TÍNH TOÁN SỰ BIẾN ĐỔI ĐƯỜNG BỜ TẠI KHU VỰC CỬA ĐẠI (HỘI AN)

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Tóm tắt Bài báo trình bày một số kết quả tính toán về sự biến đổi đường bờ tại khu vực Cửa Đại (Hội An). Các đặc trưng sóng ngoài biển khơi được tính toán bằng mô hình WAM, các đặc trưng sóng vùng nước nông ven bờ được tính toán bằng mô hình SWAN, số liệu gió với khoảng đo 6 giờ một lần trên toàn Biển Đông được thu thập từ nguồn số liệu NCEP/NCAR. Sự biến đổi của đường bờ dưới tác động của sóng được tính toán bằng mô hình GENESIS. Sự biến đổi đường bờ tại bờ phía nam sông Cửa Đại trong thời kỳ mùa mưa, khi dòng chảy sông chiếm ưu thế, được tính toán bằng cách cải tiến mô hình GENESIS với việc tính toán tốc độ vận chuyển bồi tích dọc bờ bằng mô hình của Van Rijn. Sự biến đổi đường bờ qua các thời kỳ khác nhau từ năm 1997 đến 2000 đã được tính toán và so sánh với số liệu đo đạc, nhìn chung kết quả so sánh là khả quan ngoại trừ các đoạn bờ nằm ở các biên tính toán. Kết quả nghiên cứu cho thấy rằng, những năm gần đây đường bờ phía bắc Cửa Đại đang bị xói lở, đường bờ phía nam đang được bồi tụ. Bờ phía nam sông Cửa Đại được bồi tụ nhẹ trong thời kỳ mùa khô và bị xói lở mạnh trong thời kỳ mùa mưa. Kết quả nghiên cứu cũng chỉ ra rằng có thể trong những năm tới Cửa Đại tiếp tục di chuyển về phía nam.

COMPUTATION OF SHORELINE CHANGE AROUND DAI MOUTH (HOIAN), CENTRAL VIETNAM

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Abstract A study has been carried out to understand the change of shoreline around the Dai mouth (Hoian), Central Vietnam. Wind data obtained from 6 hourly NCEP/NCAR reanalysis data over the East Sea were used to estimate the wave characteristics in the offshore and nearshore regions using WAM and SWAN wave models respectively. The change of shoreline due to wave action was simulated using GENESIS model. At the southern bank of Dai mouth during wet season when river flow dominated, longshore sediment transport rate was estimated using Van Rijn formula and used in GENESIS model. Shoreline change during different periods from 1997 to 2000 was estimated and compared, in general the computed shoreline positions show relatively good agreement with measured ones, except the shoreline sections, which are located in the computing boundaries. The studied results show that, in the recent years the northern shoreline is undergone of erosion, whereas the southern shoreline is undergone of accretion. The southern bank of the mouth is lightly undergone of accretion during dry season, and strongly undergone of erosion during wet season. The studied results also show that the possibility of Dai mouth system to move towards south direction.

I. INTRODUCTION

GENESIS (GENEralized model for SImulating Shoreline change) is based on "one-line" theory (Hanson *et al.*, 1991), this theory was developed by Pelnard-Considere (1956). Bakker (1969) extended the one-line theory to include two lines: one line representing the shoreline and the other representing an offshore contour. The one-line theory was first numerically implemented by Price *et al.* (1973). Then Kraus and Harikai (1983), Kraus *et al.* (1985), and Hanson and Kraus (1986a, 1986b) developed specifically to simulate conditions at Oarai Beach, Japan, which was reformulated in a generalized form, leading to the modeling system GENESIS. A numerical model representing the bathymetry by an arbitrary number of lines was presented by Perlin and Dean (1983). However, due to a lack of understanding of the physical phenomena involved, in particular of the cross-shore transport rate, for which no reliable quantitative relation has yet been established, these multi-line models have not found much engineering use. Kraus *et al.* (1985), and Hanson and Kraus (1986b) present an attempt to use GENESIS model as an engineering tool for making shoreline change forecasts for a real beach. In recent years, there have been many authors in the world applied GENESIS model to simulate shoreline change.

Thubon River joins the East Sea (South China Sea) at the Dai mouth, having drainage basin of 10,350 km^2 and mean rainfall of 2,500 mm (Bac, 2002). Based on the measured data from 1976 to 1993 the monthly distributions of rainfall and river discharge were mostly concentrated in September, October, November, and December (Hung, 1995), these data are shown in Tab. 1.

Tab 1. Monthly distribution of mean rainfall and river discharge

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall mm	73	4	3	10	100	93	52	47	180	1252	515	334
%	2.7	0.2	0.1	0.4	3.8	3.5	1.9	1.8	6.8	47.1	19.3	12.5
Discharge m^3/s	214	123	87.9	67.8	98.3	103	72.7	71.8	139	609	826	505
%	7.3	4.2	3.0	2.3	3.4	3.5	2.5	2.5	4.8	20.9	28.3	17.3

According to Trinh (2000) during dry season, mean current velocity of ebb and flood were approximately of 0.15 to 0.25 m/s respectively, during wet season river flow was predominately and mean current velocity were approximately of 0.3 to 0.5 m/s, maximum measured value of river flow was 1.31 m/s (7h30’ on 22 September 1997). Mean depth-averaged suspended sediment concentration during dry and wet season was approximately 13 and 150 mg/l respectively.

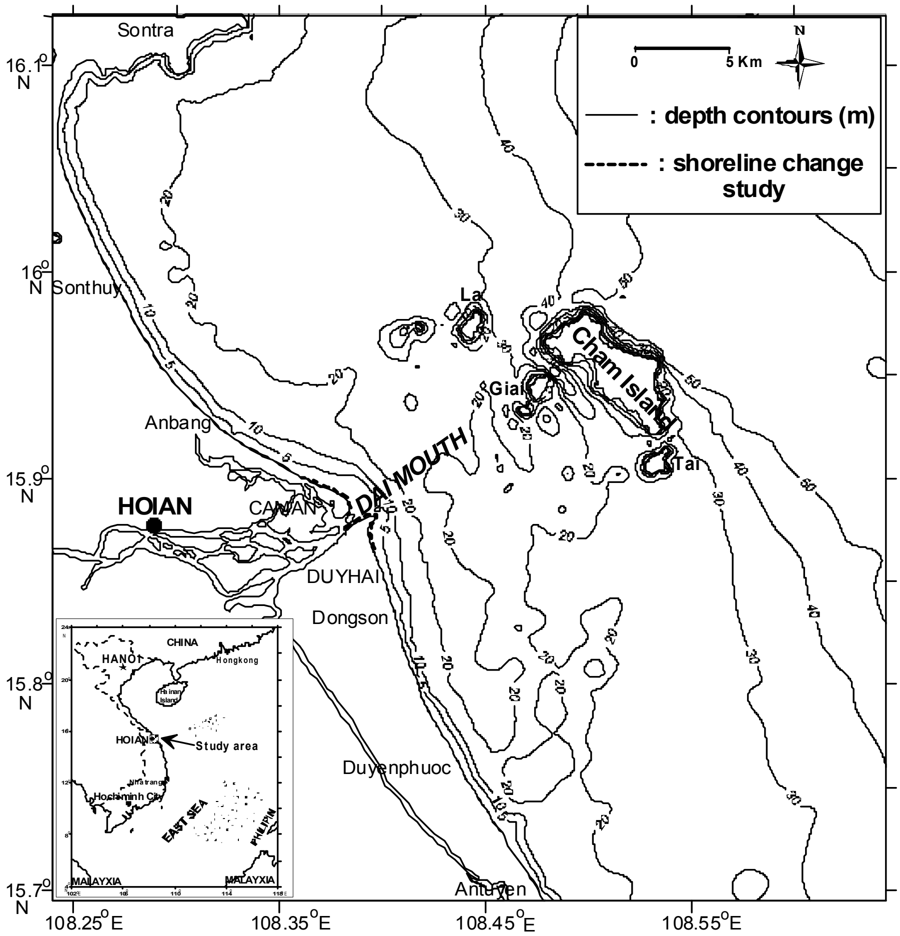

Fig. 1. Map showing study area

Oceanographic conditions of the nearshore waters along this region are subjected to seasonal variability with the reversing southwest (June – August) and northeast monsoon (September – May). The data on tides of this region were taken from Danang station, which are irregular semi-diurnal with average tidal height of 0.77 m (the mean spring tidal range was 1.36 m and the neap tidal range was 0.37 m). Study by Mau *et al.*, (2004) shows that 69 typhoons occurred in the vicinity of the Hoian coastline during 1945 to 2003 (an average of 1.2 times per year), in which 36 typhoons with maximum wind speed (V_{max})>33m/s, 20 tropical storms (17m/s ≤ V_{max} ≤33m/s), and 13 subtropical storms (V_{max}<17m/s). Occurrences of typhoons were mostly in September (26.1%), October (30.4%) and November (13%). The wave climate of this region is dominated by northeast and southwest monsoons.

The continental shelf off the study area is relatively narrow with 20 m depth contour occurring at 2 km, 30 m at 10 km and 50 m at 12 km away from the coast, except in the area of Dai mouth, where shoals are present. At about 12 km distance from the Dai mouth in the northeast direction, Cham Island of 8 km width is present. Coastline consists of long sandy beaches, with medium to fine sand with median size approximately from 0.15 to 0.2 mm. The general geomorphologic features of the study area are shown in Fig. 1.

II. MATERIALS AND METHODS

- **Bathymetry:** The bathymetry of the Hoian area was taken from the 1:100,000 topographic map published in 1980 by the Vietnamese Navy. Bathymetry around the Dai mouth was taken from the data collected during the National Project KHCN0608 in 1998 (Trinh, 2000). Bathymetry of South China Sea was taken from 'ETOPO5' bathymetry data set of the National Geophysical Data Center, Colorado, USA, which cover the region between 0^oN to 25^oN and 100^oE to 120^oE with resolution of 1^o x 1^o.

- **Winds:** Wind data at six hourly intervals during September 1997 to July 2000 collected from NCEP/NCAR data (Kalney *et al.*, 1996) were used in the study. These reanalysis global wind data in 2.5^o x 2.5^o grid were extracted and linearly interpolated for the 1^o x 1^o grid size over South China Sea.

- **Measured methods:** Wave parameters were measured using pressure gauge (Model AWH16M-1). Current velocity was measured using current meters (Model DNC-2M and BMM) suspended from a vessel. Suspended sediment concentration was collected using a 5-l Niskin bottle. Shoreline positions were measured using a GPS (Global Position System) Model Fuso FGP-722 along the line of mean high water. Measured station system is shown in Fig.3.

- **WAM model:** The offshore wave climate off Hoian was computed using WAM (Wave Modeling) model (WAMDI Group, 1988; Guenther *et al.*, 1992). The WAM model describes the evolution of a two-dimensional ocean wave spectrum. It is the third generation wave model guiding to compute the 2-d wave variance spectrum through integration of the transport equation. Input data for WAM model were bathymetry over South China Sea and wind data sets. The computational domain cover the region between 0^oN to 25^oN and 100^oE to $120^o E$ with resolution of $1^o \times 1^o$.

- **SWAN model:** SWAN (Simulating WAves Nearshore) is a third – generation wave model (Booij, *et al.*, 1999; Ris, *et al.*, 1999; Holthuijsen *et al.*, 2003) with which realistic estimates of wave parameters in coastal areas, lakes and estuaries from given wind, bottom, and current conditions can be obtained. The model is based on the wave action balance equation. The input data for SWAN model were wave boundary conditions, taken from the results of WAM model, and local wind fields. Size of the computational grid was 45 x 47.75 km, with resolution of 250 x 250 m, which covers the area from 108.24^oE to 108.645^oE and from 15.695^oN to 16.124^oN (Fig. 1).

- **Van Rjin formula:** Longshore sediment transport rate along the south bank of Dai mouth during wet season was calculated using Van Rijn formula (Van Rijn, 1991). Standard coefficient values given in the literature were used without calibration. The rate was calculated considering the local wave and current parameters. Local wave characteristics were taken from the results of SWAN model and transferred to breaking zone by internal wave model of GENESIS. The total time-averaged sediment transport rate (q_t) in a current superimposed by waves were obtained by vector addition as follows:

$$q_t = [(q_c)^2 + (q_w)^2 + 2\,|q_c|\,|q_w|\cos\Phi]^{0.5} \qquad (1a)$$

in which:
$q_c = q_{b,c} + q_{s,c}$ = total current-related transport rate
$q_{b,c}$ = current-related bed load transport rate
$q_{s,c}$ = current –related suspended load transport rate
q_w = net wave-related sediment transport rate in the direction of the largest bed shear stress

Φ = angle between current direction and wave propagation direction.
The input parameters considered in the Van Rijn formula are given below.

D_{50} = median particle size of bed = 0.2 mm; a = reference level = 0.01 m
RC = current related roughness = 0.05 m; RW = wave related roughness = 0.05 m

- **GENESIS model:** GENESIS simulates changes in position of the shoreline in response to wave action and boundary conditions (Hanson, 1987; Gravens *et al.* 1991; Hanson and Kraus, 1991; Kraus *et al.* 1983). The governing equation for the rate of change of shoreline position is formulated by conservation of sand volume as follows:

$$\frac{\partial y}{\partial t} + \frac{1}{(D_B + D_C)}\left[\frac{\partial Q}{\partial x} - q\right] = 0 \quad (1)$$

where,
y = shoreline position (m); x = distance alongshore (m); t = time interval (h)
D_B = the berm elevation (m); D_C = the depth of closure (m)
Q = the longshore transport rate (m^3/s); q = the rate of source or sink of sand (m^3/s)

- The empirical predictive formula for the longshore sand transport rate (Q) used in GENESIS is given below.

$$Q = (H^2C_g)_b\ [a_1 \sin 2\theta_{bs} - a_2 \cos\theta_{bs} \frac{\partial H}{\partial x}\ ] \quad (2)$$

where,
H = wave height (m); C_g = wave group speed given by linear wave theory (m/s)
b = subscript denoting wave breaking condition
θ_{bs} = angle of breaking waves to the local shoreline
The non-dimensional parameters a_1 and a_2 are given by

$$a_1 = \frac{K_1}{16(\rho_s/\rho - 1)(1-p)(1.416)^{5/2}} \quad (3)$$

$$a_2 = \frac{K_2}{8(\rho_s/\rho - 1)(1-p)\tan\beta(1.416)^{7/2}} \quad (4)$$

where,
K_1, K_2 = empirical coefficient, treated as a calibration parameters
ρ_s = density of sand (taken to be 2650 kg/m^3 for quartz sand)
ρ = density of water (1030 kg/m^3 for seawater);
p = porosity of sand on the bed (taken as 0.4)
$\tan\beta$ = average bottom slope from the shoreline to the depth of active longshore sand transport.

The factor 1.416 is used to convert significant wave height, the statistical wave height required by GENESIS, to root-mean-square (rms) wave height.

The first term in Equation (2) corresponds to the "CERC formula" (SPM, 1984). The second term is used to describe the effect of the longshore gradient in breaking wave height. Equation (1) can be solved by either an explicit or implicit solution scheme with stability parameters (Courant number), $R_s \leq 0.5$

or $R_s \leq 10$ respectively. The overall calculation flow used in the present study is shown in Fig. 2.

- Model simulation details: The concerned shoreline around the Dai mouth is divided into three project reaches and modeled each separately. Three model reaches considered are, the first north of the Dai mouth (Northern shoreline), second south of the Dai mouth (Southern shoreline) and the third south bank of Dai mouth (River bank). Fig. 3 shows the details of GENESIS model reaches, and associate nearshore reference depths. Empirical parameters used in GENESIS are shown in Table 2. For applying of Van Rijn formula along south bank of Dai mouth the monthly distribution of mean river flow velocity and surf zone width during wet season are shown in Table 3.

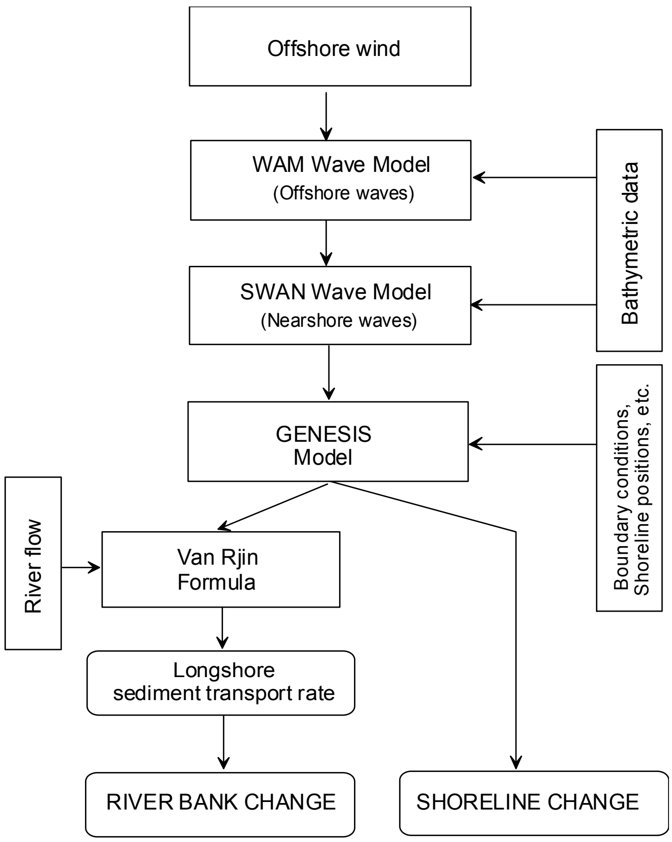

Fig. 2 Overall calculation flow used

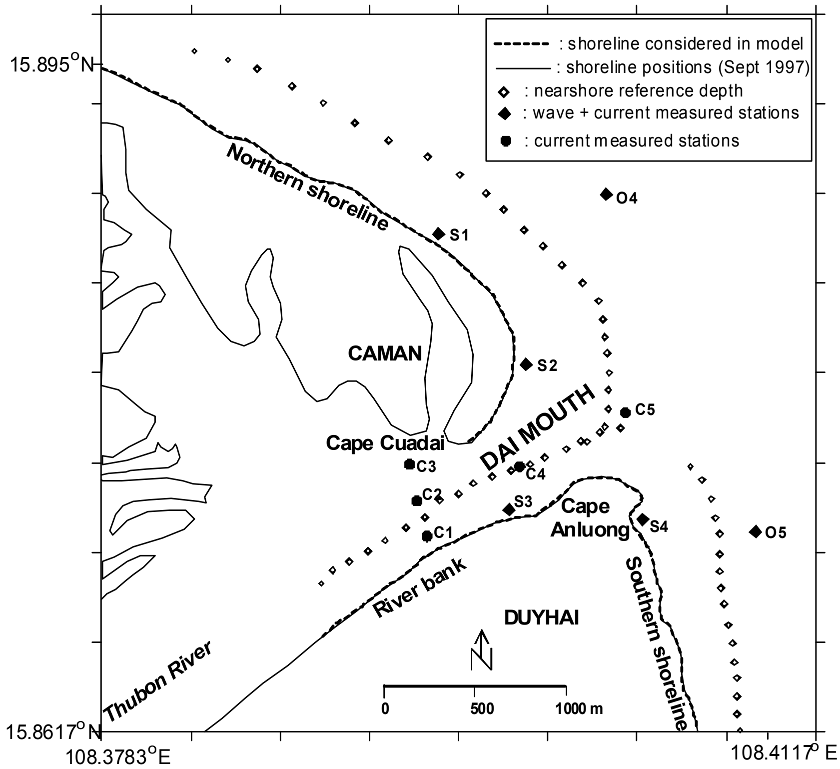

Fig. 3: Shoreline change model boundary and measurement locations

Tab. 2. Empirical parameters at model reaches

Empirical Parameters	North Reach	South Reach	River bank Reach
Transport parameter - K_1	0.15	0.5	0.58
Transport parameter - K_2	0.10	0.3	0.3
Depth of closure - D_C (m)	6	6	5
Average berm height -D_B (m)	2	2	3
Effective grain size - D_{50} (mm)	0.175	0.175	0.175
Alongshore grid spacing ΔX (m)	50	50	50
Input wave data time step - Δt (hrs)	6	6	6

Tab. 3. Monthly distribution of mean river flow velocity and surf zone width during wet season along south bank of Dai mouth

Months	September	October	November	December	January
Mean river flow velocity (m/s)	0.28	0.40	0.45	0.35	0.30
Mean surf zone width (m)	15	20	20	25	25

III. RESULTS AND DISCUSSIONS

1. Measured shoreline positions during periods from 1965 to 2000

The shoreline positions around Dai mouth in 1965 was extracted from the topographic map with scale of 1:100,000, issued in 1967 by U.S. Navy (collected data since 1965). Shoreline positions during different periods: September 1997, August 1998, August 1999, January 2000 and July 2000 were taken from shoreline surveys. Based on these data the variation in shoreline around Dai mouth from 1965 to 2000 is shown in Fig. 4.

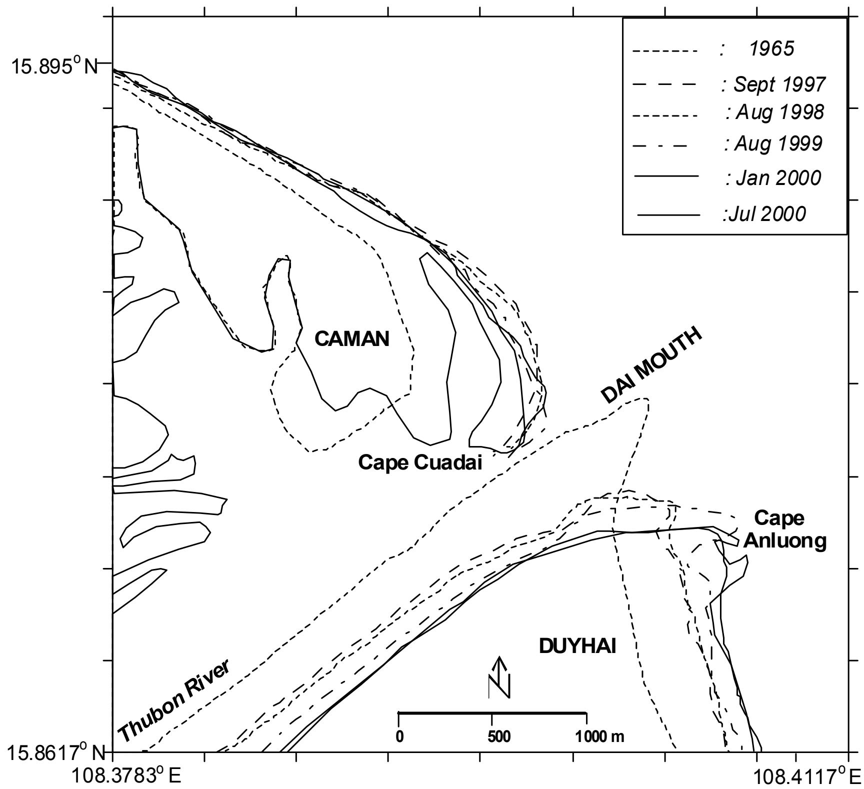

Fig. 4. Shoreline positions measured during different periods from 1965 to July 2000

Data in Fig. 4 shows that from 1965 to 2000 Cape Cuadai is advanced towards south-east direction with distance of approximately 500 m; the Southern shoreline of Dai mouth was advanced towards offshore with the distance of approximately 450 m; the River bank was moved towards south with regression value of 500 m. Therefore, in general the Northern shoreline was subjected to accretion and advanced seaward with average rate of about 10 m per year. The Southern shoreline was also subjected to accretion with average rate of advanced seaward is about 12 m per year. The River bank was subjected to erosion with average rate of regression is about 13 m per year.

2. Calculation of shoreline change under the influence of wave action using GENESIS model

Shoreline change during different periods from September 1997 to August 1998; August 1998 to August 1999; August 1999 to January 2000; and January to July 2000 were computed by GENESIS model with input parameters presented in Table 2. The computed shoreline positions were compared with measured ones and the results are shown in Fig. 5 to Fig. 8.

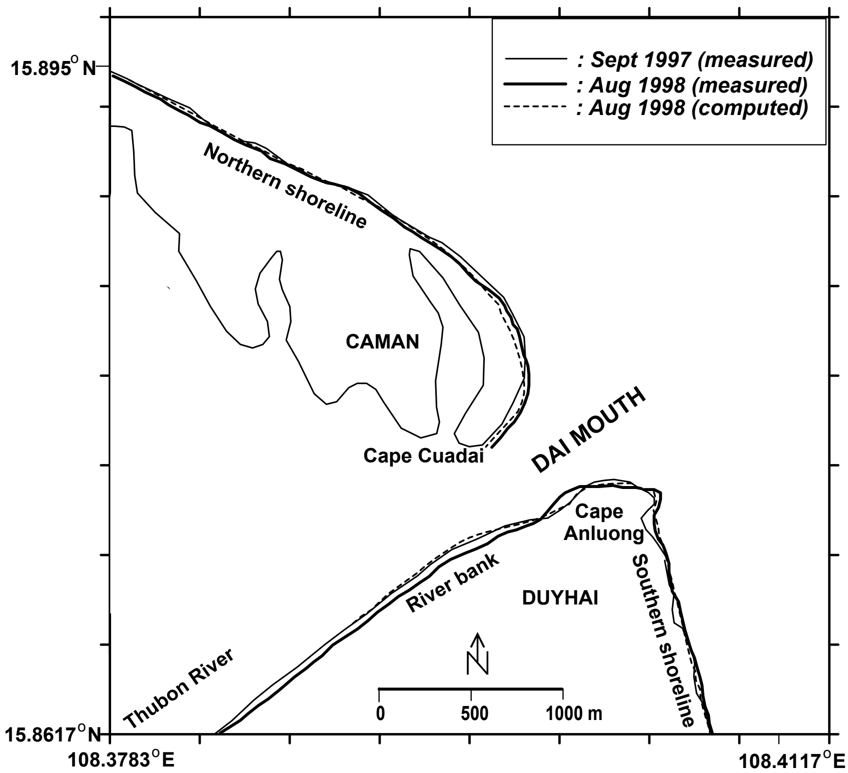

Fig. 5. Shoreline change (9/1997 – 8/1998

In general the computed shoreline positions show good agreement with measured ones, except the shoreline sections in the current dominated regions or falls in the model boundaries. In all, the Northern shoreline is undergone of eroding. Whereas, the Southern shoreline is undergone of accreting, and the River bank was slightly accreting for all computed periods. However, the computation was not reproduction the magnitude of regression at River bank, and the advanced or regression of Cap Cuadai and Cap Anluong.

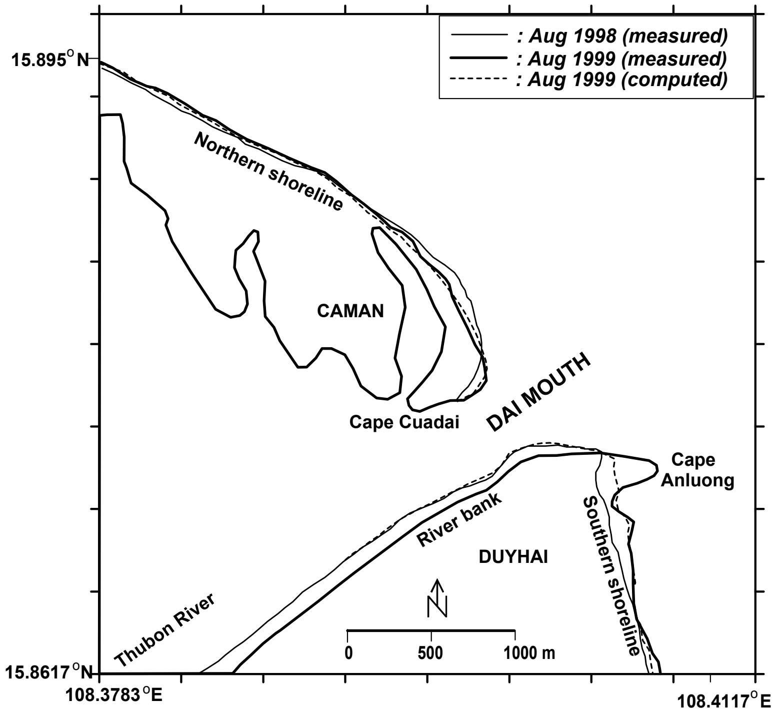

Fig. 6: Shoreline change (8/1998 – 8/1999)

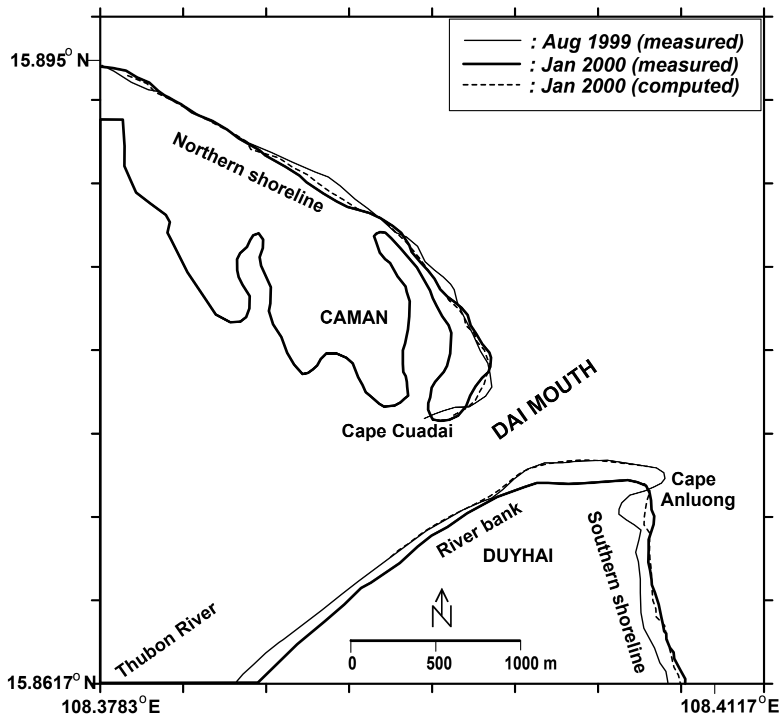

Fig 7: Shoreline change (8/1999 – 1/2000)

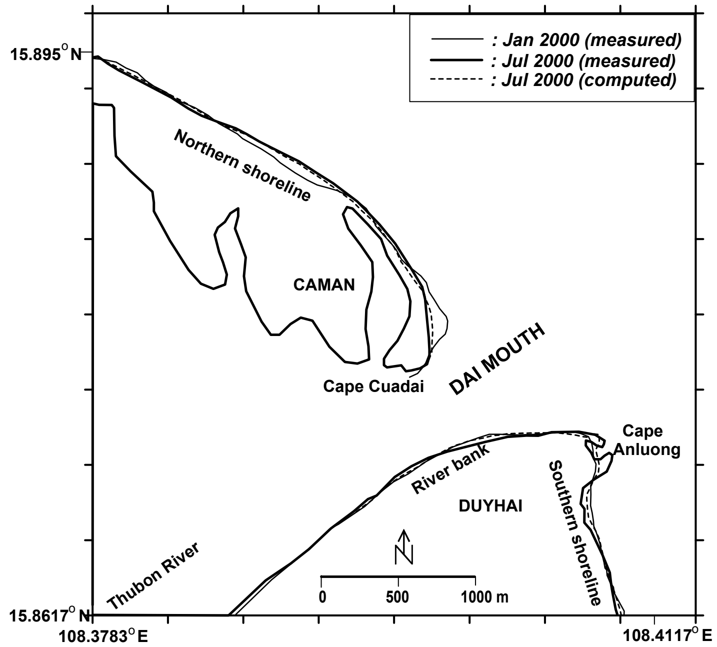

Fig. 8: Shoreline change (1/2000 – 7/2000)

3. Calculation of shoreline change in combined influence of river flow and wave action

During August 1999 to January 2000 (wet season) the shoreline at River bank was undergone seriously eroding, but the cause resulted this change was not come from wave action (Fig. 7). Therefore, in order to calculate the change in shoreline along River bank by river flow action the following steps was carried out.

- Wave characteristics along reference depth were taken from SWAN model, and are transferred in to the breaking zone according to internal wave model procedures of GENESIS (Hanson *et al.*, 1991).

- River flow velocity and surf zone width were linear interpolated on time and space based on measured data of river discharge and river flow velocity (Hung, 1995; Trinh 2000) and shown in Tab 3.

- Longshore sediment transport rate estimated by GENESIS model (Eq. 6) was replaced by Van Rjin formula in combination of waves and river flow action (Van Rijn, 1991).

- Changing in shoreline positions was estimated using GENESIS formulas (Eq. 5), and all input parameters and boundary conditions were kept as previous work in computed shoreline changes under wave action.

- The computed results show good agreement with measured ones (Fig. 9). This indicates that the River bank was undergone seriously eroding by river flow action.

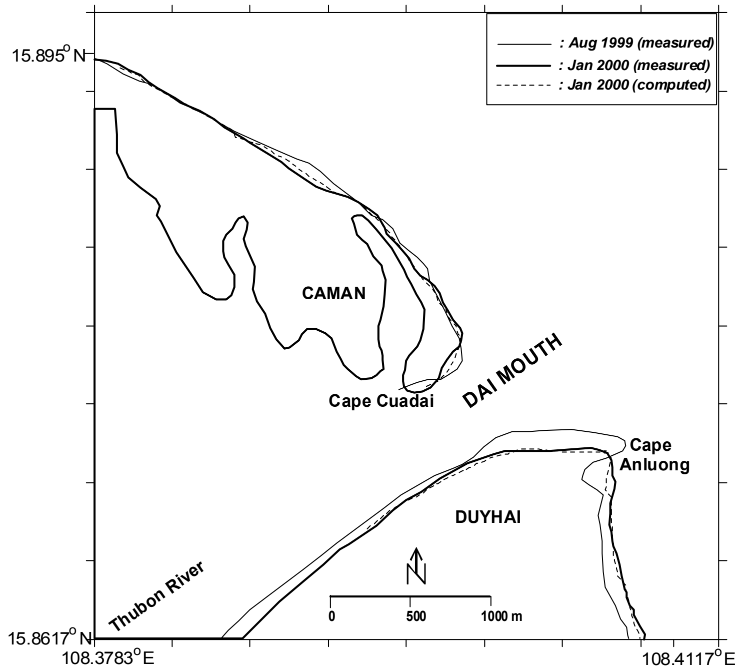

Fig. 9. Shoreline change from August 1999 to January 2000 in combined influence of river flow and waves

In general, the average relative difference between calculated and measured shoreline positions were about 20%.

4. Prediction of shoreline change

Prediction of shoreline change around the Thubon River mouth from September 2001 to September 2006 was carried out based on following conditions:

- Wave conditions were taken from the average value of wave parameters during 1997 to 2000, and all input parameters were kept similar to previous shoreline change computation.

- Starting shoreline positions were taken from the measured shoreline positions of September 2001.

- Prediction of shoreline changes at River bank considering the influence of wave and river flow during wet season. Whereas, during dry season, only wave action was considered.

Predicted shoreline change are shown in Fig. 10.

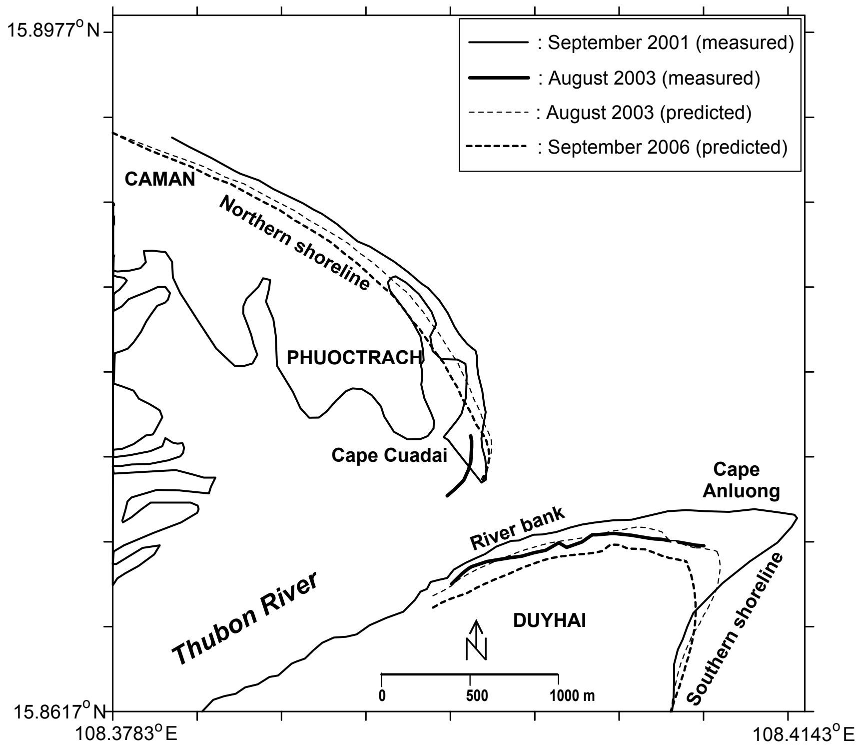

Fig. 10. Predicted shoreline change from September 2001 to September 2006

The prediction show that during 5 years (IX/2001 – IX/2006):

- Northern shoreline, in general, will continuously erode with an average value of around 50 m and maximum value of 150 m (at Phuoctrach).
- In southern shoreline: Cape Anluong will erode with an average value of around 600 m, the remaining shoreline sections will accrete with an average value of around 70 m.

- River bank, in general, will erode with an average value of around 60 m during September 2001 to August 2003, and with an average value of around 95 m during August 2003 to September 2006.

The study also shows that the predicted extent of erosion during September 2001 to August 2003 at the Cape Anluong was relatively good agreement with measured one. This indicates that under the influence of normal wave action Cape Anluong will erode and the accretion here mainly caused by the deposition of sediment of Thubon River discharge.

Based on the results of present study the tendency of shoreline change in and around the Thubon River mouth for further next recent years can be predicted as follows:

- Northern shoreline: The shoreline at Caman will be stable or slightly get eroded, shoreline at central and southern sections will be continuously eroded. Whereas, Cape Cuadai will continuously accrete and expand southward.
- Southern shoreline will continuously accrete.
- River bank will continuously erode.
- The possibility of Thubon River mouth system to move towards south-east direction.

IV. CONCLSIONS

From the present study, following conclusions can be recorded:

- The shoreline around the Dai mouth during 1965 to 2000 was subjected to changes with relatively large magnitude, the whole shoreline system of Dai mouth was shipped towards south direction with the distance approximately 500 m. That mean, the rate of advanced is approximately 12 m per year.

- During wet season (September 1999 to January 2000) the shoreline was undergone changing much higher than that of dry season (January to July 2000), especially in the River bank

- The shoreline along River bank was undergone seriously eroding by river flow action, and was slightly undergone accreting by wave action.

- The computed shoreline positions is relatively good agreement with measured ones (except the shoreline sections which lives in the model boundaries such as Cap Cuadai, Cape Anluong), and the GENESIS model can be applied to predict the shoreline changes in the Northern and Southern shorelines, and using Van Rjin formula to calculate the longshore sediment transport rate and used in GENESIS model which can be applied to estimate the shoreline change along the River bank.

- The possibility of Thubon River mouth system to move towards south.

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