Virginia Ground Water Withdrawal Permitting Program – Modeling for Resource Management

Roberta W. Patton
Virginia Department of Environmental Quality, Richmond, VA, USA

ABSTRACT

The Virginia Department of Environmental Quality (VA-DEQ) strives to manage Coastal Plain ground-water resources through a dynamic and iterative process of framework and flow system investigations, predictive ground water model simulations, and regulation of withdrawals through a permitting process. This resource management program requires partnerships between the regulatory agency, the regulated community, local government, and the United States Geological Survey (USGS). The regulated community provides information about the geologic framework and aquifer hydraulics through field work and monitoring activities required to support withdrawal permits. The VA-DEQ evaluates withdrawal requests for sustainability using field data and regional flow models. Any proposed withdrawal that adversely affects the sustainability of the aquifer system (quality or quantity) must provide appropriate mitigation, when possible, or be denied. The VA-DEQ and local governments cooperate with the USGS to develop regional flow models that accurately reflect the latest information about the aquifer system. Field observation well nests and historic pumping records are used to calibrate and to evaluate the performance of these regional models.

INTRODUCTION

The Commonwealth of Virginia has actively managed ground water resources of the coastal plain regions since 1976. By Act of Virginia's General Assembly [Va. Code § 62.1-254 *et seq.*], the right to reasonable control of all ground water resources was recognized as a right of the public in order to ensure the public welfare, safety, and health. The duties associated with the management of the resource were delegated to the State Water Control Board (a citizen appointed board) and its regulatory Agency, the Virginia Department of Environmental Quality. Management of the resource seeks to protect the withdrawals of existing, lawful ground water users and to ensure the sustainability of the managed aquifers. A "Ground Water Management Area" can be initiated when any of the following conditions is found to exist:

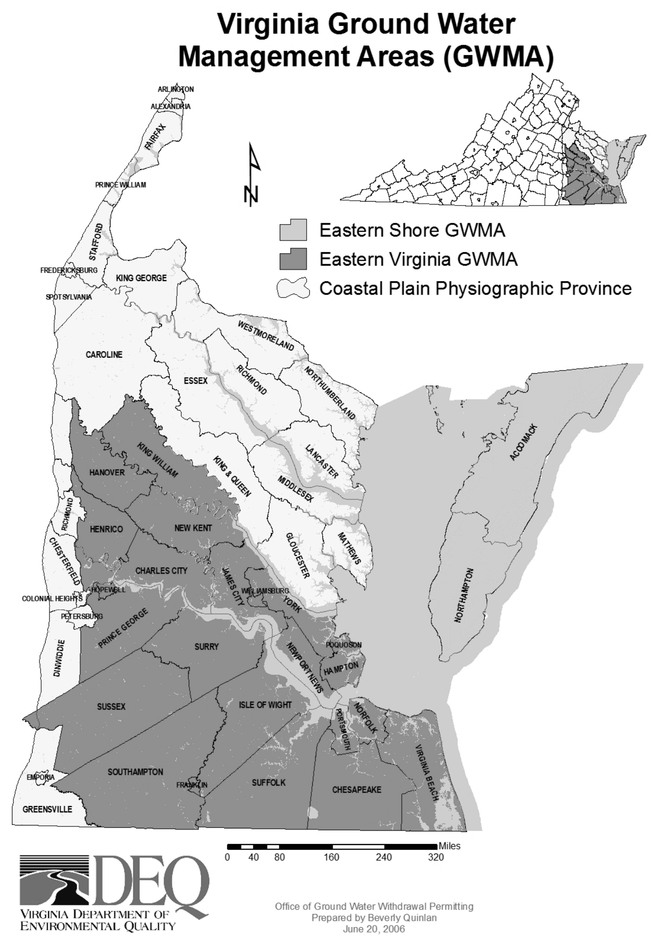

Figure 1 Ground-water withdrawals are regulated in Virginia Ground Water Management Areas.

1. Ground water levels in the area are declining or are expected to decline

excessively;

2. The wells of two or more ground water users within the area are interfering or may be reasonably expected to interfere substantially with one another;

3. The available ground water supply has been or may be overdrawn; or

4. The ground water in the area has been or may become polluted.

All four of the required conditions are considered applicable in the two Management Areas in Virginia's coastal plain.

The ground-water flow system in Virginia's Coastal Plain is an eastward thickening wedge of layered sands and clays. The wedge thins to a feather-edge on the western boundary at Virginia's Fall Zone and thickens to several thousand feet approaching the continental shelf. The transition to seawater occurs near Virginia's coast line, becomes more inland in position with depth, and is not well defined. The two counties of Virginia's Eastern Shore comprise the Eastern Shore Ground Water Management Area and the mainland region south of the Mattaponi River is designated the Eastern Virginia Ground Water Management Area. Reported ground water use within Virginia's Coastal Plain has remained relatively constant at 100 Mg/day (± 5%) for about 25 years although active permits authorize a total withdrawal rate that is approaching 200 Mg/day. Withdrawals that exceed 300,000 gallons in any month require a permit.

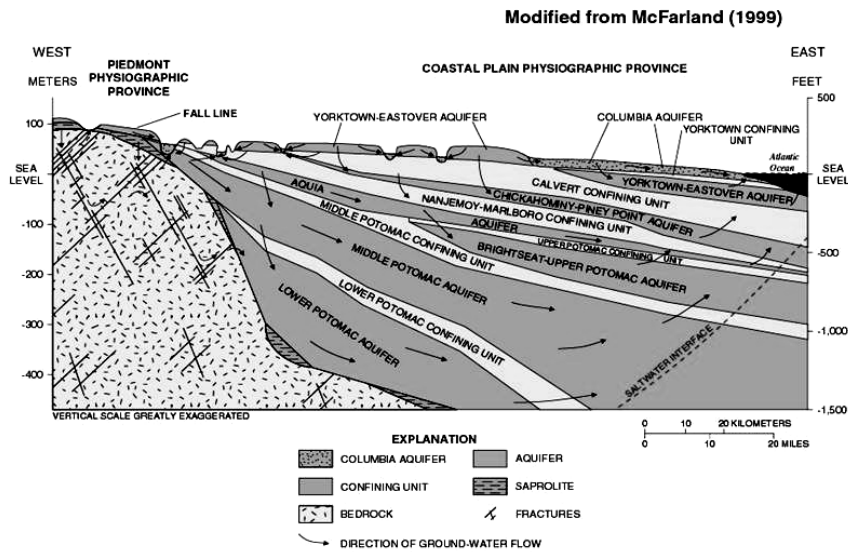

Figure 2 Generalized Coastal Plain Aquifer System (McFarland, 1999)

RESOURCE MANAGEMENT THROUGH PERMIT PROGRAM

Permits are issued for a maximum term of 10 years and specify withdrawal limits, source aquifer(s), withdrawal locations, and reporting requirements. Water Conservation & Management Plans are developed by the permittee specific to the permitted beneficial use and become an enforceable part of the final permit. The permittee is also required to mitigate any adverse impacts to existing, lawful withdrawals. These Mitigation Plans also become and enforceable part of the permit. Maps of the impact area(s) are developed by the DEQ's modeling staff and become part of the Mitigation Plan.

The DEQ staff geologists and modelers evaluate technical information provided by the applicant to evaluate the demand and to determine site-specific hydraulic parameters. Proposed uses must demonstrate that the requested withdrawal amount is the least (quantity and quality) required to support the beneficial use. Applicants are required to submit well construction information (including geophysical logs) and site-specific aquifer test data or reference an applicable nearby test. The modeling staff determines the area, in all affected aquifers, where one foot or more of drawdown is predicted to occur as a result of the proposed withdrawal. Impact areas are an enforceable part of the permit document and identify areas where the permittee has mitigation responsibilities. The largest withdrawals require use of USGS regional models while small or water table well fields require two-dimensional analysis. Some sites require development of site-specific three-dimensional models in order to most accurately simulate impacts. The proposed withdrawal is then evaluated for cumulative effects with all existing lawful withdrawals simulated at their maximum permitted withdrawal limit (Total Permitted Simulation). This evaluation uses the regional model to test for compliance with regulatory limits on allowable stabilized drawdowns to ensure long-term aquifer sustainability.

The Virginia Ground Water Withdrawal Regulations [9 VAC 25-610-10 *et seq*.] prescribe a limit to allowable drawdown that is intended to prevent aquifer dewatering. Adverse changes to water quality are also prohibited and are considered by evaluating for potential upconing and reversal of flow. Regional and site-specific ground water flow models are used by the Virginia Department of Environmental Quality to evaluate the impacts from any new or expanded withdrawal for compliance with these requirements. The regional models developed by the USGS Water Science Center in Richmond, Virginia, are used to simulate total permitted conditions in the aquifer system.

REGIONAL FLOW MODELS USED FOR REGULATORY ASSESSMENT

The Virginia Coastal Plain Model was developed by the USGS in 80's and simulates nine confined aquifers and a constant head water table (Harsh et al. 1990) using MODFLOW (Harbaugh et al. 1996). The model considers confining units through vertical conductance between aquifers. Grid cells are 3.5 miles on each side and are a reminder of processing constraints from earlier desktop computers. The Eastern Shore Model (Richardson 1994) was developed in the 1990's to evaluate several pumping scenarios for Virginia's Eastern Shore and utilized the USGS SHARP model (Essaid 1990). The salt water boundary for this peninsula system is simulated as a sharp interface. It is also a pseudo 3-D model, simulating confining units through vertical conductance between aquifers.

With VA-DEQ and other stakeholders fully active in the modeling side of the management issue, we began to track critical areas and model performance. Each year reported withdrawals are simulated to check model performance with field conditions. These simulations of actual use began to show trending deviations from field conditions in several key areas. In addition, information gathered through the permitting process began to provide new details about previously undocumented portions of the aquifer system. Stakeholder research, also revealed conflicts between the conceptual framework of the models in use and the aquifer system, like identification of the Chesapeake Bay Impact Crater by USGS and VA-DEQ. As a result, stake holders cooperated to support the development of two new models by the USGS.

The new models have been developed for Virginia's Coastal Plain using the USGS SEAWAT code (Langevin et al. 2003). These new models allow for consideration of density dependent flow and explicitly simulate confining layers as well as aquifers. This change alone has challenged a foundation concept for the regulatory program and will likely result in a regulatory change. The vertical conductance paradigm in the first regional models did not consider storage in the confining layers and therefore approached steady-state conditions in approximately 10 years. The new models, with specific treatment of the confining layers, do not approach steady-state for over 100 years.

DISCUSSION AND CONCLUSIONS

As the limit of aquifer sustainability is approached, stakeholder cooperation and technical efficiencies will have to continue to improve in order to optimize use of the ground water resources. For the future, the permitting program plans to build on the successes of using predictive modeling to support management goals. It will be necessary for all stakeholders to operate in a dynamic and iterative process of data collection and model revision with the scientific community. Even though two new models are ready for application, projects are underway to utilize new techniques from Hill and Tiedeman (2007) to evaluate locations where new monitoring and/or framework data can provide additional model improvements. Operators of large municipal water systems are supportive of continuous monitoring of transient pumping in an effort to develop pumping strategies that minimize impacts to the resource and to other users. Perhaps the most important of the planned strategies is a schedule for regular evaluations of new data and model performance to identify the need for model revisions.

REFERENCES

Essaid, H.I. 1990. The computer model SHARP, a quasi-three-dimensional finite-difference model to simulate freshwater and saltwater flow in layered coastal aquifer systems. USGS Water-Resources Investigation Report, 90-4130.

Harbaugh, Arlen W., Banta, Edward R., Hill, Mary C., and McDonald, Michael G. 2000. MODFLOW-2000, The U.S. Geological Survey Modular Ground-Water Model - User Guide to Modularization Concepts and the Ground-Water Flow Process. USGS Open-File Report, 2000-92.

Harsh, John F. and Laczniak, Randell J. 1990. Conceptualization and analysis of ground-water flow system in the Coastal Plain of Virginia and adjacent parts of Maryland and North Carolina. USGS Professional Paper 1404-F.

Langevin, Christian D., Shoemaker, W. Barclay, and Guo, Weixing. 2003. MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model--Documentation of the SEAWAT-2000 Version with the Variable-Density Flow Process (VDF) and the Integrated MT3DMS Transport Process (IMT). USGS Open-File Report, 2003-426.

McFarland, E.R., 1999, Hydrogeologic framework and ground-water flow in the Fall Zone of Virginia: U.S. Geological Survey Water-Resources Investigations Report 99-4093.

Richardson, Donna L., 1994. Hydrogeology and analysis of the ground-water-flow system of the Eastern Shore, Virginia. USGS Water Supply Paper, 2401.

Contact Information: Roberta W. Patton, Virginia Department of Environmental Quality, P.O. Box 1105, Richmond, VA 23218 USA, Phone: 804-698-4085, Fax: 804-698-4032, Email: rwpatton@deq.virginia.gov