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Environmental Degradation: A Review on the Potential Impact of River Morphology

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Abstract. River morphology involves the lateral migration of matters deposited by flowing water in the river channel across its floodplain. This is driven by the erosion along the river banks and point bar deposition over time. This paper presents a review on river morphology studies and its potential impact to the society. The reviewed studies include mathematical models and computer simulation such as FLUVIAL-11 and RVR Meander Package that are significant to illustrate a continuous research development on channel adjustment. The findings also shows that a lot more area can still be explored to aid the fundamental of understanding river morphology and that East Malaysia will provide a good platform for the researchers to investigate the lateral migration of a river due to its diversity environment.

1 Introduction

As time passed, rivers may change its shape laterally or vertically. This phenomenon needs thorough investigation as any excessive development may also contribute to the changes [1]. Environmental degradation is a deterioration of the environment through the depletion of natural resources which leads to the destruction of ecosystems and wildlife extinction. The process might occur naturally but activities such as uncontrolled deforestation, improper agronomic practices and rapid urbanization will make the scenario worsen [2]. The interaction between river channel and the floodplain landscape is known as river morphology. Since the river is dynamic, they constantly changing in both space and time. River morphology can be categorized into degradation, widening and aggradation [3]. The morphology processes are as summarized in Table 1 and illustrated in Fig. 1.

Table 1. River morphology process.

Morphology Process	Caused By	Description
Degradation	Increased flow	Lowering bed elevation
Aggradation	Decreased flow	Increasing bed elevation
Widening	Increased flow	Increasing channel width

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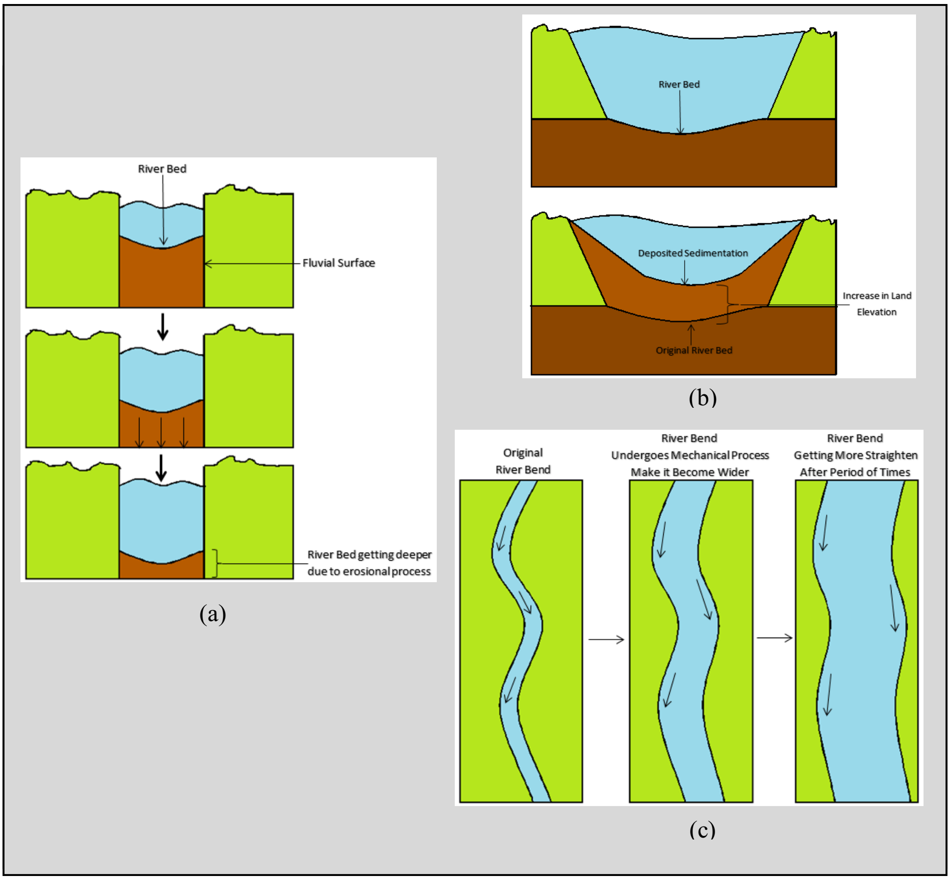

Fig. 1. River morphology process. (a) Degradation. (b) Aggradation. (c) Widening [3].

Degradation is the lowering of river bed elevation which can happen both at the downstream and also at the upstream. At the downstream, degradation can be related to the changes in the independent river channel variables such as increase in river flow, decrease in size of river bed material and decrease in river bed material discharge whereas for the upstream, it can be related to increase in the river slope which can occur as a result of natural river behaviour or human activities. Widening may occur by erosion of one of both river banks and leads to the increasing in the channel width. It is usually associated with flow acceleration due to a decreasing cross-sectional area coupled with deflection around growing bars. Aggradation is the accumulation of sediment in river channel, causing increase of the river bed elevation. It happens when the rate of sedimentation is greater than the rate of sediment transportation and when there is a decrease of bed slope [4].

2 Review on recent progress in established studies

Migration in a river is a process of river movement in which the water flow to erode the river outer bank and the sediments will be deposited on the opposite site of inner bank. Every year, there are a lot of cases being reported where properties or agriculture land which is located nearby to the river bank collapse. This tangible loss incurred to some extent is unavoidable which causing economic losses, damages and fatality.

The rate of lateral migration is unnoticeable through observations over a short period of time. In the past, time sequential of aerial photographs approximately 20 to 30 year apart have been used to measure the lateral migration rates of river bend [5]. The development of mathematical model and formula to measure the rate of lateral migration over the decade has contribute a lot to understand this lateral migration phenomenon. Studies had shown that there are a lot of factors in river migration which needs to be assessed and taken into consideration. Deep understanding on this occurrence is important as it can help researchers and local authorities to prepare and provide sufficient planning on the mitigation as a solution to the problems related to river migration.

Among the studies, there are significant numbers of findings related to river migration throughout the years. Most of the findings improve the way to assess and investigate the process and rate of river migration with some guidelines on action need to be taken. Table 2 shows the summary of studies from previous researchers since year 1984.

3 River dynamics: where the water goes

Nowadays, most of the engineers are concerned with the problem related to erosion and sediment in the river including slope stability, water quality, stream restoration and changes to the physicality of the river [14]. The purpose to understand river, both in their natural setting as well as how they respond to human induced changes in a watershed is to predict what changes will occur to the channel in response to alterations in watershed conditions and how these changes will impact the society, infrastructure and aquatic lives.

The process begins with the water coming down from the uppermost streams in the river network. It will flow down the concave-upward graded profile of water path and the high potential energy from the water flowing downward will have the ability to erode the bedrock and making a stream of water. The steeper the slope, the faster flow of the velocity will be and more energy of the stream to erode materials. When it is raining, the water will be drained from a higher elevation and cause drainage basin to occur with larger erosion problem. Once there is a drainage basin, there will be separation of the drainage basin from one another. Due to erosion, gully and rill will eventually formed up. When the water is flowing down, the potential energy in the water will be converted into kinetic energy. This will distinct the shape and the roughness of the channel. River morphology will occur when there is velocity in it. Velocity in the stream is controlled by the shape and the roughness of the channel. A smoother and narrower channel will produce larger velocity, whereas rougher and broader channel will produce smaller velocity. In a condition where there is a large velocity, erosion and deposition will occur more frequently. The larger the velocity, the more load a stream can carry. The result of these processes will leads to the formation of loads on the river bed. Sediments in rivers are transported either as bedload which is the coarser fragments or suspended load which is the finer fragments. There is also dissolved load, which are soluble products of chemical weathering process that dissolve in the stream. Generally, most material is transported as the bedload. It moves along the bed of stream by rolling, bouncing or sliding. These particles are too heavy to be carried by the flowing water. When sediment is light enough to become suspended in the water, it is carried by the stream as suspended load. Suspended load makes some streams appear to be cloudy [15].

The load is carried along by various processes. Traction is where the boulders or stones are rolled or slides along the river bed by the force of water. Suspension involves very small particles such as silt, clay and fine sands. As they float, these small particles are held up by the water and carried along the river. Then there is saltation, a combination of traction and suspension. This is where the velocity of the water lifted fragments like tiny pebbles off the river bed and they bounce along. Lastly, transportation in solution is when dissolved materials are carried in the water.

Table 2. Summary of studies from previous researchers outside Malaysia.

Year	Authors	Brief Related Research Work
1984	H. H. Chang	• Erosion on the river bank is caused by the removal of sediment on the bed of the river channel, causing the bank to collapse [6]. • Used FLUVIAL-11 to produce mathematical model of river channel. • Indicated the importance of lateral migration rate as one of the input data in modelling a river channel changes.
1984	Hickin and Nanson	• Conducted a series of investigation for 23 rivers in Canada and concentrated on channel-bend migration rates and control factors. • Found that maximum migration rates per unit width increase with increasing bend curvature. However the results may only be applied to the river with similarity in terms of hydrology and geomorphology.
1989	A. J. Odgaard	• Tested the analytical model to describe the platform development in terms of lateral and downstream migration rates. • The model is able to predict the rate, direction, magnitude and location of near-bank bed scour. However the model is non-applicable for channels with large curvatures [7].
1991	Ramasamy et al.	• Determined the river migration by observing the migratory signatures in Western India using Landsat photographs of 1:1 000 000 scale. • Explained that shifting of parent rivers greatly influenced and disorganized their tributary systems and that study on migration is important when selecting sites for dams, reservoirs and bridges [8].
1992	Alan D. H.	• Simulate the floodplain deposition model by assumes that the deposition rates decrease with distance from the closest channel and with increasing floodplain elevation. • Model combining flow and bed topography in meandering streams will provide realistic migration of simulated channels [9].
2001	Spitz et al.	• Emphasized on enhancing empirical databases to develop predictive model for bankline erodibility and floodplain characteristics. • A proper channel migration assessment are required as they may result in excess bridge pier and abutment scour, threats to bridge approaches and other highway infrastructure, worsened debris problems, and obstructed conveyance through bridge openings [10].
2006	T. J. Randle	• Simulates channel migration model by computing bank erosion as a function of sediment transport capacity, radius of channel curvature and the bank materials properties acting to resist the erosion including vegetation, large wood debris, cohesion and armouring. • Unlike previous one, this model is able to predict future channel alignments and make simulation for different hydrologic condition [11].
2008	Heo et al.	• Predicted the meandering channel migration by utilizing GIS. The result is satisfied. The longer the orthophotos-recorded, the better accuracy of the result is obtained. • The GIS approach offers simplicity and effectiveness. A specific tool such as satellite specifically used to monitor river migration may provide a better result [12].
2013	Ashraf and Liu	• Used RVR Meander package to relate migration rate to vertically averaged near-bank velocity through the use of coefficient of bank erosion (E). • The migration coefficient needs to be calibrated against historic channel centreline where the time period is chosen in such a way that it can capture large erosion events. Each section of the river bank have different coefficient value and the more coefficient used for different type of bank, the more accurate the result is [13].

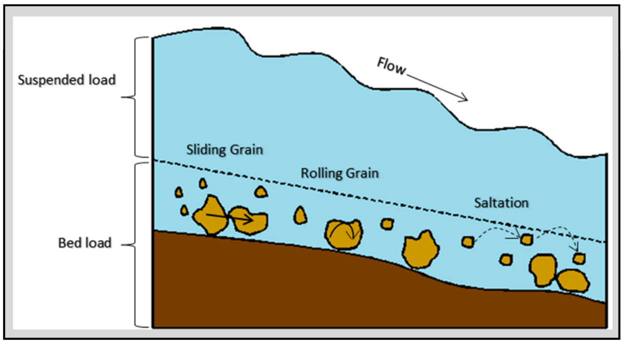

Fig. 2. Sediment motion in river morphology.

4 Potential impacts to the environment and society

The river morphology process that happens over time will have impact to the surrounding ecosystem and also the water quality. The suspended sediment increases with higher streamflow discharge. Development of landuse may accelerate surface soils erosion, gully erosion or soil mass movement along stream channels. When they are not controlled, the amount of suspended sediment might increase excessively and will affect other downstream uses of water such as hydroelectric pump, turbines and reservoir capacity. High levels of suspended sediment increase turbidity level which reduces light penetration in water and therefore can adversely affect the aquatic habitat.

As suburbanization progresses, the stream channels will have to handle risk of more frequent flood peaks. There will be changes in erosion and deposition of sediments and also to the structures in the area as it will be not very safe to live nearby the area. For example, Atrak River in North-East of Iran have shown that the rate of replacement of the river bank has reached 3.5m in year 2000 from only 0.36m in year 1956. The erosion processes that downcutting the surface or the sides of the stream will also slowly taking away the support of the trees and plants itself. In a certain period of time, landslide might occur and large woody debris will flow into the stream. Due to its large sizes, it will not be transported or affected by the speed of the water, thus making it sediments at certain point. From this, flood may occur as the discharge of the water at the downstream is lessened [16].

In rural areas, streams or rivers are their only source of daily water supply. The sediments and inputs of the erosion will have direct impact towards the physical properties of the water and the cleanliness of the water itself. This is hazardous to human health as the erosion of soil in river degrades the quality of the water. The changes of the river behaviour will also affect human daily activities such as farming due to high amount of water flow that rapidly change or even the severe erosion of riverbank. For example, 90.13% of respondents from Shantipur, India lost their land due to riverbank erosion over the past 40 years [17]. These show the significant of river morphology in engineering studies.

5 Study progress in Malaysia

Malaysia, a country which is located in Southeast Asia is rich with geographical value including rivers. The two distinct parts of this country are Peninsular Malaysia and East Malaysia. Malaysia climate is categorized as equatorial as it is located near the equator. The total land area of Malaysia is approximately 329,750 km^2. From the total land area, 1,200 km^2 is made up of water such as lakes and rivers. In total, there are 3,000 river basins with

189 of main river basins of more than 80 km², 74 from Peninsular Malaysia and 135 from East Malaysia (Sabah and Sarawak). The geographical location provides protection to the country from most of the major natural disasters such as earthquake, volcanoes eruption, tsunamis and typhoons. However, with the average rainfall of over 2,500-3,500mm per year, Malaysia tropical climate opens the country to the risk of floods, landslides and droughts problem [18].

Flooding issue has been a major concern due to uncontrolled rapid development which leads to the increase of impervious areas [19, 20]. With that, there will be more surface runoff and sediment buildup in the rivers system and overflowing water from the river banks. These will not only causing losses in terms of money, but also further damage to the economic structure and development in the area [21, 22].

As shown in Table 3, a few studies related to river morphology in Malaysia have been conducted, mostly in Peninsular Malaysia. However, there are still a lot to be explored especially the rivers in East Malaysia as both Sabah and Sarawak are known to be diverse in its surrounding environment.

Table 3. Summary of studies from previous researchers in Malaysia.

Year	Authors	Brief Related Research Work
2005	Kiat et al.	• The FLUVIAL-12 an erodible-boundary model which simulates inter-related changes in channel-bed profile, width variation and changes in bed topography was used. Good agreements were obtained for both water level and bed profiles between the measured data and predicted results as it shows the sediment size and channel geometry in Kulim River, Kedah changed significantly.
2013	Gasim et al.	• Floods occurred yearly at Pahang River especially during northeast monsoon and expected to be stimulated by the inconsistent condition of width and depth along the river which create sedimentation and meandering characteristic. The authors measured river drainage capacity, hydraulic parameters and estimation of flow discharge.
2015	Chang et al.	• The December 2014 flood in Pahang river basin affect not only to the economy but also the river morphology itself. Bank erosion, widened cross sections and sediment deposition can be easily identified after the flood recedes. Sediment size distributions were investigated.
2015	Khan et al.	• The most intense geomorphological process at the river bank is the process of erosion. Floods play a key role in landform evolution of an area Kelantan from Kemubu to Kuala Besar. The results show a significant change in the length of the cross section which suggest that the geomorphological processes play a key role in carving and shaping the river banks during the floods.

For example, Putatan River, a tributary which is located in Sabah was realigned in year 2004 to reduce flooding at the confluence with parent Moyog River at Penampang. However, detailed hydraulic investigation was not undertaken [23]. Now, the original Putatan River is no longer functioning as drainage path. It is ecologically degraded and there are rapid encroachment of housing and development into the river reserve. There is also an extensive sedimentation in the new channel, which now has limited its capacity.

Moyog River is geomorphologically unstable. Past attempts to train the river and protect infrastructure and property have been unsuccessful. One river in north Sabah, Benkoka River in Pitas experienced 15 m lateral movement per year due to large flood occurrence, with the whole villages requiring relocation. Such a large scale of relocation is unacceptable within the dense Penampang and Putatan area. Thus, this will make an interesting case study area for researchers to conduct their research in East Malaysia.

6 Conclusion

As a conclusion, having deeper understanding on river geomorphology is crucial especially on the lateral migration for the engineers. Both public and local authorities should also need to be aware of this phenomenon as many of the construction projects tend to be developed near to river banks. By assessing the rate of migration, prediction and planning for future development can be decided properly. Any structures that spanning across a river channel can be further enhance by providing a proper technique and detailed assessment of the migration rate of the river channel [24].

Usually, any river banks that have migrate and affect the structures or land used activity nearby need to be reviewed with proper river restoration methodologies [25]. Developers seldom conduct detailed hydraulic investigation as it requires time and cost. They will only investigate the water level and how often the flood happened in their construction site. It requires a lot of work and the construction proposal usually does not include detailed hydraulic investigation.

Over the years, all the breakthrough findings on lateral migration contribute a lot to the understanding of this phenomenon. The adaptation of modern technologies in recent centuries brought up the study to a whole new level [26]. The analytical model integrated with GIS that has been developed has a high potential for application and is more interactive where users are able to simulate and observe the potential impact in the affected areas. Knowledge on sediments transport is very important as it can be applied to determine the magnitude of erosion or deposition and the time and distance over which it will occur.

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