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Modeling flow conditions in a shallow river overgrown with plants

Abstract

Water flow in open riverbeds is a system of interactions between the changing amount of water, its quality, the carried debris, fluvial and morphological conditions of the river and the plants and animals occurring in this system, which varies in time and space. The need for an interdisciplinary approach to the sustainable functioning of the river ecosystem requires knowledge of the interactions between the individual elements of this system. Current trends of conscious shaping of the environment of the river and its surroundings influence the need for special recognition of the influence of vegetation on hydraulic flow conditions and determination of priorities at the spatial scale of the river in terms of maximizing capacity, pro-ecological regulation of rivers with the use of vegetation, or introduction of renaturalization processes.

The doctoral dissertation consists of a series of five peer-reviewed, thematically coherent scientific articles. These articles verified and assessed the scale of spatial and temporal variability of the impact of plants on the hydraulic flow conditions of a lowland river by examining: the distribution of plants in the riverbed, the density of plant clusters, changes in properties and impacts during the growing season, and the impact of maintenance works. The research was based on the conditions of a selected reference section of the Ślęza River, where multiple measurement sessions were carried out in 2017-2019 based on water velocity measurement and an inventory of vegetation in the riverbed. Based on field measurements, two-dimensional numerical models were built and calibrated in CCHE2D and IRIC Nays2DH software, in which simulations were performed, examining conditions beyond those measured in field tests and defining other measures of hydraulic conditions, e.g. shear stress or turbulence.

The research confirmed the significant impact of plants on shaping flow conditions in overgrowing lowland river beds. All studies confirmed the existence of the so-called vegetation damming, where in the variants with vegetation an increase in the elevation of the water table in front of the plant zones was observed. It was also found that the arrangement of plants in the riverbed can significantly influence the water velocity pattern and thus, in the long run, shape the morphological conditions in the riverbed. The limiting density was determined on the example of common reed (27-50 plants per m^2), at which a cluster of plants begins to be flowed by a stream of water, which defines such a cluster as a natural deflector in the riverbed.

As a result of examining the influence of plants in different phases of the growing season, the influence of plants in spring and autumn on the roughness coefficient values was compared, and significantly higher values were found in the beds with vegetation in full vegetation in summer and autumn. Additionally, when analyzing the spatial arrangement of the riverbed, a very significant variability in the vegetation distribution and, consequently, in the water velocity distribution was noticed during the growing season. While verifying various methods of carrying out maintenance work in the riverbed, it was also found that the method of work carried out may significantly contribute to changes in hydraulic conditions. Therefore, it seems reasonable that maintenance works should be carried out not according to the scheme adopted for the entire stream, but taking into account the main needs of a given section of the river. Adopting many different forms of maintenance work over a longer section may be the basis for increasing the biodiversity of a given river.