Hydro-morphodynamic Computation for Physical Habitat Simulation

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Abstract

This study investigates the impact of morphological change on the physical habitats after a flood. The study area is a regulated, gravel bed river reach, located downstream of a dam in Korea. For the physical habitat simulation, 1D HEC-RAS model and habitat suitability curve model are used for hydro-morphodynamic simulation and habitat simulation, respectively. Zacco koreanus, the most dominant fish species, is selected for the target fish for physical habitat simulation. It is found that erosion of the bed and deposition of sediment occur repeated in the longitudinal direction, with erosion much more dominant over the study area. This resulted in the deterioration of physical habitats in the study area significantly.

Keywords: Hydro-morphodynamic simulation, Physical habitat simulation, River morphology, Gravel-bed river, Weighted usable area

1. INTRODUCTION

Physical habitat simulation, in general, uses three habitat variables, namely flow depth, velocity, and substrate. The flow depth and velocity are obtained from the hydraulic simulation. However, the habitat suitability for the substrate is determined not from the hydraulic simulation but from the field observation. If the hydraulic simulation is replaced with the hydro-morphodynamic simulation, the change in river morphology and substrate as well as flow depth and velocity is provided. The river morphology is known to affect fish habitats seriously (Kellerhals and Miles, 1996; Vlach et al., 2005; Taylor et al., 2019), However, river morphology has been treated less importantly compared to flow variables in the physical habitat simulations (Choi et al., 2017; Kim and Choi, 2021).

This study investigated the change of physical habitats after a flood in a regulated gravel-bed river. The hydro-morphodynamic simulation was carried out to account for the morphological change. Habitat simulation was performed for the target fish species. The impact of morphological change after the flood on the quality of the physical habitat was assessed quantitatively.

2. STUDY AREA

The study area is a 12.8 km long reach, located downstream of the Yongdam Dam in the Geum-gang River, Korea. Yongdam Dam supplies agricultural water to nearby farmland through a water tunnel and releases a relatively constant discharge to the lower Geum-gang River for hydropower generation except for floods. The study reach consists of channel bends, a pool and riffle sequence. It is a gravel-bed river, regulated by an upstream dam.

2. PHYSICAL HABITAT SIMULATION

3.1 Hydraulic simulation

For the physical habitat simulation, in the present study, the HEC-RAS 1D model (USACE, 2024) was used for hydraulic simulation. The continuity and momentum equations are, respectively, given by

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=0 \qquad [1]$$

$$\frac{\partial Q}{\partial t}+\frac{\partial (VQ)}{\partial x}+gA\left(\frac{\partial z}{\partial x}+S_f\right)=0 \qquad [2]$$

where x = distance, t = time, Q = discharge, A = cross sectional area, V = velocity, g = gravitational acceleration, and S_f = friction slope. The morphological change is computed by solving Exner's equation such as

$$\frac{1}{1-\lambda}\frac{\partial Q_s}{\partial x} + B\frac{\partial z}{\partial t} = 0 \quad [3]$$

where λ is the porosity, Q_s is the sediment load, B is the width of the mobile bed, and z is the bed elevation from a certain datum.

3.2 Habitat simulation

Habitat simulation provides the evaluation of the habitat quality in terms of such habitat variables as velocity, flow depth, and substrate. In general, two methods are available for habitat simulation, namely expert-knowledge method and data-driven method. The expert-knowledge method is simple, but its results can be affected by the subject opinion of the experts. The data-driven method, an example is AI-based method, requires large amount of data. In the present study, the HSC (Habitat Suitability Curve), an expert-knowledge method, is used due to the lack of sufficient monitoring data.

3. RESULTS

Hydraulic simulation was carried out for the 2020 flood. The peak discharge was 2,904 m3/s, which is close to the 200-year flood. Morphological change was simulated, revealing that erosion of the bed and deposition of sediment occurred repeated in the longitudinal direction. However, erosion was dominant in the study reach.

The CSI distribution for the regulated flow of Q = 8.7 m3/s with the longitudinal distance is given in Figure 1. The overall pattern of the CSI distribution in the figure is that the CSI fluctuates with the distance. Another feature noticed is that the overall CSI decreases with the longitudinal distance. A comparison of the CSI before and after the flood showed that improvement and deterioration of physical habitats repeat in the longitudinal direction. This can be ascribed to the morphological change after the flood. As a result, the erosion resulted in a 24% decrease in the weighted usable area in the study reach.

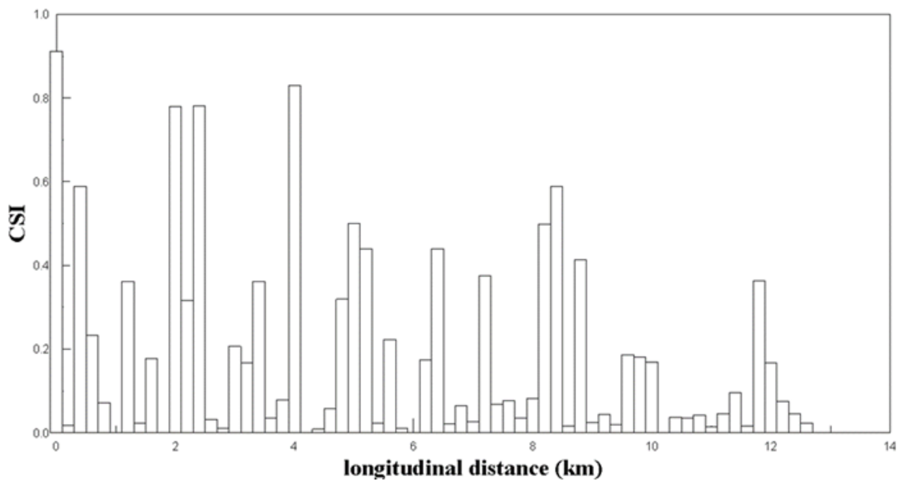

Figure 1. CSI distribution with distance

4. CONCLUSIONS

This study assessed the impact of the morphodynamic change of a regulated gravel-bed river on the fish habitats in the reach downstream of a dam after a flood. It was found that overall erosion occurred after the 2020 flood, with a repeated pattern of erosion and deposition in the longitudinal direction. The erosion after the flood decreased the quality of physical habitats, which resulted in a 24% decline in the weighted usable area.

5. ACKNOWLEDGEMENTS

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