Simulation of Ground-Water Flow in a Fractured-Rock Karst Aquifer, Shenandoah Valley, Leetown, West Virginia

By Mark D. Kozar[1] and Kurt J. McCoy[2]
[1] U.S. Geological Survey, West Virginia Water Science Center, Charleston, WV, 25301
[2] U.S. Geological Survey, New Mexico Water Science Center, Albuquerque, NM, 87109-1311

Abstract

Karst scientists are sometimes reluctant to pursue ground-water modeling of karst terranes. This is largely because many of the assumptions of Darcian flow on which models are predicated are violated in the turbulent flow systems of karst aquifers, especially within large conduit drains and caverns. However, ground-water models have been effectively developed for numerous karst systems. This abstract presents the results of a ground-water flow model developed for a fractured rock dominated karst aquifer beneath the Leetown Science Center (LSC) in the Shenandoah Valley of West Virginia, Leetown, West Virginia. The aquifer is a karst system but with a significant diffuse-flow component. As a result, both classic dye tracing and fractured rock techniques were used to collect the data necessary to develop the ground-water flow model.

The LSC is a research facility operated by the U.S. Geological Survey that occupies approximately 455-acres near Kearneysville, Jefferson County, West Virginia. The recent construction of a second research facility (National Center for Cool and Cold Water Aquaculture) operated by the U.S. Department of Agriculture and co-located on Center property has placed additional demands on available water resources in the area. To address the concerns of future water availability, a three-dimensional steady-state finite-difference ground-water flow model was developed to simulate ground-water flow in the Leetown area under normal and drought conditions.

Results of geologic mapping, LiDAR derived DEMs, and surface-geophysical surveys verified the presence of several prominent thrust faults and identified additional faults and other complex geologic structures (including overturned anticlines and synclines) in the area. These geologic structures are known to control ground-water flow in the region. Results of this study indicate that cross-strike faults and fracture zones are major avenues of ground-water flow. Prior to this investigation, the conceptual model of ground-water flow for the region focused primarily on bedding planes and strike-parallel faults and joints as controls on ground-water flow but did not recognize the importance of cross-strike faults and fracture zones that allow ground water to flow down gradient across or through less permeable geologic formations.

Results of the ground-water flow simulation indicate that current operations at the Center do not substantially affect either streamflow (less than a 5-percent reduction in annual streamflow) or ground-water levels under normal climatic conditions but potentially could have greater effects on streamflow during long-term drought (reduction in streamflow of approximately 14 percent). On the basis of simulation results, ground-water withdrawals based on the anticipated need for an additional 150 to 200 gal/min (gallons per minute) of water at the Center also would not seriously affect streamflow (less than 8 to 9 percent reduction in streamflow) or ground-water levels during normal climatic conditions. During drought conditions, however, the effects of current ground-water withdrawals and anticipated additional withdrawals of 150 to 200 gal/min to augment existing supplies result in moderate to substantial declines in water levels of 0.5-1.2 feet (ft) in the vicinity of the Center's springs and production wells. Streamflow was predicted to be reduced locally by approximately 21 percent. Such withdrawals during a drought or prolonged period of below normal ground-water levels would result in substantial declines in the flow of the Center's springs and likely would not be sustainable for more than a few months. The potential reduction in streamflow is a result of capture of ground water that would otherwise have been discharged to Hopewell Run or its tributaries as base-flow discharge. The net effect on streamflow downstream of the facility is minimal, as the majority of water withdrawn is returned to the stream after treatment.