Sediment Distribution Model at Mesjid River Estuary in The Rupat Strait, Riau Province, Indonesia

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Abstract. The sediment transport model showing the sediment derived from the Mesjid River will be distributed to the Rupat Strait with different dispersion distances and concentrations depend on the tidal current pattern. The highest concentration of suspended sediment (0.0001 kg/m³ - 0.0013 kg/m³) can be found at a distance of 3.3 km from the Mesjid River Estuary toward the Rupat Strait. Meanwhile, at a distance of 3.5 km from the estuary, the concentration have returned to normal or there is no longer any sediment derived from the Mesjid River. However, at a distance of 2.8 km to 3.3 km, or at the coordinates 101,372 - 101,376 North Latitude and 1,744 to 1,750 East Longitude, sediment deposition occurs with concentrations ranging from 0.00027 kg/m³ to 0.00035 kg/m. Based on satellite images taken on August 2, 2006 and satellite images on January 5, 2020, sedimentation in the area has resulted in accretion with an area of ± 30,454 m².

1. Introduction
The Rupat Strait, is separated from Malacca Strait by Rupat Island, located at the eastern coast of Sumatera Island, Riau Province, Indonesia. The strait is elongated and has northward, southward-openings with a length of about 88 kms from north to south and a width of about 8 kms. The outlets are leading to Malacca Strait [1, 2]. The strait is a semi-the region and by double-tidal mixed coupling type [3, 4].

The abrasion and sedimentation cuase shoreline change at the strait which is influenced by the current system flowing from the Malacca Strait, and by landuse change of the hinterland. During flood tide, the current from the Malacca Strait flows into the Rupat Strait through the north and east parts of the Rupat Strait while at ebb tide the current from the Rupat Strait flows into the Strait of Malacca through the north and east of the Rupat Strait [5].

Total sediment supply from inland Dumai City and Rupat Island to the Rupat Strait through river streams and artificial canals as large as 4,999,312-7,013,002 ton/year [6]. This condition leads to high sedimentation and sandbar formation at the estuary of the rivers, as reported by [1]. They clarify that total sediments supplied by the river was of 926 ton/day hence the sediment deposited into the estuary area was 0.024 m/year.

The Mesjid River Estuary is located in the eastern coast of central Sumatera Island, Riau Province, Indonesia. The estuary is connected to Malacca Strait by the Rupat Strait. The Rupat Strait is characterized by high sedimentation rates due to sediment discharged by current system and rivers [7]. One of the rivers is Mesjid River which has rather large drainage area flow into the strait through the estuary. The drainage area has been rapidly developed and became the center of community residents, industries, and of agriculture. Consequently, the river receives sediments from erosion of the drainage area as shown by high concentration of suspended sediment [1].

The Mesjid River Estuary receives lithogeneic sediments mainly from the Mesjid River’s drainage areas which play important role on the formation of sandbar which is shown by a belt-like area (0.5-1.0 m depth) in the Area off the river mouth. The sandbar might become a sandbank in 20 to 40 years later. High suspended sediment up to 354.61 mg/l indicates the river mouth receives lithogeneic sediments. Total of 926 ton/day of the sediments supplied by the river are deposited 0.024 m/year into the area, [1].

Since three decades ago, the Mesjid River Estuary and its environs have become one of the most intensively studied area in relation to water quality, marine biology, and marine sediments.
Significant studies in ecological and oceanographical aspects of the estuary and its environs have been carried out by [1, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24]. However, there is no any study concerning to the model sediment distribution.

2. Materials and methods

The area studied is restricted to the Mesjid River Estuary and its surrounding area in the Rupat Strait, located within the lines of 01°43'5.99''N and 01°43'31.58''N Lat. and 101°23'8.33''E and 101°23'26.20''E Long. (Figure 1). The area studied has a rather flat bottom topography and is influenced by water masses from the Mesjid River and Malacca Strait by tidal currents and anthropogenic activities, and the bottom topography gets gradually deeper northeastwards. The river with rather large drainage areas, flows into estuary of the area [1].

![Figure 1. Index map of the study area](image)

This study was conducted in the Rupat Strait from July 2017 to August 2020 to verify all research data from the previous period if necessary, where the Rupat Strait waters were used as the location for observation and sampling. These data include surface distribution, suspended sediment, sediment supply from various sources and oceanographic parameters. Furthermore, to design modeling required software (software) associated with these data.

The satellite data processed in this study consisted of 22 years of data recording with the P127/R59 study area, using Landsat Level 1 imagery consisting of Landsat 5 Thematic Mapper (TM) recorded in 1997 (4 January 1997), and Landsat 8 Landsat Data Continuity Mission. (LDCM) in 2017 (April 2019). Analysis and interpretation of the data model consists of: creating a mesh boundary, time series and point series. Area boundaries are made based on the area of the study area by entering coastline data and water bathymetry data.

Furthermore, the time series is the result of tidal elevation predictions which are saved in dfs0 format to create ocean currents models, while the point series is the result of a processed model that displays tidal data, current velocity and current direction used to verify the model with measurement data field. The current hydrodynamic modeling was made using MIKE 21 fm software.

Data obtained from observations and measurements such as water quality parameters and coastal slope are presented in tabular form, while shoreline changes, ocean flow modeling, surface sediment distribution and suspension are presented in the form of two-dimensional (2D) maps, both of which are then discussed descriptively. Data of hydrodynamic pattern is also used based on result [5] to determine sediment Distribution Model at the Mesjid River Estuary.

The formula of the model is a two-dimensional system with mean depth where the concentration in the vertical direction is assumed to be uniform. The Mud Transport (MT) module is an application for sediment transport using clay or clay as a base material. The Mud Transport (MT) module is devoted to non-cohesive modeling. The basic equation for Mud Transport (MT) is expressed in the two-dimensional transport equation based on the convection-diffusion equation, namely:
3. Results and discussion

3.1. Tidal

The tidal prediction data obtained in the waters of the Mesjid River Estuary were processed using the Admiralty method. According to [25], observation data of the tidal for 15 days or 30 days can be used for tidal forecasting using the Admiralty method. The results can be seen in Table 1 and Figure 2.

Table 1. Tidal harmonic components

| Component | Amplitude | Phase Difference |
|-----------|-----------|------------------|
| So        | 123.27    | MSL              |
| M2        | 88.53     | -185.09          |
| S2        | 26.30     | 2.73             |
| N2        | 40.46     | -79.94           |
| K2        | 6.05      | 2.73             |
| K1        | 10.24     | 326.82           |
| O1        | 14.43     | -71.14           |
| P1        | 3.38      | 326.82           |
| M4        | 5.31      | -443.20          |
| MS4       | 7.26      | -192.58          |

Figure 2. Tidal graph of the Mesjid River Estuary

Based on the tide chart in Figure 2, it can be seen that the tides that occur in the Rupat Strait occur twice and ebb tide for 24 hours at different heights. The highest tide is in the Rupat Strait at 1.26 metres, while the lowest is -1.37 metres. The type of tide in strait obtained the Formzhal Number value of 0.215, namely double daily, where there were two times the tide and two times the ebb.

Field data verification needs to be done in a numerical modeling so that we can know the extent of the deviation from the simulation results that have been carried out. A model can be considered to be valid if the results of the simulation have a pattern that is consistent with field data. In this model
the tide data will be verified with field data from direct field measurements. Verification is done by comparing the tide elevation data from Deshidros with the observation data at the tidal station observed in the field, as shown in Figure 3 and 4.

![Figure 3. Result of validation of tidal data](image1.png)

![Figure 4. Scatter plot graph of water level of model results and observations](image2.png)

3.2. Tidal flow pattern simulation

The simulation of this model is the current pattern in the Rupat Strait which influenced by the difference in water level in the open boundary found on the outside of the strait area. The process of vertical and periodic rise and fall of the water level will produce a force to generate a current pattern. The simulation of this current pattern model is carried out during high tide and low tide conditions.

The simulation results are presented in vector and velocity contours. The results of hydrodynamic modeling of tidal currents in the Rupat Strait can be seen in Figures 5 and 6. Based on the simulation
results of the hydrodynamic model, it is known that the current direction conditions in Rupat Strait waters move back and forth in tidal and low tide conditions. From the simulation results, the model also shows that the tidal flow velocity in the Rupat Strait ranges from 0.06 - 0.84 metres/second during high tide and 0.04 - 0.60 metres/second at low tide. The tidal flow velocity in the Rupat Strait ranges from 0.2 - 0.45 metres/second and of in the Dumai River Estuary which is located close to Mesjid River Estuary range from 0.04 - 0.33 metres/second [26].

The current pattern is also influenced by the depth of the water where shallower waters will cause a higher elevation thus creating a higher current velocity than deep water. [27] explained that tidal currents in strait waters are influenced by water depth conditions and affect the distribution of bottom sediments. [28] inform that changes in bathymetric conditions cause changes in sea level elevation and affect tidal flow velocity and changes in coastal sediment transport capacity.

3.3. Distribution of Suspended Sediments
Current patterns that occur at high tide and at low tide will provide a suspended sediment distribution pattern in the Rupat Strait. At high tide, the transported sediment tends to be towards the Northwest, while at low tide the distribution of suspended sediment will lead to the Southeast following the current movement pattern. According to [29], the grain size distribution pattern with the type of silt and silty sand incate the relationship between water currents and the distribution of sediment distribution. Distribution of suspended sediments at tidal can be seen in Figure 7 and 8.
Sediment transport model simulations show that the sediment derived from the Mesjid River will be distributed to the Rupat Strait with different dispersion distances and concentrations. This sediment distribution pattern tends to follow the tidal current movement pattern that occurs in the Rupat Strait.

The highest of suspended sediment concentration was distributed in the Rupat Strait from the mouth of the Mesjid River as far as ± 3.3 km, the concentration ranges between 0.0001 kg/m³ - 0.0013 kg/m³. Meanwhile, at a distance of 3.5 km from the mouth of the river, the concentration have returned to normal or there is no longer any sediment derived from the Mesjid River. However, at a distance of 2.8 km to 3.3 km or at the coordinates 101,372 - 101,376 North Latitude and 1,744 to 1,750 East Longitude, sediment deposition occurs with concentrations ranging from 0.00027 kg/m³ to 0.00035 kg/m³.

Based on satellite images taken on August 2, 2006 and satellite images on January 5, 2020, sedimentation in the area has resulted in accretion with an area of ± 30,454 m². The images can seen in Figure 9 and 10.
Figure 9. Sediment deposition derived from Mesjid River

Figure 10. The satellite images showing accretion

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