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New Module to Simulate Groundwater-Surface Water Interactions in Small-Scale Alluvial Aquifer Systems

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Abstract: When a pumping well lowers water table elevations adjacent to a nearby stream, a strong hydraulic gradient develops which results in a process referred to as streamflow depletion. Being able to accurately model the severity of this process is of critical importance in semi-arid regions where understanding groundwater-surface water interactions is crucial for sustainable water resource practices. The U.S. Geological Survey's modular finite-difference flow model, MODFLOW, is currently the standard for modeling groundwater flow. However, certain limitations persist when the program is applied on local, fine scales with dynamic interactions between an aquifer and a stream. To address these limitations, we present a new module for MODFLOW that (1) allows for multiple computational grid cells over the width of the river to allow for a finer mesh; (2) computes streamflow and stream stage along a stream reach using 1D steady shallow water equations, which allows for more accurate stream stages when normal flow cannot be assumed or a rating curve is not available; and (3) incorporates a process for computing streamflow loss when an unsaturated zone develops under the streambed. The new modeling code is tested against stream and groundwater data collected in a stream-aquifer system along the South Platte River in south Denver, Colorado. The model is being used to estimate streambed hydraulic conductivity and to estimate the impact of nearby pumping wells on streamflow. The new module can be applied to other small-scale stream-aquifer systems.

Keywords: Streamflow depletion; Numerical modelling; MODFLOW