SIMULATION OF REGIONAL-SCALE GROUNDWATER/SURFACE-WATER INTERACTION IN THE UPPER KLAMATH BASIN OF OREGON AND CALIFORNIA

Oregon Water Science Center, Portland, Oregon, mgannett@usgs.gov;
and Brian J. Wagner, Research Hydrologist, U.S. Geological Survey
National Research Program, Menlo Park, California, bjwagner@usgs.gov

As the needs for environmental flows and habitat protection have affected allocation of surface-water supplies in the upper Klamath Basin, resource managers and water users have been increasing reliance on groundwater. State and Federal water management agencies are concerned about the possible reductions in streamflow resulting from the increased consumptive use of groundwater. To help address these concerns, a regional groundwater flow model that simulates the interaction between the regional groundwater system and streams has been developed.

The model grid consists of 210 rows and 285 columns of 2,500 by 2,500 foot cells, with three layers of varying thickness. Layer thickness is controlled by geology and topography. The modeled domain (area of active cells) encompasses approximately 8,000 square miles. The distribution of subsurface hydraulic characteristics is represented by a group of homogeneous zones based on geology and structure. All major streams and lakes are simulated in the model. Evapotranspiration is simulated in broad lowlands where the water table is within the rooting depth of plants. Agricultural drains are simulated where they cover extensive areas and constitute a major boundary.

Model calibration was aided by a rich hydrologic dataset that includes approximately 5,600 head measurements from 662 wells, 443 of which had time series of measurements spanning a few years to decades. In addition there were 52 stream reaches or large spring complexes where groundwater discharge was measured or estimated. Time series of groundwater discharge were available for 10 major discharge areas.

Data clearly show that most temporal variations in hydraulic head and groundwater discharge are driven by decadal and seasonal climate cycles. Anthropogenic influences such as canal operation, reservoir stage variations, and groundwater pumping are apparent in hydraulic head time series but not in groundwater discharge time series due to the masking affects of other influences and measurement error (a signal to noise ratio problem).

The regional groundwater model is able to simulate the observed climate-driven variations in hydraulic head and groundwater discharge at a range of time scales throughout most of the upper Klamath Basin. Observed subregional to local variations in hydraulic head caused by groundwater use are simulated with reasonable accuracy in areas of concentrated groundwater withdrawal where accurate pumping information is available.

Simulations of wells placed at different areas and depths throughout the basin show that the ultimate sources of water to wells vary with proximity to different boundary types. For example, pumping wells in agricultural areas with very shallow water-table depths results in diminished discharge to agricultural drains and reduced evapotranspiration, with little reduction in groundwater discharge to streams. Simulated pumping wells in upland areas, in contrast, have little effect on agricultural drains and evapotranspiration, but result in reduced groundwater discharge to streams. Simulations show that the timing of pumping effects is also dependent on
location and depth. The effects of seasonal pumping of wells close to streams are fully manifest in less than a decade, and the impacts retain seasonal variations. Seasonal pumping of wells located several miles from streams take many decades to fully impact the streams, and seasonal variations are largely attenuated.

Although there are no direct measurements of groundwater discharge variations in response to pumping, the model’s capability to simulate a broad array of measured discharge variations at a range of temporal and spatial scales indicates that simulated changes in groundwater discharge in response to pumping are likely representative of the actual response. Model sensitivity and uncertainty analyses can be used to assess the reliability of model predictions in response to changing climatic and anthropogenic influences.