure 5.4.21 Changing of Water Depth in Second and Third Domain (Phase1: 2005～2006)

Initial geographical：2005year(15days) Initial geographical：2009year(15days)



(Upper: Second Domain, Lower: Third Domain)

Figure 5.4.22 Changing of Water Depth in Second and Third Domain (Phase2: 2006～2010)