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Numerical Simulation of Hydrodynamic for Abrupt Bathymetry in Palu River Estuary

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Abstract

The failure of numerical simulation for hydrodynamic model in abrupt bathymetry zone is one of the obstacles in solving environmental problems in coastal zone. The research aims to make three dimensional hydrodynamic model in Palu river estuary that has abrubt bathymetry using ECOMSED. The simulation was conducted on horizontal and vertical cross section with the boundary condition of model, i.e. The depth data was used at the bottom of the river and the sea, river discharge at upstream and tide constituents at downstream. Input data and interpolation program was made in solving error problem. Run time error occurred during simulation, therefore, experimental method was used by modifying input data and increasing the number of grid and time step resolution to make calculation became stable. The results revealed that the influence of tidal current in Palu river estuary is smaller than the influence of river discharge and the temperature is mainly distributed westward on the horizontal cross section. While on the vertical cross section, the direction of temperature distribution follows the current movement pattern based on the overlay between current and temperature distribution. The calculated surface elevation and current velocity on the vertical cross section well suits with the secondary data obtained from hydro oceanographic office and observed current velocity.

Keywords: Abrupt Bathymetry, Hydrodynamic, Numerical Simulation, Palu River Estuary, ECOMSED

1. Introduction

Palu City is one of the region in Indonesia that affected by el nino phenomenom. The region near to the equator line. It will makes the effect of el nino will increase the temperature significantly, and then will causes destruction for natural resources at the neritic zone. On the other side, the lower discharges is one of the problem of water crysis in Palu city.

Palu river estuary area covers most part of Palu watershed and the waters at Palu bay which located in Palu city. There are several disaster often occured near such area, i.e. flood, sedimentation, and siltation of the river[1].

Early warning systems researches are important tools to determine the probability of occurrence in a region, and to prevent or decrease the catastrophic damages and the related losses[2]. One of mitigation to decrease the impact of those disaster is making early warning system in Palu river estuary based on the prediction of hydrodynamic model.

Numerical model can be used to build the early warning system. The disaster can be predicted by changing parameters input data based on certain scenario. The modeling can be used to simplify the processes. So, with limited time and cost, the assessment of these processes can still be done.

One of the three-dimensional numerical models that can be applied to analyze the dynamics of estuary physical oceanography in the region is a model ECOMSED (Estuary Coastal Ocean Model and Sediment Transport).

The model is a state-of-the art hydrodynamic and sediment transport model which realistically computes water circulation, temperature, salinity, mixing and transport, deposition and resuspension of cohesive and non-cohesive sediments[3].

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Model ECOMSED has been applied to several estuary, i.e. Mahakan estuary[4], Marsey estuary[5], Gembong estuary[6], etc. The simulation results has been verified with observation data and showed a good agreement. But, in several cases, run time error occured during numerical calculation due to abrupt bathymetry profile. Some of research related to the problem is hydro-morphodynamic modeling in Mediterranean storms[7] and in Douglas Channel, British Columbia by using smoothing method to smooth out abrupt changes in depth in the original 50-m bathymetric data provided by the Canadian Hydrographic Service[8].

Based on the contours analysis of general bathymetric chart of the oceans digital atlas, the profile of bathymetry of Palu bay also has similar case, the abrupt changes near to the shoreline and then more and more depth to the open ocean.

2. Method

The computational domain of Palu river estuary located in the area of 119.8390 to 119.8660 (east longitude) and from 0.8640 to 0.8920 (south latitude) or from 816.084 to 819.128 meter (east) and 9.901.281 to 9.904.351 meter (north).

The selection area is based on the availability of the data for model verification. Location of the simulation is selected on a vertical cross-section at coordinates 818.205 meter (east), 9.901.910 meter (north) till 818.205 meter (east), 9.902.162 meter (north). The depth is divided into 11 layers with different thickness on each layer are as follows: 0.1 m, 0.5 m, 1.0 m, 1.5 m, 2.0 m, 2.5 m, 3.0 m, 4.0 m, 5.0 m and the maximum depth of 167.83 m.

Shoreline data is used as an input data on a closed boundary research area, this data is obtained by digitizing the shoreline on the *ikonos* imagery to identify the image of the coastline between the boundary land and water. Geometric correction is is applied at the *ikonos* imagery in year 2005 using topographic map as a reference coordinate points. Further geometry correction of the image is obtained from google earth image in year 2015 in order to get the actual information about width changes of the river and the form changes of the delta in the river mouth.

As a tidal boundary condition, six tide constituents is used as an input data at the boundary of the open sea. This data is needed as tidal generating force by imposing the tidal constituents value on the open boundary. The river discharge is used as an open boundary condition at the upstream simulation area. The data is used at the boundary, where the water flow into the model.

In this study, the river discharge is assumed to be constant throughout the simulation at 36 m^3/s, on the other side, the discharge data of 2 m^3/s is needed for verification purpose. At the open boundaries, the sea temperature and salinity is assumed each 29^0 C and 34 ppt, while the temperature and salinity at the upstream boundary of the river specifically is 28^0 C and 0 ppt respectively.

Experimental method is used by changing parameters input data such as discharge, tide, grid size, depth, and resolution related to the space and time. Due to the number of input data very large, parameters changing of simulation area is conducted by making input data and interpolation program.

3. Result and Discussion

3.1 Simulation of Bathymetry Interpolation

The result of the bathymetry interpolation simulation shows that the simulated model area has abrupt bathymetry in the sea area. The western part is included on the category of shallow waters with the depth less than 30m. While the maximum depth in the northen part is approximately 170 m. In the northern and eastern parts shows the bathymetric profile with a very large level of abruptness, ranged from 10 m to 170 m.

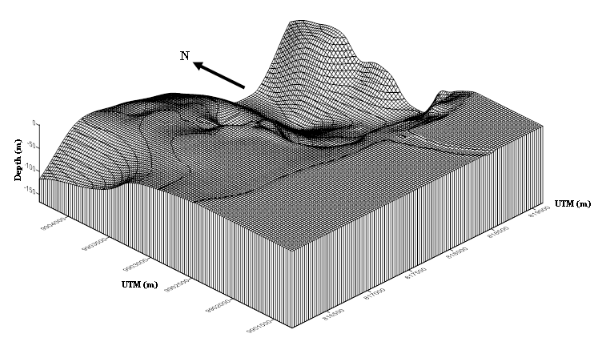

Figure 1. Three dimensional model of bathymetry in estuary of Palu river.

3.2 Run Time Error

The simulation was conducted continuously for 16 days. Run time error occurred during simulation. Numerical simulation can run stable by modifying input data and increasing resolution of simulation area by making input data and interpolation program. Run time error problem could be solved manually. But it takes so long and very difficult to be done because of the number of data very large, therefore, making input data and interpolation program is a quick solution for the problem.

3.3 The Pattern of Spatial Temperature Distribution on the Horizontal Cross Section

According to the Figure 2, the temperature value at upstream to downstream area arround 26 - 28^{0}C. When it reaches the river mouth, the spatial temperature distributed in both directions because of blocked by the delta, which is located exactly in the middle of the river mouth. The temperature moves eastward and westward with the different concentration. Variation of spatial temperature distribution on the the horizontal cross section in the western part is greater than in the eastern part.

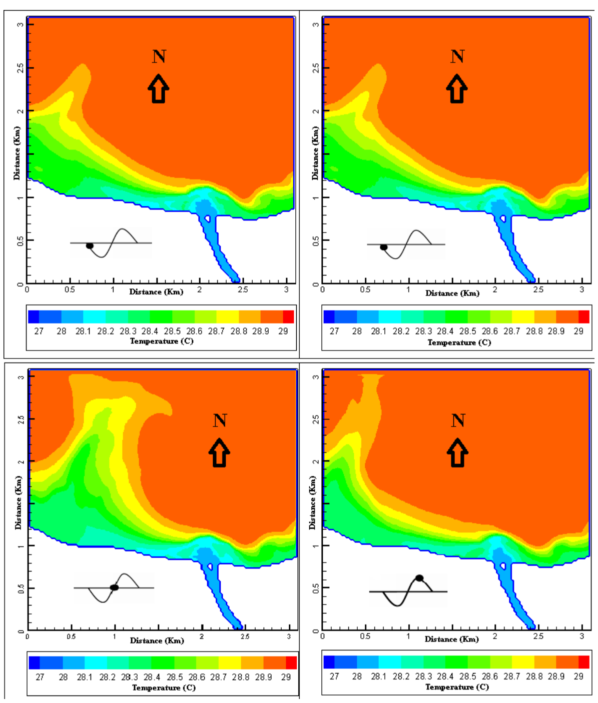

Figure 2. Spatial temperature distribution in each tidal condition on the horizontal cross section.

The cause of the large variation in the western part compared to the eastern part is caused by the difference of water depth between two locations, thus it will cause more dominant current pattern moving westward. Figure 1 shows the bathymetry of the western part is more shallow than the eastern part.

3.4 Current Velocity on the Horizontal Cross Section

The influence of tidal current in Palu river estuary is smaller than the influence of river discharge, so that the direction of current will tend to move outward the bay at the low slack water, ebb condition, high slack water and flood condition. The current velocity in estuary on each tidal conditions are as follows:

- At low slack wáter ranged from 0 to 0.54 m/s
- At ebb condition ranged from 0 to 0.54 m/s
- At high slack water ranged from 0 to 0.48 m/s
- At flood condition ranged from 0 to 0.48 m/s

3.5 Distribution of Spatial Temperature Distribution on the Vertical Cross Section

The availiability of temperature time series data on the horizontal and vertical cross section on each grid is very important to make a good model for the dynamics of spatial temperature distribution. Unfortunately, the data

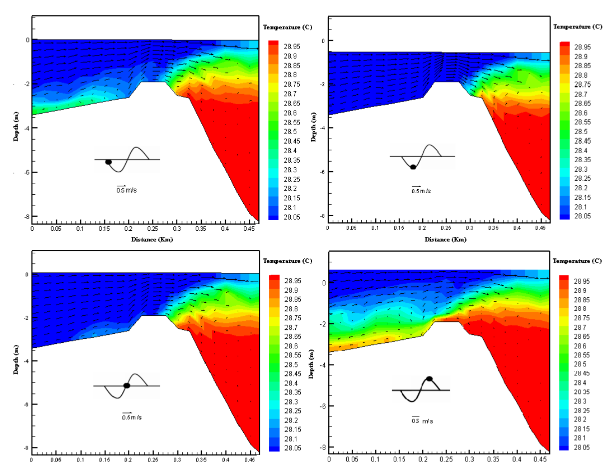

Figure 3. Spatial temperature distribution on each tidal condition on the vertical cross section.

difficult to obtained because of limited time and cost for observation, therefore, the barotropic model is used in this research.

According to the Figure 3, there is a similar pattern of temperature distribution on the vertical cross section at low slack water, ebb condition, high slack water, and flood condition at surface layer. The overlay between current pattern and temperature distribution shows a similar pattern as well. Which means that the direction of temperature distribution follows the current movement pattern.

3.6 Tidal Verification

Tidal verification was conducted by comparing secondary data on the tidal area of Palu bay from hydro oceanographic office and simulation result of model ECOMSED. The simulation was running continuously for 16 days (running time started from the date of July 15 until July 31, 2005)[10].

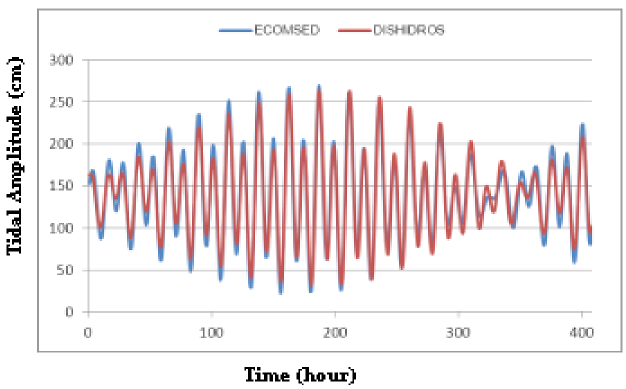

Figure 4. Comparasion of simulation result and tidal data from hydro oceanographic office (July 15 until July 31, 2005).

The verification results of the tidal between secondary data and the simulation results by using model ECOMSED in the study area, showed a relatively similar pattern. It can be seen that there is a difference between the tidal amplitude, where the amplitude result simulation is greater than the secondary data from hydro oceanographic office.

In general, the amplitude of the tidal simulation result by using ECOMSED model is smaller than the tidal amplitude which is measured in the real situation on the field. The difference of tidal amplitude between ECOMSED simulation and the data from hydro oceanographic office is caused by the difference of the data entry of number of tidal constituent (ECOMSED) and tidal prediction (hydro oceanographic office). ECOMSED requires 6 tidal constituents, i.e. S2, M2, N2, K1, P1 and O1 during simulation in this research, while hydro oceanographic office include 10 constituents tidal, i.e. M2, S2, N2, K2, K1, O1, P1, M4, MS4 and S0 to predict.

3.7 Verification of the current velocity on the vertical cross section

The simulation results for the vertical current of 2 m^3/s revealed a good agreement with the data from field observations[11]. The current velocity at the low slack water, ebb condition, high slack water and flood condition, are respectively as follow:

- At the low slack water condition, the simulation results of current velocity ranged from 0 to 0.34 m/s, whereas the observation results ranged from 0 to 0.69 m/s.
- At the low water condition, the simulation results of current velocity ranged from 0 to 0.33 m/s, whereas observation results ranged from 0 - 1.04 m/s.
- At the high slack water condition, the simulation results of current velocity ranged from 0 to 0.32 m/s, whereas the observation results ranged from 0.94 m/s.
- At the high water condition, the simulation results of current velocity ranged from 0 to 0.32 m/s, whereas observation results ranged from 0 to 0.72 m/s.

Current velocity differences probably are caused by the differences between the river depth and the discharge in the upstream area. The river depth interpolation on the model ECOMSED was conducted based on the river

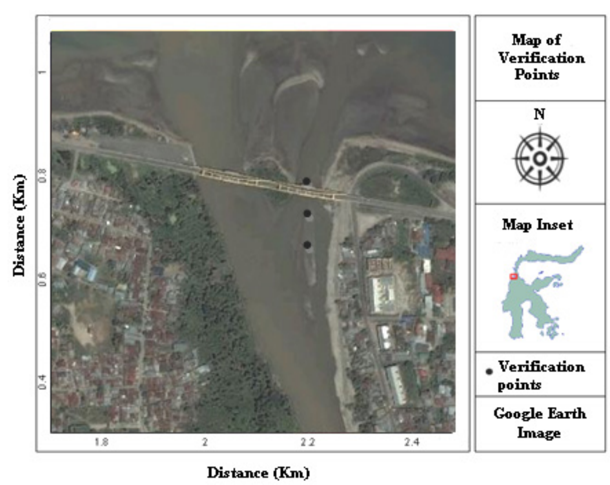

Figure 5. Map of verification points.

depth data which is obtained from the Department of Public Works - Palu 2008. As for the observation data is obtained during the field measurement in 2005.

4. Conclusion

- Run time error occurred during simulation, manipulated data and increased resolution was conducted to make calculation became stable by making input data and interpolation program.
- The temperature is mainly distributed westward on the horizontal cross section.
- The overlay between current pattern and temperature distribution revealed a similar pattern, which means that the direction of temperature distribution follows the current movement pattern.
- The influence of tidal current in Palu river estuary is smaller than the influence of river discharge, so that the direction of current will tend to move outward the bay.
- The calculated surface elevation and current velocity on the vertical cross section well suits with the secondary data obtained from hydro oceanographic office and observed current velocity.

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