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North Banten Coastline Evolution Model (Case Study Tanara Beach Serang - Tanjung Kait Beach Tangerang)

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ABSTRACT

Climate Central predicts that Banten's northern coastal land will disappear by 2030. Previously, Banten has lost more than 1 kilometer of its former land. The purpose of this research is to obtain a prediction model for the evolution of the coastline between Tanara Beach (Serang Regency) to Tanjung Kait Beach, Mauk (Tangerang Regency). The method used for this research is the One-Line Model method. Based on the coastline prediction model of segment 1, Tenjoayu progressed from 2025 to 2030. Shoreline retreat occurs significantly from 2020 to 2030 around Pedaleman. The modeled shoreline around Pedaleman to the western part of Cup Island progressed significantly from 2022-2030. The shoreline in segment 2, East of Cup Island, progressed from 2025 to 2030. West of the Ci Manceuri Estuary, the coastline retreats significantly from 2022 to 2030. East of the Ci Manceuri Estuary, the coastline tends to stabilize. Around Tanjung Kait Beach, the shoreline pattern advances in each year significantly from 2022 to 2030.

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1. INTRODUCTION

Climate Central predicts that Banten's northern coastal land will disappear by 2030. Previously, Banten had already lost more than 1 kilometer of its former land. In the records of DLHK Banten, there is a document that displays changes in the coastline in Serang Regency. For 32 years the lost land is quite extensive [1].

The impact of shoreline changes is quite a lot, both erosion and accretion. Areas that experience erosion will have an impact on environmental damage and infrastructure around the coast [2]. Coastal land will become narrower and damage to buildings, roads, rice fields, recreational areas, and settlements are eroded due to the impact of erosion on the coast. The retreat of the coastline will also trigger land conflicts related to the utilization of the coastal boundary [3]. In addition to erosion disasters, accretion events also have their own impacts, namely causing siltation of estuaries and obstruction of river flow to the sea so that the river has the potential to cause flooding. If flooding occurs, it will cause new problems for the environment in the area near the river [4].

The beach is a dynamic area with various coastal ecosystems that live interrelated with each other The changing coastline is a form of dynamization of the coastal area that occurs continuously [5]. The coastal body can increase in size (accretion or sedimentation) and can also decrease in size (erosion) so that it is called shoreline change. Accretion and erosion are caused by currents that carry sediment transport from various sources such as the sea, rivers or beach materials. Sediment transportation that continues to take place results in erosion and accretion [6].

The sediment transportation process is influenced by various factors. Factors that affect shoreline changes are classified into two, first Hydro-Oceanographic (natural) factors such as waves, currents and tides that can cause erosion. Next are Anthropogenic factors (human activities) which are also divided into two groups, namely deliberate disturbance activities that are protective of the coastline and coastal environment, for example by building jetti, groins, breakwaters or coastal reclamation. Unintentional human activities cause negative disturbances to the shoreline and coastal environment, for example the clearing of mangrove forests to be converted as ponds [7].

The North Java coastline is a coastline that experiences very high dynamization both due to Hydro-Oceanographic factors and Anthropogenic factors. The north coast of Java, better known as pantura, experiences a high level of abrasion, as the results of research conducted in Central Java Province [8] and [9]; in East Java Province [10]; and in West Java Province [11]. Similarly, in the coastal areas of Banten Province, the abrasion rate is also reported to be very high [12] and [13].

In the period 2004-2019, abrasion occurred in almost 20 villages out of a total of 23 coastal villages in Tangerang Regency. The highest abrasion was in Kohod Village, Pakuhaji Subdistrict amounting to 71.55 ha of lost land area, while the highest accretion occurred in the estuary of the Cisadane River estuary, Tanjungburung Village, Teluknaga Subdistrict [14]. Research on the coastline of Tanjung Pasir in Tangerang Regency also experienced maximum erosion [13]. Meanwhile, intensive addition of land area also occurred due to the reclamation process for Pantai Indah Kapuk housing [15].

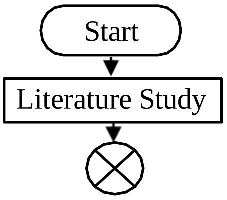
In addition to Jakarta, Tangerang is also adjacent to Serang which has experienced the highest shoreline changes from 2009 to 2016 in Banten Bay with erosion data reaching 192 ha and accretion of 308.5 ha so that the dominant accretion [16]. The results of the Tanjung Pontang Coastal Research in Serang Regency experienced serious abrasion and sedimentation problems [12].

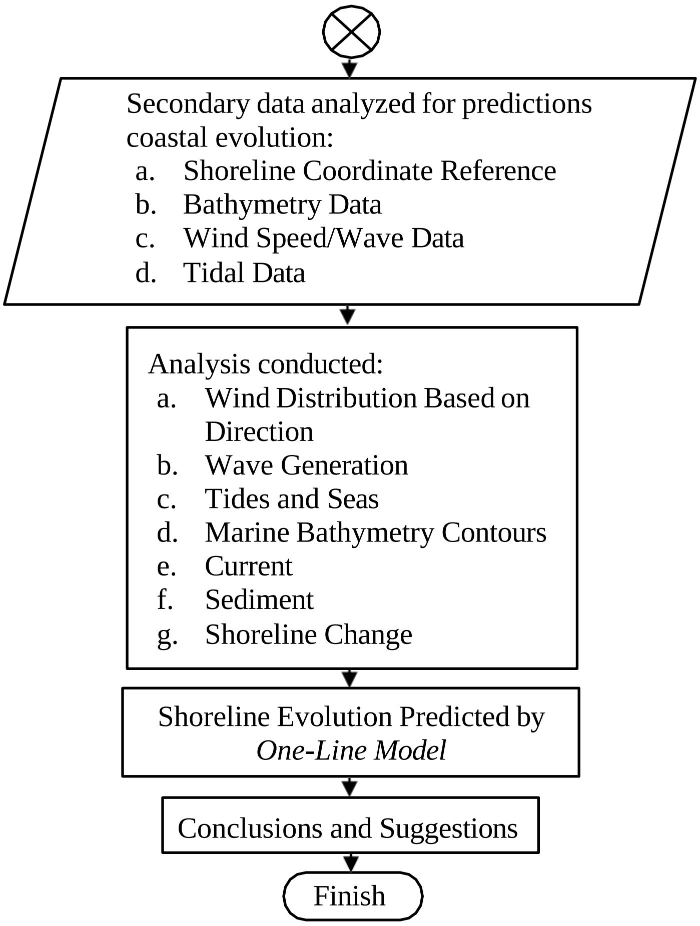
Based on the background of these problems, the author will examine changes in the coastline along Tanara Beach (Serang) to Tanjung Kait Beach (Tangerang) utilizing Google Earth Pro application technology and One Line-Model analysis.

2. METHODS

2.1 One Line-Model Method

One of the mathematical models that can be used to simulate shoreline changes is the One-Line Model. In the One-Line Model, it is assumed that the shape of the shoreline profile does not change during the simulation process. In this model, the shoreline is divided into several sections and in each section the incoming and outgoing sediment transport will be calculated.





Gambar 1. Flowchart of research on predicting the evolution of shoreline change

The data analysis method was created to assist in the analysis process to be carried out, it is depicted in the form of the diagram above and explained as follows.

a. Wave Analysis
   Wave analysis in the deep sea is calculated using wind data on land. The wind data is then converted into wave data in the deep sea.
b. Tidal Analysis
   Tidal analysis is carried out to be able to see fluctuations in sea level in the waters from Tanara to Tanjung Kait.
c. Bathymetry Analysis
   Bathymetry analysis was conducted to be able to determine how the topography of the sea in the waters of Tanara to Tanjung Kait. Bathymetry analysis is used to analyze contours in the sea along the coast of the research location.
d. Beach Sediment Analysis
   The amount of sediment transport that occurs on the beach needs to be analyzed to know how much beach sand is moving.
e. Shoreline Change Analysis
   Analysis of shoreline changes using the one-line model method. This analysis can be used to predict the evolution of the coastline so that appropriate coastal protection measures can be taken.

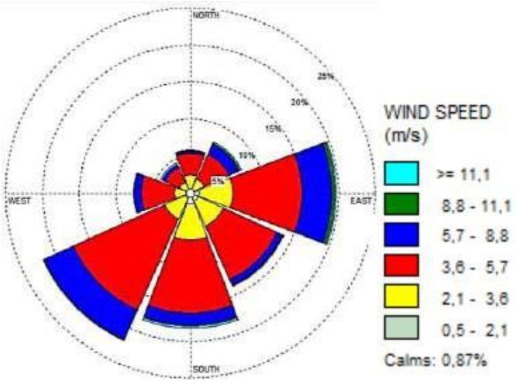
3. RESULTS AND DISCUSSION

Gambar 2. Research location North Coast of Banten (Tanara Serang - Tanjung Kait Tangerang)

Gambar 3. Research location segment 1 and segment 2

3.1 Wind

The wind data obtained comes from the BMKG Website Tangerang Geophysical Station closest to the review beach. Data in the form of maximum wind speed (m/s), wind direction at maximum speed (°) and the most wind direction (°) every hour for 11 years, namely 2012-2022. The wind data was processed into a windrose using the WRPLOT application. Figure 4 is a windrose of the processed wind data in 2012-2022 and this wind data is then used for wave analysis.



Gambar 4. Windrose of headwind events at Tanara-Tanjung Kait Beach, Banten 2012-2022

Based on the distribution of wind speed and direction, only the most dominant wind direction that affects the location of the beach is chosen, namely the wind direction towards the Southwest (SW).

3.2 Wind Speed by Return Period

Wind data that has been available for several years is only used one wind speed data for one return period as wind speed data for wave analysis. This wind speed calculation plan uses statistical analysis or often called the weibull method and fisher tippet type 1 based on the frequency of wind events.

Tabel 1. Basic statistical calculation of significant wind speed (FT-1 Method)

No	Usm, Wind Speed (m/s)	Usm, Wind Speed (m/s)	P	y_m	$U_{sm} y_m$	y_m^2	$(U_{sm} - \bar{U}_{sm})^2$	$\hat{U}_{sm}$	$U_{sm} - \hat{U}_{sm}$	$(U_{sm} - \hat{U}_{sm})^2$
1	14.93	14.93	0.950	2.963	44.245	8.778	68.296	11.329	3.605	12.993
2	6.71	6.71	0.860	1.889	12.686	3.570	0.002	9.261	-2.547	6.487
3	6.50	6.55	0.770	1.341	8.776	1.798	0.015	8.204	-1.659	2.752
4	6.55	6.50	0.680	0.952	6.190	0.907	0.029	7.456	-0.956	0.914
5	5.29	6.33	0.590	0.639	4.048	0.408	0.113	6.853	-0.520	0.270
6	5.88	5.88	0.500	0.367	2.156	0.134	0.619	6.328	-0.445	0.198
7	5.83	5.83	0.410	0.115	0.670	0.013	0.699	5.843	-0.010	0.000
8	5.00	5.33	0.320	-0.130	-0.694	0.017	1.785	5.371	-0.038	0.001
9	5.00	5.29	0.230	-0.384	-2.032	0.148	1.914	4.881	0.404	0.164
10	6.33	5.00	0.140	-0.675	-3.375	0.456	2.786	4.322	0.678	0.460
11	5.33	5.00	0.050	-1.095	-5.474	1.199	2.786	3.513	1.487	2.211
Total		**73.36**		**5.982**	**67.196**	**17.428**	**79.044**	**73.361**	**0.000**	**26.450**
Average		**6.67**								

(Sumber : Author's Analysis, 2023)

Tabel 2. Calculation of significant wind speed return period (FT-1 Method)

Return Period, T_r (th)	y_r (th)	Usr (m/s)	σ_{nr}	σ_r	Us - 1,28σ_r (m)	Us + 1,28σ_r (m)
2	0.367	6.328	0.320	0.900	5.175	7.480
5	1.500	8.511	0.535	1.503	6.587	10.435
10	2.250	9.956	0.728	2.046	7.337	12.576
20	2.970	11.343	0.925	2.600	8.014	14.671
25	3.199	11.783	0.989	2.780	8.225	15.341
50	3.902	13.138	1.188	3.339	8.864	17.412
100	4.600	14.483	1.387	3.901	9.490	19.475

(Sumber : Author's Analysis, 2023)

Tabel 3. Basic statistical calculation of significant wind speed (Weibull Method)

No	Usm, Wind Speed (m/s)	Usm, Wind Speed (m/s)	P	y_m	$U_{sm} y_m$	y_m^2	$(U_{sm} - \bar{U}_{sm})^2$	$\hat{U}_{sm}$	$U_{sm} - \hat{U}_{sm}$	$(U_{sm} - \hat{U}_{sm})^2$
1	14.93	14.93	0.946	1.711	25.545	2.926	68.296	10.778	4.156	17.271
2	6.71	6.71	0.858	1.398	9.387	1.955	0.002	9.220	-2.506	6.278
3	6.50	6.55	0.770	1.213	7.940	1.471	0.015	8.297	-1.752	3.068
4	6.55	6.50	0.682	1.071	6.961	1.147	0.029	7.589	-1.089	1.186

5	5.29	6.33	0.594	0.950	6.016	0.902	0.113	6.986	-0.652	0.426
6	5.88	5.88	0.506	0.840	4.942	0.706	0.619	6.439	-0.557	0.310
7	5.83	5.83	0.418	0.736	4.294	0.542	0.699	5.920	-0.087	0.008
8	5.00	5.33	0.330	0.633	3.377	0.401	1.785	5.407	-0.074	0.005
9	5.00	5.29	0.242	0.527	2.784	0.278	1.914	4.877	0.409	0.167
10	6.33	5.00	0.154	0.409	2.047	0.168	2.786	4.292	0.708	0.502
11	5.33	5.00	0.066	0.262	1.310	0.069	2.786	3.557	1.443	2.083
Total		**73.36**		**9.750**	**74.604**	**10.564**	**79.044**	**73.361**	**0.000**	**31.304**
Average		**6.67**								

(Sumber : Author's Analysis, 2023)

Tabel 4. Calculation of significant wind speed return period (Weibull Method)

Return Period, T_r (th)	y_r *(th)*	***Usr* (m/s)**	σ_{nr}	σ_r	*Us - 1,28σ_r (m)*	*Us + 1,28σ_r (m)*
2	0.833	6.401	0.358	1.007	5.112	7.689
5	1.269	8.575	0.539	1.515	6.636	10.513
10	1.517	9.815	0.663	1.865	7.427	12.202
20	1.731	10.878	0.776	2.181	8.086	13.670
25	1.794	11.194	0.810	2.277	8.279	14.108
50	1.978	12.110	0.910	2.558	8.836	15.384
100	2.146	12.948	1.002	2.818	9.340	16.555

(Sumber : Author's Analysis, 2023)

Tabel 5. Recapitulation of return period analysis results

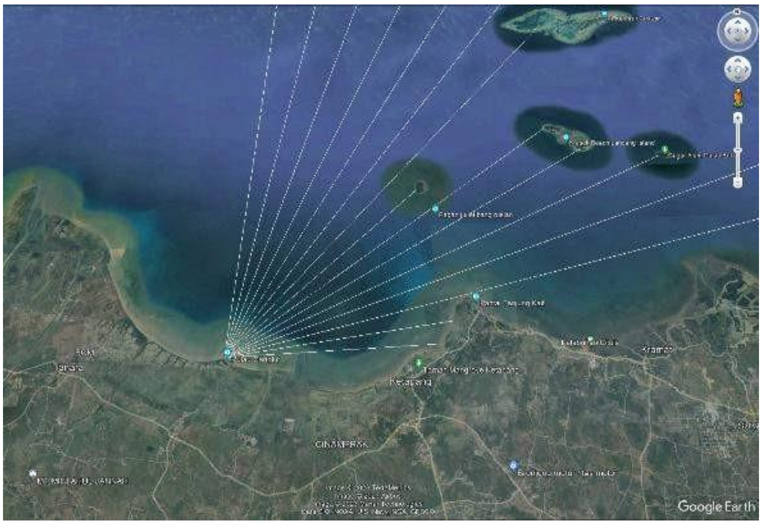
Return Period (Year)	**Fisher Tippet I Distribution**			**Weibull Distribution**		
	Wind Speed			**Wind Speed**		
	Us - 1,28σ_r (m)	**U_{sr} (m/s)**	**Us + 1,28σ_r (m)**	**Us - 1,28σ_r (m)**	**U_{sr} (m/s)**	**Us + 1,28σ_r (m)**
2	5.175	6.328	7.480	5.112	6.401	7.689
5	6.587	8.511	10.435	6.636	8.575	10.513
10	7.337	9.956	12.576	7.427	9.815	12.202
20	8.014	11.343	14.671	8.086	10.878	13.670
25	8.225	11.783	15.341	8.279	11.194	14.108
50	8.864	13.138	17.412	8.836	12.110	15.384
100	9.490	14.483	19.475	9.340	12.948	16.555
Determination Number		**0.6654**			**0.6040**	

(Sumber : Author's Analysis, 2023)

From the two distributions that have been carried out, the determination number is greater in the fisher tippet type 1 distribution, so the wind speed that will be used for wave analysis with a return period of 2 years is 6.328 m/s.

3.3 Fetch Length (Wind Trajectory)

Tanara-Tanjung Kait beach is located in the north of Java island with the coastline facing north. The wind direction that affects this beach is the direction towards the Southwest, South and Southeast. While other directions do not affect directly, but it is possible to deflect towards Tanara-Tanjung Kait Beach. The wind direction used in this study is limited to using only one of the most influential wind directions, namely the direction to the Southwest. The calculation of the fetch length uses Google Earth Pro so that it has a fairly high accuracy in determining the fetch. By drawing a long line from the review coordinates at 106°26'28.56" East and 6°1'53.43" LS, the effective fetch length with the Southwest generation area can be seen through Figure 5.



Gambar 5. Effective fetch in the southwest direction

Fetch effective Southwest (SW) = 85,62 Km

3.4 Wave Forecasting in the Deep Sea

Wave forecasting using nomograms was carried out with the Fetch Limited and Time Duration Limited systems. The results of the two systems are chosen the smallest.

Based on the graphical method, H0 and T0 are obtained from the Fetch Limited and Time Duration Limited methods as follows:

Tabel 6. Recapitulation of wave height and period in the deep sea

Return Period	*Fetch Limited*		*Time Duration Limited*	
	Wave Height, H_o (m)	**Wave Period, T_o (s)**	**Wave Height, H_o (m)**	**Wave Period, T_o (s)**
2	1,60	6,05	0,94	4,30

(Sumber : Author's Analysis, 2023)

Based on Table 6, the smallest H_0 and T_0 of the Time Duration Limited system are selected:

H_0 = 0,94 m

T_0 = 4,30 s

3.5 Breaking Wave Analysis

Tabel 7. Calculation of breaking waves

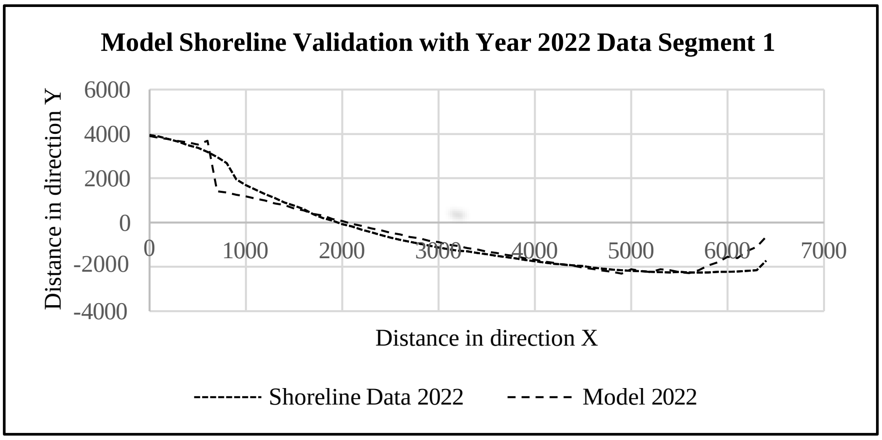
Determining H_i		**Determining Hb**		
D	**H_i**	**db**	**Hb**	**Keterangan**
10	0,90	10	7,31	Unbreakable
5	0,81	5	3,81	Unbreakable
2,00	0,81	2	1,56	Unbreakable
1,20	0,86	1,2	0,94	Unbreakable
1,16	0,87	1,16	0,91	Unbreakable
1,12	0,87	1,12	0,88	Unbreakable
1,11	0,87	1,11	0,87	Start to Break
1	0,89	1	0,79	Already Broken

(Sumber : Author’s Analysis, 2023)

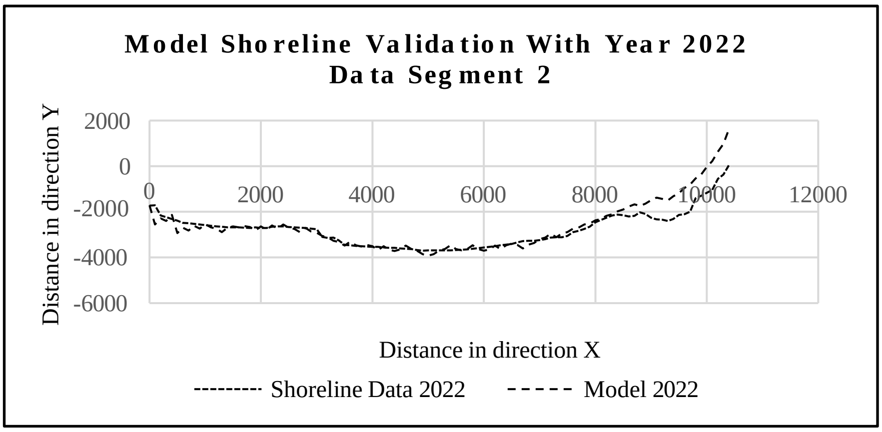
Based on Table 7, it is known that the waves begin to break at a depth of 1.11 m.

3.6 Prediction of Shoreline Evolution with One Line-Model

After the breaking wave analysis in each segment, the sediment transport calculation and modelling stages were carried out.
Comparison of modeled coastline with data in 2022:



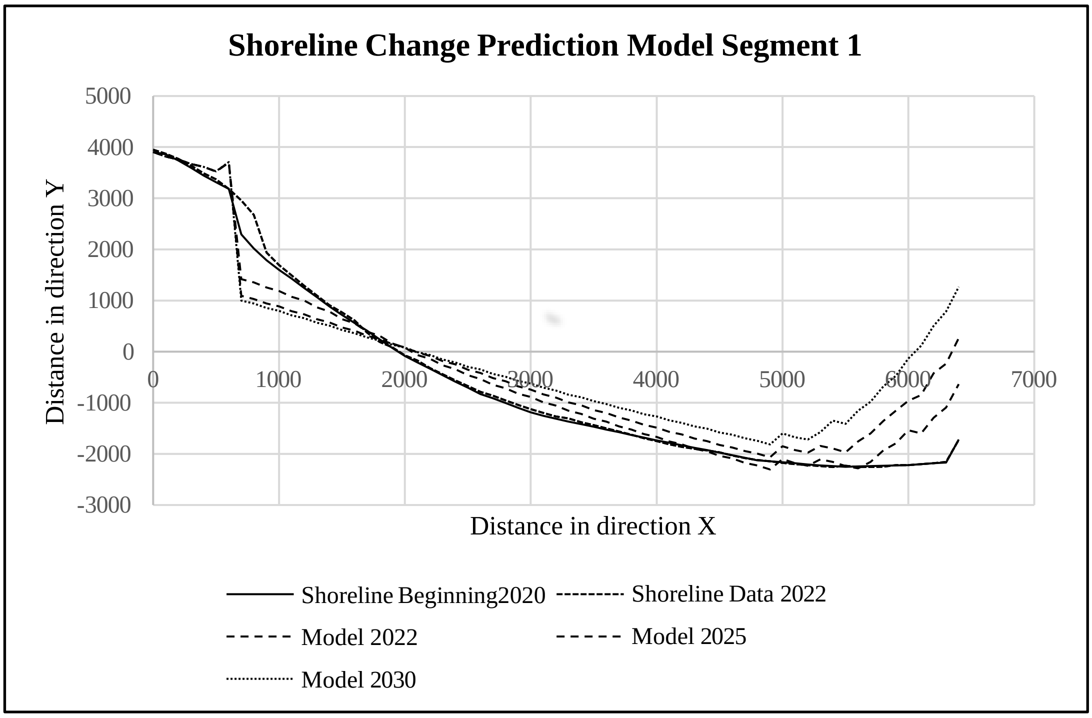
Gambar 6. Validation of shoreline model segment 1



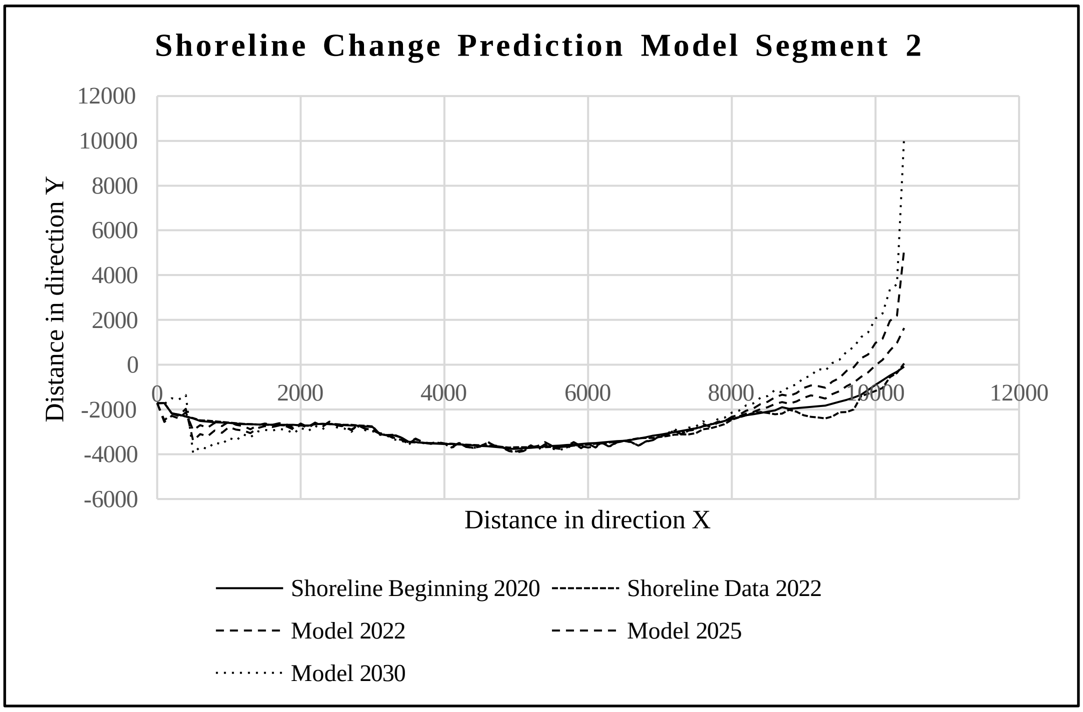
Gambar 7. Validation of shoreline model segment 2

The results of the prediction of the Tanara - Tanjung Kait coastline in 2022 with the one-line model method after adjustment/calibration are shown in Figures 6 and 7.

The following model predicts the evolution of the coastline at Tanara-Tanjung Kait Beach from 2022-2030:



Gambar 8. Shoreline evolution model segment 1



Gambar 9. Shoreline evolution model segment 2

The Tanara-Tanjung Kait coastline is divided into 2 segments because it is separated by Cup Island which is between the two segments. In the first stage of simulating shoreline changes, the model was validated against the 2022 shoreline. Based on the validation results, there is a similarity of the coastline model between the model coastline and the 2022 data coastline in almost all segments of Figures 6 and 7. After going through the first stage, namely validation and it is believed that the model has obtained the best validation results, then simulation of coastline changes is carried out until a certain period of time. In this study, shoreline change simulations were carried out until 2030.

Based on the shoreline modeling simulation, it was found that for segment 1, STA 0-500 m (Tenjoayu, Tanara), the shoreline progressed but only from 2025 to 2030. Shoreline retreat occurs significantly from 2020 to 2025 and retreat shortens from 2025 to 2030 around STA 500-2000 m (Pedaleman, Tanara). The shoreline model around STA 2000-6400 m (Pedaleman- Western part of Cup Island, Kronjo) has significant progress every year from 2022-2030.

Gambar 10. Predicted shoreline evolution in segment 1

Information:

———————	Shoreline Beginning 2020	- - - - - - - - - - -	Model 2025
-·-·-·-·-·-·-	Shoreline Data 2022	······················	Model 2030
— — — —	Model 2022		

The shoreline in segment 2 tends to be stable in the middle but unstable at the ends of the shoreline. Around STA 0-500 m (East of Cup Island) the coastline advances from 2025 to 2030. STA 500-2000 m (West of Ci Manceuri Estuary) the model shows the shoreline retreats significantly from 2022 to 2030. In the middle area of the span, STA 2000-8000 m (East of Ci Manceuri Estuary-Ketapang), the coastline tends to be stable, experiencing insignificant progress and regression. Around STA 8000-10400 m (Ketapang-Tanjung Kait Beach) the coastline pattern advances in each year significantly from 2022 to 2030.

Gambar 11. Predicted shoreline evolution in segment 2

Information
———————— Shoreline Beginning 2020
–·–·–·–·–·–· Shoreline Data 2022
— — — — Model 2022
------------ Model 2025
.... Model 2030

The results of the prediction of the Tanara Serang-Tanjung Kait Tangerang coastline with the One- Line Model Method can be used to predict the coastline in the future with a note that there is no intervention on the beach, for example the construction of coastal safety buildings, artificial islands, etc.

4. CONCLUSION

Shoreline evolution prediction model between Tanara Beach (Serang Regency) to Tanjung Kait Beach, Mauk (Tangerang Regency) was obtained by modeling simulation of shoreline changes in 2022-2030. Based on the shoreline modeling simulation, it was found that for segment 1, Tenjoayu, Tanara, the shoreline experienced accretion (forward) but only from 2025 to 2030. Shoreline erosion occurs significantly from 2020 to 2025 and erosion shortens from 2025 to 2030 around Pedaleman, Tanara. The shoreline model around Pedaleman to the West of Cup Island, Kronjo has significant accretion every year from 2022-2030. The shoreline in segment 2 tends to be stable in the middle but unstable at the ends of the shoreline. East of Cup Island, the shoreline experiences accretion from 2025 to 2030. STA 500-2000 m, West of Ci Manceuri Estuary, the model shows the shoreline erodes (retreats) significantly from Year 2022 to 2030. In the middle of the range, East of the Ci Manceuri-Ketapang Estuary, the coastline tends to be stable, experiencing insignificant accretion and erosion. Around Ketapang to Tanjung Kait Beach, the shoreline pattern is accreted in each year significantly from 2022 to 2030. This can be seen in Figures 10 and 11.

REFERENCES

[1] S. Mustika, ‘Daratan Pesisir Utara Banten Sudah Hilang Lebih dari 1Km!’, *detikTravel*, 2022.

[2] S. Pranoto, ‘Prediksi Perubahan Garis Pantai Menggunakan Model Genesis’, 2007.

[3] H. Setiawan and Supriatna, ‘Monitoring Perubahan Garis Pantai Untuk Evaluasi Rencana Tata Ruang Dan Penanggulangan Bencana Di Kabupaten Tangerang ’, *Jurnal Sains Informasi Geografi*, vol. 4, no. 2, pp. 60–67, Nov. 2021.

[4] N. P. Purnaditya, I. G. B. S. Dharma, and I. G. N. P. Dirgayusa, ‘Prediksi Perubahan Garis Pantai Nusa Dua Dengan One-Line Model’, *Jurnal Ilmiah Elektronik Infrastruktur Teknik Sipil*, pp. 1–8, 2012.

[5] Yonvitner, H. A. Susanto, and E. Yuliana, *Pengertian, Potensi dan Karakteristik Wilayah Pesisir*, 1st ed. Pengelolaan Wilayah Pesisir dan Laut.

[6] B. Triatmodjo, *Teknik Pantai*, 8th ed. Yogyakarta: Beta, 2016.

[7] Sutikno, *Kharakteristik Bentuk dan Geologi Pantai di Indonesia*, 3rd ed. Yogyakarta: Direktorat Jendral Pengairan Departemen Pekerjaan Umum, Fakultas Geografi UGM, 1993.

[8] R. Hartati, R. Pribadi, R. Astuti, R. Yesiana, and I. Yuni, ‘Kajian Pengamanan dan Perlindungan Pantai di Wilayah Pesisir Kecamatan Tugu dan Genuk, Kota Semarang’, *Jurnal Kelautan Tropis*, vol. 19, no. 2, pp. 95–100, 2016.

[9] E. Maulana, T. Wulan, D. Wahyuningsih, W. Mahendra, and W. Siswanti, ‘Strategi Pengurangan Risiko Abrasi di Pesisir Kabupaten Rembang, Jawa Tengah’, *Prosiding Seminar Nasional Geografi*, pp. 348–398, 2016.

[10] V. Utami and A. Pamungkas, ‘Identifikasi Kawasan Rentan Terhadap Abrasi di Pesisir Kabupaten Tuban’, *Jurnal Teknik Pomits*, pp. 114–117, 2013.

[11] A. Heriati and S. Husrin, ‘Perubahan Garis Pantai di Pesisir Cirebon Berdasarkan Analisis Spasial’, *Reka Geomatika*, pp. 52–60, 2017.

[12] J. Prihantono, I. A. Fajrianto, and Y. N. Kurniadi, ‘Permodelan Hidrodinamika dan Transpor Sedimen di perairan pesisir sekitar Tanjung Pontang, Kabupaten Serang – Banten’, *Jurnal Kelautan Nasional*, vol. 13, no. 2, pp. 75–88, Aug. 2018.

[13] I. Sebayang and A. Kurniadi, ‘Identifikasi dan Analisis Kerusakan Garis Pantai Tanjung Pasir di Kabupaten Tangerang, Banten’, *Rekayasa Sipil*, vol. 4, no. 1, pp. 11–20, Feb. 2015.

[14] E. Suwandana, ‘Dinamika Morfologi Pantai Kabupaten Tangerang Banten Dan Pantai Indah Kapuk Jakarta Melalui Analisis Citra Google Earth’, *Jurnal Perikanan dan Kelautan*, vol. 9, no. 1, pp. 55–68, Jun. 2019.

[15] T. Anugrahini, ‘Resiliensi Sosial Nelayan Kamal Muara dalam Menghadapi Dampak Reklamasi Teluk Jakarta’, *Jurnal Penelitian Kesejahteraan Sosial*, vol. 17, no. 1, pp. 37–46, 2018.

[16] I. Suhardi and R. Saraswati, *Perubahan Garis Pantai Pesisir Utara Jawa*, 1st ed. Depok: Departemen Geografi FMIPA UI, 2020.