Simulation of Transient Ground-Water Recharge in Deep Water-Table Settings: A Simple Water-Balance/Transfer-Function Model

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A relatively simple method is needed that provides estimates of transient ground-water recharge in deep water-table settings that can be incorporated into other hydrologic models. Deep water-table settings are areas where the water table is below the reach of plant roots and virtually all water that is not lost to surface runoff, evaporation at land surface, or evapotranspiration in the root zone eventually becomes ground-water recharge. The complexities of meteorological variations and unsaturated flow processes make it very difficult to estimate short-term recharge rates, thereby confounding calibration and predictive use of transient hydrologic models.

A simple water-balance/transfer-function (WBTF) model was developed for simulating transient ground-water recharge in deep water-table settings. The WBTF model represents a one-dimensional column from the top of the vegetative canopy to the water table and consists of two components: (1) a water-balance module that simulates the water storage capacity of the vegetative canopy and root zone; and (2) a transfer-function module that simulates the traveltime of water as it percolates from the bottom of the root zone to the water table. Input data requirements include two time series for the period of interest—precipitation (or precipitation minus surface runoff if surface runoff is not negligible) and evapotranspiration—and values for five parameters that represent water storage capacity or soil-drainage characteristics.

A limiting assumption of the WBTF model is that the percolation of water below the root zone is a linear process. That is, percolating water is assumed to have the same traveltime characteristics, experiencing the same delay and attenuation, as it moves through the unsaturated zone. This assumption is more accurate if the moisture content, and consequently the unsaturated hydraulic conductivity, below the root zone does not vary substantially with time.

Results of the WBTF model were compared to those of the U.S. Geological Survey model VS2DT (a physics-based variably saturated flow model) and to field-based estimates of recharge to demonstrate the applicability of the WBTF model for a range of conditions relevant to deep water-table settings in central Florida. Field-based estimates of daily recharge were computed for a 334-day period by analysis of water-table fluctuations at a site with well drained sand and a water table that ranged from 2 to 3.5 meters below land surface. Recharge was simulated for 1- to 2-year periods for eight hypothetical field sites by using VS2DT and synthesized values of precipitation, ET, and soil properties for combinations of two soil types (sand and loamy sand) and four water-table depths (2.5, 5, 10, and 20 meters). The WBTF model reproduced independent estimates of recharge reasonably well for the range of soil types and water-table depths tested: coefficient of determination (r^2) was 0.80 and standard error (SE) was 3.2 millimeters per day for the field-based estimates of recharge; and r^2 ranged from 0.73 to 0.90 and SE ranged from 0.48 to 1.6 millimeters per day for VS2DT-simulated estimates of recharge.