

# WATER RESOURCES DATA - VIRGINIA, 1999

## VOLUME 2. GROUND-WATER-LEVEL AND GROUND-WATER-QUALITY RECORDS

### INTRODUCTION

The Water Resources Division of the U.S. Geological Survey, in cooperation with State agencies, obtains a large amount of data pertaining to the water resources of Virginia each water year. These data, accumulated during many water years, constitute a valuable data base for developing an improved understanding of the water resources of the State. To make these data readily available to interested parties outside the Geological Survey, the data are published annually in this report series entitled "Water Resources Data - Virginia."

This series of annual reports for Virginia began with the 1961 water year with a report that contained only data relating to the quantities of surface water. For the 1964 water year, a similar report was introduced that contained only data relating to water quality. Beginning with the 1975 water year, the report format was changed to present, in one volume, data on quantities of surface water, quality of surface and ground water, and ground-water levels. Beginning with the 1990 water year, the quantity of data to be published made it necessary to present the data in two volumes; Volume 1 encompassed surface-water-discharge and surface-water-quality records and Volume 2 encompassed ground-water-level and ground-water-quality records.

This report is Volume 2 in our 1999 series and includes records of water levels and water quality of ground-water wells. It contains records for water levels at 279 observation wells and water quality at 120 wells. Locations of these wells are shown on figures 4, 5, 6, and 7. The data in this report represent that part of the National Water Data System collected by the U.S. Geological Survey and cooperating State and Federal agencies in Virginia.

Prior to introduction of this series and for several water years concurrent with it, water-resources data for Virginia were published in U.S. Geological Survey Water-Supply Papers. Data on water levels for the 1935 through 1974 water years were published under the title "Ground-Water Levels in the United States." These Water-Supply Papers may be consulted in the libraries of the principal cities of the United States and may be purchased from U.S. Geological Survey, Branch of Information Services, Federal Center, Bldg. 41, Box 25286, Denver, CO 80225.

Publications similar to this report are published annually by the Geological Survey for all States. These official Survey reports have an identification number consisting of the two-letter State abbreviation, the last two digits of the water year, and the volume number. For example, this volume is identified as "U.S. Geological Survey Water-Data Report VA-99-2." For archiving and general distribution, the reports for 1971-74 water years also are identified as water-data reports. These water-data reports are for sale in paper copy or in microfiche by the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

Additional information, including current prices, for ordering specific reports may be obtained from the District Office at the address given on the back of the title page or by telephone (804) 261-2600.

Water resources data, including those provided in water data reports, are available through the World Wide Web on the Internet. The Universal Resource Location (URL) to the Virginia District's home page is:

<http://va.usgs.gov>

### COOPERATION

The U.S. Geological Survey and agencies of the State of Virginia have had joint-funding agreements for the collection of water-resource records since 1930. Organizations that assisted in collecting the data in this report through joint-funding agreements with the Survey are:

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY, Dennis H. Treacy, executive director.

CITY OF NEWPORT NEWS, Brian Ramaley, director, Department of Public Utilities.

HAMPTON ROADS PLANNING DISTRICT COMMISSION, Arthur L. Collins, executive director.

Organizations that provided data are acknowledged in station descriptions.

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## RECORDS COLLECTED BY THE STATE OF VIRGINIA

In addition to data collected by the U.S. Geological Survey, there are included herein records for 177 index wells operated by the Virginia Department of Environmental Quality. These records are published as provided and are acknowledged in the "REMARKS" paragraph of each individual well. The Virginia Department of Environmental Quality is under the direction of Dennis H. Treacy, executive director. Published material for the ground-water wells is supplied through the Division of Water Program Coordination, Larry G. Lawson, P.E., director.

## SUMMARY OF HYDROLOGIC CONDITIONS

Eleven index wells open to water-table aquifers across Virginia were used to summarize the general response of ground-water levels to changes in precipitation and evapotranspiration during the 1999 water year. Two index wells open to confined aquifers of the Coastal Plain of Virginia were used to summarize typical changes in water levels caused by ground-water withdrawals. The locations of the index wells and other observation wells documented in this report are shown in figures 4, 5, and 6.

## Water-Table Wells

Average water levels in wells open to the water table show declines because of evapotranspiration during the growing season which begins in March or April in Virginia and generally lasts through September or October (fig. 1). October is the beginning of the water year when water levels begin to rise, if sufficient precipitation is forthcoming. The water levels will continue to rise through the autumn and winter months and recover to the levels of the previous spring, under normal conditions. Departures from this normal seasonal cycle can indicate more persistent trends such as droughts or extended periods of precipitation.

Water levels in all of the index water-table wells were within 1 or 2 ft of average levels at the beginning of October 1998, the beginning of the 1999 water year, with one exception; well 46W175 in Clarke County began the year about 4 ft above its average (fig. 1). Water levels in the two index wells in the southwestern part of the state, 14E40 in Buchanan County and 27F2 in Montgomery County, followed their normal seasonal averages, for-the-most-part, throughout the water year and ended the water year, at the end of September 1999, within 1 ft of their average.

Water levels in most of the other index wells, however, did not follow the normal seasonal cycle but declined below their normal averages in October, November, and December 1998. Most of the state experienced a severe drought during the 1999 water year. Water levels in all of the index water-table wells in the central and eastern parts of the state were below their average levels for much of the year. Water levels in wells 45N1 in Louisa County and 41Q1 in Rockingham County fell below their average levels at the beginning of the water year and remained below average for the rest of the water year, ending with levels far below average. Water levels in two other wells, 41H3 in Buckingham County and 52V2 in Fairfax County set new record lows for extended periods of the water year. The Buckingham County well ended the year with water levels 8 ft below normal and the Fairfax County well ended the year with water levels 7 ft below normal.

The drought persisted throughout much of the state until August when passing rainstorms recharged the water table in some eastern parts of the state. Wells 46W175 in Clark County and 55P9 in Westmoreland County began to rise in August 1999 and returned to normal levels in September at the end of the water year.

Torrential rains from hurricanes Dennis and then Floyd caused extensive and record floods in southeastern Virginia in September 1999. The only two index wells open to the water table in the southeast, 51G1 in Colonial Heights and 58B13 in Suffolk rose rapidly during the rains and ended the year about 3 and 4 ft, respectively, above their normal averages.

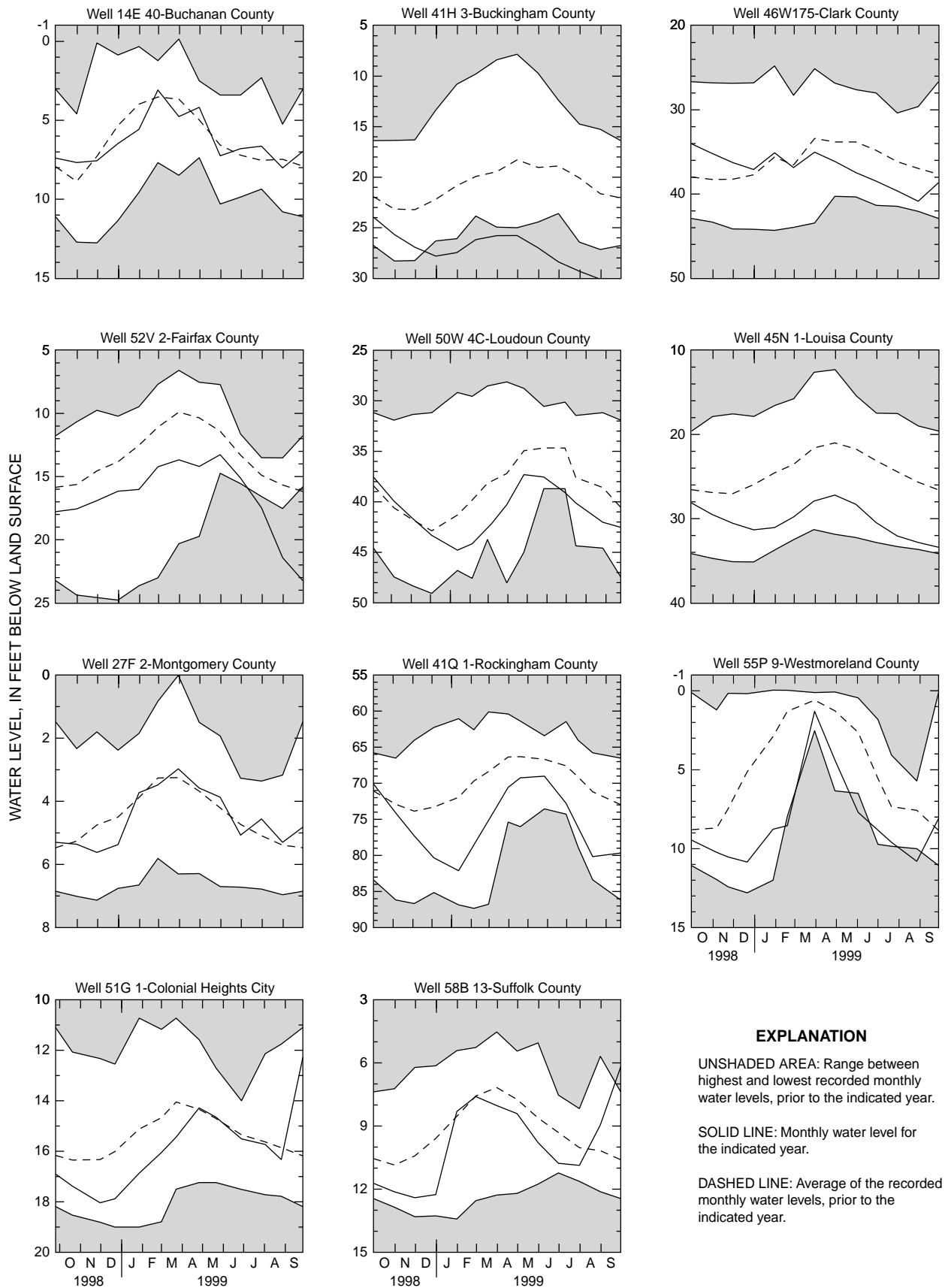


Figure 1. Monthly ground-water levels at index observation wells in water-table aquifers.

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## Confined-Coastal Plain Wells

The confined sand aquifers of the Coastal Plain of Virginia are separated by layers of silt and clay. The deep confined aquifers of the Coastal Plain supply water to industrial, municipal, agricultural, and domestic users throughout eastern Virginia and adjoining states. Water levels in most of the confined aquifers of the Coastal Plain of Virginia have declined throughout much of their period of record because of unrestricted flows and ground-water withdrawals by large-capacity pumps. Historic records from wells and from reports of the U.S. Geological Survey indicate that water levels in most of the aquifers of the Coastal Plain of Virginia were much higher during the early years of the 20th century than they are now. In fact, before ground-water withdrawals began, many wells open to the confined aquifers of the Coastal Plain flowed at land surface. Since then, however, water levels have dropped below land surface. Cones of depression around the major pumping centers have coalesced throughout much of Virginia and changes in pumping at any one location can have far-reaching effects.

Water levels in observation wells open to the deep confined aquifers of the Coastal Plain change in response to changing pumpage in and near large-capacity wells and well fields. The amplitude of the water-level response in an observation well is proportional to the proximity of the well to the change in pumpage and proportional to the hydraulic properties of the porous media between the observation well and the change in pumpage. Two index wells, 55B16 in Isle of Wight County and 56H27 in James City County show changes in water levels typical for the deep confined aquifers of the Coastal Plain of Virginia (fig. 2). Long-term records such as these can provide detailed information about the history of water use in Virginia and the impact of ground-water withdrawals on water levels.

Water levels in 55B16 in Isle of Wight County, near Franklin, Va. has incorporated a detailed history of the impact of pumping on the Middle Potomac aquifer for 4 decades. In 1962, shortly after the record for the well began in 1960, the water level in 55B16 rose to a maximum of about 100 ft below land surface (fig. 2). The water levels in 55B16 declined rapidly however throughout the remainder of the 1960's; interrupted only briefly near the end of each water year by a short recovery spike, presumably caused by brief reductions in pumping or possibly temporary shut downs. Overall water levels in 55B16 fell by more than 80 feet during the decade reaching about 185 ft below land surface in 1970.

Except for two very brief recovery spikes in the early 1970's, the water levels fluctuated around 180 ft below land surface from 1970 through 1976 and into 1977. In 1977 and 1978, the water levels in 56H27 fell about 5 to 10 ft reaching 190 ft below land surface for the first time. From 1978 through 1986, the water levels in 55B16 fluctuated between 180 and 195 ft below land surface, but overall the water levels show a steady trend. In 1987 and 1988, however, the water level in 55B16 fell steadily to about 205 ft below land surface, but then recovered to about 195 ft below land surface and held near there for the remainder of 1988, 1989, and into 1990. In 1990, the water level declined again falling 15 ft to 210 ft below land surface for the first time. The water levels in 56H27 remained near 210 ft below land surface from the end of the 1990 water year until 1992; when, the water level dipped to the record low of about 215 ft below land surface. From there, the water level recovered rapidly about 10 ft and from the middle of 1992 through 1998 and into 1999, the water level fluctuated between 195 and 205 ft below land surface, but overall showed another steady trend. However, in September 1999, at the very end of the water year, the water level in well 56H27 rose rapidly 30 ft to 170 ft below land surface; because, flooding from Hurricane Floyd had shut down the high-capacity wells pumping nearby.

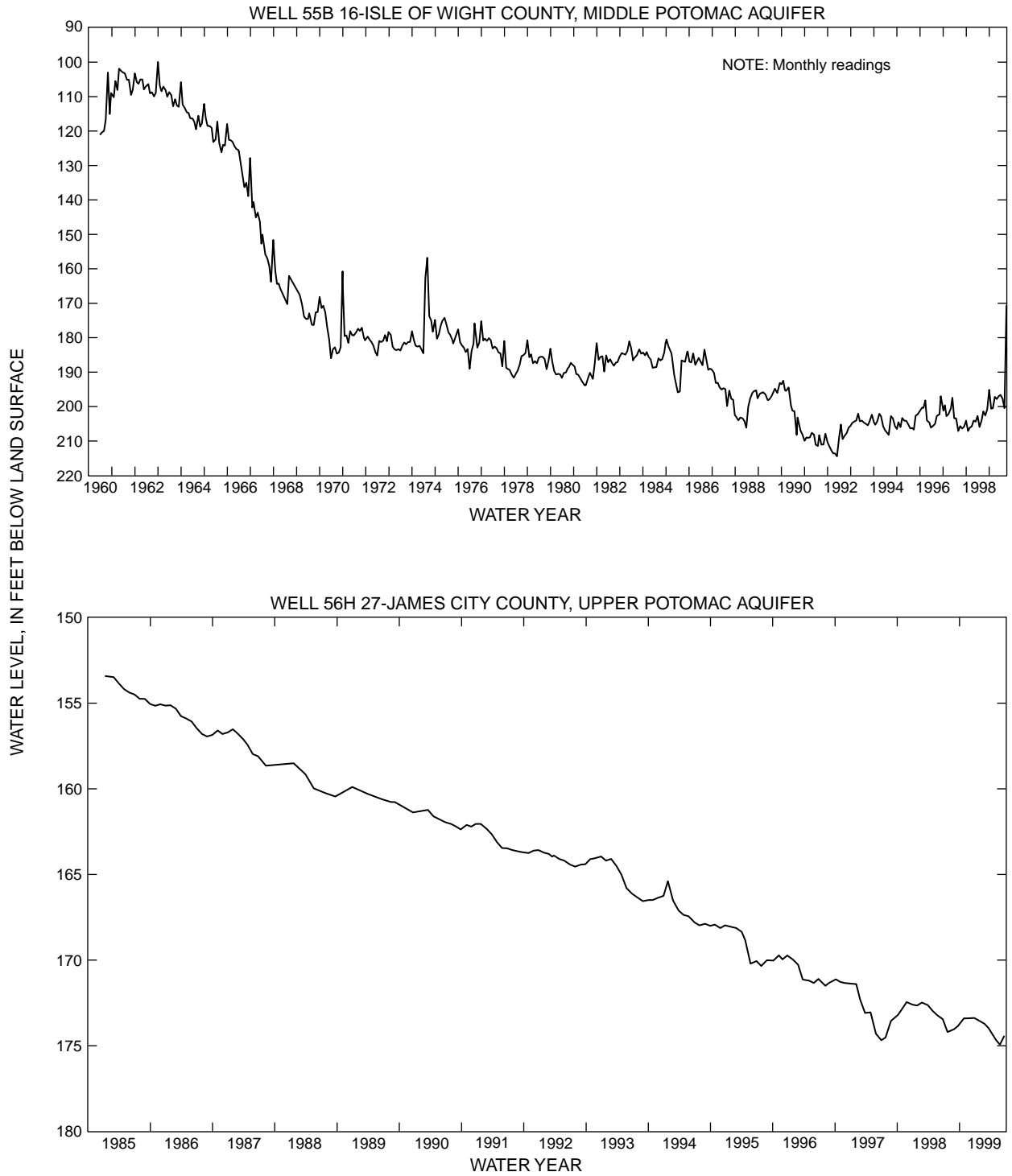
Water levels in index well 56H27 in northern James City County record 14 years of water level declines in the Upper Potomac aquifer (fig. 2). The decline was about 21 ft for the period of record; about 1.5 ft per year of uninterrupted and generally steady decline from 1985 to the end of the 1999 water year.

## EXPLANATION OF THE RECORDS

The ground-water records published in this report are for the 1999 water year that began October 1, 1998, and ended September 30, 1999. A calendar of the water year is provided on the inside of the front cover. The records contain ground-water-level and ground-water-quality data. The locations of the wells where the data were collected are shown in figures 4, 5, 6, and 7. The following sections of the introductory text are presented to provide users with a more detailed explanation of how the hydrologic data published in this report were collected, analyzed, computed, and arranged for presentation.

Station Identification Numbers

Each well in this report is assigned a unique identification number. This number is unique in that it applies specifically to a given well and to no other. The number usually is assigned when a well is first established and is retained for that well indefinitely. The system used by the U.S. Geological Survey to assign identification numbers for ground-water well sites is based on geographic location. The "latitude-longitude" system is used for wells.

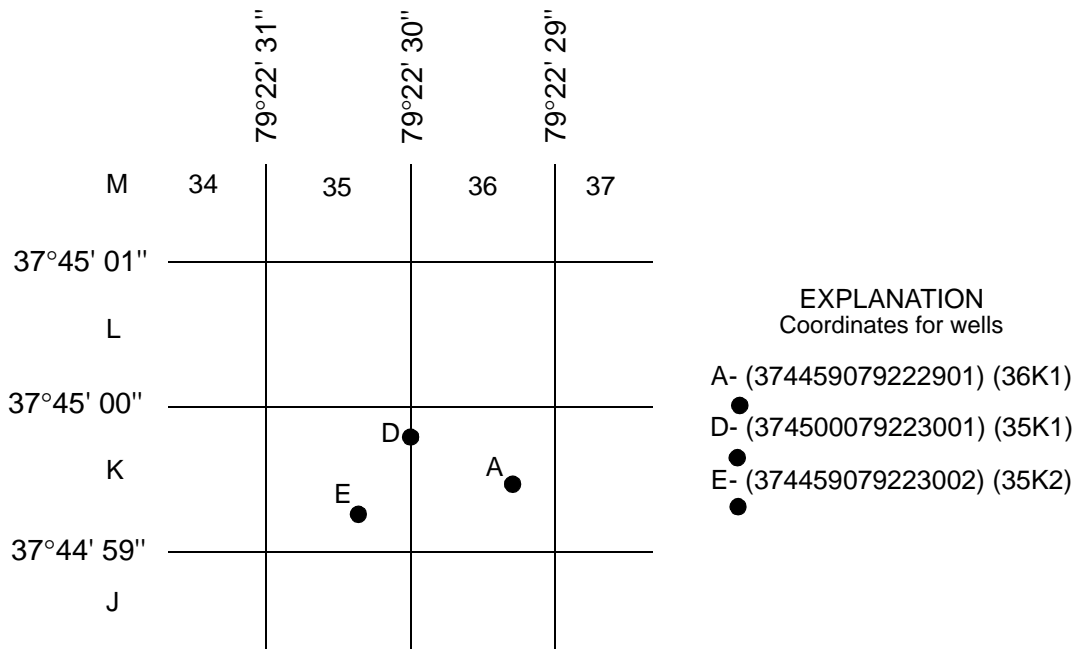


**Figure 2.** Ground-water levels in selected observation wells in confined Coastal Plain aquifers.

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## Latitude-Longitude System

The identification numbers for wells are assigned according to the grid system of latitude and longitude. The number consists of 15 digits. The first six digits denote the degrees, minutes, and seconds of latitude, the next seven digits denote degrees, minutes, and seconds of longitude, and the last two digits (assigned sequentially) identify the wells or other sites within a 1-second grid. This site-identification number, once assigned, is a pure number and has no locational significance. In the rare instance where the initial determination of latitude and longitude are found to be in error, the station will retain its initial identification number; however, its true latitude and longitude will be listed in the LOCATION paragraph of the station description.



**Figure 3.** System for numbering wells.

A second well-numbering system used in Virginia utilizes 7 1/2-minute quadrangles within the State. The quadrangles are numbered from west to east, and lettered from south to north, omitting the letters "I" and "O." The designation for each quadrangle is determined by the method "Read Right, Up." Wells are numbered serially within each quadrangle. This local well number is shown immediately after the primary well number.

Well records furnished by the State of Virginia also include the well number that is based on an indexing system used by the Virginia Department of Environmental Quality.

## Records of Ground-Water Levels

Only water-level data from a national network of observation wells are given in this report. These data are intended to provide a sampling and historical record of water-level changes in the Nation's most important aquifers. Locations of the observation wells in this network in Virginia are shown in figures 4, 5, 6, and 7.

### Data Collection and Computation

Measurements of water levels are made in many types of wells under varying conditions, but the methods of measurement are standardized to the extent possible. The equipment and measuring techniques used at each observation well ensure that measurements at each well are of consistent accuracy and reliability.

Tables of water-level data are presented by counties arranged in alphabetical order. The prime identification number for a given well is the 15-digit number that appears in the upper left corner of the table. The secondary identification number is the local well number, an alphanumeric number, derived from the township-range location of the well.

Water-level records are obtained from direct measurements with a steel tape or from the graph or punched tape of a water-stage recorder. The water-level measurements in this report are given in feet with reference to land-surface datum (lsd). Land-surface datum is a datum plane that is approximately at land surface at each well. If known, the elevation of the land-surface datum is given in the well description. The height of the measuring point (MP) above or below land-surface datum is given in each well description. Water levels in wells equipped with recording gages are reported for every fifth day and the end of each month (eom).

Water levels are reported to as many significant figures as can be justified by the local conditions. For example, in a measurement of a depth to water of several hundred feet, the error of determining the absolute value of the total depth to water may be a few tenths of a foot, whereas the error in determining the net change of water level between successive measurements may be only a hundredth or a few hundredths of a foot. For lesser depths to water, the accuracy is greater. Accordingly, most measurements are reported to a hundredth of a foot, but some are given to a tenth of a foot or a larger unit.

### Data Presentation

Each well record consists of three parts, the station description, the data table of water levels observed during the current water year, and a graph of the water levels for the current water year or other selected period. The description of the well is presented first through use of descriptive headings preceding the tabular data. The comments to follow clarify information presented under the various headings.

LOCATION.--This paragraph follows the well-identification number and reports the latitude and longitude (given in degrees, minutes, and seconds); a landline location designation; the hydrologic-unit number; the distance and direction from a geographic point of reference; and the owner's name.

AQUIFER.--This entry designates by name (if a name exists) and geologic age the aquifer(s) open to the well.

WELL CHARACTERISTICS.--This entry describes the well in terms of depth, diameter, casing depth and/or screened interval, method of construction, use, and additional information such as casing breaks, collapsed screen, and other changes since construction.

INSTRUMENTATION.--This paragraph provides information on both the frequency of measurement and the collection method used, allowing the user to better evaluate the reported water-level extremes by knowing whether they are based on weekly, monthly, or some other frequency of measurement.

DATUM.--This entry describes both the measuring point and the land-surface elevation at the well. The measuring point is described physically (such as top of collar, notch in top of casing, plug in pump base and so on), and in relation to land surface (such as 1.3 ft above land-surface datum). The elevation of the land-surface datum is described in feet above (or below) sea level; it is reported with a precision depending on the method of determination.

REMARKS.--This entry describes factors that may influence the water level in a well or the measurement of the water level. It should identify wells that also are water-quality observation wells, and may be used to acknowledge the assistance of local (non-Survey) observers.

PERIOD OF RECORD.--This entry indicates the period for which there are published records for the well. It reports the month and year of the start of publication of water-level records by the U.S. Geological Survey and the words "to current year" if the records are to be continued into the following year. Periods for which water-level records are available, but are not published by the Geological Survey, may be noted.

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EXTREMES FOR PERIOD OF RECORD.--This entry contains the highest and lowest water levels of the period of published record, with respect to land-surface datum, and the dates of their occurrence.

A table of water levels follows the station description for each well. Water levels are reported in feet below land-surface datum and all taped measurements of water level are listed. For wells equipped with recorders, only abbreviated tables are published; generally, only water-level lows are listed for every fifth day and at the end of the month (eom). The highest and lowest water levels of the water year and their dates of occurrence are shown on a line below the abbreviated table. Because all values are not published for wells with recorders, the extremes may be values that are not listed in the table. Missing records are indicated by dashes in place of the water level. A hydrograph for a selected period of record follows each water-level table.

### Records of Ground-Water Quality

Records of ground-water quality in this report differ from other types of records in that, for most sampling sites, they consist of only one set of measurements for the water year. The quality of ground water ordinarily changes only slowly; therefore, for most general purposes, one annual sampling, or only a few samples taken at infrequent intervals during the year, is sufficient. Frequent measurement of the same constituents is not necessary unless one is concerned with a particular problem, such as monitoring for trends in nitrate concentration. In the special cases where the quality of ground water may change more rapidly, more frequent measurements are made to identify the nature of the changes.

### Data Collection and Computation

The records of ground-water quality in this report were obtained mostly as a part of special studies in specific areas. Consequently, a number of chemical analyses are presented for some counties but none are presented for others. As a result, the records for this year, by themselves, do not provide a balanced view of ground-water quality Statewide. Such a view can be attained only by considering records for this year in context with similar records obtained for these and other counties in earlier years.

Most methods for collecting and analyzing water samples are described in the "U.S. Geological Survey Techniques of Water-Resources Investigations" publications referred to in the "On-site Measurements and Sample Collection" and the "Laboratory Measurements" sections in this data report. In addition, the TWRI book 1, Chapter D2, describes guidelines for the collection and field analysis of ground-water samples for selected unstable constituents. The values reported in this report represent water-quality conditions at the time of sampling as much as possible, consistent with available sampling techniques and methods of analysis. These methods are consistent with ASTM standards and generally follow ISO standards. All samples were obtained by trained personnel. The wells sampled were pumped long enough to assure that the water collected came directly from the aquifer and had not stood for a long time in the well casing where it would have been exposed to the atmosphere and to the material, possibly metal, comprising the casings.

### Data Presentation

The records of ground-water quality are published in a section titled QUALITY OF GROUND WATER immediately following the ground-water-level records. Data for quality of ground water are listed alphabetically by County and are identified by well number. The prime identification number for wells sampled is the 15-digit number derived from the latitude-longitude locations. No descriptive statements are given for ground-water-quality records; however, the well number, depth of well, date of sampling, and other pertinent data are given in the table containing the chemical analyses of the ground water.



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## Remark Codes

The following remark codes may appear with the ground-water-quality data in this report:

PRINTED OUTPUT	REMARK
E	Estimated value
>	Actual value is known to be greater than the value shown
<	Actual value is known to be less than the value shown
K	Results based on colony count outside the acceptance range (non-ideal colony count)
L	Biological organism count less than 0.5 percent (organism may be observed rather than counted)
D	Biological organism count equal to or greater than 15 percent (dominant)
V	Analyte was detected in both the environmental sample and the associated blanks.
&	Biological organism estimated as dominant

## Water Quality-Control Data

Data generated from quality-control (QC) samples are a requisite for evaluating the quality of the sampling and processing techniques as well as data from the actual samples themselves. Without QC data, environmental sample data cannot be adequately interpreted because the errors associated with the sample data are unknown. The various types of QC samples collected by this district are described in the following section. Procedures have been established for the storage of water-quality-control data within the USGS. These procedures allow for storage of all derived QC data and are identified so that they can be related to corresponding environmental samples.

## Blank Samples

Blank samples are collected and analyzed to ensure that environmental samples have not been contaminated by the overall data-collection process. The blank solution used to develop specific types of blank samples is a solution that is free of the analytes of interest. Any measured value signal in a blank sample for an analyte (a specific component measured in a chemical analysis) that was absent in the blank solution is believed to be due to contamination. There are many types of blank samples possible, each designed to segregate a different part of the overall data-collection process. The types of blank samples collected in this district are:

Field blank - a blank solution that is subjected to all aspects of sample collection, field processing preservation, transportation, and laboratory handling as an environmental sample.

Trip blank - a blank solution that is put in the same type of bottle used for an environmental sample and kept with the set of sample bottles before and after sample collection.

Equipment blank - a blank solution that is processed through all equipment used for collecting and processing an environmental sample (similar to a field blank but normally done in the more controlled conditions of the office).

Sampler blank - a blank solution that is poured or pumped through the same field sampler used for collecting an environmental sample.

Filter blank - a blank solution that is filtered in the same manner and through the same filter apparatus used for an environmental sample.

Splitter blank - a blank solution that is mixed and separated using a field splitter in the same manner and through the same apparatus used for an environmental sample.

Preservation blank - a blank solution that is treated with the sampler preservatives used for an environmental sample.

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## Reference Samples

Reference material is a solution or material prepared by a laboratory whose composition is certified for one or more properties so that it can be used to assess a measurement method. Samples of reference material are submitted for analysis to ensure that an analytical method is accurate for the known properties of the reference material. Generally, the selected reference material properties are similar to the environmental sample properties.

## Replicate Samples

Replicate samples are a set of environmental samples collected in a manner such that the samples are thought to be essentially identical in composition. Replicate is the general case for which a duplicate is the special case consisting of two samples. Replicate samples are collected and analyzed to establish the amount of variability in the data contributed by some part of the collection and analytical process. There are many types of replicate samples possible, each of which may yield slightly different results in a dynamic hydrologic setting, such as a flowing stream. The types of replicate samples collected in this district are:

Sequential samples - a type of replicate sample in which the samples are collected one after the other, typically over a short time.

Split sample - a type of replicate sample in which a sample is split into subsamples contemporaneous in time and space.

## Spike Samples

Spike samples are samples to which known quantities of a solution with one or more well-established analyte concentrations have been added. These samples are analyzed to determine the extent of matrix interference or degradation on the analyte concentration during sample processing and analysis.

## ACCESS TO USGS WATER DATA

The USGS provides near real-time stage and discharge data for many of the gaging stations equipped with the necessary telemetry and historic daily-mean and peak-flow discharge data for most current or discontinued gaging stations through the world wide web (WWW). These data may be accessed at:

<http://va.water.usgs.gov>

Some water-quality and ground-water data also are available through the WWW. In addition, data can be provided in various machine-readable formats on magnetic tape or 3-1/2 inch floppy disk. Information about the availability of specific types of data or products, and user charges, can be obtained locally from each of the Water Resources Division District Offices (See address on the back of the title page.)

## DEFINITION OF TERMS

Terms related to water quality and other hydrologic data, as used in this report, are defined below. See also table for converting English units to International System (SI) Units on the inside of the back cover.

*Acid neutralizing capacity* (ANC) is the equivalent sum of all bases or base-producing materials, solutes plus particulates, in an aqueous system that can be titrated with acid to an equivalence point.

*Acre-foot* (AC-FT, acre-ft) is the quantity of water required to cover 1 acre to a depth of 1 foot and is equivalent to 43,560 cubic feet or about 326,000 gallons or 1,233 cubic meters.

*Adenosine triphosphate* (ATP) is an organic, phosphate-rich, compound important in the transfer of energy in organisms. Its central role in living cells makes it an excellent indicator of the presence of living material in water. A measurement of ATP therefore provides a sensitive and rapid estimate of biomass. ATP is reported in micrograms per liter of the original water sample.

*Algae* are mostly aquatic single-celled, colonial, or multi-celled plants, containing chlorophyll and lacking roots, stems, and leaves.

*Algal growth potential* (AGP) is the maximum algal dry weight biomass that can be produced in a natural water sample under standardized laboratory conditions. The growth potential is the algal biomass present at stationary phase and is expressed as milligrams dry weight of algae produced per liter of sample.

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*Alkalinity* is the capacity of solutes in an aqueous system to neutralize acid.

*Bacteria* are microscopic unicellular organisms, typically spherical, rodlike, or spiral and threadlike in shape, often clumped into colonies. Some bacteria cause disease, while others perform an essential role in nature in the recycling of materials; for example, by decomposing organic matter into a form available for reuse by plants.

*Total coliform bacteria* are a particular group of bacteria that are used as indicators of possible sewage pollution. This group includes coliforms that inhabit the intestine of warm-blooded animals and those that inhabit soils. They are characterized as aerobic or facultative anaerobic, gram-negative, nonspore-forming, rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35-C. In the laboratory these bacteria are defined as all the organisms that produce colonies with a golden-green metallic sheen within 24 hours when incubated at 35-C plus or minus 1.0-C on M-Endo medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

*Fecal coliform bacteria* are bacteria that are present in the intestine or feces of warm-blooded animals. They are often used as indicators of the sanitary quality of the water. In the laboratory they are defined as all organisms that produce blue colonies within 24 hours when incubated at 44.5-C plus or minus 0.2-C on M-FC medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

*Fecal streptococcal bacteria* are bacteria found also in the intestine of warm-blooded animals. Their presence in water is considered to verify fecal pollution. They are characterized as Gram-positive, cocci bacteria which are capable of growth in brain-heart infusion broth. In the laboratory they are defined as all the organisms which produce red or pink colonies within 48 hours at 35-C plus or minus 1.0-C on KF-streptococcus medium (nutrient medium for bacterial growth). Their concentrations are expressed as number of colonies per 100 mL of sample.

*Enterococcus bacteria* are commonly found in the feces of humans and other warm-blooded animals. Although some strains are ubiquitous and not related to fecal pollution, the presence of enterococci in water is an indication of fecal pollution and the possible presence of enteric pathogens. Enterococcus bacteria are those bacteria which produce pink to red colonies with black or reddish-brown precipitate after incubation at 41-C on mE agar and subsequent transfer to EIA medium. Enterococci include *Streptococcus faecalis*, *Streptococcus faecium*, *Streptococcus avium*, and their variants.

*Bedload* is the sediment which moves along in essentially continuous contact with the streambed by rolling, sliding, and making brief excursions into the flow a few diameters above the bed.

*Bed material* is the sediment mixture of which a streambed, lake, pond, reservoir, or estuary bottom is composed.

*Benthic invertebrates* are invertebrate animals inhabiting the bottoms of lakes, streams, and other water bodies. They are useful as indicators of water quality.

*Biochemical oxygen demand (BOD)* is a measure of the quantity of dissolved oxygen, in milligrams per liter, necessary for the decomposition of organic matter by micro-organisms, such as bacteria.

*Biomass* is the amount of living matter present at any given time, expressed as the mass per unit area or volume of habitat.

*Ash mass* is the mass or amount of residue present after the residue from the dry mass determination has been ashed in a muffle furnace at a temperature of 500-C for 1 hour. The ash mass values of zooplankton and phytoplankton are expressed in grams per cubic meter (g/m<sup>3</sup>), and periphyton and benthic organisms in grams per square mile (g/m<sup>2</sup>).

*Dry mass* refers to the mass of residue present after drying in an oven at 105-C for zooplankton and periphyton, until the mass remains unchanged. This mass represents the total organic matter, ash and sediment, in the sample. Dry-mass values are expressed in the same units as ash mass.

*Organic mass* or volatile mass of the living substance is the difference between the dry mass and ash mass and represents the actual mass of the living matter. The organic mass is expressed in the same units as for ash mass and dry mass.

*Wet mass* is the mass of living matter plus contained water.

*Bottom material:* See Bed material.

*Cells/volume* refers to the number of cells of any organism which is counted by using a microscope and grid or counting cell. Many planktonic organisms are multicelled and are counted according to the number of contained cells per sample, usually milliliters (mL) or liters (L).

*Cfs-day* is the volume of water represented by a flow of 1 cubic foot per second for 24 hours. It is equivalent to 86,400 cubic feet, approximately 1.9835 acre-feet, about 646,000 gallons, or 2,447 cubic meters.

*Chemical oxygen demand (COD)* is a measure of the chemically oxidizable material in the water and furnishes an approximation of the amount of organic and reducing material present. The determined value may correlate with BOD or with carbonaceous organic pollution from sewage or industrial wastes.

*Chlorophyll* refers to the green pigments of plants. Chlorophyll a and b are the two most common green pigments in plants.

*Color unit* is produced by one milligram per liter of platinum in the form of the chloroplatinate ion. Color is expressed in units of the platinum-cobalt scale.

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*Contents* is the volume of water in a reservoir or lake. Unless otherwise indicated, volume is computed on the basis of a level pool and does not include bank storage.

*Continuing-record station* is a specified site which meets one or all conditions listed:

1. When chemical samples are collected daily or monthly for 10 or more months during the water year.
2. When water temperature records include observations taken one or more times daily.
3. When sediment discharge records include periods for which sediment loads are computed and are considered to be representative of the runoff for the water year.

*Control* designates a feature downstream from the gage that determines the stage-discharge relation at the gage. This feature may be a natural constriction of the channel, an artificial structure, or a uniform cross section over a long reach of the channel.

*Cubic foot per second* (FT<sup>3</sup>/S, ft<sup>3</sup>/s) is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute.

*Discharge* is the volume of water (or more broadly, volume of fluid plus suspended sediment), that passes a given point within a given period of time.

*Mean discharge* (MEAN) is the arithmetic mean of individual daily mean discharges during a specific period.

*Instantaneous discharge* is the discharge at a particular instant of time.

*Annual 7-day minimum* is the lowest mean discharge for 7 consecutive days for a calendar year or a water year. Note that most low-flow frequency analyses of annual 7-day minimum flows use a climatic year (April 1-March 31). The date shown in the summary statistics table is the initial date of the 7-day period. (This value should not be confused with the 7-day 10-year low-flow statistic.)

*Dissolved* refers to that material in a representative water sample which passes through a 0.45 um membrane filter. This is a convenient operational definition used by Federal agencies that collect water data. Determinations of "dissolved" constituents are made on subsamples of the filtrate.

*Dissolved-solids concentration* of water is determined either analytically by the "residue-on-evaporation" method, or mathematically by totaling the concentrations of individual constituents reported in a comprehensive chemical analysis. During the analytical determination of dissolved solids, the bicarbonate (generally a major dissolved component of water) is converted to carbonate. Therefore, in the mathematical calculation of dissolved-solids concentration, the bicarbonate value, in milligrams per liter, is multiplied by 0.492 to reflect the change.

*Drainage area* of a stream at a specific location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream above the specified point. Figures of drainage area given herein include all closed basins, or noncontributing areas, within the area unless otherwise specified.

*Drainage basin* is a part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

*Extractable organic halides* (EOX) are organic compounds which contain halogen atoms such as chlorine. These organic compounds are semi-volatile and extractable by ethyl acetate from air-dried stream bottom sediments. The ethyl acetate extract is combusted, and the concentration is determined by microcoulometric determination of the halides formed. The concentration is reported as micrograms of chlorine per gram of the dry weight of the stream bottom sediments.

*Hardness* of water is a physical-chemical characteristic that is commonly recognized by the increased quantity of soap required to produce lather. It is computed as the sum of equivalents of polyvalent cations and is expressed as the equivalent concentration of calcium carbonate (CaCO<sub>3</sub>).

*High tide* is the maximum height reached by each rising tide.

*Hydrologic Benchmark Network* is a network of 50 sites in small drainage basins around the country whose purpose is to provide consistent data on the hydrology, including water quality, and related factors in representative undeveloped watersheds nationwide, and to provide analyses on a continuing basis to compare and contrast conditions observed in basins more obviously affected by human activities.

*Hydrologic unit* is a geographic area representing part or all of a surface drainage basin or distinct hydrologic feature as delineated by the Office of Water Data Coordination on the State Hydrologic Unit Maps; each hydrologic unit is identified by an 8-digit number.

*Low tide* is the minimum height reached by each falling tide.

*Mean high tide* is the average of all high tides over a specified period.

*Mean low tide* is the average of all low tides over a specified period.

*Mean water level* is the average of all tides over a specified period.

*Membrane filter* is a thin microporous material of specific pore size used to filter bacteria, algae, and other very small particles from water.

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*Metamorphic stage* refers to the stage of development that an organism exhibits during its transformation from an immature form to an adult form. This developmental process exists for most insects, and the degree of difference from the immature stage to the adult form varies from relatively slight to pronounced, with many intermediates. Examples of metamorphic stages of insects are egg-larva-adult or egg-nymph-adult.

*Methylene blue active substances* (MBAS) are apparent detergents. The determination depends on the formation of a blue color when methylene blue dye reacts with synthetic anionic detergent compounds.

*Micrograms per gram* (mg/g) is a unit expressing the concentration of a chemical constituent as the mass (micrograms) of the element per unit mass (gram) of material analyzed.

*Micrograms per liter* (UG/L, mg/L) is a unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter.

*Microsiemens per centimeter* ( $\mu\text{S}/\text{cm}$ , US/CM) is a unit expressing the amount of electrical conductivity of a solution as measured between opposite faces of a centimeter cube of solution at a specified temperature. Siemens is the International System of units nomenclature. It is synonymous with mhos and is the reciprocal of resistance in ohms.

*Milligrams per liter* (MG/L, mg/L) is a unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represents the mass of solute per unit volume (liter) of water. Concentration of suspended sediment also is expressed in mg/L and is based on the mass of dry sediment per liter of water-sediment mixture.

*Most probable number* (MPN) is an index of the number of coliform bacteria that, more probably than any other number, would give the results shown by the laboratory examination; it is not an actual enumeration. It is determined from the distribution of gas-positive cultures among multiple inoculated tubes.

*Multiple-plate samplers* are artificial substrates of known surface area used for obtaining benthic-invertebrate samples. They consist of a series of spaced, hardboard plates on an eyebolt.

*National Geodetic Vertical Datum of 1929* (NGVD of 1929) is a geodetic datum derived from a general adjustment of the first order level nets of both the United States and Canada. It was formerly called "Sea Level Datum of 1929" or "mean sea level" in this series of reports. Although the datum was derived from the average sea level over a period of many years at 26 tide stations along the Atlantic, Gulf of Mexico, and Pacific Coasts, it does not necessarily represent local mean sea level at any particular place.

*National Stream-Quality Accounting Network* (NASQAN) monitors the water quality of large rivers within four of the Nation's largest river basins--the Mississippi, Columbia, Colorado, and Rio Grande. The network consists of 39 stations. Samples are collected with sufficient frequency that the flux of a wide range of constituents can be estimated. The objective of NASQAN is to characterize the water quality of these large rivers by measuring concentration and mass transport of a wide range of dissolved and suspended constituents, including nutrients, major ions, dissolved and sediment-bound heavy metals, common pesticides, and inorganic and organic forms of carbon. This information will be used (1) to describe the long-term trends and changes in concentration and transport of these constituents; (2) to test findings of the National Water-Quality Assessment Program (NAWQA); (3) to characterize processes unique to large-river systems such as storage and re-mobilization of sediments and associated contaminants; and (4) to refine existing estimates of off-continent transport of water, sediment, and chemicals for assessing human effects on the world's oceans and for determining global cycles of carbon, nutrients, and other chemicals.

*The National Atmospheric Deposition Program/ National Trends Network* (NADP/NTN) provides continuous measurement and assessment of the chemical climate of precipitation throughout the United States. As the lead federal agency, the USGS works together with over 100 organizations to accomplish the following objectives; (1) Provide a long-term, spatial and temporal record of atmospheric deposition generated from a network of 191 precipitation chemistry monitoring sites. (2) Provide the mechanism to evaluate the effectiveness of the significant reduction in SO<sub>2</sub> emissions that began in 1995 as implementation of the Clean Air Act Amendments (CAAA) occurred. (3) Provide the scientific basis and nationwide evaluation mechanism for implementation of the Phase II CAAA emission reductions for SO<sub>2</sub> and NO<sub>x</sub> scheduled to begin in 2000.

*The National Water-Quality Assessment* (NAWQA) Program of the U.S. Geological Survey is a long-term program with goals to describe the status and trends of water-quality conditions for a large, representative part of the Nation's ground- and surface-water resources; provide an improved understanding of the primary natural and human factors affecting these observed conditions and trends; and provide information that supports development and evaluation of management, regulatory, and monitoring decisions by other agencies.

*Organism* is any living entity.

*Organism count/area* refers to the number of organisms collected and enumerated in a sample and adjusted to the number per area habitat, usually square meter (m<sup>2</sup>), acre, or hectare. Periphyton, benthic organisms, and macrophytes are expressed in these terms.

*Organism count/volume* refers to the number of organisms collected and enumerated in a sample and adjusted to the number per sample volume, usually milliliter (mL) or liter (L). Numbers of planktonic organisms can be expressed in these terms.

*Total organism count* is the total number of organisms collected and enumerated in any particular sample.

*Parameter Code* is a 5-digit number used in the U.S. Geological Survey computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent. The codes used in NWIS are the same as those used in the U.S. Environmental Protection Agency data system, STORET. The Environmental Protection Agency assigns and approves all requests for new codes.

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*Partial-record station* is a particular site where limited streamflow and/or water-quality data are collected systematically over a period of years for use in hydrologic analyses.

*Particle size* is the diameter, in millimeters (mm), of a particle determined by either sieve or sedimentation methods. Sedimentation methods (pipet, bottom-withdrawal tube, visual-accumulation tube) determine fall diameter of particles in either distilled water (chemically dispersed) or in native water (the river water at the time and point of sampling).

*Particle-size classification* used in this report agrees with the recommendation made by the American Geophysical Union Subcommittee on Sediment Terminology. The classification is as follows:

Classification	Size (mm)	Method of analysis
Clay	0.00024 - 0.004	Sedimentation
Silt	.004 - .062	Sedimentation
Sand	.062 - 2.0	Sedimentation/sieve
Gravel	2.0 - 64.0	Sieve

The partial-size distributions given in this report are not necessarily representative of all particles in transport in the stream. Most of the organic matter is removed, and the sample is subjected to mechanical and chemical dispersion before analysis in distilled water. Chemical dispersion is not used for native-water analysis.

*Percent composition* is a unit for expressing the ratio of a particular part of a sample or population to the total sample or population, in terms of types, numbers, mass, or volume.

*Periphyton* is the assemblage of microorganisms attached to and living upon submerged solid surfaces. While primarily consisting of algae, they also include bacteria, fungi, protozoa, rotifers, and other small organisms.

*Pesticides* are chemical compounds used to control undesirable organisms. Major categories of pesticides include insecticides, miticides, fungicides, herbicides, and rodenticides.

*Picocurie (PC, pCi)* is one trillionth ( $1 \times 10^{-12}$ ) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields  $3.7 \times 10^{10}$  radioactive disintegrations per second. A picocurie yields 2.22 dpm (disintegrations per minute).

*Plankton* is the community of suspended, floating, or weakly swimming organisms that live in the open water of lakes and rivers.

*Phytoplankton* is the plant part of the plankton. They are usually microscopic and their movement is subject to the water currents. Phytoplankton growth is dependent upon solar radiation and nutrient substances. Because they are able to incorporate as well as release materials to the surrounding water, the phytoplankton have a profound effect upon the quality of the water. They are the primary food producers in the aquatic environment and are commonly known as algae.

*Blue-green algae* are a group of phytoplankton organisms having a blue pigment, in addition to the green pigment called chlorophyll. Blue-green algae often cause nuisance conditions in water.

*Diatoms* are the unicellular or colonial algae having a siliceous shell. Their concentrations are expressed as number of cells per milliliter (cells/mL) of sample.

*Green algae* have chlorophyll pigments similar in color to those of higher green plants. Some forms produce algae mats or floating "moss" in lakes. Their concentrations are expressed as number of cells per milliliter (cells/mL) of sample.

*Zooplankton* is the animal part of the plankton. Zooplankton are capable of extensive movements within the water column and are often large enough to be seen with the unaided eye. Zooplankton are secondary consumers feeding upon bacteria, phytoplankton, and detritus. Because they are the grazers in the aquatic environment, the zooplankton are a vital part of the aquatic food web. The zooplankton community is dominated by small crustaceans and rotifers.

*Polychlorinated biphenyls (PCB's)* are industrial chemicals that are mixtures of chlorinated biphenyl compounds having various percentages of chlorine. They are similar in structure to organochlorine insecticides.

*Primary productivity* is a measure of the rate at which new organic matter is formed and accumulated through photosynthetic and chemosynthetic activity of producer organisms (chiefly, green plants). The rate of primary production is estimated by measuring the amount of oxygen released (oxygen method) or the amount of carbon assimilated by the plants (carbon method).

*Milligrams of carbon per area or volume per unit time* [ $\text{mg C}/(\text{m}^2/\text{time})$ ] for periphyton and macrophytes and [ $\text{mg C}/(\text{m}^3/\text{time})$ ] for phytoplankton are units for expressing primary productivity. They define the amount of carbon dioxide consumed as measured by radioactive carbon (carbon 14). The carbon 14 method is of greater sensitivity than the oxygen light and dark bottle method and is preferred for use in unenriched waters. Unit time may be either the hour or day, depending on the incubation period.

*Milligrams of oxygen per area or volume per unit time* [ $\text{mg O}/(\text{m}^2/\text{time})$ ] for periphyton and macrophytes and [ $\text{mg O}/(\text{m}^3/\text{time})$ ] for phytoplankton are the units for expressing primary productivity. They define production and respiration rates as estimated from changes in the measured dissolved-oxygen concentration. The oxygen light and dark bottle method is preferred if the rate of primary production is sufficient for accurate measurements to be made within 24 hours. Unit time may be either the hour or day, depending on the incubation period.

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*Radiochemical program* is a network of regularly sampled water-quality stations where samples are collected to be analyzed for radioisotopes. The streams that are sampled represent major drainage basins in the conterminous United States.

*Recoverable from bottom material* is the amount of a given constituent that is in solution after a representative sample of bottom material has been digested by a method (usually using an acid or mixture of acids) that results in dissolution of readily soluble substances. Complete dissolution of all bottom material is not achieved by the digestion treatment and thus the determination represents less than the total amount (that is, less than 95 percent) of the constituent in the sample. To achieve comparability of analytical data, equivalent digestion procedures would be required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

*Return period* is the average time interval between occurrences of a hydrological event of a given or greater magnitude, usually expressed in years. May also be called recurrence interval.

*River mile* as used herein, is the distance above the mouth of Delaware Bay, measured along the center line of the navigation channel or the main stem of the Delaware River. River mile data were furnished by the Delaware River Basin Commission.

*Runoff in inches* (IN., in.) shows the depth to which the drainage area would be covered if all the runoff for a given time period were uniformly distributed on it.

*Sea level*: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

*Sediment* is solid material that originates mostly from disintegrated rocks and is transported by, suspended in, or deposited from water; it includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics, and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope, soil characteristics, land usage, and quantity and intensity of precipitation.

*Bed load* is the sediment that is transported in a stream by rolling, sliding, or skipping along the bed and very close to it. In this report, bed load is considered to consist of particles in transit within 0.25 ft of the streambed.

*Bed load discharge* (tons per day) is the quantity of bed load measured by dry weight that moves past a section as bed load in a given time.

*Suspended sediment* is the sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.

*Suspended-sediment concentration* is the velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.3 ft above the bed) expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L). The entire sample is used for the analysis.

*Mean concentration* is the time-weighted concentration of suspended sediment passing a stream section during a 24-hour day.

*Suspended-sediment discharge* (tons/day) is the rate at which dry mass of sediment passes a section of a stream or is the quantity of sediment, as measured by dry mass or volume, that passes a section in a given time. It is calculated in units of tons per day as follows: concentration (mg/L) x discharge (ft<sup>3</sup>/s) x 0.0027.

*Suspended-sediment load* is a general term that refers to material in suspension. It is not synonymous with either discharge or concentration.

*Suspended total residue* at 105 Deg. C concentration is the concentration of suspended sediment in the sampled zone expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L). A small aliquot of the sample is used for the analysis.

*Total sediment discharge* (tons/day) is the sum of the suspended-sediment discharge and the bed-load discharge. It is the total quantity of sediment, as measured by dry mass or volume, that passes a section during a given time.

*Total sediment load* or total load is a term which refers to the total sediment (bed load plus suspended-sediment load) that is in transport. It is not synonymous with total sediment discharge.

*Sodium-adsorption-ratio* (SAR) is the expression of relative activity of sodium ions in exchange reactions within soil and is an index of sodium or alkali hazard to the soil. Waters range in respect to sodium hazard from those which can be used for irrigation on almost all soils to those which are generally unsatisfactory for irrigation.

*Solute* is any substance that is dissolved in water.

*Specific conductance* is a measure of the ability of a water to conduct an electrical current. It is expressed in microsiemens per centimeter at 25-C. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids content of the water. Commonly, the concentration of dissolved solids (in milligrams per liter) is from 55 to 75 percent of the specific conductance (in microsiemens). This relation is not constant from stream to stream, and it may vary in the same source with changes in the composition of the water.

*Stage-discharge relation* is the relation between gage height (stage) and volume of water, per unit of time, flowing in a channel.

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*Streamflow* is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

*Substrate* is the physical surface upon which an organism lives.

*Natural substrate* refers to any naturally occurring immersed or submersed solid surface, such as a rock or tree, upon which an organism lives.

*Artificial substrate* is a device which is purposely placed in a stream or lake for colonization or organisms. The artificial substrate simplifies the community structure by standardizing the substrate from which each sample is taken. Examples of artificial substrates are basket samplers (made of wire cages filled with clean streamside rocks) and multiplate samplers (made of hardboard) for benthic organism collection, and plexiglass strips for periphyton collection.

*Surface area* of a lake is that area outlined on the latest USGS topographic map as the boundary of the lake and measured by a planimeter in acres. In localities not covered by topographic maps, the areas are computed from the best maps available at the time planimetered. All areas shown are those for the stage when the planimetered map was made.

*Surficial bed material* is the part (0.1 to 0.2 ft) of the bed material that is sampled using U.S. Series Bed-Material Samplers.

*Suspended* (as used in tables of chemical analyses) refers to the amount (concentration) of undissolved material in a water-sediment mixture. It is associated with the material retained on a 0.45-micrometer filter.

*Suspended, recoverable* is the amount of a given constituent that is in solution after the part of a representative water-suspended sediment sample that is retained on a 0.45 um membrane filter has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances. Complete dissolution of all the particulate matter is not achieved by the digestion treatment and thus the determination represents something less than the "total" amount (that is, less than 95 percent) of the constituent present in the sample. To achieve comparability of analytical data, equivalent digestion procedures are required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

Determinations of "suspended, recoverable" constituents are made either by analyzing portions of the material collected on the filter or, more commonly, by difference, based on determinations of (1) dissolved and (2) total recoverable concentrations of the constituent.

*Suspended, total* is the total amount of a given constituent in the part of a representative water-suspended sediment sample that is retained on a 0.45 um membrane filter. This term is used only when the analytical procedure assures measurement of at least 95 percent of the constituent determined. A knowledge of the expected form of the constituent in the sample, as well as the analytical methodology used, is required to determine when the results should be reported as "suspended, total."

Determinations of "suspended, total" constituents are made either by analyzing portions of the material collected on the filter or, more commonly, by difference, based on determinations of (1) dissolved and (2) total concentrations of the constituent.

*Synoptic Studies* Short-term investigations of specific water-quality conditions during selected seasonal or hydrologic periods to provide improved spatial resolution for critical water-quality conditions. For the period and conditions sampled, they assess the spatial distribution of selected water-quality conditions in relation to causative factors, such as land use and contaminant sources.

*Taxonomy* is the division of biology concerned with the classification and naming of organisms. The classification of organisms is based upon a hierarchical scheme beginning with Kingdom and ending with Species at the base. The higher the classification level, the fewer features the organisms have in common. For example, the taxonomy of a particular mayfly, *Hexagenia limbata*, is the following:

Kingdom:	Animal
Phylum:	Arthropoda
Class:	Insecta
Order:	Ephemeroptera
Family:	Ephemeridae
Genus:	Hexagenia
Species:	Hexagenia Limbata

*Time-weighted average* is computed by multiplying the number of days in the sampling period by the concentrations of individual constituents for the corresponding period and dividing the sum of the products by the total number of days. A time-weighted average represents the composition of water that would be contained in a vessel or reservoir that had received equal quantities of water from the stream each day for the year.

*Tons per acre-foot* indicates the dry mass of dissolved solids in 1 acre-foot of water. It is computed by multiplying the concentration of the constituent, in milligrams per liter, by 0.00136.

*Tons per day (T/DAY)* is the quantity of a substance in solution or suspension that passes a stream section during a 24-hour period.



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*Total* is the total amount of a given constituent in a representative water-suspended sediment sample, regardless of the constituent's physical or chemical form. This term is used only when the analytical procedure assures measurement of at least 95 percent of the constituent present in both the dissolved and suspended phases of the sample. A knowledge of the expected form of the constituent in the sample, as well as the analytical methodology used, is required to judge when the results should be reported as "total." (Note that the word "total" does double duty here, indicating both that the sample consists of a water-suspended sediment mixture and that the analytical method determined all of the constituent in the sample.)

*Total discharge* is the total quantity of any individual constituent, as measured by dry mass or volume, that passes through a stream cross-section per unit of time. This term needs to be qualified, such as "total sediment discharge," "total chloride discharge," and so on.

*Total, recoverable* is the amount of a given constituent that is in solution after a representative water-suspended sediment sample has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances. Complete dissolution of all particulate matter is not achieved by the digestion treatment, and thus the determination represents something less than the "total" amount (that is, less than 95 percent) of the constituent present in the dissolved and suspended phases of the sample. To achieve comparability of analytical data, equivalent digestion procedures are required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

*Tritium Network* is a network of stations which has been established to provide baseline information on the occurrence of tritium in the Nation's surface waters. In addition to the surface-water stations in the network, tritium data are also obtained at a number of precipitation stations. The purpose of the precipitation stations is to provide an estimate sufficient for hydrologic studies of the tritium input to the United States.

*Volatile Organic Compounds (VOCs)* are organic compounds that can be isolated from the water phase of a sample by purging the water sample with inert gas, such as helium, and subsequently analyzed by gas chromatography. Many VOCs are man-made chemicals that are used and produced in the manufacture of paints, adhesives, petroleum products, pharmaceuticals, and refrigerants. They are often components of fuels, solvents, hydraulic fluids, paint thinners, and dry cleaning agents commonly used in urban settings. VOC contamination of drinking-water supplies is a human health concern because many are toxic and are known or suspected human carcinogens (U.S. Environmental Protection Agency, 1996).

*Water year* in U.S. Geological Survey reports dealing with surface-water supply is the 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1985, is called the "1985 water year."

*WDR* is used as an abbreviation for "Water-Data Report" in the REVISED RECORDS paragraph to refer to State annual hydrologic-data reports (WRD was used as an abbreviation for "Water-Resources Data" in reports published prior to 1976).

*Weighted average* is used in this report to indicate discharge-weighted average. It is computed by multiplying the discharge for a sampling period by the concentrations of individual constituents for the corresponding period and dividing the sum of the products by the sum of the discharges. A discharge-weighted average approximates the composition of water that would be found in a reservoir containing all the water passing a given location during the water year after thorough mixing in the reservoir.

*WSP* is used as an abbreviation for "Water-Supply Paper" in reference to previously published reports.

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## PUBLICATIONS ON TECHNIQUES OF WATER-RESOURCES INVESTIGATIONS

The U.S. Geological Survey publishes a series of manuals describing procedures for planning and conducting specialized work in water-resources investigations. The material is grouped under major subject headings called books and is further divided into sections and chapters. For example, Section A of Book 3 (Applications of Hydraulics) pertains to surface water. The chapter, the unit of publication, is limited to a narrow field of subject matter. This format permits flexibility in revision and publication as the need arises.

The reports listed below are for sale by the U.S. Geological Survey, Branch of Information Services, Box 25286, Federal Center, Denver, Colorado 80225 (authorized agent of the Superintendent of Documents, Government Printing Office). Prepayment is required. Remittance should be sent by check or money order payable to the U.S. Geological Survey. Prices are not included because they are subject to change. Current prices can be obtained by writing to the above address. When ordering or inquiring about prices for any of these publications, please give the title, book number, chapter number, and "U.S. Geological Survey Techniques of Water-Resources Investigations."

## Book 1. Collection of Water Data by Direct Measurement

*Section D. Water Quality*

- 1-D1. *Water temperature--influential factors, field measurement, and data presentation*, by H. H. Stevens, Jr., J.F. Ficke, and G. F. Smoot: USGS-TWRI Book 1, Chapter D1. 1975. 65 pages.
- 1-D2. *Guidelines for collection and field analysis of ground-water samples for selected unstable constituents*, by W.W. Wood: USGS-TWRI Book 1, Chapter D2. 1976. 24 pages.

## Book 2. Collection of Environmental Data

*Section D. Surface Geophysical Methods*

- 2-D1. *Application of surface geophysics to ground-water investigations*, by A.A. R. Zohdy, G.P. Eaton, and D.R. Mabey: USGS-TWRI Book 2, Chapter D1. 1974. 116 pages.
- 2-D2. *Application of seismic-refraction techniques to hydrologic studies*, by F.P. Haeni: USGS-TWRI Book 2, Chapter D2. 1988. 86 pages.

*Section E. Subsurface Geophysical Methods*

- 2-E1. *Application of borehole geophysics to water-resources investigations*, by W.S. Keys and L.M. MacCary: USGS-TWRI Book 2, Chapter E1. 1971. 126 pages.
- 2-E2. *Borehole geophysics applied to ground-water investigations*, by W.S. Keys: USGS-TWRI Book 2, Chapter E2. 1990. 150 pages.

*Section F. Drilling and Sampling Methods*

- 2-F1. *Application of drilling, coring, and sampling techniques to test holes and wells*, by Eugene Shuter and W.E. Teasdale: USGS-TWRI Book 2, Chapter F1. 1989. 97 pages.

## Book 3. Applications of Hydraulics

*Section A. Surface-Water Techniques*

- 3-A1. *General field and office procedures for indirect discharge measurements*, by M.A. Benson and Tate Dalrymple: USGS-TWRI Book 3, Chapter A1. 1967. 30 pages.
- 3-A2. *Measurement of peak discharge by the slope-area method*, by Tate Dalrymple and M.A. Benson: USGS-TWRI Book 3, Chapter A2. 1967. 12 pages.
- 3-A3. *Measurement of peak discharge at culverts by indirect methods*, by G.L. Bodhaine: USGS-TWRI Book 3, Chapter A3. 1968. 60 pages.
- 3-A4. *Measurement of peak discharge at width contractions by indirect methods*, by H.F. Matthai: USGS-TWRI Book 3, Chapter A4. 1967. 44 pages.
- 3-A5. *Measurement of peak discharge at dams by indirect methods*, by Harry Hulsing: USGS-TWRI Book 3, Chapter A5. 1967. 29 pages.
- 3-A6. *General procedure for gaging streams*, by R.W. Carter and Jacob Davidian: USGS-TWRI Book 3, Chapter A6. 1968. 13 pages.
- 3-A7. *Stage measurement at gaging stations*, by T.J. Buchanan and W.P. Somers: USGS-TWRI Book 3, Chapter A7. 1968. 28 pages.
- 3-A8. *Discharge measurements at gaging stations*, by T.J. Buchanan and W.P. Somers: USGS-TWRI Book 3, Chapter A8. 1969. 65 pages.
- 3-A9. *Measurement of time of travel in streams by dye tracing*, by F.A. Kilpatrick and J.F. Wilson, Jr.: USGS-TWRI Book 3, Chapter A9. 1989. 27 pages.

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- 3-A10. *Discharge ratings at gaging stations*, by E.J. Kennedy: USGS-TWRI Book 3, Chapter A10. 1984. 59 pages.
- 3-A11. *Measurement of discharge by the moving-boat method*, by G.F. Smoot and C.E. Novak: USGS-TWRI Book 3, Chapter A11. 1969. 22 pages.
- 3-A12. *Fluorometric procedures for dye tracing*, Revised, by J.F. Wilson, Jr., E.D. Cobb, and F.A. Kilpatrick: USGS-TWRI Book 3, Chapter A12. 1986. 41 pages.
- 3-A13. *Computation of continuous records of streamflow*, by E.J. Kennedy: USGS-TWRI Book 3, Chapter A13. 1983. 53 pages.
- 3-A14. *Use of flumes in measuring discharge*, by F.A. Kilpatrick and V.R. Schneider: USGS-TWRI Book 3, Chapter A14. 1983. 46 pages.
- 3-A15. *Computation of water-surface profiles in open channels*, by Jacob Davidian: USGS-TWRI Book 3, Chapter A15. 1984. 48 pages.
- 3-A16. *Measurement of discharge using tracers*, by F.A. Kilpatrick and E.D. Cobb: USGS-TWRI Book 3, Chapter A16. 1985. 52 pages.
- 3-A17. *Acoustic velocity meter systems*, by Antonius Laenen: USGS-TWRI Book 3, Chapter A17. 1985. 38 pages.
- 3-A18. *Determination of stream reaeration coefficients by use of tracers*, by F.A. Kilpatrick, R.E. Rathbun, Nobuhiro Yotsukura, G.W. Parker, and L.L. DeLong: USGS-TWRI Book 3, Chapter A18. 1989. 52 pages.
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- 3-A21. *Stream-gaging cableways*, by C. Russell Wagner: USGS-TWRI Book 3, Chapter A21. 1995. 56 pages.

## Section B. Ground-Water Techniques

- 3-B1. *Aquifer-test design, observation, and data analysis*, by R.W. Stallman: USGS-TWRI Book 3, Chapter B1. 1971. 26 pages.
- 3-B2. *Introduction to ground-water hydraulics, a programmed text for self-instruction*, by G.D. Bennett: USGS-TWRI Book 3, Chapter B2. 1976. 172 pages.
- 3-B3. *Type curves for selected problems of flow to wells in confined aquifers*, by J.E. Reed: USGS-TWRI Book 3, Chapter B3. 1980. 106 pages.
- 3-B4. *Regression modeling of ground-water flow*, by R.L. Cooley and R.L. Naff: USGS-TWRI Book 3, Chapter B4. 1990. 232 pages.
- 3-B4. *Supplement 1. Regression modeling of ground-water flow --Modifications to the computer code for nonlinear regression solution of steady-state ground-water flow problems*, by R.L. Cooley: USGS-TWRI Book 3, Chapter B4. 1993. 8 pages.
- 3-B5. *Definition of boundary and initial conditions in the analysis of saturated ground-water flow systems--An introduction*, by O.L. Franke, T.E. Reilly, and G.D. Bennett: USGS-TWRI Book 3, Chapter B5. 1987. 15 pages.
- 3-B6. *The principle of superposition and its application in ground-water hydraulics*, by T.E. Reilly, O.L. Franke, and G.D. Bennett: USGS-TWRI Book 3, Chapter B6. 1987. 28 pages.
- 3-B7. *Analytical solutions for one-, two-, and three-dimensional solute transport in ground-water systems with uniform flow*, by E.J. Wexler: USGS-TWRI Book 3, Chapter B7. 1992. 190 pages.

## Section C. Sedimentation and Erosion Techniques

- 3-C1. *Fluvial sediment concepts*, by H.P. Guy: USGS-TWRI Book 3, Chapter C1. 1970. 55 pages.
- 3-C2. *Field methods for measurement of fluvial sediment*, by Thomas K. Edwards and G. Douglas Glysson: USGS-TWRI Book 3, Chapter C2. 1988. 80 pages.
- 3-C3. *Computation of fluvial-sediment discharge*, by George Porterfield: USGS-TWRI Book 3, Chapter C3. 1972. 66 pages.

## Book 4. Hydrologic Analysis and Interpretation

## Section A. Statistical Analysis

- 4-A1. *Some statistical tools in hydrology*, by H.C. Riggs: USGS-TWRI Book 4, Chapter A1. 1968. 39 pages.
- 4-A2. *Frequency curves*, by H.C. Riggs: USGS-TWRI Book 4, Chapter A2. 1968. 15 pages.

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*Section B. Surface Water*

- 4-B1. *Low-flow investigations*, by H.C. Riggs: USGS-TWRI Book 4, Chapter B1. 1972. 18 pages.
- 4-B2. *Storage analyses for water supply*, by H.C. Riggs and C.H. Hardison: USGS-TWRI Book 4, Chapter B2. 1973. 20 pages.
- 4-B3. *Regional analyses of streamflow characteristics*, by H.C. Riggs: USGS-TWRI Book 4, Chapter B3. 1973. 15 pages.

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- 4-D1. *Computation of rate and volume of stream depletion by wells*, by C.T. Jenkins: USGS-TWRI Book 4, Chapter D1. 1970. 17 pages.

## Book 5. Laboratory Analysis

*Section A. Water Analysis*

- 5-A1. *Methods for determination of inorganic substances in water and fluvial sediments*, by M.J. Fishman and L.C. Friedman, editors: USGS-TWRI Book 5, Chapter A1. 1989. 545 pages.
- 5-A2. *Determination of minor elements in water by emission spectroscopy*, by P.R. Barnett and E.C. Mallory, Jr.: USGS-TWRI Book 5, Chapter A2. 1971. 31 pages.
- 5-A3. *Methods for the determination of organic substances in water and fluvial sediments*, edited by R.L. Wershaw, M.J. Fishman, R.R. Grabbe, and L.E. Lowe: USGS-TWRI Book 5, Chapter A3. 1987. 80 pages.
- 5-A4. *Methods for collection and analysis of aquatic biological and microbiological samples*, by L.J. Britton and P.E. Greeson, editors: USGS-TWRI Book 5, Chapter A4. 1989. 363 pages.
- 5-A5. *Methods for determination of radioactive substances in water and fluvial sediments*, by L.L. Thatcher, V.J. Janzer, and K.W. Edwards: USGS-TWRI Book 5, Chapter A5. 1977. 95 pages.
- 5-A6. *Quality assurance practices for the chemical and biological analyses of water and fluvial sediments*, by L.C. Friedman and D.E. Erdmann: USGS-TWRI Book 5, Chapter A6. 1982. 181 pages.

*Section C. Sediment Analysis*

- 5-C1. *Laboratory theory and methods for sediment analysis*, by H.P. Guy: USGS-TWRI Book 5, Chapter C1. 1969. 58 pages.

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*Section A. Ground Water*

- 6-A1. *A modular three-dimensional finite-difference ground-water flow model*, by M.G. McDonald and A.W. Harbaugh: USGS-TWRI Book 6, Chapter A1. 1988. 586 pages.
- 6-A2. *Documentation of a computer program to simulate aquifer-system compaction using the modular finite-difference ground-water flow model*, by S.A. Leake and D.E. Prudic: USGS-TWRI Book 6, Chapter A2. 1991. 68 pages.
- 6-A3. *A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 1: Model Description and User's Manual*, by L.J. Torak: USGS-TWRI Book 6, Chapter A3. 1993. 136 pages.
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- 6-A5. *A modular finite-element model (MODFE) for areal and axisymmetric ground-water-flow problems, Part 3: Design philosophy and programming details*, by L.J. Torak: USGS-TWRI Book 6, Chapter A5, 1993. 243 pages.
- 6-A6. *A coupled surface-water and ground-water flow model (MODBRANCH) for simulation of stream-aquifer interaction*, by Eric D. Swain and Eliezer J. Wexler. 1996. 125 pages.

## Book 7. Automated Data Processing and Computations

## WATER RESOURCES DATA - VIRGINIA, 1999

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*Section C. Computer Programs*

- 7-C1. *Finite difference model for aquifer simulation in two dimensions with results of numerical experiments*, by P.C. Trescott, G.F. Pinder, and S.P. Larson: USGS-TWRI Book 7, Chapter C1. 1976. 116 pages.
- 7-C2. *Computer model of two-dimensional solute transport and dispersion in ground water*, by L.F. Konikow and J.D. Bredehoeft: USGS-TWRI Book 7, Chapter C2. 1978. 90 pages.
- 7-C3. *A model for simulation of flow in singular and interconnected channels*, by R.W. Schaffranek, R.A. Baltzer, and D.E. Goldberg: USGS-TWRI Book 7, Chapter C3. 1981. 110 pages.

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*Section A. Instruments for Measurement of Water Level*

- 8-A1. *Methods of measuring water levels in deep wells*, by M.S. Garber and F.C. Koopman: USGS-TWRI Book 8, Chapter A1. 1968. 23 pages.
- 8-A2. *Installation and service manual for U.S. Geological Survey manometers*, by J.D. Craig: USGS-TWRI Book 8, Chapter A2. 1983. 57 pages.

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- 8-B2. *Calibration and maintenance of vertical-axis type current meters*, by G.F. Smoot and C.E. Novak: USGS-TWRI Book 8, Chapter B2. 1968. 15 pages.

## Book 9. Handbooks for Water-Resources Investigations

*Section A. National Field Manual for the Collection of Water-Quality Data*

- 9-A6. *National Field Manual for the Collection of Water-Quality Data: Field Measurements*, edited by F.D. Wilde and D.B. Radtke: USGS-TWRI Book 9, Chapter A6. 1998. Variously paginated.
- 9-A7. *National Field Manual for the Collection of Water-Quality Data: Biological Indicators*, by D.N. Myers and F.D. Wilde: USGS-TWRI Book 9, Chapter A7. 1997. 49 pages.
- 9-A8. *National Field Manual for the Collection of Water-Quality Data: Bottom-material samples*, by D.B. Radtke: USGS-TWRI Book 9, Chapter A8. 1998. 48 pages.
- 9-A9. *National Field Manual for the Collection of Water-Quality Data: Safety in Field Activities*, by S.L. Lane and R.G. Fay: USGS-TWRI Book 9, Chapter A9. 1998. 60 pages.

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## SELECTED U.S. GEOLOGICAL SURVEY REPORTS ON WATER RESOURCES IN VIRGINIA

Listed below is a selection of reports on water resources in Virginia which are available through the Virginia District at the U.S. Geological Survey, WRD, 3600 West Broad Street, Room 606, Richmond, Virginia 23230.

An index of geophysical logging in Virginia by the U.S. Geological Survey, by M. P. Mulheren, J. D. Larson, and H. T. Hopkins: U.S. Geological Survey Open-File Report 82-432. 1982. 34 pages.

Annual maximum stages and discharges of selected streams in Virginia through 1990, by B. J. Prugh, Jr., E. H. Nuckels, and C. G. Humphrey: U.S. Geological Survey Open-File Report 90-587. 1991. 442 pages.

Assessment of ground-water contamination from a leaking underground storage tank at a Defense Supply Center near Richmond, Virginia, by W. G. Wright and J. D. Powell: U.S. Geological Survey Water-Resources Investigations Report 90-4091. 1990. 38 pages.

Availability and quality of ground water in the Piedmont province of Virginia, by J. D. Powell and J. M. Abe: U.S. Geological Survey Water-Resources Investigations Report 85-4235. 1985. 33 pages.

Base-flow characteristics of streams in the Valley and Ridge, the Blue Ridge, and the Piedmont Physiographic Provinces of Virginia, by D.L. Nelms, G.E. Harlow, Jr., and D.C. Hayes: U.S. Geological Survey Water Supply Paper 2457. 1997. 48 pages.

Compilation of surface-water and water-quality data-collection sites on selected streams in Virginia, by B. J. Prugh, Jr. and C. G. Humphrey: U.S. Geological Survey Open-File Report 93-462. 1994. 645 pages.

Conceptualization and analysis of ground-water flow system in the Coastal Plain of Virginia and adjacent parts of Maryland and North Carolina, by J. F. Harsh and R. J. Laczniak: U.S. Geological Survey Professional Paper 1404-F. 1990. 100 pages.

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

Documentation of a multiple-technique computer program for plotting major-ion composition of natural waters, by L. I. Briel: U.S. Geological Survey Open-File Report 93-74. 1994.

Documentation of geographic-information-system coverages and data-input files used for analysis of the geohydrology of the Virginia Coastal Plain, by M. J. Pocazio and T. B. Samsel, III: U.S. Geological Survey Water-Resources Investigations Report 93-4015. 1994. 53 pages.

Effects of fracturing on well yields in the coalfield areas of Wise and Dickenson Counties, southwestern Virginia, by W. G. Wright: U.S. Geological Survey Water-Resources Investigations Report 85-4061. 1985. 21 pages.

Estimating net drawdown resulting from episodic withdrawals at six well fields in the Coastal Plain physiographic province of Virginia, by M. J. Focazio and G. K. Speiran: U.S. Geological Survey Water-Resources Investigations Report 93-4159. 1994. 21 pages.

Evaluation of municipal withdrawals from the confined aquifers of southeastern Virginia, by D. L. Richardson, R. J. Laczniak, and P. A. Hamilton: U.S. Geological Survey Open-File Report 88-723. 1988. 50 pages

Flood of November 1985 in West Virginia, Pennsylvania, Maryland, and Virginia, by J. B. Lescinsky: U.S. Geological Survey Open-File Report 86-486. 1987. 33 pages.

Floods in West Virginia, Virginia, Pennsylvania, and Maryland, November 1985, by D. H. Carpenter: U.S. Geological Survey Water-Resources Investigations Report 88-4213. 1990. 86 pages.

Geohydrology and Geochemistry near coastal ground-water-discharge areas of the Eastern Shore, Virginia, by G.K. Speiran: U.S. Geological Survey Water Supply Paper. 1996. 73 pages.

Geohydrology and the occurrence of volatile organic compounds in ground water, Culpeper basin of Prince William County, Virginia, by D. L. Nelms and D. L. Richardson: U.S. Geological Survey Water-Resources Investigations Report 90-4032. 1991. 94 pages.

Geohydrology of the shallow aquifer system, Naval Weapons Station Yorktown, Yorktown, Virginia, by A.R. Brockman, D.L. Nelms, G.E. Harlow, Jr., and J.J. Gildea: U.S. Geological Survey Water-Resources Investigations Report 97-4188. 61 pages.

Ground-water availability along the Blue Ridge Parkway, Virginia, by H. T. Hopkins: U.S. Geological Survey Water-Resources Investigations Report 84-4168. 1985. 154 pages.

Ground-water contamination and movement at the Defense General Supply Center, Richmond, Virginia, by J. D. Powell, W. G. Wright, D. L. Nelms, and R. J. Ahlin: U.S. Geological Survey Water-Resources Investigations Report 90-4113. 1991. 36 pages.

Ground-water concerns for the Eastern Shore, Virginia, by D. L. Richardson: U.S. Geological Survey Open-File Report 93-93. 1994. 4 pages (Water-Resources Notes).

Ground-water discharge from the Coastal Plain of Virginia, by D. L. Richardson: U.S. Geological Survey Water-Resources Investigations Report 93-4191. 1995.

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- Ground-water hydrology and quality in the Valley and Ridge and Blue Ridge physiographic provinces of Clarke County, Virginia, by W. G. Wright: U.S. Geological Survey Water-Resources Investigations Report 90-4134. 1991. 61 pages.
- Ground-water in Virginia: Use during 1990, availability, and resource information needs, by McFarland, E. R. and Focazio, M. J.: U.S. Geological Survey Open-File Report 94-114. 1 page.
- Ground-water use and levels in the southern Coastal Plain of Virginia, by J. D. Larson and R. J. Laczniaik: U.S. Geological Survey Open-File Report 91-187. 1991. 165 pages.
- Ground-water withdrawals from the confined aquifers in the Coastal Plain of Virginia, 1891-1983, by T. K. Kull and R. J. Laczniaik: U.S. Geological Survey Water-Resources Investigations Report 87-4049. 1987. 37 pages.
- Guide to obtaining U.S. Geological Survey information, by K. Dodd, H. K. Fuller, and P. F. Clarke: U.S. Geological Survey Circular 900. 1985. 35 pages.
- Hydraulic characteristics of, and ground-water flow in, coal-bearing rocks of southwestern Virginia, by G. E. Harlow, Jr. and G. D. LeCain: U.S. Geological Survey Water Supply Paper 2388. 1994. 36 pages.
- Hydrogeologic and water-quality data for the Explosive Experimental Area, Naval Surface Warfare Center, Dahlgren Site, Dahlgren, Virginia, by E. C. Hammond and C. F. Bell: U.S. Geological Survey Open-File Report 95-386. 1995. 67 pages.
- Hydrogeologic and water-quality data for the Main Site, Naval Surface Warfare Center, Dahlgren Laboratory, Dahlgren, Virginia, by C. F. Bell, T. P. Bolles, and G. E. Harlow, Jr.: U.S. Geological Survey Open-File Report 94-301. 1995. 81 pages.
- Hydrogeologic framework, analysis of ground-water flow, and relations to regional flow in the Fall Zone near Richmond, Virginia, by E.R. McFarland: U.S. Geological Survey Water-Resources Investigations Report 97-4021. 1997. 56 pages.
- Hydrogeologic framework of the shallow aquifer system of York County, Virginia, by A. R. Brockman and D. L. Richardson: U.S. Geological Survey Water-Resources Investigations Report 92-4111. 1992. 36 pages.
- Hydrogeology and analysis of the ground-water-flow system in the Coastal Plain of southeastern Virginia, by P. A. Hamilton and J. D. Larson: U.S. Geological Survey Water-Resources Investigations Report 87-4240. 1988. 175 pages.
- Hydrogeology and analysis of the ground-water-flow system of the Eastern Shore, Virginia, by D. L. Richardson: U.S. Geological Survey Water-Supply Paper 2401. 1994. 108 pages.
- Hydrogeology and ground-water flow of the shallow aquifer system at the Naval Surface Warfare Center, Dahlgren, Virginia, by B. S. Smith: U.S. Geological Survey Water-Resources Investigations Report 99-4149. 1999. 40 pages.
- Hydrogeology and water quality of the shallow aquifer system at the Explosive Experimental Area, Naval Surface Warfare Center, Dahlgren Site, Dahlgren, Virginia, by C.F. Bell: U.S. Geological Survey Water Resources Investigations Report 96-4209. 1996. 37 pages.
- Hydrogeology and water quality of the shallow ground-water system in Eastern York County, Virginia, by D. L. Richardson and A. R. Brockman: U.S. Geological Survey Water-Resources Investigations Report 92-4090. 1992. 41 pages.
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- Hydrologic characteristics and water budget for Swift Creek Reservoir, by S.C. Skrobialowski and M.J. Focazio: U.S. Geological Survey Water-Resources Investigations Report 97-229. 41 pages.
- Hydrologic conditions and trends in Shenandoah National Park, Virginia, 1983-84, by D. D. Lynch: U.S. Geological Survey Water-Resources Investigations Report 87-4131. 1987. 115 pages.
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- Hydrology of Area 16, Eastern Coal Province, Virginia and Tennessee, by P. W. Hufschmidt and others: U.S. Geological Survey Water-Resources Investigations Report 81-204. 1981. 67 pages.
- Land use in, and water quality of, the Pea Hill Arm of Lake Gaston, Virginia and North Carolina, 1988-90, by M. D. Woodside: U.S. Geological Survey Water-Resources Investigations Report 94-4140. 54 pages.
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Methods for estimating the magnitude and frequency of peak discharges of rural, unregulated streams in Virginia, by J. A. Bisese: U.S. Geological Survey Water-Resources Investigations Report 94-4148. 70 pages.

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Potentiometric surface of the Brightseat-upper Potomac aquifer in Virginia, 1994, by E. C. Hammond, E. R. McFarland, and M. J. Focazio: U.S. Geological Survey Open-File Report 94-370. 1995. 1 page.

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Potentiometric surface of the middle Potomac aquifer in Virginia, 1994, by E. C. Hammond, E. R. McFarland, and M. J. Focazio: U.S. Geological Survey Open-File Report 94-372. 1995. 1 page.

Preliminary estimates of residence times and apparent ages of ground water in the Chesapeake Bay watershed and water-quality data from a survey of springs, by M.J. Focazio, L. N. Plummer, J. K. Bohlke, E. Busenberg, L. J. Bachman, and D. S. Powars: U.S. Geological Survey Water-Resources Investigations Report 97-4225. 1998. 75 pages.

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Scour at bridge sites in Delaware, Maryland, and Virginia, by D.C. Hayes: U.S. Geological Survey Water Resources Investigations Report 96-4089. 1996. 35 pages.20

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The potential for saltwater intrusion in the Potomac aquifers of the York-James peninsula, Virginia, by B.S. Smith: U.S. Geological Survey Water-Resources Investigations Report 98-4187. 1999. 24 pages.

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Use during 1990, availability, and resource-information needs, by E. R. McFarland and M. J. Focazio: U.S. Geological Survey Open-File Report 94-114. 1995. 2 pages.

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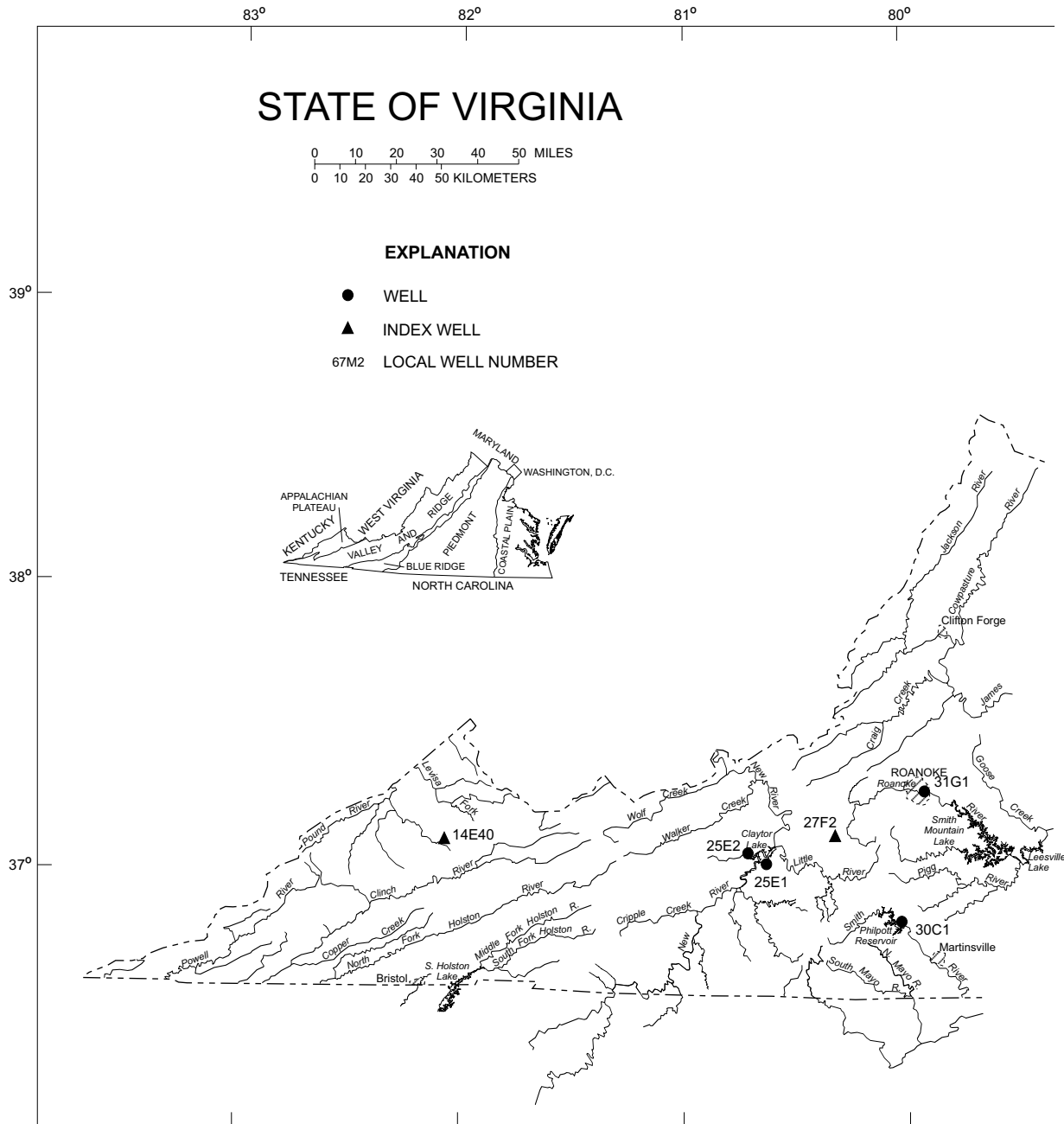
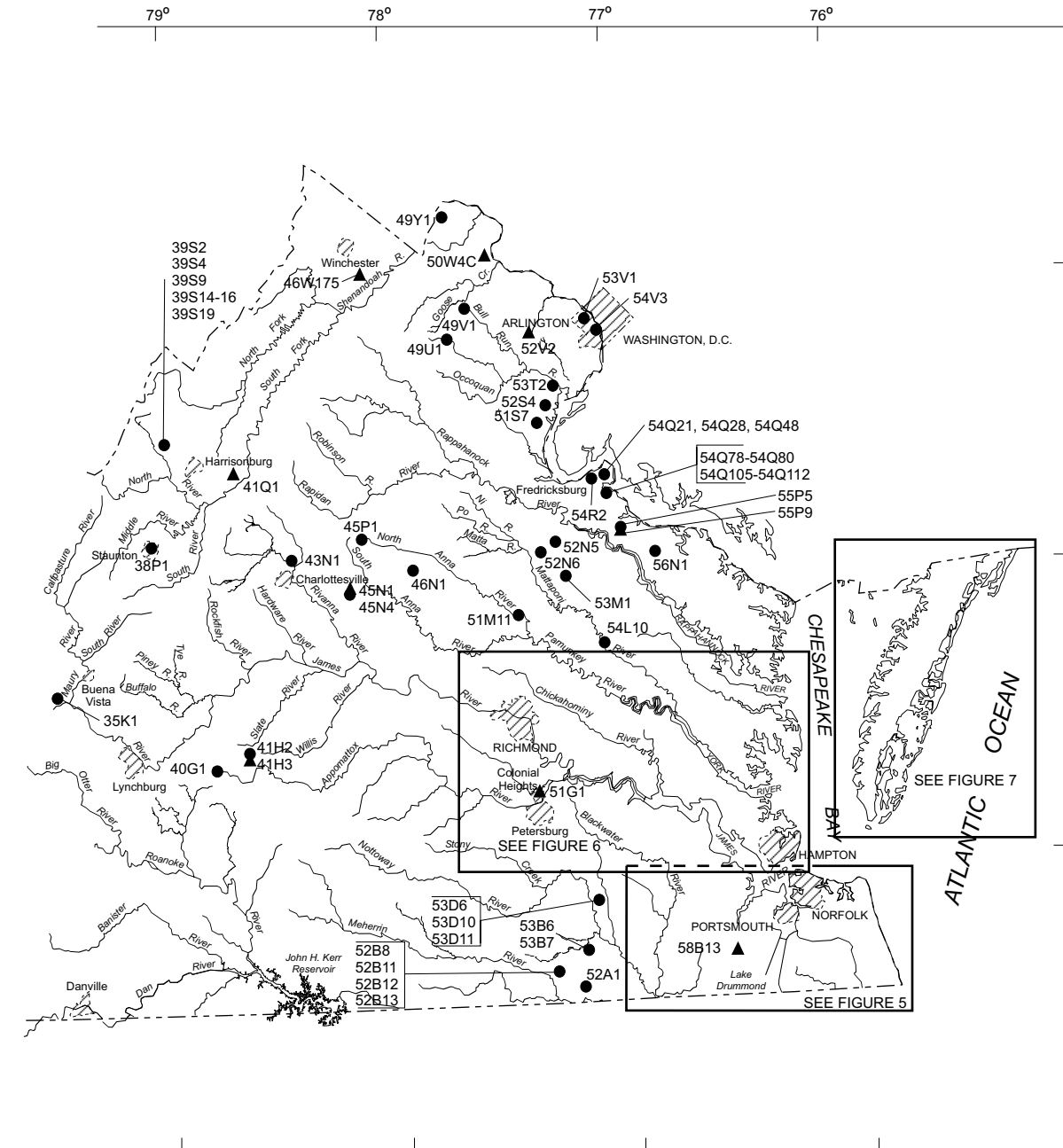


Figure 4. Location of ground-water observation wells.



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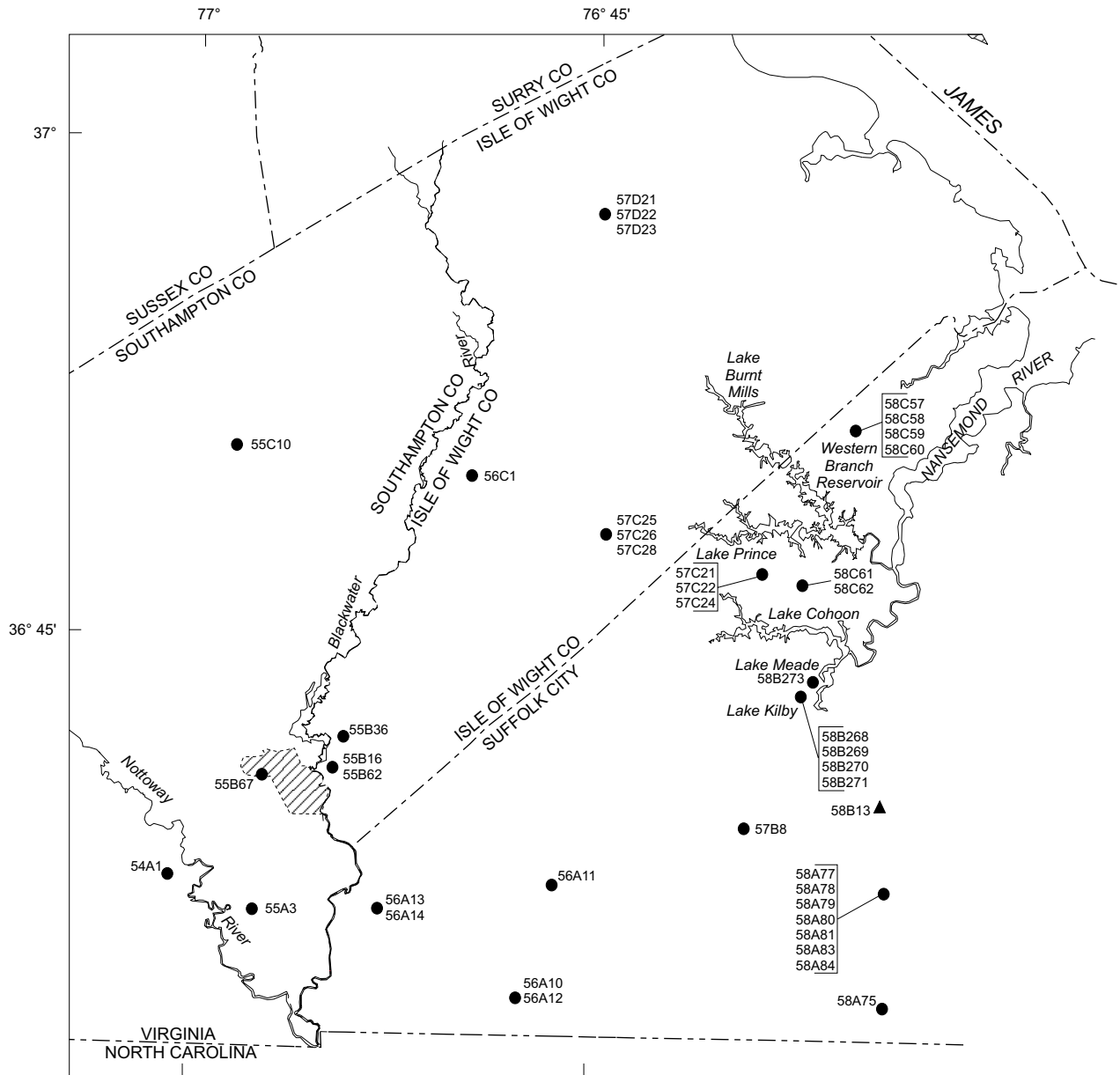
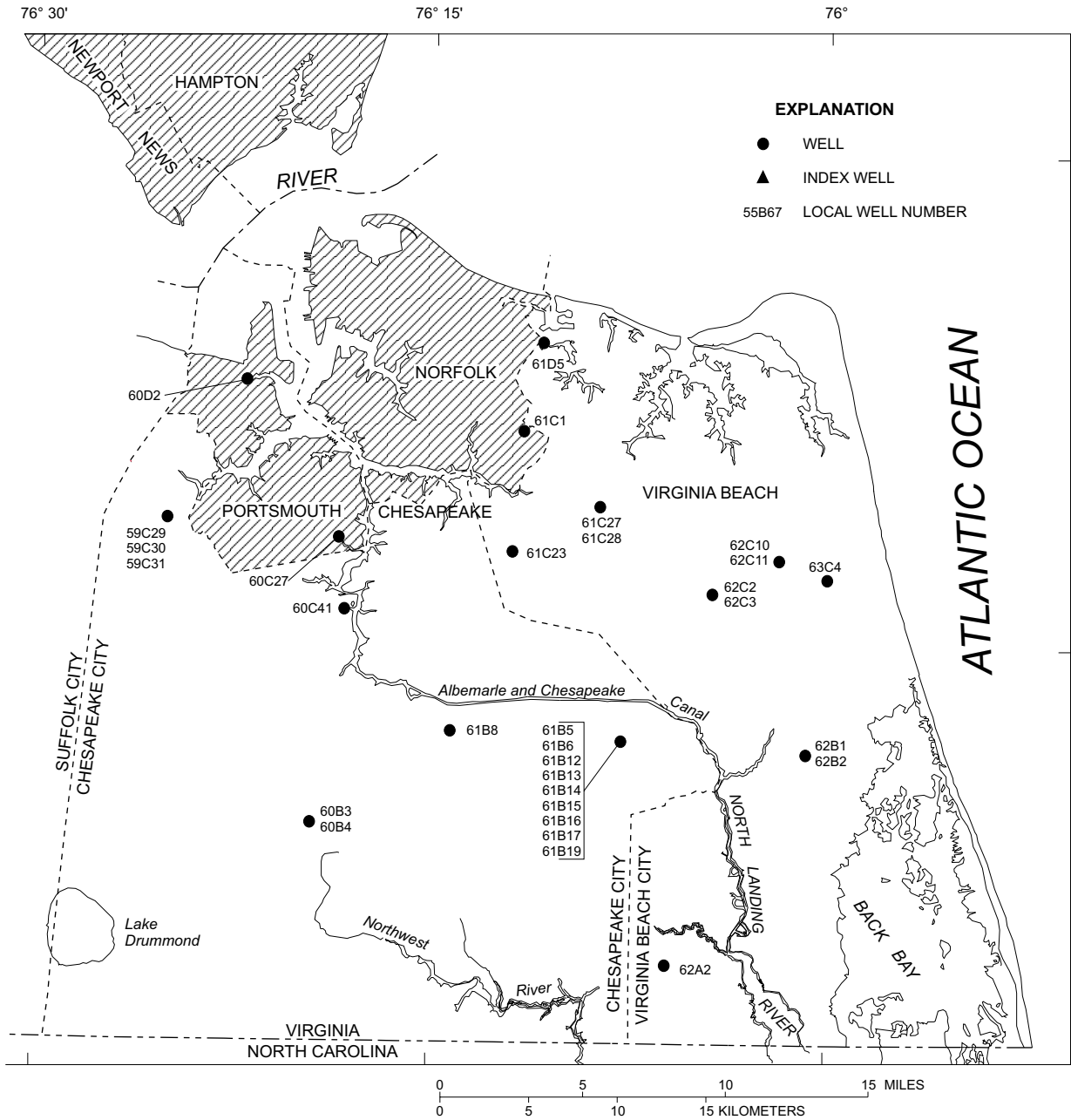


Figure 5. Location of ground-water observation wells in southeastern Virginia.



WATER RESOURCES DATA - VIRGINIA, 1999

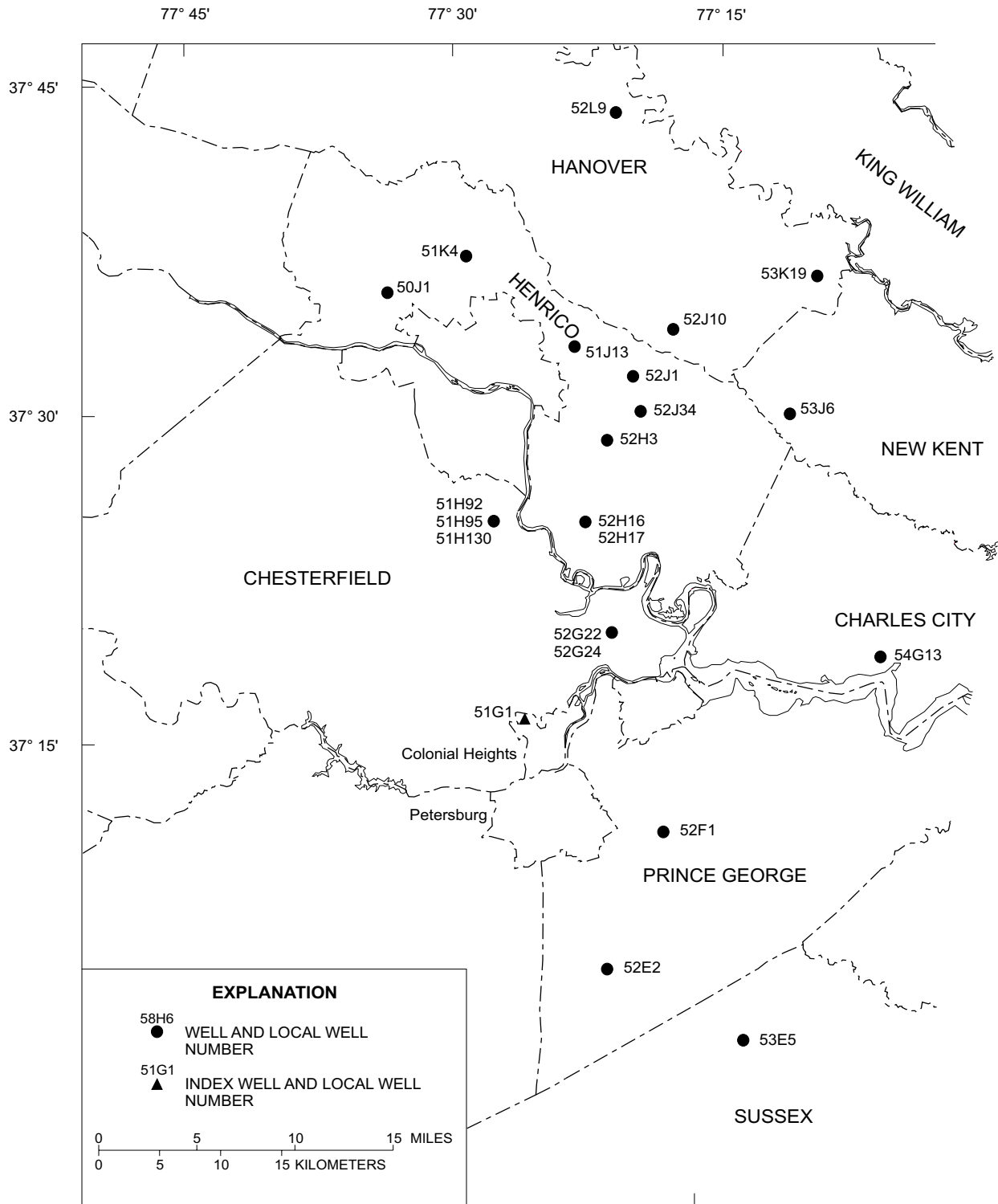
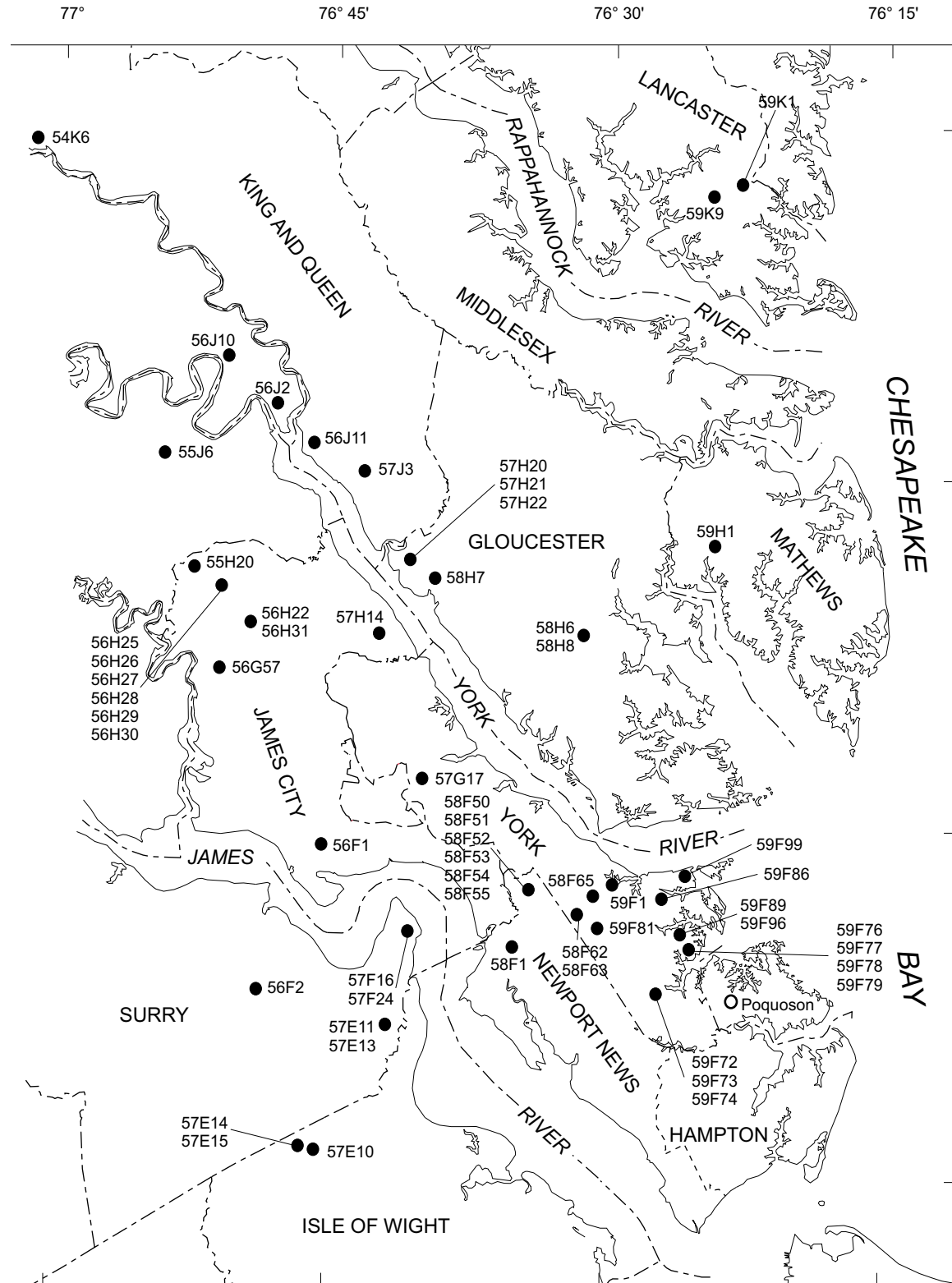


Figure 6. Location of ground-water observation wells on York-James peninsula and vicinity.



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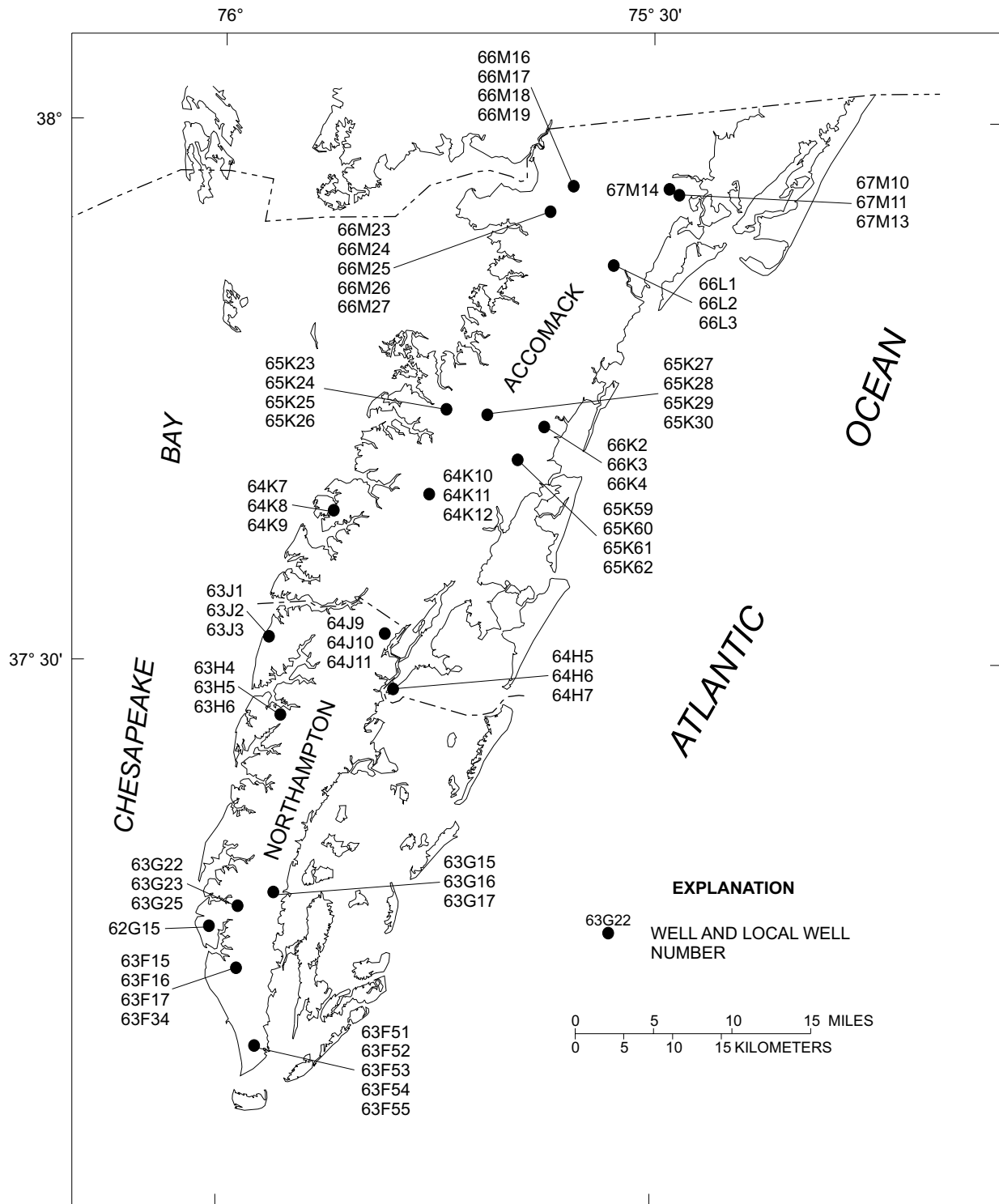


Figure 7. Location of ground-water observation wells on Delmarva peninsula.



GROUND-WATER-LEVEL RECORDS