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Investigation of Pantai Punggur Coastal Erosion by using UAV Photogrammetry

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ABSTRACT

The shoreline is the line that marks the boundary between water and land. Monitoring and analysing shoreline changes is critical because it provides a greater understanding of the shoreline changes as well as the identification of beach conditions. As its usage is more dependable and simpler than the previous technologies used, the use of an Unmanned Aerial Vehicle (UAV) or drone has become a significant technology in coastal engineering, particularly in the research of shoreline changes. The focus of this research is to assess the state of the shoreline at selected beaches, acquire shoreline data, and measure shoreline changes through processed imagery. The flight planning route has been programmed in "Pix4D Capture" application and the drone will capture the image throughout the grid line set. The Pix4d Mapper and Global Mapper software were used to process the data on shoreline changes. From the 19th of October 2020 to the 10th of August 2021, shoreline changes were monitored throughout the one-year period. The changes show that the maximum shoreline evolution is 7.47 m and the minimum shoreline evolution is 0.36 m. The changes in the shoreline were obvious in less than a year, indicating that Pantai Punggur is in a state of erosion.

Keywords: Shoreline, UAV photogrammetry, Unmanned Aerial Vehicle

1. INTRODUCTION

Coastal erosion is a natural phenomenon caused by the interactions of natural processes and structures at the beaches and oceans [1]. Coastal erosion can be defined as the removal of material from the coast by wave action and tidal currents causing a landward retreat of the coastline [2]. The combination of both natural and human influences is the reason that erosion happens continuously along the coast [3]. Coasts worldwide are undergoing constant changes, such as erosion and accretion [4]. In this situation, due to the effect of these shoreline changes on human affairs, coastal erosion is as much a major global concern [5].

Peninsular Malaysia has a coastline of 1,972 km long with a west coast fronting the Straits of Malacca and an east coast that faces the South China Sea. The coastline of East Malaysia is significantly longer at 2,837 km [6]. The National Coastal Erosion Study determined that nearly 30% of the Malaysian coast is threatened by erosion prompting the government into executing an erosion control program [7]. This problem prolonged consistently ever since the variability in climate change, sea level rise and human activities [8]. In 2017, Universiti Kebangsaan Malaysia identified 9 locations as critically eroded with approximately 4 meters/year. For example, Kampung Minyak Beku, Segenting, Sungai Ayam Laut, Sungai Suloh, Sungai Koris, Sungai Lurus, Senggarang Laut, Parit Botak and Pantai Punggur [9].

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Pantai Punggur, Batu Pahat would be a perfect study area for coastal erosion monitoring activity. It is an area with serious changes of coastline [10]. The total shoreline of Pantai Punggur is set at latitude 1. 62 ° to 1.87 N, 102.78 ° longitude to 103.19 ° E [11]. In 2020, it was forecasted in Sub-Reach 5, there is a prediction of 1.4 to 2.0 m of sea level rise in 2040 [12]. If this happens, coastal erosion will increase and cause a lot of destruction at the Pantai Punggur coastal area as shown in Figure 1 [12]. Figure 1 depicts the occurrence of rising water levels in several rivers, including Sungai Ayam, Sungai Suloh Besar, Sungai Koris, Sungai Lurus, Sungai Senggarang, Sungai Parit Botak, Sungai Tongkang, and Rengit River, near the coast of the district Batu Pahat in 2020. The total size of the affected region is projected to be 1676.97 hectares. The occurrence of rising water levels are one of the main factor that contribute to beach erosion [13].

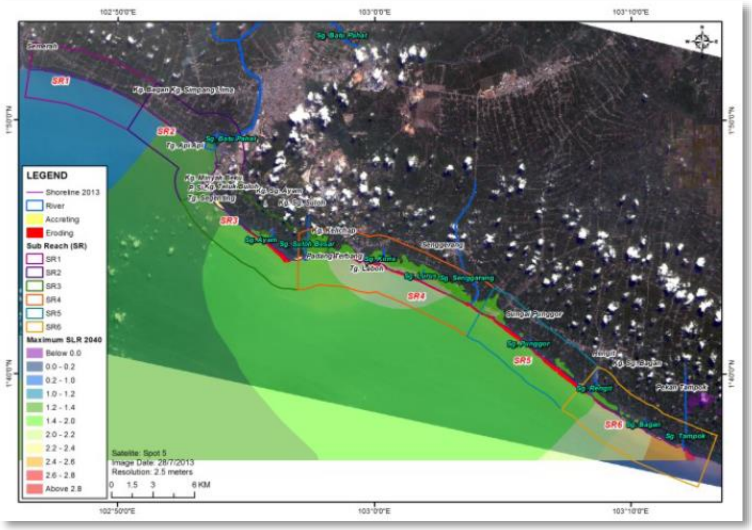

Figure 1. The sea level rise forecast in 2040 for Batu Pahat district [12].

The shoreline moved to the land up to 300 m away or ranged from 5 m to 7.50 m every year for a 40-year period [10]. Shifts in the shoreline ranged from 50 m to 200 m through an average annual move of 1.5 m to 7 m, from 1984 until 2013 [12]. This research is a follow-up study conducted by the National Hydraulic Research Institute of Malaysia (NAHRIM) in 2010 which has identified that the coast of Peninsular Malaysia will experience a projected sea level rise between 0.25 m to 0.52 m in 2100. The projected sea level rise in Batu Pahat is 0.028m (2020) and projected to be 0.066m (2040) and 0.25m in 2100 [12].

The west coast of the Peninsular Malaysian shore is prominently characterized with mud and is flat with mangrove vegetation due to wind shield by the Sumatera [14]. The wave that has occurred is usually rising from 1.5 m to 2.5 m high, although the tide is different and appears to increase too. This effect can be caused by global warming. Global warming has changed the weather and affect the state of sea water to 16; thus, making the height of the wave and tide higher than the previous one. Therefore, this paper aims to study the shoreline corrosion rate for a year from August 2020 to August 2021 by using Unmanned Aerial Vehicle (UAV) with a two-kilometer shoreline coverage, as shown in Figure 2.

Ground control points (GCPs) are points on the ground with known coordinates. GCPs are points in an aerial mapping survey that the surveyor can precisely identify with specified coordinates, allowing extensive areas to be charted accurately [15]. Ground control points (GCPs) are places on the ground atmosphere that have a specific location.

While geospatial data processing takes place, GCPs are coupled to geo-referenced images to classify real-world locations [16]. Ground control points are something that may easily be identified in photographs. They commonly resemble a small section of a checkerboard. The GCPs are commonly black and white because high contrast patterns are simpler to identify [17]. Figure 3 shows the ground control point used in this study.

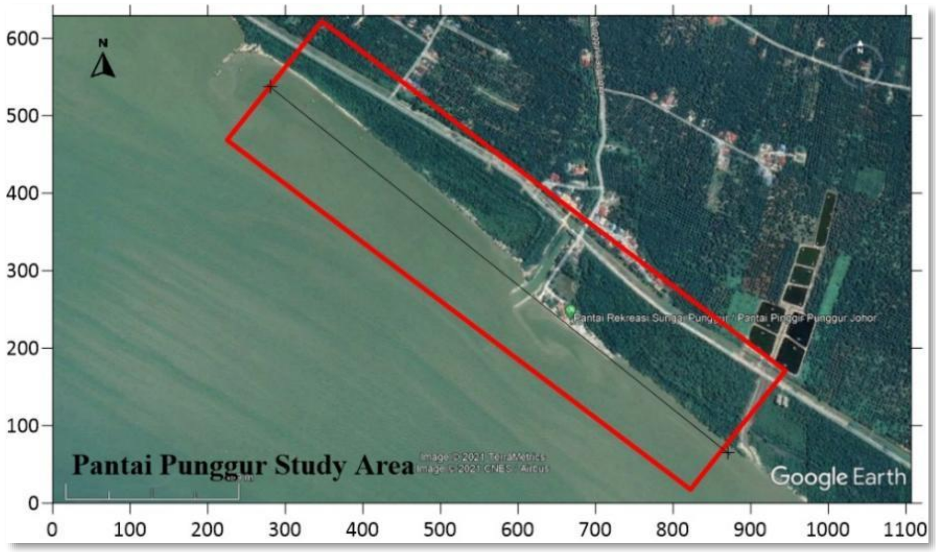

Figure 1. The study area of Pantai Punggur (Image from Google Earth).

Figure 3. Ground control point placed at the Labuan Block on Pantai Punggur.

There are 15 GCPs that have been placed throughout the shoreline of Pantai Punggur. The GCPs are being used in order to increase the accuracy of the shoreline generated by the software and to ensure the orthomosaic map generated by the software are being accurately geolocated. The distances of GCPs are 200 metres apart and are being placed at only accessible points. The conditions along the shoreline of Pantai Punggur are full of mangrove trees and mud, so only a few selected points can be used as GCP points. Figure 4 shows the placement of the GCPs along the shore of Pantai Punggur.

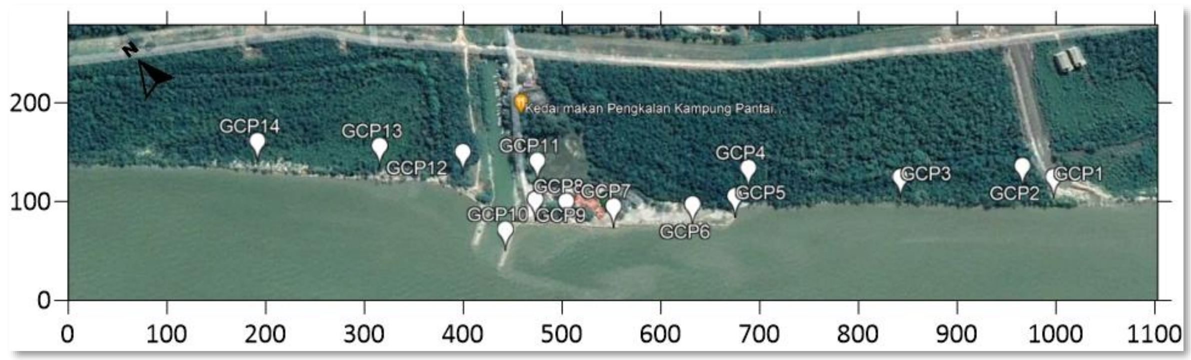

Figure 4. The location of GCPs along the shore of Pantai Punggur.

Aerial photogrammetry using unmanned aircraft, remote sensing, Light Detection and Ranging (LiDAR), Global Positioning System (GPS), and Terrestrial Laser Scanning (TLS) are some of the geoinformation approaches that could be used to map or monitor coastal erosion. However, these approaches for acquiring aerial photographs have some limits or downsides. Many tropical countries are blanketed in clouds, especially during the rainy and monsoon seasons, making it difficult to take clean photographs [18]. There are additional limits in employing satellite and manned aircraft, such as high flight costs, low ground resolution, and a limited time frame [19] [20]. As a result, using these technologies to cover a small region and at a low altitude is impractical. Thus, aerial photogrammetry is the most suitable method for this research to be carried out.

2. METHODOLOGY

In order to acquire data about shoreline changes, this study used the aerial photogrammetric approach as the major tool. As a result, the flight period of the UAV was determined by a number of factors, including tidal times and weather. The following schedule was chosen because the depth of low tide must be in the range of 0.01 m to 0.50 m. The data also shows the changes of the shoreline after monsoon changes which happen throughout the year. Table 1 depicts the flight mission schedule from the 19th of October 2020 to 10th of August 2021.

Table 1 Flight Planning Schedule

Flight	Date	Time	Depth (m)
1	19/10/2020	04.35 PM	0.32 m
2	03/03/2021	05.15 PM	0.24 m
3	29/05/2021	04.20 PM	0.11 m
4	10/08/2021	05.10 PM	0.25 m

The flying mission was executed by using Pix4D Capture through grid for 2D mapping. The process of gathering aerial images began and the drone flew along the gridline, capturing images at a height of 50 meters. The flight planning was separated into two sessions of flight route in order to gather aerial images that covered the entire study area. This precaution was taken due to the battery limit. The gridline for flight planning route covers the first region of 176 × 1241 m, while the flight route for the second region covers the area of 177 x 997 m, as shown in Figure 5.

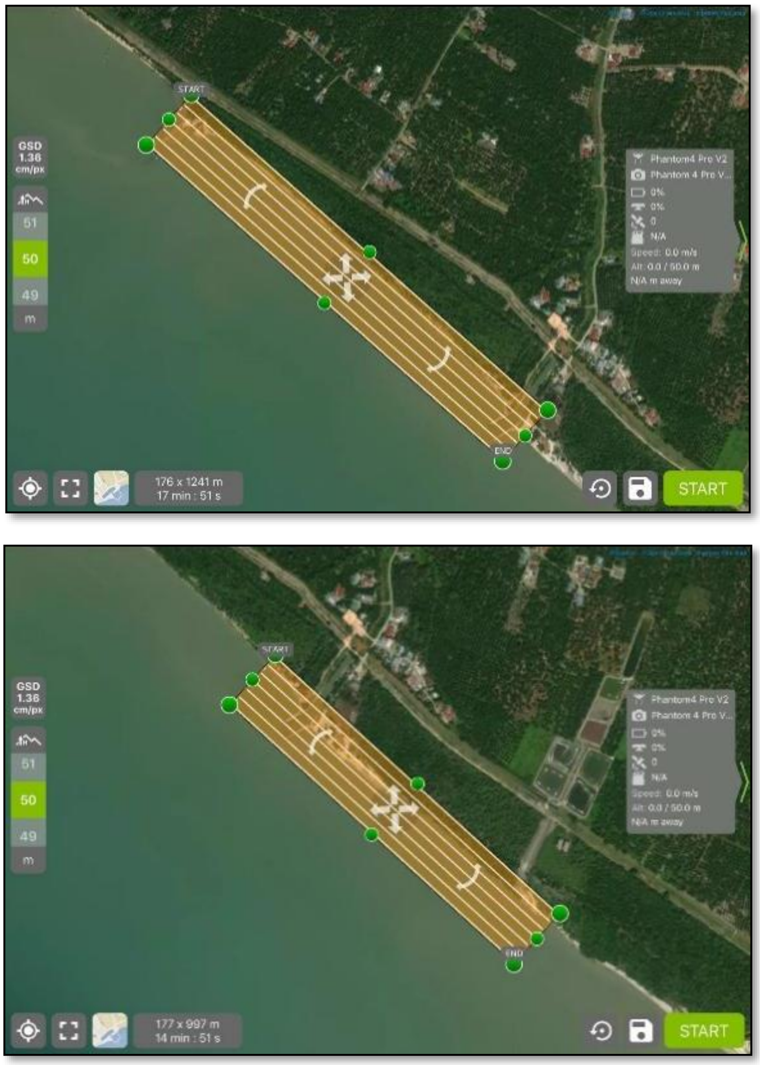

Figure 5. Flying grid mission for first region (upside) and second region (downside).

2.1 Model and Data

The Pix4D Mapper software will then merge and process all overlapped aerial images and produce the aerial map for Pantai Punggur. Basically, there are three main processes in the Pix4D Mapper. The initial processing is to sort all the images and calibrate using Aerial Triangulation and Bundle Block Adjustment. The second process generated the densified point cloud as shown in Figure 6 and provide 3D textured mesh for the model. The third step generated the Digital Surface Model, and the orthomosaic map. The orthomosaic map will then be processed using Global Mapper so that the determination process of the shoreline can be carried out. The Global Mapper processed the orthomosaic map and generated the shoreline through Normalized Difference Vegetation Index (NDVI) layer as shown in Figure 7. The white line indicates 0-meter altitude and is considered shorelines as it separates the border between vegetation and water.

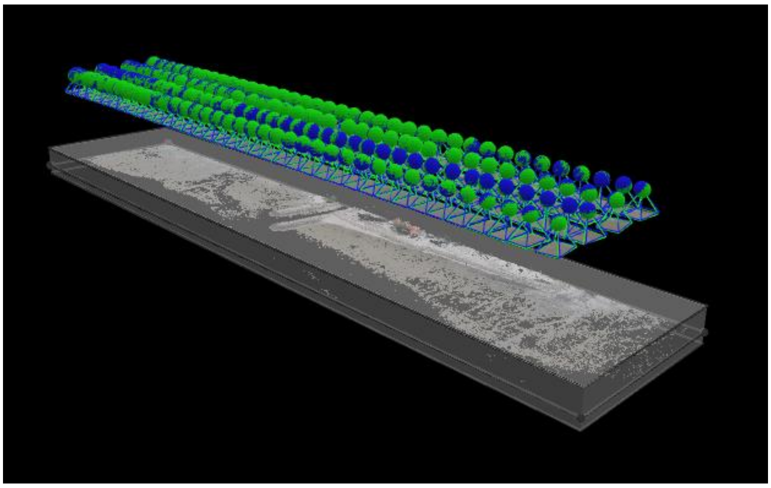

Figure 6. Pantai Punggur densified point cloud in Pix4D Mapper Software.

Figure 6 depicts the point cloud for each image that being captured by UAV. All of these photos will be automatically assembled in accordance with their original positions, resulting in a three-dimensional model image. This point cloud is used to double-check the entire model and ensure that the GCP position is right. This step is necessary for creating orthomosaic images that are accurate to every image in term of latitude, longitude, and altitude. By editing the point cloud, any noise or faults in model development can be eliminated.

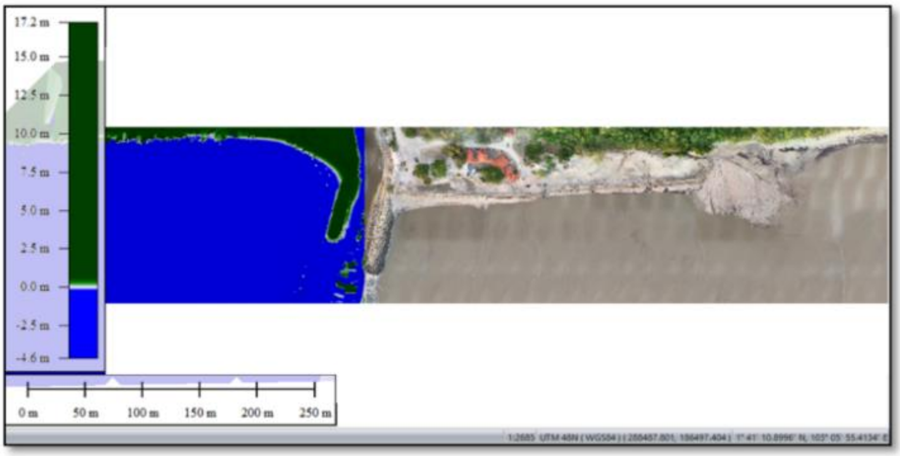

Figure 7. NDVI Layer in Global Mapper to determine shoreline.

Figure 7 shows the NDVI layer for the whole orthomosaic images. This Figure 7 has two overlap layers which are orthomosaic layer and NDVI layer. NDVI works as a filter that could present the orthomosaic features in land and water features [21]. This filter allows the process to differentiate the land and water features and being represented as the shoreline in the orthomosaic. The white line indicates zero (0) metre of water level which also being marked as the shoreline in the orthomosaic [22].

3. RESULTS AND DISCUSSION

The research of shoreline changes in Pantai Punggur was conducted for a one-year period, from 19th of October 2020 to 10th of August 2021. Based on the Global Mapper, each shoreline has a different coloured line that represent the months that have been generated, as shown in Figure 8.

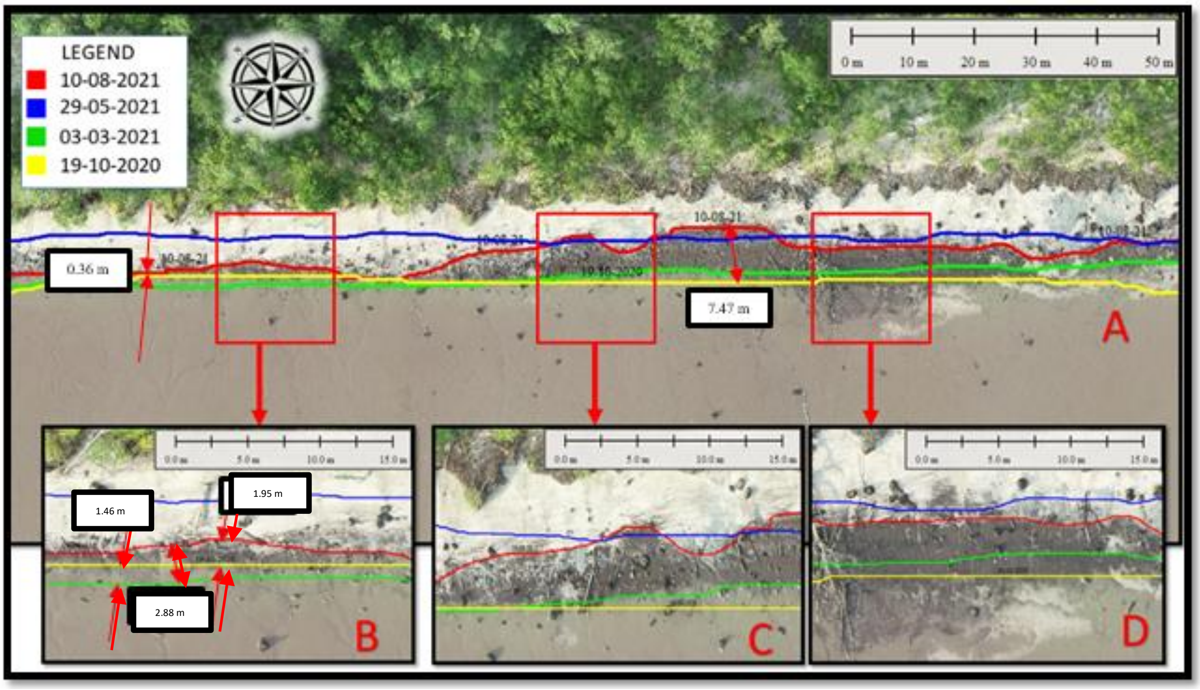

Figure 8. Subfigure A depicts the difference between the timestamps of coastlines. The base orthophoto produced from the 10-08-2021 UAV survey. Subfigure B, C & D presenting the coastline in larger scale from study area.

UAV-based remote sensing has successfully reduced the gap in scale and resolution between ground observations and mapping image acquired from satellite sensors and conventional manned aircrafts. For 2D and 3D analysis, the computer uses Digital Surface Model (DSM) and Point Cloud to ensure reliable geodata [23]. Figure 8 shows an example of the orthophoto that was generated. The Pantai Punggur orthophoto clearly shows coast side by side with mangrove forest. The coastline along the map are plainly visible, and even such as small pebbles and small branches can be seen across the mapped region. Being compared to the orthomosaic, the satellite datasets cannot produce the high resolution and precision of the generated orthophoto maps and 3D visualisations. In addition, LIDAR high resolution data packages are not yet accessible for Pantai Punggur area.

The difference in coastlines recorded on 19th of October 2020 until 10th of August 2021 indicates significant finding in the research area. All orthophoto maps were created from all four surveys, and the maximum and minimum shoreline evolution were determined using a GIS system. The shoreline changes profile is represented in the Figure 8 where the maximum distance between the shoreline on 19/10/2020 and shoreline 10/08/2021 is 7.47 m and the minimum 0.36 m. The total distances between one-year shoreline is 2.88 m. Subfigure B depicts that the shoreline of 19/10/2020 m (yellow), 03/03/2021 (green) and 10/08/2021 (red) has moved towards the landside and the changes is increases by time. However, the shoreline of 29/05/2021 (blue) has moved in the maximum value.

This shoreline does not increase accordingly with other shoreline due to this shoreline happen during inter-monsoon which happen during May to July in Malaysia [24]. Subfigure C and subfigure D show the base orthophoto are full with accretion of the mud. The accretion happen due to the location of the shoreline is nearer with the groin at the beach and causing the mud to accumulate at the seaside. The changes of the coastline marked the erosion of Pantai Punggur caused the mangrove trees to die and decrease the vulnerability of the beach [25]. Based on the result, there are several areas in this study experiencing shoreline changes phenomena either erosion or accretion.

4. CONCLUSION

This study concludes that coastal shoreline monitoring can be done by utilising UAV technology. The shoreline changes data and map can be generated using the overlapping picture method using Pix4D Mapper and Global Mapper. The aerial photographs collected by UAV are able to generate high-resolution images as the output. This study also brings out the importance of ground control points in orthomosaic mapping as it increases accuracy and reduces the error in Root Mean Square during the processing of aerial images. The usage of GCPs allow the overlapping process for the monthly data of shoreline in Pantai Punggur. In summary, it can be said that Pantai Punggur is in a critical state of erosion. This can be demonstrated by clearly visible changes on the coast within a year. This method can be implemented in the future to predict and study changes in the coastline as obtaining the data can be done in a short time. Following the methodology presented in this document, visual inspections were carried out on selected beaches and observable changes were identified. As for Pantai Punggur, the output of the data resulted in clearly visible changes in the shoreline; thus, achieving all the objectives proposed for this document.

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