C207

Optimization of sediment replenishment strategies based on numerical simulation, case study in the Naka River, Japan

○LIN JIAQI, Sameh A. KANTOUSH, Tetsuya SUMI, and Yasuhiro TAKEMON

Dams as common hydrological structures have already been widely constructed around the world for various purposes, for instance, irrigation, hydropower generation, flood mitigation, and water supply. Regardless of such different objectives, sediment is trapped by all of the dams, which may lead to significant alterations at upstream and downstream reaches. To mitigate the sedimentation issues, a novel approach called sediment replenishment (SR) has already been implemented in Japan, Europe, and the USA, which restores the sediment transportation by an artificial supply of additional sediment to downstream reach.

In this study, we focused on the erosion process of the replenished stockpile and downstream hydro-geomorpho-ecological responses. TELEMAC-MASCARET, an open-source numerical simulation tool, was utilized to investigate the hydrodynamics and sediment transportations, and meanwhile, provide us valuable information on the optimization of replenishment works through designed scenarios.

The geometric mesh was firstly generated based on the triangle finite element method with different grid sizes. The 2017 DEM data measured by Green Lidar (including the underwater part) was utilized for interpolation (Fig. 1). Regarding the boundary conditions, the upstream boundary is the releasing discharge from the Nagayasuguchi dam, while the downstream boundary is the prescribed water level near the Hitomi power station. A constant value of flow discharge and water level at two boundaries was simulated for 7 days to ensure a stable flow regime in the domain.

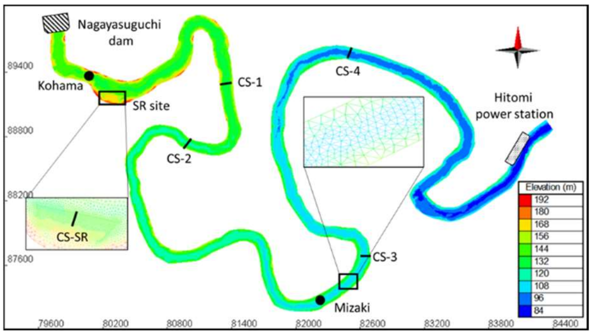

Fig. 1 The Geometric mesh of the study domain for TELEMAC-2D simulation based on 2017 DEM data.

Several model parameters regarding hydrodynamics and sediment transportation were calibrated to promote the accuracy, for instance time step, transport formulas for bedload and suspended load, critical classes shield parameter, active layer thickness, settling velocity, and angle of repose. The model was evaluated based on the measured and simulated data of flow velocity, water depth, and bathymetry. An example of flow velocity comparison was shown in Fig. 2.

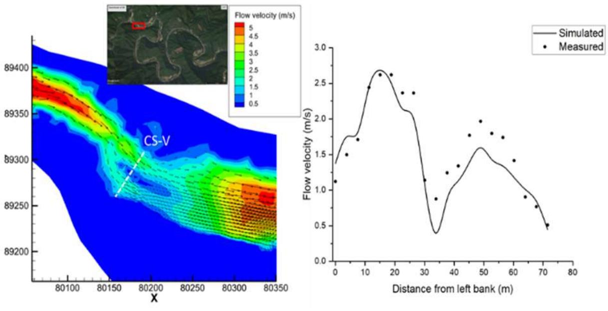

Fig. 2 The comparison between simulated results and measured results for flow velocity.

The established model was then utilized to investigate the effects of different SR characteristics (flushing flow, replenished sediment sizes, and replenished locations) on stockpile erosion and the downstream hydro-geomorphological changes. Several scientific scenarios are developed, and related indicators for evaluation were selected, including transported ratio of replenished sediment (TR), bed change indicators (BCI), and Hydro-geomorphological Index of Diversity (HMID).

The single flushing pulse with different flushing magnitudes combined with various replenished sediment sizes is investigated at first. Numerical results show that the higher magnitude of flushing flow can promote the erosion of SR sediment. However, it is not an efficient way since the increasing rate of TR is only about 2% if the flushing magnitude is enlarged by 100% (Fig. 3). Finer sediment is recommended to facilitate the SR erosion efficiently. Meanwhile, higher magnitude (SC5-F) can increase 5% to 10% of HMID value at the entire reach, which is mainly due to the facilitation of pool and bar formations at the meandering areas (Fig. 4).

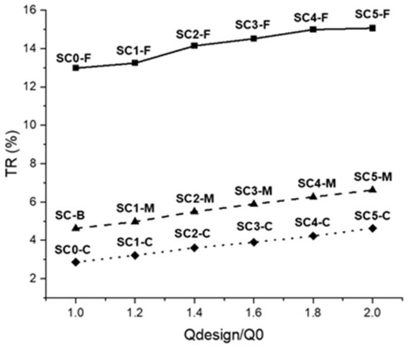

Fig. 3 The variation of TR value and eroded volume at the SR site with different flushing flow and SR materials.

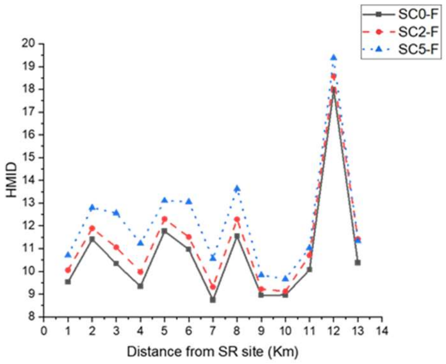

Fig. 4 The HMID value for different single flood pulse scenarios at 13 km downstream of SR site.

Then, we move to the double-flushing pulses by keeping the same increasing water volume and replenished sediment sizes. Different flushing duration and magnitudes of the second pulse are considered. Due to the additional erosion that happened at the head and tail areas, the TR increases by about 1%, and the eroded volume increases by about 2000 m^3 (Fig. 5). A turning point can be observed as well which means that the efficient value of flushing flow is existed.

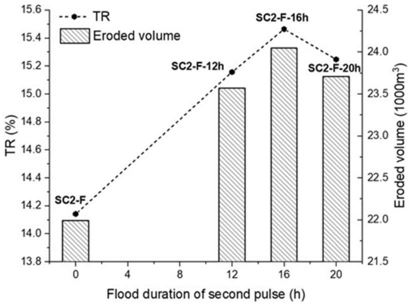

Fig. 5 The TR and eroded volume at the SR site between single flood pulse and double flood pulses.

After that, we design several new possibilities for replenishment arrangements to promote the erosion process of replenished sediment. The double stockpiles (conduct replenishment at both sides of bank) was recommended as the most efficient case. More sediment can be transported to downstream under the same flushing flow (Fig. 6). Such sediment can promote the formation of riffle-bar structures, and thus, be beneficial for the riverine ecosystems.

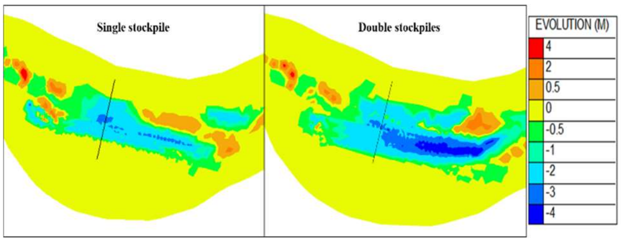

Fig. 6 The bed evolution for single and double stockpiles design at SR site.

In conclusion, increasing flushing frequency, increasing the percentage of finer sediment, and implementation of double stockpiles are three recommendations for optimization of SR works in the Naka River.