Impact Changes of Flow Rate on Stream Morphology

Jennifer R. Krawiec

Department of Atmospheric and Geological Sciences, State University of New York at Oswego

Abstract:

The EMRiver stream table is a metal “box” (has an octagonal shape) that is 94 cm wide, 275 cm long, and about 13 cm deep. The box is filled with a well sorted, ground up plastic that resembles the size of medium sand. This plastic modeling media acts as “sediment” in our model. Before each run is conducted, the sediment is smoothed and packed down and a starting channel is made. The starting channel is 2.5 cm wide and approximately 4 cm deep. The table is tilted to a constant slope (3.3 degrees). During this research project, we are using the EMRiver EM3 Geomodel stream table to observe how changing the rate of flow within a stream impacts the change in stream channel morphology.

By using this physical model, we can observe changes in stream channel morphology over time. As the physical model was running, we recorded the development of meanders and other features with time lapse video. We then measured the meander sinuosity and stream width from still photos. To measure the sinuosity it is the length of the stream (from upstream to downstream) divided by the length of the meandering stream (measuring within the channel from upstream to downstream). To measure the stream width, we measure the width of the channel at 3 different points and divide them by the width of the table. A total of 21 runs were conducted at different flow rates. The flow rate was varied between a range of 40-80 ml/s. We allow the stream model to run for about 60 min, while a Raspberry Pi camera takes still photos which are then stitched into a time-lapse video.

From this information, we can see how flow rate impacts the morphology of the stream channel. Our preliminary results suggest that as the flow rate increases, the width of the stream channel increases and sinuosity increases. This study has application to agriculture, civil engineering, and land usage planning. It also shows the impact of climate change (periods of increased precipitation or droughts) on the behavior of river systems.

Introduction

Stream channel morphology is controlled by many factors. One of the important factors is flow rate. Flow rate is a ratio of volume over time, a discharge. Based on prior knowledge and studies, streams with a low flow rate have more meanders than a stream with a higher flow rate (a braided stream) (Rosgen, 1994). In this study, we chose seven different flow rates to model on the EMRiver stream table to observe, record and measure how they affect stream channel morphology. We used a Raspberry Pi camera to take pictures and produce time-lapse videos. From our pictures, we measured stream sinuosity (how much it meanders) and stream width.

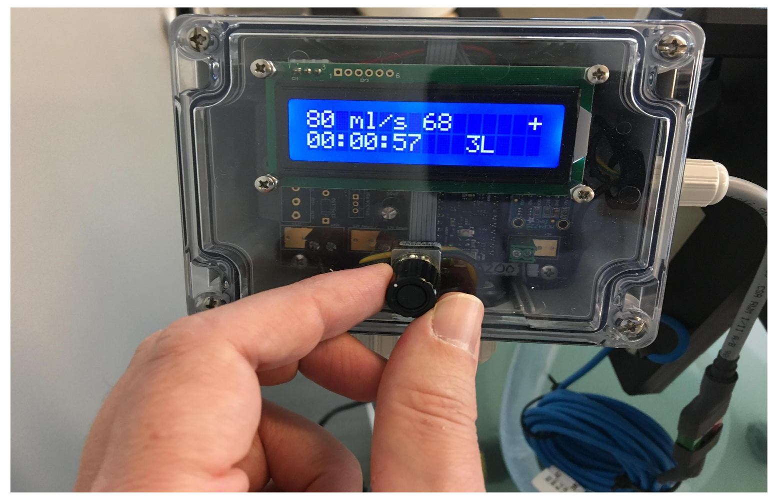

Figure 1. The control panel. Flow Rate set at 80ml/s.

Methods

Before starting a run, the sediment was smoothed and flattened, and then a starting channel is incised with a width of 2.5 cm and a depth of 4 cm. The table was then set to a slope of 3.3 degrees. Once everything was ready, the flow rate was calibrated to the desired rate and the camera was started. The camera was set to take a picture every 2 seconds for an hour, 5400 pictures, and then stitch the pictures into a time-lapse video.

Once the video was finished, pictures were selected to take measurements from. For this study, photos from the initial start, 15 min, 30 min, 45 min, and 60 min marks were chosen. From these photos, stream width and sinuosity was measured. To measure stream width, the width of the table was measured with a meter stick at three points along the channel and the width of the channel was measured along those points as well. Because the photo has a “fish-eye” effect, corrections were made to calculate the actual stream width.

To calculate stream width, we divided the width of the channel by the width of the table (at the measured point) and then multiplied by the table's actual width, To measure stream sinuosity, the length of the sinuous channel was measured with a meter string and meter stick, the straight channel was measured with a meter stick. To calculate stream sinuosity, we divided the sinuous channel length by the straight channel length. Once all calculations were made, Scatter plots for width and sinuosity were made.

Figure 2. Channel at O minute mark (start conditions) for 40ml/s flow rate.

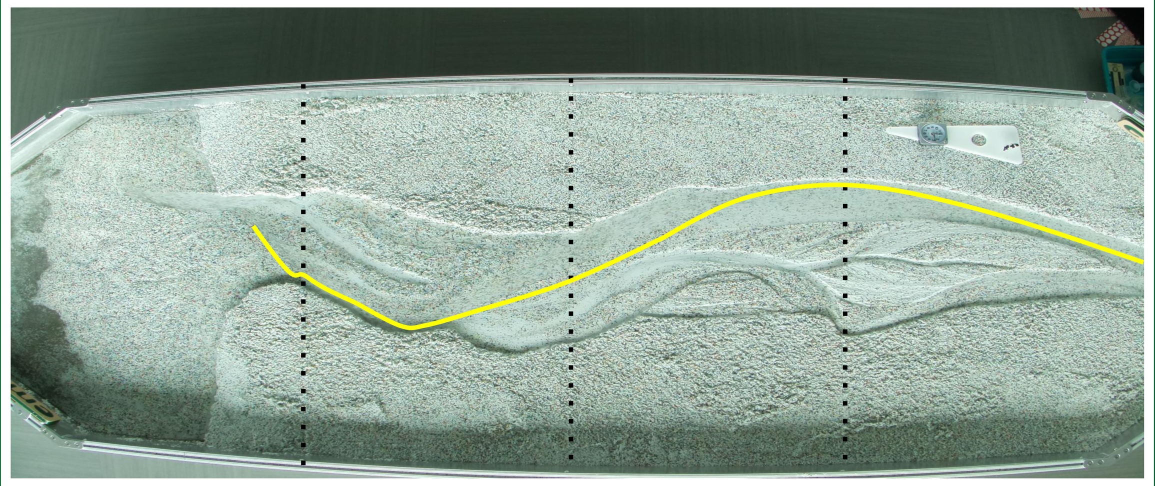

Figure 3. 15 minute mark for 70ml/s flow rate. The dashed lines indicate measuring points for width. The yellow line indicates sinuosity measurement.

Results

Channel width varied between flow rates 40ml/s, 60ml/s, and 70ml/s. For the 40ml/s run, the width of the channel did increase, however, it was a disappearing stream, therefore there was no width measurement for the third point (see Figure 4). For the 70ml/s run, the width of the channel at 15 min was wider at the start of the channel, and eventually the rest widened over time (see Figure 5). The 60 min run had a generally increase over time (see Figure 6). In the EMRiver physical model, sinuosity over all runs increased over time, with the 70ml/s run being the most sinuous. The average sinuosities for the runs are 1.057 for 40ml/s, 1.15 for 60ml/s, and 1.21 for 70ml/s. This is not expected as seen from Rosgen, where streams with higher flow rates have lower sinuosities.

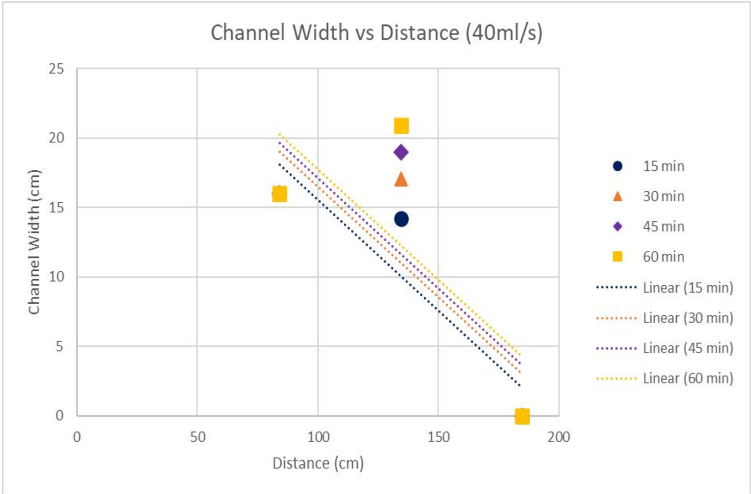

Figure 4. Channel Width vs Distance along table for 40ml/s

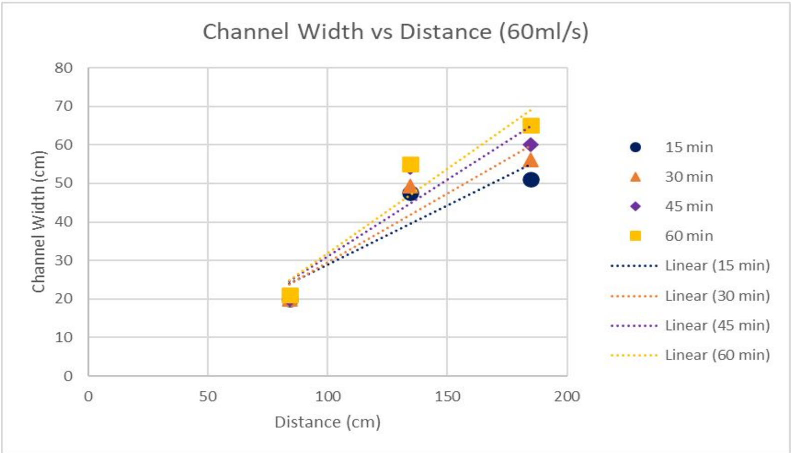

Figure 5. Channel Width vs Distance along table for 60ml/s

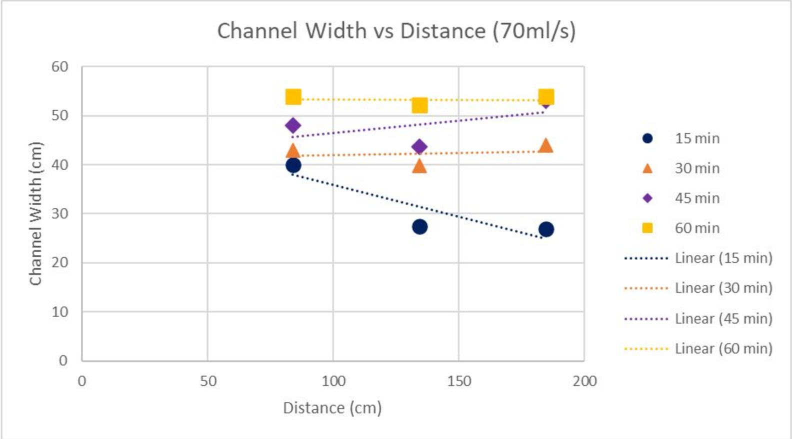

Figure 6. Channel Width vs Distance along table for 70ml/s.

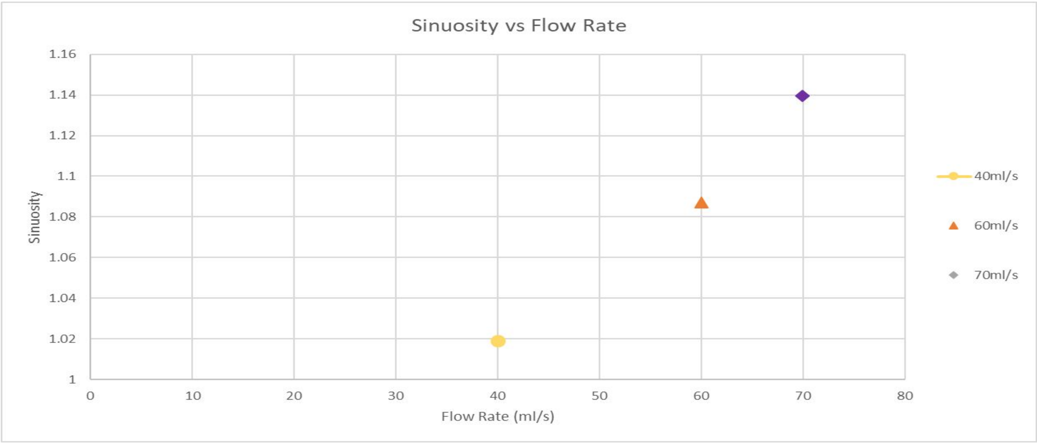

Figure 7. Sinuosity vs Flow Rate for rates 40ml/s, 60ml/s, and 70ml/s.

Discussion

Based on our results, our modeled stream acts differently than a natural stream when it comes to sinuosity. In nature, streams with higher flow rates tend to have smaller to no sinuosity (Rosgen, 1994). Our data shows that higher flow rates cause in increase in sinuosity, a contradiction to Rosgen research. Why this may be happening can be due to a few factors. The EMRiver table has a smooth, metal bottom and sides. This can cause the stream to speed up when it hits these parts. The sediment used in this study is a well-sorted, grounded plastic. It is generally the size of sand, but it is less dense than actual sand (Zaleha et. al.). This causes the stream banks to be relatively unstable. There is also more bank load then suspended load in the stream, and a lack of sediment recharge.

Conclusions

From this study we can conclude

- As flow rate increases, channel width increases over time.
- As flow rate increases, sinuosity increases over time.
- The trend we see in sinuosity is caused by sediment type, sediment load, and the stream table.

References / Acknowledgements

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