# Selected Applications of Hydrologic Science and Research in Maryland, Delaware, and Washington, D.C., 2001–2003

by Lisa D. Olsen

## Introduction

One of the roles of the U.S. Geological Survey (USGS) is to provide reliable water data and unbiased water science needed to describe and understand the Nation's water resources. This fact sheet describes selected techniques that were used by the USGS to collect, transmit, evaluate, or interpret data, in support of investigations that describe the quantity and quality of water resources in Maryland (MD), Delaware (DE), and the District of Columbia (D.C.). These hydrologic investigations generally were performed in cooperation with universities, research centers, and other Federal, State, and local Government agencies.

The applications of hydrologic science and research that were selected for this fact sheet were used or tested in the MD-DE-DC District from 2001 through 2003, and include established methods, new approaches, and preliminary research. The USGS usually relies on standard methods or protocols when conducting water-resources research. Occasionally, traditional methods must be modified to address difficult environmental questions or challenging sampling conditions. Technologies developed for other purposes can sometimes be successfully applied to the collection or dissemination of water-resources data. The USGS is continually exploring new ways to collect, transmit, evaluate, and interpret data. The following applications of hydrologic science and research illustrate a few of the recent advances made by scientists working for and with the USGS.

## Real-Time Data Transmission

Water-level data collected by the USGS are used for flood forecasting and planning, water-quality studies, water-resources management decisions, and investigations of long-term changes in hydrologic conditions. Real-time data transmission provides users, such as Government agencies, universities, private businesses, and the public, timely access to these data over the Internet.

Real-time data are transmitted from the field to a USGS office by landline telephone, land-based radio technology, or satellite telemetry. One recent advance in real-time data transmission is the use of AirLink data communications equipment, which features a wireless data platform that uses cell phone technology. These systems are inexpensive compared to other data-transmission options, but require close proximity to a cell phone tower.

In Maryland and Delaware, the USGS is cooperating with the Maryland Department of the Environment (MDE), the Maryland Geological Survey (MGS), the Maryland State Highway Administration, the Maryland Department of Natural Resources, Baltimore and Calvert Counties, the cities of Baltimore and Wilmington, the Washington Suburban Sanitary Commission, the Delaware Geological Survey, the Delaware Emergency Management Agency, the Interstate Commission on the Potomac River Basin, the U.S. Army Corps of Engineers, the National Park Service, and other partners to develop and maintain a network of stream gages and ground-water data stations that house real-time data-transmission systems. Real-time data collected by this network, including water-level data, are available on the Internet at *http://waterdata.usgs.gov/nwis/rt*.

Data collection and transmission using Sutron data recorder and AirLink data-transmission equipment. *[Photo by Richard W. Saffer, U.S. Geological Survey]*

## Continuous Water-Quality Monitoring

An increasing number of USGS data stations are being instrumented to collect *in-situ* water-quality data on a continuous basis, in addition to water-level data. In the Maryland-Washington, D.C. area, selected water-quality-monitoring stations are being equipped to include real-time reporting (15-minute intervals) of pH, dissolved oxygen, turbidity, specific conductance, and water temperature at the Northeast and Northwest Branch Anacostia River (in cooperation with MDE and Prince Georges County) and at Mattawoman Creek (in cooperation with the Charles County Department of Planning and Growth Management).

USGS scientists will use these continuous measurements, in addition to

USGS scientist inspecting a probe used for continual measurement of pH, dissolved oxygen, turbidity, and specific conductance. *[Photo by Robert J. Shedlock, U.S. Geological Survey]*

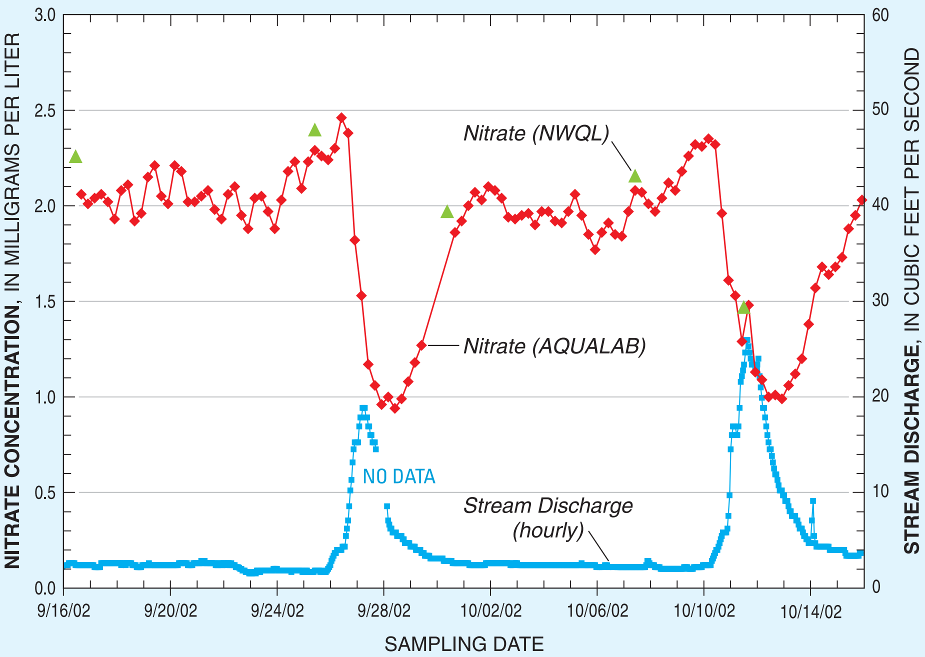

USGS scientists preparing to install the AQUALAB Analyzer at Morgan Creek, Maryland. *[Photo by James R. Jeffries, U.S. Geological Survey]*

data from a smaller number of discrete samples collected and analyzed for *Escherichia coli* (Anacostia River only), nitrate, total nitrogen, total phosphorus, and suspended-sediment concentrations, to develop regression relations between the continually measured parameters and the infrequently sampled parameters, using methods similar to those presented in Christensen and others (2000). If regression relations can be determined, scientists can use them to make real-time estimates of the concentrations of infrequently sampled parameters (on the basis of the continuous measurements), resulting in a more complete understanding of concentrations over time for nutrients, bacteria, and suspended sediment than would be possible based on sample data alone.

Ideally, scientists would prefer to obtain continuous data for nutrients, such as nitrate and phosphate, through direct field measurements rather than through regression modeling. Few technologies are available to measure most dissolved ions, including nitrate and phosphate, in the field on a continual basis. Scientists from the USGS National Water-Quality Assessment (NAWQA) Program recently collaborated with Stevens Water Monitoring Systems, Inc. in a cooperative evaluation of a nutrient analyzer that automatically collects and analyzes streamwater samples, using common laboratory techniques that have been adapted for in-field measurement.

The AQUALAB Analyzer that was tested is designed to take measurements every 2 hours of nitrate, phosphate, and ammonia, and hourly measurements of standard field parameters (pH, dissolved oxygen, turbidity, specific conductance, and temperature). Automated sample collection and analysis allows greater sampling frequency than would be possible using field technicians to collect individual samples and ship them to a laboratory, and is advantageous for capturing storm events and diurnal trends. During the 10-week evaluation, nutrient analyses by the AQUALAB Analyzer generally were within 5 percent of concentrations reported for replicate samples analyzed by the USGS National Water-Quality Laboratory (NWQL) (Michael J. Brayton, USGS, written commun., 2003).

Continuous water-quality monitoring for nutrients can provide data to determine nutrient loads and trends in natural waters, which can aid in understanding nutrient transport processes during storm events and other hydrologic conditions. Trends in nutrient concentrations over time can be characterized more fully than would be possible using less frequently collected discrete samples.




Nitrate concentrations in samples collected and analyzed continually (AQUALAB), and discrete samples analyzed by the National Water-Quality Laboratory (NWQL) for various stream-discharge conditions at Morgan Creek, Maryland. *[Graph by Michael J. Brayton, U.S. Geological Survey]*

## Hoverprobe Drilling

Drilling to collect sediment cores or ground-water samples in wetland environments is often very difficult


The Hoverprobe and support craft at Aberdeen Proving Ground, Maryland. *[Photo by U.S. Geological Survey]*

because of poor accessibility and the lack of firm sediment needed to support traditional drill rigs. The Hoverprobe was constructed to combine the utility of a drill rig with the versatility of a hovercraft. The Hoverprobe was developed by the USGS in cooperation with Hovertechnics, Inc. of Benton Harbor, Michigan, and MPI Drilling, Inc. of Picton, Ontario and is operated by the USGS Geologic Discipline in Reston, Virginia (Phelan and others, 2001).

The Hoverprobe is 21.5 feet long, weighs about 4,000 pounds, and has a ground-contact area of about 168 square feet. The pressure on the ground under the craft while at rest is about 0.17 pounds per square inch, which is about 10 percent of the pressure exerted by a standing person, making it ideally suited for wetland environments.

Hydraulically driven cams are used to generate high frequency vibrations at the cutting edge of a hollow drill string, allowing a hole to be cut, core to be retrieved, or a monitoring well to be installed rapidly, without producing cuttings at the surface or injecting fluids into the ground. The drill can be used to retrieve continuous core from saturated, unconsolidated materials to a maximum depth of about 100 feet. Drilling can proceed while the craft is on mud, solid ground, or floating on water, even if water levels or tides shift (Phelan and others, 2001).

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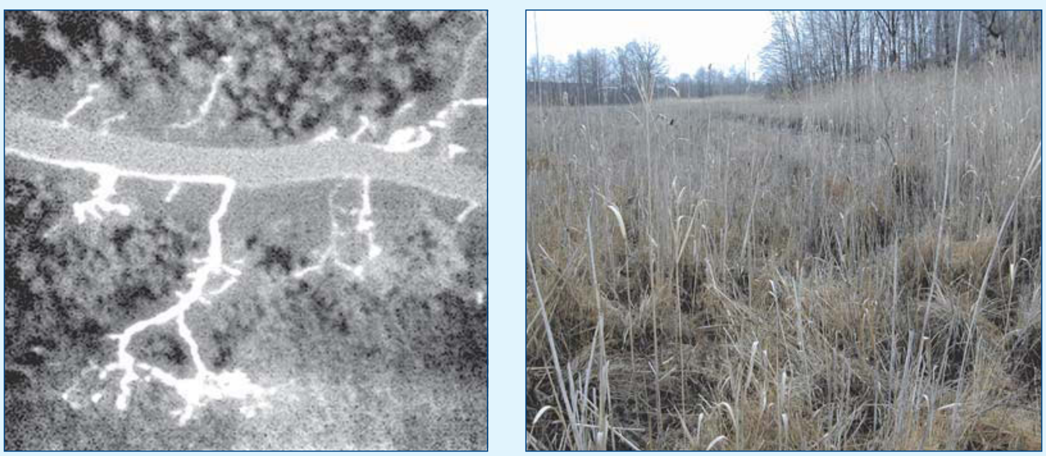
The USGS has used the Hoverprobe for geologic and hydrologic studies in shallow tidal areas, including studies performed in cooperation with the U.S. Army, the U.S. Army Corps of Engineers, the D.C. Department of Health, and MPI Drilling, Inc. USGS scientists have used the Hoverprobe to retrieve continuous cores that were interpreted by geologists to determine changes in sediment types and deposition rates resulting from sediment runoff. USGS scientists also have used the Hoverprobe to collect water samples to determine the extent of ground-water contamination in an aquifer under a tidal wetland. The Hoverprobe may be more expensive to operate than other small land-based drill rigs; however, it can decrease overall costs because of reduced mobilization and logistical expenses typical of offshore or open-water drilling, and it can access areas where traditional drilling methods cannot be used.

## Thermal-Infrared Imaging

Identifying areas of ground-water discharge (also known as "seeps") is useful in understanding certain hydrologic processes, including ground-water/surface-water interactions. In areas of known or suspected ground-water contamination, seeps are a potential pathway for contaminants to move from ground water to the overlying land or surface water. Delineating seep areas in wetlands is complicated



Thermal-infrared image (left) and still photograph of a seep in a wetland at Aberdeen Proving Ground, Maryland. The total length of this seep is about 80 feet. *[Thermal-infrared image and photo by J. Aguiar, Aberdeen Proving Ground International Image Center, Aberdeen, Maryland]* because slowly discharging ground water cannot be observed easily in areas where the ground is saturated or submerged. In addition, wetland vegetation and soft, spongy sediments can limit accessibility. Thermal-infrared (TIR) imaging can be an effective and convenient method for identifying seep areas in tidal wetlands and along stream edges (Portnoy and others, 1998; Banks and others, 1996).

TIR imaging relies on a special camera that detects thermal energy (heat) emitted by surfaces and converts this energy to a color image. TIR imaging can be used to quantify temperature variations on land surfaces and water bodies (Torgersen and others, 2001). Decreased sunshine during the winter in the northern hemisphere causes cooler air temperatures. Land surfaces and water bodies cool more slowly than air, causing a short delay in temperature drop. Ground water, which is insulated from the temperature changes at the surface, cools even more slowly, and exhibits a much longer delay in temperature drop. Thus, during the winter, discharging ground water is generally warmer than the overlying land or surface water, and seep areas are visible in TIR images as bright spots.

The USGS has used TIR imaging in cooperation with the U.S. Army to delineate seep areas at Aberdeen Proving Ground (APG), MD in support of the Installation Restoration Program. TIR camera, helicopter services, and technical assistance were provided by the U.S. Army Aberdeen Test Center at APG. TIR imaging by helicopter provides versatile images and temperature data that can be used to map seep areas, and allows rapid coverage of large wetlands. It is also far less labor-intensive than deploying large numbers of individual temperature sensors in wetland areas on foot. Seep areas identified through aerial TIR imaging can be verified on the ground, through *in-situ* temperature monitoring or other methods. Because TIR imaging captures only the thermal energy emitted by surfaces, seeps that are submerged deeply enough to allow bulk mixing with overlying surface water cannot be detected using this technique.

## Passive-Diffusion-Bag Samplers

Passive-diffusion-bag samplers (PDBs) can be used to measure volatile organic compounds (VOCs) in ground water found in wells and shallow sediments. PDBs generally are constructed from low-density polyethylene film or other material that is permeable to the analytes of interest. Bags made of the film are filled with deionized water and sealed, and protective mesh sleeves can be added to minimize the risk of puncture or damage. PDBs can be placed inside wells or directly into shallow saturated sediments (for example, in streambeds or wetlands).

Once installed, concentrations of VOCs in the surrounding ground water begin to equilibrate with the water inside the PDBs. Complete equilibration typically occurs after 2 to 3 weeks; however, equilibration times can vary based on film thickness, bag diameter, ground-water velocity, and water temperature. Concurrent sampling using other sampling methods can be used to verify the adequacy of a selected equilibration time for a specific set of conditions. Advantages of PDBs over traditional techniques include the elimination of the need to purge wells prior to sampling, elimination of potential cross-contamination through pumps and other sampling equipment, minimization of sample loss due to volatilization, exclusion of sediment particles from the sample water, and cost savings associated with reduced sampling time (Harte and others, 2000). During long-term deployment in some environments, biofilms can form on the surfaces of the bags and impede the transfer of certain compounds, necessitating additional verification using traditional sampling methods in some cases (Vroblesky, 2001).

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USGS scientist installing a passive-diffusion-bag sampler made of dialysis membrane in a monitoring well at Dover Air Force Base, Delaware. *[Photo by Jeffrey R. Barbaro, U.S. Geological Survey]*

In Maryland, PDBs have been used to measure concentrations of VOCs and methane in ground water at seep areas identified through TIR imaging at APG (in cooperation with the U.S. Army). For this application, PDBs were placed directly in the wetland sediments, approximately 6 inches below land surface (Emily H. Majcher, USGS, written commun., 2003). In Delaware, PDBs made from dialysis membrane were used to measure concentrations of inorganic and organic analytes in an area of contaminated ground water underlying Dover Air Force Base (in cooperation with the U.S. Air Force). For this application, PDBs were placed at various depths in monitoring wells to determine vertical profiles of iron, sulfate, dissolved oxygen, methane, and VOCs to assess the effectiveness of natural attenuation in reducing contaminant levels (Jeffrey R. Barbaro, USGS, written commun., 2003). PDBs employ patented technology (U.S. patent number 5,804,743) and therefore require that users purchase commercially produced samplers from a licensed manufacturer or obtain a nonexclusive license from the USGS Technology Enterprise Office at Mail Stop 211, National Center; 12201 Sunrise Valley Drive; Reston, VA, 20192 (Vroblesky, 2001).

## Hydroacoustic Techniques

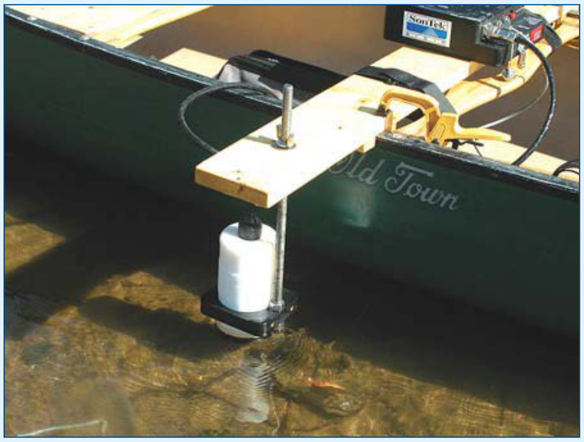
Another way the USGS collects data to support water-resources investigations is by use of hydroacoustic techniques, which employ the Doppler effect on sound pulses transmitted underwater to measure water velocity (Fisher and Morlock, 2002). Hydroacoustic devices used in the MD-DE-DC District for measuring surface-water flow velocity and discharge include the YSI/Sontek® FlowTracker and the YSI/Sontek® RiverCat.

The Sontek® FlowTracker mounts on a standard wading rod and is used to make point surface-water velocity measurements and low-flow discharge measurements. It is different from a traditional pygmy meter because it collects a true "discrete" point measurement (instead of measuring over several square inches) and can accurately measure very low velocities and flow depths as shallow as 1 inch. It also provides detailed data at 1-second increments that include the x, y, and z components of flow velocity, water temperature, and noise error.

The Sontek® RiverCat is an acoustic Doppler current profiler and provides a detailed picture of the surface-water velocity and discharge distribution, and the bathymetry from surface to bottom along a transect. The unit being used in Maryland and Delaware is designed for shallow-water applications and works in depths of about 1 to 15 feet. The USGS is using this unit to evaluate tidal flow patterns around a constructed wetland adjacent to Fort McHenry, in cooperation with the Maryland Port Administration (Gary T. Fisher, USGS, written commun., 2003). This unit can also be used for routine river measurements and moderate flood measurements.

An urban stream impacted by wastewater leaking from deteriorating sewer lines at Maidens Choice Run upstream from USGS stream-gaging station 0158935, Baltimore, Maryland. *[Photo by Gary T. Fisher, U.S. Geological Survey]*

Because the Sontek® RiverCat can be deployed from the shore or by boat, it can be used in stream reaches that are not accessible by bridge, making this approach advantageous for measurements in remote areas. Another important aspect of hydroacoustic techniques is that the flow velocity can be measured in any direction, which is important for tidal settings and for streams that have nonuniform or nonsteady flow velocity or direction.




Acoustic Doppler current profiler mounted on canoe for shallow-water flow measurements. *[Photo by Gary T. Fisher, U.S. Geological Survey]*

## Wastewater Analysis

Contamination of streams by treated and untreated sewage is a growing problem of national significance. Despite major improvements in wastewater treatment during the past century, degradation of aging sewer systems has resulted in many leaks of raw sewage into adjacent soils, and consequently into nearby water bodies. Leaks can be caused by broken or deteriorated pipes, damaged joints caused by ground movement, or overflow due to insufficient capacity.

When not caused by catastrophic failure, sewage contamination in streams can be difficult to detect. Substances that can be indicative of untreated wastewater may be present at low levels and can be hard to distinguish from other contaminant sources. Nutrients (such as nitrogen and phosphorus) can originate from sewage, but can also come from fertilizers or industrial discharges. A variety of bacteria can be associated with sewage, but can also originate from domestic or wild animals. Field studies have shown that concentrations of such bacteria vary widely in streams that are affected by leaking wastewater, further complicating their use as an indicator of contamination. Some chemical and physical changes that can indicate an influx of wastewater, such as increased streamflow, increased specific conductance, or abnormal temperatures, also can result from other human or natural causes.

Certain substances, however, are unique to human wastes and can provide unambiguous evidence of untreated wastewater in streams. These include human pharmaceuticals and food products, such as estrogen, caffeine, and flavorings, which can persist in municipal wastewater. In addition, many cosmetics, perfumes, deodorants, and insect repellents are introduced to wastewater through bathing or clothes washing. These substances, along with detergent-related compounds and some pesticides and industrial chemicals, can be used as indicators of wastewater contamination.

In support of USGS research on indicator compounds for sewage contamination, the NWQL has approved an analytical method for filtered water samples (Zaugg and others, 2002), and is developing another method for unfiltered samples. Both methods are relatively inexpensive and cover similar lists of about 60 analytes, including many compounds that are uniquely associated with wastewater and additional manmade compounds that are not unique to wastewater (certain outdoor pesticides and industrial products). By use of these methods, the USGS has reported the occurrence and persistence of these wastewater-related analytes as part of a national survey (Kolpin and others, 2002) and in local studies. The usefulness of these compounds as indicators of leaking sewage is currently being investigated by the USGS in urban streams in the Baltimore and Washington, D.C. areas and includes sampling of reference streams (Gary T. Fisher, USGS, written commun., 2003).

## Sediment Source Identification

Sediment is a key environmental issue for many waterways and is the main pollutant degrading the Chesapeake Bay. The U.S. Environmental Protection Agency (USEPA) has identified fluvial sediment as the leading cause for impairment of surface waters in the United States; however, there has been little research to date on developing approaches to identify sources of suspended sediment.

USGS scientist collecting sediment samples. *[Photo by John R. Gray, U.S. Geological Survey]*

***Sediment is a key environmental issue for many waterways and is the main pollutant degrading the Chesapeake Bay.***

Sediment source identification is a technique that can be used to determine important sources of suspended sediment within a watershed (Walling and Woodward, 1995; Motha and others, 2003). Soil scientists, geomorphologists, and agricultural and civil engineers can apply this technique to determine the statistically significant sources of suspended sediment leaving a watershed. Knowledge of the sources of suspended sediment can direct resource managers to key areas where erosion and sediment transport are occurring.

Samples of surface sediment (upper 2 centimeters) are collected from areas of the watershed that represent major upland land uses (cropland, pasture, and mining) and from areas in the channel corridor (channel bed, banks, and flood plain). Sediment samples are then analyzed for a number of characteristic properties, including mineralogy, radionuclides, magnetic susceptibility, and stable isotopes. In addition, samples of suspended sediment are collected during runoff events and analyzed for the same characteristic properties. The sediment data are subsequently linked to the watershed sources through a statistical mixing model that quantifies patterns of similarities and differences in the sediment properties. Areas and land uses that contribute the majority of the suspended sediment can then be identified.

This sediment-source identification approach has mainly been developed through the research of Dr. Desmond Walling, Exeter University, United Kingdom. This field-based technique to identify watershed sources provides a more reliable assessment than traditional sediment-transport modeling methods. Research in the application of this technique in the Chesapeake Bay watershed is currently supported by the USEPA and through the Chesapeake Bay Program.

## Water-Use Data Analysis

The USGS has been estimating water use in the United States since the 1950 inception of the National Circular, *Estimated Use of Water in the United States*. Over the years, USGS has collected and analyzed a substantial amount of water-use data, relying on a variety of data-compilation procedures.

Since 1980, the USGS MD-DE-DC District, in cooperation with MDE and MGS, has used a USGS-supported Site-specific Water-Use Database System

How much water do we use in the United States? Visit the USGS Water-Use Program for the answer: *http://water.usgs.gov/watuse/. [Photo by Lisa D. Olsen, U.S. Geological Survey]*

(SWUDS). The capabilities of this database were recently enhanced by the addition of a personal-computer-(PC) based operating platform, resulting in PC SWUDS. PC SWUDS features an easy-to-use graphical user interface and online help. The new system is integrated with the other USGS National Water Information System (NWIS) databases, including the Ground-Water Site Inventory System (GWSI), Advanced Very High Resolution Radiometer (AVHRR) Data Acquisition and Processing System (ADAPS), and the Water-Quality Database (QWDATA).

PC SWUDS offers the ability to store a wide variety of water-use information and retrieve data in commonly used PC-based formats, including spreadsheet and text. The new system will be used to store the large volumes of water-use data that the USGS collects every 5 years for the National Circular. The data will also be used for USGS studies and to meet the public-information needs of States and local communities.

***In addition to water-level data, an increasing number of USGS data stations are being instrumented to collect in-situ water-quality data on a continuous basis.***

## Borehole Geophysics

In order to obtain information about what lies below the Earth's surface, the USGS uses sophisticated methods and equipment to perform geophysical logging. Geophysical logging involves lowering a series of probes into drilled boreholes (or existing fractures or wells) as deep as several thousands of feet into the ground. One type of multiparameter probe that has been used in Maryland and Delaware measures several characteristics of subsurface properties, including natural gamma radiation, or a material's resistance to electric current, which is useful for finding a good water-bearing sand aquifer for water-supply purposes. Another type is an acoustic velocity probe, which works by transmitting acoustic signals and recording the traveltime of the acoustic wave from one or more transmitters to receivers in the probe. The recorded information can be used to measure porosity and calculate the material's density. This technique was used to determine the extent of jumbled geologic strata caused by a crater impact at the mouth of the Chesapeake Bay 30 million years ago. Another type of probe, called an Acoustic Televiewer, transmits acoustic signals to subsurface rock layers and uses state-of-the-art computer software to convert the recorded data into an actual image of the borehole. This image can be used to determine the amount of water that could be extracted from individual fractures in the rock formation.

Even though most of the parameters measured by these probes can only be determined in a newly drilled "open" borehole, certain probes emit signals that can penetrate well casings, making it possible to measure subsurface materials after a well is constructed. Gamma rays can travel through almost any type of well casing, while an "induction" probe can measure conductivity electromagnetically through polyvinyl chloride (PVC) casing. Other parameters, such as the borehole's fluid temperature and conductivity, can also be measured, making it possible to evaluate water quality. The flow direction of ground water can also be determined with several types of probes. All of this equipment enables scientists to characterize the properties of subsurface materials, improving our knowledge of what lies beneath the Earth's surface.

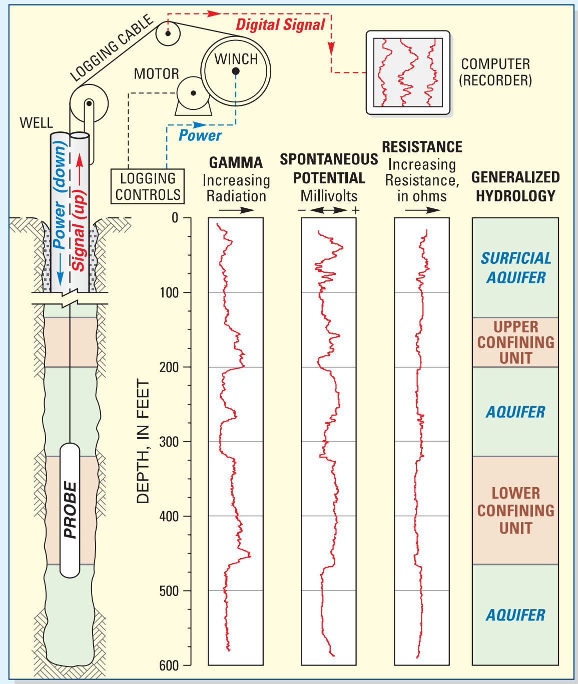
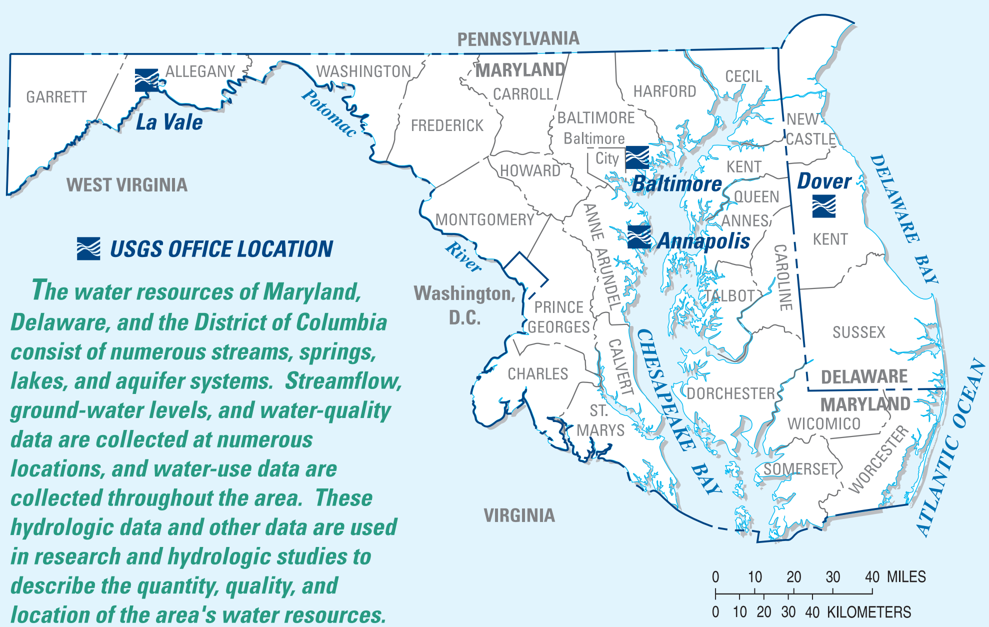



Diagram of geophysical well-logging equipment and recorded logs with generalized hydrologic units.

***The water resources of Maryland, Delaware, and the District of Columbia consist of numerous streams, springs, lakes, and aquifer systems. Streamflow, ground-water levels, and water-quality data are collected at numerous locations, and water-use data are collected throughout the area. These hydrologic data and other data are used in research and hydrologic studies to describe the quantity, quality, and location of the area's water resources.***




Locations of USGS Water-Resources offices in Maryland and Delaware.

## Acknowledgments

Many scientists in the USGS MD-DE-DC District provided information, text, photos, and graphics that were incorporated into this fact sheet. The author is grateful for the contributions of Robert James, Allen Gellis, Michael Brayton, Gary Fisher, Emily Majcher, Steve Curtin, Daniel Phelan, Jeffrey Barbaro, Jonathan Evans, Brenda Majedi, and Judith Wheeler. The author is also grateful to James Morris, Douglas Yeskis, and Cherie Miller of the USGS, and John Grace of MDE for their technical input. Thanks also go to Valerie Gaine and Timothy Auer of the MD-DE-DC District for their help in editing and preparing this document for publication.

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## Additional Information

*For further information about the hydrologic applications presented in this fact sheet, please contact:*

**District Chief, MD-DE-DC District**
**U.S. Geological Survey**
**8987 Yellow Brick Road**
**Baltimore, Maryland 21237**

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