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A survey of physically-based catchment-scale modeling over the last half century

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Integrated, process-based based numerical models in hydrology and connected disciplines (ecohydrology, hydrometeorology, hydrogeomorphology, biogeochemistry, hydrogeophysics, etc) are rapidly evolving, spurred by advances in computer technology, numerical algorithms, and environmental observation, and by the need to better understand the potential impacts of population, land use, and climate change on water and other natural resources. At the catchment scale, simulation models are commonly based on conservation principles for surface and subsurface water flow and mass transport (e.g., the Richards, St. Venant, and advection-dispersion-reaction equations, and approximations thereof), and need to be resolved by robust numerical techniques for space and time discretization, linearization, interpolation, etc. Model development through the years has continually faced physical and numerical challenges arising from heterogeneity and variability in parameters and state variables; nonlinearities and scale effects in process interactions and interface dynamics; and complex or poorly known boundary conditions and initial system states. We give an historical perspective (past 50 years) on some of the key developments in physically-based hydrological modeling, examining how these various challenges have been addressed and providing some insight on future directions as catchment modeling enters a highly interdisciplinary era.