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WATER-RESOURCES NOTES

GROUND-WATER CONCERNS FOR THE EASTERN SHORE, VIRGINIA

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The Eastern Shore of Virginia is a peninsula that is surrounded on three sides by salty water and has no major fresh surface-water sources (fig. 1); ground water provides the sole freshwater supply. Beginning in about 1965, increases in ground-water withdrawals for agricultural, commercial, urban, and industrial uses have caused water-level declines and have created cone-like depressions in the water-level surface around major pumping centers near the Towns of Accomac, Cape Charles, Cheriton, Chincoteague, Exmore, and Hallwood, Virginia. Increased water withdrawals could adversely affect the supply of fresh ground water on the Eastern Shore. In 1992, the U.S. Geological Survey, in cooperation with the Virginia Department of Environmental Quality and the counties of Accomack and Northampton, completed a comprehensive study of the ground-water resources of the Eastern Shore (Richardson, 1992). This report highlights the major results of that study.

HOW DOES GROUND WATER FLOW?

Water beneath the ground does not flow in large channels or rivers the way water flows above the ground. Water fills the tiny spaces between sediment grains and flows very slowly through the spaces. Depending on where the water enters the ground and other factors, such as the physical properties of the sediments, water can remain in the ground-water system for days, years, or centuries. The sediments beneath the Eastern Shore form a layered sequence of non-uniform aquifers and confining units. Aquifers beneath the Eastern Shore are sandy water-bearing units that readily transmit useful amounts of water to wells. The uppermost aquifer is the water-table or unconfined aquifer. The underlying aquifers (known as confined aquifers) are separated from the unconfined aquifer and one another by layers of sediments (known as confining units) that contain a large percentage of clay. The confining units impede the movement of water between aquifers; however, some vertical movement of water does occur through confining units. The water level in an aquifer determines the direction of ground-water flow. The water level is the height that water rises in a well that is open to the sediments of a particular aquifer. As water on the land surface flows downhill, ground water flows from higher water levels to lower water levels.

Fresh ground water beneath the Eastern Shore is limited to the upper 300 feet (ft) of sediments; the ground water at depths greater than 300 ft is salty. For the purposes of this report, ground water is considered salty if it contains concentrations of chloride greater than 250 milligrams per liter (equivalent to dissolving 0.25 grams of chloride in 1 liter of water). The freshwater part of the ground-water system includes the unconfined

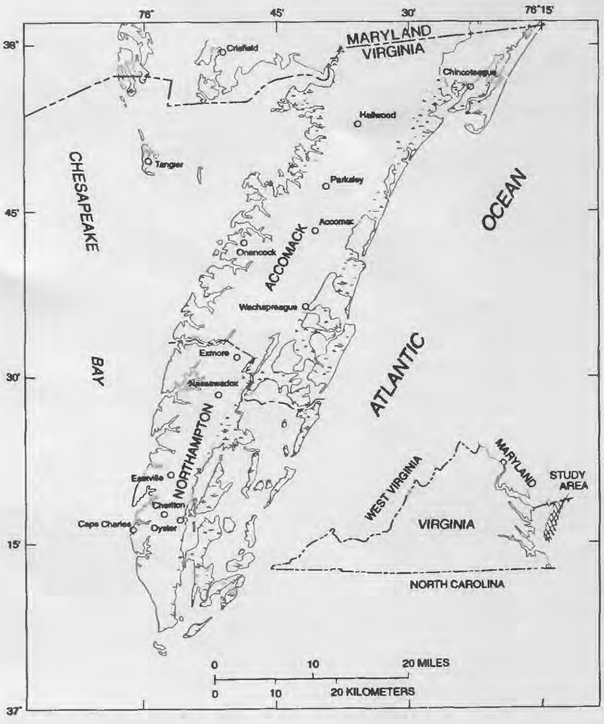

Figure 1.—Location of study area.

aquifer (Columbia aquifer) and three confined aquifers (upper, middle, and lower Yorktown-Eastover aquifers) separated by intervening confining units (upper, middle, and lower Yorktown-Eastover confining units) (fig. 2).

Freshwater enters the ground-water system primarily through precipitation that falls on the peninsula and percolates through the soil into the sediments of the Columbia (or unconfined) aquifer in a process known as recharge (fig. 2). An estimated 8.5 to 15 inches of the 43 inches of annual precipitation recharges the unconfined aquifer; the remainder is either used by plants or flows over the land to enter streams, ponds, or other surface-water sources (Cushing and others, 1973). Water in the unconfined aquifer flows downward into the lower parts of the unconfined aquifer, then laterally toward discharge sites, such as springs, streams, marshes, estuaries, the Chesapeake Bay, and the Atlantic Ocean. The lateral directions of ground-water flow generally are from the ground-water divide at the center of the peninsula westward to the Chesapeake Bay and eastward to the Atlantic Ocean. Eventually, water that is moving downward encounters the upper Yorktown-Eastover confining unit, and because vertical flow is impeded by the confining unit, much of the water is forced to move laterally through the unconfined aquifer. Under natural (pre-pumping) conditions, a comparatively small amount of water (an estimated 0.6 inches per year) is able to flow downward through the less permeable confining unit into the confined-aquifer system. Water in the underlying confined aquifers continues to flow from the recharge area near the center of the peninsula westward to the Chesapeake Bay and eastward to the Atlantic Ocean (fig. 2). Where fresh ground water from the peninsula encounters salty ground water from the Chesapeake Bay and Atlantic Ocean, the less dense freshwater is forced upward. The upward-moving fresh ground water is again inhibited by confining units but eventually discharges into marshes, estuaries, the Chesapeake Bay, and the Atlantic Ocean.

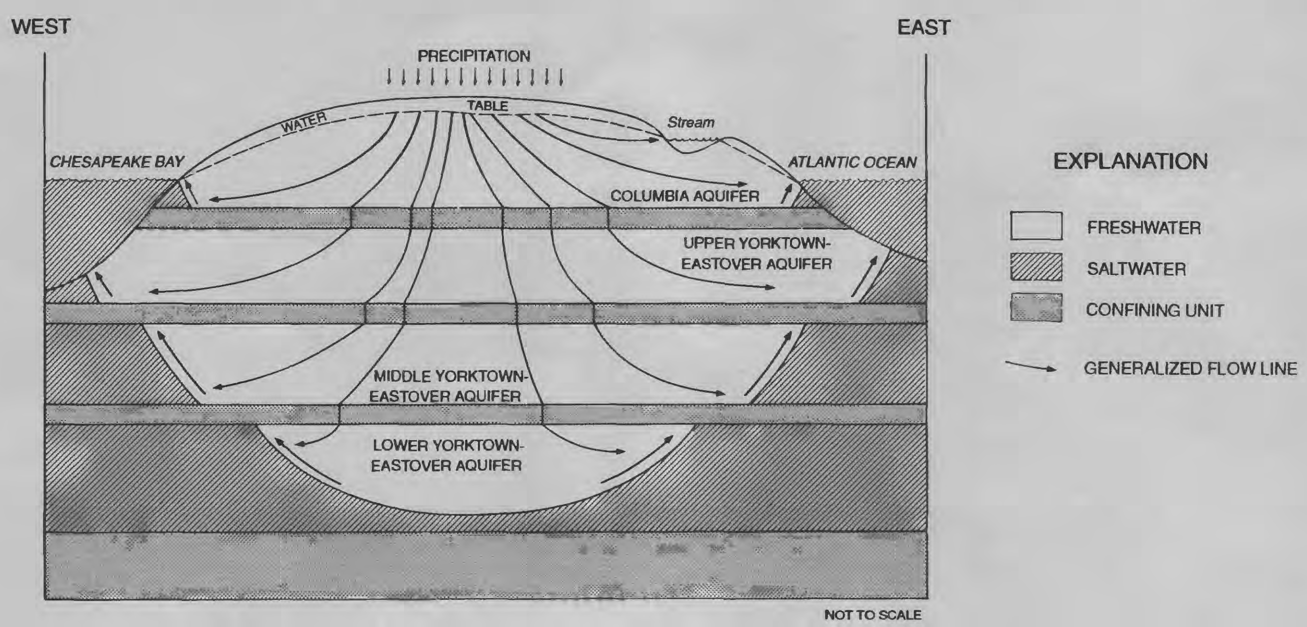

Figure 2.—Schematic diagram of aquifers, confining units, generalized flow lines, freshwater, and saltwater for the Eastern Shore.

HOW MUCH GROUND WATER IS USED?

The annual water withdrawal from the confined aquifers on the Eastern Shore is shown in figure 3. The estimates shown do not include domestic or agricultural withdrawals. Domestic use is not included because there is no practical method of collecting such data by aquifer. In addition, much of the water used for domestic purposes is returned to the ground-water system through septic systems. Ground water is widely used for agricultural purposes on the Eastern Shore; however, as of 1990, agricultural users are not required by law to report withdrawals. As a result, the specific locations, magnitudes, and aquifers tapped for agricultural withdrawals are unknown. Much of the ground water used for agricultural purposes is withdrawn from irrigation ponds in the Columbia aquifer. Agricultural withdrawals are limited to months during the growing season when the soil moisture is deficient because of a lack of precipitation. All other ground-water users in Northampton and Accomack Counties that withdraw more than 300,000 gallons per month are required to report usage data to the Virginia Department of Environmental Quality.

The middle and upper Yorktown-Eastover aquifers historically have provided most of the freshwater to users on the Eastern Shore. Prior to 1968, the largest withdrawals were from the shallowest confined aquifer, the upper Yorktown-Eastover. By 1970, the middle Yorktown-Eastover aquifer was providing more water than the upper or lower Yorktown-Eastover aquifers, and pumpage from the lower Yorktown-Eastover aquifer was increasing. Estimated total ground-water use peaked in 1974 at 6.96 Mgal/d (million gallons per day). The decline in water use from 1974 to 1983 represents the loss of several major industrial users. Since 1985, water use generally has been nearly steady. Total ground-water use (minus domestic and agricultural) was estimated to be about 5.04 Mgal/d in 1988. The upper Yorktown-Eastover aquifer supplied 36 percent of the withdrawal in 1988, and the middle and lower Yorktown-Eastover aquifers supplied 42 and 22 percent, respectively.

WHERE IS THE GROUND WATER SALTY?

The most recent chloride analysis at each well was compiled to determine the current locations of salty ground water. Water can taste too salty when the concentration of chloride exceeds 250 mg/L (milligrams per liter). Chloride concentrations in the Columbia aquifer ranged from 9 to 363 mg/L with an average value of 42 mg/L. Elevated chloride concentrations exist in the Columbia aquifer in coastal areas adjacent to salty surface water. Chloride concentrations in the upper Yorktown-Eastover aquifer ranged from 6 to 67 mg/L with an average value of 18 mg/L. Chloride concentrations in the middle Yorktown-Eastover aquifer ranged from 6 to 1,400 mg/L with an average value of 83 mg/L. Chloride concentrations in the lower Yorktown-Eastover aquifer ranged from 8 to 6,200 mg/L with an average value of 633 mg/L. Chloride concentrations in each aquifer typically are less in the middle of the peninsula than along the coast. Chloride concentrations in the confined aquifers generally increase with depth; chloride concentrations are greater in the lower Yorktown-Eastover aquifer than in the middle and upper Yorktown-Eastover aquifers.

IS THERE SALTWATER INTRUSION INTO THE GROUND-WATER SYSTEM?

The presence of an elevated chloride concentration in a well does not indicate that saltwater intrusion has taken place. Chlo-

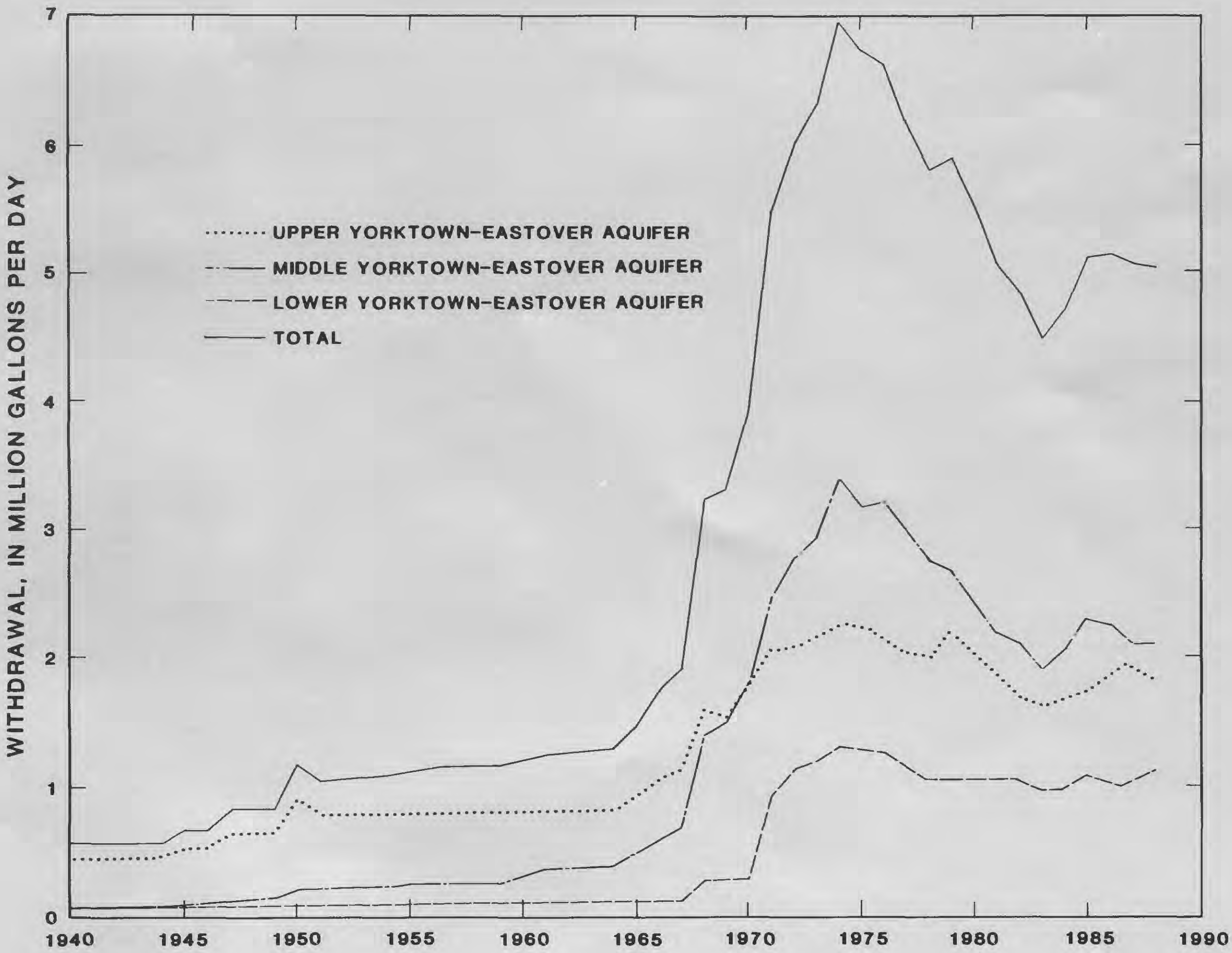

Figure 3.—Annual water withdrawal from confined aquifers underlying the Eastern Shore, 1940-88.

ride concentrations are naturally elevated near the boundary between freshwater and saltwater. Saltwater intrusion occurs when changes in the ground-water system cause salty water to replace fresh water in the aquifer sediments. Changes in the ground-water system that can result in saltwater intrusion are (1) a decrease in the amount of freshwater entering the system and (2) an increase in the amount of freshwater being removed from the system. Ground water flows slowly; therefore, saltwater intrusion takes place over long periods of time. In order to document saltwater intrusion in a well, chloride concentrations must be observed over time so that steady increases in chloride values can be seen. Currently (1993), the few wells on the Eastern Shore that have been observed over time show little or no increases in chloride concentrations. This represents a limited amount of data and only indicates an absence of saltwater intrusion at a few wells for a specific time period. Consequently, a peninsula-wide analysis of saltwater intrusion was not possible. Because of the lack of data to observe changes in chloride concentrations over time, it is possible that undocumented saltwater intrusion has taken place.

ANALYSES OF THE GROUND-WATER-FLOW SYSTEM

Results from analyses of the ground-water-flow system of the Eastern Shore indicate that increased ground-water withdrawal will continue to lower water levels throughout the confined aquifers. Any increase in ground-water withdrawals lowers ground-water levels around the withdrawal location. Water from adjacent aquifers or confining units flows toward the withdrawal location to replace the water removed. Numerous users withdrawing water from the same location results in combined water-level declines.

Investigations indicate that the water being withdrawn from wells in the confined aquifers results in an increase in the amount of water coming from the unconfined aquifer, and a decrease in the amount of water discharging from the confined-aquifer system. A reduction in the amount of freshwater that discharges from the confined-aquifer system to the Chesapeake Bay and Atlantic Ocean changes the equilibrium between the freshwater and the surrounding saltwater. The saltwater begins to move inland as it replaces the freshwater that was removed by pumping. A reduction in freshwater discharge from the confined-aquifer system also could affect salinity levels in near-shore inlets, bays, and estuaries.

Several potential pathways exist for intrusion of saltwater into the freshwater confined aquifers of the Eastern Shore. Saltwater intrusion can occur through lateral movement of saltwater within an aquifer and through upward or downward leakage of saltwater from adjacent aquifers or surface-water sources. Analyses indicate that water-level declines near the boundary between saltwater and freshwater have the most dramatic effect on the rate of lateral saltwater intrusion. Large water-level declines in the center of the peninsula have a minimal effect on the rate of movement of the saltwater; however, small water-level declines in coastal areas adjacent to the saltwater position can result in a noticeable increase in the rate of saltwater intrusion. Downward vertical leakage of saltwater from salty-surface sources into the freshwater parts of the uppermost confined aquifer occurs when freshwater withdrawals in coastal areas cause water levels to decline offshore. Upward leakage of saltwater from an underlying salty aquifer (also known as upconing) occurs when water levels in a freshwater aquifer decline below the water levels in an underlying salty aquifer.

MANAGEMENT OF THE GROUND-WATER RESOURCE

Ground water provides the sole freshwater supply for the Eastern Shore; therefore, the protection of the ground-water resource is of importance to managers and residents of the region. This study indicates water-level declines and saltwater intrusion are concerns that need to be considered by managers of the ground-water resource.

Water-level declines result from ground-water withdrawals. Water-level declines could necessitate lowering of pump intakes or the drilling of deeper wells. The amount of water-level decline that is acceptable to water managers depends on the location of the withdrawal, the hydrogeology of the area, and the needs of the community.

Saltwater intrusion also results from ground-water withdrawals. Lateral movement of saltwater is accelerated when withdrawals are near the boundary between freshwater and saltwater. Downward movement of saltwater from salty surface-water sources occurs when withdrawals along the coast cause offshore water-level declines in the freshwater parts of the uppermost confined aquifer. Saltwater intrusion can also occur when water-level declines in the lowermost freshwater aquifer cause upward movement of water from the underlying aquifer that contains salty water. Saltwater intrusion could be minimized by locating withdrawals in the center of the peninsula rather than along the coast and by placing the largest withdrawals in the upper and middle Yorktown-Eastover aquifers, and in the upper part of the lower Yorktown-Eastover aquifer.

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