Changes of fluvial processes caused by restoration of an incised mountain stream

Changements des processus fluviaux causés par la restauration d'un cours d'eau de montagne au lit incisé

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RÉSUMÉ

Au milieu du XXe siècle, la construction d'un barrage sur la montagne de Krzczonówka, dans les Carpates polonaises, a entraîné plusieurs changements préjudiciables pour la zone située en aval. Avant l'abaissement du barrage de correction visant à rendre la structure franchissable par le biote de la rivière, des rampes de blocs rocheux ont été construites dans le chenal profondément incisé en aval du barrage. Alors que l'abaissement du barrage de correction était en cours, une forte inondation s'est produite, déversant depuis le barrage une quantité considérable de sédiments qui ont été efficacement piégés par les rampes de blocs rocheux dans le tronçon situé en aval. Un inventaire effectué avant, pendant et après les travaux de restauration a documenté des changements bénéfiques dans la section située en aval du cours d'eau. Le lit du chenal s'est élargi de 0,44 m en moyenne, passant d'un substrat rocheux à un substrat alluvial. La qualité hydro-morphologique du cours d'eau s'est améliorée, et 3/5 des sections transversales évaluées comme étant de qualité moyenne sont désormais considérées comme étant de bonne qualité. Les vitesses d'écoulement et les contraintes de cisaillement du lit associées aux écoulements des canaux ont été réduites et la rétention des eaux de crue dans la zone inondable a augmenté. L'étude a démontré l'efficacité des rampes de blocs rocheux dans la restauration d'un ruisseau de montagne au lit incisé.

ABSTRACT

Construction of a high check dam on mountain Krzczonówka Stream, Polish Carpathians, in the mid-20th century resulted in a number of detrimental changes to the downstream reach. Before a lowering of the check dam aimed to make the structure passable for river biota, boulder ramps were constructed in the deeply incised channel downstream of the dam. When the check-dam lowering was underway, a major flood occurred on the stream, flushing out from the dam a considerable amount of sediment that was efficiently trapped by the boulder ramps in the downstream reach. An inventory carried out before, during and after the restoration works documented beneficial changes in the downstream reach of the stream. The channel bed aggraded by 0.44 m on average and changed from bedrock to alluvial one. Hydromorphological quality of the stream improved, with 3/5 of the evaluated cross-sections upgraded from moderate to good quality class. Flow velocities and bed shear stresses associated with channel flows were reduced and floodwater retention in the floodplain area increased. The study demonstrated effectiveness of boulder ramps in restoration of an incised mountain stream.

KEYWORDS

Boulder ramps, channel incision, flood flow hydraulics, hydromorphological quality, stream restoration

1 INTRODUCTION

Construction of a high check dam on mountain Krzczonówka Stream, Polish Carpathians, in the mid-20th century resulted in a number of detrimental changes to the downstream reach. Entrapment of bed material behind the dam caused long-lasting sediment starvation of the downstream reach leading to channel incision and transformation of the former alluvial channel into a bedrock-alluvial or bedrock channel. High flow capacity of the incised channel was reflected in high velocity and bed shear stress associated with flood discharges of given recurrence intervals, which prevented in-channel deposition of bed material delivered from the upstream reach. Concentration of flood flows in the incised channel considerably reduced floodwater retention in the floodplain area, hence contributing to rapid downstream passage of flood waves and to an increase in their peak discharges. Finally, hydromorphological quality of the stream was degraded as a result of morphological, sedimentary and hydraulic changes in the downstream reach coupled with the disruption of longitudinal stream continuity for aquatic biota caused by the check dam.

In the early 2010s a restoration projected was initiated to lower the check dam and make the structure passable for fish. To trap the sediment flushed out from above the dam in the incised channel, several boulder ramps were constructed in 2013, before the onset of the works on the check dam. The check dam was lowered in 2014 and when the works were underway, a major flood occurred on the stream, flushing out a considerable amount of sediment from the dam. The sediment was efficiently trapped by the boulder ramps in the downstream reach. Inventories carried out before, during and after the restoration works documented changes that occurred in the downstream reach of the stream. This study aims at investigating how the environmental problems caused by the long-term sediment starvation of the stream were mitigated by the restoration works.

2 STUDY METHODS

Channel morphology and physical habitat conditions in the stream were surveyed prior to restoration activities (2012), after the installation of boulder ramps but with still existing check dam (2013), during (2014) and after the check-dam lowering (2015). These surveys were done in 10 cross-sections delimited in the downstream reach of the stream. Data about cross-sectional stream morphology, channel slope as well as channel and floodplain roughness were used for one-dimensional hydraulic modelling of flood conditions typifying the stream before (2013) and after (2015) deposition of the sediment trapped by the boulder ramps. The modelling was performed using HEC-RAS software. Hydromorphological quality of the stream was evaluated in 2012 and 2015 using the River Hydromorphological Quality (RHQ) method especially suitable for the assessment of effects of river restoration activities (Hajdukiewicz et al., 2017).

3 RESULTS

Deposition of the sediment flushed out from above the lowered check dam caused burying of the boulder ramps on the distance of ca. 1.2 km from the dam (Fig. 1), whereas the sediment wave reached 1.6 km from the dam. About 17000 m^3 of bed material were retained in the stream, resulting in re-establishment of alluvial channel bed and an average increase in bed elevation amounting to 0.44 m. A maximum increase in bed elevation in the surveyed cross-sections equalled 0.8 m at a distance of 470 m from the dam, whereas a maximum increase of the water surface at low flows reached 1 m. Bed aggradation increased peak flood stages, hence increasing a proportion of flood flows conveyed over the floodplain and reducing mean flow velocity and mean bed shear stress in the total cross-section and in the channel zone. While these effects varied along the channel, at the mid-length of the sediment accumulation formed downstream of the dam, peak stage of a 2-year flood increased by 0.7 m, while that of a 50-year discharge by 0.37 m. At this location, mean flow velocity decreased by 9% at a 2-year flood and by 16% at a 50-year discharge, whereas mean bed shear stress was reduced by 39% and 46%, respectively. Increased inundation of the floodplain was reflected in increased retention potential of floodwater, i.e. a proportion of the total cross-sectional flow area in which floodwater would remain motionless, thus being temporarily retained in the floodplain (Wyżga, 1999; Czech et al., 2016). At the 2-year flood, the retention potential of floodwater increased from 0% in 2013 to 4% in 2015, while at the 50-year discharge it increased from 14% to 20%. Before the restoration works, only 1/5 of the evaluated stream cross-sections was classified as representing good hydromorphological quality, whereas after the works 4/5 of the cross-sections fell in this class of hydromorphological quality. The hydromorphological quality improvement mainly reflected changes in bed substrate, erosional and depositional channel features and longitudinal stream connectivity.

Figure 1. View of Krzczonówka Stream in the vicinity of one of study cross-sections shortly after installation of a boulder ramp (2013) and after the passage of the flood of May 2014. Visible the entrapment of a considerable amount of gravel and burying of the boulder ramp.

4 CONCLUSIONS

Inventories performed before and after the restoration works conducted in the deeply incised Krzczonówka Stream documented effectiveness of boulder ramps in the entrapment of gravel flushed out from above the lowered check dam. With the deposition of the material, channel bed considerably aggraded and changed from bedrock to alluvial one. The bed aggradation changed hydraulic conditions of flood flows, reducing flow velocity and shear forces within the channel and increasing floodwater retention in the floodplain area. Hydromorphological quality of the stream improved, with 3/5 of the evaluated cross-sections upgraded from moderate to good quality class.

The restoration works were performed during the project KIK/37 ‘The Upper Raba River Spawning Grounds’ supported by a grant from Switzerland through the Swiss Contribution to the Enlarged European Union. The authors thank Victorine Castex and Sébastien Guillet from the University of Geneva for their help in translation of the abstract to French.

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