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MODELING PORT STRUCTURE IMPACT TO SEDIMENTATION PATTERN IN TUDI BAY, PROVINCE OF GORONTALO, INDONESIA

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ABSTRACT: Numerical modeling using Surface-water Modelling System (SMS) is carried out to simulate the hydrodynamic and sediment transport pattern in Monano Bay, Gorontalo Province, Indonesia. The model applies scenarios of the existing bay before and after berthing structures development. Field data acquisition and secondary data collection are carried out to complete the model. The field measurement includes bathymetry, tide elevation, and current velocity measurements. Validation of the model and field measurement shows good agreement. The validated parameters are the tidal elevation and velocity data. The model shows that in flood and ebb condition, the current flows to the south-east and north-west direction, respectively. The velocity is in the range of 0.1 – 0.25 m/s. The sedimentation modeling shows that the seabed changes are not significant for model scenarios before and after the port development. It is found that the potential increment of sedimentation in Monano Bay with berthing structure being there is about 10 – 15 cm in a one-year simulation.

Keywords: Numerical modeling, SMS, Port, Sedimentation

1. INTRODUCTION

Sedimentation is an important constituent to be evaluated in port structure design because the maintenance dredging and its disposal may pose costly consequences. It is necessary to investigate the impact of the port layout on the sediment transport [1] to mitigate any negative impacts on the bay. As previously carried out by Sharaan et al. (2018), it is shown that modifying fishing harbor layout in Egypt may reduce the siltation rate using numerical modeling [2].

This research will investigate the impact of port structure on sedimentation patterns along the area. The studied port is situated in North Gorontalo Regency. The research consists of field data acquisition and numerical modeling using Surface-water Modelling System (SMS). The numerical models are hydrodynamic and sedimentation models. Another alternative method to study sedimentation in a certain area is by a physical model which even able to detect turbulence and intra-wave [3]. However, the physical model requires a large area, a relatively higher amount of funding, and a relatively long duration. Besides, similarity and dimensional analysis are required to scale the prototype to a laboratory scale and vice versa [4].

Some numerical model tools are widely used recently, such as Delft3D [5], MIKE21 [6,7], SMS [8,9], ROMS [10] and FVCOM [11]. In this study, the SMS is chosen which has been demonstrated successfully in the previous study, especially for sediment transport-related topics. [12,13].

2. METHODOLOGY

2.1 Domain of Study

The details of the study location are given in Table 1. The locations of the North Gorontalo Regency and Anggrek District are shown in Fig. 1(a) and Fig. 1(b), respectively. To support the logging industry in North Gorontalo Regency, a port is planned to be built, and the specific site is given in Fig. 1(b) and Fig. 2.

Table 1 Details of study location

District	Anggrek
Regency	North Gorontalo
Province	Gorontalo
Country	Indonesia
Latitude	0.882 North
Longitude	122.717 East

2.2 Data Compilation

As a part of this study, four field activities are carried out. They are bathymetry, tide elevation, current velocity, and bottom sediment field data acquisition. Bathymetry or bed elevation measurement is carried out using a single beam echosounder with 20 meters sounding gap and a 500 meters gap for crosscheck line. The coverage of the bathymetry survey is shown in Fig. 2 as a

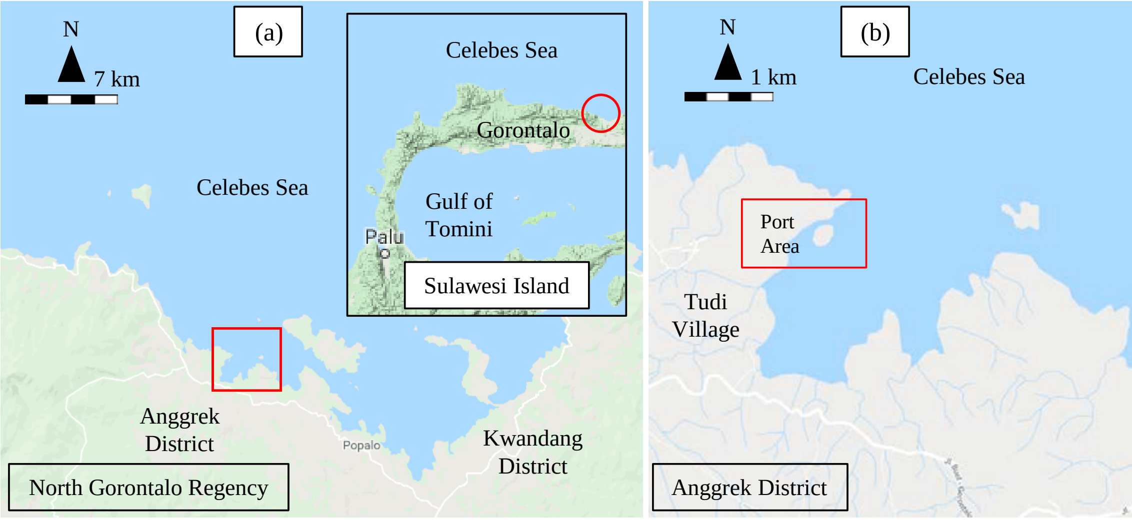

Fig. 1 The overview of (a) North Gorontalo Regency and (b) the area of interest

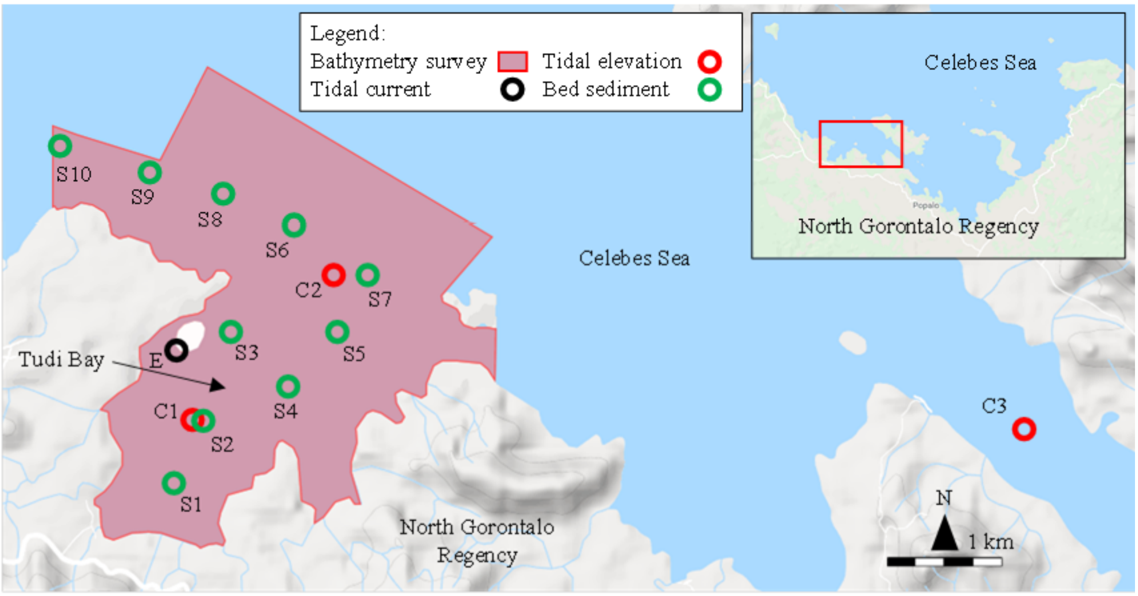

Fig. 2 The locations of field measurements in Tudi bay

red area. The water depth is found to be between 8 to 35 meters.

Tide elevation measurement is conducted in an area marked by the black dot shown in Fig. 2. The tidal elevation is measured using staff-gauge, as seen in Fig. 3b. The data is recorded hourly for 15 days. Current velocity measurement is conducted in three locations, denoted as red dots in Fig. 2. The measurement uses Aanderaa Current Meter RCM-9. The outputs are the magnitude and direction of the sea current. The first location (C1) represents current measurement inside the bay, the second location (C2) being the bay entrance, and the third location (C3) is in a narrow channel in the eastern area.

The bottom sediment survey is conducted by taking the seabed sample using bottom grabber at ten locations, as given in Fig. 2 as green dots. The samples are used for sieve analysis to get median grain sizes of the bay bed sediments. The field activities are documented and shown in Fig. 3(a) to Fig. 3(d) for bathymetry, tide elevation, current velocity, and sediment field data acquisition, respectively.

2.3 Model Schematization

Hydrodynamic modeling is carried out using the RMA2 (hydrodynamic model) and SED2D (sedimentation transport model) modules of SMS. The RMA2 module outputs are the water level and current velocity spatially and temporally. The SED2D module output is seabed changes.

To secure a good model in the domain of study, the modeling is staged into the global models (global model of Celebes and Gorontalo), and regional model, which covers only the Tudi bay and the nearby strait. Each of them is shown in Fig. 4(a) to Fig. 4(c) respectively. The Celebes model covers a large area of the Celebes Sea. Gorontalo model covers waters off the coast of the North Gorontalo Regency. The regional model detailed covers the specific site of the planned port. Mesh resolution grows finer from Celebes, Gorontalo, to regional models.

The online nesting is also conducted as the grid

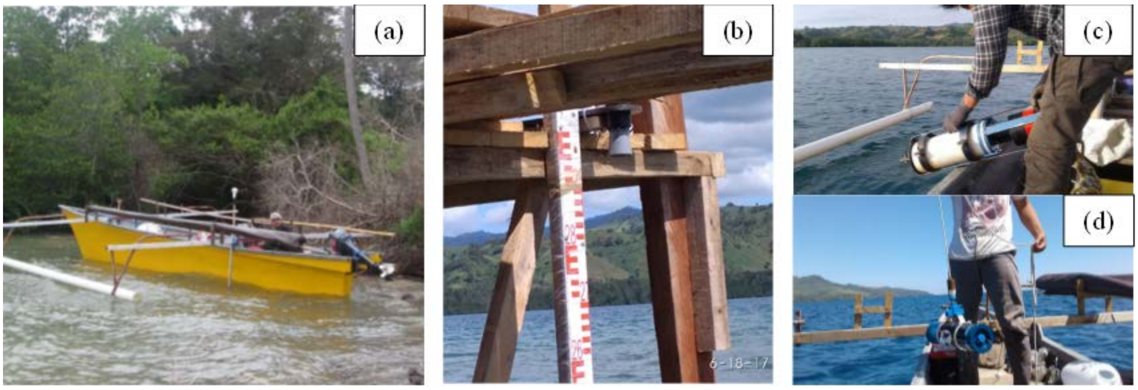

Fig. 3 Documentations of (a) bathymetry, (b) tide elevation, (c) current velocity and (d) bottom sediment surveys

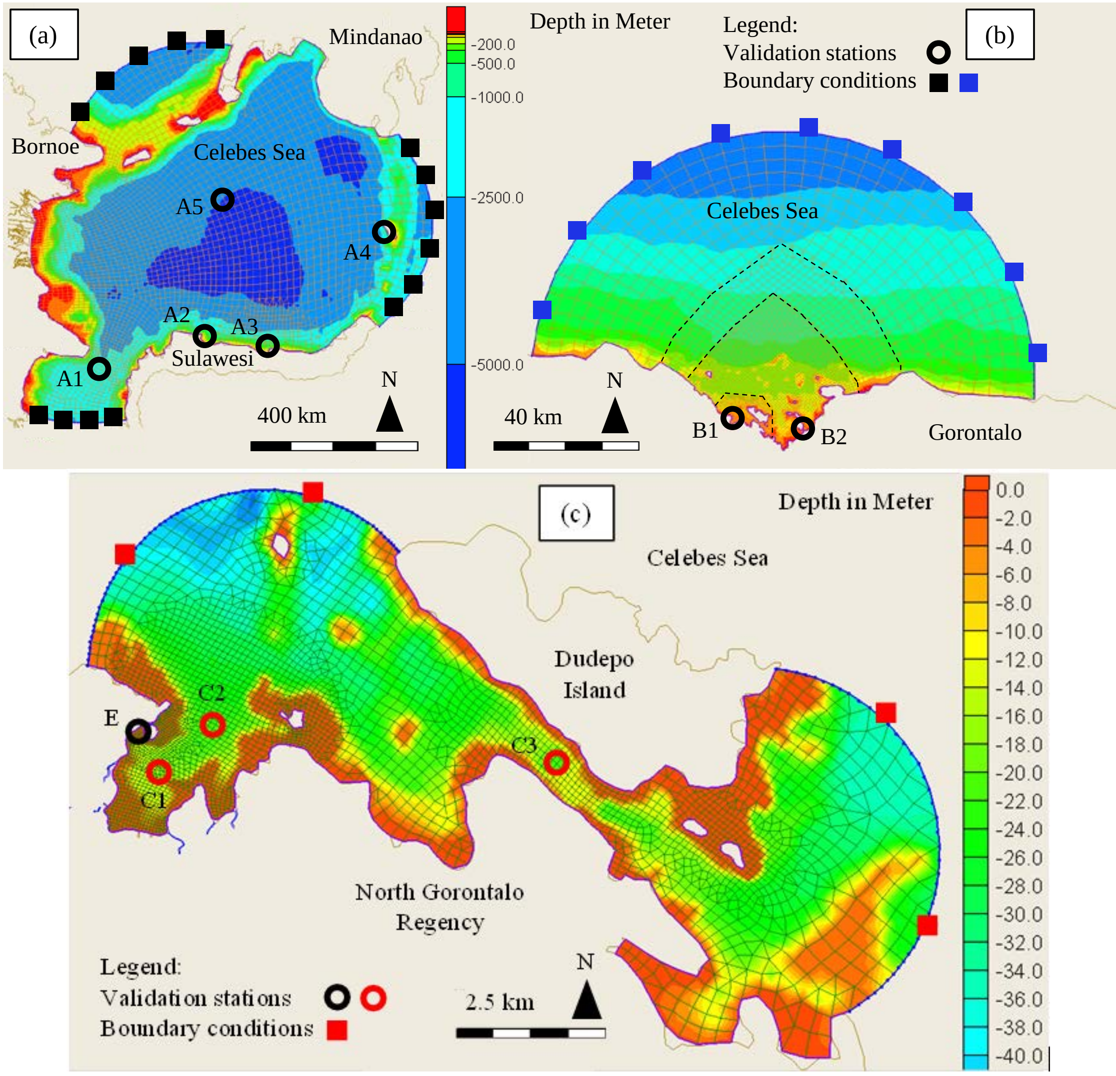

Fig. 4 The domains of (a) Celebes, (b) Gorontalo and (c) regional models

got smaller to the area of interest. For instance, in the Gorontalo model, the grid size starts from 4 x 4 km^2 to 2 x 2 km^2, 1 x 1 km^2, and ends at 0.5 x 0.5 km^2, separated by the dotted black line. In the local model, the resolution even affords to represent the port configuration, starts from 200 x 200 $meter^2$ and 25 x 25 $meter^2$ at the port site.

The bathymetry is compiled from processed data of field survey and digitation of the navigational chart produced by the Indonesian Navy. The boundary conditions for the Celebes Model shown as black boxes in Fig. 4(a) are generated from the Naotide of Poseidon [14]. While boundaries for the Gorontalo model (blue boxes in Fig. 4(b)) are extracted from the Celebes model, and for the regional model (red boxes in Fig. 4(c)) are obtained from the Gorontalo model.

Later, modeled data in each domain will be compared with field data. After well-validated, a local model is constructed from the regional model.

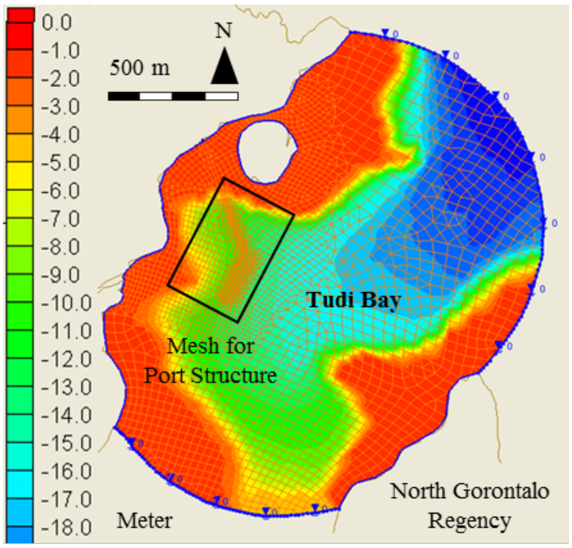

Fig. 5 The domain of local model in Tudi Bay

The model aims to develop a sediment transport

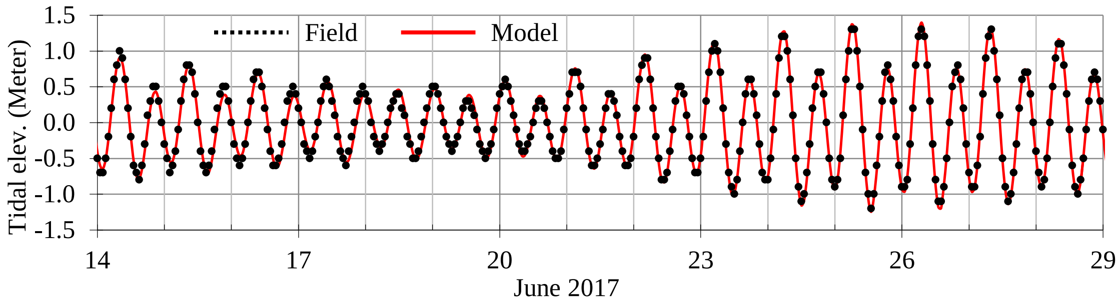

Fig. 6 Comparison of the modelled (red line) and field measurement (dotted) elevation data at E

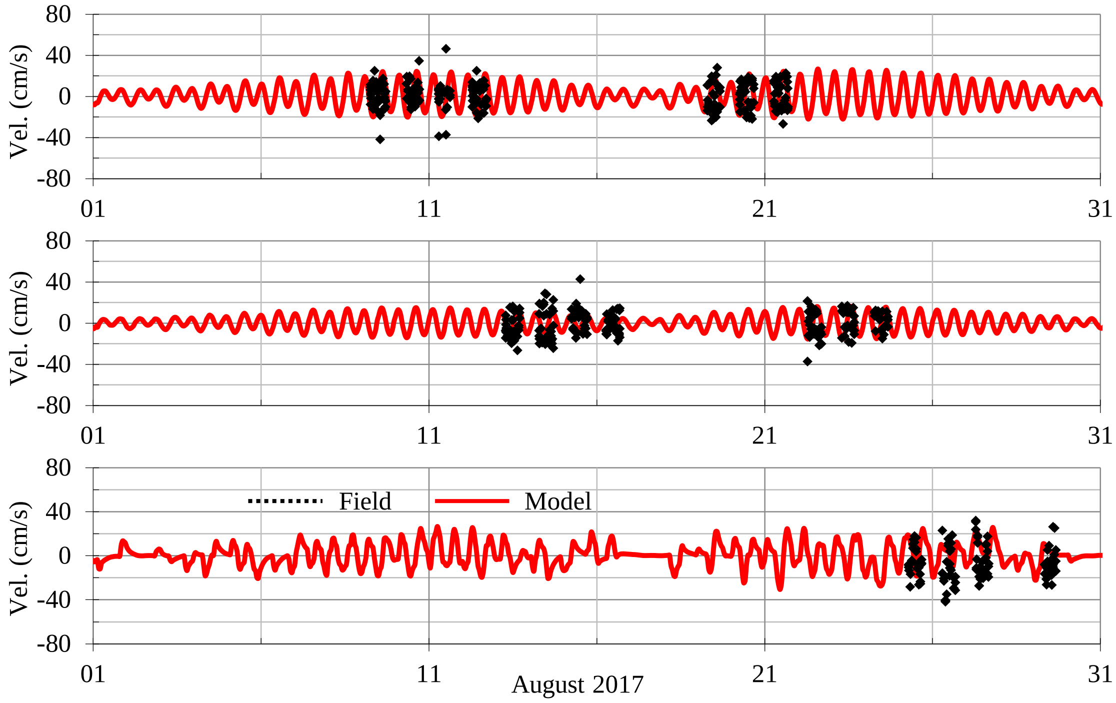

Fig. 7 Comparisons of the modelled (red line) and field measurement (dotted) velocity data at C1, C2 and C3 respectively

simulation using SED2D and investigates the sedimentation changes impacted by the port structure. The local model is shown in Fig. 5.

2.4 Model Validation

The model results are validated with the secondary and field data to assess model reliability. Comparative data are taken from the tidal data produced by the Indonesian Navy tidal table at Toli-Toli, Kwandang, and Tahuna stations and from field measurement conducted at the port site [15]. The locations of validation stations are shown in Fig. 3 and Fig. 4 as black dots. The summary of validation errors is presented in Table 2. The numbers shown are acceptable. A time-series graph is also presented in Fig. 6 which shows both amplitude and phase of model data result coincide with data of field measurement.

Current velocity validation is also carried out. There are 3 measurement points as shown as red dots in Fig. 4. The time series comparison between the modeled and measured velocity are given in Fig. 7. It also shows a correlation between amplitude and phase for both data.

3. RESULTS

3.1 Hydrodynamic

The measured tidal elevation is given in Fig. 6,

Table 2 Summary of tide elevation validation

Domain	Station	Points	Error (%)
Celebes	Toli-toli	C1	2.4
Celebes	Kwandang	C2	3.4
Celebes	Tahuna	C3	4.3
Gorontalo	Kwandang	G1	2.8
Gorontalo	Measurement	G2	1.1
Regional	Measurement	R1	1.1

together with modeled elevation. With the least square method analysis, the tidal constituent is written in Table 3. The Formzhal number is 0.23, so the tidal is a semi-diurnal type with a tidal range of around 2.75 meters.

The spatial tide elevation for flood (June 21st ,2019, 03:00) and ebb condition (June 21st ,2019, 09:00) are given in Fig. 8. This flood and ebb condition are pointed as red box and triangle, respectively, in Fig. 9. In flood conditions, it is seen that the water flows to south-east direction and also into the bay with a velocity of around 0.1 – 0.25 m/s. In ebb condition, the water flows to the north-west and out of the bay with the same velocity range.

3.2 Sedimentation Changes Impacted by The Port Structure

The resulting spatial bed changes are given in Fig. 10(a) and Fig. 10(b) for existing (before) and after port development scenarios. It is obtained that the port development scenario results in bigger

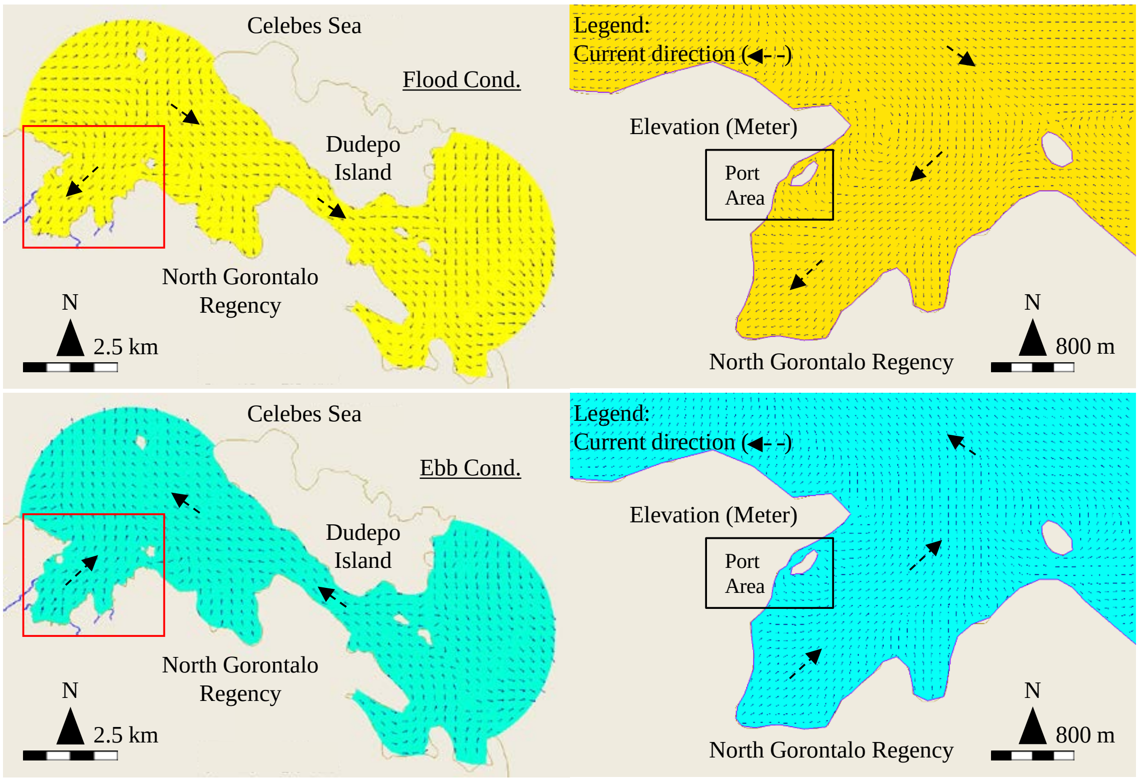

Fig. 8 Hydrodynamic in the regional model for flood and ebb condition (top and bottom respectively)

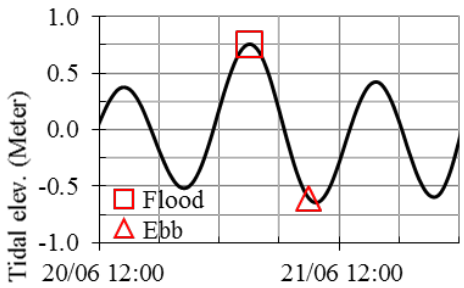

Fig. 9 Elevation at flood (box) and ebb (triangle) condition.

Table 3 Tidal constituent at Anggrek Water

Constituent	Amplitude (cm)	Phase
M2	63.76	53.63
S2	38.78	216.64
N2	9.97	37.96
K2	11.56	-87.7
K1	13.09	184.73
O1	10.94	194.06
P1	6.77	10.42
M4	0.02	-17.41
MS4	0.07	206.19
SO	0.06	

sedimentation than the existing (before port development). Two cross-sections as shown in Fig. 11 are drawn to compare bed changes for the two scenarios clearer. The results of the sections bed changes are given in Fig. 12. As presented in Fig. 12, the bed change differences between the two scenarios is found to be insignificant near the port. However, based on Fig. 10, some areas inside the bay, such as in the southern side of the domain is having an increment of sedimentation around 10 – 15 cm within a one-year simulation.

4. CONCLUSION

Field measurement on bathymetry, tidal

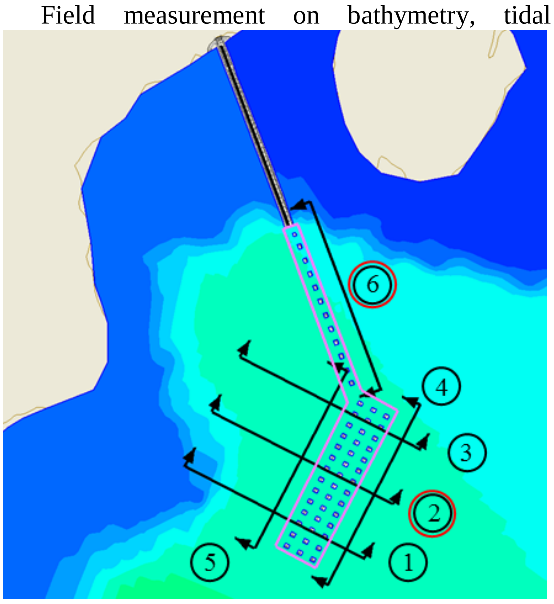

Fig. 11 Cross-sections for observation. Sections 2 and 6 are investigated

elevation and current velocity are conducted to support numerical model establishment. Based on measured data, the tidal type is found to be a mixed diurnal type with 2.75 meters tidal range. Furthermore, the validation between model and field data indicates a good agreement.

The validated hydrodynamic model shows that in a flood condition, the water flows southward and northward for the ebb condition. After modeling sediment transport for 1 year, it is found that the port development is not significantly

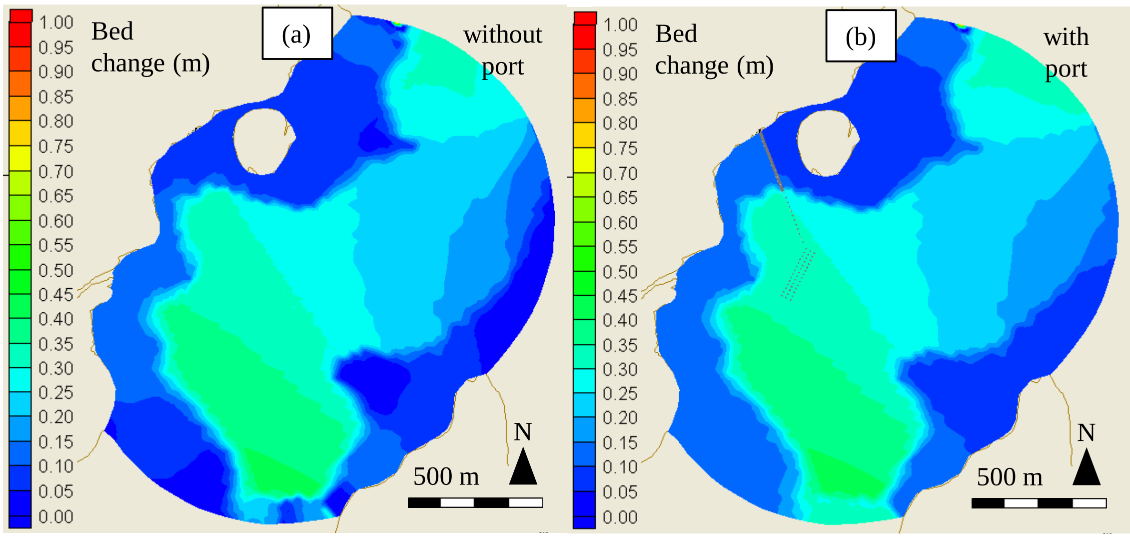

Fig. 10 Yearly bed change for (a) existing and (b) port scenario

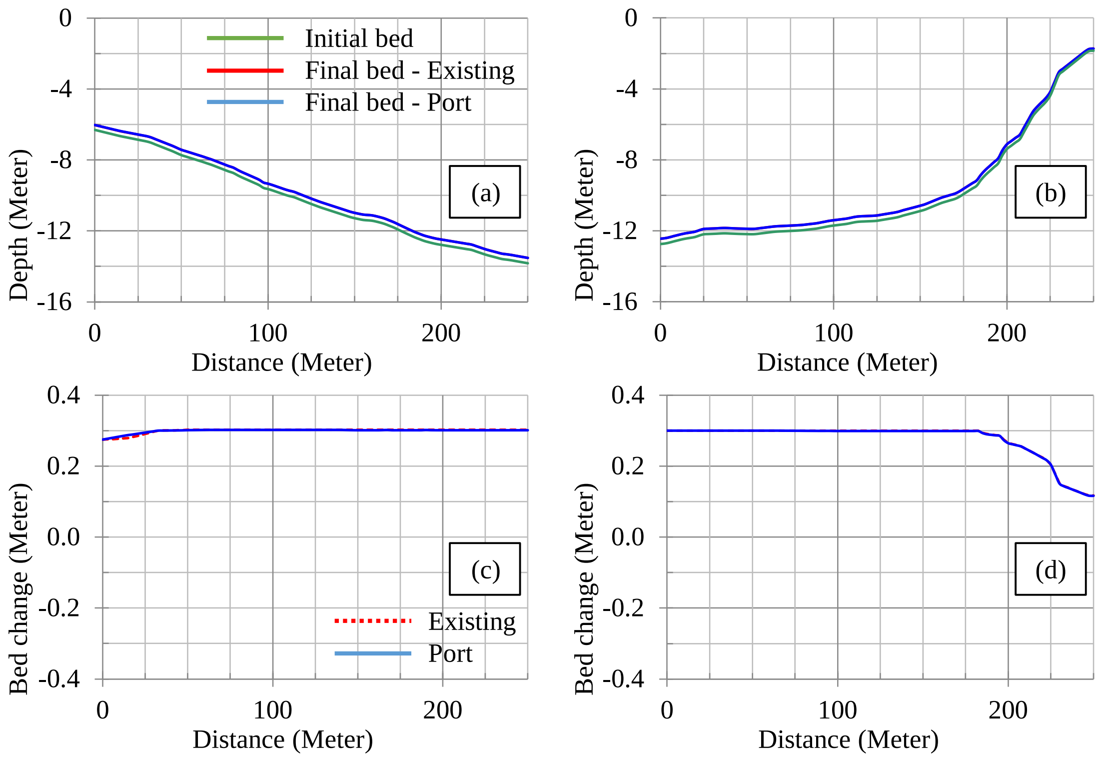

Fig. 12 The comparison of (a-b) bed elevation and (c-d) bed change for existing and port scenario

influencing the sedimentation transport/bed changes near the port location. However, notable changes can be seen in the southern part, inside the bay. In the next study, putting more attention in river inlet is recommended to prevent a negative impact from the port structure.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Ferreira A.M.G.S. & Santos C.S.N., "Sedimentation and Erosion in Harbor Estuaries." Sedimentation Engineering, Ed. Ata Amini: IntechOpen, 2018, pp. 31-55.

[2] Sharaan M., Ibrahim M.G., Iskander M., Masria A. & Nadaoka K., "Analysis of Sedimentation at The Fishing Harbor Entrance: Case Study of El-Burullus, Egypt." Journal of Coastal Conservation, Vol. 22, No. 6, 2018, pp. 1143-1156.

[3] Sutherland J. & Soulsby R.L., "Guidelines for Physical Modelling of Mobile Sediments." Coastalab 2010 – Proceedings of The Third International Conference on The Application of Physical Modelling to Port and Coastal Protection, Barcelona, 2010, pp. 1-15.

[4] Ajiwibowo H., "Physical Modeling for Measuring The Effectiveness of Single Curtain Pile Foundation Breakwater in Intermediate Water Depth." International Journal of Geomate, Vol. 14, No. 43, 2018, pp. 160-166.

[5] Takagi H., Esteban M., Mikami T. & Fujii D., "Projection of Coastal Floods in 2050 Jakarta." Urban Climate, Vol. 17, 2016, pp. 135-145.

[6] Wibowo M. & Kongko W., "Study of Dike Effects to Control Sedimentation Process on Patimban's Port Plan Using Computation Modeling." Majalah Ilmiah Pengkajian Industri, Vol. 12, No. 2, 2018, pp. 85-96.

[7] Ajiwibowo H., Lodiwa K.S., Pratama M.B. & Wurjanto A., "Field Measurement and Numerical Modeling of Tidal Current in Larantuka Strait for Renewable Energy Utilization." International Journal of Geomate, Vol. 13, No. 39, 2017, pp. 124–131.

[8] Hariati F., Ajiwibowo H., Hadihardaja I.K. & Nugroho J., "Modeling Adaptation to Salinity Intrusion in Segara Anakan Estuary Due to Sea Level Rise." International Journal of Geomate, Vol. 16, No. 53, pp. 9-17.

[9] Ajiwibowo H., Ash-Shiddiq R.H.B. & Pratama M.B., "Water Quality and Sedimentation Modeling in Singkarak Lake, Western Sumatra." International Journal of Geomate, Vol. 16, No. 54, pp. 94-102.

[10] Nur A.A., Mandang I., Mubarrok S. & Riza M., "The Changes of Water Mass Characteristics using 3-Dimensional Regional Ocean Modeling System (ROMS) in Balikpapan Bay, Indonesia." IOP Conf. Series: Earth and Environmental Science, Vol.

162, 2018, pp. 1-14.

[11] Lunyu W., Changsheng C., Peifang G., Maochong S., Jianhua Q. & Jianzhong G. "An FVCOM-Based Unstructured Grid Wave, Current, Sediment Transport Model, I. Model Description and Validation." Journal of Ocean University of China, Vol. 10, No. 1, 2011, pp. 1-8.

[12] Ajiwibowo H., "Numerical Modeling for The Selection of Effluent Outlet Location." International Journal of Geomate, Vol. 14, No. 45, 2018, pp. 192-201.

[13] Ajiwibowo H. & Pratama M.B., "The Effect of Gate Existence at L Island on The Seabed Profile due to The Reclamation of Jakarta Bay." International Journal of Engineering and Technology, Vol. 9, No. 5, 2017, pp. 3763-3774.

[14] Matsumoto K., Takanezawa T. & Ooe M., "Ocean Tides Models Developed by Assimilating TOPEX/POSEIDON Altimeter Data into Hydrodynamical Model: a Global Model and a Regional Model around Japan." Journal of Oceanography, Vol. 56, 2000, pp. 567-581.

[15] Tide Tables of Indonesia. Indonesia: Dinas Hidro-Oseanografi TNI-AL, 2017.