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# CHARACTERISTICS OF TIDES, WAVES, AND BATHYMETRY IN THE WATERS OF BAYUR BAY PADANG CITY, WEST SUMATRA

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## ABSTRACT

This study aims to examine the characteristics of tides, waves, and bathymetry in Bayur Bay, Padang City, West Sumatra. Data collection was conducted in October 2024 through a survey method that included tidal observations for 15 days, wave measurements at three stations for 3 days, and measurements of water quality parameters (temperature, salinity, and brightness). Secondary data were obtained from ECMWF and GEBCO and analyzed using Surfer 13 and ArcGIS. The analysis results show that the tides are of a mixed type, leaning towards double daily with a Formzahl value of 0.51. Wave heights vary between 0.15 and 0.6 m, and validation with ECMWF data yields low RMSE values (0.1263-0.2983), indicating the suitability of the model and field data. The bathymetry of Bayur Bay ranges from 0 to 45 m, with the seabed dominated by fine sand. This information is important as a basis for coastal zone management, shipping, and maritime infrastructure development.

**Keywords:** Tides, Waves, Bathymetry, Bayur Bay, Coastal Oceanography

## 1. INTRODUCTION

A bay is a body of water that juts into the land and serves as a center for various economic, social, and ecological activities[1]. However, increased use of bay areas often causes environmental problems such as mangrove damage, erosion, and sedimentation. Sedimentation that can disrupt the balance of coastal ecosystems[2,3]. Sedimentation in port areas, for example, can reduce water depth and hinder loading and unloading activities due to ship grounding. This condition underscores the need for understanding water dynamics in bay areas to support safe and sustainable maritime activities.

Teluk Bayur, located on the coast of Padang City, West Sumatra, faces the Indian Ocean and is an important center of activity in the region. This area not only serves as a port for trade and transportation, but also as a center for fishing, tourism, and various industrial activities, including Pertamina and coal ships[4]. The high intensity of activities in Teluk Bayur has the potential to put pressure on the coastal environment, requiring monitoring and scientific studies to minimize adverse impacts across ecological, social, and economic domains.

In this context, physical oceanography plays an important role in providing basic information on water dynamics. Physical oceanography studies the physical properties and processes of the sea, including tides, waves, and bathymetry, which can affect ship navigation, coastal engineering planning, coastal disaster mitigation, and marine resource management[5,6].

This study aims to examine the physical oceanographic characteristics of Bayur Bay by analyzing tides, waves, and bathymetry. This basic information is expected to serve as a reference for coastal zone management and support the sustainability of maritime activities in this region.

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## 2. RESEARCH METHOD

### Time and Place

The research location was in the waters of Bayur Bay. Data collection was carried out in October 2024. Data processing was carried out at the Physical Oceanography Laboratory, Faculty of Fisheries and Marine Sciences, Universitas Riau.


**Figure 1.** Research location map

### Method

The method used in this study was a survey, with data collected from both primary and secondary sources. Primary data were collected through direct field observation, including survey activities and measurements at the research site. Meanwhile, secondary data were used to supplement the primary data obtained.

### Procedures

### Determination of Research Location

The research location was determined through direct field surveys in Teluk Bayur. Station I is located in waters near the port (Teluk Bayur Port, PELINDO); Station 2 is located in natural waters; and Station 3 is located in a tourist area (Taman Nirwana).

### Data Collection

Data collection in this study consisted of primary data. Obtained through direct measurements in the field, including waves, tides, and water quality parameters, such as temperature, salinity, and brightness. Secondary data were collected from various sources, including historical wave and bathymetry (depth) data. This secondary data is used for validation and comparison with field data, particularly for wave measurements.

### Data Processing

Processing is carried out both manually and using software, depending on the type of data being analyzed. Tidal, wave, and bathymetric data are processed using different approaches according to their characteristics. Tidal data analysis was performed using the Admiralty method[7]. To determine the tidal type, the formzahl value must be known, using the following formula:

$$F = \frac{O1 + k1}{m2 + S2}$$

Description:

| | | |
|---|---|---|
| O1 | : | Amplitude of the primary tidal component caused by the gravitational pull of the moon |
| K1 | : | Amplitude of the primary single tidal component caused by the gravitational pull of the sun |
| M2 | : | Amplitude of the primary double tidal component caused by the gravitational pull of the moon |
| S2 | : | Amplitude of the primary double tidal component caused by the gravitational pull of the sun |

### Field Wave Data Processing

Wave measurements in the field produce wave height data (Hs), which is calculated through the following data-processing stages[8].

$$HS = \frac{H1 + H2 + \ldots + Hn}{n}$$

Description:

| | | |
|---|---|---|
| N | : | 33,3% x number of Hs |
| Hs | : | wave height (m) |
| H1..n | : | wave height to-1, 2, 3,…..n (m) |

### ECMWF Wave Data Processing

Wave data from ECMWF is retrieved as a time series, a sequence of values arranged in chronological order, enabling the retrieval of historical wave data for a specific period. Wave data is obtained by downloading it directly from the European Centre for Medium-Range Weather Forecasts (ECMWF) website.

**Bathymetry**

The bathymetry data processing begins by downloading bathymetry data for Bayur Bay waters from GEBCO. After the download is complete, the next step is to calculate the sea depth using this data. The software used in this processing is Microsoft Excel and Surfer 13. Microsoft Excel is used to perform tidal reduction calculations and determine sea depth. Meanwhile, Surfer 13 is used to display Bathymetric data in three-dimensional (3D) form.

## 3. RESULT AND DISCUSSION

Hilly contours and relatively calm waters surround the Bayur Bay area. The seabed substrate in these waters generally consists of sand and coral reefs, which support coastal ecosystems and navigation. Several important areas border the waters of Bayur Bay: Padang Barat District to the north, Bungus Bay and Karsik Bay to the south, Lubuk Begalung District to the east, and the Indian Ocean to the west. The Bayur Bay area has intensive, dynamic land use, especially along the coast. The dominant activities in this region include shipping, logistics, loading and unloading, and the presence of ships anchored.

The waters of Bayur Bay make it an area with a relatively high level of anthropogenic disturbance. This condition causes changes in the physical characteristics of the water, such as altered local current directions, sediment accumulation in the port area, and potential changes in the seabed contour resulting from dredging and reclamation activities.

Based on the results of tidal harmonic constants, the formzahl value obtained is 0.51. This value indicates that the type of tide in the waters of Teluk Bayur is classified as a mixed tide prevailing semidiurnal, in accordance with the range 0.25 < F ≤ 1.5. This type is characterized by two high tides and two low tides in a day, but with different heights and periods[9].

**Table 1.** Tidal harmonic constants of Bayur Bay waters

| | So | M2 | S2 | N2 | K2 | K1 | O1 | P1 | M4 | MS4 |
|---|---|---|---|---|---|---|---|---|---|---|
| A (cm) | 70,66 | 30,0 | 23,3 | 5,4 | 7,9 | 17,3 | 9,9 | 9,6 | 0,10 | 0,11 |
| g° | | 212,2 | 105,6 | 336,3 | 258,4 | 186,2 | 2,95 | 300,2 | 113,7 | 67,2 |

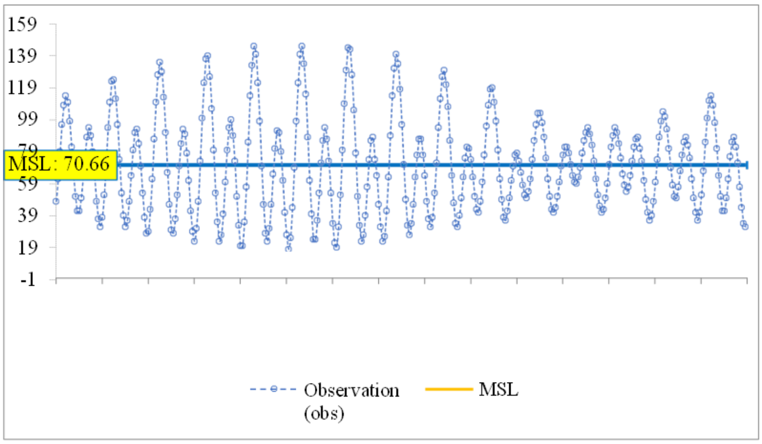


**Figure 1.** Tidal harmonic

Harmonic constant analysis shows that the dominant components originate from semidiurnal tides (M2= 30 cm and S2 = 23.3 cm), which are larger than the diurnal components (K1 = 17.3 cm and O1 = 9.9 cm). This pattern is similar to the results of tidal studies in the western Indian Ocean region of Indonesia, where semidiurnal tides are more dominant[10].

This finding is important because the type of tidal action will affect various aspects of activity in coastal areas. The dominance of semidiurnal tides with sufficient amplitude has implications for port activity planning, particularly for ship loading and unloading and for determining sailing times. During maximum ebb conditions, areas with shallow depths are prone to grounding, requiring extra caution during navigation. In addition, this tidal pattern is closely related to sediment transport, which can trigger silting in port areas and coastal waters. Thus, understanding harmonic constants not only serves an academic purpose but also offers practical benefits for water management.

The analysis results show that the mean sea level (MSL) in Bayur Bay is 70.66 cm. The highest tide (HHWL) reaches 145 cm, while the lowest tide (LLWL) is only 18 cm. The average height at high tide (MHWL) was recorded at 122.93 cm, while the average low tide (MLWL) was 29.67 cm. These values indicate that the maximum tidal range reaches 127 cm, which can affect current distribution and navigation planning in the port area[11]. In this study, wave height analysis was conducted to compare direct field measurements with ECMWF secondary data. This comparison aims to assess the suitability of wave patterns between observation results and reanalysis model data, thereby providing an overview of the accuracy and consistency of both data sources[12,14].

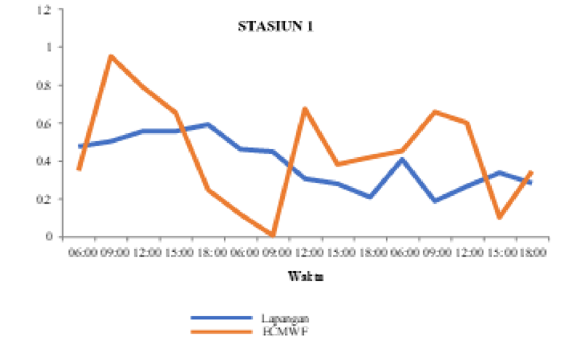


**Figure 2.** Wave height graph station 1

The comparison graph shows the comparison of wave heights from field measurements and ECMWF data at Station 1 during the observation period from 06:00 to 18:00. In general, the graph shows that wave heights from ECMWF data have sharper fluctuations compared to field measurements, which tend to be more stable in the range of 0.3-0.6 m. ECMWF data recorded the highest wave peak of approximately 1 m at 09:00, while field data showed lower variations, with the highest value in the range of 0.6 m.

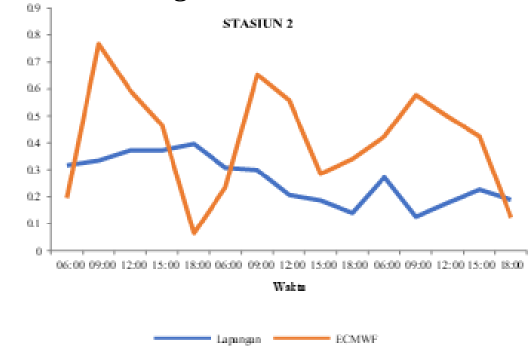


**Figure 3.** Wave height graph station 2

The comparison graph shows the comparison of wave heights between field measurements and ECMWF data at Station 2 during the observation period from 06:00 to 18:00. In general, the ECMWF data pattern shows more dynamic wave fluctuations with a range of values reaching 0.1-0.8 m, while field data tends to be more stable in the range of 0.2-0.4 meters. The highest wave peak based on ECMWF occurred around 09:00, with a height of nearly 0.78 m, while field measurements showed lower variations, with the highest value around 0.4 m.

Bayur Bay is a semi-enclosed bay facing directly onto the Indian Ocean, so its wave patterns are influenced by both local winds and swells from the open sea. Based on field measurements, the average wave height in Bayur Bay is only about 0.14-0.27 m at high tide and 0.14-0.22 m at low tide[15].

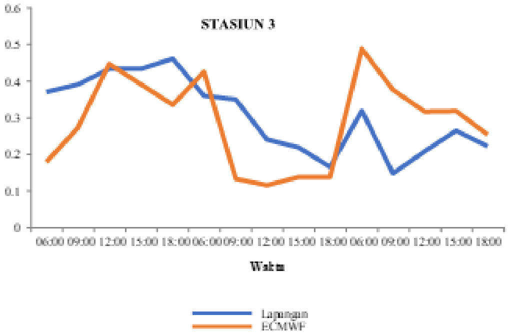


**Figure 4.** Wave height graph station 3

Figure 4 compares wave heights between field measurements and ECMWF data at Station 3 during the observation period 06.00-18:00. Field data ranged from 0.15 to 0.47 m with a relatively stable pattern, while ECMWF data was slightly more fluctuating with peaks approaching 0.5 m. The results of this processing are visualized as a two-dimensional (2D) contour map, a three-dimensional (3D) model, and cross-section profiles, as shown in Figure 5.

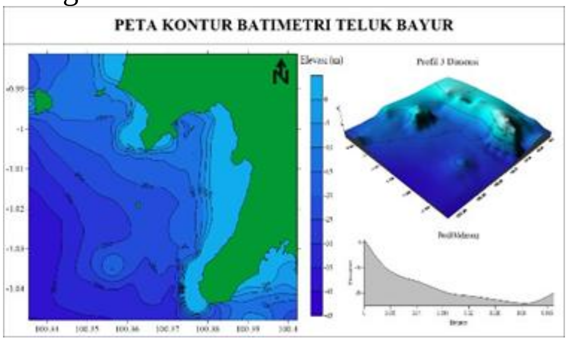


**Figure 5.** Bayur Bay

Bayur Bay is a basin that juts into the mainland and is bordered on several sides, so its waters are relatively protected from open-sea waves15. The bathymetric contour map of Bayur Bay (based on GEBCO data, visualized with Surfer 13) shows a striking depth variation between the shallow coastal part of the bay and the much deeper central part near the mouth. Based on research by Pisyam et al.[16], the depth of Bayur Bay generally ranges from about 2 m near the coast to more than 100 m in the deepest area near the mouth of the bay. Field measurement data and satellite imagery show that the maximum depth in Bayur Bay reaches approximately 125-128 m at the outer part of the bay, while in the harbor basin and surrounding areas, the depth is relatively shallow, only about 2-11 m. This illustrates the shape of the bay's base, which slopes at the edges and steepens towards the open sea, creating a kind of basin or bowl.

The basic structure of the Bayur Bay seabed generally consists of loose sedimentary materials such as fine sand and mud. The results of sidescan sonar image classification in the port area show that the seabed substrate can be divided into several sediment classes, including sandy silt, silty sand, fine sand, and coarse sand. The dominance of fine-grained material indicates that Bayur Bay is a low-energy environment, allowing fine particles to settle more easily on the seabed. In the inner part of the bay, the seabed tends to be flat and covered with soft sediments, indicating active sedimentation. Conversely, in the deeper outer part of the bay, the seabed may consist of more rigid material or coarse sand due to the influence of stronger ocean currents.

## 4. CONCLUSION

Based on the research results, the following conclusions can be drawn. The results of the analysis using the Admiralty method show that the tidal type in Bayur Bay is a mixed semidiurnal tide with a Formzahl (F) value of 0.51. The sea level elevation values include MSL of 70.66 cm, HHWL of 145 cm, LLWL of 18 cm, MHWL of 122.93 cm, and MLWL of 29.67 cm. Wave heights in Bayur Bay vary between 0.15 and 0.6 m at three observation stations. Field data shows that Station 1 (port) has waves of 0.3–0.6 m, Station 2 (natural waters) 0.2–0.4 m, and Station 3 (tourist area) 0.15–0.47 m. Validation against ECMWF data produced small RMSE values (0.2937 at Station 1, 0.2640 at Station 2, and 0.1263 at Station 3), indicating that the ECMWF model is sufficiently accurate in modeling wave conditions in this region.

Analysis of bathymetric data from GEBCO shows that the depth of Bayur Bay ranges from 0 to 45 m, with contours that become deeper towards the southwest. The seabed morphology is dominated by fine-grained sediments, including fine sand and silt, indicating a low-energy environment and potential sedimentation in Bayur Bay.

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