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Geographic Information System Design And Analysis of Sea Water wave Forecast for Early Detection of Seashore Erosion

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Abstract:- Scientific process occurred in seashore is the erosion in a seashore area and then to be transported so other area from the mentioned seashore area will form sediment. Sea wave is one of seashore processes that give great contribution to sediment transport rate. Sea wave can be measured directly or to be generated by using wind data. Due to limitation of resources the direct measurement to sea wave in long term is very rarely conducted so it is often to be conducted by using forecast method. In this research it is conducted sea wave forecast at Lebih Beach in order to continuously monitor the seashore processes that occur in Lebih Beach. By using wind data from BMKG of area III Denpasar it is conducted analysis of wind frequency distribution to get dominant wind direction and speed that has effect in Lebih Beach. Based on the wind data it is formed wind data correction reference table whether the elevation factor, location factor, temperature difference factor, and wind stress factor. Then the fetch effective value is calculated. According to fetch value and wind stress value from the conversion reference table it is carried out plotting of wave forecast by using wave forecast graphic so it is obtained the wave forecast reference table. Based on wind data and wind speed that has effect it produced the forecast of wave period and height at Lebih Beach. In addition, it also produced an application that focused on the wave forecast process.

Keywords:- sea wave forecast, beach erosion, wave forecast

I. INTRODUCTION

Natural process that occurred in seashore is the erosion in a seashore area and then to be transported so other part of the mentioned seashore area will experience sedimentation. The causes of the natural process are among others the wind, wave and high and low tide. Sea wave is one of the important components that can affect seashore sediment transport rate. Sea sediment transport will determine the coast line change that occurred. To show the process it needs wave data in time period of measurement for some years. The wave data can be obtained by two ways those are the direct wave measurement or wave data from prediction result. Measurement of wave in long term is still rarely carried out, difficult and even expensive, on the other side the wind measurement has been carried out often. Therefore, it used wave generation based on wind data [1].

Small wave ripples will emerge when there is wind that blows on a calm sea water surface. It indicates that there is a wind wave effect to the generation of sea water wave [2]. The wind is used to predict the wave period and height on deep sea [3]. Before predicting deep sea wave period and height, correction will be performed to the wind data. There are five factor adjustments that should be implemented and those are the factors of elevation, duration, stability, location and displacement coefficient [4]. Direct wave measurement of the beaches in Bali Island is still very rarely conducted. Effendi [5] carried out research to the change of the coast line at Sanur Beach after the construction of beach building. In this research it is mentioned that wave data that was used is a direct measurement result that is using the wave recorder tool by *Balai Wilayah Sungai Bali Penida* (Bureau of Bali River Area of Penida) in 2004. But due to the limitation of resources so there are many researches about coast line change use wave data that is generated from wind data, among others: research by Susanti [6] that predict the coast line change at river mouth area of Tukad Yeh Ho by using wind data of 1991-2000 from BMG Ngurah Rai Station, Hidayah et al [7] analyzed the change of Jasri Beach coast line at Karangasem Regency by using wind data from BMG Ngurah Rai Station for twenty years from 1990 to 2009. Purnaditya et al [2] researched the prediction of coast line change at Nusa Dua Beach by using daily maximum wind data of 1991-2010 from BMKG station of Area III Denpasar and Triwahyuni [3] conducted numeric simulation to coast line change of western side of Badung Regency by using monthly average wind data of 2001-2010 from BMKG Station Ngurah Rai Tuban.

Lebih Beach located at Gianyar Regency is one of beaches that popular with its beauty and characteristic of its seafood culinary tourism. But erosion history becomes a serious problem along this beach. Erosion of Lebih Beach is caused by the transportation of sediment along the beach so it causes the movement of sediment from one place to another [8]. The Government of Bali Province has tried to overcome the erosion that occurred by building cribs from concrete blocks. But the cribs built were damaged struck by the wave so this effort has not yet succeeded [9]. In April 2011 revetment was started to build from andesite amor stone material along 851.50 m and the improvement of the old revet mentalong 264 m. In addition, walk way was also being built from paving block pass along 1.115.50 m [10]. Continuous monitoring to Lebih Beach should be kept carried out even though overcoming and protection have been conducted. This is due to continuous attack from wave and relatively high rainfall that can affect the resistance of the revetment so erosion still happens to erode the existence of brushed stone [11]. Direct wave measurement for long term is also never conducted at Lebih Beach. The newest and closest direct measurement to Lebih Beach is the measurement at Pabean Beach, Ketewel Village, Sukawati Sub-district, Gianyar Regency performed by breakwater building feasibility study [12]. Therefore, to continuously monitoring Lebih Beach in this research it is conducted wave forecast by using monthly average wind data obtained from BMKG of Area III Denpasar for time period of ten years from 2005 to 2014.

Based on wind data obtained, it is carried out wind frequency distribution analysis to get influential dominant wind direction at Lebih Beach. By using the dominant wind it is carried out the formation of wind data conversion reference table then the fetch effective value is calculated. By using the fetch value and UA value from the conversion reference table it is carried out plotting of wave forecast by using wave forecast graphic so it is obtained wave forecast reference. By using again wind data and direction owned then wave forecast (height and period) at Lebih Beach is produced whether the Fetch Limited or the Time Duration Limited. It is also proposed an algorithm design and the implementation of predicting process of sea wave in an application program.

II. LITERATURE REVIEW

A. Wind Data and Wave Formation

By the present of wind that blows upon the water surface, then wind energy will be moved to the water. Tension on the sea surface will be generated by the wind speed so calm water surface will change and small wave ripples emerge. If wind speed increases then the ripples will be bigger and if the wind continues to blow it will form wave. The stronger and longer the wind blows it will form bigger wave. The wind includes the speed, duration of blowing, direction and fetch that affect the wave period and height [1]. Wave forecast uses data at sea surface on the generating location. Wind direct measurement upon the sea surface or wind measurement at the land closest to the location of forecast study which is then to be converted to be wind data on sea are two methods that often to be carried out to get wind data. Generally, wind data is recorded in every hour. Wind with certain speed and duration, maximum speed, direction and average of daily wind speed can be found out based on the record on the mentioned hours [1]. By wind recording on the mentioned hours if they were accumulated for some years they will produce great wind data amount therefore the wind data should be presented in the form of summary or diagram called the *wind rose*.

B. Forecast Of Sea Water Wave

Before wave period and height to be predicted, wind data should be converted and adjusted by the correction factors among others the elevation, stability, location and displacement coefficient. Procedures that should be carried out to perform wave forecast are as the following [2]:

a. Adjustment of Wind Speed at Height 10 m (U_{10})

Wind speed should be changed into elevation of 10 meter if wind data is not measured on the mentioned elevation by using equation 1. U_y is wind speed at y meter height.

$$U_{10} = U_y \left(\frac{10}{y}\right)^{\frac{1}{7}} \tag{1}$$

b. Speed Conversion of U_{10} to be Wind Speed upon Sea Surface (U)

The location factor (R_L) is the transformation of wind from land to sea wind is needed because generally in wind data formula to be used is the wind data on sea. Correlation between the wind upon the sea and wind on the closest land is given by $R_L = U_W/U_L$. Equation 2 is the adjustment for the stability factor and this location.

$$U_{10} = U_{10} R_L R_T \tag{2}$$

R_T is the ratio for land-sea water temperature difference, because temperature difference between air and water cannot be found out, it is assumed as an unstable condition that is $R_T = 1.1$ [3], [4].

c. Determinataion and Calculation Fetch Effective (F_{eff})

Fetch is an area that has constant wind direction and speed. Wind direction can be stated as constant if the changes are no more than 15^o. Wind speed is stated to be constant if the changes are no more than 5 knots from the average speed. Fetch will affect wave height and period, big fetch will form wave with long period [1]. Fetch is measured at each wind direction on sea and it is measured for every 6^o angle at distance from -42^o to 42^o at every direction of influential winds come. And the equation to calculate effective fetch is by using equation 3. With X_i is the length between coast line and the closest land at every part of angle distance (sub-interval).

$$F_{eff} = \Sigma X_i \cos\alpha / \Sigma \cos\alpha$$

d. Determination of Wind Stress Factor (U_A)

By using equation 4, the wind stress factor is implemented at every wind speed data after previously being converted to various wind speed conversion.

$$U_A = 0{,}71\ U^{1{,}23} \quad (4)$$

e. Determination of Height (H_o) and Period (T) of Wave Using Wave Forecast Graphic

By using fetch length, wind stress factor and duration of wind blows then the wave forecast by using graphic (Figure 1) can be done so the value of height and wave period can be found out [1]. Correlation between U_A with the duration of wind blows is called *Time Duration Limited* and correlation between fetch effective with U_A is called Fetch Limited. *Time duration limited* is determined from the average of storm wave duration at study location. Due to difficult wind duration data some literatures usually use value of 4 hours for tropical area of [1] and [2].

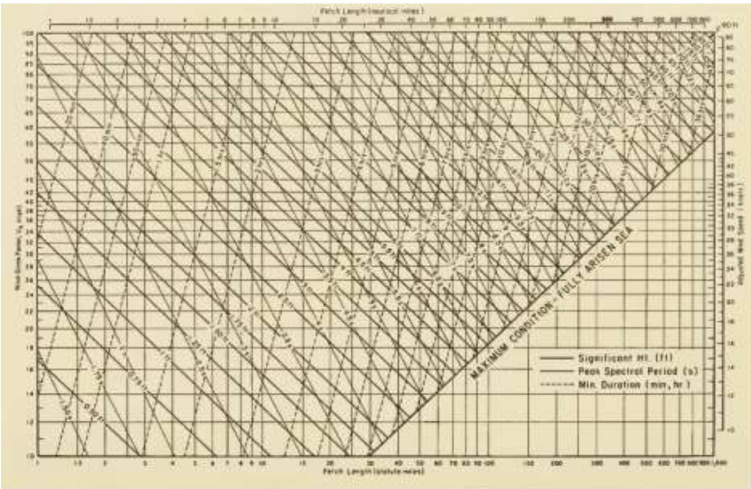

Fig. 1 Wave forecast graphic [1], [2], [4]

III. RESEARCH METHOD

Problem definition is to predict the wave (height and period) in order for monitoring and upgrading information at Lebih Beach that was carried out in the beginning, in order to make easy data collection and literature study. By using wind data from BMKG of Area III Denpasar wind frequency distribution analysis was performed to get influential dominant wind direction at Lebih Beach. Based on the dominant wind, study and formation of wind data conversion reference table was performed whether the elevation (U10), location (RL), temperature difference (RT) and wind stress factor (UA). In addition, based on the dominant wind it is also conducted calculation of fetch effective value. Furthermore by using obtained fetch value and UA value from conversion reference table it is carried out wave forecast plotting by using wave forecast graphic (figure 2) so the wave forecast reference table can be obtained whether for the Fetch Limited or the Time Duration Limited. By using data of influential wind direction and speed, wave forecast was performed at Lebih Beach so high value and significant period was obtained whether the Fetch Limited or the Time Duration Limited. Based on result obtained of high and wave period, the research was finished by summarizing research result.

IV. RESULT DISCUSSION

Wind data of year 2005-2014 was analyzed by using WRPLOT View freeware software from Lake Environment. Analysis result shows that southeast direction is the most dominant wind direction (figure 2). Wind directions to be observed in this research are the east, southeast, south, and southwest direction with percentage of occurrence such as in table 1.

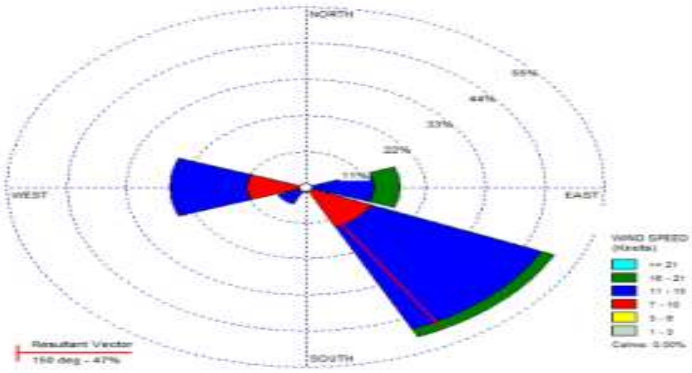

Fig. 2 Windrose data of 2004-2015

Table 1 Direction, percentage of occurrence and calculation result of fetch effective

Directions	Percentage of occurrence	Fetch Effective
East	17,50%	910,441
Southeast	50%	1000
South	1,67%	1000
Southwest	5,83%	806,874

The southeast direction has significantly higher percentage value compare to the percentage of other directions. West direction doesn't affect to the formation of wave because it doesn't have fetch length. The fetch effective is measured for the influential four directions on the formation of wave those are the east, southeast, south, and southwest directions. Result of fetch effective calculation is shown on table 1. The extreme fetch value came from the southeast and south directions. The southeast direction will have trend for big wave because the wave formation area is big and the percentage of occurrence is also high. Even though south direction has big fetch but the percentage of occurrence is small which only 2 data from total 120 data so the formation of wave is also small.

Based on monthly average wind data during ten years period obtained from BMKG of Area III Denpasar there are 120 data of wind speed and direction, cut of these data as in table 2. But due to west direction doesn't have fetch length wind speed data from west direction cannot be analyzed. Therefore for next calculation it will only use 91 data. By considering wind speed data and direction from 91 data, table 3 was made that gives conversion value to various wind speed. Based on the value of U and UA are obtained, presented in table 3. Based on wind data, maximum wind speed from data is 10 knot or UA = 7.87 m/sec with elevation of 15 m. More detailed UA value is presented in table 4. To determine wave height and period it is plotted height determination and wave period whether for the Fetch Limited or the Time Duration Limited at wave forecast graphic (figure 2).

Table 2 Cut of data of wind speed and direction year 2005-2014

Data to (of 120 data)	Speed of 15m elevation (U15) (knot)	Rounding off (knot)	Directions	Data to (of 120 data)	Speed of 15m elevation (U15) (knot)	Rounding off (knot)	Directions
1	6,7	7	West	21	7	7	Southeast
2	6,6	7	West	22	6,6	7	Southeast
3	5,8	6	West	23	6	6	Southeast
4	7	7	Southeast	24	6,3	6	Southeast
5	6,6	7	Southeast	25	6,3	6	West
6	5,9	6	Southeast	26	5,5	6	West
7	9,9	10	Southeast	27	5,1	5	West
8	7,4	7	Southeast	28	4,7	5	Southeast
9	7,4	7	Southeast	29	5,7	6	Southeast
10	6,9	7	Southeast	30	5,8	6	Southeast
11	5,8	6	Southeast	31	7	7	Southeast
12	5,1	5	West	32	5,5	6	Southeast
13	5,9	6	West	33	5	5	Southeast
14	6,6	7	West	34	5,5	6	Southeast
15	5,4	5	West	35	5,2	5	Southeast
16	5,7	6	Southeast	36	5,2	5	Southeast
17	6	6	Southeast	37	4,4	4	West
18	6,6	7	Southeast	38	5,6	6	West
19	7	7	Southeast	39	4	4	Southeast
20	7,3	7	Southeast	40	4,3	4	Southeast

Table 3 Conversion of various wind speed on land

Speed (Knot)	Speed (m/s)	U_{10} (m/s)	RL	RT	U (m/s)	U_A (m/s)
1	0,514	0,48507	2	1,1	1,067161	0,769097
2	1,028	0,97015	1,855	1,1	1,979583	1,644539
3	1,542	1,45522	1,755	1,1	2,809301	2,529497
4	2,056	1,94029	1,675	1,1	3,574989	3,402407
5	2,57	2,42537	1,6	1,1	4,268644	4,2317
6	3,084	2,91044	1,525	1,1	4,882261	4,991858
7	3,598	3,39551	1,47	1,1	5,490543	5,767467
8	4,112	3,88059	1,425	1,1	6,082817	6,54195
9	4,626	4,36566	1,38	1,1	6,627069	7,269153
10	5,14	4,85073	1,325	1,1	7,069941	7,871179

If UA value is under 6 knots (+4.99 m/s) the wind effect is less significant to be calculated so minimum limit is used that is UA = 5 m/s. Forecast result of wave period and height with Fetch Limited shows that fetch length in every direction is in fact cannot be reached. Thus, based on wave forecast graphic when wind data = 10 knots or UA = 7.87 m/s, the possible fetch to reach is 200 to 250 km. Whereas for Time Duration Limited, in this research uses minimum limit of storm wave duration at tropical area which is 4 hours. Result of wave forecast for wind speed of 1 knot to 10 knots in 15 m elevation is presented in table 4. Cut of determination result of wave period and height can be seen in table 5 and table 6. Result of wave period and height from time duration limited has smaller value than determination result with fetch limited, so the value of the height and period will be used for next calculation.

Table 4 Sea wave forecast in height and period for Fetch Limited and Time Duration Limited

Data to	Speed of 15 m elevation (U15) (knot)	U_A (m/s)	Fetch Limited								Time Duration Limited	
			Wave Height (H) (meter)				Wave Period (T) (second)					
			East	Southeast	South	Southwest	East	Southeast	South	Southwest	H (m)	T (s)
1	1	0,769097	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
2	2	1,6445389	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
3	3	2,5294974	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
4	4	3,4024069	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
5	5	4,2317005	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
6	6	4,9918576	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
7	7	5,7674674	0,85	0,85	0,85	0,85	4,93	4,93	4,93	4,93	0,45	3,25
8	8	6,5419498	1,09	1,09	1,09	1,09	5,5	5,5	5,5	5,5	0,54	3,4
9	9	7,2691528	1,25	1,25	1,25	1,25	6,06	6,06	6,06	6,06	0,58	3,5
10	10	7,8711786	1,6	1,6	1,6	1,6	6,7	6,7	6,7	6,7	0,65	3,72

Algorithm Design of Wave Forecast was initiated by the reading of conversion factor table, forecast table, and reading of input data. Based on those three things, the calculation for wave height and period of fetch limited and time duration limited was carried out for all dominant directions. The program will read input data line by line until finished, after that output process of writing is conducted of wave forecast into output final table as in tabel 5 and table 6.

Table 5 Cut of forecast result of wave height and period

Data to	Speed of 15m elevation (U15) (knot)	Rounding off (knot)	U 15 (m/s)	U10 (m/s)	RL	RT	U (m/s)	UA (m/s)
4	7	7	3,598	3,3955	1,47	1,1	5,4905	5,76747
5	6,6	7	3,598	3,3955	1,47	1,1	5,4905	5,76747
6	5,9	6	3,084	2,9104	1,525	1,1	4,8823	4,99186
7	9,9	10	5,14	4,8507	1,325	1,1	7,0699	7,87118
8	7,4	7	3,598	3,3955	1,47	1,1	5,4905	5,76747
9	7,4	7	3,598	3,3955	1,47	1,1	5,4905	5,76747
10	6,9	7	3,598	3,3955	1,47	1,1	5,4905	5,76747
11	5,8	6	3,084	2,9104	1,525	1,1	4,8823	4,99186
16	5,7	6	3,084	2,9104	1,525	1,1	4,8823	4,99186

Table 6 Cut of forecast result of wave period and height continuation

Data to	Fetch Limited								Time Duration Limited	
	Wave Height (H) (m)				Wave Period (T) (second)					
	East	Southeast	South	Southwest	East	Southeast	South	Southwest	H (m)	T (s)
4	0,85	0,85	0,85	0,85	4,93	4,93	4,93	4,93	0,45	3,25
5	0,85	0,85	0,85	0,85	4,93	4,93	4,93	4,93	0,45	3,25
6	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
7	1,6	1,6	1,6	1,6	6,7	6,7	6,7	6,7	0,65	3,72
8	0,85	0,85	0,85	0,85	4,93	4,93	4,93	4,93	0,45	3,25
9	0,85	0,85	0,85	0,85	4,93	4,93	4,93	4,93	0,45	3,25
10	0,85	0,85	0,85	0,85	4,93	4,93	4,93	4,93	0,45	3,25
11	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96
16	0,65	0,65	0,65	0,65	4,22	4,22	4,22	4,22	0,38	2,96

V. CONCLUSION

Generation of wave period and height at Lebih Beach can be done by using wind data obtained from BMKG of Area III Denpasar within 10 years period from 2005 to 2014. By using analysis result of wave forecast, the calculation can be implemented into an application of wave period and height determination that refers the wave forecast table, various wind conversion factor table, and input data of dominant wind direction and speed.

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