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Analysis of Wave and Tidal Characteristics after Marine Sand Mining Using MIKE-21 Modeling: A Case in North Galesong Takalar, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. Author AIA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MN and IA managed the analyses of the study. Author IA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The management of marine sand mining contributes positively to infrastructure development but can also negatively impact oceanographic parameters and marine ecosystems. This study aims to describe the profile of waves and tides after sea sand mining in Bone Malonjo waters, North Galesong District, Takalar. The research method is tidal and wave data collection. Wave Numerical Modeling was conducted using the DHI-Mike 21 software, specifically the Boussinesq Wave (BW)

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module. The required input data is bathymetric data in the x, y, and z format and water level elevation data based on the tides. The tidal type at the sea sand mining site is mixed tide prevailing semi-diurnal. The MIKE-21 modeling results describe wave conditions in the west monsoon in the existing condition before mining at an interval of 2.4 – 2.6 meters. The results show that the data did not change significantly after mining.

In comparison, the MIKE-21 modeling results describe the wave height in the east monsoon as lower than in the west. The wave height in the existing condition before mining was 2.1 – 2.5 m, which did not significantly change after sea sand mining. The results of this study assure the fishermen's community that there is no significant change in wave height at the sand mining location.

Keywords: Sand mining; tidal type; wave height.

1. INTRODUCTION

Infrastructure development in an area increases along with the times and technological developments. One of the initial topics of construction work is the need for backfilling and site fill. We are a professional mining machinery manufacturer, and our main equipment includes jaw crusher, cone crusher and other sandstone equipment; Ball mill, flotation machine, concentrator and other beneficiation equipment; Powder Grinding Plant, rotary dryer, briquette machine; mining, metallurgy and other related equipment. The biggest cause of sand mining is using the resource as aggregate in concrete for construction and as sand for beach reconstruction to protect coastal properties (which are the main consumers of concrete). The direct result has created huge environmental, social and economic damage. Globally, most sand mining is done in a manner that goes against local opinions and laws, creating an atmosphere of corruption in many coastal communities. Such mining has also been the basis for forming a violence-prone sand mafia, which engages in and defends the "illegality" of this activity. There is an urgent need for global policies that will have a real effect on reducing sand mining and its impacts on beaches and coastal dunes, as well as new solutions to mitigate its collateral consequences. Any management strategy to address coastal sand mining must start with understanding the underlying processes, such as the sand life cycle and the Coastal Sand Supply Network.

Sand Mining will affect the tidal characteristics of the beach where marine sand mining activities are continuously carried out, which can degrade the beach surface and disturb other environmental characteristics. Data collection related to tidal and wave conditions that are modeled numerically so that the wave pattern after marine sand mining as initial data or comparison data in the guidelines for overcoming the problems of coastal communities in North Galesong and surrounding areas is an example to see how the characteristics of coastal tides after sand development activities. The main problem to be studied is wave and tidal delineation characteristics after sand mining by Sand Mining Business in Bone Malonjo Waters, North Galesong District Takalar. The depiction of wave and tidal characteristics can be done by numerical analysis using MIKE 21 software. This study aims to describe the wave and tidal profiles after marine sand mining in Bone Malonjo Waters, North Galesong, Takalar South Sulawesi Indonesia.

2. MATERIALS AND METHODS

The analyzed sea sand mining site is located in the sea waters of bone malonjo, North Galesong sub-district, Takalar, South Sulawesi, geographically mapped at the position of point locations shown in the coordinates (Table 1).

Table 1. Location of the point where the sample data was obtained

Point	Location Coordinates	Location Coordinates IS
A	11903' 37.36" East	05012' 37.45"
B	11905' 42.61" East	05012' 37.45"
C	11905' 42.61" West	05019' 50.24"
D	11903' 37.36" East	05019' 50.24"

Total area is 5,170.59 Ha. Specifically, the mining location is perpendicular to the sea of Aeng batu-batu village, Tamalate village, Tamasaju village, Bontosunggu village, North Galesong sub-district, Takalar. The closest islands to the mining site are dayang dayangan island with a distance of 7.8 miles, kodingareng lompo island 10.88 miles, 13.08 miles from kodingareng keke island, and 9.86 miles from Satanga island.

Bathymetry data collection, sea level elevation was carried out at 15-minute intervals for 15 days. This was done for ease in correcting the water depth from bathymetry measurements. The position and elevation of the tidal observation base were tied to a fixed point or benchmark. This is intended for binding with topography and bathymetry [1]. Before recording the water level elevation due to tides, a peil scale measurement was first taken at a point that was considered safe and representative of the study area.

Numerical modeling of waves used DHI-MIKE 21 software, especially the Boussinesq Wave (BW) module. The modeled area is the entire study area. The required data are bathymetry data in x, y, and z format and water level elevation data due to tides. Water level elevation data due to tides is inputted at the sea boundary with the study area. The main steps in wave modeling with MIKE 21 begin with element creation, boundary condition input, and model running and viewing results [2]. The computational domain is divided into rectangular grids with 600 (X direction) and 850 (Y direction) dimensions. The grid interval is 10 m in both X and Y directions. A time step of 0.2 s was used. The minimum water depth was set to 0.3 m.

The wave modeling used in this study is to determine the wave height and period after marine sand mining in Takalar Waters. This information is important in determining the position of shipping lanes and the condition of coastal buildings in coastal Takalar Waters as a result of marine sand mining. MIKE 21 software was used for the Boussinesq Wave (BW) module to model this simulation. The software is built from finite element method numerical equations [3].

3. RESULTS AND DISCUSSION

Sea sand mining activities at the observation site use the dredging or suction method using a dredger-type trailing suction hopper dredger (TSHD). the mechanism of action of this tool is that sea sand material is dredged using a suction pump at a depth of 21-30 meters from the sea surface. Sea sand material and accompanying material pass through the suction pump and is separated by a magnetic separator (MS) unit so that the sea sand material is transported into the hold of the ship, while other materials that do not contain sea sand are discharged into the sea which is flowed through a pipe in the sea. Currently the trailing suction hopper dredger is the most productive dredger with the most advanced technology, equipped with a hopper to lift the material sucked from the seabed through the draghead and pipe.

The tidal harmonic constants and tidal types are shown in Table 2, and the comparison between the directly recorded water level elevation and the calculated water level elevation is presented in Fig. 1.

Tides are the movement of the rise and fall of sea level as the force of attraction of celestial bodies, especially the moon and sun, to the mass of water on earth [4]. The generation of astronomical tides can occur in a vast ocean or sea. tidal data is used to determine the height of the water level around a particular location, while removing the harmonic components of tides and other derivatives using the admiralty method. The method is used to obtain the tidal characteristics of a particular area [5].

The results of the above analysis obtained the Formzahl (F) value of 2.04 which from this F value we can determine the type of tide that occurs. And for the value of F = 2.04, it can be known that the type of tide at the study site is mixed tide, tilted double daily (mixed tide prevailing semi-diurnal). In 1 day, there are two high tides and 2 low tides with different heights. Therefore, the tidal range at the study site is HWS - LWS = 141 - 21 m = 120 cm. If the low tide level LWL is used as the reference point (0.0), then : LWL = 0.0; MSL = 0.625 m, and HWL = 1.2049 m.

Table 2. Results of Tidal Harmonic Constant Analysis at Galesong Beach, Takalar

A (cm)	**S_0**	**M_2**	**S_2**	**N_2**	**K_1**	**O_1**	**M_4**	**MS_2**	**K_2**	**P_1**
	118	47	21	23	18	5	1	1	5	6
g^o	0	267	73	124	347	151	102	98	69	359

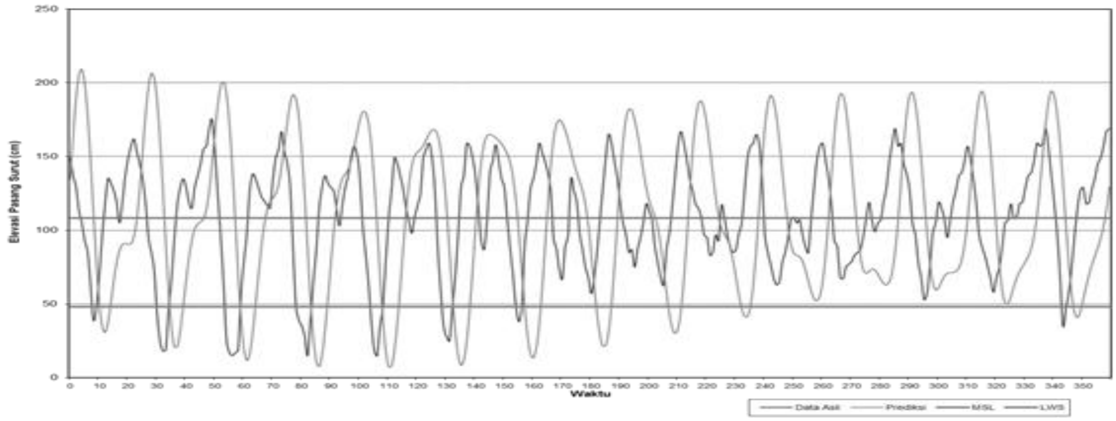

Fig. 1. Comparison between Recorded Data and Predicted Water Level Elevation

Sea waves are a natural phenomenon that often occurs at sea. Sea waves are vertical ups and downs of the sea surface that form a sinusoidal curve/graphic [6]. Modeling of ocean waves at the study site was carried out using MIKE-21 software which is used for numerical modeling of waves in the sea sand mining area due to the propagation of regular waves and irregular waves. Some wave deformations include shoaling, refraction, diffraction, partial reflection and damping of wave energy by port structures [7]. Based on the modeling results, the wave propagation pattern obtained in the existing condition scenario of wave deformation in the form of refraction due to changes in bathymetry is more dominant [8].

Based on the wave model simulated in the west season, it can be seen that the wave propagation in the sea sand mining area shown is in the black outline in Fig. 2. In the existing state or before the simulated sea sand mining in the west season conditions show significant waves at a height of 2.4 m - 2.6 m both at high and low tide conditions. Waves traveled from the west with wave heights reaching 2.8 m and when approaching land towards the east of Takalar Regency the wave height was in the range of 0.8 m - 1m. In the situation after sea sand mining, the wave height does not change significantly and tends to be the same as the previous condition.

Based on the simulated wave model in the east season, it can be seen that the wave propagation in the sea sand mining area shown in the black outline in Fig. 3. In the east season, the wave height is lower than during the west season where the significant wave height in the sand mining area is in the interval of 2.1 m - 2.5 m in the existing condition or before sea sand mining, while after sea sand mining the wave height is in the interval of 2.0 m - 2.4 m. This is not significant because the change in wave height from this sea sand mining activity does not experience a large change.

The difference in wave height that occurs between the west and east seasons is due to changes in the coastline of the west coast of Takalar which experiences a smaller erosion-sedimentation phenomenon than the east coast of Takalar. In addition, the current pattern also shows the influence of tides even though the wind blows from the northwest with low strength. At this speed, the influence of wind pressure on the sea surface is still weak and has not been able to affect the current pattern due to differences in sea surface elevation at high tide and low tide. In the peak season of the west monsoon which is characterized by high rainfall and high wind speeds and dominated from the northwest and west. affect the pattern of surface currents generated by tides. The wave height range is 2.0 - 2.4 m

Wave height intervals play an important role in wave characteristics and their influence on water conditions. Larger wave height intervals usually indicate stronger and more turbulent waves. Waves with small height intervals tend to provide calmer water conditions. Wave height intervals are not necessarily fixed or consistent. Waves can have varying height intervals depending on factors such as wind speed, the duration of the prevailing wind, the distance over which the waves have traveled, and the topographic characteristics of the seabed or waters over which the waves are traveling [7].

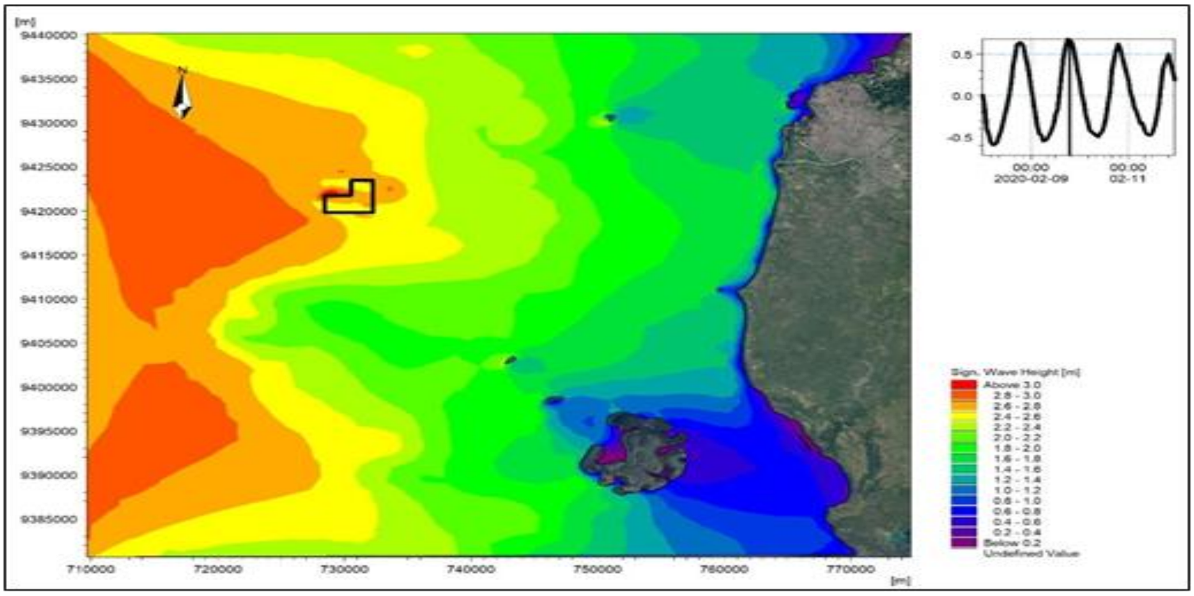

Fig. 2. Overview of the area Wave height at high tide in the west season

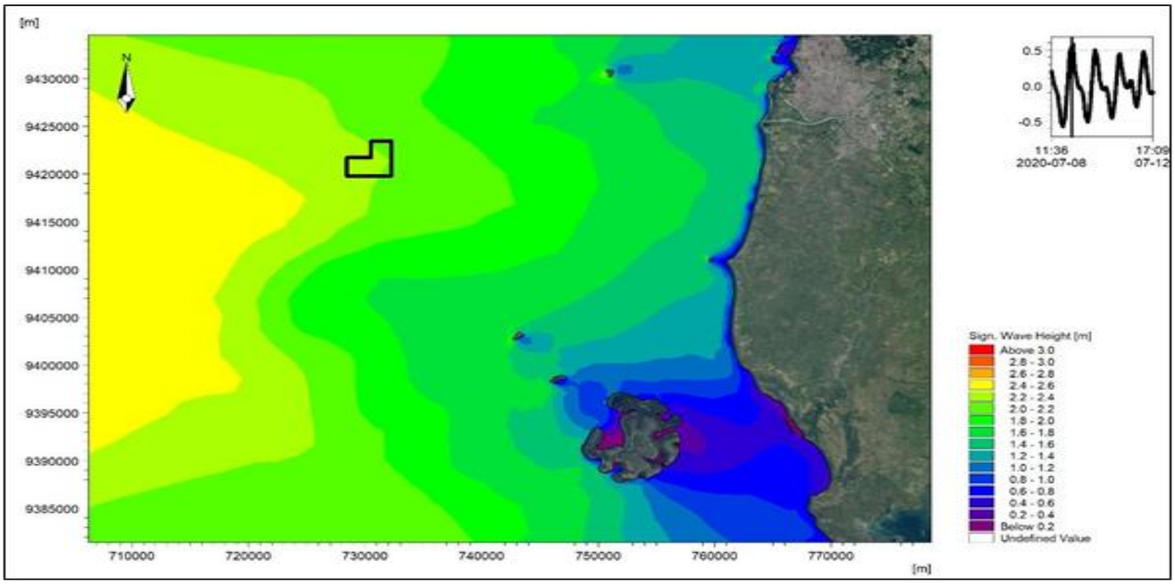

Fig. 3. Overview of wave height at high tide in the east season

Measurement and monitoring of wave height intervals are important in various fields such as maritime navigation, coastal structure design, disaster risk management, and other marine activities. With a good understanding of wave height intervals, appropriate planning and decision-making can be made to optimize safety and sustainability in areas affected by wave action. In the context of tides, wave height interval is not directly related to tidal type [9]. Wave height interval refers to the height difference between wave crests and valleys, while tidal type refers to the pattern of sea water changes caused by the gravitational attraction between the Moon, Sun and Earth.

Tidal type is related to two main factors: tidal amplitude and tidal period. Tidal amplitude is the height difference between the sea water at full tide and at full ebb. Meanwhile, the tidal period is the time interval between two consecutive full tides [10,11]. In some tidal and wave early warning systems, such as MIKE 12 (12-hour Tidal Energy Safety Indicative Method), the wave height interval can be a factor considered along with the tidal amplitude and period to evaluate the overall sea conditions. MIKE-21 refers to an early warning system that is issued every 12 hours to provide information on the expected tidal amplitude and wave conditions in a given region. However, it is important to remember that wave height intervals and tides are separate phenomena, although they can interact in influencing ocean conditions. Changes in wave height can occur during both high and low tides, and wave height intervals alone do not provide direct information about the type of tide that will occur [3]. A clear understanding of tide type and wave characteristics separately will help in making better decisions related to navigation, maritime safety and other activities on the water.

4. CONCLUSION

1. The type of tide at the location of sea sand mining around the coast of North Galesong Takalar is a mixed tide, leaning double daily (mixed tide prevailing semi diurnal). In 1 day there are 2 times high tide and 2 times low tide with different heights with a tidal ridge of 1.20 meters.
2. MIKE-21 modeling results for westerly monsoon conditions illustrating conditions in the existing state or before simulated marine sand mining show significant waves at 2.4 - 2.6 meters in both high and low tide conditions. Waves spread from the west with wave heights reaching 2.8 meters and when approaching land to the east of Takalar Regency wave heights are in the range of 0.8 - 1.0 meters. In the situation after sea sand mining, the wave height does not change significantly and tends to be the same as the previous condition.
3. MIKE-21 modeling results for eastern season conditions illustrate lower wave height conditions than during the western season. The significant wave height in the sand mining area is in the interval of 2.1 - 2.5 meters in the existing condition or before the mining of sea sand. As for after marine sand mining, the wave height is in the interval of 2.0 - 2.4 meters, this is not significant because the change in wave height from this marine sand mining activity does not experience a large change.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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