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INITIAL MODEL FOR SEDIMENT TRANSPORT AND TOPOGRAPHICAL CHANGE AT THE RED RIVER MOUTH, NORTHERN VIETNAM

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ABSTRACT

The Red River is the biggest river mouth in the North Vietnam where a huge amount of sediment is annually deposited. Therefore topographical changes in the region are rapidly and complexity taking place. The paper presents a numerical model that deals with bed load and suspended load of sediments due to river flows for predicting topographical changes. Initial results forecast the erosion along the shoreline of present shoal (Vanh, Lu shoals) and the potential of forming a new shoal in the offshore area from present shoal about 300-900 m.

Keywords: *numerical model, river flows, Red River, Vietnam, sediment transport*

Introduction

The accretion of Red River has created most of the area of Northern delta in Vietnam. The annual amount of sediments transported by the river into the South China sea is about $111.46 \times 10^6 \text{ m}^3$. About 37.8% of whole mass of the sediments was transported over the Red River mouth (Balat mouth). Consequently Red River mouth (Fig. 1) is a very rapid accretion zone with the velocity of deposition much higher than sea level rise (1-2 mm/year) and tectonic subsidence (about 1 mm/year). The shoreline at Red River mouth is now reaching towards the sea about 15-100 m each year. The land expanding creates a very useful environment for aquatic plantation and mangrove development. However, the accretion in front of the Red River mouth has caused the sediment deficit and erosion in the adjacent areas. The erosion causes the lost of land, expanding the area of saline intrusion. The regions of rapid erosion are the Van Ly (Hai Hau district, Nam Dinh province), the Dong Long (Tien Hai district, Thai Binh province) communes. The velocity of erosion in these regions can reach 10-15 m/year.

Therefore the sediment distribution and transport plays a very important role in the regulation of accretion and erosion. In order to contribute for promoting the merits of landuse and avoiding the hazards related to accretion and erosion, the paper presents a research on sediment transport and topographical changes at the Red River mouth.

The possibility of modeling topographical change, sediment transport and accretion, erosion characteristics are illustrated by some numerical models. So far, lots of data have achieved during the frame-work of some projects. The data could be used for input and boundary condition of models.

Methods and materials

Topographical changes due to river flows and sediment loads have been studied by a number of numerical models as showes in [1], [2], [5], [8], [12], [13] and [15]. In the paper, the authors present a numerical model that was firstly established by Deguchi et al., 2000 [3]. The model was also calibarated by laboratory tests in the same project.

The numerical model consists of two sub-models. One is the numerical model for calculating flow and another is the model for predicting topography change. The flow field was calculated based in depth and time averaged equations of mass and momentum flux conservation. Topography change was calculated

using a continuity equation of sediment transport. Bed load transport was estimated by using van Rijn's formula (1985) and suspended load transport rate was evaluated based on the flux model proposed by Sawaragi, Deguchi (1993). The x-axis is taken offshore and y-axis is alongshore direction. Water surface displacement was measured upward from the still water level and the depth was measured downward.

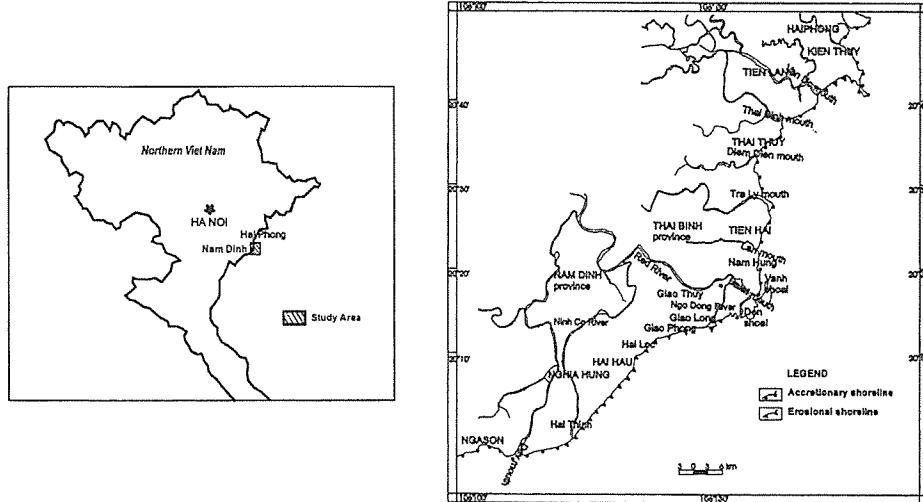


Fig. 1. Location of the study area

Boundary condition: the location of shoreline and the circumstances of the area affected by river flow.

Calculation of flow field

$$\frac{\partial \bar{\eta}}{\partial t} + \frac{\partial}{\partial x} \{U(h + \bar{\eta})\} + \frac{\partial}{\partial y} \{V(h + \bar{\eta})\} = 0 \quad (1)$$

$$\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + V \frac{\partial U}{\partial y} = -g \frac{\partial \bar{\eta}}{\partial x} - \frac{\tau_{bx}}{\rho(h + \bar{\eta})} + k_{xx} \frac{\partial^2 U}{\partial x^2} + k_{xy} \frac{\partial^2 U}{\partial y^2} \quad (2)$$

$$\frac{\partial V}{\partial t} + U \frac{\partial V}{\partial x} + V \frac{\partial V}{\partial y} = -g \frac{\partial \bar{\eta}}{\partial y} - \frac{\tau_{by}}{\rho(h + \bar{\eta})} + k_{yx} \frac{\partial^2 V}{\partial x^2} + k_{yy} \frac{\partial^2 V}{\partial y^2} \quad (3)$$

where (U, V) are the depth and time averaged velocities of x and y directions, g is the acceleration of gravity, ρ is the density of water, $\bar{\eta}$ is the mean water surface, $(k_{xx}, k_{xy}, k_{yx}, k_{yy})$ are the lateral mixing coefficients.

Calculation of topography change

$$\frac{\partial h}{\partial t} = \frac{1}{(1-\lambda)} \left\{ \frac{\partial}{\partial x} \left(q_{sx} + q_b + \epsilon_s |qbx| \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(q_{sy} + q_{by} + \epsilon_s |qby| \frac{\partial h}{\partial y} \right) \right\} \quad (4)$$

where 1 is the void ratio of bed material, ϵ_s is the empirical coefficient, (q_x, q_y) are the local sediment transport rates in x and y directions and are evaluated from Eqs. (5) and (7) where subscript b and s mean that the quantities concerning the bed load and suspended load.

Bed load transport rate (van Rijn, 1985):

$$qbx = C_b \cdot \delta_b \cdot u_b \cdot \frac{U}{\sqrt{U^2 + V^2}}, \quad qby = C_b \cdot \delta_b \cdot u_b \cdot \frac{V}{\sqrt{U^2 + V^2}} \quad (5)$$

$$\begin{aligned}
C_b &= 0.18 \cdot C_0 \frac{T_p}{D^*} , \quad C_0 = 0.015 \cdot \frac{d_{50}}{0.01(h + \eta)} \cdot \frac{T_b^{1.5}}{D^{*0.3}} \\
\delta_b &= d_{50} \cdot D^{*0.7} \cdot T_p^{0.5} x 0.3 , \quad u_b = 1.5 T_p^{0.6} [(\rho_s / \rho - 1) g d_{50}]^{0.5} \\
T_p &= (u^*{}^2 - u_c^*{}^2) / u_c^*{}^2 , \quad D^* = d_{50} [(\rho_s / \rho - 1) g / v^2]^{1/3}
\end{aligned} \quad (6)$$

Suspended transport rate (Sawaragi, 1993):

$$q_{sx} = \bar{C} \cdot U(h + \bar{\eta}) , \quad q_{sy} = \bar{C} \cdot V(h + \bar{\eta}) \quad (7)$$

where the depth and time averaged suspended sediment concentration \bar{C} is calculated from the following advection-diffusion equation (Deguchi, 1994):

$$\frac{\partial \bar{C}}{\partial t} + U \frac{\partial \bar{C}}{\partial x} + V \frac{\partial \bar{C}}{\partial y} = \frac{\partial}{\partial x} \left(k_x \frac{\partial \bar{C}}{\partial x} \right) + \frac{\partial}{\partial y} \left(k_y \frac{\partial \bar{C}}{\partial y} \right) + Q_s \quad (8)$$

$$Q_s = \frac{1}{h + \eta} \left[(1 - r) \bar{C}_0 w_f \left(1 - \frac{u^*}{w_f} \right) + \alpha \bar{C} w_f \right] \quad (9)$$

These equations were transformed into finite difference equations and were solved numerically.

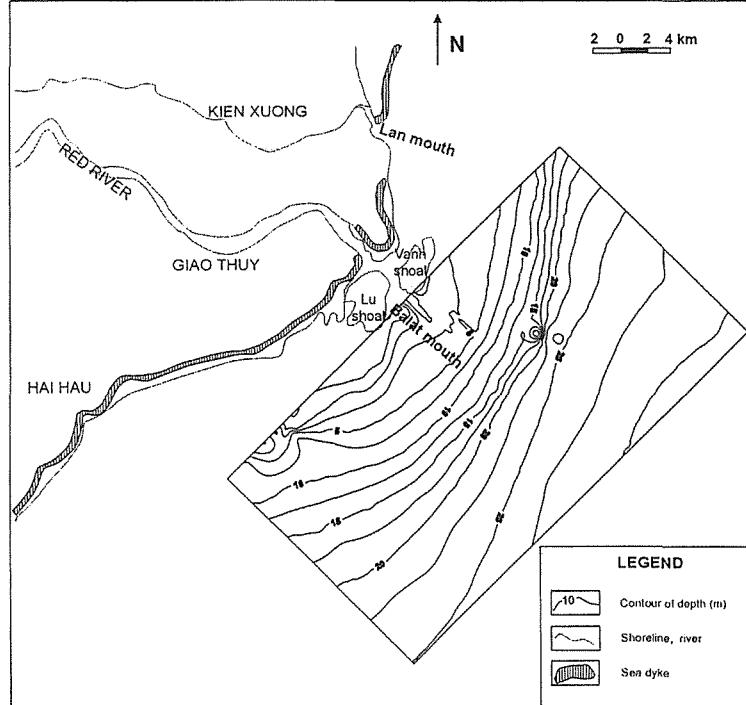


Fig. 2. Initial relief in 1996 of the Red River mouth

The boundary condition for flood was given by water level and velocity measured the river at the upstream side of the calculation region in the experiment. A so called moving boundary condition was applied to

determine the shoreline. Flow field was first calculated at the grid points set at the distance of $dx = dy = 100$ m and a time interval $dt = 10$ s. Then the topographic change was calculated and iterated at time interval of one second to take into account of the interaction between topography change and flow.

The topography of the Red River mouth was defined based on results of marine investigation in 1996 (Nhuan et al., 1996) (Fig. 2).

Hydrodynamic and seabed sediment parameters were inferred from some sub-projects such as [2], [8] and [14]. It is divided into some groups such as: hydrology of the Red River (water discharge, water level, suspended matter), hydrology of sea (salinity, temperature, suspended matter, flow velocity and direction, tidal regime), surface sediment characteristics, bottom topography.

Results and discussions

Because the river flow velocity usually changes after seasons, it is slow in dry season and becomes much faster in wet season. Therefore a sinusoidal river flow will be a suitable selection.

The flow is assumed to start at onshore boundary. Based on the results of hydrological monitoring in the Red River delta program, the maximum and minimum flow velocity at the Red River mouth are 60.0 cm/s and -20 cm/s, respectively. Therefore the function of flow velocity applied for the model is $V = 60\sin(\omega t)$ (cm/s). The value of ω is supposed to be $\pi/14400$ and the maximum velocity will be achieved after 20 hours. The bottom relief is defined by topographical measurement in 1996.

The area of calculation is symmetry to the Red River with the x-axis in alongshore direction. The y-axis stretches from the shoreline to the boundary between present and old sediments (this boundary was defined by Duc et al., 2000).

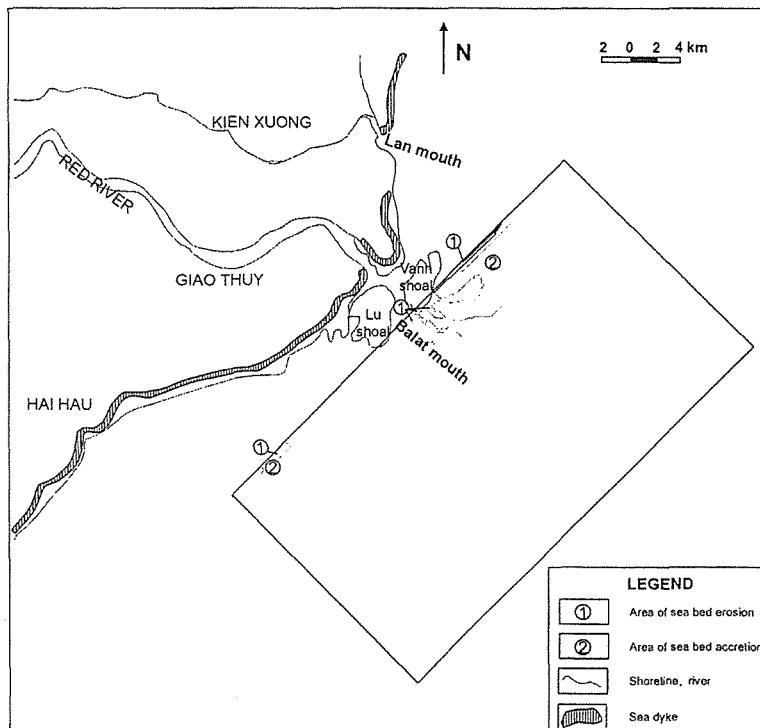


Fig. 3. Topographical changes after 20 hours

The suspended matter and medium diameter (D_{50}) of sediment transported are determined from the results of OBSs and granulometry. The value of 0.2 g/l of suspended matter and 0.1 mm of D_{50} have been used.

The result of calculation for 20h is shown at Fig. 3. shows the erosion along the shoreline of present shoals (the Vanh and Lu shoals) and the potential of forming a new shoal that is further offshore about 300-900 m. It is suitable to the present state at the scene.

Nowadays, the model can not calculate for large and real case of time due to very long time of using computer and it does not deals with wave, wave-induced current and tidal regime. So it should be upgraded in the future to solve the actual problem at the Red River mouth. The model also needs some topographical measurement in the future to be checked and calibrated.

Conclusions

With sufficient data for determining boundary conditions, a numerical model that deals with bed load and suspended load of sediments due to river flows can be used for predicting topographical changes.

- Initial results forecast the erosion along the shoreline of present shoals (Vanh, Lu shoals) and the potential of forming a new shoal in the offshore area from present shoal about 300-900 m.
- The model can not calculate for large and real case of time and does not deals with wave, wave-induced current and tidal regime in the calculation. It should be upgraded in the future to solve the actual problem at the Red River mouth.

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