PRELIMINARY INVESTIGATION OF SHORELINE RESPONSE IN SAN JUAN, LA UNION, PHILIPPINES

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1. ABSTRACT:

Coastal erosion has been affected by environmental factors and human development. The investigation of the coastal erosion in San Juan, La Union covers the analysis and quantitative data that can be applied to protect the coastal community, to minimize economic losses, and to plan for the improvement of coastal process response. The main objective of this study was to investigate the shoreline response based on the extent of the coastal erosion problem of the 5.36 km - coastline of San Juan La Union and predict the long-term erosion pattern and shoreline change. The characteristics of the triggering factors of coastal erosion were evaluated during normal and extreme weather conditions. The areas along the coastline were characterized whether it experienced dominant deposition or erosion. Changes in shoreline position were assessed to predict future shoreline change scenarios. Sediment transport analysis was conducted by using the Kamphuis Formula and the CERC Formula. For Kamphuis, it was found that the beach slope had a significant effect on the amount of sediment transport rate. The values for normal conditions range from 9969 to 70857 $m^3/year$ while extreme conditions range from 202,703.99 to 10,640,468.54 $m^3/year$. For CERC, it was found that all were having the same value per month. The values for normal conditions range from 43215 to 158819 $m^3/year$ while extreme conditions range from 1,535,746,276 to 51,912,451,224 $m^3/year$. The shoreline positioning analysis showed that the southern region of the study area was dominated by erosion and the central to northern regions were dominated by deposition. The 1985 to 2020 shoreline change indicated an average movement of shoreline at 57.036 cm/yr and at 51.903 cm/yr characterized by recession and advancement, respectively. Furthermore, the shoreline prediction analysis reveals that the rate of displacement from 2020-2050 is 131.56 cm/yr and 173.04 cm/yr showing deposition and erosion patterns, respectively.

2. METHDOLOGY:

2.1 WIND HINDCASTING:

According to Barua (2005), "Wave hindcasts refer to the predictions of wind waves on the water surface for a past event. Wave nowcasts and forecasts similarly refer to the predictions in real time and in the future, respectively". With the wind data obtained from online sources, as well as from Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), a relationship can be established between the wind data and wave characteristics.

2.2 SEDIMENT TRANSPORT ANALYSIS:

The displacement of sediments was computed through different numerical formulas. These numerical formulas include Kamphuis 1991 Formula and CERC Formula. The Kamphuis formula, equation 1, takes into account parameters such as wave breaker direction, wave breaker height, bed slope, sediment grain size, effect of swells. The CERC formula, equation 2, was applied along with models to estimate the sediment transport rate in different zones. The analysis begins by determining the wave current and readjustment of pumps under the model. Then, the conditions of the wave were designed to simulate longshore transport.

EQUATION:

$$Q_{vol} = (6.4x10^4)(H_{sbr})^2\,(T_{op})^{1.5}\,(m_b)^{0.75}\,(D_{50})^{-0.25}sin^{0.6}(2\theta_{br}) \quad \text{(Eq. 1)}$$

Where:

$$\mathrm{Q_{vol}} = \text{total longshore transport rate, m}^3\text{/year}$$
$$\mathrm{H_{sbr}} = \text{Height of breaker wave}$$
$$\mathrm{T_{op}} = \text{Peak Wave Period, Seconds}$$
$$\mathrm{m_b} = \text{Slope of Beach, Meters}$$
$$\mathrm{m_b} = \frac{\text{Average Depth}}{500\text{ m}}\ \text{(with reference to mean sea level)}$$
$$\mathrm{D_{50}} = \text{Mean Grain Size, Millimeters}$$
$$\theta_{br} = \text{Break Wave Angle, }\theta$$

$$Q = (2.9x10^6)(H_{sb}^{\frac{5}{2}})(\sin(\theta_b)) \quad \text{(Eq.2)}$$

Where:

$$\mathrm{Q} = \text{Submerged total longshore transport rate, m}^3\text{/year}$$
$$\mathrm{H_b} = \text{Significant wave height at breaking, meters}$$
$$\theta_b = \text{Breaker Wave Angle, }\theta$$

3. RESULTS AND DISCUSSION:

From the accessed data of NAMRIA, Figure 3.1 shows the tide data with respect to the mean lower low water (MLLW) for years 2010 to 2020 in Curimao Tide Station (Ilocos Norte). The tide data were on a per hour basis for each day so the researchers used the minimum, maximum, and average values for each day. With the given data, the researchers found that the tide elevation usually increases from June to September then decreases back to its normal tide height. The recorded tide heights from these months were usually the highest and can reach up to greater than 200 cm and the highest recorded height was 238 cm. The lowest tide heights for the on the other hand were lower than 100 cm and the lowest recorded height was 70 cm. The average tide height was near the 150 cm mark.

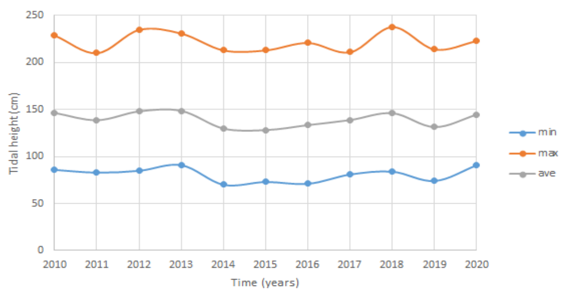

Figure 3.1 Tide Data for Years 2010-2020 (NAMRIA)

With the wind data accessed from PAGASA and researchers' use of wind hindcasting method for wave height and maximum time of wave, Figure 3.2 represents the yearly sediment transport rate of both Kamphuis and CERC Formula for normal conditions. The values obtained from using the CERC formula had higher values compared to the values obtained from Kamphuis Formula. The percent difference between the two equations would range between 239 to 261 percent. This is caused by the CERC formula which can sometimes overestimate/underestimate the sediment transport rates due to the K coefficient. The K coefficient is used as a calibration tool obtained from the experimental setup of the beach. Both follow the same trend, having an increasing value of sediment transport from 2000 to 2015 and decreasing in the year 2019. The upward trend could be used to predict the future sediment transport rate.

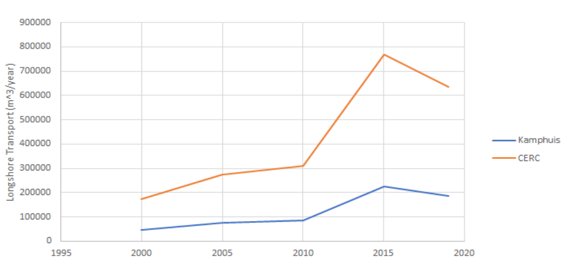

Figure 3.2 Comparison between Kamphuis and CERC Formula (Normal Conditions)

With the results obtained from the application of the Kamphuis and CERC formulas to predict the future sediment transport rates, a trendline was acquired. This was done by finding a relationship between the values obtained from the sediment transport rates using the Kamphuis and CERC formula and forming a trendline. In analyzing the trendline, it was found that the best formula which had the highest coefficient of determination was the polynomial. Figure 5.2.4.1 shows the trendline equation with the corresponding coefficient of determination from 2000 until 2050. It can be seen that the trend of sediment transport rate is increasing exponentially throughout the years until the year 2050. The culmination of this explanation is seen in Figure 3.3.

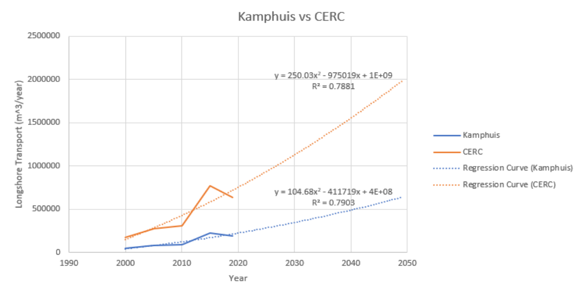

Figure 3.3 Prediction of Sediment Transport Rates projected to year 2050

The change in shoreline position over a time scale period would generate either a deposition scenario or an erosion scenario. It was important to note that even though the net change of area would be determined as deposition or erosion, both processes still occur within the study area. Table 3.1 shows that the years from 1985 to 2005 yielded to an erosion change of the area. Meanwhile, the other time periods (2005-2010, 2010-2015, and 2015-2020) resulted to deposition in littoral net balance. Overall, the net change throughout the years was deposition throughout the study area.

Table 3.1 Summary of change in area for the different time periods

Year 1	Year 2	Characteristic	Change in Area (m^2/year)
1985	2005	Erosion	-4970.04
2005	2010	Deposition	10000.79
Year 1	Year 2	Characteristic	Change in Area (m^2/year)
2010	2015	Deposition	16168.69
2015	2020	Deposition	2030.03
		Total	23229.47

With the transects established and by computing the perpendicular distance for every interval of 50 meters across the shoreline for each time period with the use of QGIS, the estimated scenarios for future shoreline shape were found. The first scenario for prediction (Figure 3.4) was to obtain the linear rate of displacement and project it over the deposition and erosion area of shoreline change from 2015 to 2020. The second scenario (Figure 3.5) for prediction was to obtain the best fit line from the graphed rate of displacement in terms of erosion and deposition and project the shoreline displacement in terms of the areas of deposition and erosion from the change in shoreline from 1985 to 2020. In Figure 5.5.3, the year 1985 was set as the origin. The best fit line from the formed respective trendlines for deposition and erosion was then projected to forecast the scenarios for 2030, 2040, and 2050. The rate of displacement in terms of deposition for the year 2030, 2040, 2050, with reference to the year 2020 was approximately 495.754 cm per year, 563.98 cm per year, and 632.206 cm per year respectively. The rate of displacement in terms of erosion for the year 2030, 2040, 2050, with reference to year 2020 was approximately 268.954 cm per year, 286.922 cm per year, and 304.89 cm per year respectively.

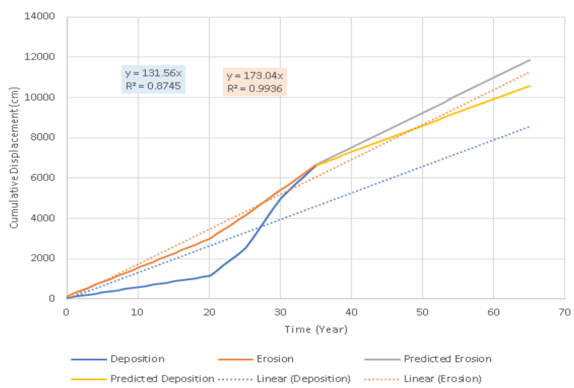

Figure 3.4 First Scenario: Linear Rate of Displacement to Predict Shoreline Shape in 2030, 2040, and 2050

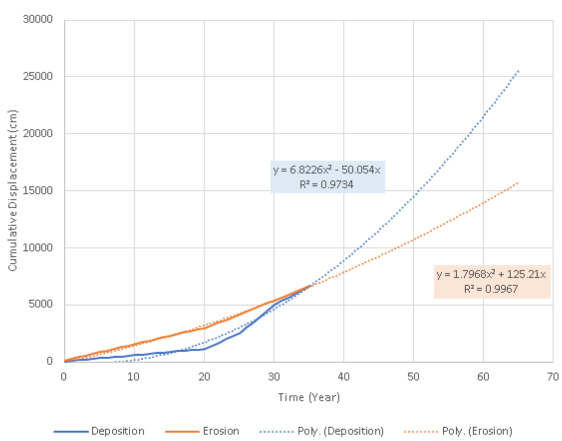

Figure 3.5 First Scenario: Linear Rate of Displacement to Predict Shoreline Shape in 2030, 2040, and 2050

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