Channel Pattern Evolution Due To The Non-Migrating Mid-Bar

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Abstract
Channel evolution is a net outcome of erosion and deposition. It initiates and develops width adjustment and planform evolution. Structures such as bridges, highway, flood control contraptions and building are built within the vicinity of the river will be affected by river meandering and its distance. And at these structures area, mid-bar will be occurred that influence the hydraulic properties. Therefore, the aim of this paper is to determine the pattern of the of the bankline due to the non-migrating mid-bar. The morphology evolution is affected and influences expansion area of mid-bar, low-curvature degree in the channel planform and presence of obstacle This research was carried out on a physical river channel model measuring 10m long, 2.4m wide and 1.8m deep located at Universiti Teknologi MARA Puncak Alam. This paper presents bankline pattern with a different discharge. From the experiment, its shows that morphology of the river will be changed from straight to meander river and its effected to spatial patterns of rate of width change, cross-sectional of the profile and degree of deflection to lateral migration rate.

Keywords: river meandering, channel pattern evolution, non-migrating mid-bar

1.0 Introduction

River morphology is a process of river migration with tendency of widening a cross section. It shows that the river has a high tendency in dynamic evolution because of natural phenomenon which occurs in the absence of specific disturbances. A river changes its characteristics over time and space with changes in environmental controls. Climate change and human activities in the surrounding area have impact on the changes in environmental controls. From engineering point of view, the changes in river morphology will affect flow depth and channel width. As a result, it will affect the conveyance of water, sedimentation, navigation, water supply, fishery and environmental (Lanzoni, 2000).

In a river system, erosion and transportation plays a constant role in removing water and sediment at various points over time. A river develops a wide range of networks and channel forms; therefore, the characteristics of the forms relative to the fundamental processes at river are major concerns. Knowledge on the extent of migration due to natural river processes is essential in hydraulic and design of hydraulics structure is required to improve the techniques.

Lateral migration is a process of channel migration due to bank erosion. There are two (2) major processes of bank erosion: hydraulic action and mass failure. Hydraulic action is associated with velocity gradient closer to the bank. At the convex of meander bends, bend apices with the steep velocity gradient and the high shear stress are commonly associated with the bank retreat (Knighton, 1998). However, mass failure depends on the geometry, structure and material properties of the bank. It is also related to soil moisture conditions which decreases the cohesiveness, cause subsequent reduction in the strength of the bank material and decreases the bank stability.

Lateral migration process will lead to sediment deposition on the river bed. Deposition occurs when flow or shear velocity decreases and the particle (sediment) settles on the bed. Particle size has significant impact on the settling velocity of the particles, which determines the magnitude of deposition. The coarser fractions tend to be deposited prior to the finer ones. Deposition of sediment determines the bed configuration, which includes bedforms and bars. The bedforms including ripples, dunes and antidunes remain submerged except during drought. In addition, bars refer to bedform configuration and are disclosed with low flow. Mid-bar refers to the bars in the middle of the channel, which is associated with the erosion of the concave and the lateral migration process of the river. The distance of channel migration expands in perpendicular direction to the bankline in the migration process of the channel.

Migration, erosion and deposition are natural processes occurred in natural rivers. However, it can be accelerated as a result of human activities such as logging, sand mining and distraction of land use. Formation of mid-bar derived from instability condition of erodible bed is subjected to turbulent flow in a river system. Sediment and flow can be described as a process of interrelationship in the formation of either migrating or non-migrating mid-bars. Therefore, this study focuses on the effects of non-migrating mid-bars on lateral migration channel.

1.1 Objective of the research

From previous researches, there have been no historical records and results on the effect of non-migrating mid-bar to lateral migration. Therefore, this study attempts to investigate bankline evolution in the river system under the influence of non-migrating mid-bar. Objectives of this study is to determine the pattern of the bankline due to the non-migrating mid-bar. The factor will give a predictive study on lateral migration influence by the mid-bar. This study is desirable to ensure safety on the behaviour of lateral migration process especially during designing process of any structures and infrastructure such as the railway, highway, pipeline system, building and other structures built near waterways should take into consideration the morphological river process.

1.2 Lateral migration process

Migration is a process of river movement in which water flow to erode the riverbank at outer bank and sediment will be deposited on the inner bank. The process of migration can be characterised as lateral channel movement. The channel will be shifted and moved perpendicular to the channel centreline over time. The process of lateral migration involves erosion and deposition processes. In natural river, the process of lateral migration depends on strength of bank material, cohesion, armouring and vegetation (Julien, 2002). Bend migration is a major consideration in structural design of facilities along rivers as it may damage or destruct the structures or facilities. This is as a result of excessive scouring and loss of conveyance due to misalignment and point bar development. Due to these problems, it may exacerbate watershed conditions such as land use change, aquatic life disturbance and removal of vegetation

Channel migration is a process of the river shifting in lateral movement whether in a dynamic state equilibrium or in an unstable state adjusting from equilibrium condition to another (Richard, 2001). This dynamic physical process of river includes movement of water and sediment migration over time. This migration process includes bank erosion and avulsion. Lateral movement can take different forms depending on the input conditions. A river may become narrow or widen, experience meander migration avulsion and cut-offs. The river exhibits different planform types with different movement rate as a result of different causes or mechanisms (Friedman et al, 1998). Several studies on lateral migration of meandering river were carried out at site and in laboratory (Richard, 2001; Park, 2007; Yeh, 2009; Kuang, 2011 & Lagasse et al, 2004) reported meander can be affected by mass failure, bank retreats, debris removal and meander migration through scouring along the outer bank, deposition along the inner bank and renewed constriction. Lateral movement occurs in different processes, resulting in different rates of lateral migration. From the study by Mosselman in 1995 on Jamuna River in Bangladesh, it was found that fluvial mechanisms can cause a higher level of aggregation in channel width adjustment, channel migration, island formation, channel creation and channel abandonment.

1.3 Experimental setup

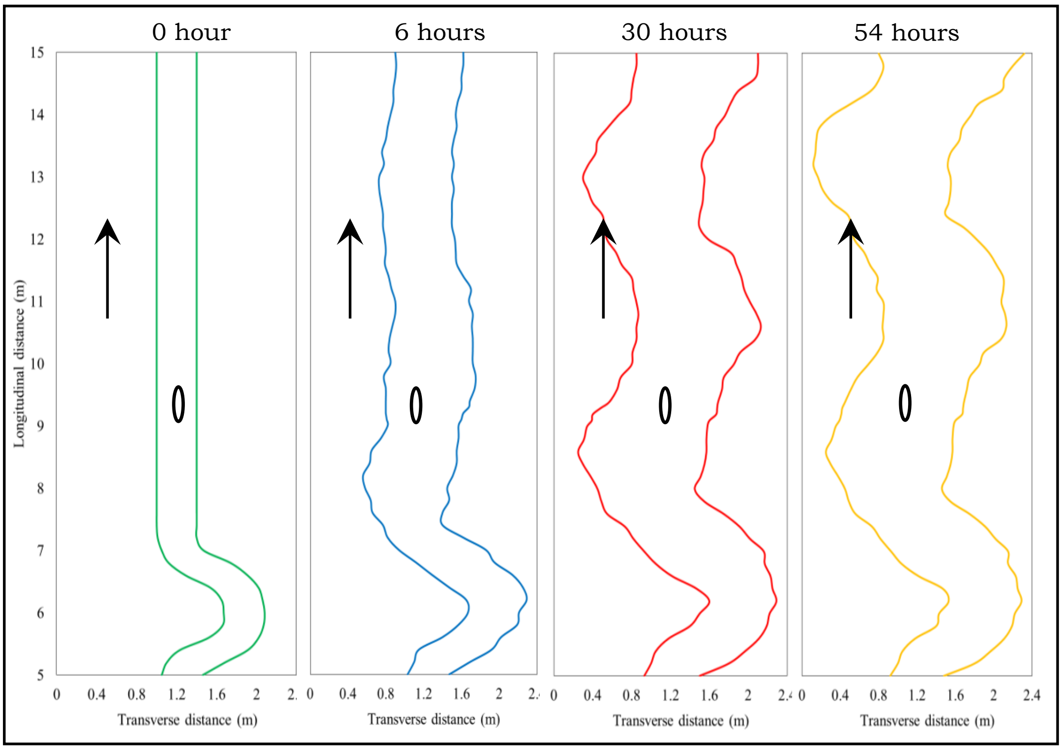
The experiment was conducted in a concrete flume measuring 45m long, 2.4m wide and 1.8m deep, located at Universiti Teknologi MARA. Three (3) main types of equipment had been installed, which are water pump, V-notch angled at 60 degrees at the entrance of flume, and pipes with varied sizes ranging between 102 mm to 76 mm diameter. To ensure the initial slope, three (3) sticks levelling gauge were installed along the side of the brick wall. The experiment was conducted in a wide and shallow flume of sufficient size to permit the stream to meander freely. The initial channel was moulded with 10m long, 0.4m width and 0.15m deep which is rectangular cross-section. The flume is connected with a water tank (6m long, 6m wide and 1.8m height) through connected pipes supply as mentioned above. This channel was designed with a size large enough to accommodate the channel to migrate either to the left or the right of the bank. The channel was carved using a mold on the sand bed to simulate the natural process of meander of a natural river. In order to get varied pattern of bankline, this experiment was conducted for 25 sets of experiment which are consist of different flow rate, different sizes of non-migrating of mid-bar and different initial pattern of the channel.

2.0 Result and discussion

In this study, the cross-section of channel profiles were mapped at several points along the channel. These experiments represent different discharge to get different experimental results. Cross-section profile was measured at 5cm interval in the horizontal and 20cm in the longitudinal direction using laser distance meter. The mapped bed profiles of 51 cross-sections consisted of approximately more than 2500 bed topography points along 10m channel and every cross-section was labelled as chainage (CH).

2.1 Channel pattern evolution

The measured data was digitised and aided by ArcGIS 10.2 software. A triangulated irregular network (TIN) is a digital data structure used in a geographic information system (GIS) for the representation of a surface. The chainage as a reference lines were generated from 6 hour- time steps aided by AutoCad 2007 software. The cross-sectional profiles were plotted from the surface and chainage at several points. The banklines were superimposed from the previous step. As an example, experiment no. 12 in Figure 1 (a), (b), (c) and (d) show the planform evolution of the channel at different time steps from initial condition, which is 0 hour, 6 hours, 30 hours and until 54 hours. This experiment was stopped after 54 hours because the channel has reached the equilibrium condition and the channel experienced constraint to move in the flume. This figure also shows that the non-migrating mid-bar promoted lateral migration with meandering because high velocity occurred at the non-migrating mid-bar. While, without any obstruction of the bar, the channel will migrate but in transvers migration (Tholibon, 2016).



(a) (b) (c) (d)

Figure 1: The bankline evolution at (a) initial condition (b) 8 hours (c) 30 hours and (d) 54 hours for experiment 12 (Q = 6.64 m^3/hour)

The morphology behaviour of a straight and meander channels with constant flowrate were examined for every experiment. The experiment was set up with various flowrate as mentioned as mentioned above, while the designated flow was a steady non-uniform flow. The bed and river bank of the channel were designed with a 0.01 slope along the channel. Figure 2-5 illustrate the planform of channel migration from start until the end of the experiment. These figures show a comparison on the evolution of channel for four (4) different flowrates. Experiment 2 (Figure 2) was carried out with highest flowrate. It was difficult to obtain the development of meander channel from this experiment than in other experiment (with lower flowrate). Figure 2 (b) and (c) illustrate the evolution of the channel for lower flow rate than Experiment 2. These figures show the channel became widened at 7 m chainage onwards.

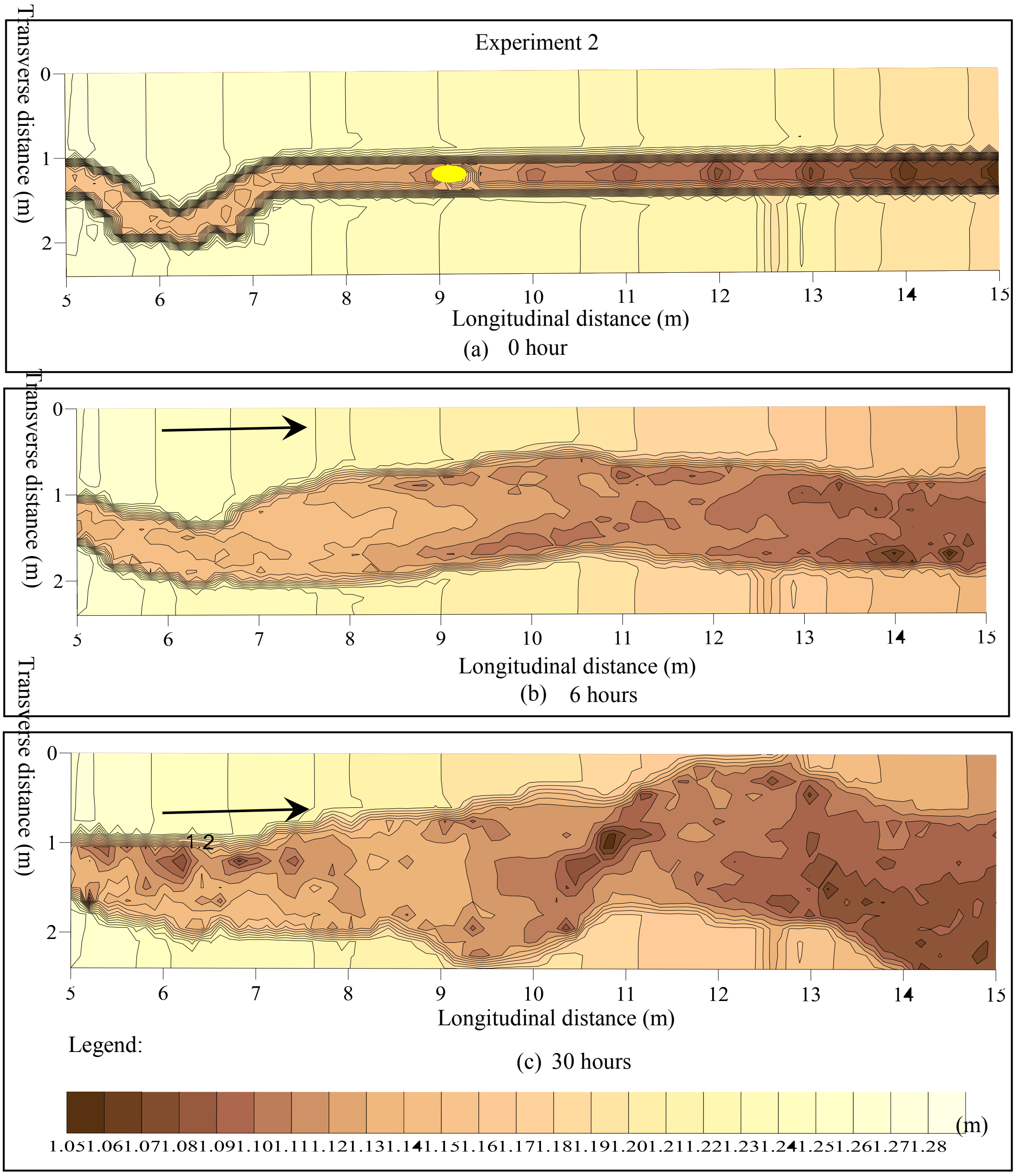


Figure 2: Development of channel planform (a) initial condition (b) 6 hours (c) 30 hours for experiment 2 (Q = 13.53 m^3/hour)

At the end of the experiment, movement of channel is constrained by space limitation. There is evidence of erosion throughout the channel on both sides of the bank. Large bank retreat occurred before the non-migrating bar and proceeded downstream with broadened channel width. Based on planform and slope, the channel is widened and made shallower with developed flood plain at the end of the experiment. In experiment 5, 13 and 18 (Figure 3 - 5), the channel exhibited a more uniform migration at lower flowrate. Thus, channel progression took place laterally. This development promoted meandering of the channel as documented by Nagata et al. in 2000. The constructed mid-bar was fully covered with deposited sand as bank material got eroded and transported downstream (Figure 2). Therefore, in the following experiment, the constructed mid-bar was lifted-up at the same level as the channel bank, so that this structure would not be covered with sediment.

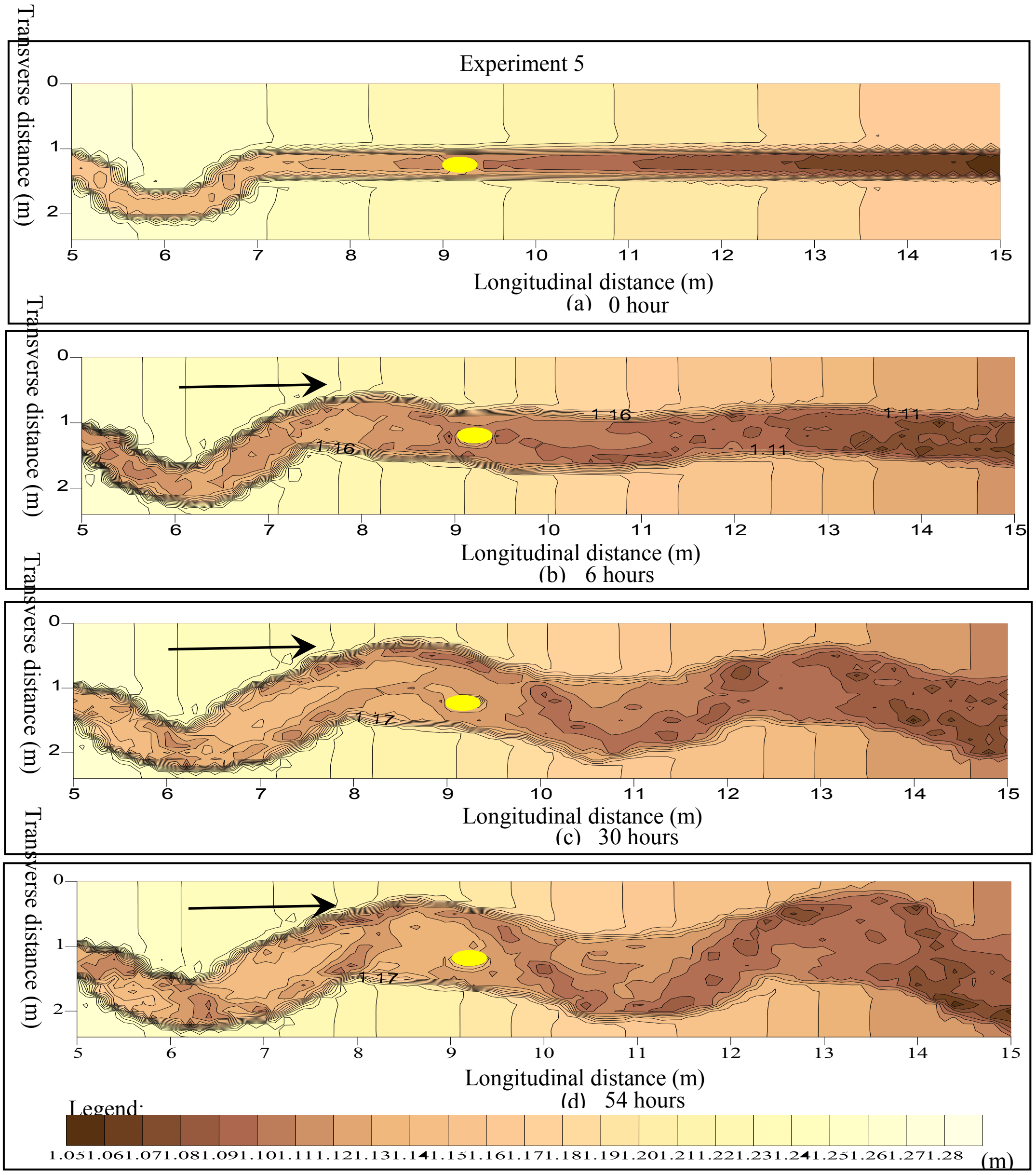


Figure 3. Development of channel planform (a) initial condition (b) 6 hours (c) 30 hours (d) 54 hours for Experiment 5 (Q = 6.64 m^3/hour)

Experiment 13 (Figure 4(c)) gives illustration of the migration process with rigid structure introduced at the centre of the river width. The effect of the widened channel width due to the migration process is evident. The limit of widening is related to the thresholds limit of the migration process. Therefore, a thresholds limit is important in river control and engineering.

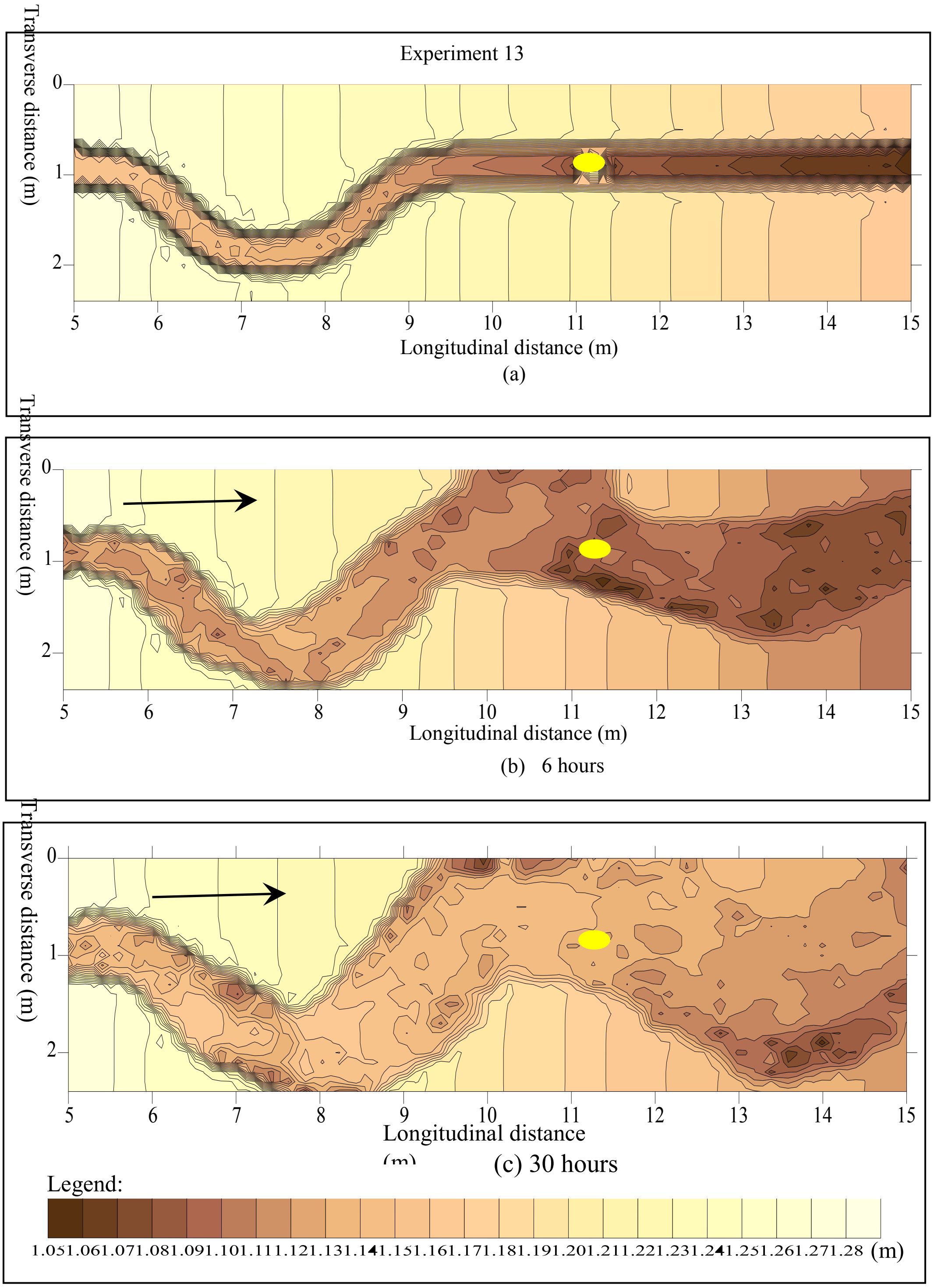


Figure 4. Development of channel planform (a) initial condition (b) 6 hours (c) 30 hours for experiment 13 (Q = 10.91 m^3/hour)

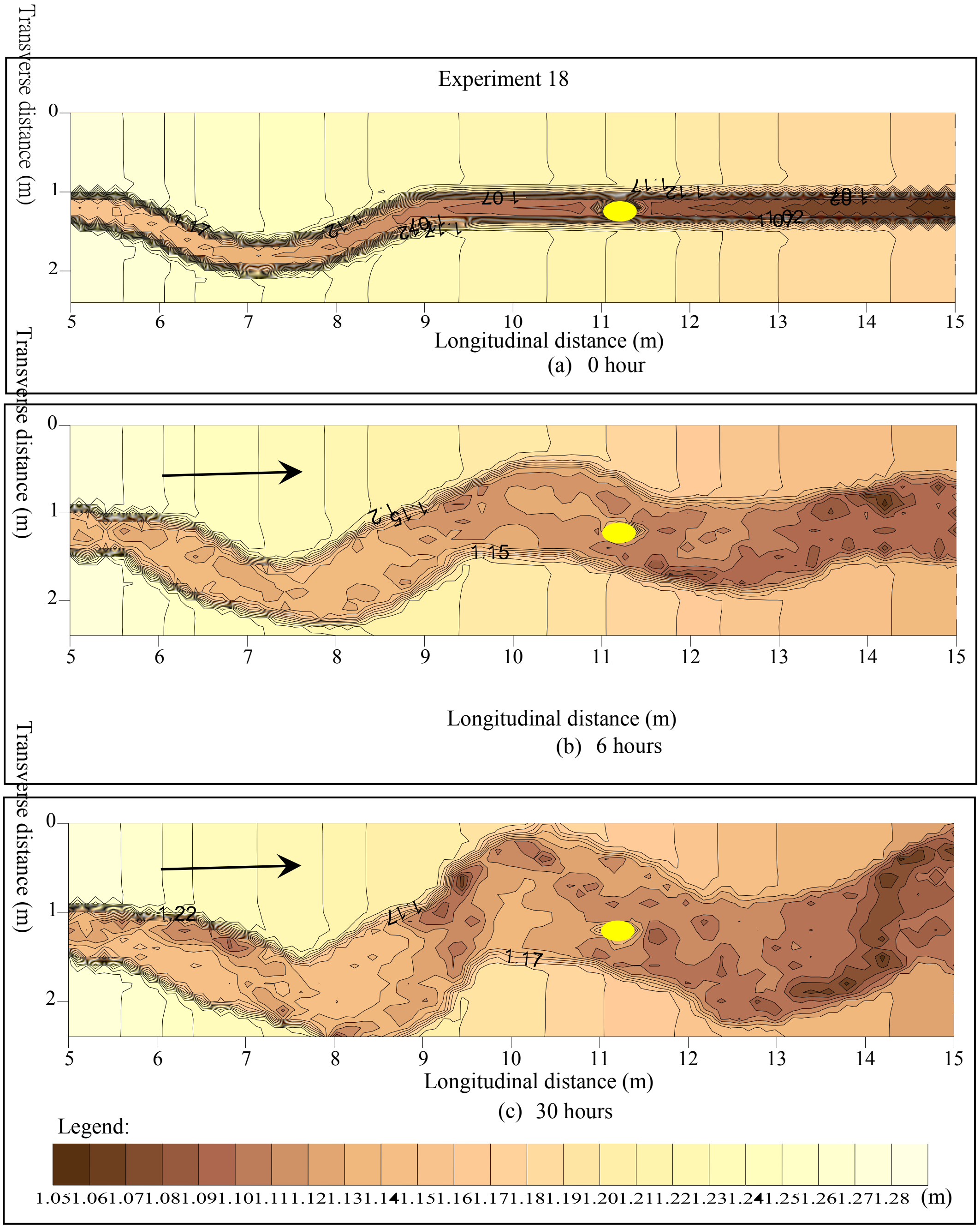


Figure 5*:* Development of channel planform (a) initial condition (b) 6 hours (c) 30 hours for experiment 18 (Q = 8.62 m^3/hour)

3.0 Conclusion

Based on the analysis of morphological change, results show that there exist some relationship between spatial patterns of rate of width change, channel cross section profile, and slope and degree of deflection to lateral migration rate. There is an evidence of erosion throughout the channel on both sides of the bank. Large bank retreat occurred before the non-migrating bar and proceeded downstream with broadened channel width. Based on planform and slope, the channel is widened and made shallower with developed floodplain at the end of the experiment.

Different constant discharge and degree of deflection created specific pattern of velocity either mean velocity or velocity at point which has influenced the erosion and deposition processes and thus, the channel planform migrate from straight channel to meander channel. On the other hand, non-migrating mid bar also took into consideration on the effects of the pattern of velocity and the channel profile. This structure has caused the channel to widen at non - migration mid–bar area. Therefore, a thresholds limit is important in river control and engineering.

4.0 Acknowledgements

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