

Some research results on erosion and deposition in the coastal zone of Haiphong

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Abstract: Haiphong is a major industrial and port city in Vietnam. It plays an important role in the coastal shipping routes in the northern part of Vietnam. In recent years, the deposition and erosion of the coastal zone of Haiphong has increased in terms of intensity and scale, which has seriously influenced the social-economic activities of the area. Of Haiphong's 125 km coastline, approximately 16.1 km is being eroded (about 23.0%). The erosion occurs at Dinh Vu Island, the southern part of Bai Nha Mac, alongside of the road N°14, Cat Hai Island and Phu Long area at a rate of 1.2 to 9.6 m/year (averaging 5.4 m/year). The deposition in the coastal zone of Haiphong occurs in a complicated manner also, especially in the Cam River. Annually, the amount of dredging of the river bed is about 2.5 to 2.9 million tonnes. In addition, southwest of the Doson Peninsula is strongly affected by the deposition phenomenon. This leads to a difficulty in construction of the deep-sea port in the area.

Keywords: erosion, deposits, deep-sea port.

1. Introduction

The deposition and erosion phenomena of the coastal zone is one of the most important natural processes, causing the loss of land and deposition of sediment in port areas, thus influencing local social-economic activities. The Haiphong Port is one of the biggest ports in Vietnam (the cargo handled was 15 millions tons in 2007). In the development plan of the Haiphong port, the construction of a new port in the Doson Peninsula are currently being developed.

The coastline of Haiphong is 125 kilometers long, and it has five estuaries belonging to the Hong-Thai Binh River system that run into the sea. The erosion occurs in the Dinh Vu Island area, the south of Bai Nha Mac, alongside of the road No.14, Cat Hai Island and Phu Long areas at a rate of 1.2 to 9.6 m/year, 5.4 m/year on average [3]. However, sediment deposition in the estuary and channels in recent years has increased, obstructing the activities of the port. In addition, the south-west of the Doson Peninsula is also strongly affected by sediment deposition. Therefore, building the deep-sea port in this area in the future will be pressured from sediment deposition from the channels.

This paper presents preliminary results of sediment erosion and deposition in the coastal zone of Haiphong, and discuss the implications of these processes on the environment and the Haiphong Port extension.

2. Material and method

This paper uses the data produced by several projects, including the National Project KHCN-5a "Research of Prediction and Control of Coastal Erosion in the North of Vietnam from Quang Ninh to Thanh Hoa" completed in 2000 (reference), and the basic project of IMER "Assessment of erosion, deposition situation and propose usage of the southern-west

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of the Doson peninsula” completed in 2002 (reference), and the project “Prediction of erosion and deposition phenomena in coastal zone estuaries in the Northern area and solutions to prevent” 2004 (reference).

The following basic methods were used:

- Analysis and integration of data.
- Statistics of data in meteorology and hydrology.
- Application of SBEACH (Numerical Model for Simulating Storm-Induced Beach Change) to calculate the height of the sea bottom according to section in a short period.
- CERC method to calculate transport of mud and sand by coastal wave
- Analysis of effect of deposition, erosion by Sundborg diagram.

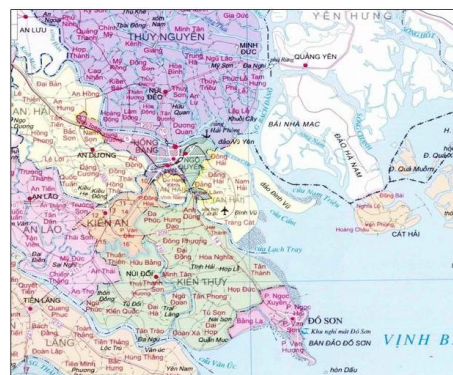


Figure 1. The Map of Study Area

3. Results and discussion

3.1. Erosion in the coastal zone of Cat Hai Island

- Results of the calculation of sand transport along the coastline caused by wave energy using the CERC model in Cat Hai:

The calculation was done at three different points Ben Got, Gia Loc and Hoang Chau. Based on survey data of wave in March (dry season), sediment transportation was calculated in Ben Got toward to the eastern was of -894 m^3 , in Gia Loc toward to the eastern was of -148 m^3 and Hoang Chau toward to the western was of 205 m^3 , the transportation at Gia Loc occurs in both directions Ben Got and Hoang Chau. In August (rainy season), these values were $6,065 \text{ m}^3$, $7,421 \text{ m}^3$, $7,644 \text{ m}^3$, respectively, and the transportation was from Ben Got to Hoang Chau (the western). Calculated for twelve months, the volume of sediment transported at Ben Got was $98,370 \text{ m}^3$, at Gia Loc was $131,656 \text{ m}^3$ and at Hoang Chau $163,617 \text{ m}^3$. The results showed that, in all years, all three areas lost sediments toward the northwest of Hoang Chau [2].

- Results of the calculation of erosion and deposition frequency according to Sundborg diagram in Cat Hai:

- In the dry season (March), there was an erosional trend in Cat Hai area. The Gia Loc area experienced the most erosion (58.9%), in which the erosion was in the west and weak in the east. At Hoang Chau, erosion was on average (25.9%), in which the erosion in the east was stronger than in the west. The deposition at Ben Got was on average level (<30%), the deposition in the east was stronger than in the west [4].

- In the rainy season (August), the erosional trend occurs in the Cat Hai area also. In Hoang Chau, Ben Got, the trend and volume of the erosion and deposition was the same as the dry season, in Gia Loc, there was deposition trend in the east and erosion trend in the west.

- The calculation results of bottom variation according to the SBEACH model in Cat Hai:

Calculated with the same conditions (size of sedimentation M_d , height of wave,...) for both rainy and dry season, the results were similar:

- There was bottom scrape phenomena in all the sections, but its distribution was different from the coast to the sea (Figure 2).
- In Hoang Chau: the maximum of bottom scrape was 0.060 m, far from the coast was about 250m.
- In Gia Loc: the bottom scrape was occurred in length 180-260 m from the coast, the maximum of bottom scrape was 0.072 m.
- In Ben Got: the bottom scrape was occurred in length 180-260 m from the coast, the maximum of bottom scrape was 0.066 m.

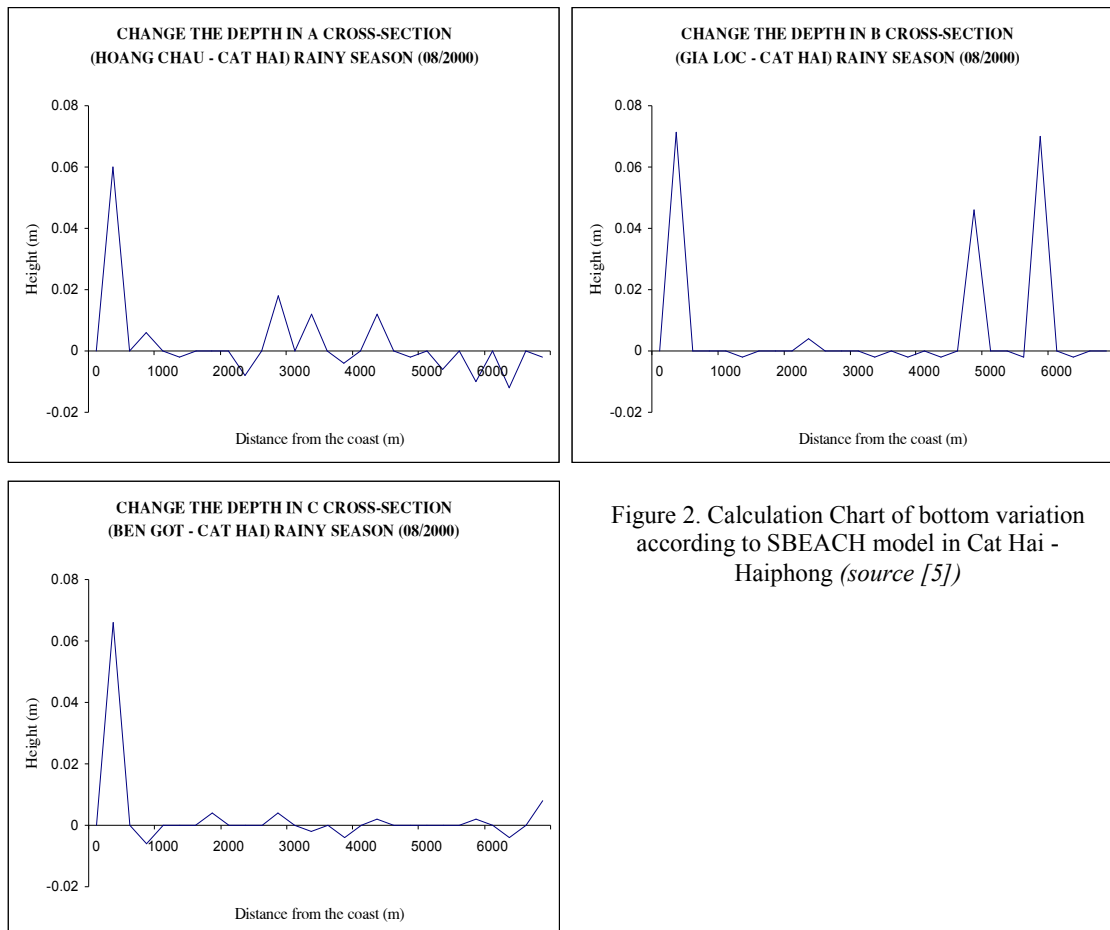


Figure 2. Calculation Chart of bottom variation according to SBEACH model in Cat Hai - Haiphong (source [5])

The coastal zone in Cat Hai has an eroded coastal length of about 6200 m (table 1). Of this, 4000 m of breakwater was very weak and dangerous due to the concentration of residents near coast in Gia Loc-Hoa Quang (1500 m), in Van Chan-Hoang Chau (2500m). In the period from 1930 to 1996, the sea encroached the island by about 230 m at the Cat Hai Town area, 360 m at Van Chan-Hoang Chau area and 600 m at Gia Loc area. The coastal length in Cat Hai Town and Van Chan was stoned soon so the rate of erosion has been reduced in recent years, the coastal length in Gia Loc has continued to undergo natural erosion, at a rate of up to 21 m/year.

Table 1. The erosion evolution in Cat Hai coast (source [2])

Period	1930 - 1965	1965 - 1990	1990 - 2000
Number of erosion sections	3	5	3
Total of erosion length (m)	6000	6200	6400
Among: weak	0	3700	3060
average	1800	0	0
strong	4200	0	2040
very strong	0	2500	1300
Average erosion velocity (m/year)	4.5	5.0	12.9
Max erosion velocity (m/year)	8.5	10.0	50.0
Velocity of erosion (m/year)	2.7	3.09	8.27

Assessment shows that, the surface of ground near the dike footing was scraped at a rate of 15 to 32 cm/year. In the last seventy years, although the coast was protected by a dike system, the scale of erosion in Cat Hai has increased a small amount, but the intensity of the erosion has increased significantly and the total area of erosion was 250 ha. Beside the of erosion in high banks, more than 1000 ha of low tidal flats were also eroded and scraped into pools with depths ranging from 0.5 to 2.0 m. A prediction for the velocity of natural erosion in the Cat Hai coastal area for the next twenty years is about 6.5 to 26.5 m/year, 1.0 m/year in average [2].

3.2. Erosion situation in Dinh Vu pesunanly

Table 2. The erosion evolution in coastal zone of Dinh Vu and neighbough areas (source [3])

Section	Period 1965 - 1994			
	Status	Length (m)	Average velocity (m/year)	Area (m ²)
South of Vu Yen	erosion	890	1.2	30972
Dinh Vu	erosion	3000	8.6	498800
The road N ^o 14	erosion	3400	4.2	414120
South of Bai Nha Mac	erosion	1700	1.2	59160
South Cat Hai	erosion	6400	6.4	454720
Phu Long	erosion	3300	9.6	918720
Total		18690	5.4	2376492

By application of GIS and Remote sensing using SPOT multi-spectrometer photographed in 1994, IKONOS photographed in 2001 and data from field surveys [3], it was showed that: in the south and the south-east of Dinh Vu, the zero line of the sea chart (0m) in 1934 was directed near parallel with channels of Cua Cam and Nam Trieu, it created two sandbars at low tide and last to the sea and get close two estuaries. Section of low tidal flat in the south, the zero line of sea chart was uneven, saw-tooth shape. In 1991, the tail and middle sections of sand bars were cut and pushed toward the south-east creating high sand bars with tops that were higher than the average seawater level. The zero line of sea chart had saw-tooth shape of low tidal flat in the south of Dinh Vu that was deposited and widened toward the sea by eroded sediment from the high tidal flat. The general change of the zero line of sea chart was expanded toward the south (Cam Estuary) - the largest

section was 800 m - but eroded in Nam Trieu Estuary and creating sand bars higher than the average seawater level. These sand bars had trend to transport into the west and reach distance from 700 to 800 m. Ten years after building of Dinh Vu Dam (1991), the Cua Cam Channel behind Dinh Vu Dam was absolutely deposited and become to low tidal flat, the erosion length of Dinh Vu was about 300 m (table 2). In 2001, twenty years after building of Dinh Vu Dam, the Cua Cam Channel behind Dinh Vu Dam was higher than the average seawater level and it was banked into aquaculture ponds. At present, the distance of Dinh Vu and Trang Cat coasts is only 100 to 200 m and it was used as canal to collect and irrigate water for aquaculture ponds.

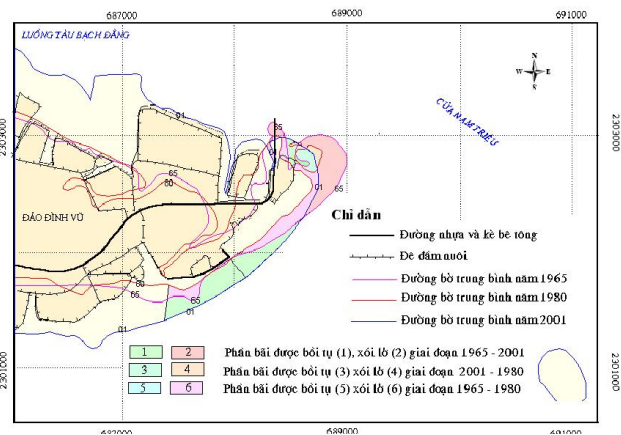


Figure 3. The chart of deposition- erosion in south-east of Dinh Vu area in 1965-1980-2001 (source [3])

In summary, the trend of deposition and erosion in the south and south-east Dinh Vu was erosion of high tidal flat, deposition in the channel and low tidal flats that occurred in long time ago. Noticeably, after 1981, with the completion of Dinh Vu Dam, deposition of channels and low shore in the west and south-west of Dinh Vu increased suddenly and filled up the Cua Cam Channel, and it begins to occur the trend of widen deposition of high tidal flat. However, in the section of the concreted dyke in the south of Dinh Vu to Nam Trieu Estuary, deposition in high tidal flat has slowly reduced, and erosion has occurred at many high banks.

At present, there is a depositional trend of low tidal flats and deep canals by natural processes and by the Dinh Vu Dam building, but in the high coast in the south-east of Dinh Vu is strong eroded continuously. This result was originated from the facts and was determined by comparison of two high coasts (2,3m/0m) on the SPOT multi-spectrometer satellite photo taken in 1994 and the IKONOS photo taken in 2001. On the coastal length of near 1500m from the concreted dyke to Dinh Vu that was building in seven years (1994-2001), the high coast was eroded continuously. The intensive coastal erosion in the south-east of Dinh Vu can be divided into four levels: strong (velocity > 10 m/year) occupied about 10.3%, a mildly strong (5 to 10 m/year) occupied 24%, average (2.5 to 5 m/year) occupied 31.5%, and weak (<2.5m/year) occupied 34.2%. Thus, about one-third of coast in the south-east of Dinh Vu underwent strong erosion (>5m/year), one-third underwent average erosion and one-third underwent weak erosion.

The study result of deposition and erosion variation of average coastline in the south-east of Dinh Vu showed that:

Table 4. The dredging amount in port of Haiphong

Year	Dredging amount (million m ³) (*)
2001	2.950
2002	2.361
2003	2.404
2004	2.845
2005	2.470
Fisrt quarter in 2006	1.480

(*): the above amount did not include the dredging amount of the Improve Project of Haiphong port phase II in 2004-2005 for Ha Nam canal and Lach Huyen.

Source: Hai Phong Port Administration, 2006.

- In the period from 1965 to 1980 (before building of Dinh Vu Dam), this was the period that the erosion was strongest with the highest velocity 11.8 m/year. The eroded coast was 1,610 m long, occupied 83% of the erosion/deposition coast length and the strongest eroded coast was 1,250 m long, occupied 64.4% of erosion/deposition coast length and occupied 77.6% of eroded coast length (Figure 3). Average velocity of erosion was 7.7 m/year. The strongest erosion coast was about 1 km from the concrete dyke toward the eastern part. There were two old sand bars in this area before, and outside of old sand bars was high tidal flat with mangrove.

Table 3. Deposition-erosion variation of average coastline in the southeast of Dinh Vu in 1980-2001 (source [3])

The average coast length (m)	The average coast width (m)	Area (ha)			Average velocity (m/year)
		Deposition	Erosion	Blance erosion-deposition	
1100	150	16.5	-	+16.5	+7.1
210	52	-	1.1	-1.1	-2.5
150	53	-	0.8	-0.8	-2.5
300	10	-	0.03	-0.03	-0.5
Total: 1490		16.5	1.93	14.6	+3.5

(+) *The blance and velocity of deposition, (-) The blance and velocity of erosion*

- In period from 1980 to 2001 (Dinh Vu Dam was completed), the effect of Dinh Vu Dam to the average coast was quite high express in the reduce of not only erosion velocity but also the length of the erosion coast. (table 3). However, as analyzed in the 1994 SPOT image and 2001 IKONOS image, it was showed that the coast was continuously eroded in seven years with an average velocity of 4.2 m/year. According to survey data of bathymetry and our survey results in last ten years [3], although the low tidal flat in the southeast of Dinh Vu had a deposition trend toward the sea, there were always existence of a small canal far away from the average coast about 250-500m and last to the northeast-southwest then changed into south-north. This canal eroded low tidal flats and created shallow (1 to 1.5 m deep) pools compared to the surface of the tidal flat.

3.3. Deposition status in the coastal zone of Haiphong

The coastal zone of Hai Phong is facing a sediment deposition problem, especially for the channels entering Hai Phong Port. The port was built along the Cam-Bach Dang Estuary. These two rivers control the hydrodynamic regime of the area, and both flow to the sea through Nam Trieu Estuary. The total annual average water discharge through the Nam Trieu Estuary was 12 km³ and the mud-sand discharge was approximate 5.0 million tons. The concentration of sand is high and changes depending on the season. In the rainy season, the average turbidity changed in range of 53 to 215 g/m³ to a maximum of 700 to 964 g/m³. In the dry season, the average turbidity changed in range from 42 to 94 g/m³ to a maximum of 252 to 860 g/m³, turbidity was high in the mouth of the river due to the wave and tidal current. The mud-sand amount in August was highest, comprising 35 to 40% of total mud-sand of the year, the mud-sand amount in March was lowest, only 0.5 to 1.0% total mud-sand of the year [6]. According to table 4, in the period from 2001 to 2005, the annual dredging volume of the channel and Hai Phong Port was 2.3 to 2.9 million m³.

Table 5. Predicted results of isobathymetry contour site in the southwest of Do Son area in the next 50 years compared to 2002 (source: [1])

Velocity and site of isobathymetry contour compare to 2002		Radian coast		
		Cong Hong 2.5 km	Bang La 1.5km	Quan Muc 1.7 km
Average seawater level	Deposition velocity (m/year)	70	56	50
	Site compare to Average seawater level in 2002 (m)	3500	2800	2500
0m Sea Chart	Deposition velocity (m/year))	40	50	30
	Site compare to 0m Sea Chart 2002 (m)	2000	2500	1500
2m	Deposition velocity (m/year))	30	20	20
	Site compare to 2m Sea Chart 2002 (m)	1500	1000	1000
4m	Deposition velocity (m/year))	18	16	14
	Site compare to 4m Sea Chart 2002 (m)	900	800	700

The coastal zone in the southwest of Do Son Peninsula is the northeast edge of the Hong River Delta that extends from Do Son to Lach Truong. The evolution of the sedimentary environment of the area during the Holocene shows that the accumulation of sediment occurred continuously during the last 80,000 years with an average velocity of 2.2 mm/year. About 3,000 years ago, the velocity of sediment accumulation increased strong and reached an average 5 mm/year, exceeding the rising sea water level and depression tectonic (approximately 3 mm/year). The major supply source of alluvium for the area now is the Van Uc River with an alluvium discharge of about 11 million tons/year. The average coastline represents clear phases of erosion and deposition with a cycle of about 30 to 40 years, the average velocity was approximate 10 m/year reaching a maximum of 100 m/year in short periods of time. The erosion/deposition balance of two phases deposition and erosion was adjoining each other to trend deposition encroach the sea. The zero line of sea chart had deposition trend continuously when erosion-deposition balance with average deposition velocity over 10 m/year, maximum to 70-80m/year, express unclear erosion-deposition phase. In the side of coast, the erosion-deposition balance in isobathymetry contours showed the continuous deposition trend and encroached toward to the sea clearly with velocity higher tens times compare to the coast. Prediction, that in the next 5 to 10 years, the deposition velocity of coast and coast side will be the same in the period of ten years ago, the average coastline will extend from the current coastline by about 500 to 600m, the zero line of sea chart for deposition will come to sea about 600-700m, and in depth about 4-12m, the deposition velocity will be as strong as at present. In next twenty year, the deposition velocity of coast and submarine coast will reduce compared to the 1992 to 2002 period but many times higher compared to 1934 to 1965 period, the average coast will have shape similar to one meter height contour upper the zero line of sea chart at present. In the next 50 years, the side of submarine coast near shore with deposition activity of wave will create submarine sand bar in the southeast of Hon Dau, the zero line of sea chart will come across to Van Set bay, near the current isobathymetry contour 2m and the average coastline will come to near Van Huong bay.

The southwest of the Do Son area belongs to a delta area with strong sediment deposition characteristics,, the shape is convex toward the sea, the isobathymetry contour and coastline always changes strongly while the deep-sea port always need to maintain channels's depth over ten meters. Therefore, building of a deep-sea port in this area is not fit for nature rule.

4. Conclusions

The coastal zone of Hai Phong and the northeastern of Do Son is characterized by Bach Dang Estuary, the erosion-deposition phenomena are complex and are increasing in terms of both intensity and frequency in recent years. Noticeable erosion phenomena in Cat Hai coast, Dinh Vu coast was dominated by a horizontal erosion trend, deposition of channels, in which deposition of Nam Trieu, Bach Dang Channels, Cam River Channel that get into Hai Phong Port related natural processes that decided system - geography nature and geological environment of delta estuary area and even derivative effect of human works leading change hydrographic structure of delta estuary. The total length of the Hai Phong eroded coast was 16.1 km, 23% of the 125 km coastline, in which, the erosion phenomenon in Cat Hai coast was most serious compared to the total coastline of Hai Phong, after that, it was the southeastern area of Dinh Vu Peninsula. The deposition phenomena in coastal zone of Hai Phong also occurs complex, especially Cam River Channel - the major channel of Hai Phong Port. With current deposition velocity, the dredging amount of channels was 2.5 to 2.9 million tons/year. In addition, the southwestern part of Do Son Peninsula belongs to a delta area with noticeable deposition and with the planned building of the deep-sea port in this area there will be high pressure from deposition from the channel.

5. References

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