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Modeling bioretention systems using different sets of simplified preferential infiltration models

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Sustainable Urban Drainage Systems (SuDs) have grown in popularity in recent decades as an efficient and effective solution for urban drainage systems, with the aim of reducing flood risk, improving urban amenity and reducing negative impacts on receiving waters. Infiltration is a critical factor in both the management and modelling of SuDs. Predicting infiltration behaviour is rendered difficult by the inherent heterogeneity of substrate characteristics. Much research has been devoted to understanding the physical processes responsible for preferential flows in soils and developing simplified and physically-based infiltration models for predicting preferential flows and water infiltration into heterogeneous soils. In this study, INFILTRON-mod, a generic physically-based package, is proposed. This package involves infiltration models for uniform and non - uniform flows in soils, considering the Darcian approach and mass balance. Uniform and non-uniform flows are modeled using the single and dual permeability approaches, respectively. The dual permeability concept assumes that the soil comprises two regions, i.e., the general matrix and the fast-flow regions, each obeying the Darcian approach. Then, different sets of infiltration models can be considered for the description of water infiltration into the single permeability soils and, by analogy, into each region of the dual-permeability soils. In this study, we investigate different sets of infiltration models, including the Green and Ampt model and other specific custom-made models. The different sets combined with either single or dual permeability approaches were tested against numerically generated data and real experimental data obtained with INFILTRON-exp, a specific large ring infiltrometer deployed on several experimental sites.

First, we validated the proposed sets against numerically generated data for six different synthetic soils representing contrasting behaviors (sand, loam, silt, etc.). The synthetic data were generated with HYDRUS. The cumulative infiltrations were then compared, and the performance of the proposed sets of models was assessed. The results confirm that some sets fit well, whereas others are less accurate. The results also depended on the considered initial conditions.

Then, INFILTRON-mod was extended to the modeling of bioretention systems with the implementation of all the components of the hydrologic cycle (evapotranspiration, overflow, exfiltration to surrounding soils, water storage in the filter, and underdrain discharge). The

different sets of models were then compared to observations from the Wicks Reserve Bioretention Basin (Melbourne, Australia), including the height of water in the filter layer and the outflow fluxes. The sets of models were then calibrated using two rainfall events before being validated over 20 rainfall events. The model performance was assessed for both the single and dual permeability approaches. We obtained very good fits of the experimental data with a median NSE above 0.8 for outflows, particularly for two infiltration models with the dual permeability approach, demonstrating the benefit of including preferential flows in the model. Our findings will help to develop the INFILTRON-mod package for modeling water infiltration into heterogenous soils and modeling bioretention systems.