C109

# 3D Numerical Simulation of Bed Deformation Considering Bank Erosion in Uji River

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## 1 Introduction

Bank erosion is an important river morphodynamic process, resulting in channel migration, loss of agricultural lands, and damaging hydraulic structures and infrastructure. Based on the results of cross-sectional topographic surveys, there was a significant trend of riverbed lowering in the downstream area of the Uji River, particularly pronounced in the bend near the section 43.0 km away from the river mouth (CS43), where the bank retreated by approximately 70 m at maximum from 1967 to 2006 (Azuma and Sekiguchi, 2008). According to the analysis of the satellite images of Google Earth, the average erosion rate of the section with the maximum bank retreat after 2004 is about 4 m per year (Aly El-Dien, 2016; Karki, 2019).

As a result, in the present study, a 3D model considering sediment transport and bank erosion built on OpenFOAM was employed to reproduce a flood event in this area to investigate the causes of severe bank erosion.

## 2 Study area

As shown in Fig. 1, in the vicinity of CS43, the nearest upstream and downstream observation stations are the Mukaijima Observation Station (44.9 km away from the river mouth), and the Yodo Observation Station (38.9 km away from the river mouth), respectively. Both observation stations can provide continuous hourly water level and flow rate data. Therefore, we selected the 6.0 km long river reach between these two observation stations as the study area. The simulation domain includes the region between the leaves on both sides of this reach.

The river bathymetry generated by Karki (2019) through spatial interpolation based on the cross-sectional topographical data at intervals of 200 m measured in January 2016 was used in this study.

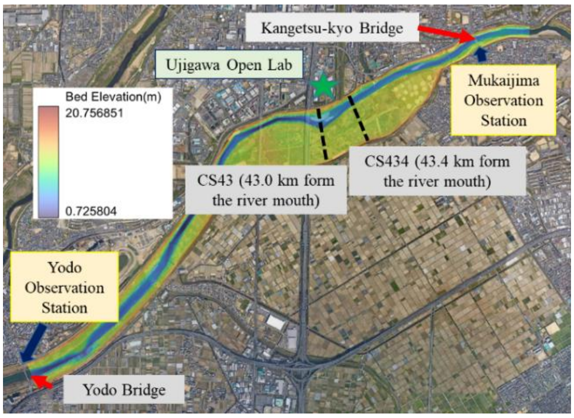


Fig. 1 Study area (source: Google Earth)

## 3 Results and discussions

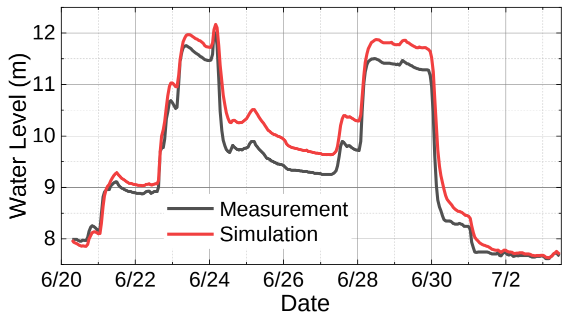


Fig. 2 Simulated and observed water level at Mukaijima Observation Station

The flood event in 2016 from June 20 to July 3 was reproduced, with a simulation duration of 316 h. The simulated and observed water level processes at Mukaijima Observation Station were plotted in Fig. 2. The simulated water level and observed water level exhibited synchronous variations, being nearly equal during low water levels. There was a slight overestimation during high water levels, but the highest water levels were very close.

The simulated bed deformation is presented in Fig. 3.

In the straight channel portions upstream and downstream of the bend, erosion was concentrated in the center of the main channel, while deposition occurred on its both sides.

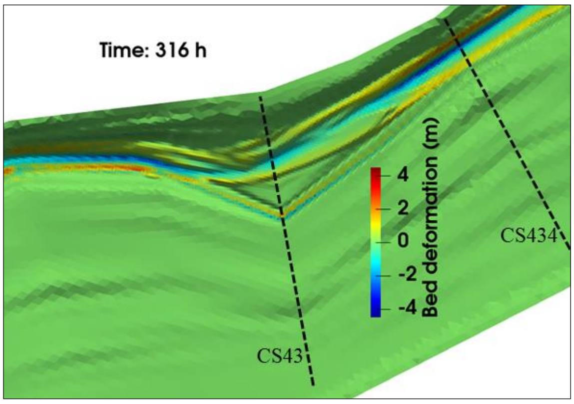


Fig. 3 Simulated bed deformation in the vicinity of CS43

The cross-section evolution over time for section CS43 was plotted in Fig 4. The initial left bank was quite steep, and as the water level rose, the critical slope angle decreased, leading to bank mass failure, forming a stable left bank. The bank top retreated by approximately 4 m. Afterward, due to erosion being concentrated in the center of the main channel and the absence of erosion at the toe of the left bank, the slope of the left bank remained unchanged, and no further bank failure occurred.

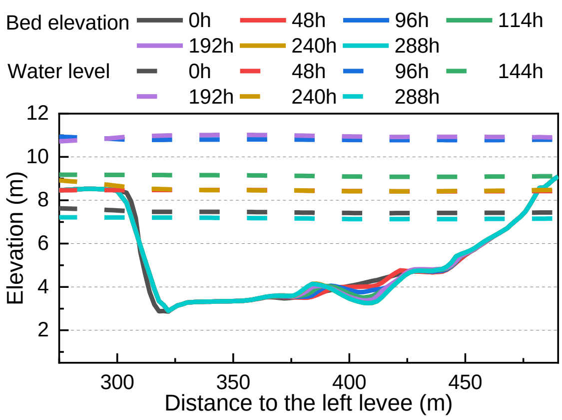


Fig. 4 Cross-section evolution of CS43

Overall, the model could simulate the bank failure of this reach to some extent, but there are some deficiencies in predicting the fluvial erosion in the main channel and near the bank toe, which might be caused by the neglect of sediment heterogeneity and the inapplicability of the formula for the average step length for bed load transport in large-scale simulations.

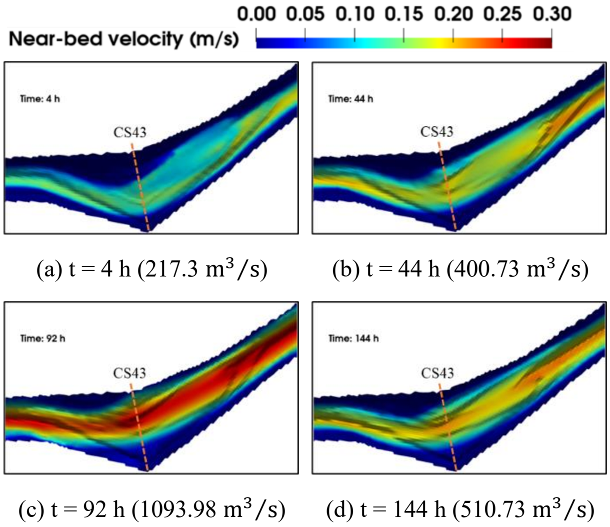


Fig. 5 Contours of near-bed velocity in the vicinity of CS43

The contours of near-bed velocity near the CS43 in the main channel (bed elevation lower than 11 m) at four different stages are shown in Fig. 5. Upstream of the CS43, under small flow and low water level conditions, the main flow was closer to the left bank, making it more likely to carry away sediment from the bank toe. As the flow increased, the main flow began to shift towards the right bank, resulting in reduced flow velocity at the left bank toe, especially during peak flow. It could be inferred that the bank erosion process of this reach involves the erosion of the bank toe at a low flow stage, followed by collapse as the bank sediment strength decreases during or after the flood peak.

**References**


Aly El-Dien, A., 2016. Modelling the Hydraulic Erosion and Failure Processes of Cohesive Riverbanks (PhD Thesis). Kyoto University.

Azuma, R., Sekiguchi, H., 2008. Geomorphological Evolution and Sediment Budget Analysis with the Uji River, Kyoto.

Karki, S., 2019. Study on Hydro-morphological Characteristics of Meandering Channels with Groynes (PhD Thesis). Kyoto University, Kyoto.