USGS Ground-Water Flow Model

An Essential Tool for Managing the Water Supply of the Virginia Coastal Plain

Virginia needs a reliable water supply to sustain its growing population and expanding economy. In 1990, the aquifers in the Coastal Plain supplied about 100 million gallons per day (mgd) to the citizens, businesses, and industries of Virginia. It is estimated that by the year 2000, demand will increase by another 10 mgd and likely will continue to increase in future years.

Ground water is the only source of usable water in rural areas of the Coastal Plain and increasingly is being used to support a growing urban population. Current withdrawals have led to declining water levels in most Coastal Plain aquifers. Further declines are likely to occur, posing a threat that saltwater will move into parts of these freshwater aquifers.

How can we sustain this important water supply?

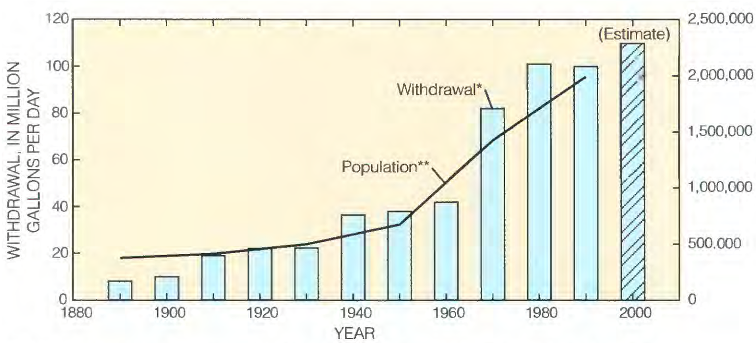
To ensure that the Coastal Plain aquifers do not become overdrawn, the Commonwealth of Virginia regulates large ground-water withdrawals in ground-water management areas. A computer model of regional ground-water flow developed by the USGS is used by the Virginia Department of Environmental Quality (DEQ) to permit new water-supply wells and to assess long-term stresses to the ground-water system. Local communities use results from the Coastal Plain model to plan for their future water-resource needs. The model is a useful and well-accepted tool for supporting many important ground-water management decisions.

The model needs to be fine-tuned periodically so that it will continue to support wise ground-water management decisions into the 21st century.

Coastal Plain aquifers supply water to Virginia homes . . .

. . . businesses and industry . . .

. . . and agriculture.



Population and ground-water use are increasing in the Virginia Coastal Plain. *Based on DEQ data. **Based on Census Bureau data.

Does heavy ground-water use affect everyone?

Yes. Large withdrawals can have wide-ranging effects that cross city, county, and even state boundaries. In the Northern Neck of Virginia, for example, ground-water levels and flow probably have been altered by pumping in southern Maryland.

Excessive ground-water withdrawals can mean

- less water available for private and public supplies because of declining water levels
- higher water bills as pumping costs increase
- conflict among users of ground water
- degraded water quality from saltwater intrusion (saltwater moving into freshwater areas)
- reduced streamflow, which harms fish and other aquatic life as well as opportunities for recreation

Development and uses of the Coastal Plain model

The ground-water flow model was developed by the USGS in the early 1980s to help scientists better understand the flow system in the Coastal Plain and how it is affected by withdrawals. Since then, USGS hydrologists have worked with DEQ to revise the model: more current information on the aquifer system has been incorporated, and simulations have been performed using updated data on withdrawals.

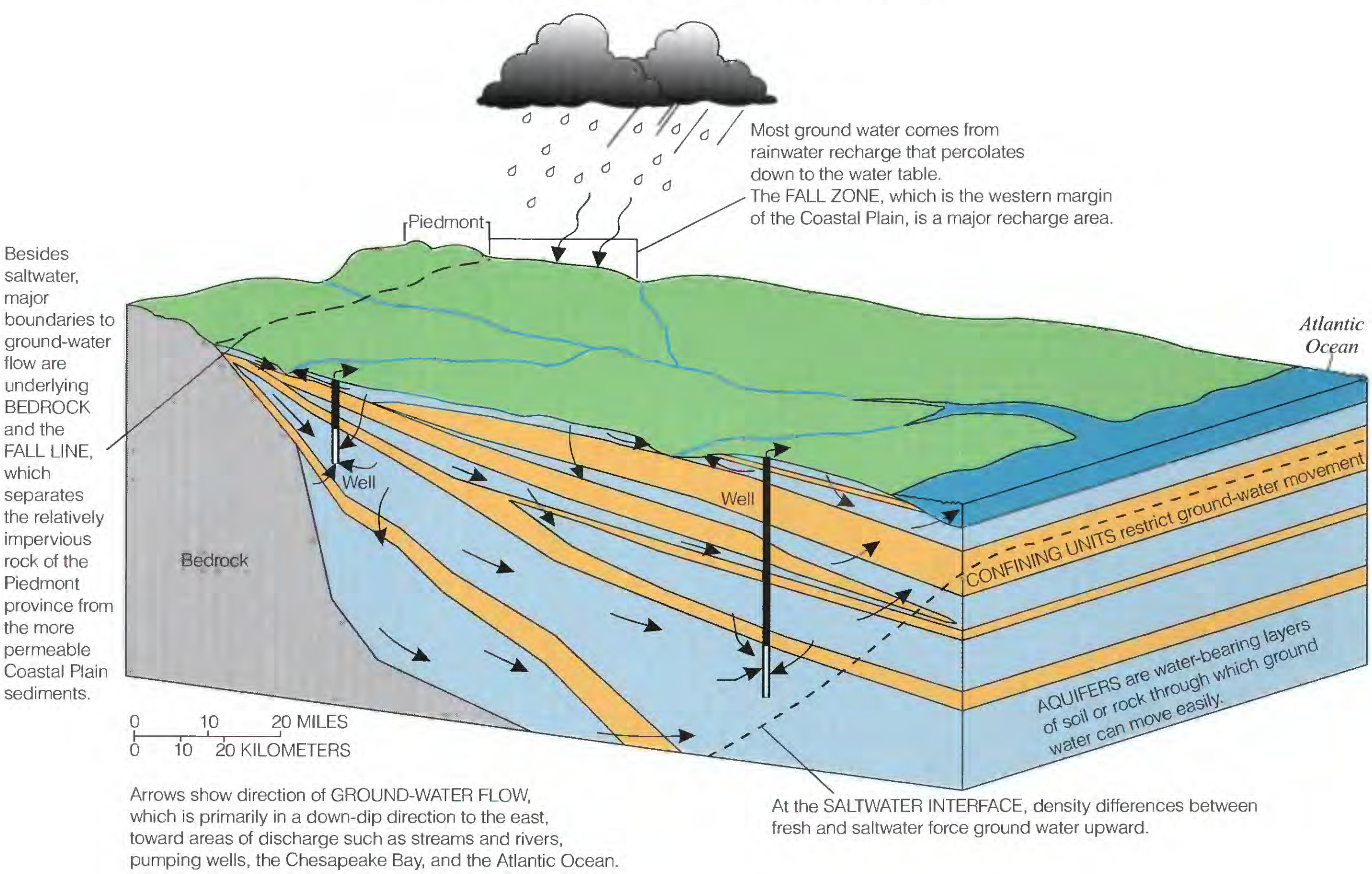
The model is used to

- examine trends in ground-water levels and flow rates
- evaluate the cumulative impact of actual withdrawals
- predict the effects of proposed large-scale withdrawals that will affect more than one aquifer

Because the Coastal Plain aquifers are greatly stressed in Hampton Roads and other areas, users of large amounts of ground water (300,000 or more gallons per month) from a designated ground-water management area must obtain a ground-water withdrawal permit. DEQ uses the model to determine the "area of impact" for withdrawals proposed by these permit applications.

In 1992, the Ground Water Management Act decreased the term of withdrawal permits—once good for life, the permits now must be renewed every 10 years—and users are allowed to withdraw only as much ground water as needed to serve current demands. This policy was influenced by model simulation results, which predicted that increased pumping in southeastern Virginia would lead to "considerable well interference among ground-water users and potential degradation of water quality" (Hamilton and Larson, 1988).

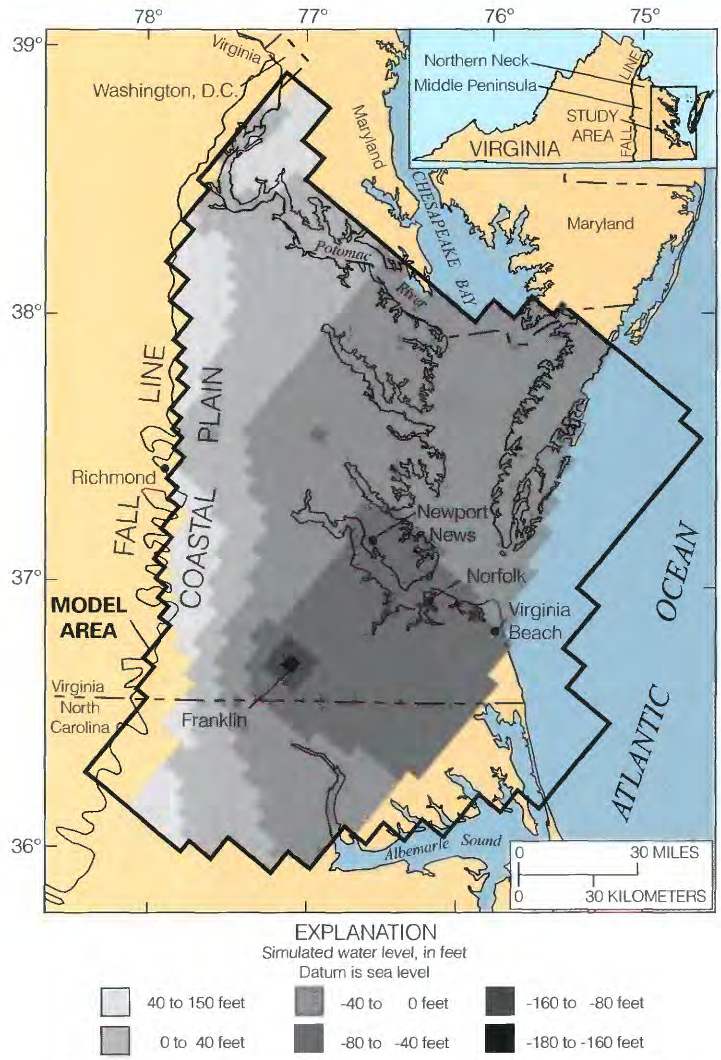
The Virginia Coastal Plain Aquifer System



Improvements needed to the model

The USGS model has significantly enhanced the way the Commonwealth manages its ground-water resources. Improvements to the model are needed, however, to sustain its ability to make accurate predictions. Several discrepancies have been identified between model simulations and actual conditions. For example, simulated water levels frequently differ from measured levels, particularly near large pumping centers. In addition, scientists now have a better understanding of the Coastal Plain aquifer system, and stresses on this system are increasing.

The project to improve the model—named **CPM-2000**—will be a cooperative effort of the USGS, DEQ, and local communities. CPM-2000 will provide the information needed to plan effectively for new ground-water withdrawals. It will also allow the Commonwealth to continue permitting these withdrawals in a fair and technically defensible manner.



Results of model simulations show declining ground-water levels in a Coastal Plain aquifer.

How computer models create a "virtual ground-water system"

How do you study an extremely complex system that is hidden from view? Scientists use computer models to simulate the movement of water underground. First, they collect data that will be input to the modeling program to represent sources of recharge and discharge (water coming into and leaving the ground-water system) and aquifer characteristics that affect ground-water movement.

"To build the input data sets, we gather all the information that's already available about the ground-water system," said USGS hydrologist Randy McFarland. "To fill in the gaps, we do further studies in the field. Then we create a conceptual model, which is a set of ideas about how we think the system works. Next we build the input data sets for the modeling program." He noted that a good computer model will represent the ideas of the conceptual model.

The model performs calculations using the input data and generates output data that simulate ground-water flow rates and directions and ground-water levels. GIS (geographic information system) adds real-world geographical references so that maps can be created to illustrate regional ground-water conditions. "These maps can tell us where the water's coming from, where it's going, how much water's moving, and how fast," McFarland said.

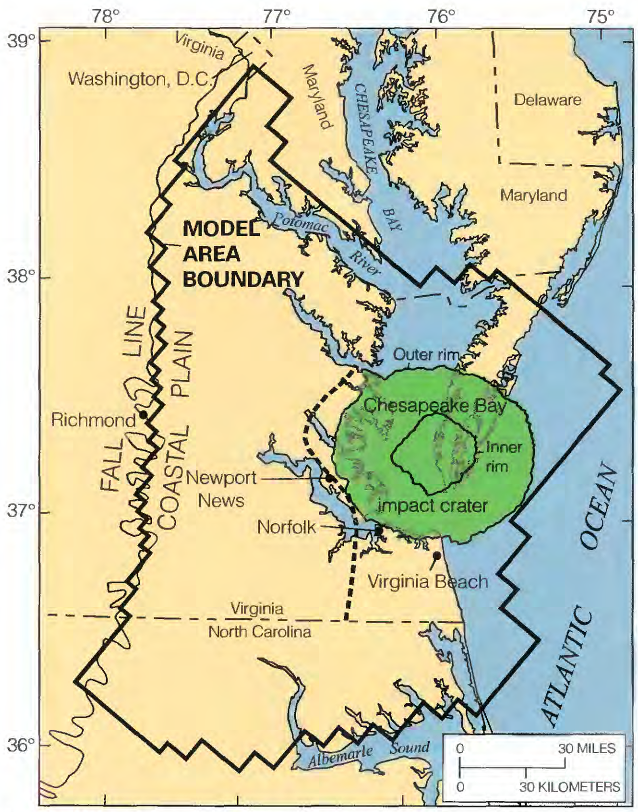
Model simulations must be compared to real-world conditions, and then the model is calibrated, or adjusted, to decrease error. Usually, this means revising both the conceptual and computer models. Additional simulations based on possible future conditions must be performed when models are used to predict future changes (such as how water levels might rise or decline as a result of either restricted or increased pumping).

"A model needs to be updated to keep it a useful ground-water management tool," said McFarland.

CPM-2000 will include new and updated information about

- Coastal Plain aquifers—USGS will gather more data on the Northern Neck and Middle Peninsula, which are among the least well-understood parts of the aquifer system. Within the next 5-10 years, these areas in the northern portion of the Coastal Plain will likely be part of Virginia's designated ground-water management area.
- Effects of the Chesapeake Bay impact crater—USGS scientists recently have discovered that a comet or meteorite struck the Earth about 35 million years ago near the present-day mouth of the Chesapeake Bay. The resulting 56-mile wide crater severely disrupted several Coastal Plain aquifers and created Virginia's "inland saltwater wedge" that limits the amount of fresh water available in the lower bay region (Powars and others, 1994). Several ground-water withdrawal projects in the Hampton Roads area are near the crater's outer rim. In order to accurately simulate withdrawals and ground-water flow in this area, information about the effects of the impact crater will be incorporated into the model.
- Connections between ground and surface water—The model will incorporate recently discovered connections between the aquifers and the streams and rivers along the Fall Zone. These connections could be significantly affecting the availability of ground water in the Coastal Plain.
- Effects of increasing withdrawals—Large withdrawals are occurring in areas near the boundaries of the model, such as in Hampton Roads, in southern Maryland along the Potomac River, and along the Fall Zone. More accurate simulations are needed of how water levels respond to these withdrawals. After comparing results of simulations with current data on withdrawals, the model will be recalibrated to better represent current ground-water conditions.

—Martha L. Erwin and E. Randolph McFarland, USGS, and T. Scott Bruce, Virginia Department of Environmental Quality



The effects of the Chesapeake Bay impact crater will be incorporated into the model. Dotted line shows the extent of the "inland saltwater wedge," where fresh ground water meets salty water in the middle Potomac aquifer.

Fact sheet based on

McFarland, E.R., 1998, Design, revisions, and considerations for continued use of a ground-water-flow model of the Coastal Plain aquifer system in Virginia: U.S. Geological Survey Water Resources Investigations Report 98-4085, 49 p.

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