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Modeling nonequilibrium and preferential flow and transport with HYDRUS.

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Accurate process-based modeling of nonequilibrium water flow and solute transport remains a major challenge in vadose zone hydrology. The objective of this presentation is to describe a wide range of nonequilibrium flow and transport modeling approaches available within the latest version of the HYDRUS-1D software package. The formulations range from classical models simulating uniform flow and transport, to relatively traditional mobile-immobile water physical and two-site chemical nonequilibrium models, to more complex dual-permeability models that consider both physical and chemical nonequilibrium. The models are divided into three groups: a) physical nonequilibrium transport models, b) chemical nonequilibrium transport models, and c) physical and chemical nonequilibrium transport models. Physical nonequilibrium models include the Mobile-Immobile Water Model, a Dual-Porosity Model, a Dual-Permeability Model, and a Dual-Permeability Model with Immobile Water. Chemical nonequilibrium models include the One Kinetic Site Model, the Two-Site Model, and the Two-Kinetic Sites Model. Finally, physical and chemical nonequilibrium transport models include the Dual-Porosity Model with one Kinetic Site, and the Dual-Permeability Model with Two-Site Sorption. Example calculations using the different types of nonequilibrium models are presented. Implications for the formulation of the inverse problem are also discussed. The many different models that have been developed over the years for nonequilibrium flow and transport reflect the multitude of often simultaneous processes that can govern nonequilibrium and preferential flow at the field scale.