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DECONSTRUCTING A JETTY TO RECTIFY THE DOWNDRIFT EROSION

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Abstract: A jetty is a coastal structure constructed across the surf zone to prevent sediment deposition at a river mouth. It creates updrift accumulation and downdrift erosion. Deconstructing the jetty may restore the situation but create another problem. This study used the Cha-am beach in Thailand to simulate future shoreline positions under different scenarios. The main tool used in the study was the software package LITPACK. The calibrated simulations showed that, if no action was taken, the updrift part of the beach would be widened by as much as 130 m in 25 years but the downdrift side of the jetty would experience severe coastal erosion. Deconstructing the jetty would alternate the outcome. The area where the erosion was foreseen along the downdrift shoreline would not occur anymore. The sediment once intercepted by the jetty would move to pass the inlet. However, the updrift shoreline would adjust its alignment, eroding existing houses and other buildings. While jetty deconstruction would restore the downdrift part of the beach, it would at the same time destroy some properties along the updrift section. Removing the jetty may experience great social resistance. Decision-makers should be equipped with adequate information and coastal engineering can provide some necessary inputs.

Keywords: Coastal protection, coastal engineering and management, beach erosion, longshore sediment transport, Thailand.

Introduction

Many countries have experienced coastal erosion (Cao & Wong, 2007; Saengsupavanich *et al*., 2009; Boateng, 2012; Cellone *et al*., 2016; Martínez *et al*., 2018; Neelamani, S., 2018; Rattharangsri *et al*., 2019), which is a result of both anthropogenic causes and natural environment changes. Coastal developments such as urban settlements, construction of coastal protection structures, breakwaters, coastal reclamation, or jetty construction can benefit certain stakeholders while negatively affecting others (Prukpitikul *et al*., 2018; Wu *et al*., 2018). Attempts have been undertaken to solve or mitigate the damage caused by the erosion, including hard options, soft options, management schemes, or even law enactment (Saengsupavanich, 2017; Pagan *et al*., 2018). In 2015, a new Act was legislated in Thailand on the Promotion of Marine and Coastal Resources Management (Department of Marine and Coastal Resources, 2019). It grants the authority to correct any negative impacts of any coastal structures, or even to demolish them. However great care must be taken before a decision-maker can proceed. Integrated coastal management (ICM) can be a useful approach, especially where it involves inter-governmental, inter-sectoral, spatial, and science-management integrations (Cicin-Sain & Knecht, 1998). Options to rectify the situation must be studied carefully as some mitigation measures can be expensive but ineffective. Deconstructing any coastal structure may solve one problem but create other undesirable outcomes. Thailand's government should consider cautiously and weigh the benefits against unpleasant consequences. Alternatives that produce the least negative impacts may be selected. Coastal simulation is one of the most effective tools to help decision-makers to assess possible results using a reliable, inexpensive approach and then implement a successful option.

A jetty is a coastal structure that is constructed across the surf zone to prevent sediment deposition at a river mouth or an inlet. It is well-aware that the up drift side of the jetty experiences sediment accumulation while the downdrift side encounters erosion (Thiruvenkatasamy & Girija, 2014; Garel *et al*., 2015). Many management options are available to resolve downdrift erosion, such as constructing additional offshore breakwaters or revetments, beach nourishment, sand bypassing, or even removing the jetty. Each management option for jetty produces different consequences. This article is one response to the Act on the Promotion of Marine and Coastal Resources Management 2015 that provides legal power to remove any coastal structure creating a problem. This research focuses on whether deconstructing the jetty will reverse the downdrift erosion without producing any additional negative impact. Applying a one-line model, this article presents a research outcome on a case study of a jetty at Cha-am Beach, Thailand. Other similar cases may undertake a similar approach to reach a solution.

Methodology

The research involved simulations of future shoreline positions in two cases: the future shoreline where every coastal structure remained the same, and the scenario where the jetty was removed. The main tool used in the study was the software package LITPACK (DHI, 2019).

Study Site

Cha-Am is located in southern Thailand (Figure 1). Cha-am Beach is famous among domestic and international visitors (Tourism Authority of Thailand, 2018). One of the reasons that Cha-Am beach is long and wide is because of a jetty at the Cha-Am canal. The jetty extends approximately 1 km from the shoreline, totally blocking all alongshore sediment transport within the surf zone. The jetty was constructed more than 20 years ago, resulting in sediment building up on the updrift side while eroding the downdrift side annually.

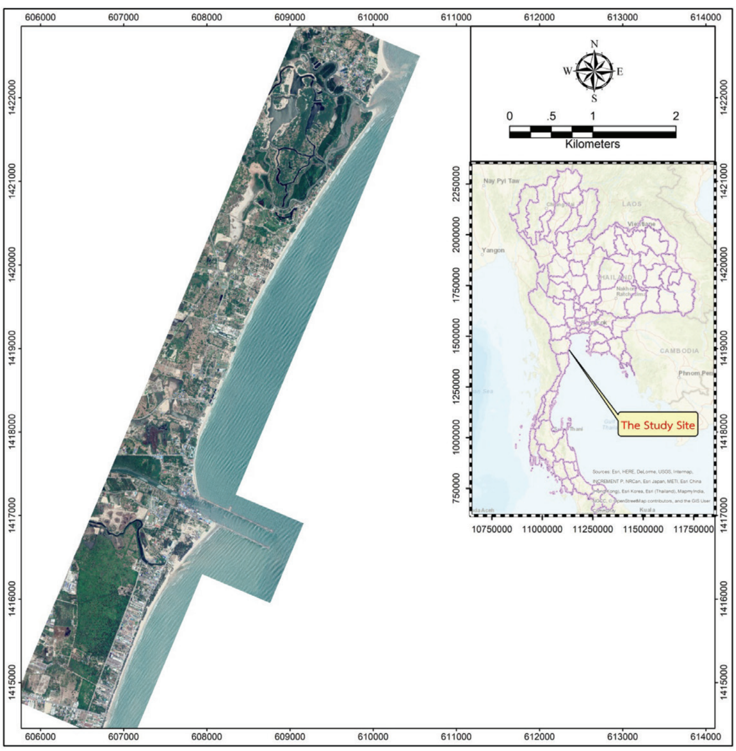

Figure 1: Cha-Am beach

A bathymetric map was surveyed by single-beam echo-sounding in August 2018 (Figure 2). Wind data was collected from the nearest meteorological station recorded by the Thai Meteorological Department. The JONSWAP method was applied to synthesize moderate wave climate at Cha-am beach (Figure 3). The predominant wave direction is south-southeast, indicating that sediment would deposit at the south of the jetty. All elevations were referred to as the national mean sea level (MSL). Beach sediments were also sampled. The sand on the beach berm had a median diameter (D_{50}) of 0.33 mm, but the grain size reduced to 0.22 mm in the surf zone. This information was necessary as inputs for predicting the future shoreline at Cha-am beach.

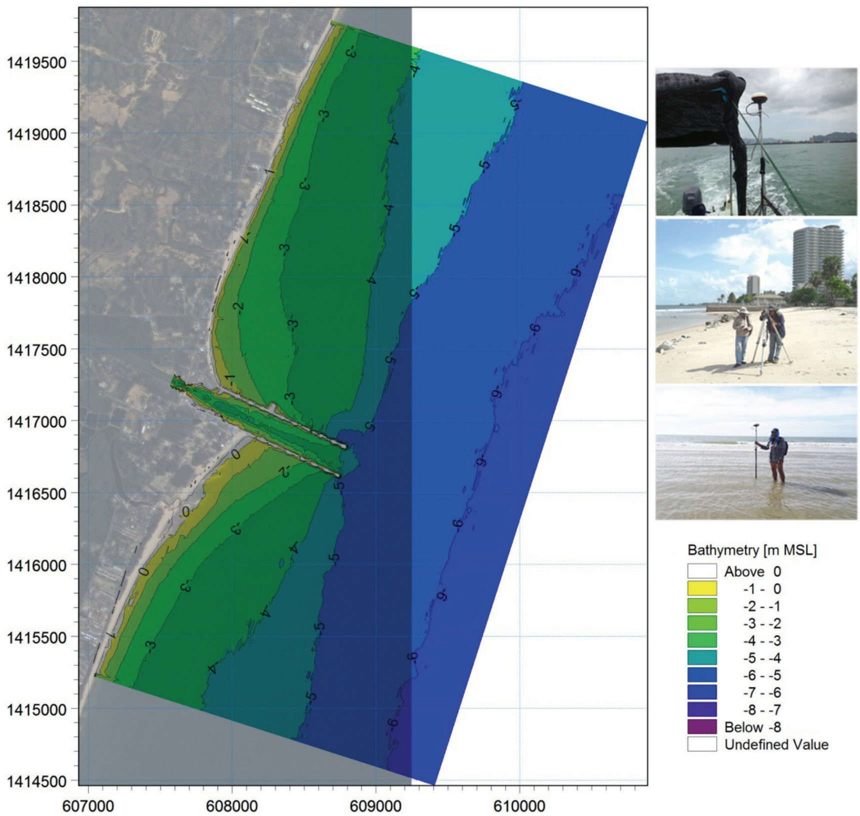

Figure 2: Surveyed bathymetry

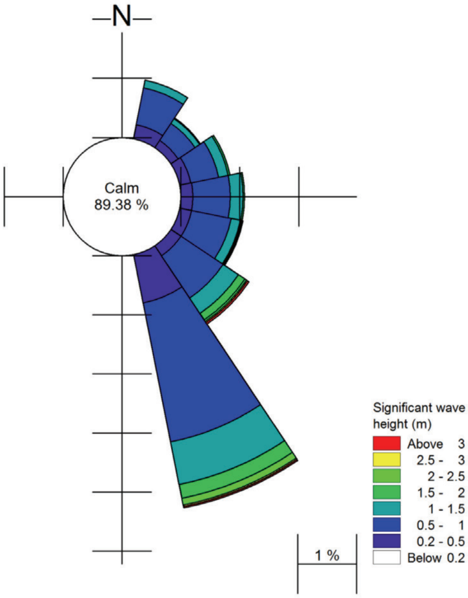

Figure 3: Annual wave climate at Cha-am beach

Historical Shoreline Change

The 2014 (Pleiades) and 2018 (WorldView3) satellite images for the study area were purchased since they were taken in the same general period during summer. Time of image capturing was approximately 10:30 am (GISTDA, 2019). Comparing the two images revealed the severity of the downdrift erosion as well as the magnitude of the updrift deposition (Figure 4). During the four years between images, the updrift side of the jetty had continuously accumulated at a maximum rate of 17 m/yr, and a lower rate farther away from the jetty. On the other hand, the downdrift erosion was as much as 7 m/yr. Some property owners had put up their revetments to prevent the damage but some did not. The shoreline positions extracted from the Pleiades and the WorldView3 satellites were also used in the calibration process of LITPACK.

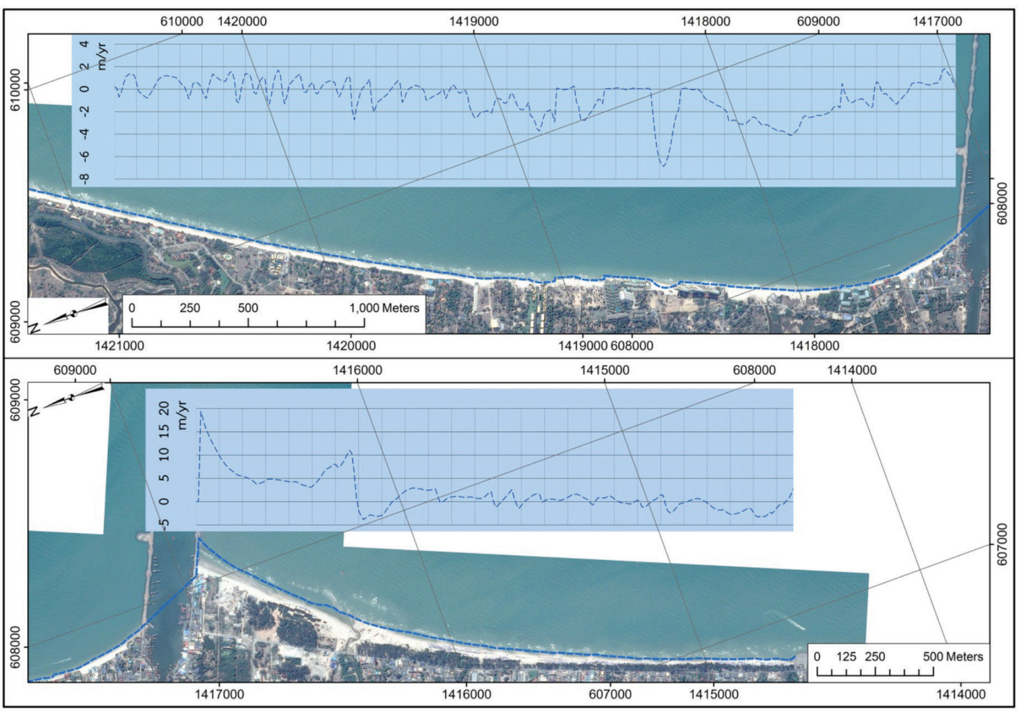

Figure 4: Historical shoreline change between 2014 and 2018

Future Shoreline Prediction

LITPACK is a one-line model that relies on the continuity equation for sediment volumes (Eq. 1):

$$\frac{\partial y_c(x)}{\partial t} = -\frac{1}{h_{act}(x)}\frac{\partial Q(x)}{\partial x} + \frac{Q_{sou}(x)}{h_{act}(x)\Delta x} \qquad \text{(Eq. 1)}$$

where $y_c(x)$ is the coastline position from baseline (m), t is time (s), $Q(x)$ is the longshore transport rate (m^3/s), and $Q_{sou}(x)$ is the supply of sediment from sources (m^3/s). The total height of the active profile $H_{act}(x)$ consists of three contributions: the active depth relative to the mean water level, the height of the beach above mean water level, and finally possible dunes which may erode if the coastline reaches their position during erosive states, but will not accrete again (DHI, 2019).

The software can forecast the behaviour of a non-cohesive beach due to effects of coastal structures and has been applied by numerous researchers (Khalifa *et al*., 2017; Noujas & Thomas; 2018; Saengsupavanich, 2012). Necessary inputs to the LITPACK simulation were shoreline positions digitized from past satellite images, beach profiles extracted from the surveyed bathymetry, sediment properties, annual wave climate, tidal information, and the locations of existing coastal structures (Nassar *et al*., 2018).

The 2014 digitized shoreline was used as the starting point to predict the 2018 shoreline. All existing coastal structures were inserted into the simulation. The simulated 2018 shoreline position was then compared with the digitized one. Calibration parameters were the height of the active beach (3 m) and the active depth (3 m). The sediment transport table was not modified. The calibration result yielded an RMSE value of 5.35 m. After the calibration process had been completed (Figure 5), two scenarios were simulated. The first scenario was the predicted shoreline position in the next 25 years if no mitigation measures were undertaken. The second scenario was the predicted coastline adjustment in the next 25 years if the jetty were removed. The effectiveness of demolishing the jetty was assessed.

Results

Shoreline Position in Next 25 Years If No Measures are Undertaken

If no action is taken, the jetty would continue to intercept all the alongshore sediment transport. The updrift part of the beach would be widened by as much as 130 m in 25 years. The sediment deposition would gradually decrease farther away from the jetty. On the other hand, the downdrift side of the jetty would experience severe erosion. The erosion would occur far from the jetty since the landowners living next to the jetty had already constructed their revetments. At the end of the coastal protection structures, the erosion would be very severe. It was predicted that the erosion would be greater than 330 m (13.2 m/yr) shoreward (Figure 6).

Shoreline Position in Next 25 Years If Jetty Is Completely Removed

Deconstructing the jetty would change the outcome. There would be no erosion along the downdrift shoreline. Instead, sediment would be transported by natural processes, distributing the sand along the downdrift section. There would be some sand deposition in front of the existing revetments that the landowners had put up against the downdrift. The downdrift erosion previously created by the jetty would not occur (Figure 6). In contrast, the updrift part of the beach would be eroded (Figure 6) as the sediment once intercepted by the jetty would be transported to the north. The updrift shoreline would adjust its alignment, eroding houses and other buildings. What used to be a wide beach favoured by many tourists would disappear. Some restaurants, resorts, huts, and other facilities on the updrift part of the beach would also be destroyed. In other words, the jetty deconstruction would not simply restore the downdrift part of the beach, but at the same time, it would also destroy some properties along the updrift section.

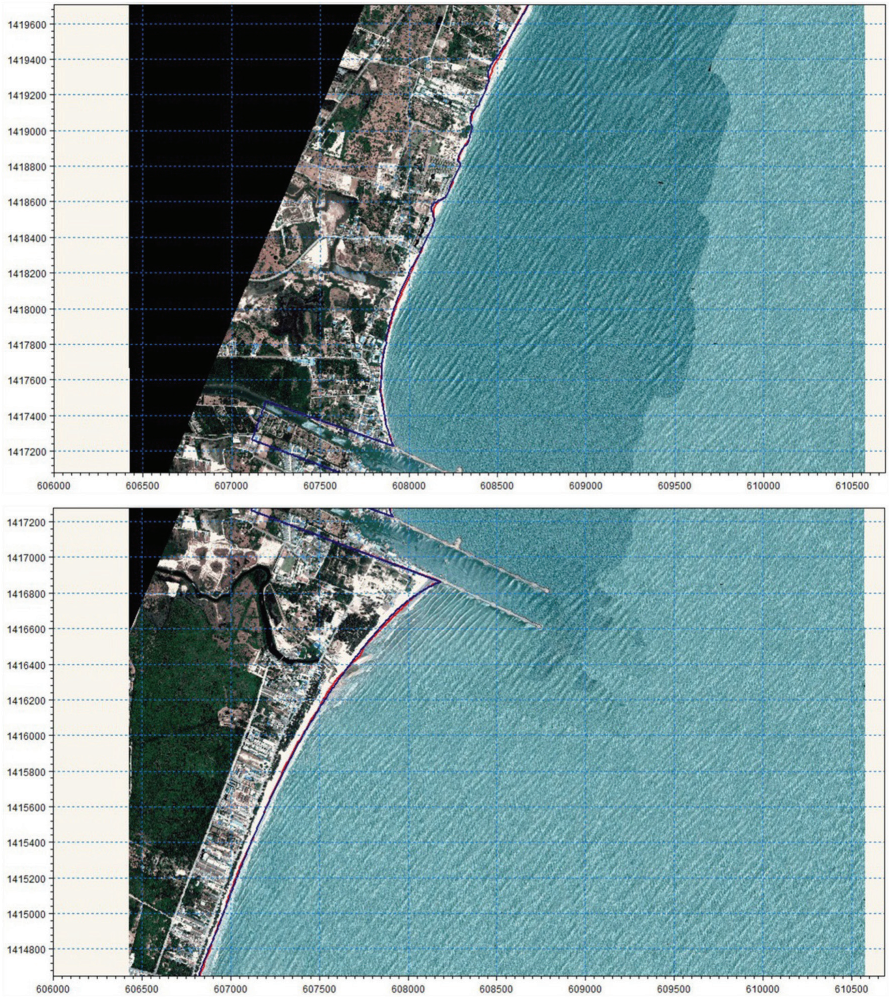

Figure 5: LITPACK calibration result (The red line is the 2018 shoreline digitized from the WorldView3 satellites, and the blue line is the simulated 2018 coastline position)

Discussion

Coastal structures have numerous functions, but sometimes they can create inevitable negative impacts. There has been a jetty at Cha-am beach for more than 20 years. It prevents sedimentation, provides safe navigation, mitigates inland flooding, and widens the updrift beach that has become one of the most visited tourist destinations in Thailand. However, it induces downdrift erosion, destroying the coastline by as much as 13.2 m/yr at one location. Considering only the aspect of shoreline change, certain stakeholders especially people living along the downdrift section may want to deconstruct the jetty to restore the beach alignment. However, removing the jetty would induce losses of other jetty-originated benefits.

Managing the jetty-created downdrift erosion is complex and requires many resources. The concept of ICM suggests inter-governmental, inter-sectoral, spatial, and science-management integrations

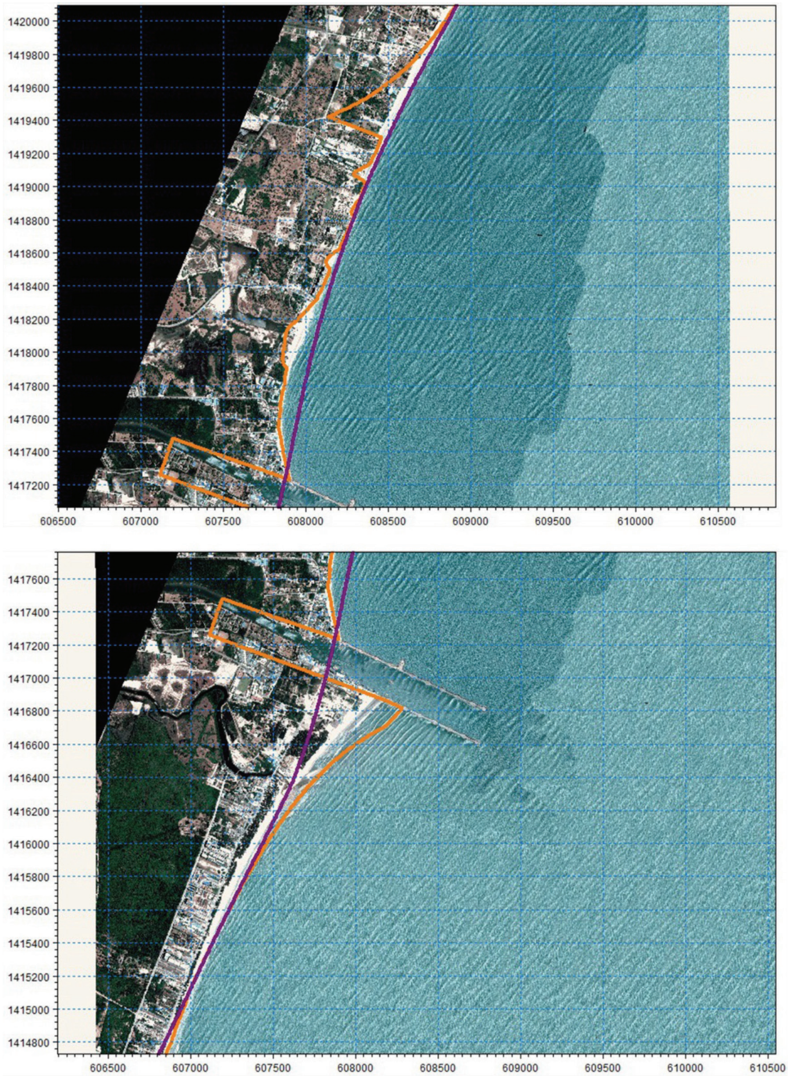

Figure 6: Shoreline position in next 25 years, if nothing is done (orange line), and if the jetty were removed (purple line)

as indispensable ingredients. However, implementing the ICM in Thailand is difficult, time-consuming, and involves handling much conflict resolution among stakeholders and many governmental departments (Saengsupavanich, 2012). Although deconstructing the jetty is one of the possible options, this may not be practical in Thailand at the moment because it would involve a lot of stakeholders and involve legal issues enforced by different governmental departments. The jetty at Cha-Am beach is one clear example of where ICM has failed and so the problem has remained unresolved for more than 20 years.

Many researchers have studied values of eroded beaches and demanded immediate mitigation measures (Dribek & Voltaire, 2017; Logar & van den Bergh, 2014; Thinh *et al.*, 2018). Saengsupavanich (2019) monetized the Cha-Am downdrift beach erosion and found that if preserved, the downdrift eroded beach could produce annual non-market benefits of approximately THB 20.1 billion or USD 609.9 million/yr. This huge value indicated that the Thai government must take urgent action. If deconstructing the jetty is not possible, beach nourishment or sand bypassing may be good alternatives.

Unlike some countries where erosional impacts of modified inlets have been addressed using beach nourishment (Houston & Dean, 2016; Luo *et al*., 2016), Thailand has struggled with erosional countermeasures such as beach nourishment and sand bypassing. Obstacles in beach nourishment are discussed in the literature (Parkinson & Ogurcak, 2018). Thailand has not been successful in solving the issues because borrow areas with an adequate quantity of suitable sediment are scarce, maintenance of beach nourishment demands a continuing annual budget allocation by the government, environmental impacts during sediment dumping, and social resistance can be strong due to the frequent disruptions from construction activities impacting negatively on tourism operations. It may seem that any erosional measure has its retardants. Nevertheless, management of the jetty-induced erosion at Cha-Am beach must be addressed. Further research including questionnaires, stakeholder analysis, morphological change analysis as well as physical modelling, and a feasibility study may be useful to assist the government to decide on a suitable plan of action.

Conclusions

The study emphasizes that the demolition of a well-established jetty to rectify downdrift erosion is not always the right decision. A software package (LITPACK) use applied to forecast shoreline positions under different scenarios. The numerical simulation provided the information necessary to decision-makers. If the jetty is to be removed, great care should be taken. The simulations showed that deconstructing the jetty does not always result in positive outcomes. While jetty deconstruction would restore the downdrift beach, it would erode the updrift area, reversing the current situation with the jetty in place. The jetty has been in place for so long that the local people are used to it, have constructed buildings on the deposited area resulting from the original jetty construction, and have utilized the wide beach as their income generator. Removing the jetty may experience great social resistance as well as inflate conflicts among the different governmental departments responsible for enacting different pieces of legislation. The Act on the Promotion of Marine and Coastal Resources Management 2015 may not be easily implemented. Although the new Act grants the power to the relevant government department to demolish the jetty, the positive and negative consequences of such action should be seriously considered. The decision should be made carefully.

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