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Numerical simulation of surface-subsurface flow interaction during border irrigation

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The surface and subsurface flow interaction is of great importance in studying surface flow, infiltration and saturated-unsaturated zone flow and processes, in irrigation planning, in aquifers recharge, in flood routing problems and generally in infrastructure planning and water management.

In this study, a numerical model is presented simulating the surface and subsurface flow interaction. The unsteady surface flow is considered one-dimensional, in an open channel with initially dry bed and with lateral outflow, which is described by the Saint-Venant equations. The infiltration from the channel bed and the subsurface flow in the unsaturated zone is considered to be vertically one-dimensional or two-dimensional in a vertical plane along the channel axis, which is described by the one or two-dimensional Richards equation, respectively. The MacCormack, finite difference, explicit, predictor-corrector computational scheme, which is of second order accuracy, conditionally stable and convergent, is used to solve the Saint-Venant equations. The time step is determined by using the Courant-Friedrich-Lewy condition as well as by the stability criterion on account of the friction term, which was found to be important in cases of low discharge rates and/or high infiltration rates, both resulting generally to low flow depth. The time step determined in this way, is also sufficient for the Richards equation solution. The Richards equation is solved by using the finite element method. The above mentioned equations are solved separately but iteratively for the same time step and are coupled through the infiltration rate, which represents the lateral outflow term in the surface flow equations and is computed from the Richards equation.

This model, as it has been presented in its two versions, is evaluated by using on site data of border irrigation on an alfalfa field in northern Greece. It is concluded that

the proposed model is able to satisfactorily compute or predict the surface flow (flow depth, advance length, etc) as well as the infiltrated water volume through the soil surface and the hydraulic head and moisture distribution in the soil profile. It could be used in practical, real-world field problems and especially in surface irrigation planning through numerical experimentation.