MODELING OF SHORELINE CHANGE BY CONSIDERING NATURAL SEDIMENT BYPASSING

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1. INTRODUCTION

Since introduced in 1956, the principal one-line model had been applied by many researchers especially in study about shoreline change in long time scale. The long-shore transport gives influence in the parallel movement of beach profile by variation of transport quantities alongshore, which is adopted in the model. Moreover, the simple governing equation makes quick run in terms of calculation effort compare with the process based model which has more complex equation. Some researchers had tried to simulate river mouth condition or delta growth by using one-line model (Kraus and Harikai, 1983). Most of them simulated the river mouth by make the river flux as source component, as one cell or section. Recently, the model was developed by incorporating the local process especially in tidal inlet (Hoan et al., 2011). In that works, the shoal development and bypassing bar at tidal inlet were included in the one-line model by using the reservoir model, which was developed by Kraus (2002).

In this study, the one-line model was applied to simulate shoreline change around river mouth and the river mouth influence was incorporated in the model in terms as sand terrace development. The objective of this study is to investigate the influence of short term process in river mouth to the long term shoreline change. The development and set-up of model was explained in next section.

2. MODEL DEVELOPMENT

The reservoir model, which is introduced by Kraus (2002), is suited to simulate the emerging of sand terrace in river mouth. This study used that model with some adjustment by disregard the initial purpose and application of reservoir model, which is for simulating tidal inlets behavior. The existence of sand terrace, the component and pathway of sediment transport in river mouth is depicted in Figure 1.

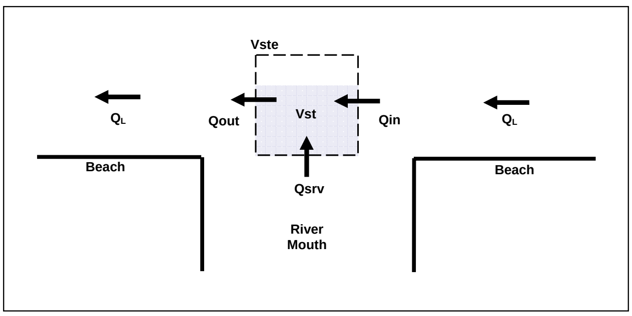

Fig.1 Definition sketch for simulating sand terrace

Figure 1 shows sketch of river mouth situation with the simple case of long-shore sediment transported from right to left. The shoreline around river mouth might be influenced by the obstruction of river mouth to the long-shore sediment transport. The existence of sand terrace in front of river mouth is one mechanism of controlling the sediment bypassing from up-drift to down-drift side of river mouth. The volume of sand terrace area at any given time is V_{st} with the corresponding equilibrium value of V_{ste}. The volume of sand terrace area at any given time was expressed as: (Kraus, 2002)

$$V_{st} = V_{ste}\left(1 - e^{-\alpha t}\right) \tag{1}$$

$$\alpha = \frac{Q_{in} + Q_{srv}}{V_{ste}} \tag{2}$$

where Q_{in} is the long-shore transport rate from up-drift beach side and Q_{srv} is sediment transport rate induced by river water discharge and fill in the sand terrace area. The ratio between instantaneous volume and equilibrium volume of sand terrace can be used to simulate the bypassing factor (*Byp*):

$$Byp = 1 - \frac{V_{st}}{V_{ste}} \tag{3}$$

The existence of sand terrace will obstruct the long-shore sediment transport. The sediment bypassing will low when the sand terrace fully develop and vice versa.

Total shoreline around the Nanakita River mouth for simulation is about 4,000 m. The Nanakita River mouth was simulated with 180 m width in open condition. The spatial step of shoreline was set at 30 m and coincided with spatial step of bathymetry. The simulation was performed from 1994 until 2009. There are three boundaries exist in the model, i.e. left, right and river mouth boundary. The left boundary represented the Sendai Port breakwater, which completely blocked the long-shore sediment transport. The right boundary was determined as fixed boundary because the shoreline is relatively in stable condition.

The river mouth boundary was sketched in Figure 2 with simple case that long-shore transport from right to left. The long-shore transport component of Q_3,Q_4,Q_7,Q_8 were calculated from wave parameter. The long-shore transport components at river mouth boundary (Q_5 and Q_6) were important to simulate the river mouth influence. These components were determined based on how the river mouth will be modeled. This study setup the shoreline change model with three different conditions in river mouth boundary. These are for examining the improvement in shoreline change model by incorporating the influence of river mouth in more detail. The conditions are follows:

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Model 1

First model simulate the condition without considering the river mouth influence. The river discharge was assumed no exist. The long-shore sediment transport components at both sides of river mouth boundary were determined as follows:

$$Q_5 = Q_4, \quad Q_6 = Q_7 \qquad (4)$$

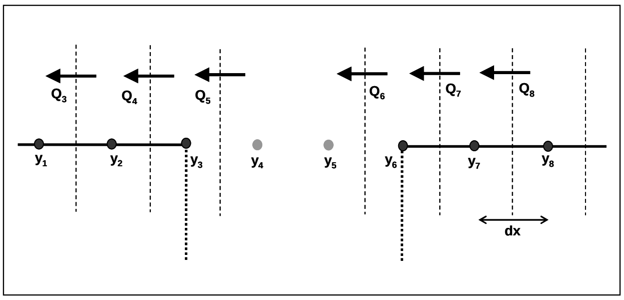

Fig.2 The definition sketch of river mouth boundary

Model 2

Model 2 simulate the natural sediment bypassing. The bypassing coefficient varies and was controlled by the existence of sand terrace in front of river mouth. The sand terrace was simulated by applying the principal of Reservoir model (Kraus, 2002). The transport components at river mouth boundary can be determined as follows:

$$Q_5 = Q_6 = Byp \times Q_7 \qquad (5)$$

In this model the flushing out sediment from sand terrace was assumed loss to the offshore.

Model 3

Model 3 has same condition with Model 2 and additional condition that the downstream transport component at river mouth boundary was added by the flushing out sediment from sand terrace. The transport components were determined as follows:

$$Q_6 = Byp \times Q_7 \qquad (6)$$
$$Q_5 = Byp \times Q_7 + c_k \times Q_{stout} \qquad (7)$$

where Q_{stout} is the sediment leaving the sand terrace and c_k is coefficient distribution of sediment from river to the both sides of shoreline depending on the direction of long-shore transport.

3. RESULTS AND DISCUSSIONS

Figure 3 shows the result of simulation for each model. There are still many discrepancies between measured and simulated shoreline in area from Sendai Port breakwater until section 2000. It is possibly caused by the result of wave ray modeling, which make the shoreline near break water was eroded and deposited in that area. For the right side, the simulated shoreline agrees well with the measured one. Considering the river mouth only influence the surrounding area, Figure 4 shows the detail in 500 m around river mouth.

The Model 1 and 3 are over estimate on the left side but perform well on the right side. Model 2 shows good agreement with measured shoreline both on left and right side. The root mean square error (RMSE) was also calculated to justify the results of simulation. The RMSE values are 16.1 m, 7.0 m and 27.7 m for Model 1, 2 and 3 respectively. The RMSE results suggest that by incorporating the river mouth influence in shoreline change model, the accuracy was increase and better than without detail simulation.

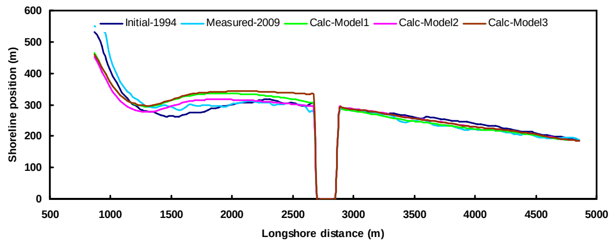

Fig.3 Results of shoreline change model

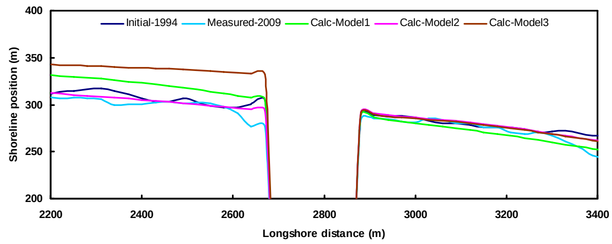

Fig.4 Comparison in 500 m around river mouth

4. CONCLUSION

The consideration of natural sediment bypassing in shoreline change model has been performed by incorporating the reservoir model in one-line model. The incorporation of sand terrace simulation, which obstructs the long-shore transport, has increased the accuracy of shoreline change model around river mouth. However, the simulation of river mouth influence as sediment supplier still needs improvement again.

ACKNOWLEGEMENTS

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