B117

Evaluation of Channel Geomorphology and Ecological Function Change Following Two Weir Removal Cases in a Gravel Bed River

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Introduction

Three of eight weirs (Fig.1) have been removed in the Katsura River (0-18K) segment located in Kyoto City for flood mitigation. Along with the removal, riverbed excavating work and embankment construction were also carried out to further reduce the flood risk in this densely populated area.

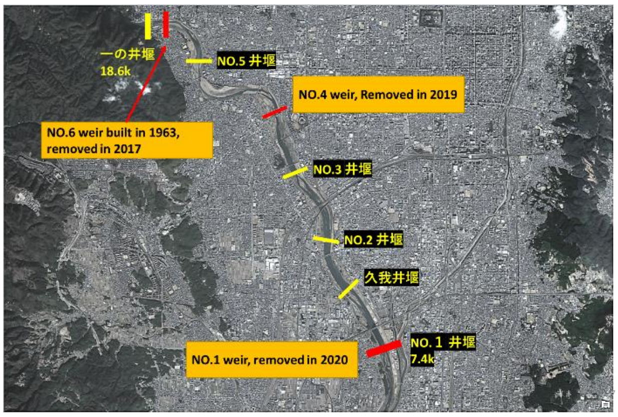

Figure 1, weirs in the study segment of Katsura River

By greatly altering the river geomorphology, the weir removal and flood mitigation works might have a significant influence on the river ecological functions, e.g., quantity and quality of aquatic habitat structures and hyporheic exchange.

The purpose of this study is to quantitatively understand the ecological influence of weir removal and flood mitigation works, to give scientific support for the decision-makers from the environment aspect when managing instream geomorphic structures like weirs, low-head-dams, and run-of-river dams, due to the fact that despite their relatively small individual size, their numbers are far more than the large impoundment dams.

This paper aims at 1) quantifying the influence of weir removal and sediment excavating work on the aquatic habitat structures by comparing the number and size before and after weir removal; 2) understanding the general influence of weirs on the ambient riverbed hyporheic exchange rate and pattern. 3) giving suggestions for the improvement of similar river managing works.

Materials and methods

(1) Riverbed geomorphology and habitat structure change before and after weir removal.

Riverbed geomorphology and habitat change were mainly analyzed by aerial photos and biennial ground cross-sectional surveys conducted by the Yodo river bureau. Four sets of aerial photos were selected, namely 2013, 2015, 2017, and 2019. In total 5 habitat types (4 riffle types: Diverse I Diverse II Transverse and Concentrate, plus Rapid) were selected and identified from the aerial photo (Kobayashi and Takemon, 2013).

(2) Estimation of Hyporheic Exchange

Hyporheic exchange pattern and rate near the NO.1 weir were estimated using the Laplace equation and Darcy's Law.

$$\nabla^2 h = 0$$

$$q = -K\nabla h$$

Where h is the hydraulic head, ∇^2 is the Laplace operator, K is the hydraulic conductivity and q is the

Darcy flux.

Results

(1) Geomorphology and habitat change before and after NO.6 weir removal (Fig.2).

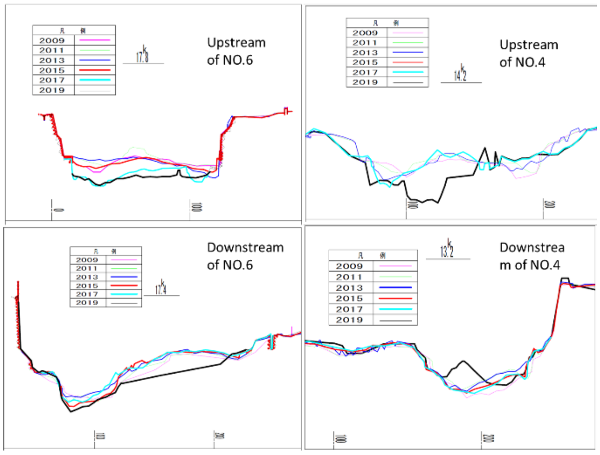

Figure 2, cross-section changes upstream and downstream of NO.6 and NO.4 weir. In both cases after removal, the upstream channel showed significant erosion (more than 1m), and the downstream channel aggraded.

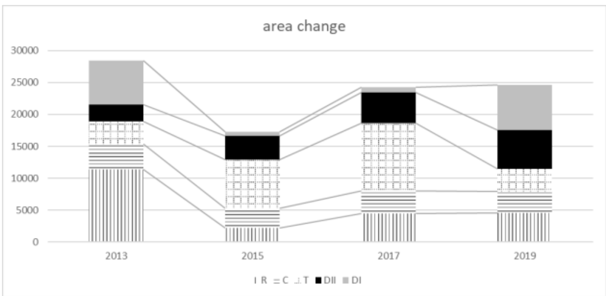

Figure 3a, Habitat area changes of the study segment

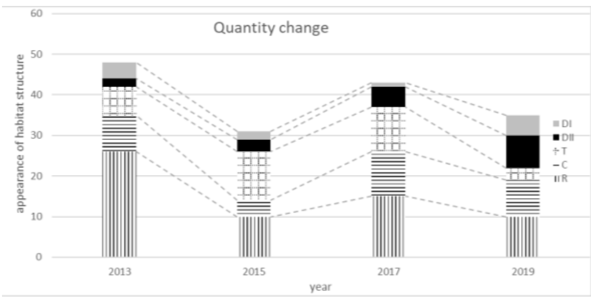

Figure 3b, Habitat area change of the study segment

(2) Estimation of Hyporheic exchange rate induced by NO.1 weir under low flow conditions.

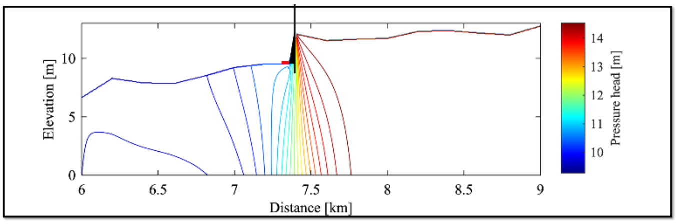

Figure 4, results of Laplace model with real geomorphic data of NO.1 weir. Vertical color lines are the equipotential lines, flow lines were not drawn in this picture while they should be perpendicular to the equipotential lines. Our field survey of K value in the upstream of NO.1 weir has proved that the K is very low (almost 0) due to the fine sediment deposition, which indicates the hyporheic exchange should be very low in the NO.1 weir.

Conclusion

(1) After NO.6 and NO.4 weir removal, both cases showed significant upstream erosion and downstream deposition which coincides with previous studies.

(2) After weir removal, both the quantity and quality of habitat structures increased significantly, mainly upstream of the former weir site due to the water level drop-down in the former impoundment, however, the increasement didn’t happen downstream near the removal site but appeared further downstream near the conjunction.

(3) The Laplace model showed that the weir will concentrate the downwelling flow very near to the upstream end of the weir, and flow will penetrate to the hyporheic zone and finally come out again downstream of the weir. However, the hydraulic conductivity upstream of the weir is proved very low based on our field investigation results, thus, the hyporheic exchange is greatly reduced by the fine sediment clogging due to the hydraulic effect of the weir.