Ground Water
Resource Characterization and Monitoring

As a nation, efforts to monitor and characterize ground water resources with regard to quantity and quality have been sporadic and, while successful in some local jurisdictions and watersheds, largely inadequate. We need to collect more reliable, consistent, and comprehensive data that will sufficiently characterize ground water quality and quantity in order to support critical water resource use, protection, and management decisions. This should be done through a coordinated (federal, state, and local) national data collection and monitoring program that gives decision makers the ability to identify such critical information as:

Key Message

- Baseline ambient ground water quality.
- Where and how ground water quality is being degraded.
- Location of ground water recharge areas.
- Patterns of ground water withdrawal and recharge within identified watersheds (to sustainably allocate resources and maintain healthy ecosystems).
- Ground water contribution to stream baseflows and areas of ground water/surface water interaction.
- Relationship and significance of ground water quantity and quality to the maintenance of healthy rivers, lakes, streams, wildlife habitats, and fisheries within given hydrogeologic settings.

Photo: Tom Litke, Idaho DEQ

Left: Snake Plain Aquifer discharging ground water to the Snake River in the Thousand Springs area near Twin Falls, Idaho. Right: Eutrophication in the Snake River in the Thousand Springs area.

Do We Have Enough Water?

"The primary challenge related to hydrologic forecasting is in forecasting coming variations in water availability (and water quality), not just amounts of water expected based on 'average conditions.' To make advances in forecasting, more comprehensive assessments of the amounts of water stored in the atmosphere, surface, and subsurface, as well as the exchange between these, are needed."

Science and Technology to Support Fresh Water Availability in the United States | Report of the National Science and Technology Council Committee on Environment and Natural Resources | November 2004

why ground water Resource Characterization and Monitoring matter…

While we have made strides in understanding how ground water/surface water systems work, our ability to characterize how our human activities affect the many natural processes and interactions inherent to specific systems has been constrained. This is primarily due to the lack of long-term sustained support and funding for ground water quality and quantity data collection, analysis, research and development trends, and information dissemination.

At a time when water scarcity is a concern in so many areas of the country, when water allocation and withdrawal practices are creating conflict and upsetting natural systems, and when contamination threats to ground water from human activities are pervasive, we cannot afford to come up short in our ability to ensure an adequate water supply for our nation's future. Without the benefit of reliable and comprehensive data on the quantity and availability of ground water resources, it is difficult to support pivotal and increasingly contentious decisions regarding the allocation of ground water resources among states, regions, communities, and a variety of competing uses.

According to a July 2003 report by the United States General Accounting Office (GAO)—"National water availability and use has not been comprehensively assessed in 25 years, but current trends indicate that demands on the nation's supplies are growing." The National Ground Water Association (NGWA) has stated: "We lack fundamental data necessary to understand adequately the nation's ground water resources and make informed decisions regarding its use and management." (NGWA, 2004) And according to a June 2004 GAO report, ground water level data are not being collected by any federal agencies on a national scale; although the U.S. Geological Survey (USGS) and National Park Service are collecting data on a regional basis.

GROUND WATER LEVELS 1991 – 2001
MONROE COUNTY, MICHIGAN

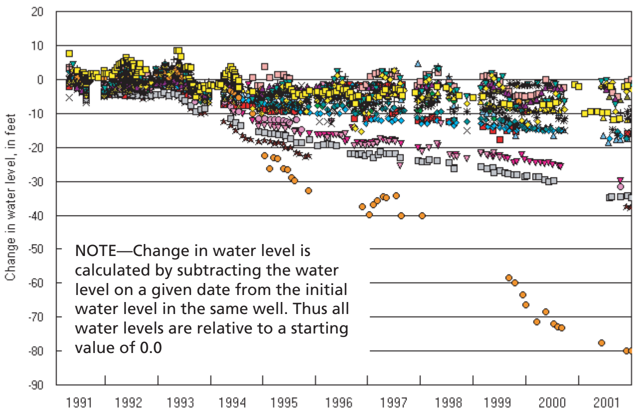


***Figure 1:** This chart shows the change in ground water level in USGS observation wells in Monroe County, Michigan, from 1991 to 2001 (Nicholas and others, 2001). During this time period, ground water levels declined 10 feet or more in 17 of the 33 USGS observation wells in the County.*

Source http://mi.water.usgs.gov/splan6/sp11000/monroe.php

The need to expand research and monitoring efforts and develop a comprehensive, consistent, and reliable database from which to better understand and characterize existing conditions, identify existing and potential problems, establish priorities, and develop viable water policies and strategies is at the very least compelling. Current programs of acquiring and managing water-monitoring data are inadequate to meet our water quantity and quality challenges.

The potential for severe economic consequences has not been exaggerated. Policy makers at all levels of government will be faced with crucial decisions regarding growth and development alternatives and tradeoffs. These decisions must be based on high-quality data. Because our water resources are integrated, decisions in one area can have negative repercussions in other areas. With adequate and reliable monitoring programs and data, such negative consequences can be managed and minimized.

In this report, the Ground Water Protection Council is adding its voice to a growing chorus of distinguished entities (e.g., NGWA, GAO, the National Science and Technology Council's Committee on Environment and Natural Resources) that have carefully assessed our ability to secure sustainable freshwater resources and have decried the overall lack of fundamental ground water data and a system for managing such data.

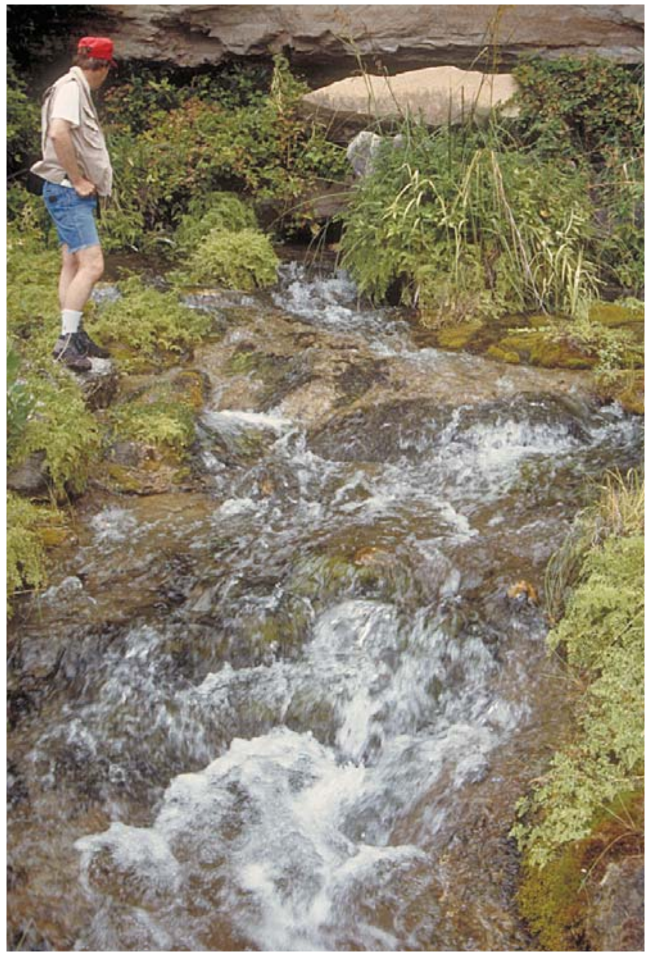


Photo: Copyright © Larry Fellows, Arizona Geological Survey

This karst spring in Val Verde County, Texas, issues from the Edwards Aquifer at the edge of the Edwards Plateau.

CHARACTERIZING AND MONITORING THE GROUND WATER SYSTEM

As stated by the NGWA (2004), "Obtaining accurate data on water use and the sustainable yield of aquifers, knowing past and current land-use and pumping rates as well as identifying human and ecosystem water needs are integral to managing and protecting the nation's ground water resources." In this regard, we have a lot of catching up to do in understanding the status and relationships of our ground water and ground water/surface water systems. For example, one of the most fundamental realities concerning surface water and ground water is that they are, in many cases, hydraulically connected—what happens to one affects the other. Yet this crucial fact has been all too often ignored in water management considerations and policies.

Since ground water is out of sight and less accessible than surface water, it is more difficult and expensive to monitor with respect to quality, quantity, and movement in specific aquifers. It is relatively simple to take a water sample from a stream in order to monitor surface water, but it takes drilling and well sampling to monitor ground water. In layered aquifers, sampling is even more expensive and complicated because it is necessary to determine which layer(s) should be monitored, which may entail coring the formation ahead of time. (Winter et al. 1998)

Ground water management should be aquifer-based and an integral part of watershed management. Aquifers are the natural units of management for ground water within the watershed context. For example, we can only get a complete picture of the impacts, or potential impacts, of contamination sources by monitoring the whole watershed, including ground water. When determining the Total Maximum Daily Load (TMDL) for a stream segment, it is critical to monitor the ground water contributing to the stream. It is incorrect to think that ground water/surface water resource protection and development decisions can be made in the absence of a comprehensive resource assessment.

OUR INCOMPLETE RESOURCE ASSESSMENT

Currently, our understanding of ground water availability and quality is like a jigsaw puzzle with a substantial assortment of missing pieces—the insufficient data. This shortage of critical ground water information was recognized by the Subcommittee on Water Availability and Quality, part of the National Science and Technology Council's (NSTC's) Committee on the Environment and Natural Resources, in its November 2004 report *Science and Technology to Support Fresh Water Availability in the United States.*

The NSTC is a cabinet-level council, and it is the principal means for the President to coordinate science and technology policies across the federal government. An important objective of the NSTC is the establishment of clear national goals for federal science and technology investments. The 2004 report focuses on science issues and policy related to needed

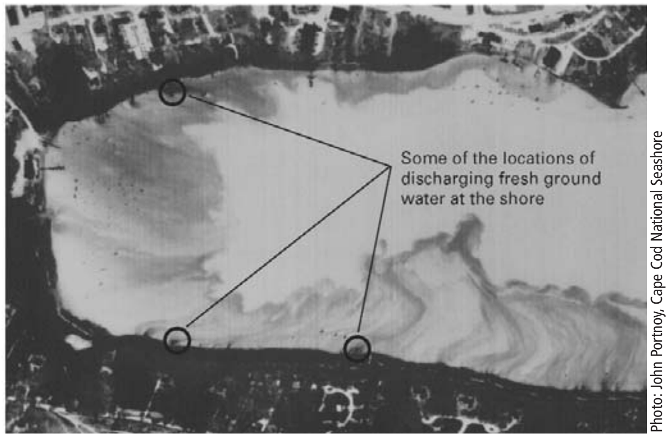


Figure 2. *Aerial thermal infrared scan of Town Cove, Nauset Marsh on Cape Cod, Massachusetts. Discharging fresh ground water is visible as dark (relatively cold) streams flowing outward from shore over light-colored (warm) but higher density estuarine water. Data were collected at low tide at 9:00 p.m. eastern daylight time on August 7, 1994.*

Source: USGS Circular 1262

improvements in technology and research that will advance the goal of ensuring a safe and sustainable supply of water in the United States for human and ecological needs.

The report does a good job of defining the problem, providing recommendations for action, and identifying the types of information that needs to be collected from monitoring efforts in order to answer important questions. It also does a good job of acknowledging the importance of ground water and specifically states the need for "renewed synthesis and collection of ground water resources data on the regional and national scale through process-based regional assessments of the nation's ground water resources." This is perhaps the strongest statement of need and urgency for monitoring that has come from the federal level in quite some time.

USEPA and State Monitoring Programs

Section 106(e)(1) of the Clean Water Act (CWA) requires USEPA to determine that a state is monitoring the quality of navigable waters, compiling and analyzing data on water quality, and including this information in the state's Section 305(b) report prior to the award of Section 106 grant funds. However, states are not required to report on ground water quality and conditions.

In March 2003, USEPA took the step of publishing the guidance *Elements of a State Water Monitoring and Assessment Program,* which states were expected to follow in developing strategies and plans to monitor their water resources. The guidance "...recommends the basic elements of a state water-monitoring program and serves as a tool to help EPA and the state determine whether a monitoring program meets the prerequisites of CWA Section 106(e)(1)" (from cover memo).

The first of ten required "elements" of the guidance says that state monitoring strategies are to address all state waters, including ground water. According to the results of a GWPC-NGWA 2006 Survey of State Ground water Programs, 30 states have included some ground water monitoring component in their monitoring program strategies, but the amount of USEPA support or emphasis placed on the ground water components of the strategies varies among regions.

There are several reasons why ground water monitoring is often either left out or minimized in many state strategies:

- Those at USEPA responsible for coordinating with states to develop strategies are largely in the agency's surface water monitoring programs (i.e., National Pollutant Discharge Elimination System [NPDES] and Total Maximum Daily Loads [TMDLs], so coordination with states focuses primarily on state surface water programs, and not state ground water programs. Clearly, the lack of a viable ground water program within USEPA creates a void for communicating the ground water portion of the strategy guidance to state ground water monitoring programs.
- Federal funding to support state surface water and ground water programs comes from the same "pool" of grant monies—CWA Section 106. Without clear instruction from USEPA that the state monitoring strategy must address ground water as well as surface water, it is not in the best interest of state surface water (monitoring) programs to include a ground water monitoring component that would effectively divert resources away from and diminish their own efforts. And, only the monitoring described in these strategies is eligible for CWA Section 106 funding.

If a state monitoring strategy does not include a ground water monitoring goal, there is little basis for USEPA to press states to meet that goal or to assist them in meeting that goal by providing supplemental funding. Without such funding, many states do not have the resources to develop and implement a statewide, ambient ground water monitoring program. Given that the monitoring described in the strategy is to be completed within 10 years, many states have yet to begin any systematic ground water monitoring whatsoever. That being said, some states do have long-standing, strong ground water monitoring strategies and programs. Others have recently made progress.

USES OF RECHARGE POTENTIAL MAPS

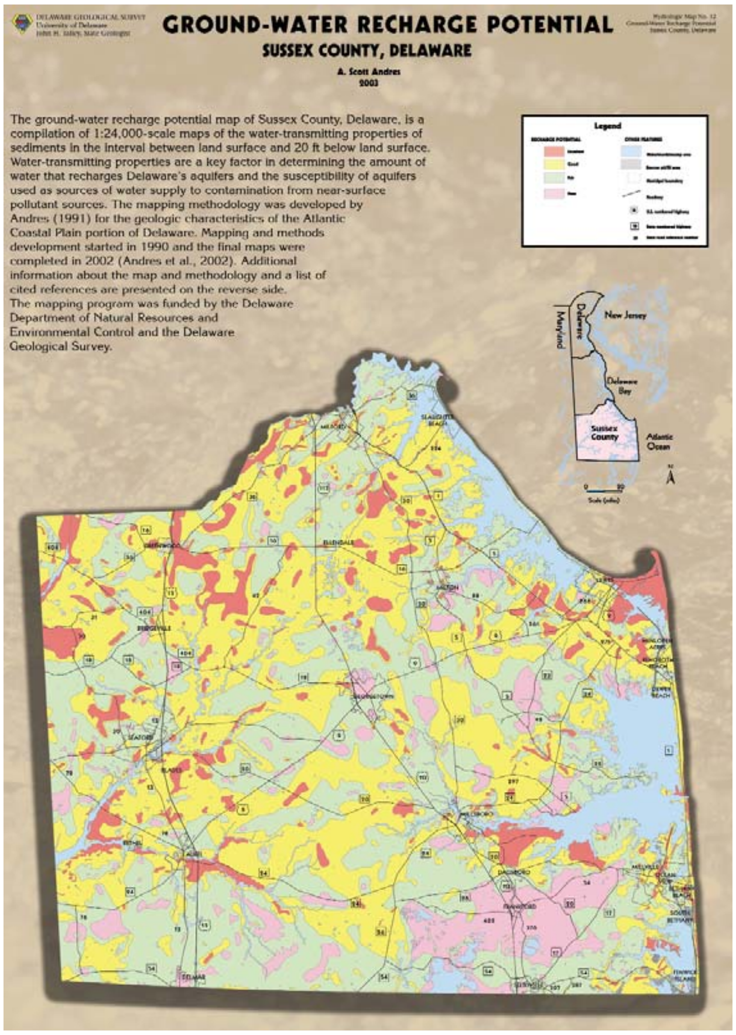


Figure 3. *The ground water recharge potential map of Sussex County, Delaware, is a compilation of 1:24,000-scale maps of the water-transmitting properties of sediments in the interval between land surface and 20 feet below land surface. Water-transmitting properties are a key factor in determining the amount of water that recharges Delaware's aquifers and the susceptibility of aquifers used as sources of water supply to contamination from near-surface pollutant sources. The red in this map indicates excellent recharge potential, yellow =good, green = fair, and pink = poor.*

Source: http://www.udel.edu/dgs/Publications/pubsonline/hydromap12.pdf

TMDL STUDY IDENTIFIES GROUND WATER'S CONTRIBUTION TO PHOSPHORUS LOADING IN WASHINGTON STATE'S MOSES LAKE

Moses Lake has historically exhibited eutrophic or hypereutrophic conditions, and is listed as a federal Clean Water Act 303(d) "impaired waterbody." Phosphorus has been identified as the limiting nutrient for the lake. Based on characteristic uses of the lake, an in-lake total phosphorus concentration target of 0.050 mg/L has been proposed to manage water quality concerns. In order to develop an allocation strategy for phosphorus loading to the lake, a TMDL study was conducted by the Washington State Department of Ecology.

To better characterize the concentration and potential source of nutrients in ground water directly discharging to the lake, 12 lake-bed monitoring stations were installed. The majority of stations (75%) exhibited ground water organophosphorus (OP) concentrations above the 0.050 mg/L surface water target criteria. Concentrations of OP in ground water generally increased from north to south, paralleling increases in concentrations of parameters that indicate anthropogenic (human-caused) impact to water quality.

A statistically significant relationship was established between OP concentration and the relative percentage of urban development upgradient of each station. These findings suggest that urban releases of wastewater to the aquifer are the primary source of phosphorus entering the lake via ground water discharge. Loading calculations predict an annual OP mass flux to the lake from approximately 400 to 40,000 kgop per year via ground water discharge, with a value from 10,000 to 20,000 kgop per year considered the best estimate of field conditions.

Source: http://www.ecy.wa.gov/pubs/0303005.pd

PERSPECTIVE MODEL OF THE BASE OF THE SANTA FE GROUP AQUIFER SYSTEM

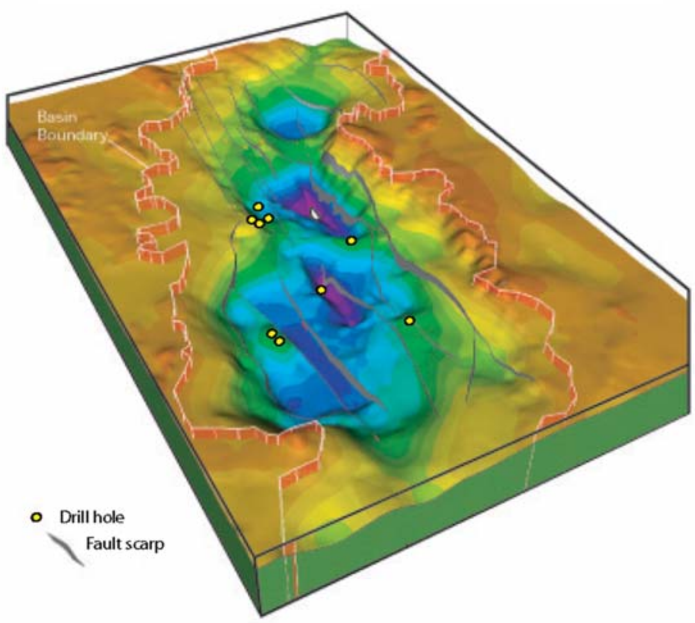


Figure 4. *Perspective view of the southern part of a model of the Middle Rio Grande Basin showing the base of the Santa Fe Group aquifer system. The model was derived from gravity data and constrained by information for the deep drill holes shown as yellow circles. (Courtesy of V.J.S. Grauch, USGS.)*

Source: http://pubs.usgs.gov/circ/2002/circ1222/pdf/chap3.pdf

For example, in Vermont, lawmakers recently (2006) gave a crucial jumpstart to a long-ignored law when they appropriated more than $300,000 to get a mapping program started. Although the Agency of Natural Resources has had the statutory authority to map the state's ground water since 1985, this is the first time money has been earmarked specifically for the purpose of mapping, which is an essential first step. As demand for ground water continues to grow (two-thirds of the state's population relies on ground water for its drinking water), the state's lawmakers are recognizing the importance of ground water and taking needed action toward passing comprehensive ground water protection legislation. As a start, the House passed a requirement that most large users of ground water report how much water they are using.

Recently, USEPA, along with the USGS and the Ground Water Protection Council (GWPC), has taken a very positive step to encourage ground water monitoring on a national scale. In January 2007, a national Subcommittee on Ground Water was formed by the Advisory Committee on Water Information (ACWI). Members include representation from USGS, American Society of Civil Engineers, NGWA, GWPC, Water Environment Federation, USEPA, Association of State Geologists, Interstate Conference on Water Policy, and the National Water Quality Monitoring Council.

The goal of the new subcommittee is to develop a national framework and network design for ground water monitoring, with particular emphasis on changes in the availability of potable water. Integrated monitoring design and consistent data reporting will improve information needed to make timely and economically efficient and effective ground water management decisions.

In 2006, the NGWA and the GWPC developed a detailed set of questions regarding ground water quality and quantity protection programs from a comprehensive list of ground water agencies. The results of this survey will help assess existing ground water quality and quantity data availability issues.

In late 2006 the American Water Works Association Research Foundation announced that it will survey utilities and user groups in an attempt to assess their interest in having accessible ground water quality and quantity data. The results of this study could be a catalyst for increased national interest and funding for a centralized ground water data center.

And What About TMDLs?

Short-changing attention to ground water monitoring has an impact on Total Maximum Daily Load (TMDL) development. Section 303(d) of the Clean Water Act requires states to identify waters that are impaired by pollution and to establish a TMDL of selected pollutants to ensure that water quality standards can be attained. TMDLs are intended to quantify all pollution sources, including point discharges from municipalities and industry and nonpoint sources.

A TMDL is a calculation of the maximum amount of a pollutant that a body of water can receive and still meet its designated use as determined by water quality standards. On that basis, a specified amount of pollutant becomes acceptable for discharge into the water body. In other words, a TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. If pollutant loads coming from ground water into surface water are not included in this calculation, then those pollutants are not being factored into the protection of a given water body.

Photo: Dan Hippe

Gary Holloway welds glass ampules for age dating ground water from a spring discharge from the Upper Floridan aquifer to a spring pond located in the Dougherty Plain of southwest Georgia.

Ground water can be a major contributor to streams and rivers, and contaminated aquifers that discharge to streams can thereby serve as nonpoint sources of contaminants to surface water. Quantifying the contribution is, therefore, a critical step in developing water quality standards and criteria, issuing permits, and meeting Clean Water Act goals for swimmable, fishable, and drinkable waters. Yet ground water inputs are typically not included in estimates of contaminant loads in streams. The TMDL process should include ground water so that all pollution sources will be considered and the process will be effective in protecting and restoring streams.

Likewise, surface water can be a major contributor to ground water, serving as a major nonpoint source of contamination to aquifers, particularly where high-capacity public water supply wells are located near streams and rivers. While ground water is generally thought to be safe for consumption without water treatment, ground water from wells located near streams can share the same contaminants as the surface water recharging the well. Water managers should consider such connections when developing source water and wellhead-protection strategies. (NAWQA, 2007)

WHAT DO WE NEED TO KNOW ABOUT GROUND WATER?

Hydrogeologic mapping and ground water monitoring networks (including ambient, impacted-area, and targeted monitoring) are needed to ensure the availability of quality data at the appropriate scale to make sound ground water planning, management, and development decisions. Information is necessary to determine:

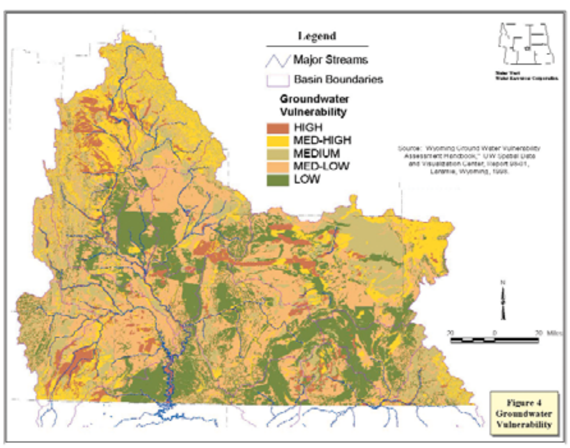
- Where ground water resources are located (both current and future sources of drinking water as well as ground water that may be more suitable for other uses).
- Where ground water/surface water interaction is occurring.
- How much ground water is sustainably available for human uses (i.e., the ability of the ground water resource to support current and additional population growth and development).
- How much ground water is needed to sustain healthy ecosystems.
- Location of ground water recharge areas.
- Background quality of ground water (i.e., ambient ground water monitoring).
- Appropriate uses of ground water of varying quality.
- Design and effectiveness of ground water management and protection programs.
- Short- and long-term changes in ground water recharge, storage, flow direction, and quality, as impacted by land use, land-use changes, climatic variability, and water use.
- Potential opportunities to artificially recharge the ground water supply in order to renew the resource and provide cost-effective water storage water for future use.

What Constitutes Sufficient Characterization and Monitoring?

Sufficient characterization and monitoring refers to the development of a comprehensive, consistent, and defensible database from which to better understand and characterize existing conditions, identify existing and potential problems, establish priorities, and develop viable water policies and strategies. It includes identifying the appropriate period of monitoring, the number of wells or stations per watershed, and the group of parameters monitored in order to represent adequate indicators of pollution.

An October 1993 USEPA document, *Ground Water Resource Assessment,* written during a time when ground water received a good deal more attention within the agency than it does today, contains valuable information that is as valid today as it was when the document was published. The document lists ten components that are necessary to characterize the physical and chemical properties of the ground water resource:

GROUND WATER VULNERABILITY AND CONTAMINANT SENSITIVITY MAPS



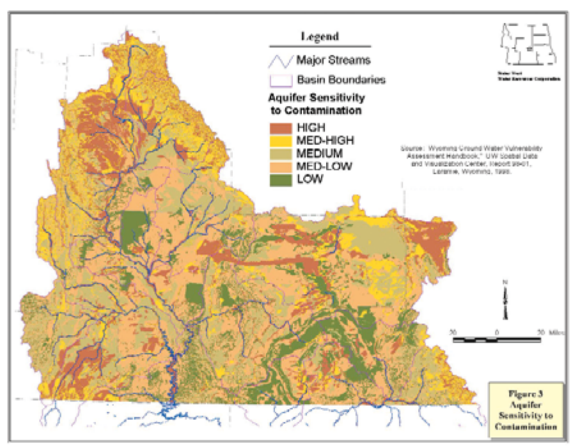


Figure 5. *The Wyoming Department of Environmental Quality, in conjunction with the Wyoming Department of Agriculture and USEPA, contracted with the University of Wyoming to develop statewide vulnerability maps to assess the tendency or likelihood for contaminants to reach a specified position in the ground water system after being introduced at a location above the uppermost aquifer. Ground water vulnerability maps were developed to determine the potential impact of anthropogenic influences on the ground water quality. The left map shows ground water vulnerability; the right map shows sensitivity to contamination.*

Source: http://waterplan.state.wy.us/plan/green/techmemos/swquality.html

MONITORING, MAPPING, AND RECHARGE AREAS: NEW JERSEY'S EXEMPLARY GROUND WATER CHARACTERIZATION PROGRAM

The State of New Jersey has put in place three essential ground water characterization and monitoring elements that serve as excellent examples of what can and should be taking place at state and national levels: an ambient ground water quality monitoring network, a subsurface mapping program, and ground water recharge mapping and ranking.

The Ambient Ground Water Quality Monitoring Network

The Ambient Ground Water Quality Monitoring Network (AGWQMN) is a NJDEP/USGS cooperative project. The original (pre-1999) network mainly focused on determining ground water quality as a function of geology throughout the state using public, private, irrigation, observation, and other types of existing wells. The goals of a recently completed redesigned network are to determine the status and trends of shallow ground water quality as a function of land-use-related nonpoint-source pollution in New Jersey. Most of the shallow wells used were installed by the New Jersey Geological Survey (NJGS) or its contractors to meet the goals of the redesigned network.

This network consists of 150 wells screened at the water table that are sampled 30 per year, on a five-year cycle. The first cycle was completed and the second started in 2004. The NJGS manages the network design, well installation, well maintenance, and data interpretation and reporting. The NJDEP Bureau of Fresh Water and Biological Monitoring and USGS collect the well water samples, and the USGS laboratory in Denver, Colorado, analyzes them. Chemical and physical parameters analyzed at each well include: field parameters such as pH, specific conductance, dissolved oxygen, water temperature and alkalinity, major ions, trace elements (metals), gross-alpha particle activity (radionuclides), volatile organic compounds, nutrients, and pesticides.

Source: http://www.state.nj.us/dep/njgs/geodata/dgs05-2.htm

Subsurface Mapping

The NJGS geophysicists assist the NJGS mapping section by providing remotely sensed subsurface information. This greatly increases the value of geologic maps by providing three-dimensional information (cross-sections). This is especially important where buried valley aquifers only occupy a narrow part of a river valley, but supply ground water to an entire region. NJGS also provides support to USGS to help establish the subsurface geologic framework.

Ground Water Recharge (GWR)

GWR refers to the water that infiltrates the ground and reaches the water table regardless of the underlying geology. It supports aquifer recharge, stream baseflow, and wetlands. New Jersey estimates recharge by using the methodology outlined in NJGS Report GSR-32, *A Method of Evaluating Ground-Water-Recharge Areas in New Jersey,* by E. G. Charles and others (1993). Application of this method using the Arc/Info geographic information system (GIS) produced 19 county and 20 watershed management area ground water recharge GIS coverages. The county recharge coverages were created by overlaying three coverages: (1) soils, (2) land use and land cover, and (3) municipalities. These three coverages provided the following attributes: soil series names, land-use and land-cover (LULC) categories, and climate factors, respectively. These data were then used to calculate ground water recharge values. The recharge factor and constant are determined by the cross tabulation of LULC and soil series. The climate factor is determined using zonal statistics and is a ratio of precipitation over potential evapotranspiration.

http://www.state.nj.us/dep/njgs/geodata/dgs02-3/mercer.htm - associated graphic

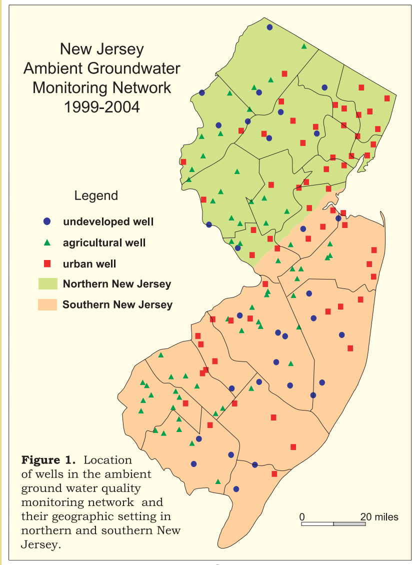


Figure 6. *Location of wells in the Ambient ground water quality monitoring network and their geographic setting in northern and southern New Jersey.*

- **Regional hydrologic setting:** Factors that control the regional occurrence, movement, and availability of ground water.
- **Aquifer and aquifer-system occurrence:** Real distribution and three-dimensional position of aquifers in the geologic setting.
- **Water table levels:** The upper surface of the saturated portion of an aquifer.
- **Hydraulic properties:** Soil, rock, sediment, and other geologic materials that govern the movement of water into, through, and out of an aquifer.
- **Confinement and interaction among aquifers:** Ease with which leakage among aquifers occurs—greater confinement, less interaction.
- **Ground water recharge and discharge characterization:** Where and at what rate ground water is recharged by precipitation and discharged to a water body or land surface.
- **Ground water and surface water interaction:** Where and at what rate water moves between ground water and surface water, including stream baseflow. Baseflow is a critical parameter that is typically not adequately established. It is important in relation to quantifying ground water contribution to surface waters, especially in relation to modeling TMDL.
- **Ground water budget:** An accounting of all natural and anthropomorphic removals from and additions to the ground water system.
- **Chemical and physical characteristics of ground water and overlying and underlying materials:** Characteristics that impact water quality and affect the fate and transport of contaminants.
- **Ambient ground water quality:** The quality of ground water at a baseline time selected by the decision-making agency (ambient quality refers to the natural quality of ground water or may be the quality as affected by widespread historical contamination).

The last point is especially prescient. Ambient monitoring has been and still is being ignored by most states and federal agencies, which focus instead on regulatory compliance and enforcement of standards that have been developed largely on the basis of impacts of contaminants on humans. This information has little value for evaluating the benefits of environmental regulation to the health of ecosystems. For the latter we must design ambient monitoring networks that combine chemical, microbiological, hydrogeological, and biological parameters. These networks must be designed to be free from the direct influence of point-source pollution in order to reflect how the entire system is reacting to all the regulatory measures and BMPs on which millions of dollars are being spent.

THE NAWQA MODEL FOR GROUND WATER MONITORING

The USGS implemented the National Water Quality Assessment (NAWQA) Program in 1991 to develop long-term consistent and comparable information on streams, rivers, ground water, and aquatic systems in support of national, regional, state, and local information needs and decisions related to water quality management and policy. The program is directed at answering the following questions:

- What is the condition of our nation's streams, rivers, and ground water?
- How are these conditions changing over time?

USGS Chief Hydrologist, Bob Hirsch, experiences karst terrain firsthand while kayaking on Cedar Creek, located about 20 miles south of Winchester, Virginia. Cedar Creek is a tributary of the North Fork of the Shenandoah River. In 2005 there were two streamgages on Cedar Creek,

WHAT IS A PRINCIPAL AQUIFER?

A principal aquifer is defined as a regionally extensive aquifer or aquifer system that has the potential to be used as a source of potable water. An aquifer is a geologic formation, a group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. Aquifers are often combined into aquifer systems.

Source:http://water.usgs.gov/nawqa/studies/praq/images/USAaquiferMAP11_17.pdf

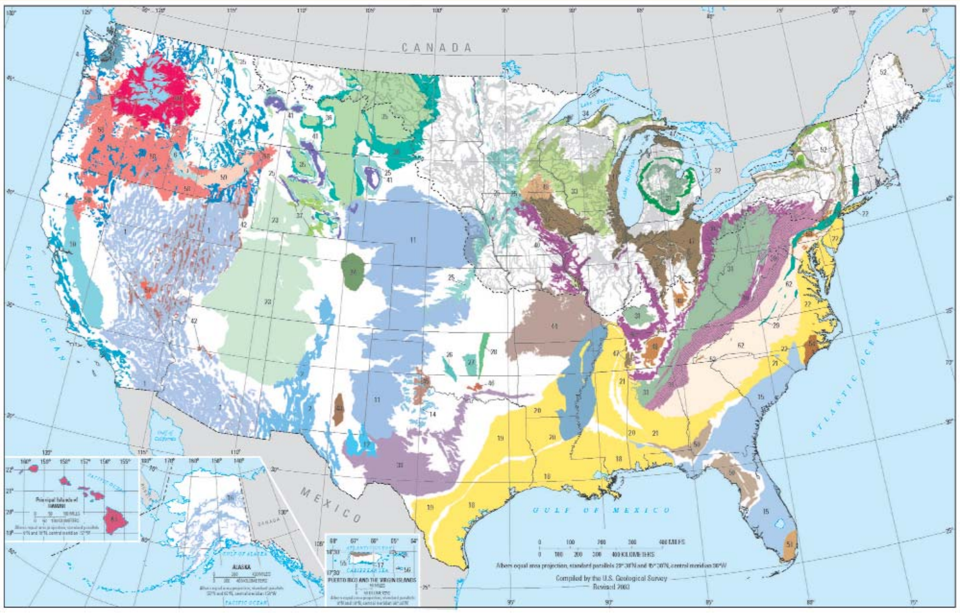


Figure 7.

- How do natural features and human activities affect these conditions, and where are those effects most pronounced?

Through NAWQA, USGS scientists collect and interpret data about surface and ground water chemistry, hydrology, land use, stream habitat, and aquatic life in parts or all of nearly all 50 states using a nationally consistent study design and uniform methods of sampling analysis. Their work is a major and positive step in the direction of what should be happening nationwide at a far more expansive level of aquifer coverage.

From 1991–2001, NAWQA conducted interdisciplinary assessments and established a baseline understanding of water quality conditions in 51 of the nation's river basins and aquifers, referred to as "study units." Descriptions of water quality conditions in streams and ground water were developed in more than a thousand reports. Nontechnical "summary reports," written primarily for those interested or involved in resource management, conservation, regulation, and policy making, were completed for each of the 51 study units. Nontechnical national summary reports on pesticides, nutrients, and volatile organic compounds (VOCs) were also completed, comparing water quality conditions to national standards and guidelines related to drinking water, protection of aquatic life, and nutrient enrichment. (*http://water.usgs.gov/nawqa/)*

A major focus of the NAWQA Program in its second decade (2002–2013) is on regional- and national-scale assessments of ground water status and trends in principal aquifers. The USGS Office of Ground Water has identified 62 principal aquifers in the United States, about one-third of which are the focus of water quality assessments at the principal aquifer scale by NAWQA. (See Figure 7.) The principal aquifer assessments consider the physical setting of the aquifer, in addition to its susceptibility and vulnerability to contamination.

A brand new USGS publication *The National Water-Quality Assessment Program—Informing Water-Resource Management and Protection Decisions* (2007) documents its many projects and provides numerous examples of how the data their efforts has generated has been used by states to initiate and support critical ground water protection programs and activities.

MOVING TO A WATERSHED PARADIGM

Characterizing and monitoring ground water must be carried out within the natural boundaries of the three-dimensional watershed (i.e., including both surface water and ground water). The notion of watershed monitoring has been much discussed; however, little attention has been given to scoping out details of what is needed. It is difficult for some groups to agree on how to define a watershed; and when they do agree, they may still not know how to delineate the actual boundaries. To this end, USGS has developed a series of hydrologic unit codes (HUCs) to aid in ground water assessments.

Much more research is needed, however, in order to better understand how we can move to a true watershed paradigm that includes both surface water and ground water dimensions. The following are examples of the type of work that is needed:

- Develop a scientifically acceptable definition of a watershed.
- Develop methods of delineating watershed boundaries.
- Develop remote-sensing techniques to locate areas of ground water/surface water interaction within identified boundaries.
- Develop methods for quantifying ground water contribution as baseflow to surface waters.
- Develop methods for calculating a water budget for a given watershed.
- Develop geophysical methods for locating and describing the morphology of conduits and channels through which interaction between surface and ground water is likely.
- Apply water-aging and tracing (e.g., dye, isotope, bacteriophage) techniques to help in quantifying ground water or surface water sources within a watershed.
- Conduct basic research to develop numerical models to use in multiporosity aquifers that are interacting with surface waters.

GETTING ORGANIZED

A plan for organizing available ground water resource information, determining data gaps, and assigning responsibilities for moving forward with a coordinated program sounds logical, but it is not happening. As the GAO points out in its June 2004 report *Watershed Management: Better Coordination of Data Collection Efforts Needed to Support Key Decisions*: "The coordination of water quality data is falling short of its potential." The problem is even more acute with regard to the status of ground water data collection and coordination.

The GAO report identifies the following four key factors that impede effective water quality—and we would add to these water quantity, data collection, and coordination:

- Significantly different purposes for which groups collect data.
- Inconsistencies in data-collection protocols.
- Lack of awareness on the part of data collectors as to which entities collect what types of data.
- Low priority given to data coordination.

It is incumbent upon us to complement and reinforce the NGWA position (2004) pertaining to action the federal government should take to organize long-term ground water quality and quantity monitoring efforts, including:

- Synthesizing, in coordination with state and local governments, existing data and identifying data gaps.
- Developing guidelines that set out a consistent methodology for data collection to enable data sharing.
- Developing guidance for establishing ground water monitoring networks in differing hydrogeological settings.
- Establishing milestones to measure progress in reaching data-collection goals and committing to provide adequate funding to reach those milestones.
- Promoting the use of more robust data sets to better inform and reduce the uncertainty of incorporating federal requirements into state and local ground water decision making, such as decisions regarding the application of the Endangered Species Act.
- Developing statistical analysis guidelines for identifying long-term trends for each basin, aquifer, or watershed (choosing which depends on how extensive and well planned the monitoring network is).
- Establishing a national clearinghouse to store or link collected data.

Recommended Actions

In addition to the recommended actions listed here, the Ground Water Protection Council supports the recommendations (and was part of the working group that developed the recommendations) contained in the National Ground Water Association's (NGWA) "Ground Water Level and Quality Monitoring Position Paper" (April 2006).

To Congress:

- **Support the efforts by, and provide the necessary funding to, federal and state geologic surveys and water resource agencies to further hydrogeologic mapping and ground water monitoring networks (e.g., ambient, impacted-area, targeted) needed to understand, manage, and protect the nation's ground water resources.**

To USEPA:

- **Ensure that ground water is clearly identified as an integral part of EPA's strategic plan, national monitoring strategy, and other federal agency resource management plans. Specific changes should include:**
  - Giving states flexibility in their use of the Clean Water Act §106 and §319 funding for ground water protection.
  - Guidance to states to include ground water as part of state monitoring strategies and monitoring reports, such as Clean Water Act §305(b) reports.

To USGS:

- **Ensure the availability of quality data at scales amenable to watershed-based decision making associated with water planning and allocation, management, and development, especially in watersheds that may cross state boundaries and jurisdictions.**
- **Continue to actively support, including financially, the Advisory Committee on Water Information's Subcommittee on Ground Water.**

To Governors and State Legislatures:

- **Provide funds to establish, operate, and maintain ground water quality and quantity monitoring networks that include ambient, targeted, and impacted areas.**

Policy makers at all levels of government will be faced with crucial decisions regarding growth and development alternatives and tradeoffs. These decisions must be based on high-quality data.

Photo: JECO Photo

NEW TECHNOLOGIES FOR TRACKING GROUND WATER FLOW AND NUTRIENT TRANSPORT TO DELAWARE AND MARYLAND COASTAL BAYS

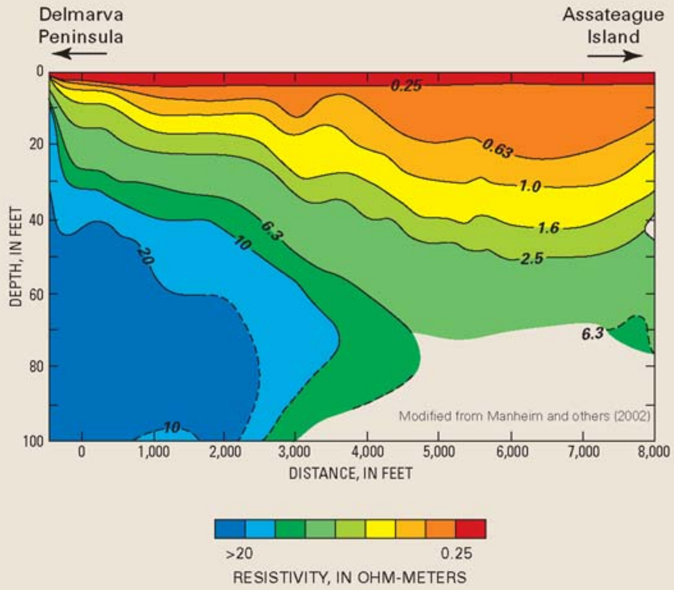


Figure 8. *Innovative drilling and geophysical techniques have been used to map the sediments that make up the surficial aquifer and to determine the water chemistry and age of ground water beneath the bays. For example, in the photograph on the left, researchers are sampling sediment coring and ground water quality from the USGS Hoverprobe in a tidal wetland of Maryland. Drilling is done by hydraulic vibracore equipment in the center of the hoverprobe craft. The map on the right depicts a representative resistivity profile across Chincoteague Bay, Maryland. The blue zones are interpreted to be fresh ground water flowing from the upland area west of the bay and mixing with saltwater beneath the bay (shown by the yellow to red zones).*

Source: http://pubs.usgs.gov/circ/2003/circ1262/

Section 3 References: Ground Water Resource Characterization and Monitoring

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