 https://doi.org/10.1051/e3sconf/202346801002

Effect of breakwater layout on waves at Puger beach Jember with Delft3D modeling

Retno Utami Agung Wiyono[1], *Ardiasho* Fadhilla[1], *A* Royyan Maulana Ma[1], *Gusfan* Halik[1], *Wiwik* Yunarni Widiarti[1], and *Entin* Hidayah[1]

[1]Civil Engineering Program, Jember University, 68121 Jember, Indonesia

Abstract. Puger Beach located in Puger Village, Jember Regency which is often passed by fishing boats to Puger Fish Market. The problem of high waves is often experienced by fishermen. In 2014, a breakwater was built in the estuary of Puger Beach to overcome the problem. However, the construction of the breakwater is considered not optimal because the layout of the building only dampens waves from the west. Based on this background, this study aims to model the sea waves that occur in the estuary of Puger Beach due to the influence of the breakwater layout. Waves were modeled based on the dominant wind direction at the study site: southwest, west, and south. Modeling was made using Delft3D software by creating five breakwater placement schemes. The modeling results obtained southwest, west, and south respectively are: the first scheme reduced the wave height by 31.01%, 27.33%, and 37%; the second scheme reduced the wave height by 28.95%, 31.59%, and 36.63%; the third scheme reduced the wave height by 78.12%, 82.08%, and 65.32%; the fourth scheme reduced the wave height by 79.91%, 47.28%, and 76.54%; the fifth scheme reduced the wave height by 94.53%, 99.78%, and 96.78%.

1 Introduction

Water characteristic information is an important source of information in every sector of life, especially for the marine sector, one of which is related to ocean waves [1]. Waves are one of the events generated by several factors, including wind and tides [2].

Indonesia is one of the countries in the world that has the potential for ocean wave energy so that the exploration of this energy for future energy fulfilment is important [3]. Puger Beach is one of the beaches in Jember Regency located in Puger Village, Puger Kulon Sub-district which is close to the Bedadung River estuary and borders the Indian Ocean, so it is often passed by fishing boats as an entrance and exit to Puger Fish Market. Puger fishermen often experience problems related to shipping safety due to bad weather conditions and high waves [4]. It was recorded that during the period of 2007-2017 there were ten ship accidents due to high waves. One of them, an accident that caused the death of 6 fishermen and 4 fishermen missing which occurred in 2017 due to the capsizing of a fishing boat [5].

Generally, ship accidents occur due to the ship capsizing because the position of the ship is perpendicular to the direction of the incoming high waves [6]. When the ship enters the estuary area, high waves come and are not dampened so that it can endanger the safety of fishermen. Therefore, in 2014 a coastal safety building was rebuilt in the form of a breakwater to overcome high waves. Yuliamangesti [7] evaluated the performance of breakwater in Puger Beach Jember based on the layout and stability of the building in existing conditions. The results of the analysis state that the existing building layout can only reduce waves coming from the west. In line with this research, Izzati [8] stated that coastal safety buildings have not fully worked effectively in reducing waves and holding back sediment transport. Therefore, it is necessary to redesign the coastal safety building at Puger Beach.

There were several studies on wave modeling with various breakwater layout [9, 10]. However, there are no recent studies on this topic in Puger Beach. In the same time, ship accidents continue to occur in Plawangan Area, Puger Beach. It is very important to model breakwater configurations suitable for the site.

The purpose of this study is to determine how the influence of the breakwater layout at the research site on waves by modeling using Delft3D based on the layout. Modeling was made by applying five breakwater placement schemes at the research site. The result of this research is to identify each breakwater placement scheme that may be applied in reducing waves around Puger Beach.

2 Research Methods

This study aims to perform numerical simulation of wind wave together with tides in Puger Beach, Jember. Delft3D-FLOW and Delft3D-WAVE are utilized for modeling. There are two main steps for modeling. The first step is validation of tidal wave. Observation data from previous study is utilized for comparison with simulation results.

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

The second step is to model five schemes of jetty in Puger Beach. Significant wave height is analyzed for every step.

2.1 Research Location

The research site is located in Puger Kulon Village, Puger Subdistrict which is 35 km south of the center of Jember City. The existing breakwater is located at (8.386º S, 113.476º E) to (8.387º S, 113.475º E) (see Fig. 1). The breakwater was located at the mouth of the Bedadung River (Plawangan Area) [11].

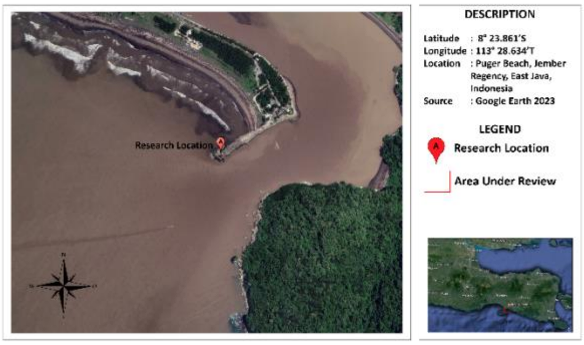

Fig. 1. Research location [12]

2.2 Data Preparation

This research data comes from primary and secondary data obtained from observations and manual digitization. The data used are wind data, tidal data, bathymetry data, and shoreline data.

The wind data used is the maximum wind direction and wind speed data for each month. Samples were obtained from the observation of the Aviation Meteorological Post of Noto Hadinegoro Jember Airport from 2019 to 2022.

Tidal data is data from direct observations in previous research [13] located at Puger Beach at 8.3844º S and 113.47640º E for 15 days of observation (October 04 - 19, 2019).

Bathymetry data is data from the Tanah Air Indonesia website. The data is in the form of blocks with an area of 5x5 with retrieval boundaries at coordinates 5º N - 10º S and 110º E - 115º E. Bathymetry data is then processed with QGIS software, as input for modeling. Shoreline data is the result of manual digitization on Google Map at 8.3976 º S and longitude 113.4772º E.

3 Wave Analysis

Waves that occur in the sea are a movement of seawater energy caused by wind [14]. Wind is one of the dominant elements in wave formation. The longer and stronger the wind blows, the bigger the waves formed [2]. Wave analysis was performed by calculating the length of effective fetch, correction of wind data based on location, conversion to wind stress factor, and finally hindcasting process to estimate wave height.

3.1 Shipping Safety

According to Taryono et al. the average significant wave height in the southern waters of Java is considered longer than the Pacific Ocean. With wave sizes that exceed the percentage of ship dimensions, it can also be dangerous [15]. In this case, according to BMKG [16] there are several wave height criteria that need to be considered for the risk of shipping safety.

1. Fishing boats (wind speed more than 15 knots and wave height above 1.25 m)
2. Barges (wind speed more than 16 knots and wave height above 1.5 m)
3. Ferries (wind speed more than 21 knots and wave height above 2.5 m)
4. Large size vessels such as cargo ships / cruise ships (wind speed more than 27
5. knots and wave height above 4.0 m)

3.2 Layout Schematic

In this study, wave modeling was carried out by applying several breakwater placement schemes. The schemes are made to find out which breakwater layout is optimal in reducing wave speed and current when the boat will enter the river mouth. At this stage, five breakwater placement schemes were made at the location. Figure of each placement is shown in results and discussion part.

The first scheme simulates conditions without the use of breakwater. The second scheme simulates the alignment based on the existing site. The third scheme simulates the placement based on previous research suggestions by Yuliamangesti [7] by making changes to the layout and dimensions of the breakwater. The fourth scheme simulates the placement based on the dominant wave direction. The fifth scheme simulates the placement based on previous research suggestions by Izzati [8] by adding a pair of breakwaters on the right and left sides of the estuary.

4 Result and Discussion

4.1 Model Validation

In order to perform model validation, observation data for 15 days on October 4-19, 2019 at Puger Beach is utilized [15]. The data was analyzed using Delft3D Tide to obtain harmonic constant components (K1, O1, P1, Q1, M2, S2, N2, K2) as input in wave modeling.

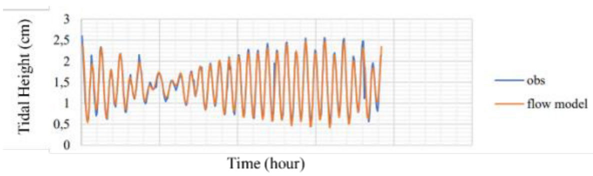

Fig. 2. Tidal Validation in Puger Beach.

After obtaining the harmonic component of tides, the observation data then be used as input tidal data in the flow model. Validation is carried out between the observational data and the data from the flow analysis in Fig. 2.

It is shown that modeling results (red line) could well reproduce the observation data (blue line). Thus, the wave modeling could be continued by five scenarios as planned before.

4.2 Modeling Result

The analysis was carried out after obtaining output from the computational results of modeling using the Delft3D program with five breakwater placement schemes that had been made. To determine the effect of each breakwater placement scheme in the Puger Jember Estuary, an analysis of the physical characteristics of the waves formed during 2 days of observation, from October 4, 2019 to October 6, 2019. The analysis was carried out by placing two different observation points. OBS point B (-8.3869, 113.47237) as an observation point for waves before entering the estuary and OBS point A (-8.3876, 113.4724) as an observation point around the estuary where accidents often occur.

1. First Scheme Analysis

Based on the modeling results, the highest significant wave height occurred on October 4, 2019 at 09.40 WIB (see Fig.3).

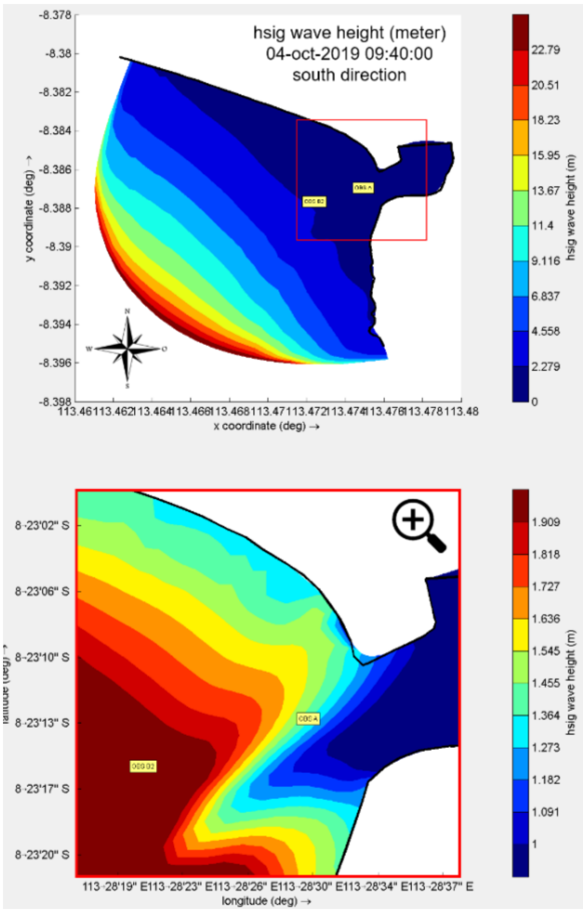

Fig. 3. Modeling Results of the First Scheme in South Wave Direction.

The first scheme simulates conditions without the use of breakwater. This scheme aims to see the actual wave potential if the research location is not built coastal protection buildings

Fig. 3 shows that the significant wave height of each observation point is at its respective interval. The following are the results of observations at OBS B and OBS A points in each direction of incoming waves in Table 1.

Table 1. Wave Simulation Results of the First Scheme.

Parameters	Observation Point					
	Southwest		West		South	
	B	A	B	A	B	A
Hsig wave height (m)	1,90	1,31	1,67	1,22	2,16	1,36
Wave reduction	31,01%		27,33%		37,00%	
Risky Wave at 1,25m (Obs A)	At risk		Not at risk		At risk	

Based on the simulation results of the first scheme in Table 1, there is a significant wave reduction from OBS point B to OBS point A in each direction. Even though it is made without any coastal protection buildings, the reduction that occurs according to Triadmodjo [2] can be caused by differences in beach slope height, wavelength, and other factors. In addition, the results of the first scheme simulation show that the incident wave (OBS B) has not been reduced effectively when it is in the estuary area (OBS A) with an average reduction of 31.78%.

2. Second Scheme Analysis

The second scheme simulates the alignment based on the existing site. This scheme aims to validate previous research by Yuliamangesti [7] and Izzati [8] which states that the building in the existing condition has not fully worked effectively in reducing waves. The location of the second scheme breakwater is at coordinates (-8.386, 113.476) to (-8.387, 113.475) with breakwater dimensions 130 m long and 20 m wide (see Fig. 3).

The modeling results obtained the highest significant wave height occurred on October 04, 2019 at 09.40 WIB (see Fig. 4).

Fig. 4 shows that the significant wave height of each observation point is at its respective interval. The following are the results of observations at OBS B and OBS A points in each direction of incoming waves in Table 2.

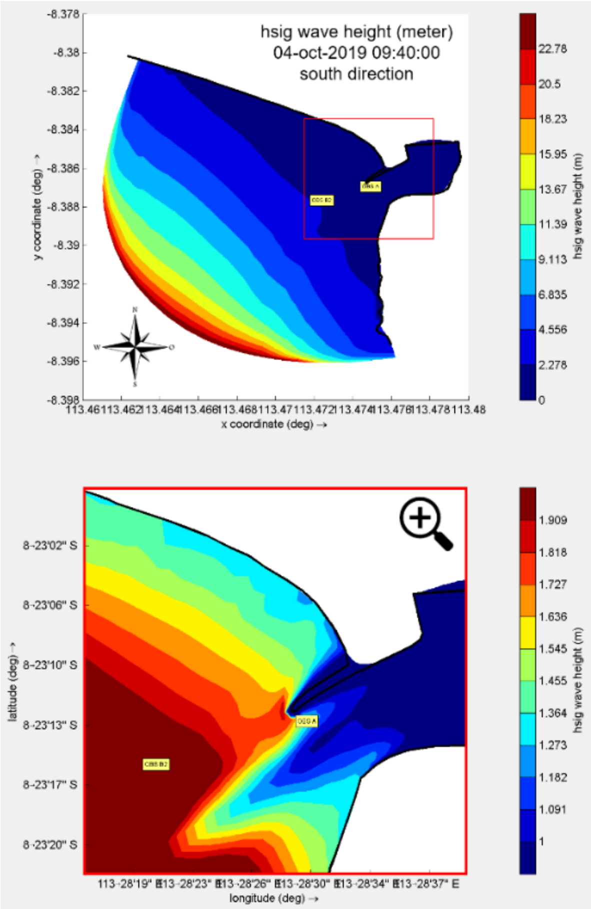

Fig. 4. Modeling Results of the Second Scheme of South Wave Direction.

Table 2. Wave Simulation Results of the Second Scheme.

Parameters	Observation Point					
	Southwest		West		South	
	B	A	B	A	B	A
Hsig wave height (m)	1,89	1,34	1,67	1,14	2,17	1,38
Wave reduction	28,95%		31,59%		36,63%	
Risky Wave at 1,25m (Obs A)	At Risk		Not at Risk		At Risk	

Based on the simulation results of the second scheme in Table 2, there is a significant wave reduction from OBS B point to OBS A point in each cardinal direction. The results of the second scheme simulation show that the incident wave (OBS B) has not been effectively reduced when it is in the estuary area (OBS A) with an average reduction of up to 32.39%. This is because the estuary area lacks protection from the breakwater. When high waves enter the estuary area, the surrounding water conditions can be categorized as "at risk", especially against high waves from the southwest (1,344 meters) and south (1,375 meters). These results can be said to be in line with previous research statements by Yuliamangesti [7] and Izzati [8] that the building layout in the existing condition is still not able to reduce waves effectively.

3. Third Scheme Analysis

The third scheme simulates the placement based on previous research suggestions by Yuliamangesti [7] by making changes to the layout and dimensions of the breakwater. This scheme aims to validate whether after making changes, the breakwater can work effectively. The third scheme breakwater location is at coordinates (-8.387, 113.474) to (-8.385, 113.475) with breakwater dimensions 250 m long and 15 m wide.

The modeling results obtained the highest significant wave height occurred on October 04, 2019 at 09.40 WIB (see Fig. 5).

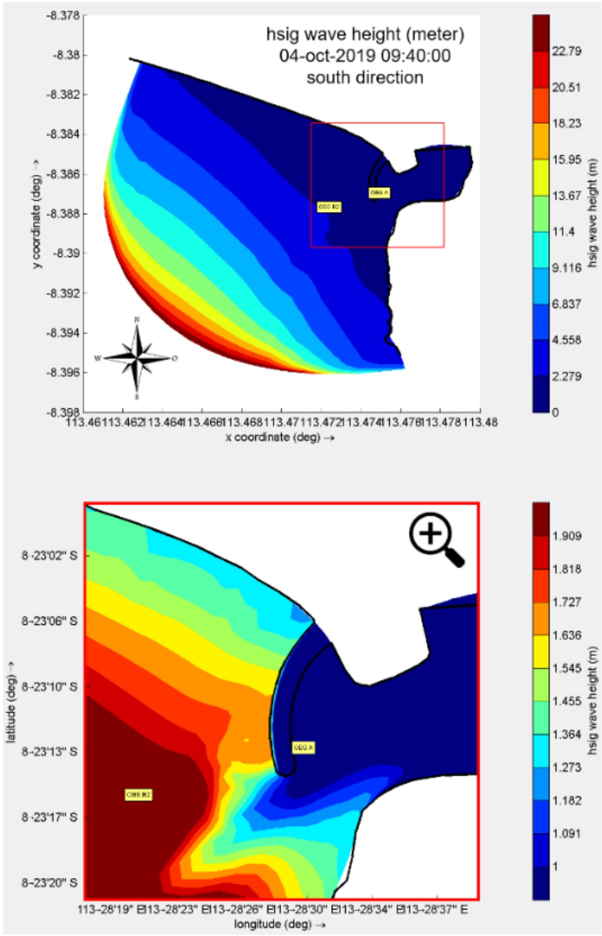

Fig. 5. Modeling Results of the Third Scheme in the South Wave Direction.

Fig. 5 shows that the significant wave height of each observation point is at its respective interval. The following are the results of observations at OBS B and OBS A points in each direction of incoming waves in Table 3.

Based on the simulation results of the third scheme in Table 3, there is a significant increase in wave reduction from OBS B point to OBS A point in each direction. The results of the third scheme simulation show that the incident wave (OBS B) can be optimally reduced when it is in the estuary area (OBS A) with an average reduction of up to 75.18%.

Table 3. Wave Simulation Results of the Third Scheme.

Parameters	Observation Point					
	Southwest		**West**		**South**	
	B	**A**	**B**	**A**	**B**	**A**
Hsig wave height (m)	1,86	0,41	1,67	0,30	2,18	0,76
Wave reduction	78,12%		82,08%		65,32%	
Risky Wave at 1,25m (Obs A)	Not at Risk		Not at Risk		Not at Risk	

The reason is that the estuary area gets protection from the breakwater on the right side, so that waves from the west and southwest can be optimally reduced. The water conditions in the estuary area can be categorized as "not at risk" to high waves from the southwest (0.407 meters), west (0.299 meters), and south (0.756 meters) according to the wave height criteria required by BMKG.

4. Fourth Scheme Analysis

The fourth scheme simulates the placement based on the dominant wave direction. Based on the results of wave forecasting, it was found that the dominant wave came from the southwest, so a change in the layout of the breakwater was made on the left side of the estuary. This change is made so that the mouth of the estuary does not directly face the direction of the incoming waves, so that the estuary area is not affected by waves at sea [2]. The location of the fourth scheme breakwater is at coordinates (-8.387, 113.473) to (-8.389, 113.475) with breakwater dimensions 250 m long and 15 m wide

The modeling results obtained the highest significant wave height occurred on October 04, 2019 at 09.40 WIB (see Fig. 6). Fig. 6 shows that the significant wave height of each observation point is at its respective interval. The following are the results of observations at OBS B and OBS A points in each direction of incoming waves in Table 4.

Table 4. Wave Simulation Results of the Fourth Scheme.

Parameters	Observation Point					
	Southwest		**West**		**South**	
	B	**A**	**B**	**A**	**B**	**A**
Hsig wave height (m)	1,87	0,38	1,64	0,87	2,22	0,52
Wave reduction	79,91%		47,28%		76,54%	
Risky Wave at 1,25m (Obs A)	Not at Risk		Not at Risk		Not at Risk	

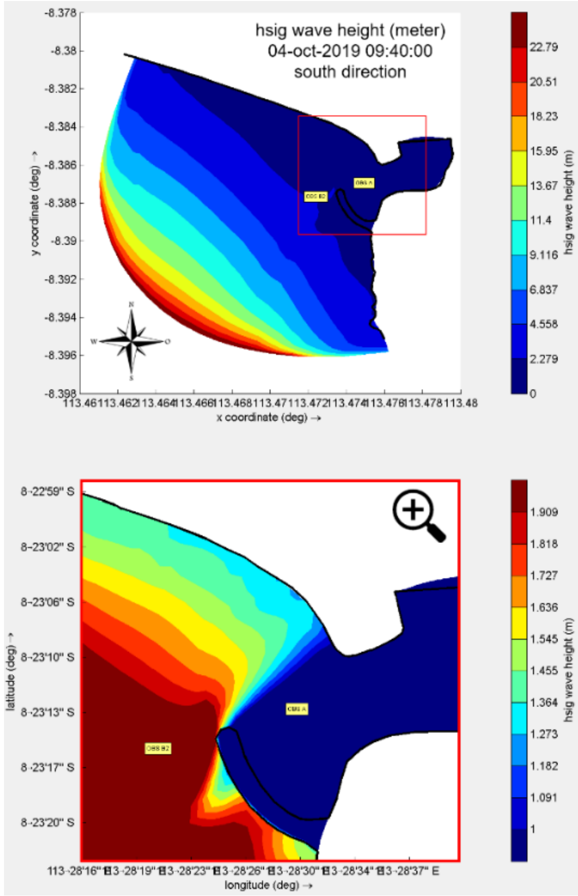

Fig. 6. Modeling Results of the Fourth Scheme of South Wave Direction

There is a significant increase in wave reduction from OBS B point to OBS A point in each direction. The results of the fourth scheme simulation show when the incident wave (OBS B) can be optimally reduced when it is in the estuary (OBS A) with an average reduction of up to 67.91%. This occurs because the breakwater layout in the fourth scheme is on the left side of the estuary, which makes waves from the south and southwest can be reduced optimally. Water conditions in the estuary area can be categorized as "not at risk" of high waves from the southwest (0.376 meters), west (0.867 meters), and south (0.521 meters) according to the wave height criteria required by BMKG [12].

5. Fifth Scheme Analysis

The fifth scheme simulates the placement based on previous research suggestions by Izzati [8] by adding a pair of breakwaters on the right and left sides of the estuary. This scheme aims to validate whether the addition of a pair of breakwaters can reduce waves effectively. The location of the fifth scheme breakwater is at coordinates (-8.387, 113.473) to (-8.389, 113.475) for the left side and (-8.387, 113.474) to (-8.385, 113.475) for the right side, with dimensions of each breakwater 250 m long and 15 m wide.

The modeling results obtained the highest significant wave height occurred on October 04, 2019 at 09.40 WIB (see Fig. 7).

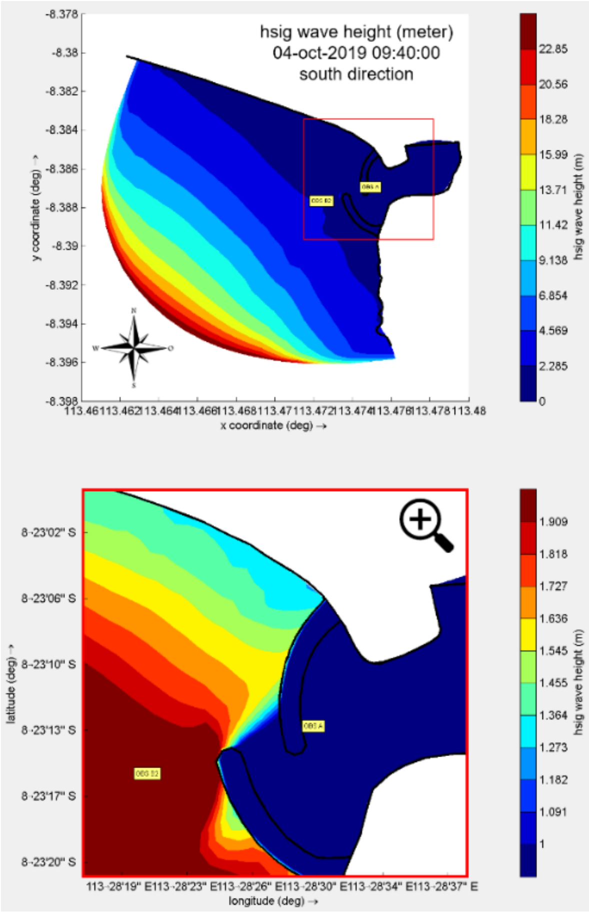

Fig. 7. Modeling Results of the Fifth Scheme of South Wave Direction

Fig. 7 shows that the significant wave height of each observation point is at its respective interval. The following are the results of observations at OBS B and OBS A points in each direction of incoming waves in Table 5.

Table 5. Wave Simulation Results of the Fifth Scheme.

Parameters	**Observation Point**					
	Southwest		**West**		**South**	
	B	**A**	**B**	**A**	**B**	**A**
Hsig wave height (m)	1,87	1,31	1,64	0,004	2,23	0,07
Wave reduction	94,53%		99,78%		96,78%	
Risky Wave at 1,25m (Obs A)	Not at Risk		Not at Risk		Not at Risk	

There is a significant increase in wave reduction from OBS B point to OBS A point in each direction. The results of the fifth scheme simulation show when the incident wave (OBS B) can be optimally reduced when it is in the estuary area (OBS A) with an average reduction of up to 97.03%. The increase occurs because the breakwater layout in the fifth scheme protects each side of the estuary area against incoming waves. These results can be said to be in line with previous research statements by Izzati [8] that by adding a pair of breakwaters on the right and left sides of the estuary can reduce waves effectively. Water conditions in the estuary area can be categorized as "not at risk" of high waves from the southwest (0.102 meters), west (0.004 meters), and south (0.072 meters) according to the wave height criteria required by BMKG.

5 Conclusions

Based on the results of wave modeling on the influence of breakwater layout in the estuary of Puger Jember Beach using Delft3D, several results were obtained from the application of several schemes. For the first scheme without breakwater, wave height from southwest, west, and south respectively were able to be reduced up to 31.01%, 27.33%, and 37%.

The second scheme was developed based on the existing condition layout. The second scheme can reduce the wave height from southwest, west, and south respectively by 28.95%, 31.59%, and 36.63%.

The third scheme was performed by changing the breakwater layout based on previous research. It is found that the third scheme can reduce wave height from southwest, west, and south respectively by 78.12%, 82.08%, and 65.32%.

The fourth scheme included the left side of the breakwater. It is found that the fourth scheme can reduce the wave height from southwest, west, and south respectively by 79.91%, 47.28%, and 76.54%.

The fifth scheme performed by using a pair of breakwaters on the right and left sides of the estuary. It is obtained that the fifth scheme can reduce the wave height from southwest, west, and south respectively by 94.53%, 99.78%, and 96.78% of waves from the south.

Based on the simulation results, it is known that the first and second scheme were unable to create a safe condition of wave height for shipping while the third, fourth, and fifth schemes were able to create a safe condition of wave height for shipping.

References

[1] H. R. Maulana, Analisis Karakteristik Gelombang Laut Dan Prediksi Gelombang Ekstrim Dengan Periode Ulang Terkait Keselamataan Pelayaran Di Perairan Utara Jakarta (2018)

[2] B. Triadmodjo, Perencanaan Bangunan Pantai, 3rd ed. Yogyakarta: Beta Offset Yogyakarta, (2014)

[3] I A H Aswad "Pemodelan Tinggi Gelombang Untuk Kajian Energi Gelombang Laut Di Perairan Barat Provinsi Lampung" Wave: Jurnal Ilmiah Teknologi Maritim, **15**, 75-84, Nomor 2, (2021)

[4] BPBD, Kejadian Laka laut Pelawangan Puger Kab. Jember, PPID (2022) https://ppid.jemberkab.go.id/berita-ppid/detail/kejadian-laka-laut-pelawangan-puger-kab-jember#

[5] R. U. A. Wiyono, Fenomena Kecelakaan di Pantai Pancer Puger, 7–8, (2020) https://magister-sipil.teknik.unej.ac.id/fenomena-pancer-puger/

[6] M. Kadhafi, Mitigasi Kecelakaan Kapal di Pelawangan Pantai Pancer Kecamatan Puger Kabupaten Jember, War. Pengabdi., **13**, 28, no. 1, (2019) doi: 10.19184/wrtp.v13i1.9461.

[7] A. A. Yuliamangesti, Evaluasi Kinerja Bangunan Pemecah Gelombang Di Pantai Puger Jember" Universitas Jember, (2017)

[8] A. Izzati, Redesign bangunan Pengaman Pantai Sebagai Alur Masuk Pelayaran Pelabuhan Perikanan Jember, Institut Teknologi Surabaya, (2018)

[9] I Syahputra, Pemodelan Kecepatan Arus dan Tinggi Gelombang Pada Rencana Breakwater Kolam Pelabuhan Meulaboh Dengan Menggunakan Program Delft3D, http://jurnal.abulyatama.ac.id/tekniksipilunaya, Jurnal Teknik Sipil Unaya, **5**, 11-19, no. 2, (2019)

[10] Sujatmoko, B., Fauzi, M., and Putra, D. A. "Wave Pattern Simulation around the Breakwater Configuration in Bantan Coast, Bengkalis". MATEC Web of Conferences 276, 04018 (2019) ICAnCEE (2018)

[11] MA, A.R.M., Wiyono, R.U.A., Irawan, J.F., Pratama, M. B., Halik, G., and Widiarti, W. Y., Numerical Simulation of Breakwater Layout in Puger Beach Jember Due to Tidal Wave, IOP Conference Series: Earth and Environmental Science, **437** (2020) https://iopscience.iop.org/article/10.1088/1755-1315/437/1/012026

[12] Google Earth (2023)

[13] Riyanto, N.A., Wiyono, R.U.A, and Hidayah, E., Studi Peramalan Pasang Surut Di Pesisir Pantai Pancer Kecamatan Puger, Kabupaten Jember, Maspari Journal, **14,** no. 1 (2022)

[14] Coastal Engineering Research Center, Shore Protection Manual I, 4th ed., **I**. Vicksburg: Department of the Army, (1984)

[15] S. Tredup, Dangerous Waves and Your Boat, (2011) https://oceannavigator.com/dangerous-waves-and-your-boat/

[16] BMKG, Saran Keselamatan Berlayar, Pusat Meteorologi Maritim, (2020) https://maritim.bmkg.go.id/info/37/Saran-Keselamatan-Berlayar