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Quantifying flow retention due to vegetation in an earthen experimental channel using the Aggregated Dead Zone (ADZ) dilution approach

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Understanding of flow resistance of forested floodplains is essential for floodplain flow routing and floodplain reforestation projects. Although the flow resistance of grass-lined channels is well-known, flow retention due to flow-blocking by trees is poorly understood. Flow behaviour through tree-filled channels or over forested floodplain surfaces has largely been addressed using laboratory studies of artificial surfaces and vegetation.

Herein we take advantage of a broad, shallow earthen experimental outdoor channel with headwater and tailwater controls. The channel was disused and left undisturbed for more than 20 years. During this time period, small deciduous trees and a soil cover of grass, herbs and leaf-litter established naturally. We measured flow resistance and fluid retention in fifteen controlled water discharge experiments for the following conditions: (a) natural cover of herbs and trees; (b) trees only and; (c) earthen channel only. In the b-experiments the herbaceous groundcover was first removed carefully and in the c-experiments the trees were first cut flush with the earthen channel floor. Rhodamine-B dye was used to tag the flow and the resultant fluorescence of water samples were systematically assayed through time at two stations along the length of the channel. Dilution-curve data were analysed within the Aggregated Dead Zone (ADZ) framework to yield bulk flow parameters including dispersion, fluid retention and flow resistance parameters after the procedure of Richardson & Carling (2006).

The primary response of the bulk flow to vegetation removal was an increase in bulk velocity, with depth and wetted width decreasing imperceptibly at the resolution of measurement. An overall reduction in flow resistance and retention occurred as discharge increased in all experiments and flow retention. Retentiveness was more prominent during low flow and for all three experimental conditions tended to converge on a constant low value for high discharges. Reach mean travel times and the advective time delays decreased very slightly from experiments (a) to (b) which is not surprising given the sparse nature of the herbaceous soil cover. Thus in these two initial experiments, the trees provided the majority of the resistance in contrast to the aggregate effect of grass, herbs and litter. Removing the trees leaving an earthen channel further decreased travel times such that the ADZ residence time was more than halved moving from (a) to (c). The overall bulk flow effect of tree cover on retention is here expressed by the dispersive fraction parameter, indicating retention volume and time, which reduced from typically 0.4 to closer to 0.2 when vegetation was removed. The Darcy-Weisbach friction factor during low discharges was higher for experiments (a) compared with (b) but the friction factors converged on the low earthen channel value as discharge increased. In conclusion the effect of vegetation on hydraulic retention compared with an unvegetated channel is prominent during low discharges but becomes negligible during high discharges as momentum increasingly dominates the flow.