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https://doi.org/10.5109/7151697

出版情報：Evergreen. 10 (3), pp.1487-1494, 2023-09. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan
バージョン：
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Sediment Transport and Suspension Analysis to Support Development Planning for Port Pota, East Nusa Tenggara, Indonesia

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(Received July 5, 2023; Revised September 2, 2023; accepted September 26, 2023).

Abstract: A port is one of the places that supports transportation and the country's economy. It functions as the center of the community's economy, used for the purposes of the entry and exit of goods and human activities in it. To be in accordance with its function, a port must have complete facilities. One of the ports that does not meet the criteria mentioned above is the Port of Pota. The port of Pota has not yet operated; one of the reasons is that it does not yet have a stipulation for shipping lanes. The process of making shipping lanes involves dredging in order to get the appropriate depth; it is very important to conduct an investigation of the suspension material. Therefore, research on sediment transport is the basis for the development of port development and aims to be able to determine the hydro-oceanographic conditions in the waters of Pota Harbor. Based on the results of sample testing, it shows that the highest sediment content is at low tide, reaching 0.0087 g/L and the lowest is at high tide, reaching 0.0057 g/L. The simulation results of sediment levels for 24 days show that there is an increase in concentration at Pota Harbor of 0.94 kg/m3. The waters of the Port of Pota have a dominant current direction that tends to be parallel to the shoreline, or it can be said that the currents that occur in these waters are tidal currents. There is a stirring of sediment on the shore, which is then transported by currents and settles as the current velocity decreases due to shallower depths.

Keywords: conformity assessment, port, water quality, pota port

1. Introduction

A port is one of the most important places for supporting transportation and the country's economy. The port serves as the center of the community's economy, used for the purposes of entry and exit of goods (exports and imports) and human activities. In order to be in accordance with its functions, a complete port must have a pier, breakwater, port pool, shipping lanes, passenger and goods terminals, fish landing terminals, processing , and waste disposal facilities (reception facilities/garbage and sewage treatment and disposal facilities), emergency response systems, as well as port operation supporting facilities such as warehouses, container processing facilities, stacking yards, fish auction places, cold storage for fishery products, road networks, electricity networks, telecommunications networks, clean water networks, drainage networks, various loading and unloading equipment, workshops and different hydro-acoustic surveys[1-3)]

Suspended sediment mainly consists of sediment types, namely fine sand, silt, and clay (with an average size of 63 m), carried to rivers and streams from the highlands and transported downstream[4-6)]. Over time, under certain conditions, such as reduced flow velocity and momentum, sediment can, therefore, temporarily accumulate in channels or riverbeds, and under most common hydraulic systems, entrained and remobilized sediments return to

the outflow[7-8].

Where slow velocities and the weight of submerged particles come into play, the sediment settles and is saved. In addition, sediments can also be deposited in reservoirs at rest by the action of gravity[9-11]. Thus, it reduces their storage capacity. Sedimentation problems also choke and disrupt the normal hydrological system of river flows and water areas[12-15].

One of the ports that does not yet have complete facilities is the Port of Pota, East Nusa Tenggara, the port is People's port which is used for public transportation in Sambi Rampas, East Manggarai Regency, East Nusa Tenggara, Indonesia. Until now, Pota Port has not yet operated; this port is used as a local feeder port with the designation people's port. The Port of Pota does not yet have a Shipping Navigation Assistance Facility (SNAF) and does not yet have a stipulation of shipping lanes. One of the port development plans that will be carried out is the dredging of port or shipping lanes and port pools. In port development planning, it is very important to conduct an investigation of suspension material because the dredging plan at the port will cause sedimentation. Therefore, research on sediment transport is the basis for port development.

This study aims to produce the direction of sediment transport that is in the planning of the port of Pota, East Nusa Tenggara, using the hydrodynamic method. This research is also a preliminary study in determining the initial steps in accelerating the government's development program. The results of this study were carried out by taking parameters, namely, using primary data measured directly in the field in the form of water depth and bathymetry data and also sea surface currents in the planning waters of the port.

2. Methods

2.1 Research Location and Methods

This research was conducted at the Port of Pota, which is precisely located in Nanga Baras Village, Sambi Rampas District, East Manggarai Regency, East Nusa Tenggara Province. October to November 2020, as shown in Fig. 1, while the research flow chart can be seen in Fig. 2.

Fig 1: Research Location

The method used in this study is a quantitative one. The field data used are tidal data, sea surface currents, bathymetry, sediment, and wind. The data obtained were then processed using DHI MIKE 21 software, which can describe hydro-oceanographic conditions that affect sediment transport patterns. The method of determining tidal harmonics is using the least squares and admiralty methods.

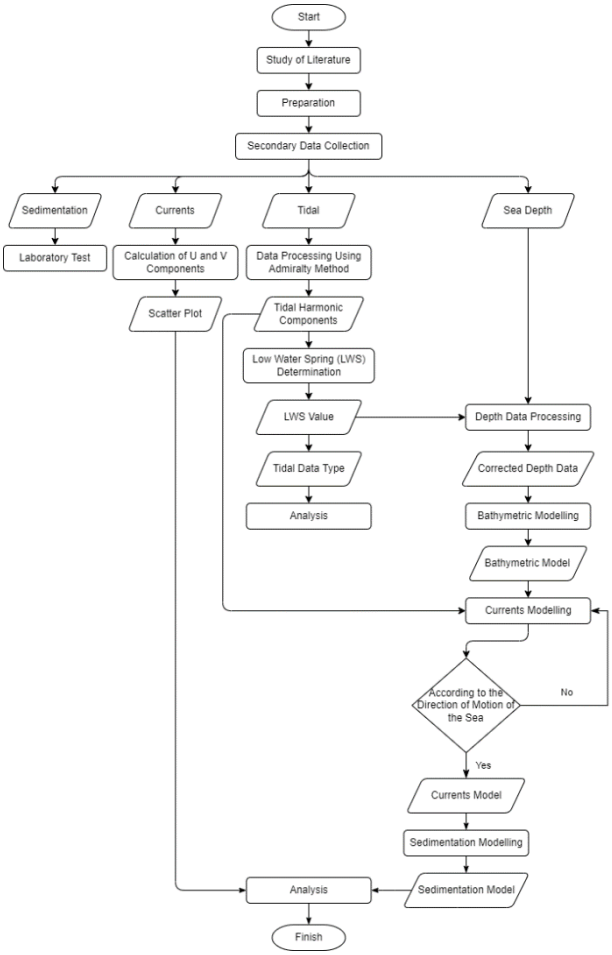

Fig 2: Research flow chart

2.1 Data Collection Technique

The data used in this study is secondary data in the form of depth data, current data, tidal data, and sediment sample data. Tidal data collection is carried out by installing tidal palms and tide gauges in a place that is in accordance with the requirements for the installation of tidal palms, among others, being safe from waves, not changing position, not close to shipping activities or ship docking, not damaged when exposed to waves or currents, and easy to use. clearly visible during manual observation. In addition, it should also be noted that at high tide, the tidal palm is not submerged in water, and at low tide, it is still inundated by water.

The procedure for recording tidal primary field data for 29 days of observation is as follows:

1. Observing the water level, which is carried out once every 60 minutes manually using a tidal

palm, The high and low sea levels can be observed directly by looking directly at the pasur palm.
2. Recording tidal data is done by reading the water level indicated by the palm scale.
3. The tide gauge records or records data automatically every 15 minutes.

The method used in collecting depth primary field data in this study is the generalization method. Perum lanes are carried out at 25-meter intervals for bathymetric dredging in the waters of the harbor pool and shipping lanes. The lanes are plotted on the Hypack software as a navigation tool during the bathymetric survey.

The procedure for collecting depth data in the waters of the Port of Pota is as follows:

1.Tool Preparation

The echosounder is connected to the transducer and GPS antenna. Adjust the draft transducer to keep it submerged, usually 0.3 m deep or according to the required draft. The transducer and GPS antenna are installed in a straight line so that depth and fixed coordinates are obtained in the depth measurement process.

2.Calibration

The Echosounder Ceeducer ProTM instrument reads the real depth value, namely the total depth from the bottom to the water surface, so to get the appropriate data, calibration (barcheck) must be carried out by placing a metal plate with a measuring line at the depth of the water.

$$d=(a–k) \quad (1)$$

Where d is the total depth from the bottom to the surface, a is the depth from the transducer to the bottom, and k is the constant index or system delay originating from the transducer and circuit.

3. Recording data

The primary field data recording process is carried out in accordance with the sounding plan line; the interval between the lines is 10 meters. Maximum ship speed is 4 knots. Automatic depth and position data are X, Y, and Z. Sounding data is needed as a parameter determining the layout of the harbor cruise line design (water side). The coordinates of the points in the bathymetric map are determined using geographic coordinates, local coordinates, or UTM. Current data collection is carried out using the Euler method, which is a method of measuring current at a fixed location in a pool of water so that current data is obtained at a certain point in a function of time [16-18]. Current data retrieval using the AEM213-D Current Meter tool. The procedure for data collection on currents in the waters of the Port of Pota is as follows: Enable and set recording on the current meter AEM213-D.

a. Mark survey coordinates using GPS.

b. Measure the ocean currents at a depth of 0.2 d; 0.6 d; and 0.8 d at 1hour intervals for 24 hours, under Neap and Spring conditions.

The measurement method used in this study was carried out in situ (directly) at locations that experienced siltation and were indicated to have high concentrations of TSS. In addition, sediment sampling will also be carried out, and laboratory tests will be carried out on the TSS samples that have been taken. The procedure carried out in the implementation of the TSS sampling survey in the waters of the Port of Pota is as follows:

1. Prepare the tools needed for TSS measurement.
2. Mobilization to the measurement location using a survey ship and marking the measurement location using GPS
3. Perform TSS measurements at depths of 0.2 s, 0.6 d, and 0.8 d.
4. Taking sediment samples using a Nansen bottle or sediment grab

The field data obtained were processed using the admiralty method. Tidal calculations are calculated based on observational data by taking into account the known frequency harmonic components. This tidal component data will be used to determine the tidal type at the location of the water.

Determine the LWS value and the type of tide [19] in the waters of the Port of Pota. From this analysis, the following will be obtained:

LWS (Low Water Spring)

$$LWS = So – Z \quad (2)$$

After obtaining the tidal components, process the tidal data into the Mike 21 software using the Time Series Module. The depth data obtained will be corrected against sea level elevation in order to obtain accurate depth data. Correction of the value of the reduction in accordance with the position of the sea level when the measurement is carried out using the following formula:

$$Rt = TWLt – Z \quad (3)$$

Information:
Rt : Tidal reduction at time t;
TWLt : True water level at time t
Z : Temporary depth

After that, the actual depth value is calculated:

$$D = rt – LWS \quad (4)$$

Information:
D : Actual depth;
LWS : receding face; and
rt : Reduction of tides at time t.

Furthermore, bathymetric modeling will be carried out which will later be used as input for current and sediment modeling.

From the field measurement data, the magnitude and direction of the current will be obtained, and then the data will be broken down into components U (east-west) and V (north-south). The magnitude of the U and V components is obtained from the formula[20]:

$$U = V_{Total} \sin \frac{Dir\ \pi}{180} \quad (5)$$

$$V = U_{Total} \sin \frac{Dir\ \pi}{180} \quad (6)$$

The value of is 3.14, and Dir is the direction of the current. The results of the calculation of the U component and V component are then plotted into ascatterplot graph using Microsoft Office Excel 2019 software so that it will describe the current pattern that occurs. After that, current data modeling will also be carried out using the Mike 21 Hydrodynamic Module to obtain current models in conditions of high tide, low tide, and lowest low tide.

3. Result and Discussion

3.1 Tides

Based on the processing of tidal data for Pota Port for 29 days from July 7, 2020, to August 3, 2020, the data obtained for the tidal type of Pota Port is a type of Mixed Tidal tends to Daily Double, where in this tidal type there are two high tides and two low tide times with different (irregular) periods on the same day. In a day there will be two high tides and two low tides in seawater, but the period and wave height are different. This type of tide often occurs in eastern Indonesian waters. The tide diagram can be seen in Fig. 3.

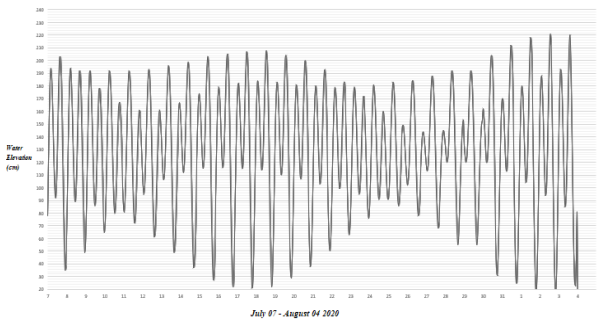

Fig 3: Tidal diagram of the Pota Port

Data analysis was in the form of tidal processing using the admiralty method to obtain tidal and elevation components and important tidal water level elevation values, which can be seen in tables 1 and 2.

Table 1. Tidal components

Component from tides	Amplitude (cm)	Fase (g°)
Zo	129,37	
M2	52,44	220,87
S2	16,26	57,54
N2	7,45	86,53
K1	23,52	125,59
O1	20,06	319,27
M4	2,00	265,76
MS4	2,00	188,60
K2	4,391	57,54
P1	7,76	125,59

Table 2. Tidal elevation value

Tidal Reference	Elevation (cm)
Highest Eater Spring (HWS)	241,65
Mean Sea Level (MSL)	129,37
Lowest Water Spring (LWS)	-176.965
F	**0,634**

3.2 Bathymetry

Before making a current and sediment model, you must first create a meshing area to determine the boundary conditions to be modeled from the primary field data of bathymetry. The meshing area is a triangular-shaped point that is the result of interpolation from sea depth input. The points will determine the results of the flow vector distribution; the more points, the more accurate the resulting modeling. Making a meshing area using the software Mike 21: Mesh Generator Module.

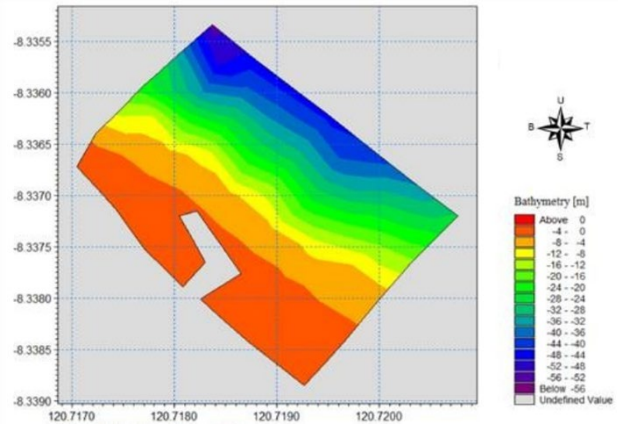

Fig 4: Bathymetric model drawing

The bathymetry model can represent the depth of the waters of the Pota Port, which has water depths ranging

from above -4 meters above sea level to below -56 meters above sea level. This shows that the waters of the Port of Pota have safe conditions for shipping, namely in the form of the deep sea.

3.3 Sea surface current

Based on the results of current data processing and observations in the field, ocean currents have varying speeds, with current speeds in all waters ranging from 0.07 m/s to 0.51 m/s, a minimum current velocity of 0.01 m/s to 0.23 m/s, and a maximum current velocity of 0.18 m/s to 0.64 m/s. The dominant direction of port waters tends to be parallel to the shoreline, or it can be said that the currents that occur in these waters are tidal. The current direction of the harbor waters tends to move from the southeast to the south of the pier in spring conditions, and vice versa, from the south to the southeast of the pier in winter conditions.

The results of previous research conducted in West Nusa Tenggara show that the speed of the sea surface current is 0.001–0.018 m/s with the direction of the sea surface current coming from the east and southeast, and the current velocity at low tide is 0.001-0.014 m/s with the direction of the sea surface current, which goes back and forth from the east 21). The results of previous studies have the same direction, while the value of the velocity of sea surface currents around the POTA port is stronger.

Sea surface currents generated in this study indicate that there is an influence on the speed and direction of sea surface currents. The direction and speed of this sea surface current will carry sediment and determine where the sediment is suspended[22-23]. Scatter plots of sea surface currents in high and low tide conditions can be seen in Figures 5 and 6.

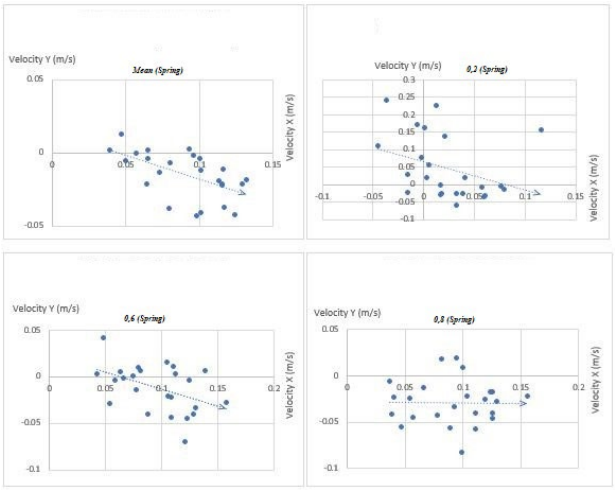

Fig 5: Scatter plot of sea surface currents at high tide

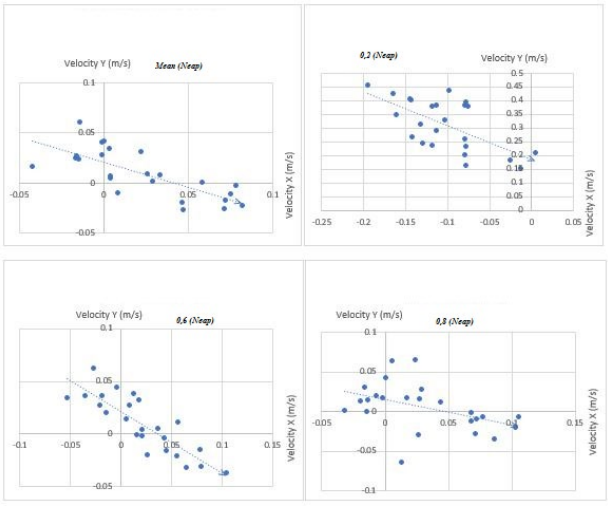

Fig 6: Scatter plot of sea surface currents at low tide

It can be seen in the current scatterplot of tidal and tidal conditions that the current velocity will decrease in value as the depth increases. In tidal conditions with a depth of 0.2 d, the current speed can reach 0.24 m/s and gets smaller to a depth of 0.8 s, with the highest current speed only reaching 0.02 m/s at low tide. This can happen because the influence of current-forming factors such as wind will be higher at the surface.

The results of the modeling of ocean currents in the waters of Pota Port show that in conditions of high tide, the maximum speed reaches 2.4 m/s for the entire area and 0.504 m/s in the waters below and around the pier. In the conditions toward the tide, it can be seen that the ocean currents move to the southeast.

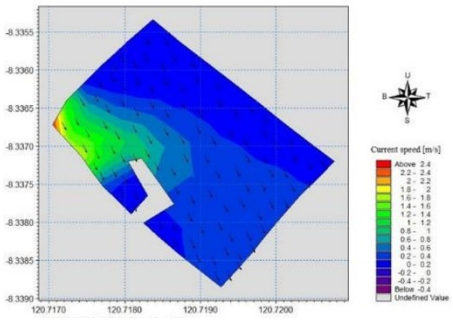

Fig 7: Sea Surface Current Conditions Towards Tidal

In high tide conditions, ocean currents reach a maximum speed of 3 m/s across the entire area and a speed of 0.518 m/s in the waters around the pier. At high tide, it can be seen that the ocean currents move slightly from the southeast to the south of the pier.

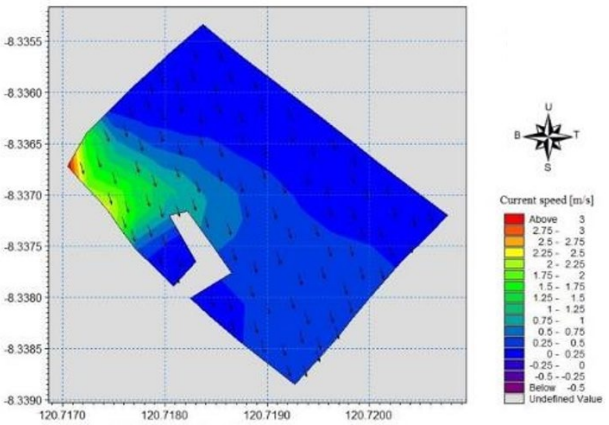

Fig 8: Sea Surface Currents Tidal Conditions

At low tide, sea currents reach a maximum speed of 3 m/s in the entire area and a speed of 0.514 m/s in the waters around the pier. At low tide, it can be seen that the ocean currents move back from the south to the southeast of the pier.

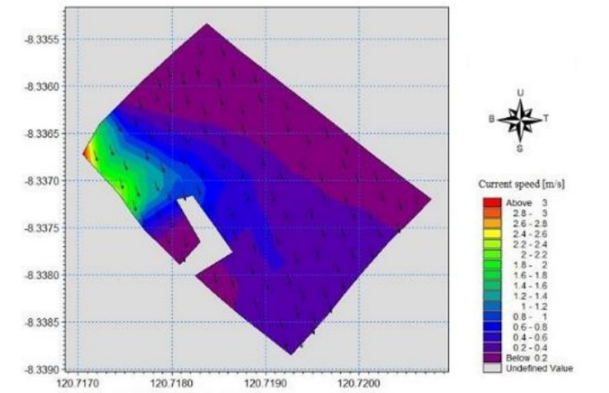

Fig 9: Sea Surface Current Conditions Towards Low tide

At low tide, ocean currents reach a maximum speed of only 1.8 m/s in the entire area and a speed of 0.46 m/s in the waters around the pier. At low tide, the ocean currents move to the southeast again.

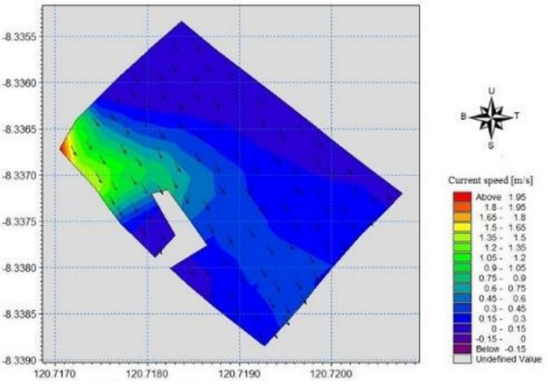

Fig 10: Sea Surface Currents Low tide

[24-25] stated that wind is a key factor in determining the magnitude and direction of sea surface currents in a body of water, with characteristics and morphology being open waters or high seas, as in the waters of East Nusa Tenggara. In the rainy season (October), the currents around West Nusa Tenggara and along the coastal waters of Bali have two different directions. Sea surface currents will move from the east, which is then deflected towards the southwest, towards the open waters of the Bali Sea [26]. Sample testing in this study was also carried out by carrying out test results from the laboratory, while the results of testing samples taken in the waters of the Port of Pota can be seen in table 3.

Table 3. Sediment Sample Lab Test Results

Point sampling	Concentration (g/L)		Information
	Neap	Spring	
ST TSS	0.0058	0.0057	0.2d
ST TSS	0.0076	0.0061	0.6d
ST TSS	0.0087	0.0068	0.8d

The test results show that the sediment concentration will increase with increasing depth and has a high value in low-tide conditions. The highest sediment content at low tide reaches 0.0087 g/L, while the lowest sediment content at high tide reaches 0.0057 g/L.

The results of the sedimentation modelling show that the distribution of sediment at the Port of Pota is in accordance with the direction of the current, namely along the dominant coast from the southeast to the south. The analysis of the sedimentation rate in this study was calculated for 24 days to provide an overview of the sedimentation conditions that occurred in the field at the time of the survey.

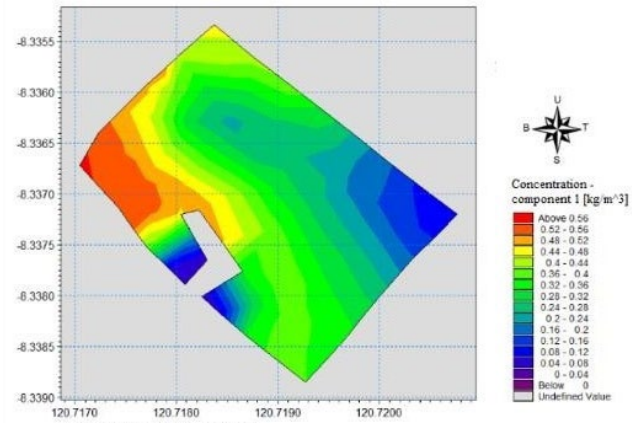

Fig 11: Sediment Model Under Neap Conditions on 7 July 2020

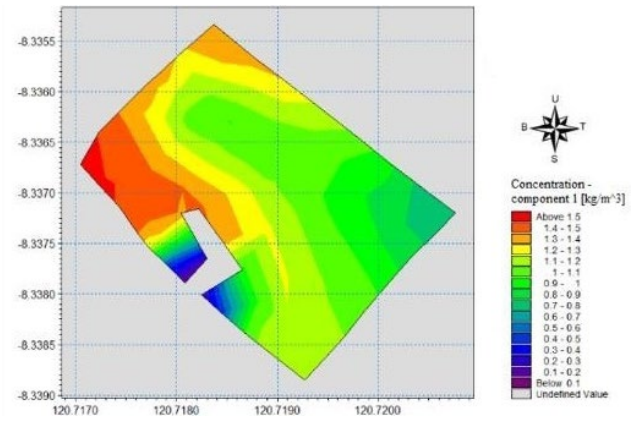

Fig 12: Sediment Model Under Neap Conditions on 30 July 2020

It can be seen that the addition of sediment concentration (sedimentation) in the waters of the Port of Pota was 0.94 kg/m3 during a 24-day simulation. Sedimentation that occurs around the pier is higher when compared to sedimentation around the estimated shipping lane location, where the addition of sediment thickness has a smaller value because it is further away from the movement of tidal currents[27-29].

The shipping lane, which is one of the important components in the process of building a port, is also important to pay attention to the process of sediment thickening. The shipping lane is determined based on the size of the ship that will dock at the port. Based on related research, the shipping lane of Pota Port is located at a depth of -30 mLWS to -80.70 mLWS to the northeast perpendicular to the pier with one lane.

Based on the survey results, the technical data for shipping channel plans are ± 3.35 NM or ± 6.2 Km from POTA Port and the width varies from 60 m, the channel depth varies from -5.7mLWS to -31mLWS, and pool depth varies from -1 to -10 mLWS

The sedimentation pattern from the modeling results shows that the sedimentation that occurs in harbor waters occurs around bridges and piers with the highest concentration. In the long term, high sediment concentrations will disrupt port activities, so there must be further research on solutions for high sediment concentrations in Pota Harbor waters.

4. Conclusions

From the results of this study, it can be concluded that the tidal type in the waters of the Port of Pota is Mixed Tidal Sloping to Double Daily. The dominant direction of port waters tends to be parallel to the shoreline, or it can be said that the currents that occur in these waters are tidal currents. In the waters in the POTA port, sediment agitation occurs at the shore, which is then transported by currents and settles as the current velocity decreases due to shallower depths. Based on the results of sample testing, its show that the highest sediment content is at low tide. Based on the simulation results of sediment levels for 24 days, there was an increase in the concentration at the Port of Pota by 0.94 kg/m^3. The difference between the sample test results and the simulation results for the highest sediment content in Mike21 is 0.93 kg/m3. This port can be said to still be suitable for operation, namely at depth standards and operational standards in the national community port class in Indonesia. The recommendation in this research activity is to continue to monitor sedimentation and abrasion so that the port remains stable and there is no damage caused by the physical sea

Acknowledgements

Special gratitude is also extended to Politeknik Negeri Batam, for providing reliable advice in writing this article from both academic and industrial perspectives.

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