

Characteristics of Waters during Transitional Season, Senimba Waters

Muhammad Zainuddin Lubis^{1,*}, Ganda Surya¹,
Daniel Sutopo Pamungkas², Beginer Subhan³, Henry M Manik³,
Husnul Kausarian⁴ and Wenang Anurogo¹

¹Geomatics Engineering, Politeknik Negeri Batam, Batam 29461, Indonesia

²Electrical Engineering, Politeknik Negeri Batam, Batam 29461, Indonesia

³Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), 16680 Bogor, Indonesia

⁴Engineering Geology Program, Faculty of Engineering, Universitas Islam Riau, Senapela, Kota Pekanbaru, Riau, Indonesia

(*Corresponding author's e-mail: zainuddinlubis@polibatam.ac.id)

Received: 29 July 2020, Revised: 10 August 2021, Accepted: 29 August 2021

Abstract

Characteristics of Waters During Transitional Season, Senimba Bay, Batam Indonesia. Senimba Bay is a water area in Batam City. It is necessary to develop the waters of Senimba Bay due to its location around the bay, which is still not arranged. Development such as changes in sea transportation lines and structuring the bay area requires Hidro-oceanography data, such as current data, waves, tides, and bathymetry. The research discusses the Gulf of Senimba waters' characteristics in the transition season, namely in April-May. The primary data taken is current data, bathymetry, waves, tides, and secondary data is wind data from ECMWF. Retrieval of current and wave data using ADCP (Acoustic Doppler Current Profiler) with several layers of depth. The method used for tides is Least-Square. Flow in the transition season in the Gulf of Senimba waters has a southwest direction during the high tide and northeast when low tides with mixed tides are double inclines, and the direction of the wind blows dominant towards the northeast. These waters have a minimum depth of -12.60 m Mean Sea Level (MSL) and maximum value -0.03 m MSL with current modeling. It produces no significant changes and only occurs in the direction of current in specific locations because location bathymetry factors influence it.

Keywords: Senimba bay, Oceanography, ECMWF, ADCP, Least-square

Introduction

Senimba Bay is one of the bays in the city of Batam with a very high level of bay use activity. This bay has long been utilized as a shipyard industrial area. The bay area's industrial growth rate is relatively fast due to the strategic location of the bay, very close to the Singapore Strait. This bay is used not only for shipyard industry activities but also used by the surrounding community as their daily livelihood, ranging from fishing for fish, installing cages, and many others. In the Senimba Bay area, there are also international ports, with majors Indonesia-Singapore and Indonesia-Malaysia.

The Transitional Season, which runs between March-May, is characterized by wind, unstable rainfall. This also affects the surrounding waters, but offshore winds this season are likely to cause shallow tongues to move west along the bottom of the waters in the South China Sea. This seawater mass is expected to be closer to Malaysian coastal waters compared to during the southwest season. So the Riau Archipelago waters experience water mass changes twice a year [1].

Water characteristics from the biological aspect; in this case, the phytoplankton community is essential to know as a basis for determining water management because, in the area, many farms use water [2]. Ocean currents are the transfer of water masses from one place to another, caused by various factors such as pressure gradients, gusts of wind, differences in density, or tides. In general, the characteristics of ocean currents in Indonesian waters are affected by winds and waves [3,4]. An understanding of water conditions is essential as analysis reduces the negative impacts that occur in planning the development of coastal and marine areas [5]. Flow is one component of oceanography. Flow

measurement is one of the 1st steps to monitoring water conditions. The pattern of the current movement in the broad scope of the study is to take field data and use a mathematical approach [6,7].

Modeling natural conditions is another alternative that is cheaper and easier to obtain a picture of the distribution that occurs in the present and predictions in the future [8,9]. Indonesian territory is affected by monsoon wind patterns and varying seasons. Wind also acts as a wave energy generator in the ocean [10]. The height and period of the waves are influenced by the speed of the wind, the fetch (the trajectory the wind passes), and the wind blowing [11]. Waves from the sea will carry materials causing sedimentation in the coastal area, while waves can also carry stuff from the coast to other areas causing erosion [12,13].

Ocean currents are the displacement of water masses from one place to another, caused by various factors such as pressure gradients, gusts of wind, differences in density, and tides. In general, the characteristics of ocean currents in Indonesian waters are affected by winds and tides [3]. This requires research on the waters' characteristics to find out more about the state of Senimba Bay, Batam. Factors that influence these characteristics are Flow, Bathymetry, Tides. This also relates to being able to see how the tides in the bay, so that it can be seen tides in the dominant Senimba bay area to the Daily Double, Single, or Mixed Double. All supporting parameter data obtained from this study are data for the parameters for making hydrodynamic numerical modeling using MOHID software.

Materials and methods

Research location and time

This research activity was carried out in Senimba Bay, Batam City, Riau Islands, with the coordinates of the research location 103° 55' 17,677" East longitude and 1° 5' 56,710" North latitude (**Figure 1**). Data collection was performed with an extensive 573,44 Ha out of date April 16, 2018, until May 1, 2018, the duration of time is very short because the location of this research is in a reservoir, and 3 days of measurement is representative of taking water level determination (15 Piantan).

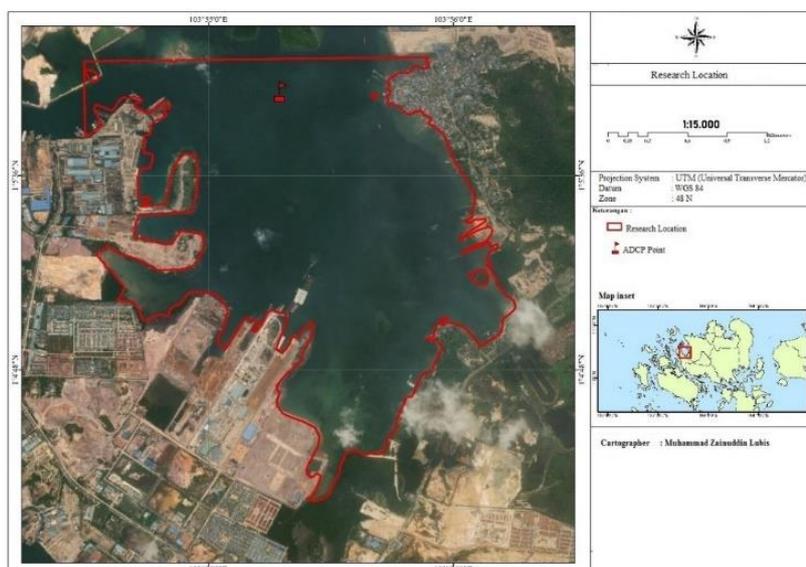


Figure 1 Research location map.

Data acquisition technique

In this study, the data needed is Bathymetry, Current Speed of each layer, Wind, Tides, and Waves. Wind data are obtained from the ECMWF (European Center for Medium-Range Weather Forecasts), which is a European meteorological body that provides wind data globally. The data uses a grid system with a size of 1.5°×1.5°.

Seawater movements or currents are measured by the Euler Method, carried out by lowering the ADCP (Acoustic Doppler Current Profiler) gauge installed on the survey ship. This tool can measure the direction and speed of movement of water flow continuously. In addition to static analysis, dynamic sea

current analysis is also carried out by preparing a hydrodynamic model of ocean currents to wind and tides. The current pattern model was built using the model in MOHID - Water Modelling System (<http://www.mohid.com>), the modeling generated by the MOHID Model software is an object-oriented integrated numerical program (Integrated Object-Oriented Model). has been also applied to ocean waters such as in seamounts [14]. Tidal measurements begin with the determination of benchmarks or points of measure. Tidal measurements using tidal palm for 15 days at 1-hour intervals. Analysis for 15 days with the consideration that there has been a full moon (one tidal cycle). The recording water level is done manually every hour.

Data from tidal recording results in the field, then the tidal harmonic analysis is performed using the Admiralty method so that the tidal harmonic constants are obtained, M_2 , S_2 , K_2 , N_2 , K_1 , O_1 , P_1 and Q_1 . Tidal harmonic constants can calculate the faces of MSL (Mean Sea Level), HHWL (Higher High Water Level), and LLWL (Lowest Low Water Level) using Eq. (1). The tidal harmonics constant is also obtained by the Formzahl (F) number.

$$F = \frac{O_1 + K_1}{M_2 + S_2} \quad (1)$$

Where:

- F : Formzahl number
- O_1 : the amplitude of the leading single tidal component caused by the full force of the moon,
- K_1 : the amplitude of the leading single tidal component caused by the pull of the moon and the sun,
- M_2 : amplitude of major double tidal components caused by the tensile force of the moon, and
- S_2 : amplitude of the leading double tidal component caused by the tensile force of the sun

Based on the F value, tidal types can be grouped as follows;

- $F < 0.25$: double tidal type
- $0.26 < F < 1.50$: ups and downs of double inclined mixture type
- $1.51 < F < 3.00$: ups and downs of a single-type skewed mixture
- $F > 3.00$: single tides

Tidal data processing so that it becomes a tidal harmonic component using the least square method. The Least Squares method is a harmonic analysis method that decomposes tidal waves into several tidal harmonic components where the water level caused by tidal waves is the result of the sum of the components of the tidal generating force.

Bathymetry data collection using a single beam echosounder Garmin GPS 585 echosounder. The instrument has a single beam transmitter used to determine the position of the public company and elevation depth. ADCP instrument current data collection scheme can be seen in **Figure 2**. The bathymetry assessment model is obtained from the interpolation results of the height measurement points before the datum graph has corrected the bathymetry data with the formula:

$$(D = d - r) \quad (2)$$

Measurements using Argonaut-XR type Multi-Cell ADCP equipment. In measurements with ADCP at a depth of 6.0 m LWS, the current speed is measured at 5 depth points (d), i.e. at a depth of 0.0 - 1.0, 1.0 - 2.0, 2.0 - 3.0, 3.0 - 4.0 and 4.0 - 5.0 m. The measurement of current speed is carried out for 15×24 h with data recording intervals per 10 min (**Figure 3**). This measurement must be concurrent with tidal measurements so that the depth of the waters when the velocity measurements can be known.

Tidal Value Measurement uses the Least-Square method. This method is a solution to the many pairs of components. In this method, the meteorological factor is ignored by the results of the Least Square method, because the components of the tide can be which can be determined by the tidal type through the calculation of Formzahl values. The direction of the meteorological wind is the direction from which the wind rises. Wind direction increases 0°, east wind 90°, southern wind 180°, and the west wind is 270° because trigonometry uses a polar coordinate system in which 0° along the x-axis.

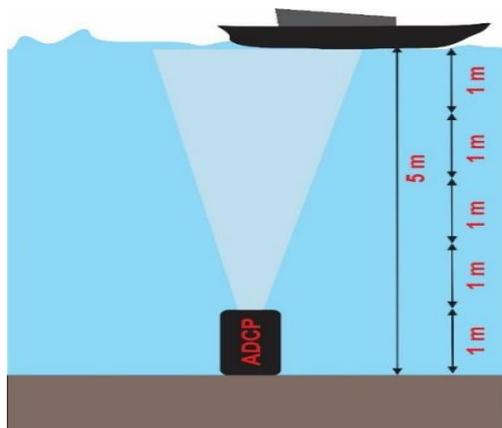


Figure 2 ADCP current data collection scheme.

Results and discussion

Analysis of speed and direction of ADCP data

The results in this study indicate that although the location of the ADCP station is almost outside the bay, this can also be influenced by; 1) the effect of tides on the current, 2) The pattern of current velocity and direction of the current is almost the same as the tidal conditions of the seawater, this is influenced by the rise and fall of sea level, 3) The value of the dominant current velocity is higher when it is at the highest peak of sea level compared to when it is at the lowest position of the face seawater, 4) At a depth of 0 - 1 m, the direction of the dominant current is unstable because of influences such as ship activity, waves, etc.

Based on the results of the ADCP station current data processing, the current velocity varies with the average speed in all water columns ranging from 11.5 - 13.5 cm/s, minimum current speed of 0.0 - 0.1 cm/s, and the maximum current speed of 35.5 - 48.9 cm/s. The velocity graph is the result of recording from the ADCP instrument, which gets a value with data on 3 variables, namely Velocity, Direction, and Tide at the location of the ADCP announcement point. The largest current velocity at an average depth is 36.7 cm / s, with an average speed of 11.5 cm/s. The largest current velocity at a depth of 4.0 - 5.0 m (Cell 1) is 36.3 cm/s, with an average speed of 11.7 cm/s (Figure 4). The largest current velocity at a depth of 3.0 - 4.0 m (Cell 2) is 35.5 cm/s, with an average speed of 11.3 cm/s (Figure 5). The largest current velocity at a depth of 2.0 - 3.0 m (Cell 3) is 37.8 cm/s, with an average speed of 11.8 cm/s (Figure 6). The largest current velocity at depths of 1.0 - 2.0 m (Cell 4) is 36.8 cm/s, with an average speed of 12.3 cm/s (Figure 7). The largest current velocity at a depth of 0.0 - 1.0 m (Cell 5) is 48.9 cm / s with an average speed of 13.5 cm/s (Figure 8), the movement of the current at high tide is western power, and current movement at low tide is northeast.

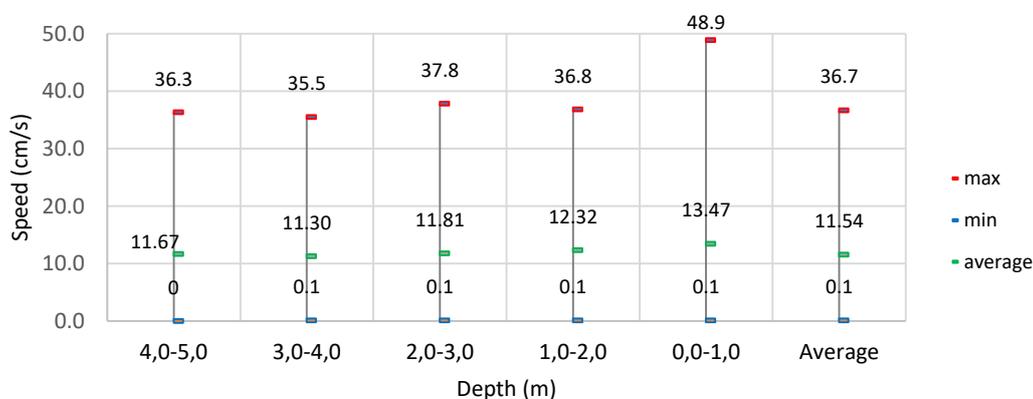


Figure 3 Current velocity graph for each depth from ADCP instrument data recording.

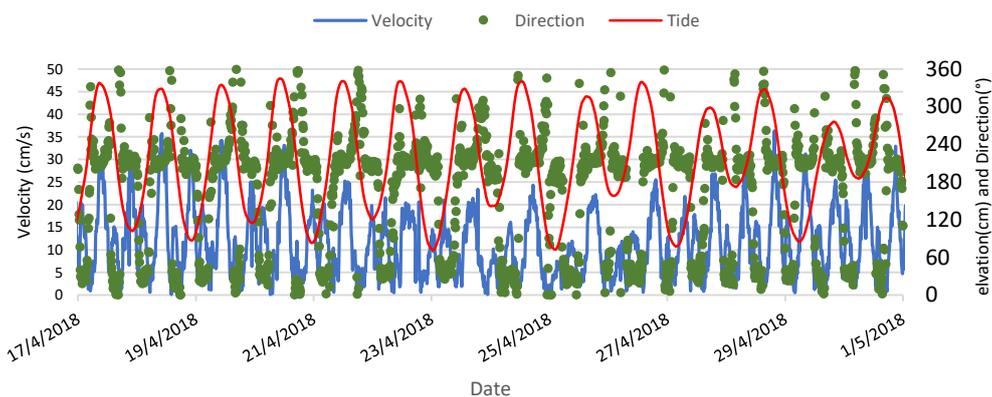


Figure 4 Flow velocity graph with tidal cell 1 (4 - 5 m) from ADCP instrument data recording.

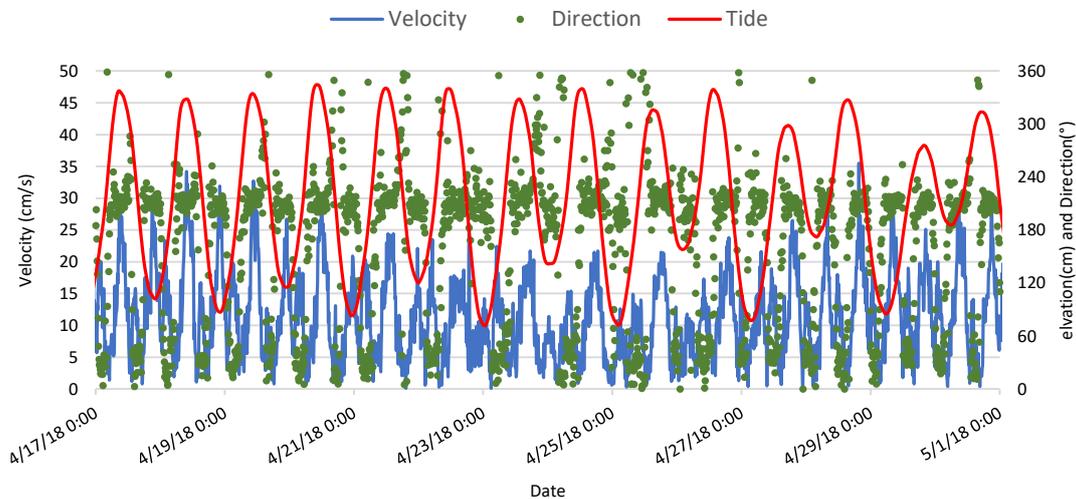


Figure 5 Flow velocity graph with tidal cell 2 (3 - 4 m).

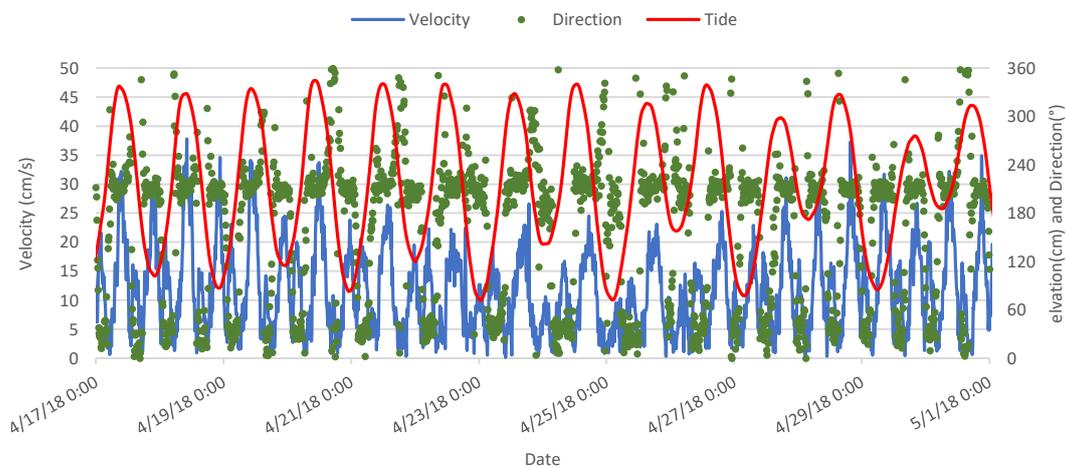


Figure 6 Flow velocity graph with tidal cell 3 (2 - 3 m) from ADCP instrument data recording.

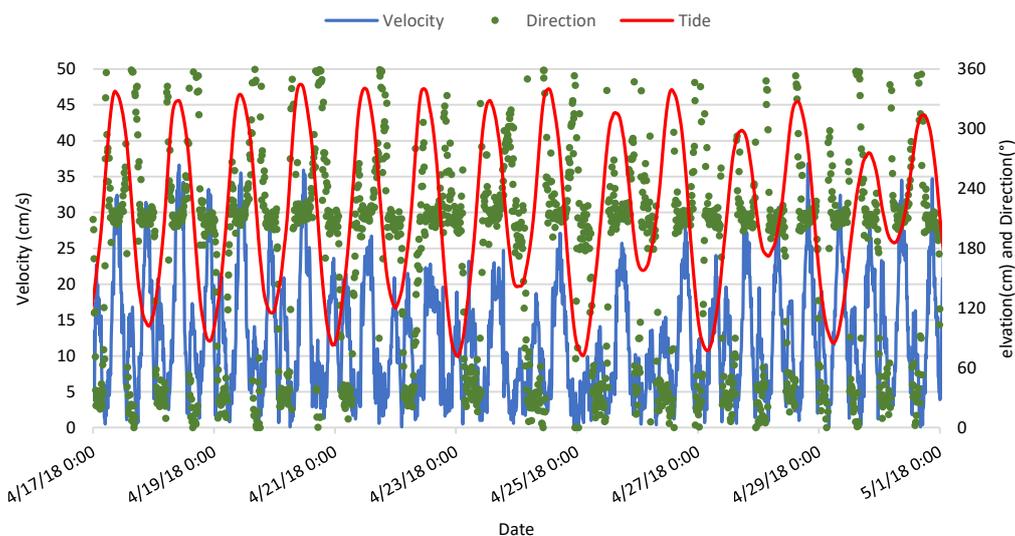


Figure 7 Flow velocity graph with tidal cell 4 (1 - 2 m) from ADCP instrument data recording.

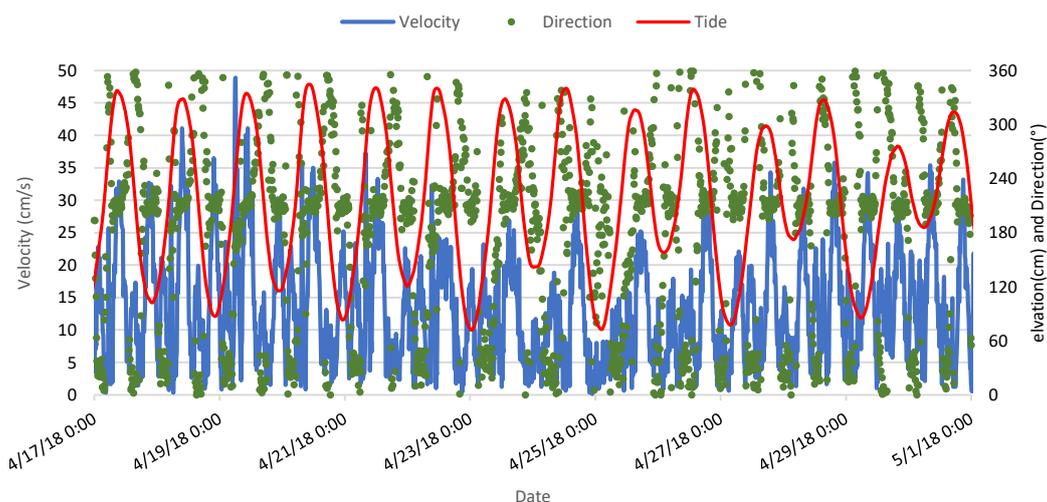


Figure 8 Flow velocity graph with tidal cell 5 (0 - 1 m) from ADCP instrument data recording.

Wave height, period and tidal

In addition to current characteristics, the monsoon wind will also affect the wave characteristics in the waters. These waves are formed due to wind friction on the wind's surface, and energy transfer occurs [15]. The components of water needed analysis of these waves between the west and east seasons. One important parameter to consider is the significant wave height (Hs) in both seasons [16]. Significant wave height graphs in the waters of the Senimba Bay can be seen in **Figures 9 and 10**.

Based on the results of data processing height and a wave period of the ADCP station presented in **Figure 2**, the figure of daily wave height from April 16, 2018, to May 1, 2018, can be seen on **Figures 9 and 10**. It can be concluded several things, including:

- a. The maximum wave height that occurs is 17.0 cm, with a maximum period of 6.3 s.
- b. The average wave height is 7.9 cm, with an average period of 3.4 s.
- c. The minimum wave height is 1.6 cm, with a minimum period of 1.7 s.

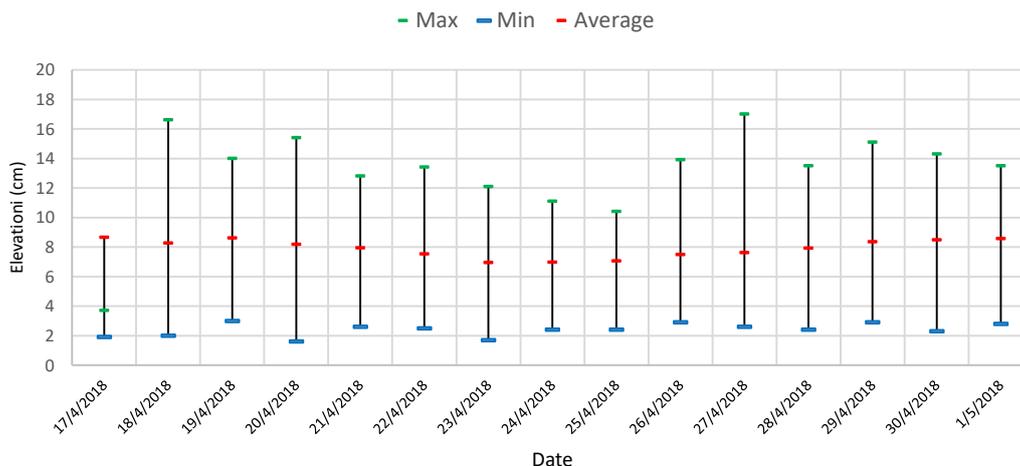


Figure 9 Daily wave height from 16 April 2018 to 1 May 2018.

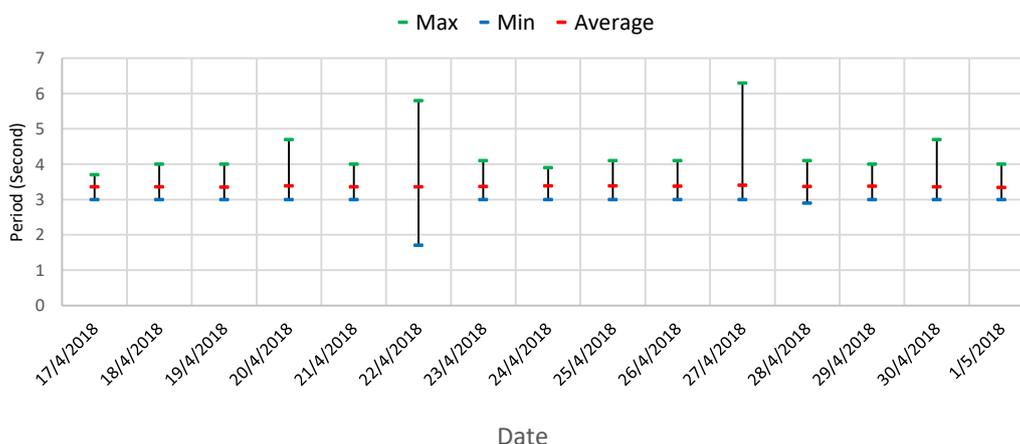


Figure 10 Daily wave period from 16 April 2018 to 1 May 2018.

December-January-February (DJF) [17]. When the east monsoon, the wind moves from the Asian Continent to the Australian Continent. Contrary to the eastern monsoon, the west monsoon will move from the Australian Continent to the Asian Continent [18]. The influence of this monsoon wind will also affect Bangka's waters mainly because of its location, which lies between the Natuna Sea and the Java Sea, a monsoon wind flow area [19]. These results are similar to studies conducted by [20] shows tidal results with the same island. The tidal range value is 330 cm. Other studies conducted at the same island location, namely Batam island, conducted in Nongsa waters by [13] show a tidal range of 200 cm with the same tidal type.

Based on the analysis of tidal observational data, the types of tides in the Senimba waters are obtained, Batam is a mixed tide for tides, wherein one day there are 2 pairs and 2 pairs with different heights. Based on tidal observational data, the tidal range is 367.53 cm (Figure 11), and tidal constants from observation data (Tidal Component) can be seen on Table 1. The number of components resulting from processing the harmonic tidal data has 10 components by processing the data using the least square method. The mean sea level of the tidal ruler is 212.29 cm against the tidal ruler. Based on the binding of tidal observational data to BM-049, obtained important values from water level to 0 MSL are as follows.

Benchmark-049	: +206.01 cm
HWL	: +155.53 cm
LWL	: -212.00 cm

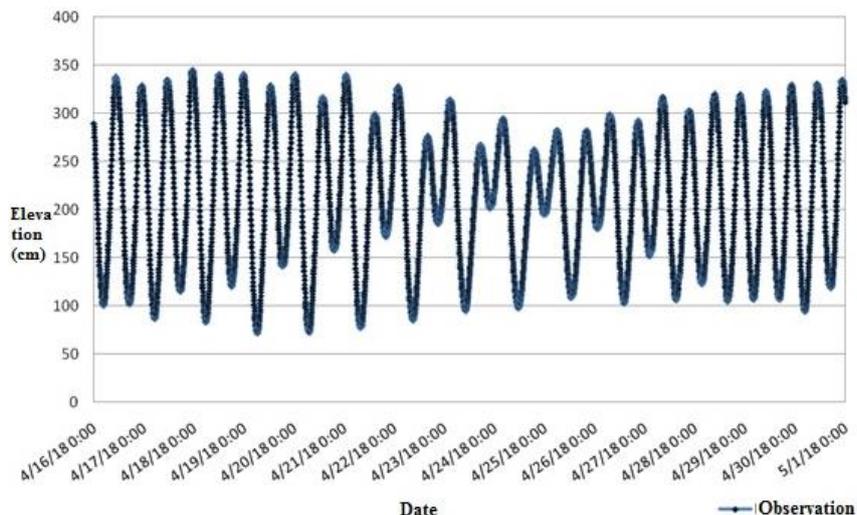


Figure 11 Tides measurement on April 16, 2018, until April 30, 2018.

Table 1 Tidal constants from observation data.

Constants	A (cm)	(°)/h
Z0	212.00	0
M2	77.79	17.49
S2	34.054	335.16
N2	17.71	121.81
K1	47.38	342.61
O1	30.35	180.14
M4	2.468	30.00
MS4	3.099	10.093
K2	9.20	21.379
P1	26.97	164.56

- F : 0.69
- Type : Tidal mixture inclined to double daily
- LLWL : -13.76 cm
- HHWL : 371.14 cm
- MSL : 212.00 cm
- HWL : 367.54 cm
- LWL : -13.58 cm

Bathymetry and flow model

Based on the analysis of bathymetry scoring data, the waters of the location have a minimum depth of -12.60 m MSL. At the same time, the maximum depth is -0.03 m MSL. The depth of the Senimba Bay area has a depth ranging from -8 to -12 m from the results of the data analysis. Marina beach area has a depth ranging from -5 to -6 m. Waters less than -3 m deep are located in the eastern, western, and southern regions of the bathymetry area. Contour and 3D map of bathymetry results in Senimba Bay, Batam City, Riau Islands can be seen in Figure 12.

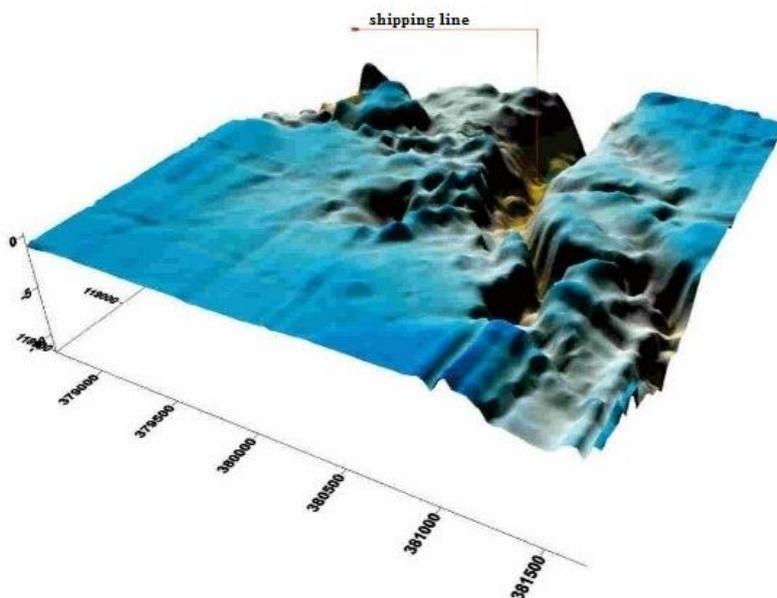
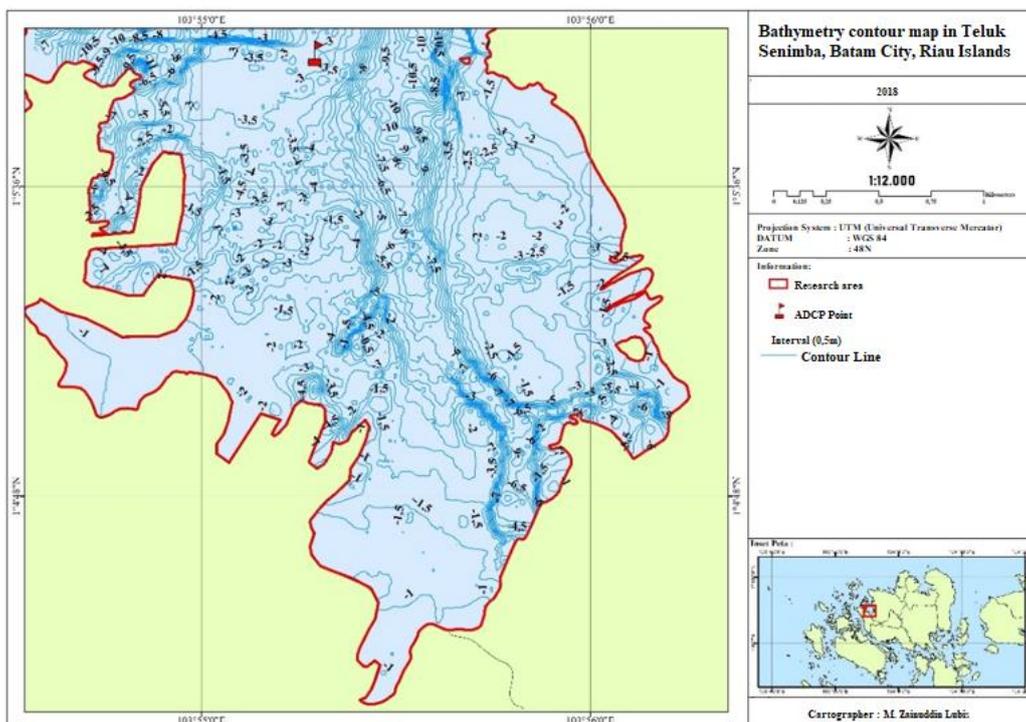


Figure 12 Contour and 3D map of bathymetry results in Senimba Bay.

Based on the results of modeling the ebb flow towards the Senimba Bay tide in the existing conditions, the results obtained that the current velocity in the Senimba Bay inlet area ranges from 0.04 to 0.56 m/s. the current speed in the Senimba Bay ranges from 0.04 to 0.28 m/s (**Figure 13**), and for the results of the modeling of the tidal current speed toward low tide, the range of current velocity values at the location is 0 –0.45 m/s (**Figure 14**). This clearly shows the results that the current velocity value which has a greater value is when the condition is tidal current speed toward low tide. The current movement at low tide toward the tide is dominated towards the northeast direction. The research conducted showed different things with research conducted by [21], where the research resulted in the value of the maximum current velocity in the strait when the tide reached 0.32 m/s, while the average speed in the model area was 0.12 m/s.

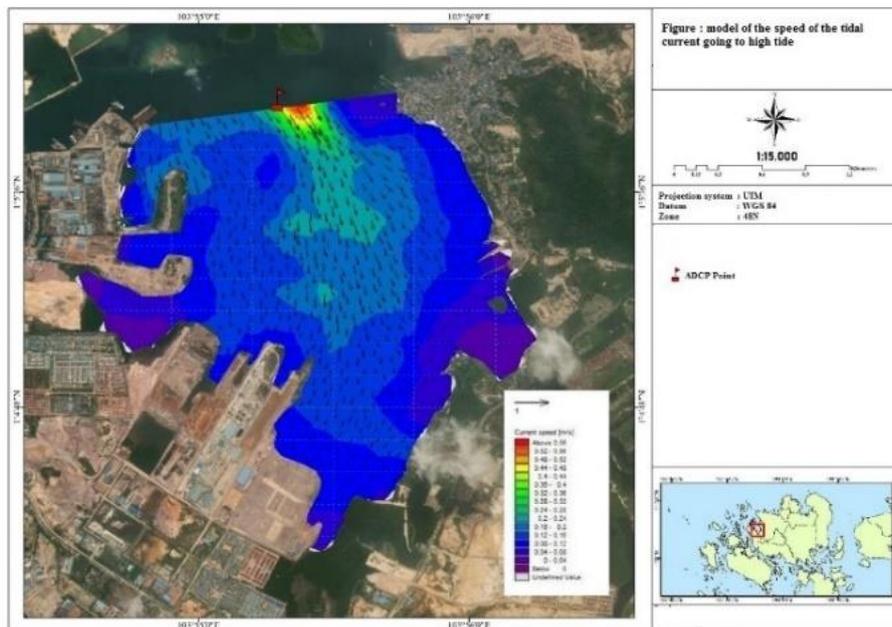


Figure 13 Model of the tidal current speed to the tide.

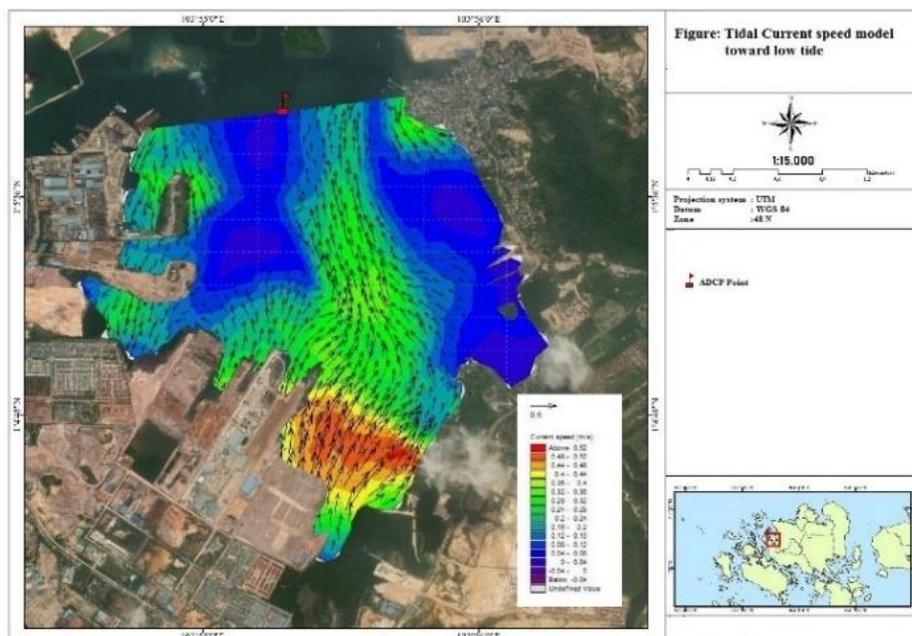


Figure 14 Model of the tidal current speed toward low tide.

Conclusions

The current character of the waters of the Gulf of Senimba is relative. Currents at high tide toward the Southwest and for Tides Towards Northeast with a double inclined mixed tidal type. The depth of Senimba Bay waters has a minimum value of -12.60 m MSL. At the same time, the maximum value is -0.03 m MSL. Senimba Bay wind conditions have a dominant direction to the Northeast with a frequency of 16.50 %, with a dominant wind speed of > 0 - 5 m/s with a 51.71 % frequency. The maximum wind speed is > 10 - 15 m/s, with a rate of occurrence of 0.35 %. The results of current modeling in the Gulf of Senimba's waters explained that there was no significant change in the speed of the present and only a difference in the direction of the current at specific locations.

Acknowledgements

We would like to thank Politeknik Negeri Batam, because they have provided facilities and funds in conducting this research.

References

- [1] H Thoha. Pengaruh musim terhadap plankton di perairan Riau Kepulauan dan sekitarnya. *Makara J. Sci.* 2003; **7**, 59-70.
- [2] IW Abida. Struktur komunitas dan kelimpahan fitoplankton di perairan muara sungai porong sidoarjo. jurnal kelautan. *Indones. J. Sci. Technol.* 2010; **3**, 36-40.
- [3] Al Tanto, T Wisna, UJ Kusumah, G Pranowo, WS Husrin, SI Ilham and A Putra. Karakteristik arus laut perairan teluk benoa-bali. *Jurnal Ilmiah Geomatika* 2017; **23**, 37-48.
- [4] M Syahdan, AS Atmadipoera, SB Susilo and JL Gaol. Variability of surface chlorophyll-A in the Makassar Strait-Java Sea, Indonesia. *Int. J. Sci. Basic Appl. Res.* 2014; **14**, 103-16.
- [5] UJ Wisna, S Husrin and J Prihantono. Hydrodynamics banten bay during transitional seasons (august-september) (hidrodinamika perairan teluk banten pada musim peralihan. *Indonesian J. Mar. Sci.* 2015; **20**, 101-12.
- [6] X Zhang and JA Church. Sea level trends, interannual and decadal variability in the Pacific Ocean. *Geophys. Res. Lett.* 2012; **39**.
- [7] A Atmadipoera, R Molcard, G Madec, S Wijffels, J Sprintall. A Koch-Larrouy and A Supangat. Characteristics and variability of the Indonesian throughflow water at the outflow straits. *Deep-Sea Res. I: Oceanogr. Res. Pap.* 2009; **56**, 1942-54.
- [8] SM Maxwell, EL Hazen, RL Lewison, DC Dunn, H Bailey, SJ Bograd and S Benson. Dynamic ocean management: Defining and conceptualizing real-time management of the ocean. *Mar. Policy* 2015; **58**, 42-50.
- [9] M Zhang and HV Storch. Toward downscaling oceanic hydrodynamics-suitability of a high-resolution OGCM for describing regional ocean variability in the South China Sea. *Oceanologia.* 2017; **59**, 166-76.
- [10] A Koch-Larrouy, G Madec and D Iudicone, A Atmadipoera and R Molcard. Physical processes contributing to the water mass transformation of the Indonesian throughflow. *Ocean Dyn.* 2008; **58**, 275-88.
- [11] M Li, AL Gordon, J Wei, LK Gruenburg, G Jiang. Multi-decadal timeseries of the Indonesian throughflow. *Dyn. Atmospheres Oceans.* 2018; **81**, 84-95.
- [12] MZ Lubis and U Amri. Beach profile (oceanography factors) of Labuhan Bilik Island, Aruah Island, Rokan Hilir District, Indonesia. *In: Proceedings of the International Conference on Applied Engineering, Batam, Indonesia.* 2018, p. 1-6.
- [13] MZ Lubis and AP Daya. Pemetaan parameter oseanografi fisik menggunakan citra landsat 8 di wilayah perairan nongsa pulau batam. *J. Integrasi.* 2017; **9**, 9-15.
- [14] H Coelho and R Santos. Enhanced primary production over seamounts: A numerical study. *Thalassas* 2003; **19**, 144-5.
- [15] VS Kumar, CS Philip and TB Nair. Waves in shallow water off west coast of India during the onset of summer monsoon. *Ann. Geophys.* 2010; **28**, 817-24.
- [16] H Jiang and G Chen. A global view on the swell and wind sea climate by the Jason-1 mission: A revisit. *J. Atmos. Ocean. Technol.* 2013; **30**, 1833-41.
- [17] ZX Wei, GH Fang, RD Susanto, TR Adi, B Fan, A Setiawan and XM Gao. Tidal elevation, current and energy flux in the area between the South China Sea and Java Sea. *Ocean Sci. Discuss.* 2015; **12**, 517-31.
- [18] A Pamungkas. Karakteristik parameter oseanografi (pasang-surut, arus, dan gelombang) di Perairan Utara dan Selatan Pulau Bangka. *Buletin Oseanografi Marina* 2018; **7**, 51-8.
- [19] A Pamungkas and MA Farhaby. Hydro-oceanography modelling characteristic (tides, waves, and currents) in Kelabat Bay, Bangka Belitung. *In: Proceedings of the International Conference on Maritime and Archipelago, Bangka Belitung, Indonesia.* 2018, p. 401.
- [20] MZ Lubis, W Anurogo, MA Mufida, H Taki, SM Antoni and RA Lubis. Physical condition of the ocean to global climate change variability: Case study in the Batam waters, Indonesia. *In: Proceedings of the International Conference on Applied Engineering, Batam, Indonesia.* 2018, p. 1-4.
- [21] A Riyadi and M Santos. Kondisi oseanografi di selat matak kabupaten kepulauan anambas melalui model hidrodinamika. *Ilmu kelautan: Indonesian J. Mar. Sci.* 2014; **20**, 101-12.