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Article

Consequences of Massive River Bank Erosion to The Local Society at Pasir Parit, Kelantan

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Abstract: The population living near the river basin is at risk of river bank erosion. As a consequence of hydraulics and hydrological processes, as well as floods and development activities along the river, the morphology is changing. Many ecological characteristics, including flora and fauna, human life, basin structure, and so on, may be lost as a consequence of river bank erosion. The objectives of this research are to (1) identify the impact of soil texture on river bank erosion; (2) determine the consequences of river bank erosion on the local community; and (3) propose river bank erosion mitigation strategies for the study region. We use both quantitative and qualitative approaches to analyse data in this study. An observational technique, a questionnaire survey, and a personal interview were utilised to collect data. To support our findings, we acquired secondary data from government entities (Drainage and Irrigation Department). The river bank erosion in this case study affected 17 dwellings, totalling 103 people, and two homes were consumed by the river. The impacted area of river bank erosion at the site, according to the research conclusions based on aerial photography and departmental statistical data, is roughly 120 metres in a period of 6 months. The volume of sediment lost due to bank erosion was estimated to be 360,000 cubic metres, or 1.4 hectares. As a consequence of the massive river bank erosion, the victims endured loss and worry. The following technique for preventing river bank erosion is proposed: build a concrete river cliff or gabion as soon as possible, and change the low weir so that flowing and flood water is contained in the river's main channel.

Keywords: Disaster; Environmental Hazards; Community Risk; Sustainable Development and Environmental Management.

Introduction

River bank erosion is a natural disaster that occurs all around the globe, including in Malaysia. River bank erosion may be caused by a variety of causes, including river shape, rainfall amount, flood occurrences, and so on. Bank erosion may add sediment to river bank load (Trimble, 1997; Bull, 1998; Walling et al., 1999; Wilkinson et al., 2009), with the amount dependent on a variety of factors. River bank erosion may be identified by the transfer of soil particles, botanical alteration, and the presence of atypical morphology (Lawler, 1993). Soil erosion resistance is determined by soil erodibility, soil structure, infiltration levels, and organic matter concentration. River bank erosion may result in silt build-up, exacerbating the issue of river pollution. The action of velocity, bedform conditions, and kinetic energy at the river bed all contribute to the commencement of sediment movement (Yang, 2006). In general, river bank erosion is caused by hydraulic shear, mass collapse, and a subaerial preparation process (Lawler, 1995). Channel characteristics like planform curvature and the width-to-depth ratio may potentially impact bank erosion rates (Walker and Rutherford, 1999). According to Mohd Ekhwan and Haryati (2007), the less vegetative land cover increases the likelihood of river bank erosion. The purpose of vegetation is to grasp the soil with its roots so that the structure is strong

enough to prevent erosion. As a result, if river banks are exposed directly to rainfall or river water without plant cover, river bank erosion may occur more easily (Guneralp and Rhoads, 2009). Man-made activities like urbanisation, sand mining, and barrier construction also contribute to some unpredictability (Julien, 2012). These operations had an indirect impact on stream wave action, gravel extraction, and stream bed lowering, which might result in a flood catastrophe, cliff collapse, property loss, and trauma. (Jaycee and colleagues, 2014)

In relation to the above-mentioned causes, Das. et al. (2017) found that seepage flows caused 74% of the bank erosion locations on the Mississippi River in the United States. Approximately 28% of the bank portions contain signs of river traffic-induced damage. Many other causes, including eddy currents, disrupted flows generated by exposed tree roots, surface drainage, and so on, contributed to erosion. Furthermore, floods occur often in Bangladesh, making this the most important cause of river bank erosion in the nation. According to Seow and Roslin (2017), deforestation, landslides, other unplanned embankments, and the destruction of hills for road building transported a large quantity of silt into the river underneath Bangladesh's tributaries. As a consequence, silt accumulates.

This results in the rivers' water holding capacity decreasing. The river's course is altered, and the river's bank is eroded as a result. Similarly to other nations, Malaysia, a tropical country, has been dealing with river erosion for many decades. The weather, rainfall, and humidity of this nation may have an impact on the weathering, erosion, and deposition processes in the river. People living near an eroding river in Rajang River, Sarawak, are being compelled to move and relocate their homes (Yuhora et al., 2009). Many additional river bank erosion incidents have been identified in Malaysia, including the Kelantan River, as a result of man-made activities that have altered human and habitat behaviour. For the case study in Kelantan River, bank erosion is now occurring, with several severe consequences. The purpose of this article was to look at the rate of erosion on the Kelantan River bank, specifically in Kg Pasir Parit. This is due to the fact that by estimating the erosion rate, we can take the appropriate measure to keep the cliff from collapsing. Aside from that, this research discusses in situ implications and suggests practical approaches to address the difficulties. This kind of study is critical for ensuring the health of the basin and lowering costs and losses.

Literature Review

Bank erosion is a natural geomorphic process or disturbance that takes place during or shortly after floods (Mohd Ekhwan and Haryati, 2007). It can be caused by floods themselves. Riverbanks are transitional boundaries, also known as ecotones, between aquatic and terrestrial ecosystems. As a result of the naturally dynamic hydrologic circumstances, riverbanks are always undergoing change. The term "bank erosion" refers to the process through which sediment is removed from this particular landform. Sediment that has been eroded travels along the topographic gradient in a direction that is either laterally toward the channel or downstream. Banks are frequently identified by the presence of bare sediment, living vegetation, or snags (Roy *et al*., 2003). Bank erosion occurs in systems that are relatively straight, braided, or multiple-channelled, and it is frequently coupled with changes in water and sediment supply that ultimately led to incision (Simon *et al*. 1999; Thorne 1999). Adjustments to the channel that enhance bank height and instability in incised channels ultimately lead to a broadening of sediment surfaces at altitudes that favour the growth of riparian trees and the deposition of more sediment on those surfaces (Simon, 1989). It is possible for bar accretion in braided channels to cause local bank erosion since the flow will be redirected around the bar and toward the bank. In river systems with several channels, bank erosion makes avulsion more likely, which in turn generates new channel habitat patches within the floodplain while leaving others uninhabited. Therefore, bank erosion is one component of a variety of geomorphic processes that govern channel evolution and lead to the morphological diversity in the habitat that is necessary to maintain riparian biodiversity. These geomorphic processes can be broken down into two categories: those that govern channel evolution and those that lead to morphological diversity in habitat.

Hard-structural elements that are meant to stop bank erosion (also called revetment, erosion control, or bank stabilisation structures) should be implemented to avoid riverbank erosion. Such strategies frequently centre their attention on human values, which can include the destruction of property and the loss of land, the

risk of flooding (Piegay *et al.,* 1997; Casagli *et al.*, 1999), and the possibility of negative effects on aquatic habitats caused by bank-derived fine sediment contributions (EPA 2007). Those hard-structural elements have to be implemented in the correct place and fit the geographical needs as well. This is because not every location has the same characteristics of soil type, river morphology, water depth, water velocity and so on. Hence, the right implementation can increase the effectiveness of managing the risk of riverbank collapse.

1. Socio-Economic Impacts of Riverbank Erosion

Riverbank erosion has a devastating impact, both socially and economically, on the people who live in our nation. People are frequently harmed as a result of this phenomenon, as it frequently results in the destruction of standing crops and infrastructure, the levelling of towns, and interference with communications. In recent years, the amount of economic loss and human misery has increased, and the total yearly monetary loss is anticipated to be roughly USD 500 million. This is despite the fact that the number of people affected has remained relatively constant (Hasan, 2011).

There is no limit to the amount of damage that riverbank erosion can do to persons who are forced to relocate. In addition to the loss of land, they also lose other goods, and the fact that they are displaced leaves them without any assets. They are uprooted from their community, which severs their familial and social relationships. On the one hand, victims of erosion lose their agricultural and homestead lands. On the other hand, they lose their land because of erosion. The impact is enormous, and it will be very difficult, if not impossible, to make up for the loss. Those evacuated by riverbank erosion frequently seek shelter in nearby settlements. As a result, people get cut off from the community with which they normally interact. They are cut off from their social connections.

Riverbank erosion may also cause many people to lose their farms and homes. When erosion is moderate, they can relocate their home goods. However, when erosion occurs swiftly and threatens their homes, they deconstruct their homes together in an effort to relocate household goods. Nevertheless, none of them has sufficient time to collect housing supplies. Many of them are repeatedly victims of such incidents. Smaller landowners suffer greatly. After being uprooted from one's home, the search for homestead land becomes the first priority, and only a few succeed in becoming landowners. Due to riverbed erosion, numerous farmers fall into poverty overnight. As agriculture is the primary source of income for most people, the loss of cultivable land renders them economically insecure. Finding no other options, the majority of farmers turn to daily labour. Sometimes they are unable to adapt to changing circumstances.

Any kind of relocation has an immediate and direct impact on the typical sources of income and activities that households engage in to generate money. They were unable to maintain the standard of life they had before since they had lost their source of income, which forced them to live in abject poverty. In their new communities, they have a difficult time discovering new sources of income. Those who have been uprooted as a result of riverbank erosion look for safety in remote areas or move to urban centres. Family heads who are struggling financially and have no access to land or employment occasionally end up abandoning their families.

Moreover, the demographic and socioeconomic repercussions of riverbank erosion in our country are far-reaching and frequently catastrophic (Islam et al., 2011). It is estimated that fifty per cent of all homeless individuals are victims of riverbank erosion and are unable to restore their homes owing to poverty and lack of resources (Islam et al., 2011). Those displaced by erosion-induced events go through various problems - personal, familial and social. One major personal problem is related to income erosion, which leads them to live a substandard life. As displacees' incomes are eroded, it influences their amount of food intake, health care, and education for their children.

2. Degradation in Quality of Life

River erosion-caused evacuees frequently undergo profound social transformations. The impacts on the victims may be positive or negative. But in most cases, the impacts are negative. Due to riverbank erosion, the victims lose their homesteads, cultivable lands, crops, livestock, plants and trees, business centres etc. Losing all these, they suffer from income erosion and are compelled to lead sub-standard lives. They cannot

spend more money on food, health care, education and the other necessary things of life. This kind of tragedy may bring lots of impacts on their quality of life. For example, they need to move to a new place and adapt to the new environment to settle their life. This may cause them to be unable to adapt since all of their skills and knowledge are related to farming, but now they have to run a small business to generate income. So, when the disaster happened, not only did the environment change but also the community routine and the quality of life also changed. On the other hand, when the affected community has to leave their old living place, it will also cause stress or anxiety for them to face all the consequences due to the disaster that happened to them. Usually, children will feel stressed to move to a new house and might be depressed after a family member gets injured or dies due to the riverbank failure disaster. Therefore, while riverbank erosion may not seem like a frequent phenomenon and that it brings fewer consequences to humans; however, when it causes riverbank failure or collapse, it will be a nightmare for the nearby community and degrade their quality of life as well.

Methodology

This study gathered all of its data and information utilising a mixed-method approach. The study conducted three phases of a site survey to collect aerial data as evidence and estimate soil loss. During the site survey, the bank soil loss was estimated using a DJI Phantom 4 unmanned aerial vehicle (UAV). This method was also used to survey the collapsed structures and impacted areas of vegetation. Experts in the field will analyse aerial data such as photographs, videos, and area measurements to create a detailed description for this study. This research also conducts focus groups with disaster victims in order to get socioeconomic impact data. FGD is quite effective for revealing the event's chronology and its influence on those living along the river, particularly those affected by the disaster. FGD was conducted by dividing two groups of five interviewees, each into two subgroups.

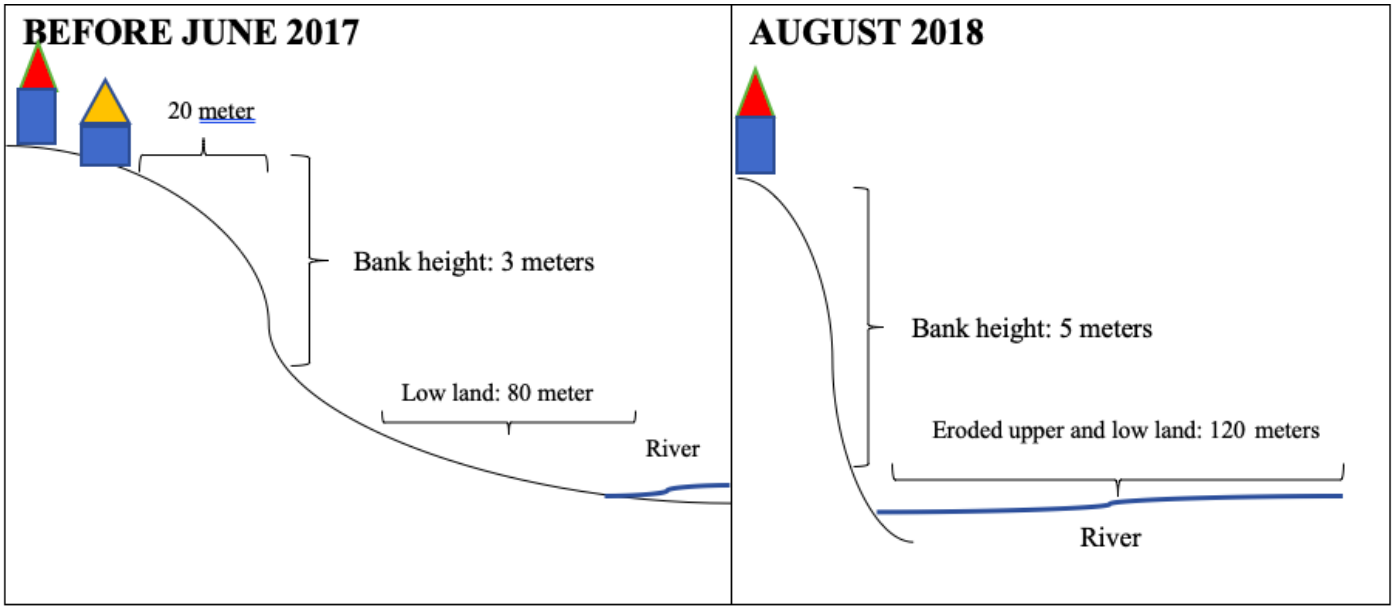
In addition, the study collects riverbank soil and bed debris for laboratory analysis. This is essential for determining the relationship between soil type or soil characteristics and riverbank erosion. The hydrometer method was applied to determine the soil texture. The soil texture will be determined by comparing the final calculated data with the soil texture triangle. The hydrometer approach was selected since it is the most important approach for analysing soil texture and can be properly performed in the hydrogeomorphology laboratory. This approach is a multi-step procedure that must be performed in a laboratory using site samples and laboratory equipment, and it takes 1-2 days to complete all sample analyses. To ensure the completeness of this investigation, the findings will be presented in the form of a table, figure, graph, and explanation.

The Findings

1. Effects of Soil Texture on the River Bank Failure

In April, June, and August of 2018, there were three site inspections in a row. According to three site assessments and a study, river bank erosion in Kg Pasir Parit is a big problem. This is attributable to the estimated 36,000 meters cubed of deteriorated land. Figure 1 illustrates that the cliff or river bank is 3 metres high, and the low land is 80 metres long before the monsoon season in June 2017. In contrast to August 2018, the river bank had eroded significantly, resulting in a major shift in stream morphology (a "U" shape) (Figure 2c). The illustration displays a river bank that was cut straight from higher ground to the water level of a stream. The low area was entirely ruined by stream flow erosion to the bank. Furthermore, the flood had already consumed a residence erected beside the river.

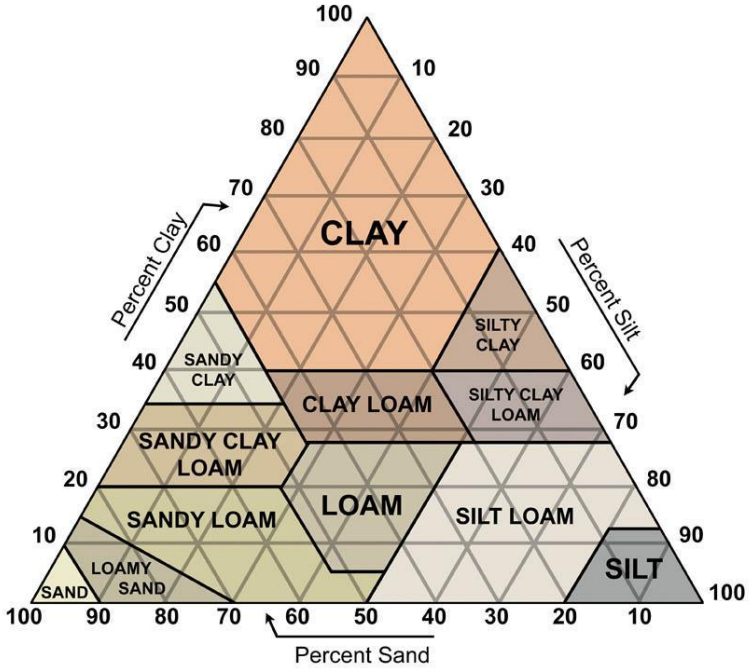
Figure 1. Comparison of river bank erosion at Kg. Pasir Parit



This study also highlights the massive erosion that occurred at Kg. Pasir Parit as a result of the existence of a river barrier. The barrier is made of an iron rod and is around 6 metres tall (KADA, 2018). KADA built this barrier to divert water flow to their pump house, enabling them to provide water for farming and agriculture (Figure 2).

Figure 2. Barrier built across the river near the KADA pump house
Source: Fieldwork on August 2018

Figure 3. Soil Texture Triangle



Source: Natural Resources Conservation Service Soil, USDA, 2012

The research shows the texture of soil for two samples, river bank soil and riverbed soil, using the hydrometer technique. Figure 3 depicts the soil texture triangle, which we utilise as a parameter to distinguish both soil textures. The experiment's results are shown in Table 2 below.

Table 1. Soil texture of sediment from the river bank and bed sediment of Sg Kelantan at Kg. Pasir Parit

Soil Texture	River Bank Soil (%)	Riverbed Soil (%)
Clay	10	8
Silt	10	12
Sand	80	80

Source: Lab Analysis

Table 1 shows that river bank soil was only 10% clay, indicating that the river bank was prone to falling into the river or eroding. The logical explanation for this result is that clays are pastier and stickier and hence may offer an "adhesive pattern" to interlocking soil particles. The riverbed soil does not have a lot of clay texture; just 8% of the samples taken had it. Following that, 10% silt in river bank soil is just 2% higher than in riverbed soil. In any case, both soil samples had an 80 per cent sand texture. So, with so much sand texture, the soil erosion rate is certain to be greater. This is due to the sand texture's inability to carry or retain the river bank from collapsing when exposed to heavy rainfall or impacted by river flow.

2. The Effects of River Bank Erosion on the Local Community

At Kg. Pasir Parit, the erosion of the river bank has had a substantial impact on the local human population. According to the study, the effects of bank erosion on humans include loss of settlement, land loss, trauma, and safety issues. People who reside along the river's edge have been forced to migrate. The most difficult aspect of relocating was that they didn't have another house to move to or land on which to construct their new home. The loss of their homestead renders them unable to live a respectable life (Figure 4). According to the information we have gathered through fieldwork, several victims have said that they would never relocate their homestead before the erosion occurred. The major reason for such behaviour is that they have insufficient

income to rebuild their houses before they completely collapse. During the interview, respondent A said that he was fortunate to be able to relocate to his second home, which was located a little farther away from the river bank. Respondent B, on the other hand, said that he does not know where to go if his home falls into the river as a result of the river bank's ongoing eroding. According to this issue, they said that government authorities such as KADA and DID would investigate and accept responsibility for their loss. However, the victims of river bank erosion did not get any compensation from them until August 2018.

Figure 4. A house that collapsed due to massive river bank erosion

Source: Fieldwork on June 2018

Farmers who farm on low ground or in flood plains are also affected by river bank erosion in Kg. Pasir Parit. They have enough area to grow agricultural items such as beans, maise, watermelon, sugar cane, and so on because of the low land or floodplain. They also grow homestead plants to meet their everyday needs. As a result, if low-lying land is eroded by the river, farmers will lose revenue over time. They will feel depressed if they suddenly lose their money and are unable to pay their living expenses. As a result, it was shown that land loss might result in a loss of income for individuals who rely significantly on agricultural land for both main and secondary activity.

Victims are traumatised as a result of the third effect generated by river bank erosion. Respondent C said that her daughter got traumatised because she was concerned that the river bank fall might endanger them. Her daughter is often sobbing and wants to leave their residence as soon as possible before things grow worse. Aside from that, river bank erosion endangers those who reside along the unstable river bank. According to observations, river bank erosion at Kg. Pasir Parit is a massive and dramatic erosion instance for the Kelantan River. One thing we are concerned about is that there is still one family of nine individuals who has not moved to a safer location.

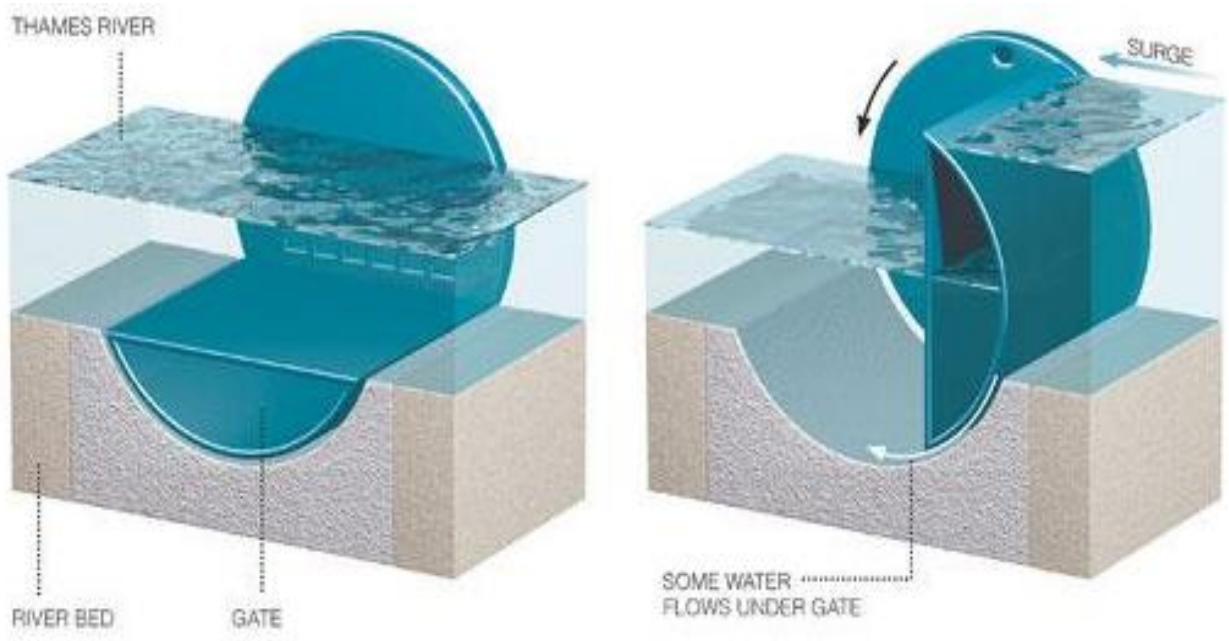
In a nutshell, river bank erosion has a negative influence on livelihood by destroying homesteads, destroying cultivable grounds, and reducing job prospects. Homesteads in riverside regions are often positioned after agricultural fields. When a homestead is wiped out, this suggests that the family or individual's whole assets are gone. When erosion occurs, individuals are left with little choice but to absorb the losses. Such loss forces them to flee to an area where they have little or no chance of survival. People in erosion-prone locations must take various actions to deal with the destruction caused by river bank erosion.

3. River Bank Failure Mitigation Approaches

Massive river bank erosion occurred at Kg. Pasir Parit as a result of a KADA barrier built across the river. Furthermore, the investigation discovered that the soil texture of the river bank and riverbed was too poor, which may easily lead to erosion during rainy or flood seasons. Reconstructing the barrier, building gabion mattresses, reinforced concrete, and groynes are some practical procedures that may be used for the Kg. Pasir Parit river bank to avoid erosion. Because of the massive erosion of the river bank at Kg. Pasir Parit, it is no longer appropriate to apply landscape or vegetate methods to defend the river wall. The first step for officials is to rebuild the current barrier. The barrier cannot simply be used to obstruct the river flow, as shown in Figure 2c. Instead, authorities, namely KADA, must modify it to be more adaptable to silt and water movement.

According to Encyclopaedia Britannica (2018), a mobile or adjustable barrier known as the Thames barrier is already in place in London (Figure 5). Depending on the river flow, the movable barrier gates may be adjusted. This is an excellent approach for KADA to obstruct the river's flow in order to deliver water to irrigate agricultural areas located distant from the river, in comparison to the present iron bar, which may create silt accumulation in the stream or raise the danger of river bank erosion. As a result, the Thames barrier is a preferable measure to prevent these problems.

Figure 5. Thames barrier



Source: Encyclopaedia Britannica, 2018

The second option advised by this research to strengthen river banks is to install a gabion mattress. This stage is comparable to riprap, but since smaller stones may be applied, there is a better possibility of covering the bank with a tiny amount of flora. Furthermore, it is more environmentally friendly and may be more accepted. This gabion mattress is simple to install at the study site. When adopting this approach, the wire baskets are vulnerable to abrasion and are best covered by flora placed in the mattress. (See Figure 6)

Figure 6. Gabion mattress installed to prevent river bank erosion

Source: B. Toprak *et al.* (2016)

Installing reinforced concrete or a reinforced wall is the next idea for reducing river bank erosion at Kg. Pasir Parit. This technology uses appropriately planned concrete retaining walls to offer long-term erosion prevention. Reinforced concrete is highly beneficial for protecting river banks from erosion, but construction must begin during the dry season or at a low water level so that the river flow does not impact the wall, causing the concrete to tumble down, erode, and collapse. (See Figure 7)

Figure 7. Reinforced concrete to protect the weak river bank

Source: B. Toprak *et al.* (2016)

Furthermore, Groynes are an excellent way to prevent river bank erosion in Kg. Pasir Parit. Groynes are also known as retards, spur dikes, and so on. It is a wall built from the river bank to a certain distance into the river, more or less perpendicular to the flow direction, with the goal of inducing the water to flow some distance from the river bank where the constructions are attached (Figure 8). A field of Groynes is a collection of structures that work together to regulate a river's flow route and the placement of sediment deposition. (King, 2015) This approach roughens the river bank, lowering the velocity of the flow directly against the bank and increasing the possibility of sediment deposition rather than erosion.

Figure 8. Groynes on the Waal River in the Netherlands

Source: King (2015)

Conclusion

This research reveals a lot about Kelantan River bank erosion in Kg. Pasir Parit. Based on the findings and discussions, this river bank failure may be classified as an enormous disaster since the estimated impacted area is large (approximately 36,000 m^3) and has had a significant impact on the people living nearby. So, by doing the observation and having interview sessions with the community, the study also identified the consequences due to the disaster, which caused stress and fear of living in the same place. Due to this, they are forced to move to a place of safety as well. However, it has become a problem for those who do not have another second house; they have to temporarily stay at a friend's or relative's house until they get their compensation. From the survey also, we are able to share some relevant suggestions to reduce the likelihood of the same disaster happening. We suggested that all the people, such as authorities, the community, and NGOs, should be aware of all the activities done around the riverside to avoid river bank erosion. This study also suggested building suitable barriers according to morphological characteristics. This mitigation approach is usually completed by other states, such as Canada, America, or China, to mitigate river bank erosion due to high river flow eroding the wall. However, to enhance the mitigation, one must count the project's financial cost against the benefits of the project, even though it is necessary to reduce the risk to the community. This kind of disaster is very rare, but the risk is real for those who live nearby the river. Therefore, we have to raise

awareness and preparedness among the community and, at the same time, find an effective solution according to the local cases so that disaster management can achieve the objective without paying a high cost.

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Conflicts of Interest: The authors declare no conflict of interest.

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