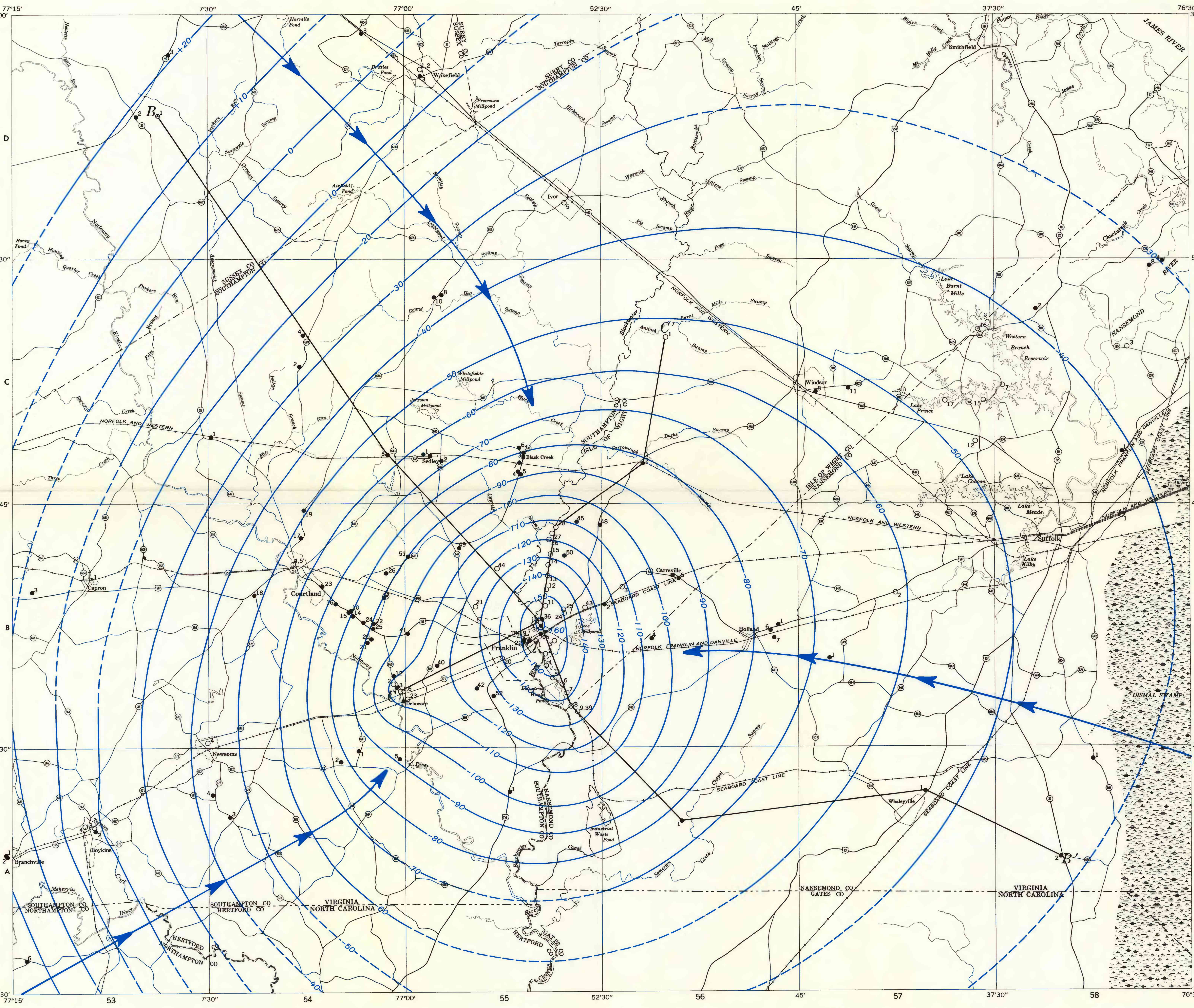
PREPARED IN COOPERATION WITH THE
VIRGINIA STATE WATER CONTROL BOARD
BUREAU OF WATER CONTROL MANAGEMENT



EXPLANATION

General direction of ground-water flow

—40— Potentiometric contour
Shows altitude of potentiometric surface. Dashed where approximate; contour interval 10 feet; datum is mean sea level

•2 Domestic well and number

○27 Municipal, industrial, institutional or commercial well and number

⊕ Destroyed well

53A
Well-numbering system
The well-numbering system used by the U.S. Geological Survey in Virginia is based on the "Index to Topographic Maps of Virginia." The 7½-minute quadrangles are identified by numbers and letters starting in the southwest corner of the State. The quadrangles are numbered 1 through 60 from west to east beginning at longitude 83°45′ and are lettered A through Z (omitting letters I and O) from south to north, beginning at latitude 36°30′. These numbers and letters are shown in the left and bottom margins of the potentiometric map. Wells are numbered serially within each 7½-minute quadrangle. For example, well 55B is in quadrangle 55B and is the fourth well inventoried in that quadrangle

B————B′ Location of geologic section

MAP OF POTENTIOMETRIC SURFACE OF LOWER CRETACEOUS AQUIFER, DECEMBER 1971

LOWER CRETACEOUS AQUIFER

GEOLOGY

The Lower Cretaceous deposits (Potomac Group) are composed of interbedded clay, sandy clay, and sand. Plant remains and limonite are found throughout the Lower Cretaceous, and variegated clay is common. Individual sand and clay beds are commonly not more than 40 feet thick but may be as thick as 100 feet in places. The thick sand beds are the major water-bearing units in the Franklin area.

The sand is predominantly quartz, with lesser amounts of feldspar, and is commonly micaceous. The sand varies in texture from fine to coarse, with gravelly sand occurring locally. Interstitial silt and clay are generally present. Thin streaks of water-bearing sand are interbedded with thin streaks of clayey sand and clay. In places, more than half the total thickness of sediments of Early Cretaceous age is relatively clean water-bearing sand. Studies of formation samples indicate that sand constitutes about 50 percent of the Lower Cretaceous at the site of well 54B6 and about 35 percent at the site of well 55B28.

Lower Cretaceous deposits form a wedge that deepens and thickens from west to east (sections *A-A′* and *B-B′*). Along the western edge of the Franklin area, the top of the section ranges in altitude from just above sea level to about 100 feet below sea level, and the total thickness ranges from 200 to 300 feet (W. F. Lichtler, oral commun. May 1972). At well 53D1 (section *B-B′*), Lower Cretaceous deposits were found at an altitude of -127 feet and are 283 feet thick. Farther east, at well 55B10 near Franklin, the top of these sediments is at an altitude of -224 feet, and they are about 600 feet thick. Along the eastern edge of the area, the top of the Lower Cretaceous ranges from about 400 feet below sea level in the northeast corner to about 700 feet below sea level in the southeast corner. The thickness ranges from about 1,400 feet in the northeast to about 1,300 feet in the southeast. In the southeast corner, these beds were reached at 524 feet below sea level and are 1,294 feet thick in well 58A2.

Both the thickness and composition of individual beds vary considerably over short distances. The absence of reliable horizon markers makes it difficult to correlate beds between wells. The reason for the poor lateral continuity of these beds lies in their origin, which has been attributed by Cederstrom (1945, p. 21–25) to deltaic deposition. Sand was deposited in stream channels, while silt and clay were deposited as natural levees and flood plains and in interchannel marshes, lakes, and bays. Thus, most of the sand beds are lenses, no more than a few miles long, that grade laterally into fine-grained sediments.

Electric logs, measuring natural electrical potentials (spontaneous potential) and resistance (resistivity) were useful in determining relative clay content and relative porosity of sediments. Natural gamma-ray logs record the natural gamma radiation emitted by the sediments. Higher gamma-ray counts in the Franklin area generally indicate a higher relative content of clay. However, glauconitic or phosphatic sand also gives high gamma-ray counts. The correlation diagram shows the correlation of a gamma-ray log, an electric log, and a time-drilling log of well 54B6 near Franklin. The time-drilling log is a graphic representation of the rate of penetration of the drill. Drilling was rapid in sands and slower in the more clayey sediments. The thick sand section from 555 to 610 feet penetrated by this well illustrates how these logs can be used jointly to determine lithology. The logs show a low gamma-ray count, negative spontaneous potential, high resistivity, and rapid rate of penetration. The sandy clay immediately below, from 610 to 615 feet, reacts in an opposite manner, with a high gamma-ray count, positive spontaneous potential, low resistivity, and slower drilling rate.

SOURCE OF GROUND WATER

Precipitation is the source of all fresh ground water in the Coastal Plain. A part of the precipitation that soaks into the ground recharges the aquifers. A small amount of the recharge to the Lower Cretaceous aquifer occurs directly on the outcrops along the Fall Line. But, as these outcrops are scarce, most of the recharge is by downward percolation from shallower ground-water bodies that overlie the Lower Cretaceous aquifer. Water seeping downward over the entire Coastal Plain into the Lower Cretaceous represents a significant source of recharge. Upward water movement through the weathered and fractured zone of the basement rocks underlying the Lower Cretaceous aquifer may contribute a small amount of recharge.

MOVEMENT OF GROUND WATER

The prehistoric potentiometric surface of the Lower Cretaceous aquifer throughout the Coastal Plain had a gradient from the Fall Line eastward to the sea. Before ground-water was withdrawn, water moved downgradient (eastward) to a point where the static head in the aquifer became higher than the head in the overlying beds. From this point eastward, water also moved upward through the semipermeable confining beds into the overlying aquifers. The average recharge in and near the Fall Line was balanced by this natural discharge into the upper aquifers, a process called dynamic equilibrium by Hantush (1955, p. 45) in his work in the Roswell Basin, N. Mex.

When pumping began from Lower Cretaceous sand beds, the dynamic equilibrium was disturbed and in the Franklin area, the head was lowered so that it became lower than that in the upper aquifers. The upward movement of water from the Lower Cretaceous beds ceased, and water began moving downward from the upper aquifers to recharge the underlying Lower Cretaceous aquifer. This downward movement of water through the semipermeable confining layers is a major source of recharge.

The lateral movement of ground water is now (1972) toward Franklin from all directions, as shown by the arrows on the potentiometric map. The gradient of the 1971 potentiometric surface is gentle east of Franklin and steep west of Franklin. This difference is caused mainly by an eastward increase in transmissivity. As discussed previously and as shown on the diagrammatic section *A-A′*, the Lower Cretaceous thickens appreciably eastward. Transmissivity probably increases in approximate proportion to this increase in thickness to a point a few miles east of Franklin and remains fairly constant from there to the eastern edge of the area.

The great lateral variation in the character of the Lower Cretaceous sediments restricts application of a single determined value of transmissivity to a small area. In addition, all the methods used to determine transmissivity assume that certain physical conditions are satisfied by the aquifer and the wells penetrating it. As none of these conditions can be wholly satisfied, any determined value of transmissivity is approximate.

The authors have determined transmissivity by several methods. The circumference method developed by D. O. Gregg (oral commun., June 1972) was used to compute a transmissivity value from the spacing of the contours on the potentiometric map. The value computed by this method for the area between the -50-foot and -70-foot contours around Franklin is about 19,000 ft^3/day/ft (cubic feet per day per foot) or 140,000 gpd/ft (gallons per day per foot) and is probably a good average value for the area around Franklin. A series of estimates of transmissivity were calculated using the slope of the 1971 potentiometric surface. The lowest of these estimates is 6,000 ft^3/day/ft (45,000 gpd/ft) between Branchville and Boykins in the southwest corner of the map area. Next greater is 15,000 ft^3/day/ft (110,000 gpd/ft) at a point 10 miles west of Franklin. The highest estimate calculated by this method is 24,000 ft^3/day/ft (180,000 gpd/ft) for the area beginning about 4 miles east of Franklin to the eastern boundary of the area. This estimate agrees well with Geraghty and Miller's (1967) values for the Norfolk city well field in Nansemond County. The authors conclude that several miles east of Franklin the value of transmissivity for the Lower Cretaceous aquifer reaches a maximum and remains relatively constant to the eastern boundary of the area.

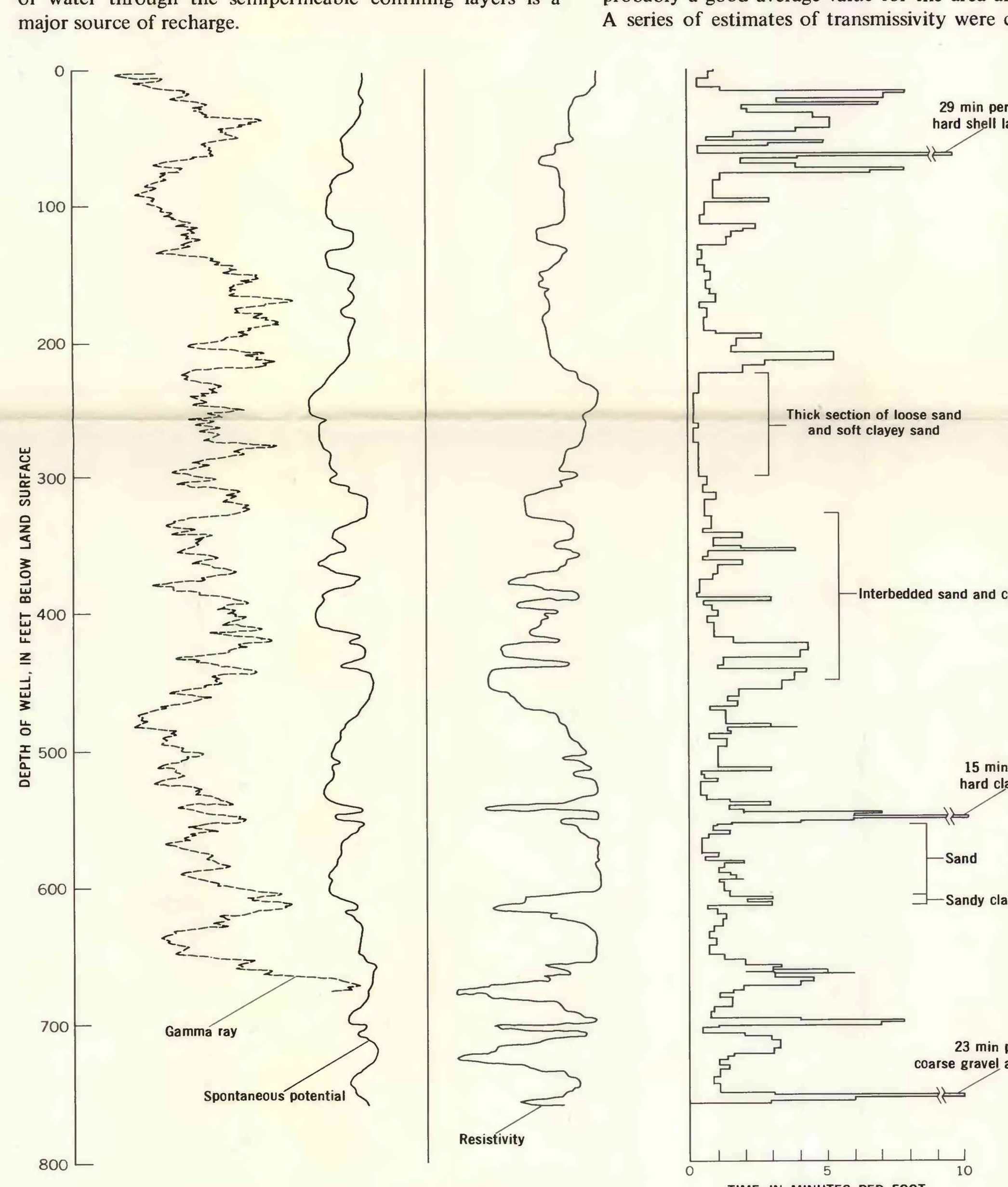
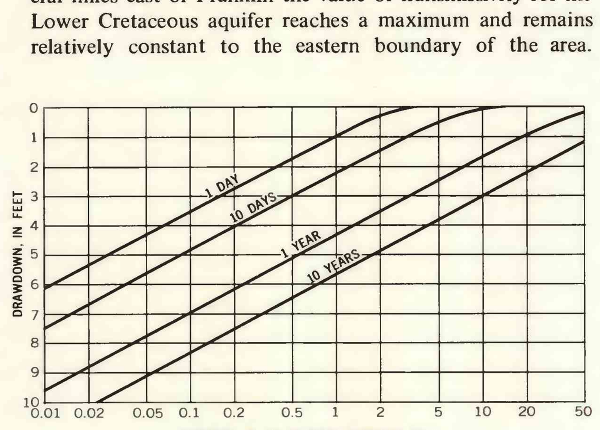


DIAGRAM SHOWING CORRELATION OF GAMMA-RAY, SPONTANEOUS POTENTIAL, RESISTIVITY, AND TIME-DRILLING LOGS, WELL 54B6



THEORETICAL DISTANCE-DRAWDOWN GRAPH FOR THE FRANKLIN AREA, SHOWING DECLINE CAUSED BY A WELL PUMPING 700 GPM (1 MGD). TRANSMISSIVITY 19,000 FT^3/DAY/FT (140,000 GPD/FT); COEFFICIENT OF STORAGE 0.0003

DISCHARGE OF GROUND WATER

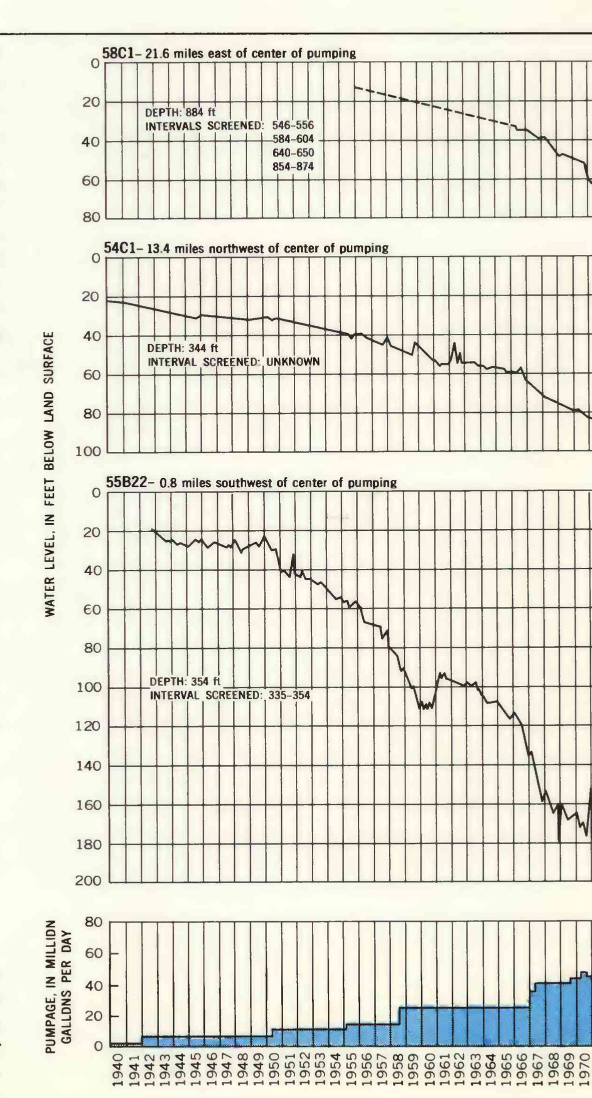
Development of water from the Lower Cretaceous aquifer began in the late 1800's. The artesian head was sufficient to allow many homes, farms, and industries to have flowing wells. The hydraulic ram was commonplace. The city of Franklin, which for many years depended on the Blackwater River for its water supply, switched to ground water about 1927. Flowing wells continued to be popular, but, as more and more water was withdrawn from the Lower Cretaceous for industrial and municipal supplies, the artesian head in the aquifer declined, and so did the number of flowing wells. By the late 1940's, nearly all wells tapping the Lower Cretaceous aquifer had ceased flowing.

Originally, water from the Lower Cretaceous aquifer discharged upward through the overlying confining beds; now water moves downward through these confining beds and recharges the aquifer. All discharge is now through wells. Large industrial and municipal water supplies are drawn from wells tapping the Lower Cretaceous. At the end of 1971, approximately 47 mgd (million gallons per day) of water was pumped from wells in the Lower Cretaceous aquifer in the Franklin study area. About 45 mgd was pumped from large-yield industrial and municipal wells within a 5-mile radius of the center of the city.

Water-level measurements made during 1937–39 by Cederstrom (1945) indicated that a small cone of depression had formed around Franklin. At the center of the cone, water levels were slightly lower than 20 feet above sea level.

The potentiometric map shows the configuration of the potentiometric surface in December 1971, at which time water levels at the center of the cone were 165 feet below sea level. The water-level decline map shows that declines of the potentiometric surface ranging from 30 feet to 170 feet have occurred in the Franklin area between 1937–39 and December 1971. In December 1971, water levels in the center of the cone had declined about 185 feet (180' contour not shown on map).

The graphs show the relation between pumpage at Franklin and water levels in three observation wells. The water level in well 55B22, owned by the city of Franklin, declined 159 feet from 1942 to 1971. At Sebrell, the water level in well 54C1 declined 63 feet from 1940 to 1971. The water level in well 58C1 declined 45 feet from 1956 through 1971.



GRAPHS SHOWING RELATION BETWEEN WATER LEVELS IN LOWER CRETACEOUS OBSERVATION WELLS AND PUMPAGE NEAR FRANKLIN

During 1971, withdrawals by the main industrial user at Franklin were reduced by 15 percent. This resulted in stabilized water levels at the center of the cone of depression, although levels in wells elsewhere continue to decline. If pumpage is not increased, outlying water levels will probably decline at decreasing rates, and the potentiometric surface may eventually reach equilibrium. Discharge through wells would be balanced by downward leakage from overlying aquifers and recharge from the Fall Line. If, however, the water level at the center of the cone declines below the top of the Lower Cretaceous aquifer, which is at an altitude of about -220 feet, dewatering of the aquifer will begin.

In most places in the Franklin area, wells in a single Lower Cretaceous sand may be expected to yield as much as 700 gpm (1 mgd). Many of the wells at Franklin, screened in several sand beds, yield 2,000 to 2,500 gpm (3.6 mgd). A theoretical distance-drawdown graph shows the decline in the potentiometric surface caused by a well pumping 700 gpm (1 mgd) continuously for specified periods of time, assuming a value of transmissivity for the aquifer of 19,000 ft^3/day/ft (140,000 gpd/ft) and a coefficient of storage of 0.0003. For example, after 10 years of pumping, drawdown 1 mile from the pumped well would be 5.6 feet. If pumping was 2 mgd instead of 1 mgd, the drawdown would be twice as great or 11.2 feet. The drawdown factor obtained from the graph would be modified by recharge due to leakage from overlying aquifers and by the regional decline in water levels. The curves are approximations of drawdown due only to the withdrawal of water from storage at the specified pumping rate.

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1974

GROUND-WATER CONDITIONS IN THE FRANKLIN AREA, SOUTHEASTERN VIRGINIA

By
G. Allan Brown and Oliver J. Cosner

1974