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Head losses modelling and Darcy-Weisbach coefficient derivation on a rough surface under partial inundation

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In models of ground surface flow at the watershed scale, hydraulic resistance is characterized by the Darcy-Weisbach friction coefficient accounting for the surface roughness.

In experimental works available in literature, the definition of the Darcy-Weisbach friction coefficient of natural ground surfaces for free surface flow is similar to the one used for pipe flows. Consequently, the Darcy-Weisbach coefficient is considered as a function of Reynolds number and of the surface relative roughness.

However when the flow depth and the boundary roughnesses are of similar size, and particularly for "partial inundation" as defined by Lawrence (1997, 2000), the analogy with the one dimensional flow in pipes is weak. Indeed, in this case, even if turbulence is not dominant, the flow is strongly disturbed by the topography of the surface. Emerged roughnesses has an influence which varies with the flow depth and may become dominant over the influence of Reynolds number.

The present work aims to better account for surface micro topography effects for partial inundation conditions, by means of both numerical simulation of flow patterns and pathways and experimental characterisation of these patterns.

The model performs the computation of head losses over the channels of a network evolving with the water depth. For a given depth, the network is built-up on the basis of the topography of roughness given by laser scanning of the sample surface. The medium plan of the rough surface is defined by least squares ajustment. Assuming that the free surface of the flow can be represented by a plan parallel to the medium plan, a binary image representing the emerged and submerged part of the surface is generated for each depth. The network is determined by the skeleton of the submerged area. For each free surface level, defining nodes and links over the network, we use an hydraulic head losses model accounting for losses due to friction and hydraulic jumps to calculate the head at the nodes, the local velocities on links, the global discharge and finally the global Darcy-Weisbach friction coefficient. The local and global Reynolds and Froude numbers are also computed for a more complete characterisation of the flow.

Experimentally, flow is performed for various discharges and slopes over the rough surface. Dye imaging techniques are used to estimate the water depth on the ground sample and to characterize the flow patterns. The experimental Darcy-Weisbach friction coefficient is derived from the data, particularly to examine the dominant influence of the inundation ratio as predicted by Lawrence partial inundation model.