Publications of the Institute of Geophysics, Polish Academy of Sciences
Geophysical Data Bases, Processing and Instrumentation
vol. 453 (E-14), 2025, pp. 45–48
DOI: 10.25171/InstGeoph_PAS_Publs-2025-037
XLII International School of Hydraulics, Radocza, Poland, 20–23 May 2025

Investigating the Change in River Bed Morphology under the Influence of Blockage – Physical Modelling in a Curved Laboratory Channel

Zuzanna CUBAN✉, Magdalena WIŚNIEWSKA, and Tomasz KOLERSKI

Gdańsk University of Technology, Gdańsk, Poland
✉ zuzana.cuban@pg.edu.pl

A b s t r a c t

River restoration and pro-ecological design are essential in modern hydrotechnical projects, yet guidelines for the design of sinuous channels with erodible beds under blockage conditions remain lacking. This study investigates the effects of blockages – caused by ice, debris or litter – on sediment transport and river bed morphology. Experiments were conducted in a 2 m wide, 60 m long meandering channel with a sediment recirculation system. Velocity was measured using ADV and PTV and bathymetric data was collected using a FARO 3D scanner. The results show how blockages disrupt flow, increase turbulence, and intensify sediment transport, providing critical insights for designing resilient, ecologically functional river channels.

1. INTRODUCTION

The restoration of rivers and the design of pro-ecological solutions are now standard practices in the modernisation and construction of hydrotechnical structures. Numerous guidelines have been developed for the design of sinuous riverbeds in order to optimise both ecological functions (providing habitat for the development of flora and fauna) and hydraulic performance (maintaining the correct flow height, capacity, etc.) (RRC 2002, Rohde et al. 2005, Soar and Thorne 2001). However, there is still a clear need for specific guidelines for the design of sinuous channels with erodible beds to take account of blockages.

Blockages are increasingly caused not only by seasonal (e.g. ice) or local (e.g. fallen trees) obstructions, but also by an increase in litter blockages. Such litter often enters surface waters as a result of improper waste management, illegal dumping or run-off from urban areas during heavy rainfall. In this study, a blockage is defined as an accumulation of floating material that completely covers the water surface over a given area.

A blockage significantly changes the hydrodynamics of the river cross-section where it occurs. The first visible effect is an increase in the wetted perimeter and a reduction in the cross-sectional flow area below the obstruction. This results in higher average flow velocities and shifts the maximum velocity closer to the river bed. Obstructions such as ice jams, fallen trees or debris typically have irregular shapes which, when submerged, disrupt local flow patterns and create increased turbulence. The increased flow and turbulence enhance sediment transport, which is controlled by factors such as flow velocity (especially the vertical component), channel geometry, and sediment characteristics (e.g. shape, size, and concentration). Uncontrolled sediment discharge can lead to local erosion and deepening of the river bed and banks.

This study aims to advance the understanding of how blockages impact sediment transport and riverbed dynamics, providing insights critical for the ecological and hydraulic design of meandering river channels.

2. METHODOLOGY

2.1 Experimental setup

The research was conducted in a curved, meandering channel located at IBW PAN. The channel, shown in Fig. 1a, is 2 m wide and 60 m long along its axis. A reservoir at the end of the channel collects sediment, which is pumped back to the beginning of the channel, providing a constant supply of sediment during the experiments. This setup allows precise modelling of large-scale river bed formation phenomena.

The blockage was made up of 0.5 litre polypropylene plastic bottles, as shown in Fig. 1b.

2.2 Velocity measurements

Velocity measurements were made using Acoustic Doppler Velocimeters (ADV) at the cross sections shown in Fig. 1a. In each cross section, 2–5 vertical profiles were defined (depending on the bed configuration) and velocity was measured at 1 to 4 points per vertical profile.

Surface velocity was determined using Particle Tracking Velocimetry (PTV). High resolution cameras were used to record wood particles floating on the water surface. After removing camera and perspective distortions, the velocity was calculated from the film frames.

a) b)

Fig. 1: a) Photo of the laboratory channel. The measured cross sections are marked in blue. The white dashed line indicates where the blockage started; b) Photo of a blockage formed by bottles in a laboratory channel.

2.3 Bathymetry

A FARO Focus 3D scanner was used to collect full bathymetric data. Images from 25 points around the site were used to create a point cloud, resulting in a three-dimensional bathymetric map. In addition, bathymetric measurements were taken manually in all cross sections during velocity measurements.

2.4 Grain size analysis

After each series of experiments, sediment samples were collected at three locations in each cross section: the channel centreline and 20 cm from each channel wall. These samples were subjected to grain size analysis.

3. RESULTS

The placement of a blockage in the channel has caused significant changes in the channel bed morphology, as shown in Fig. 2. The presence of the blockage resulted in a reduction of the average sand layer thickness upstream of the blockage by 5 cm relative to the initial condition. During the initial conditions, sediment accumulation occurs along the inner bend of the channel, while scouring takes place along the outer bend. In contrast, with the blockage placed, sediment is eroded more uniformly across the entire width of the channel. Additionally, significant erosional changes have been observed along the outer bend at the front of the blockage, with a maximum depth of 15 cm compared to the initial state.

These changes are driven by modifications in the velocity profile and an increase in flow velocity caused by the local reduction in flow depth due to the blockage. Furthermore, the introduction of the blockage increases the surface roughness, which alters the transverse velocity direction. Under free conditions, this process leads to erosion of the outer bank and deposition of sediment on the inner bend of the meander.

a) b)

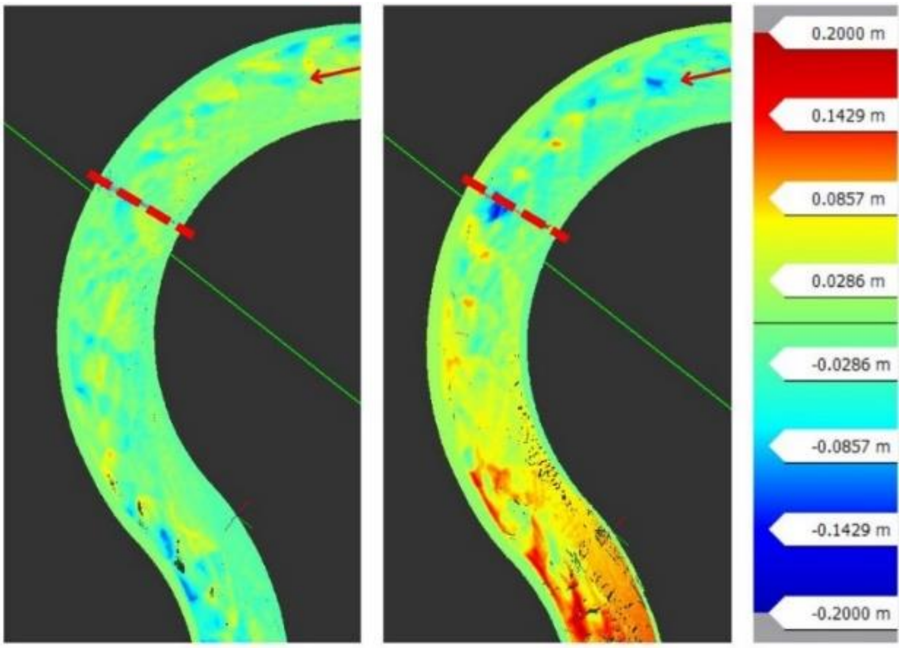

Fig. 2: a) Scan of the laboratory channel before the obstruction occurred; b) Scan of the laboratory channel after the obstruction was created using empty bottles with a constant flow maintained in the channel for 4 hours. The red dashed line indicates the grid visible in Fig. 1b, and the red arrow indicates the direction of flow.

Further research will be conducted under various flow conditions and different blockage configurations to better understand the impact of these factors on channel bed morphology and flow dynamics.

References

Rohde, S., M. Schütz, F. Kienast, and P. Englmaier (2005), River widening: An approach to restoring riparian habitats and plant species, *River Res. Appl.* **21**, 10, 1075–1094, DOI: 10.1002/rra.870.

RRC (2002), Manual of river restoration techniques, River Restoration Centre, Silsoe, U. K.

Soar, P.J., and C.R. Thorne (2001), Channel Restoration Design for Meandering Rivers, Final Report, Coastal and Hydraulics Laboratory, ERDC/CHL CR-01-1, U.S. Army Corps of Engineers, Washington, DC, 454 pp.