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Evolution of Hubbert -Toth Models: from static flow nets to studies of dynamic head distributions, baseflow generation, and hyporheic processes

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Half-a-century ago, J. Tóth proposed a seminal conceptualization, alternative to M.K. Hubbert's, to describe the nested structure of regional groundwater flow systems observed in nature. Even today, this conceptualization plays a fundamental role in our understanding of subsurface flow and transport and how we treat natural systems both numerically and observationally. Tóth's results triggered explosive proliferation of models with distributed parameters in subsurface hydrology, further facilitated by computerization, increasing availability of hard field data, and accessible databases. Today, these models are still being applied to various hydrogeological systems with minimal changes to the original framework and extended to different scales. Examples include modeling of flow and residence times in basins, chemical reactions in hyporheic zone, and structural effects of permeability on flow and transport processes, just to name a few, but it is difficult to trace all hydrogeological studies where these models play a substantial role. However, discussions by various authors support the need for a paradigm shift and a path forward by changing the conceptualization of the aquifer processes and their drivers to accommodate surface water-groundwater interactions, which are fundamentally transient. In this work, we present a new model that explicitly considers spatially and temporarily varying groundwater recharge, delineating the dynamics of moving water table, surface water-groundwater interactions, and baseflow. As a proof-of-concept, we present a cross-sectional, two-dimensional model that explicitly generates transient baseflow. The conceptual model can be extended to account for different spatio-temporal recharge patterns, three-dimensional systems, groundwater withdrawals, and various types of surface water- groundwater connections. (Research was supported by the grants to VZ (NSF EAR 1744719) and JGV (NSF EAR 1830172, and SBR SFA at the PNNL)).