FORECASTING HIGH WAVES IN THE COASTAL WATERS OF CLUNGUP AS A SUPPORT FOR THE RESILIENCE OF COASTAL ECOSYSTEMS

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ABSTRACT

Coastal ecosystems are very vulnerable to environmental changes, and one of the variables of resilience in coastal areas is wave height. Clungup Beach is one of the beaches located in South Java with the characteristics of high waves. Analysis of wave height forecasting to minimize environmental damage in the future. The wave height forecasting method is carried out by two methods, namely Fisher Tippet-1 and Weibull, with the aim of comparing the results of forecasting the resulting waves and validating the forecast data. The source of wave data for 10 years (2009 - 2018) was obtained from the ECMWF (European Center for Medium-Range Weather Forecasts) website. The results of data analysis show that the wave height of Clungup Beach for a period of 10 years (2009 - 2018) with the highest value in July 2013, namely 2.67 m and the lowest in June 2010 with a value of 2.28 m, which is classified as a wave extreme in accordance with the Regulation of the Head of BMKG No. KEP. 009 of 2010. Wave forecasting with the Fisher Tippet-1 method return period in 2020 is 2.48 m and in the next 50 years (2069) is 2.76 m. Whereas in the Weibull method, the wave value for 2020 is 2.43 m and for the next 50 years (2069) is 3.01 m. The two methods used have the equation that the wave height that will occur in the Clungup Beach area will experience an increase (upward trend). This will be the basis for determining the scenario of coastal area protection, so that the resilience of coastal ecosystems will be well realized.

Keywords: *Extreme Waves, Fisher Tippet-1, Weibull, and ECMWF*

1. INTRODUCTION

Changes in the ecosystem and environmental patterns can occur due to natural and anthropogenic factors. Ecosystem resilience is a study that studies environmental patterns so that they can be maintained and as a solution to prevent environmental damage. According to Effendi *et al.* (2018), the ecosystem is an ecological system formed by the reciprocal relationship between living things and their environment.

A coastal area is a meeting place between land and sea that has enormous potential (Bengen, 2000). This area is an area that is vulnerable to natural disasters, one of which is coastal damage (Hidayah dan Okol, 2018), where coastal damage can be caused by the movement of wind, currents, and waves (Supriyadi *et al*., 2017). Other phenomena that can cause coastal damage are climate change, increased intensity of extreme weather events in an area, changes in rain patterns, and increases in temperature and sea level (Isdianto dan Oktiyas, 2019). Rising sea levels can cause damage to coastal areas, and become an increasingly serious problem when the existing sea levels increase in line with the increase in the earth's temperature. This coastal damage can also be influenced by several other factors such as the influence of wind, waves, and the influence of tides (Isdianto *et al*., 2014).

Wind-generated waves are very important for coastal and marine areas. According to Rahmadani, *et al*. (2019), wave is a phenomenon of the movement of up and down water perpendicular to the surface so as to form a sinusoidal curve. Ocean waves can be formed as a result of wind gusts, volcanic eruptions, seabed subsidence, or ship traffic (Yulius *et al*., 2017). Wave calculations can be done by measuring directly in the field, although in practice it requires large costs and the terrain is difficult to do (Supiyati, 2008).

Waves are one of the important aspects of oceanography in planning a coastal building, determining the layout of the port, shipping lanes and managing the marine environment (Huda *et al*., 2015). The right calculation in determining the height of the waves will help in determining the scenario in the protection of buildings in the coastal area, because sea waves have 2 types according to their nature, namely destructive and constructive (Dhanista, 2017). One example of a destructive wave is a significant extreme sea wave with a height of more than 2 m, according to BMKG Head Regulation Num. KEP. 009 of 2010. Extreme sea waves can cause coastal abrasion, which is a phenomenon where there is coastal erosion caused by the energy of ocean waves and destructive currents (Amri *et al*., 2016).

Clungup Beach is one part of the southern coast of Java, precisely in the southern part of the Sendang Biru Malang Conservation area, which has been developed as a marine ecotourism destination with a fairly high level of tourist attendance. Clungup Beach has a variety of ecosystems, but the ecosystem that dominates on the beach is the coastal ecosystem. The coastal ecosystem at Clungup Beach is dominated by mangrove forests. Mangrove plants on this beach are composed of natural mangroves and artificial mangroves (Imron & Anwar, 2019). The number of tourist visits in 2016 amounted to 61,490 tourists and in 2017 there were 55,151 tourists. It can be estimated that tourist visits will decrease, this is due to the ecotourism management principles applied by CMC (Clungup Mangrove Conservation), namely Community Based Tourism. (Tribowo *et al*., 2017). According to Yachya *et al*. (2016), Community-Based Tourism is a community-based conservation area management, which has the aim of maintaining the resilience and stability of the ecosystem and also improving the standard of living of the people in the Clungup Beach area.

According to Alfansuri dan Ervita (2014), the south coast of east java has a characteristic wave height that is constant and above the average between 2.00 - 3.00 m per year increasing the potential for abrasion. The phenomenon of abrasion that occurs in this coastal area requires countermeasures, and the main thing that must be done is forecasting waves using a return period that is expected to be equaled or exceeded once in T years (Setiawan *et al*., 2015).

Prediction of sea wave height can be done by various methods ranging from simple methods to complex methods (Rahmadani *et al*., 2019). For wave prediction with the return period method, wave data with a fairly long period of time is required. The data used can be in the form of direct data or forecasting results from wind data (Setiawan *et al*., 2015). In this study, wave height prediction was carried out using the return period method with two methods, namely weibull and fisher typpet-1, with the aim of providing good results for determining the protection scenario of the Clungup Coastal Area in the future.

2. METHOD

Observations were made at Clungup Beach, southern Malang (Figure 1.). Data obtained through wave measurement results by ECMWF.

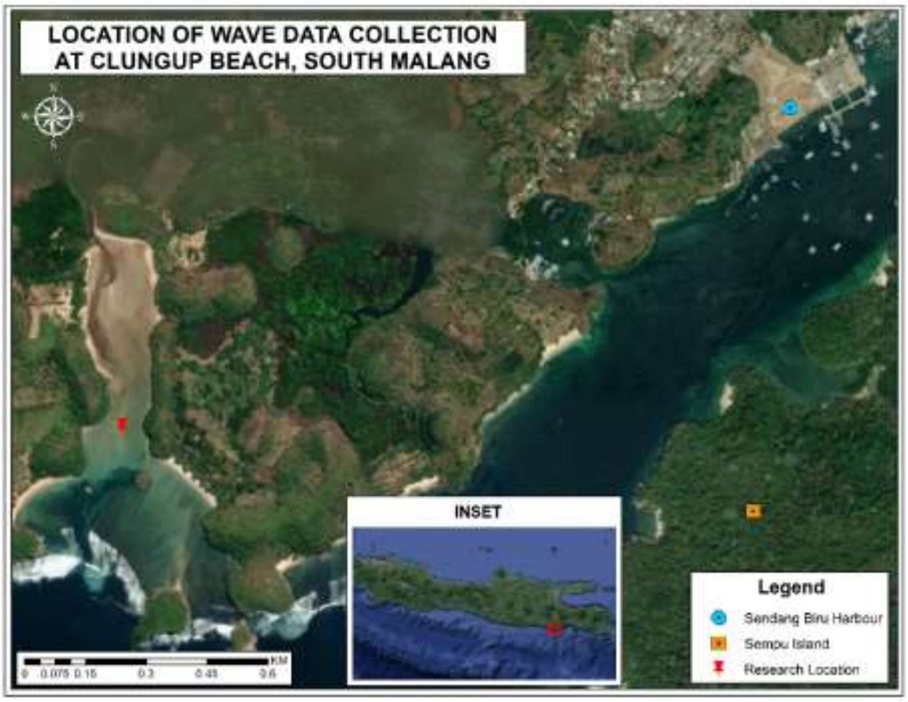

Figure 1. Research Location

2.1 Data Processing

This data processing is carried out using two methods, namely Fissher typpet-1 and weibull. The data used is wave data from ECMWF (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era-interim) for 10 years (2009 – 2018).

Wind and wave data from ECMWF is used to obtain representative waves and directions (Purwanto *et al.*, 2020). The data obtained in the form of a .NetCDF file is processed and modeled with the help of ODV software and Microsoft Excel, producing data in the form of text (.txt) in the form of a representative wave every month and Hmax every year for ten years (2009-2018).

The results of wave forecasting can be adjusted with a return period of up to 50 years, or in this study in 2069, for reasons of limitation, it is considered to provide a representative significant number of wave height predictions for the protection of Clungup Beach. In forecasting wave heights with return periods, there are two methods, namely the Gumbel method/Fisher-Tippet Type I method and the Weibull method (CERC, 1992).

The work steps in predicting wave height with a wave return period using the Weibull method are almost the same as the Fisher-Tippet Type I method, but the formulas and coefficients used have different methods. The following is the coefficient of the standard deviation of each method :

Table 1. Coefficient of Standard Deviation of Each Return Period Forecasting Method

Distribution	α1	α2	k	c	ε
Fisher Tippet -1	0,64	9	0,93	0	1,33
Weibull (k=0.75)	1,65	11,4	-0,63	0	1,15
Weibull (k=1.00)	1,92	11,4	0	0,3	0,9
Weibull (k=1.4)	2,05	11,4	0,69	0,4	0,72
Weibull (k=2.0)	2,24	11,4	1,34	0,5	0,54

2.2 Data Analysis

Data analysis in this study was carried out descriptively with a quantitative method

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approach. According to Sugiyono (2009) quantitative method is a method using numerical data and statistical analysis or models. Descriptive data analysis is an explanation of the results of each method used, along with the characteristics of the waves in the waters. Furthermore, a comparison between the results of the two methods used is used. The results of this wave forecast are the maximum wave height, minimum wave height, and also the average wave height of each time period that is determined sometime in the future.

There are two methods for predicting waves using the return period, namely the Fisher tippet type 1 method and the Weibull method. The two distributions have the following formula :

1) Fisher-Tippett Type 1

$$P\ (H_s \leq\ \hat{H}_s) = e^{-e^{-\left(\frac{\hat{H}_s\ -\ B}{A}\right)}}$$

2) Weibull

$$P\left(H_s \leq\ \hat{H}_s\right) = 1 -\ e^{-\left(\frac{\hat{H}_s\ -\ B}{A}\right)^K}$$

Explanation :

P $(H_s \leq\ \hat{H}_s)$: probability that $\hat{H}_s$ is not exceeded

H : representative wave height

Ĥ : wave height with a certain value

A : scale parameters

B : location parameters

K : shape parameters

In this study, literature studies were also carried out in several journals, to see the potential of this wave forecasting to help the resilience of coastal ecosystems on Clungup Beach. In addition to the journal, this data analysis is also based on the exposure of the results of interviews with the surrounding community related to natural phenomena about high waves that occur, besides the interviews are also strengthened by several sources from existing news.

3. RESULT AND DISCUSSION

3.1 Analysis of Extreme Wave Conditions in Clungup Coastal Waters

Maximum wave height readings are obtained from the ECMWF website, presented using a graphic form to see the maximum wave at Clungup Beach every year, from 2009 to 2018.

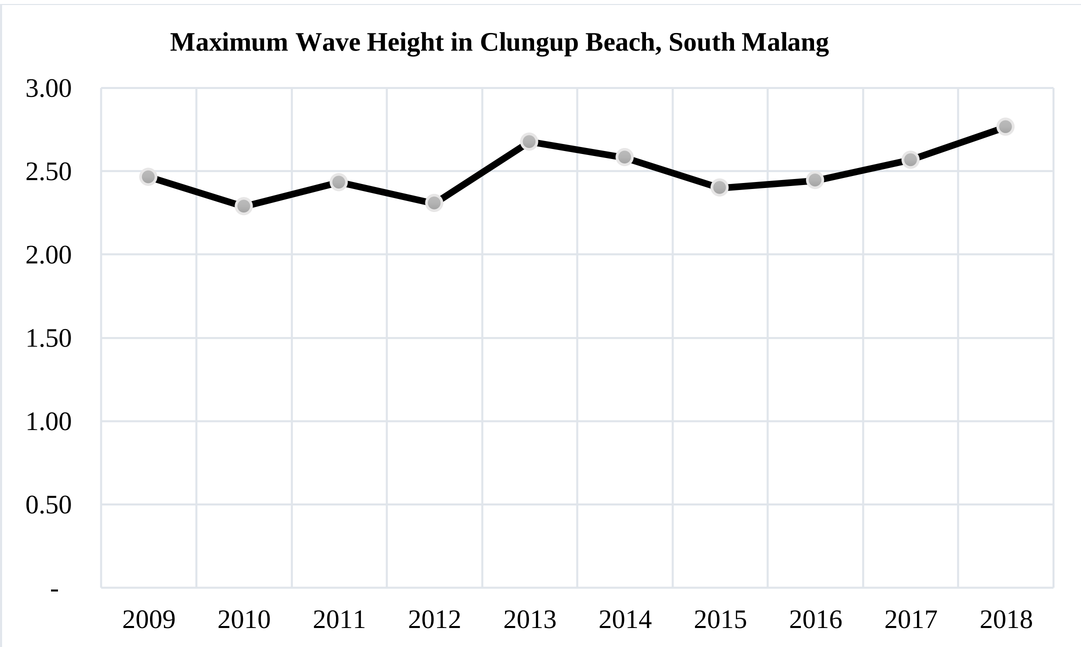

Figure 2. Clungup Coastal Wave Height Chart 2009-2018

The wave height on Clungup Beach has a height of more than 2 m and can be categorized as extreme waves according to the Regulation of the Head of BMKG No. KEP. 009 of 2010, which states that extreme waves are ocean waves with a height of ≥ 2 m. The value of the maximum wave in each year is very volatile but tends to increase. The highest maximum wave was in 2018 (July) with a value of 2.67 m, and the lowest was in 2010 (June) with a value of 2.28 m.

The waves that occur in Clungup Coastal Waters are waves generated by the wind because they are located in the southern part of the island of Java facing directly to the Indonesian Ocean, so they have a very long fetch distance. Long fetch, will generate high waves (extreme) because wave generation occurs more than 200 km and is not blocked by anything.

The maximum waves in the Clungup Coastal Waters occur on average in the east monsoon, with the direction of the waves with the wind direction coming from the south. The eastern season occurs when the sun shifts to the northern hemisphere from April – August (Yananto dan Rini, 2016). In addition, it is strengthened by research that has been carried out by Fadika *et al*. (2014), that the wind will blow from the Australian continent to the west during the east monsoon. Therefore, it will affect the direction of the wind blowing so that it can generate high waves in the southern waters of Java, including the waters around Clungup Beach.

3.2 Wave Forecast Fisher Tippet-1

Wave forecasting using the Fisher Tippet-1 method was carried out for 50 years (2019 – 2069), using basic data from wave heights on the ECMWF site.

Table 2. Result of wave forecasting method Fisher Tippet-1

Return Period (Years)	Hsr (m)	Hsr-1.28Ơr (m)	Hsr+1.28Ơr (m)
2	2,48	2,41	2,55
5	2,57	2,46	2,68
10	2,63	2,47	2,78
20	2,69	2,49	2,88
25	2,70	2,49	2,91
40	2,74	2,50	2,98
50	2,76	2,51	3,01

From the results of wave forecasting using the Fisher Tippet-1 method, it can be seen that every year there is a tendency to increase. According to Alamrarti, dan Bambang (2017), the results of wave forecasting with this method become more accurate because it has been tested with an 80% confidence interval. This test is carried out by placing the significant value of the wave at the specified confidence interval (Hs value – 1.28σr and Hs value + 1.28σr).

The wave forecasting results show that in two years (in 2020) the value of the wave height will reach 2.48 m until in the next 50 years (2069) it is 2.76 m. The return period is the number of predicted year values.

The Fisher Tippet distribution was first discovered by Emil Gumbel, initially used to model flood flows, but in its development, it can be used for forecasting extreme values of waves. The value of the Gumbel method does not depend on the distribution ($\sigma > 0$) (Mathwave, 2020).

3.3 Wave Forecast Weibull

Wave forecasting using the return period of the Weibull method is carried out for 50 years (2019 – 2069), using the same basic data from wave heights on the ECMWF site.

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Table 3. Welbull Method Forecasting Results

Return Period (Years)	**Hsr (m)**	**Hsr-1.28Ơr (m)**	**Hsr+1.28Ơr (m)**
2	2,43	2,34	2,52
5	2,57	2,36	2,78
10	2,69	2,36	3,02
20	2,82	2,36	3,28
25	2,86	2,35	3,37
40	2,96	2,35	3,57
50	3,01	2,35	3,67

In this method, we can see that the tendency of the calculation results from wave modeling in the return period changes which tends to increase every year. This method uses a confidence interval of 80%, to be able to see the maximum and minimum values of the wave height.

The results of wave forecasting using the Weibull method, the wave height in the next 2 years (in 2020) is 2.43 m and the wave height for the next 50 years (2069) is 3.01 m and is obtained from the use of the values a1 and a2 higher, which is worth 1.65 and 11.4.

This method was invented by Wallodi Weibull, to solve problems in materials science, but thanks to its flexibility it can be used in various fields. In this Weibull method when the value of the constant α = 1, this distribution is reduced to an Exponential model, and when α = 2, this distribution imitates the Rayleigh distribution. In addition, if α = 3,5 it will resemble a normal distribution (Mathwave, 2020).

3.4 Comparison of Fisher Tippet-1 Method with Weibull

In general, the wave height is strongly influenced by the wind speed, especially the existing Fetch. Fetch is the area where the wave is generated which is bounded by the land surrounding the area (Wakkary dan Ihsan, 2017). From a statistical point of view, the probability of the return period wave value will be greatly influenced by the amount of data and the wave height at the previous time. The more the amount of data, the better the modeled data will be.

In general, the trend of wave height values will increase every year (Purwanto *et al.*, 2020). The results of the graph of calculations between the two methods (Fisher tippet-1 and Weibull) did not show a significant difference. Both methods have the same calculation results, namely the trend of increasing wave height values every year.

However, both methods have different coefficients and confidence intervals, so the values generated from wave modeling with return periods have different values. The Weibull method has a higher standard deviation, the confidence interval of the resulting linear equation has a higher value, so the Weibull method is more suitable for forecasting return period waves.

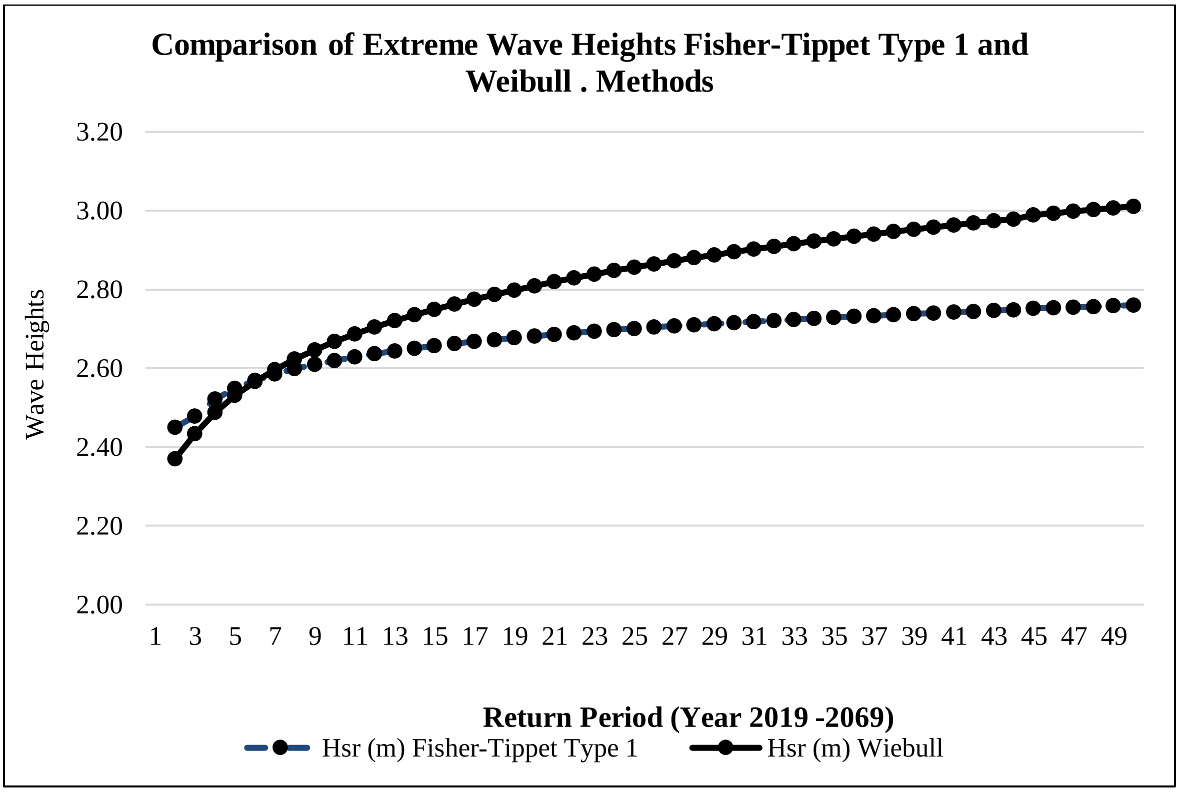

Figure 3. Wave Height Comparison Graph With Two Methods

In Figure 3. It can be seen that in the initial 5 years the graph value of the Weibull tends to be lower than the Fisher Tippet-1, while for the return period over 5 years later the value of the Weibull has a very drastic change until it is above the graph on the Fisher Tippet. This can happen because modeling using Weibull has a more flexible nature. Each increase in the existing constant will change the value of the existing equation. In the return period of 1 to 5 years, the constant used is 0-1. Then in the next 6 years, the constants used have arrived at numbers 2 to 3.

3.5 Coastal Ecosystem Resilience

According to Holing (1996), From an ecological perspective, resilience can be defined as the amount of disturbance that can be absorbed before a change in the structure of the system occurs. This system says that resilience is not only a matter of time, but also how much disturbance can be suppressed and still manageable within critical limits. Resilience emphasizes reducing short-term damage and building long-term adaptive capacity. While the ecosystem is a relationship of interaction (reciprocity) between living things and their environment (Susilawati *et al.,* 2016). Coastal areas are the areas most vulnerable to changes due to biodiversity factors, fluctuating water quality and also dynamic coastline changes, which are influenced by hydro-oceanographic factors and human intervention in carrying out their life activities. Some of the definitions above can be concluded that the resilience of coastal ecosystems is the amount of disturbance that can be absorbed by ecosystems in coastal areas.

Beaches in Malang district on average have a sloping or steep morphology with a straight and bay shape. The Clungup Beach area itself has a sandy substrate, the shape of the beach is bay. According to Sheila *et al.* (2014), south malang beach has a very high disaster potential. Potential for disaster because it is located between the confluence of two very active plates (Eurasia and IndoAsutralia) and the source where the tsunami occurred, besides that the south coast is also directly adjacent to the Indian Ocean so it has the potential for high waves to occur.

The wave factor is one of the variables that enter into the resilience of coastal ecosystems. as we know that waves have two kinds of destructive and constructive properties (Dhanista, 2017). Destructive waves (Figure 4.) are waves that damage the coast. This wave has a height >1 m. The wavelength is relatively short and the frequency is more frequent (10-14 waves/min). The higher the frequency of the waves, the more often the waves reach the land and the flow back to the sea will be more and more. Backwash from waves will inhibit other flow rates towards the coast, therefore the destructive wave swash is weaker than the backwash. The magnitude of the backwash rather than the swash will result in a lot of beach sediment being carried to the sea, which can also be called the occurrence of abrasion (the erosion of the coastal area by waves). If it continues, it will endanger the resilience of the coast. Destructive waves are usually closely related to Extreme waves. As we know, extreme waves are high waves that reach a height of more than 2 m. Judging from the characteristics of destructive waves and coastal morphology on Clungup Beach, it can be concluded that the average wave in the southern part of Java has the potential for destructive extreme waves.

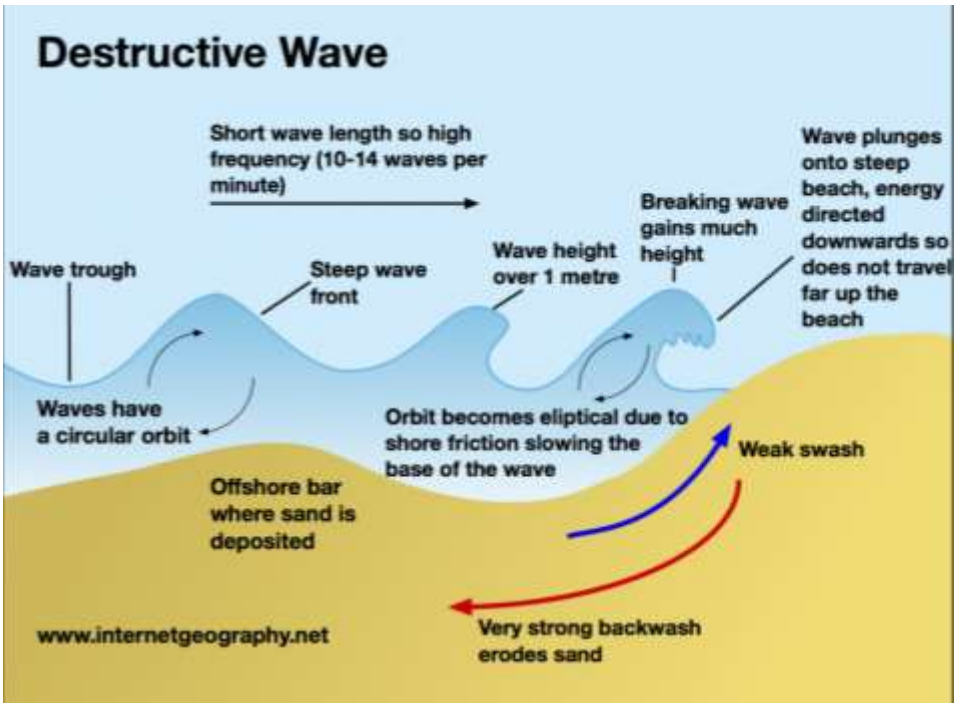

Figure 4. Destructive Wave

This tidal flood on the Clungup beach last occurred on May 26, 2020 – May 27, 2020 (Medcom, 2020). According to a statement from the BMKG, tidal flooding can be caused by tidal activity, high wave conditions and high rainfall. From the results of interviews, local residents also said that this tidal flood usually occurs every 4 years, but this year is the largest tidal flood that occurred on Clungup Beach. According to the manager of the CMC (Clungup Mangrove Conservation) area, Mr. Saptoyo, this tidal flood caused the mangrove area to be submerged in CMC, which damaged almost half of the pine shrimp that had been planted previously.

4. CONCLUSION AND SUGGESTION

The waters of Clungup Beach, located in South Malang, have a wave height that can be called an Extreme wave because the average wave height is 2 m. This extreme wave height during the 10-year period (2009 – 2018) was highest in July 2013 with a value of 2.67 m, and the lowest was in 2010 (June) with a value of 2.28 m.

The return period wave forecasting is done by using two methods: Weibull and Fisher tippet. Wave forecasting with the return period of the Fisher tippet method in the next 2 years (2020) is 2.48 m, then in the next 50 years (2069) it is 2.76 m. In the Weibull method, the wave value for the next 2 years (2020) is 2.43 m, then for the next 50 years (2069) it is 3.01 m. The two methods used have the equation that the wave height has increased (uptrend), and the method used by the Weibull method is considered more suitable for Clungup Coastal Waters to get a higher wave forecast than the Fisher tippet method.

Wave forecasting at the clungup beach is carried out to calculate the wave height in the future as an effort to protect the coastal area in order to design the scenarios needed to reduce the impact of abrasion and extreme waves. Scenarios of overcoming the impact of extreme waves and abrasion are one of the efforts that can be used to support the resilience of coastal ecosystems. So that further research is needed to see the vulnerability index of the coast in Clungup Beach.

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