HYDRODYNAMIC MODEL OF TIDAL CURRENTS IN THE GREEN MUSSEL CULTIVATION AREA (*Perna viridis*) WATERS OF BREBES REGENCY

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Abstract

Brebes Regency has waters that are directly connected to the Java Sea and are strongly influenced by external factors, such as monsoon winds. Hydrodynamic conditions greatly affect the processes that occur in coastal and marine waters. Tidal hydrodynamic studies can be carried out by direct measurements or using remote sensing technology. Current occurs due to the displacement of water masses caused by differences in water density, differences in pressure and generating force. Current patterns and characteristics include the dominant type of current, the direction of the current, and the speed of the current. Current is one of the components of oceanography, modeling current is one of the first steps to monitor the characteristics of a body of water. Modeling hydrodynamic currents uses a numerical approach using continuity and momentum equations. The model results are analyzed to determine the current pattern by field measurements as an accuracy test process using *scatter* plots and the RMSE method. The result of modeled hydrodynamic currents are obtained to obtain tidal current patterns in each season. The average pattern current moves from East to West. The configuration of the scatter plot on the model has no results that have similarities with field results due to differences in mesh size, the use of inappropriate measuring instruments, and weather in the field. The RMSE accuracy test values show values of 0.0126; 0.0046; and 0.0753 which means the current velocity value of the model with field has valid results. The highest current speed in the western season is 0.084m/s, the transitional season I is 0.05m/s, the eastern season is 0.062m/s, and in the transitional season II is 0.043m/s.

Keywords: Hydrodynamic Model; Brebes; Oceanography; Validation; Tidal Current.

1. Introduction

1. The problem intended to be solved,

Renewable marine resources and fisheries are strong candidates for alternative energy sources in coastal areas and the importance of environmental mapping is an important step for the development of the region [50]. Coastal Areas are environments rich in biological and non-biological resources. The coastal environment is usually used for residential, aquaculture, agricultural, and tourism activities. High-intensity utilization and lack of public awareness in conservation will produce negative impacts on physical and social conditions that will affect the vulnerability of the region [51]. Brebes Regency is located on the north coast of Java and is a shallow waters, this happens because the Brebes area is an *alluvial* plain due to several large and small river activities that emptied in the water area [52]. The Brebes area is directly adjacent to the sea area which has a ±72.93 km of coastal length and has a very high potential for the surrounding community, such as productive food sources, mineral sources, shipping lanes, and recreational areas for coastal communities. The coast of Brebes Regency has the characteristics of sandy, muddy beaches and mangroves. In addition, Brebes Waters are open waters that are directly connected to the Java Sea so that they are influenced by external conditions such as wind, seasons [53].

A water condition is influenced by hydro-oceanographic factors such as waves, ocean currents, wind, and tides. Current occurs due to the displacement of water masses caused by differences in water density, pressure differences, and other generating forces such as long waves and wind. Current patterns and characteristics include the dominant type of current, velocity, and direction [54]. The hydrodynamic condition of a body of water is influenced by several factors, including coastal morphology, water depth, river *run-off* to the effects of air masses blowing over the sea. The tides that occur in coastal waters also cause large tidal currents compared to those in the open seas. The existence of tidal phenomena will bring changes to the conditions of concentration of suspended sediments in a water [55]. The study of tidal hydrodynamics in a water can be carried out through various methods including direct measurements in the field or through remote sensing. Remote sensing technology such as using numerical model applications is one of the other ways that can be taken, the data needed is sufficient for validation purposes, so that field surveys are enough to be carried out in just a few days as material for field validation of models for prediction [56].

Climate change can cause changes in wind direction, speed, air pressure patterns and rainfall patterns that cause floods and droughts [57]. Increased coastal activity and development of surrounding urban centers can trigger coastal imbalances and land subsidence events [58]. Hydrodynamic conditions are one of the aspects that greatly affect the processes that occur in coastal and marine waters. The distribution of sediments, pollutants, and biotic communities in a water will largely depend on hydrodynamic conditions [55]. The coastal area of Brebes Regency is a very dynamic area and has complex problems, because the water area is influenced by several natural factors such as ocean currents, coastal sedimentation, coastal erosion, and sea level rise [59]. According to [60] The sedimentation rate in the Brebes region has an average of 0.211 cm / year which indicates that the condition of water movement as a sediment transport medium is very volatile. In recent years the sedimentation rate in the region has increased due to deformation of current patterns due to changes in basic morphology that only appear at low tide conditions (*betting*).

Current is one of the components of oceanography, modeling current is one of the first steps in monitoring the condition of the characteristics of a body of water. The pattern of current movement in a wide scope of study is by taking field data and using a numerical (mathematical) approach. Based on this, it is necessary to conduct studies to model and find out the pattern of tidal currents in Brebes waters with the aim of comparing the accuracy value of the current model results in the *hydrodynamic module* with *the results in situ* and identifying current patterns that occur in each season during 2022.

2. Materials and Methods

2.1 Research Location

The research location is in Grinting Village Waters, Brebes Regency located at 6°47'25.47"S - 6°50'5.30"S to 108°54'39.98"E - 108°59'13.14"E. Field observations will be carried out in March to July 2022 and the time to be modeled consists of four seasons, namely the western season (December 1, 2021 – February 28, 2022), transitional season I (March 1 – May 31, 2022), eastern season (June 1 – August 31, 2022) and transitional season II (September 1 – November 30, 2022). According to [51] Brebes waters belong to the category of shallow waters with slope topography and double daily inclined tidal type.

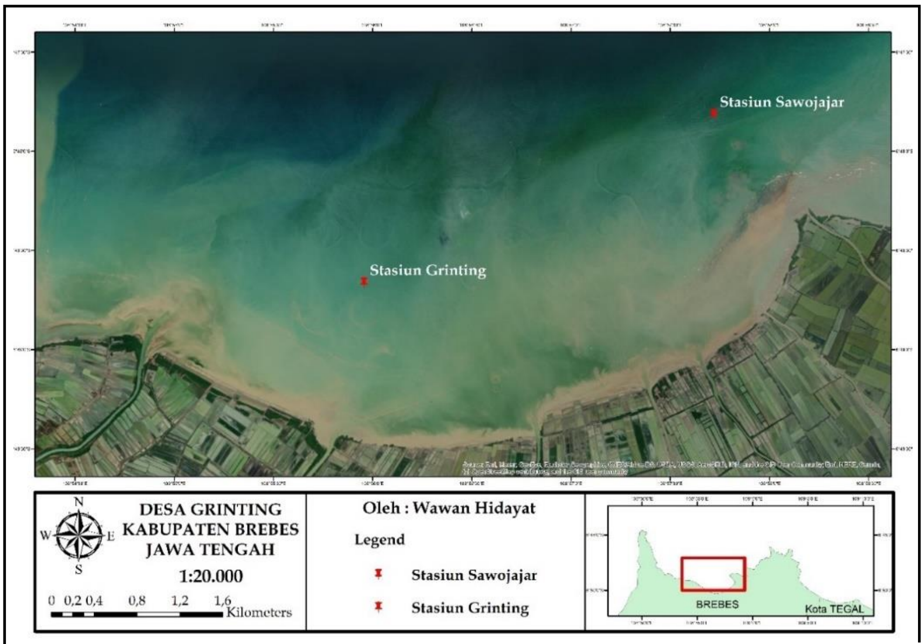

Figure 1. Research Location Map

2.2 Material and Method

The tools and materials used in this study were the Global Positioning System (GPS Garmin Etrex 10), Flowmeter Flowatch FL-03, Tide Gauge Waterproof Ultrasonic Module AJ-SR04M, Ocean Data View Software, Hydrodynamic Module, Google Earth Pro Software, Global Mapper, ArcGIS 10.4.1. The materials used are secondary and primary data, primary data is data on current velocity and current direction, secondary data in the form of tidal data from prediction results, bathymetric data from https://tanahair.indonesia.go.id/, and wind data from *the https://cds.climate.copernicus.eu.*

The method used is the observation method. This study uses primary and secondary data, primary data is used for model validation to be made by making direct observations in the field, while secondary data is needed to model tidal current hydrodynamic patterns. The method used in the research sampling is to use the *purposive sampling* method. This study used an oceanographic model approach with *hydrodynamic module* flow FM (*Flexible* Mesh) module. The use of the model in this study is more efficient with consideration of the cost and time required. This modeling is useful for describing tidal current patterns temporally and spatially. *Hydrodynamic Module* is used to make a hydrodynamic model of tidal current, the creation of the model uses two equations, namely the continuity equation and the momentum equation with the following formula

Continuity equation:

$$\frac{\partial h}{\partial t} + \frac{\partial h\bar{u}}{\partial x} + \frac{\partial h\tilde{v}}{\partial y} = 0$$

Momentum equation

- On the axis X

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial x} + \frac{gp\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] - \Omega_q$$

$$- fVV_x + \frac{h}{p_w}\frac{\partial}{\partial x}(\rho_a) = 0$$

- On the axis Y

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial y}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial y} + \frac{gp\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy}) + \frac{\partial}{\partial x}(h\tau_{xy})\right]$$

$$- \Omega_p - fVV_y + \frac{h}{p_w}\frac{\partial}{\partial y}(\rho_a) = 0$$

Each model of each season is carried out in 3 *stages of model settings*, namely *Preprocessing Model*, *Running Program*, and *Post Processing Model*. At this stage of *Preprocessing the Model* by creating a limit condition *of the model boundary*. The *Running Model* stage is to enter parameter values in the form of *mesh boundaries*, tidal data, wind data and bathymetric data into numerical calculations, time intervals, duration of the model, all adjusted to *trial and error*. The *Post Processing Model* stage is to display the results of the calculation and the results of visual processing to be verified and validated with the measurement result data in a field or *in situ*.

2.3 Analysis Data

Data analysis of hydrodynamic models each season will be carried out in a description and mathematical model approach through the *Hydrodynamic Module FM Model* for current pattern models. Then to describe the results of the current pattern model in each season is depicted with *the time step* of the model results, to see the results of the model pattern and the speed of the current in one year it will be taken during the full tides, bandage tides, highest tides, lowest ebbs, conditions towards the highest tides and towards the lowest ebbs. The current pattern of each season will be analyzed and the differences will be seen.

Validation of model results is carried out by comparing *the running* data of the model measurement results with the data of measurement results *in situ*. Validation is performed to find out how big the modelling error has been committed. The validation process is compared with the model result data using the *Root Mean Square Error* (RMSE) equation to find *the error* value can use the formula below:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}}$$

In addition to using *the Root Mean Square Error* (RMSE) equation in the validation process, this study used *Scatter plot* graphs for the validation process of secondary and primary current data. *Scatter plot* is a component of the chart present in regression analysis by connecting two varied factors on a continuum. In this study, the two varied factors that will be connected are the components U and V in the current resulting from *in situ* and secondary confinement.

3. Results and Discussion

3.1. Result

3.1.1 Hydrodynamics in Brebes Waters

Hydrodynamic conditions are a condition of a body of water that has important aspects in the processes that occur in coastal and marine waters. The spread of suspended sediments, pollutants, and biotic communities in a body of water will largely depend on the influence of hydrodynamic conditions. Currents have an important role in the spread of biotic components and pollutants in a body of water. The current speed that has been modeled will be compared with the results of field measurements to find out how much *error* value is in the model. The results of the comparison of *in situ* measurements with the results of the model are presented in the form of *the following scatter plot* using *mesh* sizes 15000, 20000, 25000 and 30000 with time intervals of 10, 30 and 60 minutes each size of the *mesh*. The comparison results are presented in Figure 1, Figure 2, Figure 3 and Figure 4.

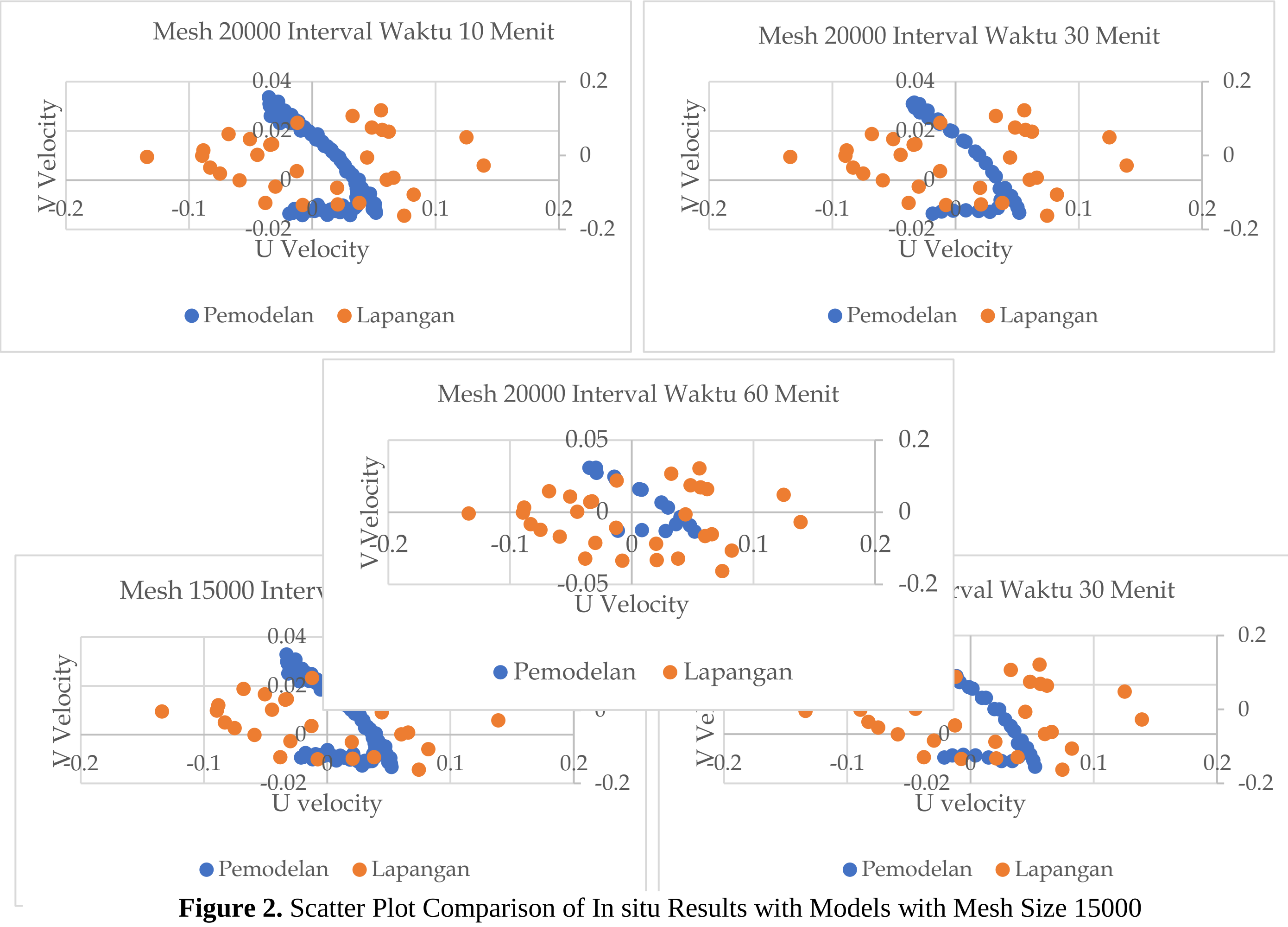

Figure 2. Scatter Plot Comparison of In situ Results with Models with Mesh Size 15000

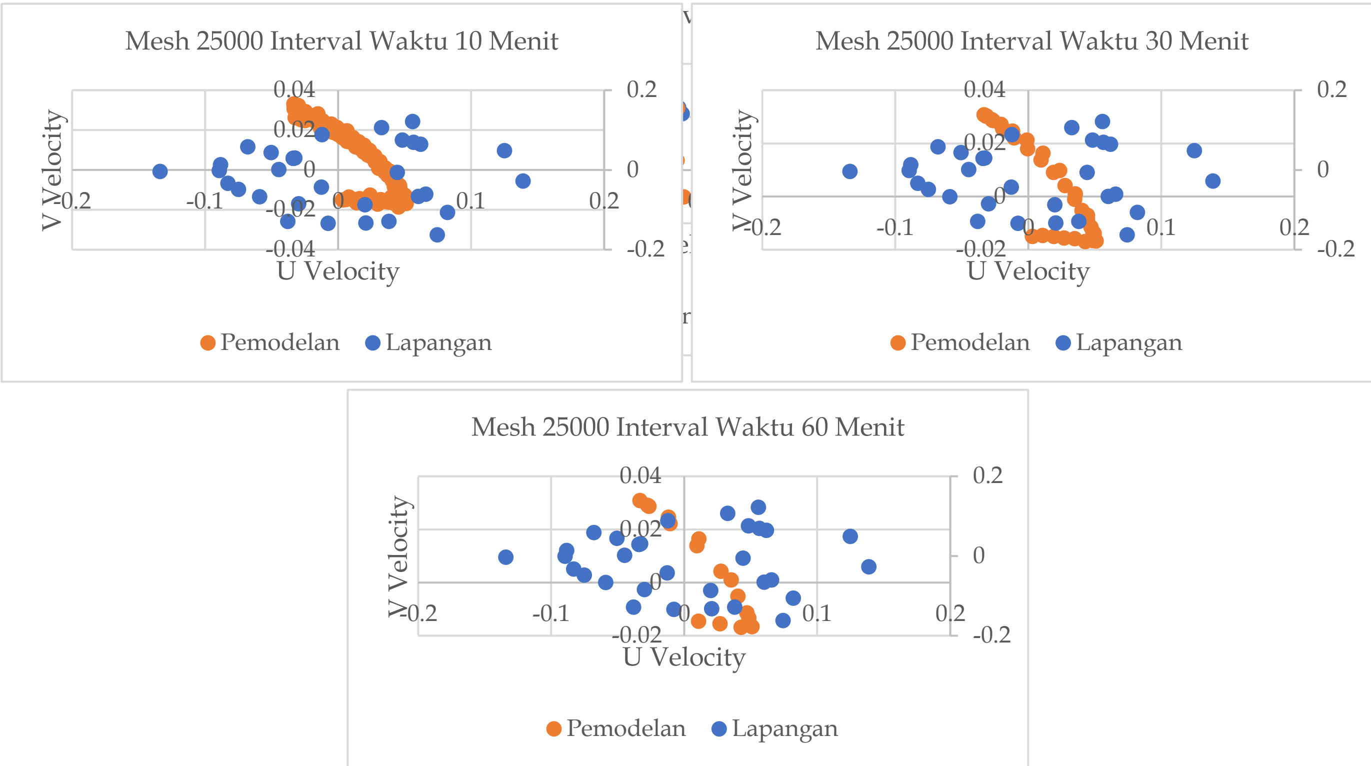

Figure 3. Scatter Plot Comparison of In situ Results with Models with Mesh Size 25000

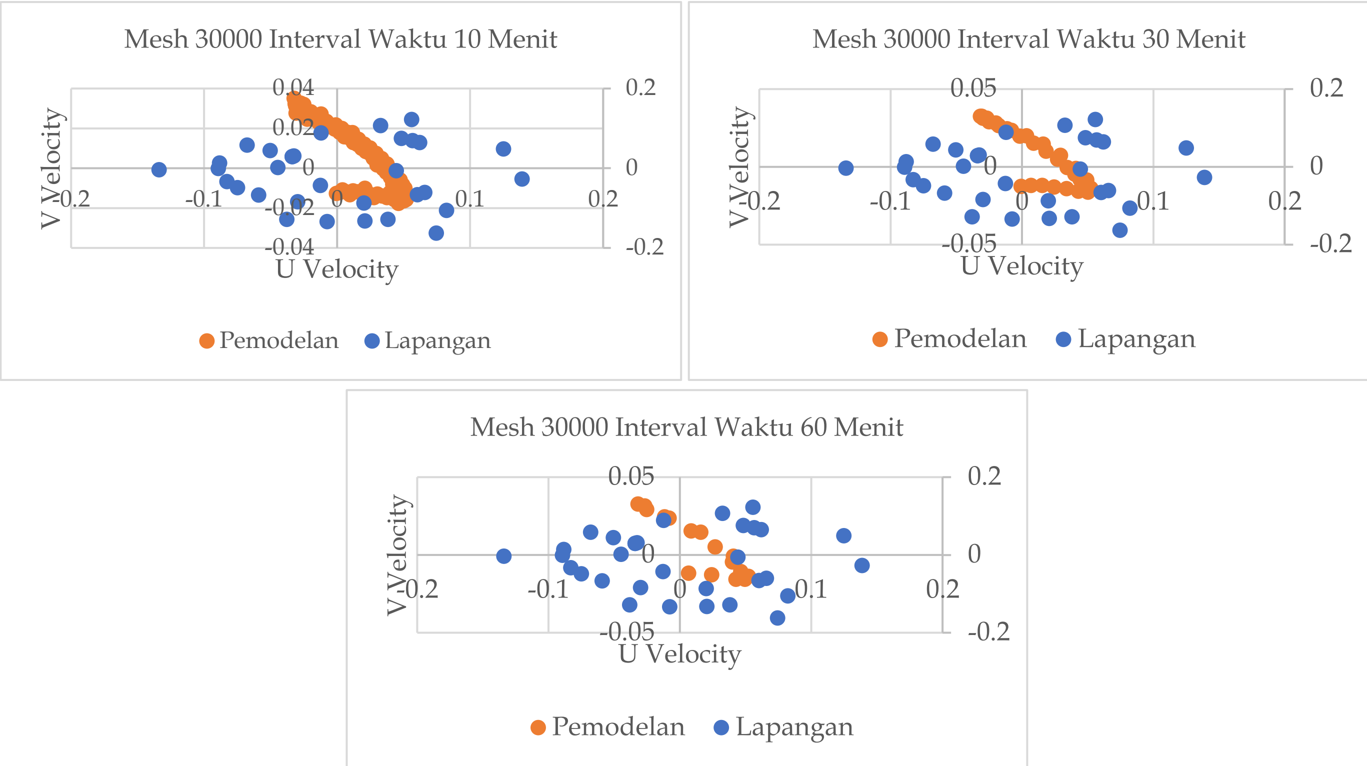

Figure 5. Scatter Plot Comparison of In situ Results with Models with Mesh Size 30000

Based on the *scatter plot* results used in the model simulation configuration above, there are no model results that have similarities with the measurement results *in situ*. This happens because the configuration used in the manufacture of *the mesh* does not have a good fit in the method of using *the mesh* and the size of the *mesh* used. The use of *mesh* and *mesh* size is an important job in the modeling process because it can affect the results of the model to be made. Then the specification of the tool used when measuring is not suitable for measuring ocean currents because of the lack of accuracy values, in addition to the influence of climatic conditions when measuring. Verification of current data was carried out on *in situ* measurement data on April 17, May 27, and June 25-26, 2022 with model flow data with hours and time intervals that have been adjusted to the time when measuring *in situ*. In addition to using *scatter plots* in the configuration, the results of the comparison of the speed of the modeling current with the field show the *Root Mean Square Error* (RMSE) values which can be seen in the following **Tabel.1**.

Table 1. *RMSE Value Comparison of Model Results with In situ Data*

Number	Month	RMSE Value
1.	April	0,0126
2.	May	0,0046
3.	June	0,0753

According to [61] made a model with the smallest RMSE result of 0.037 which occurred in March, where from the calculation it was found that the RMSE value < 1 and close to 0. So that it can be concluded that bring the results of the modeling carried out to get good and valid results.

3.1.2 Tidal Current Patterns in Brebes Waters

Simulation of tidal current hydrodynamic models was carried out using the *Hydrodynamic Module*. The results of tidal current modeling differ in tidal conditions at full moon and bandage, highest tide, lowest ebb, heading towards the tide, and towards ebb in each season. So that based on the results of the simulation of the tidal current hydrodynamic model, a current pattern will be seen that occurs in each season in the Grinting Waters. The results of the observed tidal current model were compared in each season as presented on **Table.2**:

Table 2. *The Speed of The Tidal Currents of Grinting Waters In Each Season*

	Western Season (m/s)	Transitional Season I (m/s)	Eastern Season (m/s)	Transitional Season II (m/s)
Pasang Purnama	0,015	0,05	0,03	0,04
Surut Purnama	0,023	0,045	0,024	0,038
Pasang Perbani	0,02	0,046	0,062	0,042
Surut Perbani	0,037	0,023	0,036	0,027
Pasang Tertinggi	0,015	0,05	0,03	0,04
Surut Terendah	0,05	0,03	0,023	0,032
Menuju Pasang	0,013	0,047	0,03	0,043
Menuju Surut	0,084	0,018	0,04	0,026

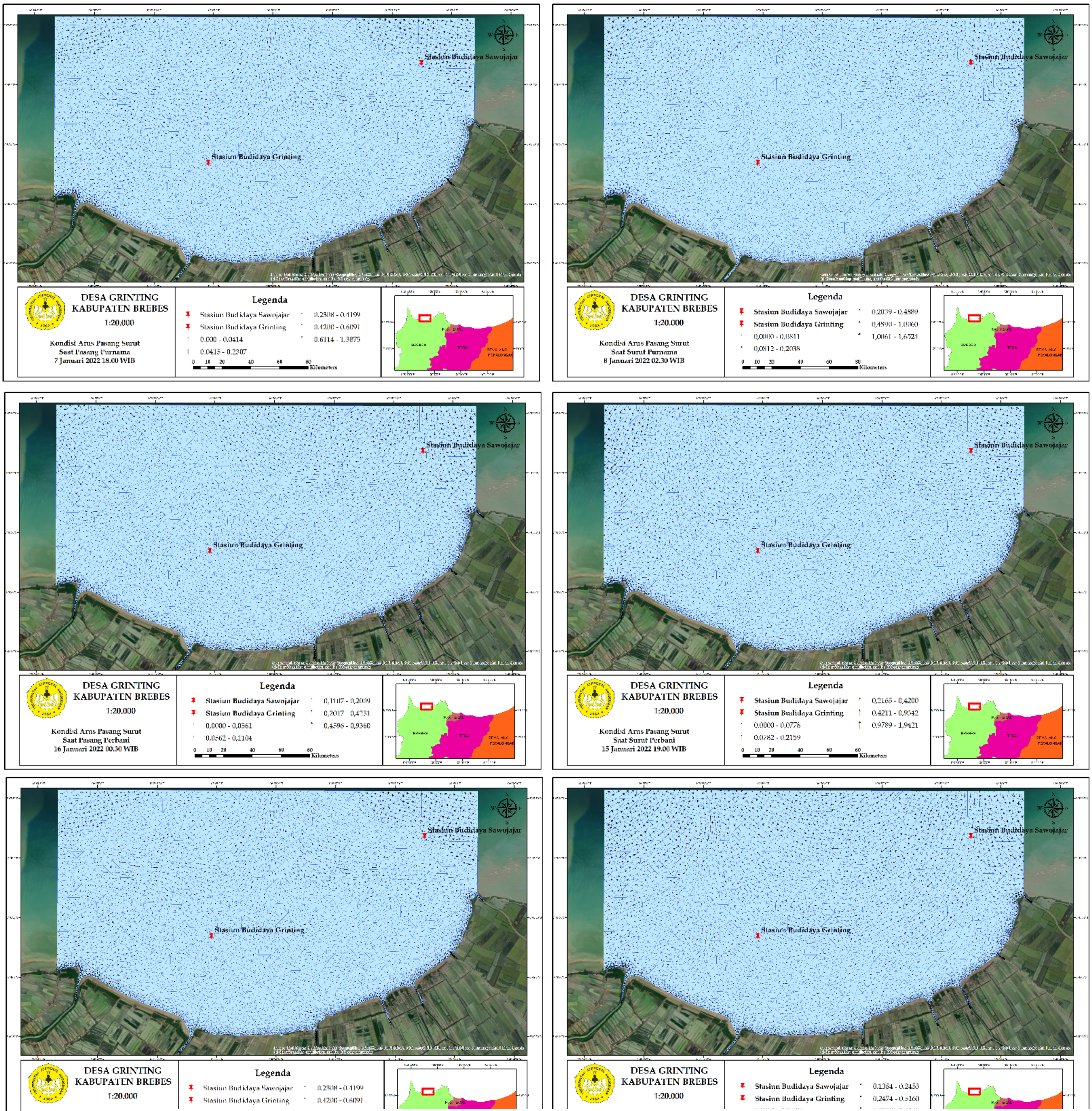

Figure 6. Tidal Conditions In The Western Season During Spring Tides, Neap tides, Highest Tides, and Lowest Tides

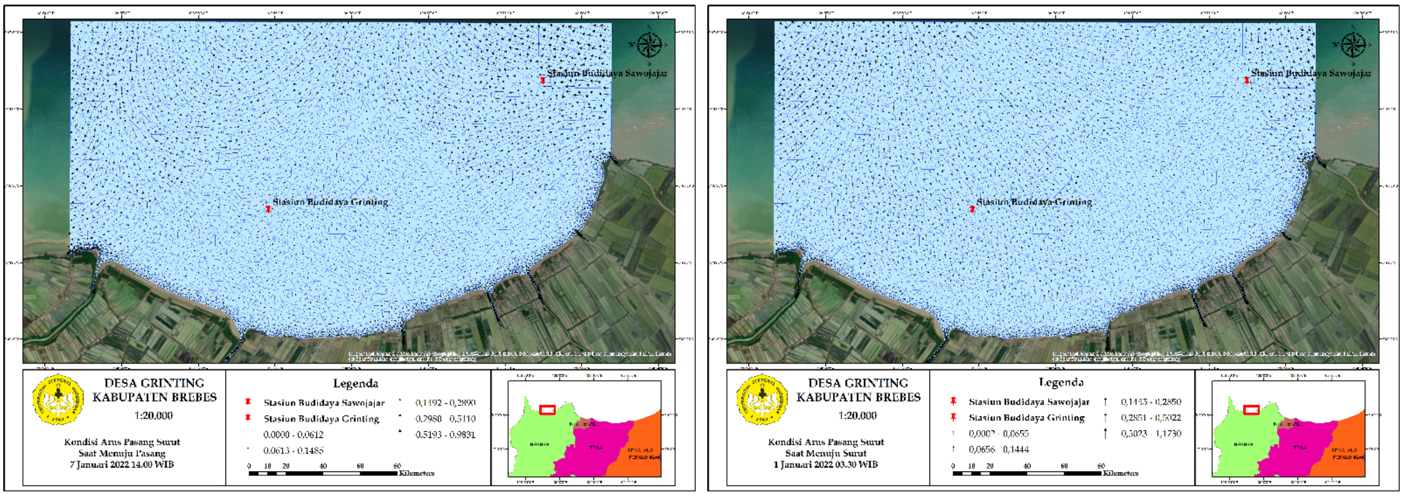

Figure 7. Tidal Conditions In The Western Season When Heading Towards the Highest Tide and When Heading Towards the Lowest Tide

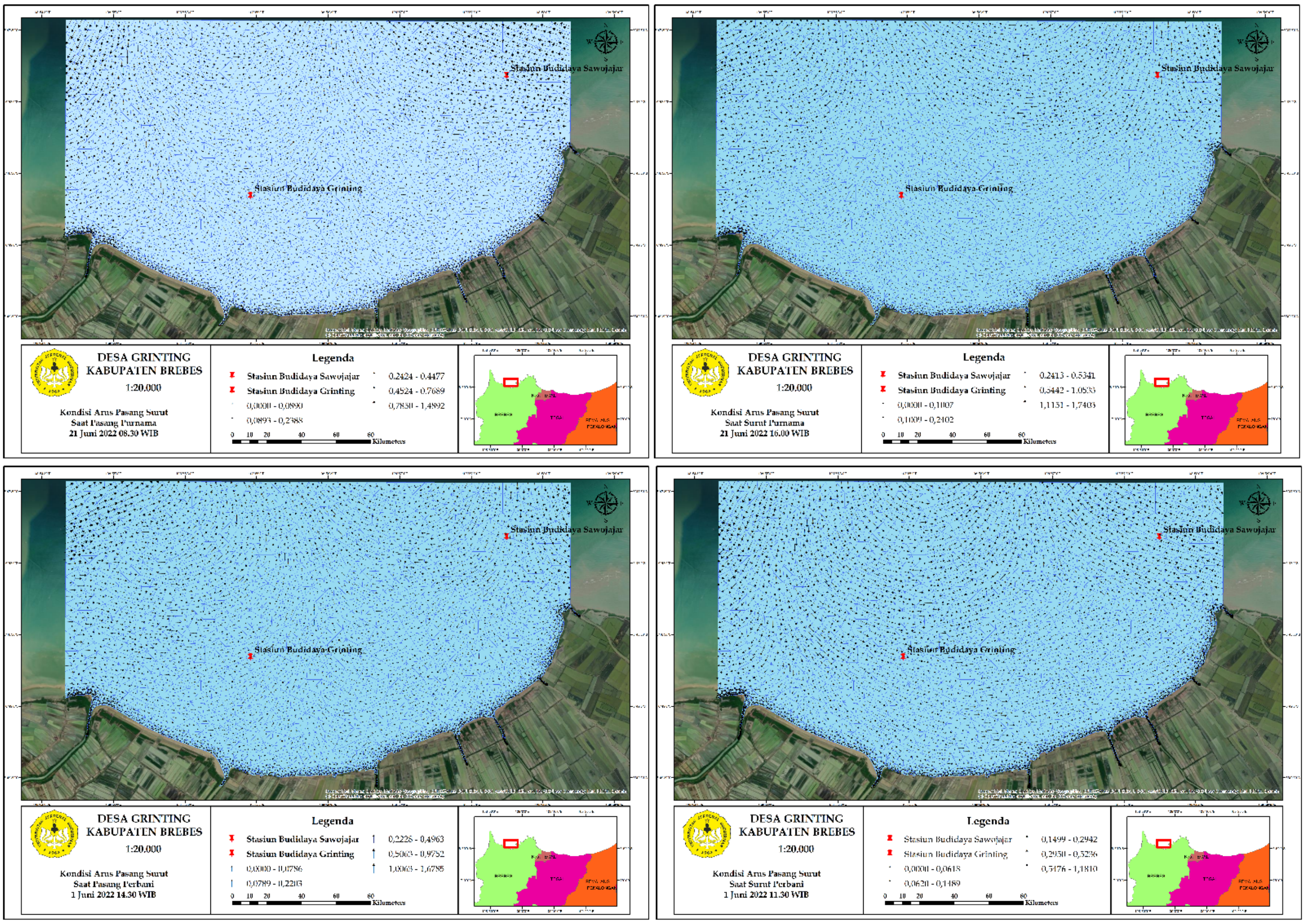

Figure 8. Tidal Conditions In The Eastern Season During Spring Tides and Neap Tides

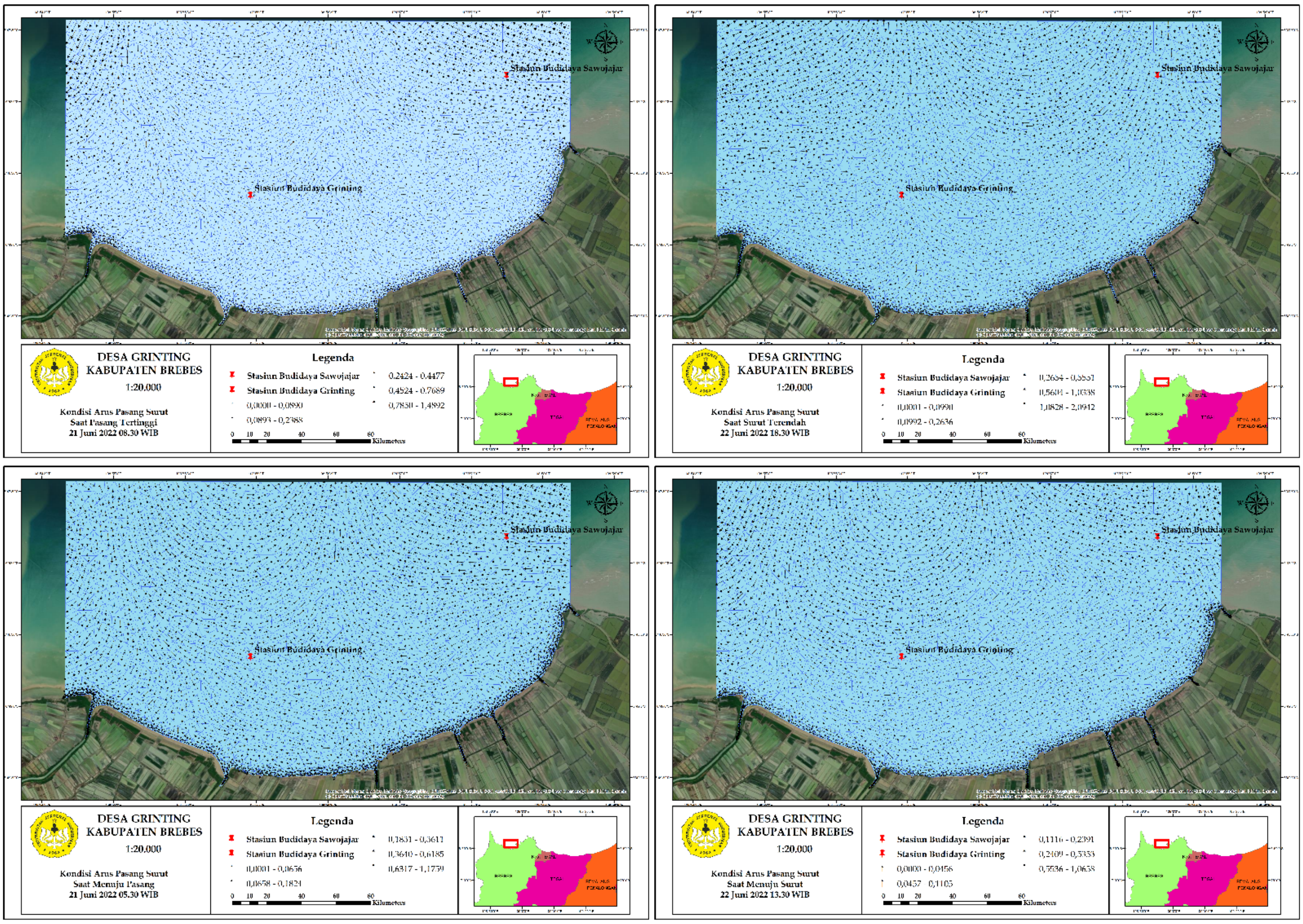

Figure 10. Tidal Conditions In The Eastern Season When The Highest Tides, Lowest Tides, Towards the Highest Tides, and Towards the Lowest Tides

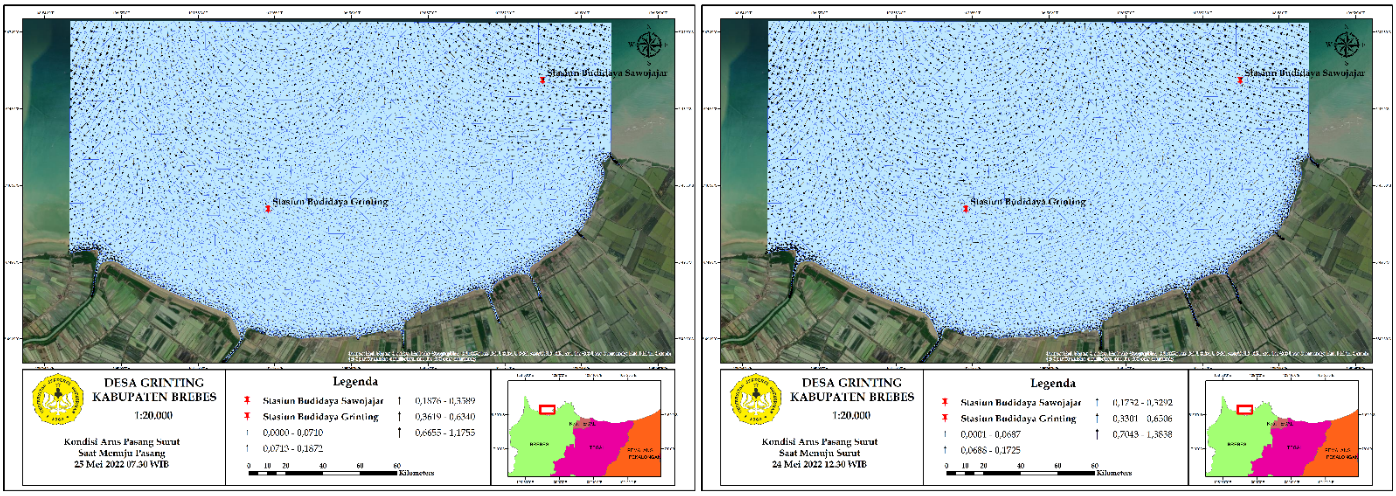

Figure 9. Tidal Conditions In Transitional Season I When Heading Towards the Highest Tide and When Heading Towards the Lowest Tides

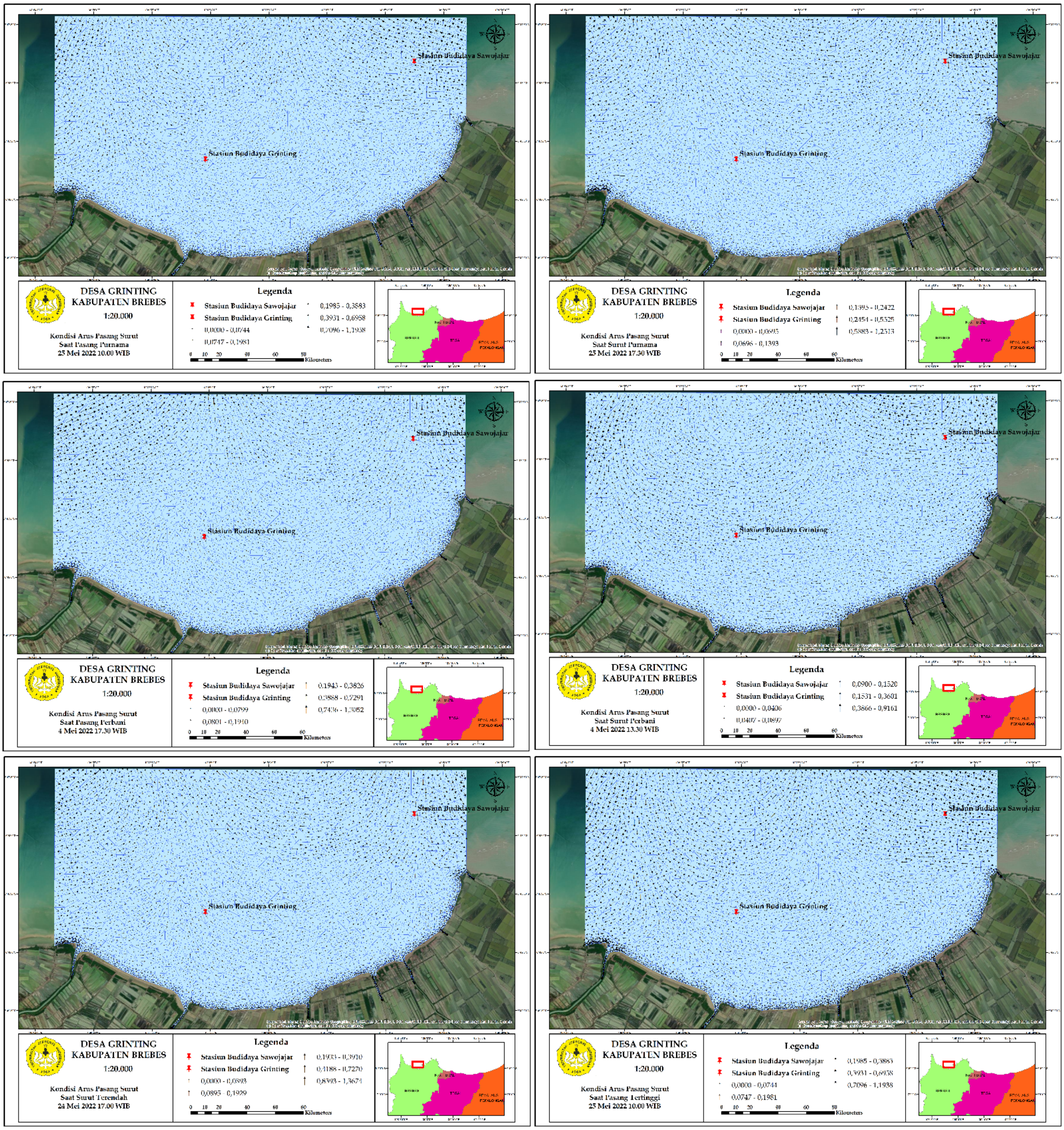

Figure 11. Tidal Conditions In Transitional Season I During Spring Tides, Neap tides, Highest Tides, and Lowest Tides

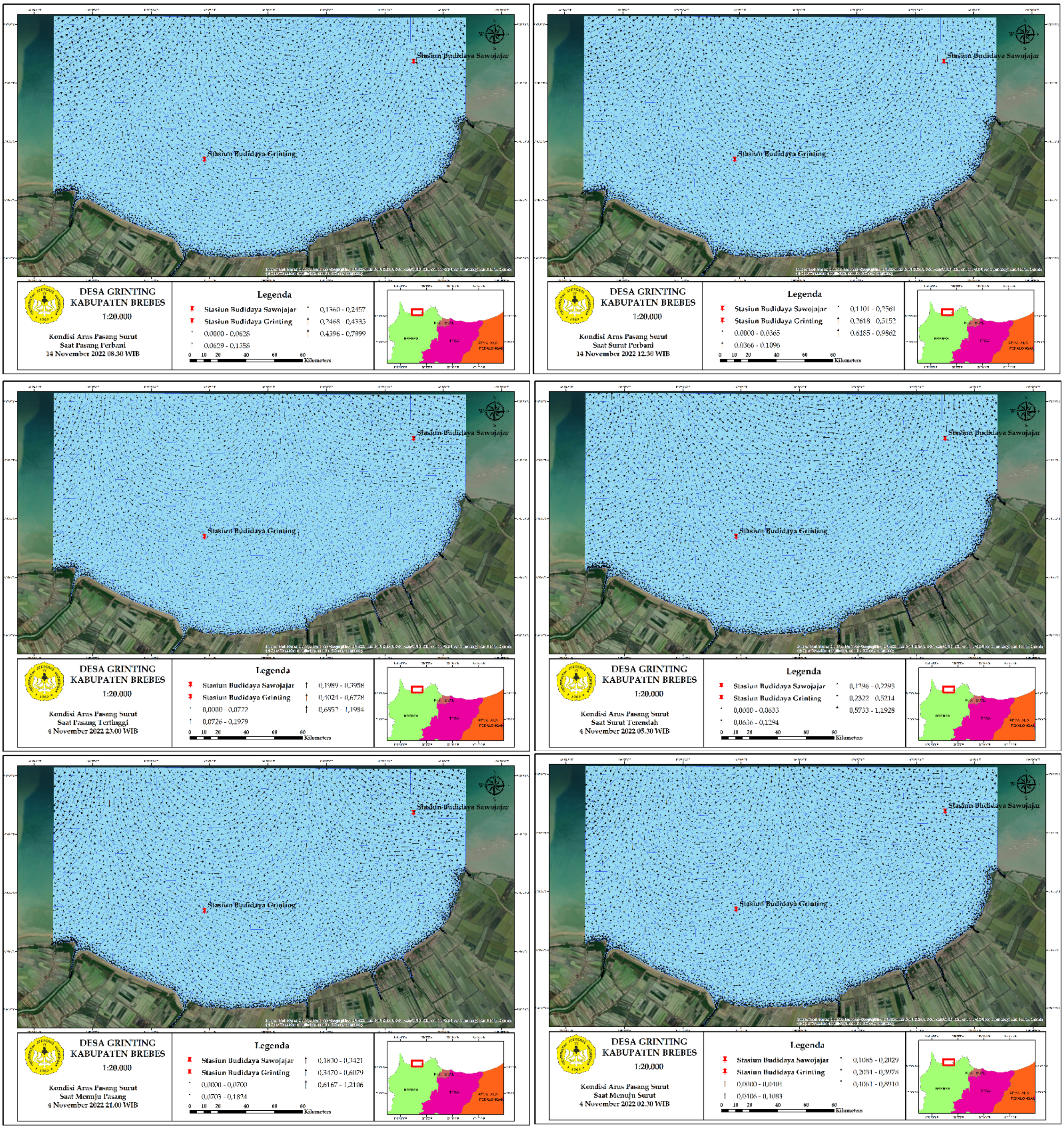

Figure 12. Tidal Conditions In Transitional Season II During Spring Tides, Neap tides, Highest Tides, and Lowest Tides

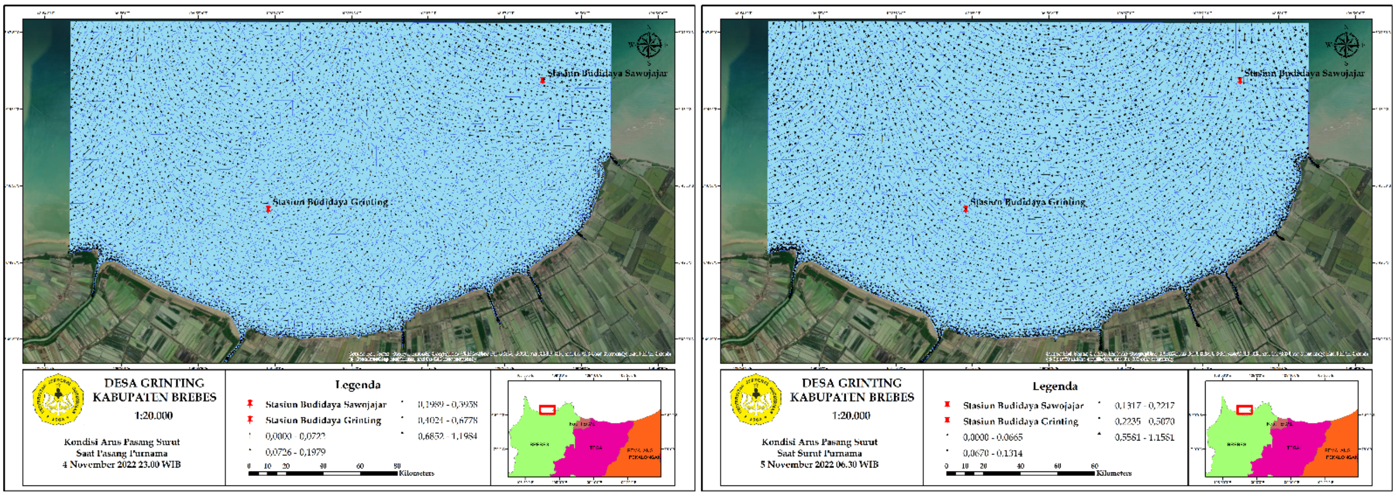

Figure 13. Tidal Conditions In Transitional Season II When Heading towards the Highest Tide and When Heading Towards the Lowest Tide

3.2 Discussion

The current pattern that occurs in each season shows the dominant direction with the average coming from east to west. The current pattern that forms each season follows the direction of the wind that blows in each season. The circulation of water masses on the surface of Javanese waters is influenced by the monsoon system. Surface water circulation at the time of the northwest monsoon peak in February and the southeast monsoon peak in August. While the middle month is part of the transition period from the western season to the eastern season (September-November) and the eastern season to the western season (March to May) [62]. This is in accordance with [63] that the current on the circulation on the surface is dominated by the current generated by the wind. According to [64] states that the current pattern that occurs in the waters of the Java Sea will follow the pattern of wind blowing.

During the western season the highest current speed occurs during full receding conditions of 0.084m/s and lowest of 0.013m/s, transitional season I at receding bandages of 0.05m/s and lows of 0.018m/s, eastern seasons at low tide of 0.062m/s and lows of 0.023m/s, and in transitional season II at low tide of 0.043m/s and lows of 0.026m/s. According to [65] says that the appearance of a strong current occurs during the full state while at the time of bandage there is a weak current. In the transitional season I, the eastern season and the transitional season II are high at low tide because at low tide the bandage will weaken due to the weak pulling force of the moon, the high speed of the current because it is influenced by a large river discharge from each river mouth so that it deflects the direction of the current towards the west. According to [66] this results in minimal movement of the tidal current, so the speed of the current that occurs becomes small. So that the discharge of the river affects the circulation pattern and speed of currents in the waters.

4. Conclusion

The simulation configuration of the model has no results that have similarities with the results of *in situ* measurements caused by inappropriate mesh size and area, measuring instruments used in the field, and weather when measuring. The RMSE value of the model results and *in situ* measurement results in April, May, June obtained values of 0.0126; 0.0046; and 0.0753. So that it can be concluded that the modeling results get good and valid results. The current pattern of each season in 2022 shows the dominant direction coming from east to west. The current pattern that forms each season follows the direction of the winds that blow in each season.

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Authors' Contributions

Each author participates in every research process from data collection, data processing, and data analysis to the completion of the final manuscript accompanied by discussion of the results and contributing to revising the final manuscript.

Conflict of Interest

The author states that they have no interests that compete with each other including interests in financial terms as well as competing in other matters.

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