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INFILTRON-mod, a simplified preferential infiltration model for modeling bioretention systems

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The preferential flow and transport through unsaturated zones have received considerable attention in the soil and agricultural fields, particularly in increasing discharge rates and amounts and the subsequent transportation of pollutants to groundwater. Over the past century, traditional stormwater control has been replaced by a new low-impact development (LID) approach called "on-site alternative design strategy", which aims to restore or maintain the hydrological functions of urban watersheds by using the capacity of soil and vegetation to retain and filter wastewater pollution, such as bioretention facilities. Therefore, obtaining an accurate estimation of water infiltration within Bioretention basins is crucial. The Bioretention modeling usually refers to the implicit reservoir base model, which is based on the mass balance and interaction between all the components of the hydrologic cycle (evapotranspiration, overflow, exfiltration to surrounding soils, infiltration through filter media or non-saturated zone, and underdrain discharge) during the time. Among the existing bioretention models, the unsaturated zone or filter medium is considered a homogeneous medium, and the flow is calculated with conceptual infiltration models, such as the Green-Ampt model, the Horton model, etc. Despite our knowledge that the soil reservoir medium is heterogeneous (e.g., coarse materials, plant root systems), it is, therefore, necessary to use a physics-based infiltration model that considers the impact of non-equilibrium and preferential flow on the hydrological and hydrogeochemical performance of bioretention facilities. The INFILTRON-mod, a generic physics-based package, has been proposed for this aim.

This package consists of infiltration models, including the Green-Ampt model and three other specific custom-made models, for uniform and non-uniform flows in soils based on the Darcian approach and mass balance. Uniform and non-uniform flows are modeled using the single and double permeability approaches, respectively. The dual permeability concept assumes that the soil consists of two reservoirs, i.e., the general matrix and fast flow regions, each obeying the Darcian approach. We assumed instantaneous exchange between the two regions. Consequently, we assumed that the wetting fronts in the two reservoirs advance at the same rate. Then the different sets combined with the single or double permeability approaches were tested against numerically generated data using HYDRUS and real experimental data obtained with INFILTRON-exp, "a

specific large ring infiltrometer" deployed at several experimental sites.

The results show that the custom-made models lead to different results, with some being better. In addition, considering the dual permeability models improved the fits of the experimental data acquired with the infiltrometer. Then, the improved model was used to model the observations from the Wicks Reservoir bioretention basin (Melbourne, Australia), including the water head in the filter layer and outflow rates, and this led to satisfactory results. The results obtained from this study will be used to develop the INFILTRON-mod package that can be easily integrated into the LID modeling performance for calculating the infiltration element in the unsaturated filter medium.