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The National Water-Quality Assessment Program—Science to Policy and Management

In 1991, the U.S. Congress established the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) to develop long-term, nationally consistent information on the quality of the Nation's streams and ground water, and thereby support scientifically sound decisions for water-quality management, regulation, and policy decisions. The objectives of NAWQA are to assess the status and trends of national water-quality conditions and to understand the factors and processes that govern those conditions, thus, addressing the questions:

1. What is the quality of the Nation's streams and ground water?
2. How is water quality changing over time?
3. How do natural factors and human activities affect the quality of streams and ground water?

NAWQA Science to Decision Making:

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NAWQA's role in responding to national water-resource questions

Our water resources are the basis for life and our economic vitality. These resources support a complex web of human activities and fishery and wildlife needs that depend upon clean water. Population growth and increasing demands for water, however, coupled with contamination from point and nonpoint sources, threaten the quality and quantity of our water resources.

Increasing demands for multiple beneficial uses, such as for drinking, agriculture, aquatic ecosystems, and recreation is challenging at all levels—local, State, interstate, and national—and requires us to better prioritize our water needs for high quality water, in conjunction with economic considerations. Three water-quality challenges make these choices even more difficult, including:

- Most water-quality problems are caused by diffuse "nonpoint" sources of pollution from agricultural land, urban development, forest harvesting, and the atmosphere. These sources are more difficult to monitor, evaluate, and control than point sources, such as discharges of sewage and industrial waste. Pollution from nonpoint sources varies in amount from hour-to-hour and season-to-season, making it difficult to monitor and quantify the sources over time.

- Water-quality issues have become more complex. Forty years ago, concerns about water quality focused largely on the sanitary quality of rivers and streams. Specifically, we were interested in bacteria counts, nutrients, whether there was enough oxygen in the water for fish, and a few measures like temperature and salinity. While these factors are still important, over the last 25 years new and more complex issues have emerged. Hundreds of synthetic organic compounds, like pesticides and volatile organic compounds (VOCs) in solvents and

"In 1991, Congress established the National Water Quality Assessment to answer a critical question that any policymaker should be concerned about: Are the nation's waters becoming cleaner or more polluted? By answering this question, policy-makers and professionals concerned about clean water are able to gage whether efforts undertaken since passage of the Clean Water Act of 1972 are having the desired effect. NAWQA is the only non-regulatory federal program that provides long-term, scientifically-based monitoring of our Nation's streams and groundwater. WEF members—water quality practitioners—depend on the information NAWQA collects in order to do their jobs. The watershed approach calls for targeting limited resources in order to achieve the greatest water quality benefit, and reliable information about the sources and magnitude of water pollution is needed to make these targeting decisions. NAWQA is the only program that provides consistent and comparable information across the nation on water-quality conditions and ecosystem health. NAWQA is succeeding in its mission and should enjoy the full support of this Administration." (Bill Betera, Executive Director, Water Environmental Federation, Fall 2005)

gasoline products have been introduced into the environment. Over the last ten to fifteen years, improved laboratory techniques have led to the "discovery" of microbial and viral contaminants, pharmaceuticals, and hormones that could not be measured before. Because these "emerging contaminants" have not been monitored previously, it is difficult to assess their effects on water quality and aquatic ecosystems.

- Evaluation and monitoring of pollution sources and the general state of U.S. water resources have been limited because available information is fragmented. Data must be pieced together from a variety of sources and studies, many of which are not designed to characterize nationwide water quality or changes over time. For example, state water-quality data have been inconsistent in types of information, analytical methods, and temporal and spatial scales. Therefore, as stated by the U.S. General Accounting Office in March 2000 in their report to the Congressional Subcommittee on Water Resources and Environment, and in subsequent reports in 2004 and 2005, the precise extent of water-quality problems, the nature and location of the severe problems, and the location of high-quality waters that need to be protected are still uncertain.

NAWQA's unique design

It is important to understand that a single monitoring design cannot solve all of our Nation's water-resource challenges or issues. For example, depending on specific interests or responsibilities, one might ask:

- Is the water meeting beneficial uses; that is, is it acceptable for drinking or swimming or irrigation or for sustaining aquatic habitat?
- What percentage of streams is impaired within a State?
- Are regulatory requirements being met?
- How does water quality of one water body compare with those nearby or across the Nation?
- Is water quality getting better or worse? Does it change during certain times of the year?
- What are the sources of contamination and causes of the problems?
- How do changes in land use or management practices affect water quality?

Key questions that NAWQA is answering...

- What contaminants are found in the Nation's rivers, streams, and aquifers?
- Are contaminants in water, sediment, and fish tissue present at levels of concern for human health and aquatic ecosystems?
- What is the condition, or health, of aquatic communities in streams and rivers, and what environmental factors most influence biological communities?
- What contaminants occur in streams and ground water used as drinking-water sources?
- Is water quality changing over time and at what time scales—seasonal, annual, decadal, or longer?
- Are water-quality conditions better or worse at certain times of the year?
- How do agriculture and urban development affect water quality?
- Do natural features make some streams and ground water more vulnerable to contamination than others?
- How do human modifications of hydrologic systems affect the movement of contaminants through the environment?

Different types of monitoring—such as "probabilistic" and "targeted" designs—answer different sets of these types of questions. NAWQA employs a targeted design, which brings an understanding of the relations between water quality and the natural and human factors that affect water quality in different places and through time (see inset for types of questions NAWQA is answering). Other monitoring designs may vary in the timescales and spatial scales covered and answer different sets of questions. For example, probabilistic designs are useful and cost-effective for getting an unbiased, broad geographic snapshot of whether there is a problem, and how big the problem is, answering questions such as "*What percentage of the Nation's waters is impaired?, and What percentage of streams is meeting their beneficial uses?*" Although the different designs answer different sets of questions, they both contribute to statewide, regional, or national assessments, and improve understanding of the water resources. The designs cannot, and should not, however, substitute for one another. In contrast, continued focus should be on the integration of findings that can take us beyond what each design can provide individually, particularly in predicting conditions in unmonitored areas and forecasting conditions in the future.

Characteristics that define the NAWQA Program include:

- *NAWQA adheres to a national design that stresses consistent sampling and analytical methods.* This allows Program goals to be addressed at multiple scales, ranging from local to national. The design ensures that water-resource conditions—including chemical, biological, and physical characteristics—in a specific locality or watershed can be compared to those in other geographic regions and can be combined for national assessment. NAWQA thereby builds local knowledge about the condition of water resources, emerging issues, and controlling processes in specific basins and aquifers. At the same time, it builds an understanding of how and why water conditions vary regionally and nationally. Consistent and systematic information collected over many years helps to distinguish long-term trends from short-term fluctuations. Analysis of long-term trends is essential for assessing how environmental controls and best management practices are working and for choosing cost-effective strategies for the future.
- *A targeted design,* in which study areas and sampling locations are chosen because they represent important environmental settings across the country. Data obtained are suited to answer questions, such as "*What are the causes of water problems, and how do land-use changes affect water quality*?" The NAWQA design targets sites that represent certain land uses, such as agricultural and urban areas, and samples them over a range of hydrologic conditions to assess seasonal or climatic effects. Statistical and process-based models are used to address specific questions, with a focus on the linkages among sources, transport, and fate of contaminants. Understanding how water moves and is transported is the key to ultimately understanding and predicting the fate of contaminants in the environment and their effects on human and ecosystem health. The knowledge gained by this approach helps decision makers to identify streams, aquifers, and watersheds that are most vulnerable to contamination; target actions based on causes and sources of contamination; and monitor and measure the effectiveness of those actions over time.
- *Long-term and cyclical activities* so that trends in water quality can be analyzed to determine whether conditions are getting better or worse.
- *An interdisciplinary approach* that links chemical and physical conditions of streams (such as flow and habitat) with the biological status of fish, insect, and algae communities. Water conditions are evaluated in an overall hydrologic context, which is important because contaminants and their potential effects on drinking-water supplies and aquatic ecosystems vary over time and largely depend on the amount of water flowing in streams and discharging from aquifers. By incorporating interconnections among water quality, hydrology, and biological systems, NAWQA assessments address the susceptibility of specific groups of aquatic organisms to water-quality degradation and determine how biological responses vary among the diverse environmental settings across the Nation.
- *Consideration of the total hydrologic resource,* including conditions in streams, the unsaturated zone, underlying aquifers, and surface-water and ground-water interactions. These assessments are not limited to a specific site or water-resource issue but rather focus on the condition of the total resource in a hydrologic context.
- *Source-water-quality assessments* that characterize the quality of the available, untreated resource, such as river water supplying water- treatment plants and ground water withdrawn by domestic and public-supply wells. Findings complement monitoring of drinking-water supplies by Federal, State, and local programs, which focus primarily on post-treatment compliance with regulatory levels and other criteria established to protect human health. Such information provides a scientific basis for prioritizing water-resource decisions that involve competing demands for drinking water, irrigation water, aquatic ecosystem health, and recreation.
- *A human-health and ecosystem context* in which contaminant concentrations in water, sediment, and fish tissue are compared to available U.S. Environmental Protection Agency (USEPA) drinking-water standards, USGS health-based screening levels (http://water.usgs.gov/nawqa/HBSL), and national and international aquatic-life and sediment-quality guidelines to provide perspective on the potential importance of detected compounds on humans and aquatic organisms.

"The area studied by the NAWQA program is the most heavily populated and developed area in Alaska. We regard NAWQA as a high quality, scientifically credible assessment effort that has furnished a significant amount of new information on watersheds in this area for which no, or very limited, information previously existed. Of particular value was the program's comprehensive approach which included surface water, land use, conventional pollutants, toxic pollutants, habitat, physical conditions, and biological components. The information obtained through this program complements our state monitoring efforts to understanding of water quality conditions within the Cook Inlet Basin. The reports produced have been well-written, informative, and contained excellent data evaluations, graphics, and maps. They are frequently consulted for information, and will continue to be consulted as important references for managing the area's water resources." (Ron Klein, Alaska Department of Environmental Conservation, Division of Air and Water Quality, June 2004, USGS Circular 1240)

The comparisons are a starting point, not a substitute, for comprehensive risk assessments by other agencies, which would include consideration of additional avenues of exposure.

- *Integration of modeling and other scientific tools with monitoring* so that water-quality understanding can be extrapolated to unmonitored areas, trends can be forecasted, and future water-quality conditions can be better anticipated as a result of various resource- and land-management scenarios.
- *Integration of data from other organizations* into NAWQA assessments, where appropriate, so that findings more comprehensively span geographic and temporal scales, and remain relevant to local, state, regional, and national issues.
- *Commitment to high-quality products and readily accessible information* that meet the water-resource needs of a wide range of stakeholders through diverse formats. More than 1,200 technical and non-technical reports, water-quality data sets, maps of chemical use and occurrence, and models evaluating contaminant concentrations in the Nation's streams and aquifers are accessible at http://water.usgs.gov/nawqa. NAWQA manages a data warehouse that hosts more than 14 million records representing about 7,600 stream sites, 8,100 wells, and 2,000 water-quality and ecological constituents.
- *Collaboration and liaison* with Federal, State, and local governmental organizations, academia, public interest groups, professional and trade associations, academia, and the private industry to ensure relevance to local, State, regional, and national water-resource issues. NAWQA data continue to support national collaborative efforts such as the Heinz Center State of the Nation's Ecosystem Reports (http://www.heinzctr.org/ecosystems/index.shtml) and the U.S. Environmental Protection Agency State of the Environment Reports (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190806). In addition, the Program supports a National Liaison Committee, the multi-agency Gulf of Mexico Nutrient and Hypoxia Task Force, and the National Water Quality Monitoring Council.

NAWQA's Approach to Integrate Monitoring with Modeling

NAWQA assessments of water-quality conditions and their relations to natural and human factors provide a foundation for estimating the occurrence and distribution of selected chemicals at unmonitored sites under a range of possible circumstances, supported through the development and validation of statistical predictive models. (To learn more, access SPARROW and WARP).

The models are essential tools for cost-effective management of our water resources because managing contaminants requires far more information than we can afford to directly measure for all the places, times, and contaminants that are important. In addition, many management decisions—including how much to spend on implementing a management strategy, monitoring priorities, and approving a compound registrations—inherently depend on predicting the potential effects on water quality for locations that have never been measured.

The NAWQA models integrate information on water quality, chemical use, land use, and environmental factors that help to explain water-quality conditions over broad regions. In general, the NAWQA Program, thereby, uses a regression approach with results in expressions of statistical correlations between water-quality concentrations or detections and those natural or human factors that influence the concentrations. Specifically, modeled estimates are made from associating measurements of concentrations or frequencies with known contaminant sources (such as estimated chemical use), as well as land-management practices (i.e. irrigation and tile drains) and characteristics of each hydrology and landscape (i.e. soils, geology, and climate), both of which affect and control the transport of the chemicals within the watersheds and ultimately to streams, rivers, and ground water.

A strong emphasis is placed on the inclusion of data from other USGS programs, such as the National Stream Quality Accounting Network, and other Federal agencies, and regional, State, Tribal, and local organizations to maximize the use of stream-monitoring information for broad water-resource understanding.

Such tools are useful to water managers and scientists in assessing resource vulnerability and sustainability for future supply across broad regions and in developing cost-effective monitoring programs.

Progress

Assessments during 1991-2001

During its first decade or "Cycle 1" (1991-2001), NAWQA completed assessments in 51 major river basins and aquifers across the Nation. The assessments included sampling at nearly 500 stream sites and more than 5,000 wells. Together, the 51 assessments characterized the source of water for more than 60 percent of the Nation's drinking water and water for irrigation and industry. Each provided baseline data and information on the occurrence of more than 600 compounds, including pesticides, nutrients, volatile organic compounds (VOCs), trace elements, and radon in water, and on the condition of stream habitat and fish, insect, and algal communities. Chemical and biological measurements were assessed in relation to human activities, land use, and natural factors that can affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Observed conditions were compared to national water-quality standards, guidelines, and benchmarks to assess the potential effects of water-quality conditions on human health and aquatic life. National assessments were completed for pesticides in streams and ground water and VOCs in ground water.

NAWQA publications and data are readily available

Since 1991, the Program has published more than 1,300 documents, including books, journal articles, and USGS Circulars (http://water.usgs/gov/nawqa).The large NAWQA data warehouse on national water-quality conditions and other information is accessible over the Internet at http://water.usgs.gov/nawqa/data to all interested individuals and organizations. The data warehouse manages more than 14 million records representing about 7,600 stream sites, 8,100 wells, and 2,000 water-quality and ecological constituents. The NAWQA Program encourages the use of the national database for a wide range of analyses at national, regional, State, and local scales.

Assessments during 2001-2012

During the Program's second decade or "Cycle ll" (2001-2012), NAWQA continues to address the status of water quality by adding monitoring in geographic gaps, investigate new contaminants (such as new pesticides, wastewater compounds, and chemicals in personal care products), and address the occurrence of contaminant mixtures and degradation products. National assessments continue on nutrients, aquatic ecology, trace elements, pesticides, and, to a lesser extent, VOCs. Analysis and modeling efforts are done on a regional basis that considers surface-water-quality in eight major river basins and ground-water-quality in 19 of the Nation's 62 principal aquifers.

The Program focuses largely on trends and understanding factors affecting water quality. The NAWQA Program is assessing long-term trends at 113 stream sites that have more than 10 to 15 years of consistent water-quality data. In addition, about 40 percent of the ground-water networks sampled in Cycle I will be resampled in Cycle 2 to assess trends. NAWQA continues to assess how natural features and human activities affect water quality and understanding the key processes that control water-quality conditions. The increased focus establishes links among sources of contaminants, the transport of contaminants through the hydrologic system and the potential effects of contaminants on humans and aquatic ecosystems. Five key topics under study include: (1) the fate and transport of agricultural chemicals, (2) effects of urbanization on stream ecosystems, (3) effects of nutrient enrichment on stream ecosystems, (4) bioaccumulation of mercury in stream ecosystems, and (5) transport of contaminants to public-supply wells.

Increased emphasis is placed on the quality of source water and drinking water during Cycle 2 studies. In 2001, NAWQA initiated a national assessment of domestic wells, and a 10-year effort to assess the occurrence of more than 260 anthropogenic organic compounds in source water associated with drinking-water supply wells, stream intakes, and in finished water associated with about 50 large community water systems.

Meeting stakeholder needs

NAWQA findings to date have provided a significant and credible scientific basis for governmental decision makers, managers, and planners, as well as for those in nongovernmental organizations, industry, academia, and the public sector to cost-effectively address a wide range of water-quality issues related to natural and human influences on the quality of water and potential effects on aquatic ecosystems and human health. NAWQA findings highlight, for example, (1) natural and man-made contaminants in surface-water intakes and public-supply and domestic wells; (2) effects of agriculture and urbanization

on aquatic health, nutrient enrichment, and stream ecosystems; (3) the role of hydrology and contaminant transport on water quality, drinking water, and ecosystem health; and (4) changes in selected contaminants in streams and ground water over time.

Because each NAWQA assessment adheres to a nationally consistent study design and methods of sampling and analysis, the findings have proven relevant at all scales—local, State, regional, and national. Water-quality conditions in a specific locality or watershed can be compared to those in other geographic regions. At the same time, the consistent study design and methods allow contaminants and ecosystem health to be assessed on a comprehensive national basis, and help to understand how and why water quality varies regionally and nationally.

Local, State, Tribal, regional, and national stakeholders use NAWQA information to cost-effectively address a multitude of water-resource issues related to human health and aquatic ecosystems in different hydrologic and land-use settings across the Nation. For example, the information has proven useful to:

- Assess sources and transport of contaminants in agricultural and urban areas (p. 11);
- Assess vulnerability to help prioritize geographic areas, basins, and aquifers for management and protection (p. 17);
- Understand trends—whether conditions are getting better or worse over time (p. 18);
- Assess source-water quality used for drinking (p. 21);
- Assess and sustain aquatic ecosystem health (p. 28);
- Link tributaries to receiving waters (p. 32);
- Support development of regulations, standards, guidelines, and criteria for contaminants (p. 33);
- Contribute to State assessments of beneficial uses and impaired waters (Total Maximum Daily Loads or TMDLS), strategies for source water protection and management, pesticide and nutrient management plans, and fish-consumption advisories (p. 37);
- Improve strategies and protocols for monitoring, sampling, and analysis (p. 42);
- Communicate science to policy (p. 45)

Addressing National to Local Issues

"The U.S. Geological Survey (USGS) is responsible for the two main water-quality monitoring programs for the Nation's waterways. These are the National Water Quality Assessment Program (NAWQA) and the Toxic Substances Hydrology Program. These two programs are crucial to understand water quality. Without a long-term commitment to monitoring, the Nation will lose its ability to assess trends in water quality, impacts of climate change, impacts of new and under-studied contaminants, and efficacy of policy-decisions that impact water quality." (Nancy K. Stoner, Co-Director, Water Program, Natural Resources Defense Council, in a Testimony to the House Science Committee, March 4, 2009 21st Century Water Planning: The Importance of a Coordinated Approach)

"NAWQA is providing key national leadership in monitoring, reporting, and assessing the quality of surface water and groundwater resources across the Nation. Furthermore, NAWQA is playing a vital role in balancing its good science with responsiveness to policy and regulatory needs. Many states are using NAWQA data and findings in developing their resource management programs. This is a strong indication that NAWQA is providing valuable information to those managing water resources." (National Academy of Sciences, National Research Council, in [Opportunities to Improve the USGS National Water Quality Assessment Program], 2002)

"USEPA values USGS as the principal source of high quality, accessible, and useful data on the nature, location, and characteristics of our Nation's waters." (Tracy Mehan, former Assistant Administrator, USEPA Office of Water, June 2003)

"In partnership with the NAWQA Program, we collected a significant amount of ground-water-quality data that neither agency could have obtained individually. The data provide an important snapshot of the overall health of ground water –the region's primary source of drinking water. The information generated through this partnership will help our region formulate more effective ground-water management strategies in the future." (Michael P. Ekberg, Miami Conservancy District, June 2004, USGS Circular 1229)

"The NAWQA Program does an excellent job at reporting its high quality, credible, and unbiased information in an understandable way that creates the needed links between science and water-resource policy. Our organization, which is a leader of a nation-wide river movement made up of thousands of river and watershed groups, depends on the water-quality and ecosystem data generated from this Program to help support the protection of our Nation's rivers." (Betsy Otto, Watersheds Program, American Rivers, November 2004)

"The New England Coastal Basins NAWQA study has been very valuable to the U.S. Environmental Protection Agency's New England regional water programs. The study has provided contaminated sediment data which will be incorporated into our National and regional sediment inventories; has highlighted the importance of arsenic in drinking water wells in New England; and has established relationships between land use and environmental quality of rivers and streams, including flow, nutrient status, and biological communities. The data from, and the monitoring approaches of, the study will help the USEPA in its monitoring and regulatory roles." (Matthew Liebman, U.S. Environmental Protection Agency-New England. June 2004. USGS Circular 1226)

Addressing National to Local Issues, continued

"The USGS is an indispensable partner in local watershed management. The information from USGS is believable, dependable, scientifically sound, and—of greatest importance—immediately useful to those of us involved in day-to-day management of our watersheds. No other science agency has the same degree of local acceptance and relevance as USGS." (Mr. Dennis Bowker, Sacramento River Watershed Program, March 2001)

*"Southwestern Pennsylvania provides a good example of how a national-level program can generate water quality monitoring data at regional and local scales in a timely, responsive, and reliable manner that can be used in support of decision making. The NAWQA program, in particular, for several years sought to gain understanding of water quality conditions, trends, and stressors in the Allegheny and Monongahela basins but unfortunately, that focused effort has been terminated for budgetary reasons. Nonetheless, data collected on water quality are maintained by the USGS, are available to the public, and provide a long-term term, rich source to track changes and trends in water quality in the Allegheny Monongahela and Ohio Rivers." (*National Academy of Sciences Report, "Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania", 2004)

"The NAWQA study results from the upper Illinois River assessment are extremely valuable to assist with efforts of water resource planning and management, given the potential predicted population growth, limitations on the use of Lake Michigan and the status of the sustained recharge of the deep aquifer system in northeastern Illinois." (Richard Cobb, Illinois Environmental Protection Agency, 2001)

"The USGS National Water-Quality Assessment work is the only systematic, basin-wide water quality work in the Yakima River Basin, [Washington] and a really important contribution to the understanding of what is going on and what we can do about it—from sediment to flows to biological uptake. USGS work has always been professional and unbiased. There have been few other entities that have provided such high caliber research and data collection. USGS work is used and respected by all parties in a basin where water-related controversies drive politics. In order to deal with issues such as 'saving the salmon' and developing TMDL's we need to have 'independent third parties' such as USGS working in the basin." (Brent Renfrow, Washington Department of Fish and Wildlife, November 2002)

"The USGS provides us [U.S. Fish and Wildlife Service] with top quality data that both the development community and the environmental community can trust. The USGS in Austin excels in quality control, quality assurance, and accurate reporting of water-quality data. This type of information forms the primary basis for many scientific decisions. Without your support our only choice would be to assume the "worse case" scenario, which could have more impacts than necessary on the development [of] communities within Central Texas. We need more water-quality information to understand the true interactions of chemical pollutants with our environment." (Matt Lechner, U.S. Fish and Wildlife Service, Austin, Texas, March 2001)

"The NAWQA Program should be commended for putting together an excellent database on water quality conditions in the [San Joaquin] Basin. Their study, which was summarized in USGS Circular 1159, is an example of what can be done when the USGS staff cooperates with the state and local agencies within the basin. Working with other agencies, your staff identified the water-quality concerns that were a priority for these agencies and then developed the database to document, in a purely scientific way, the extent of that problem. Granted, this is not an end in itself but it set the stage for focusing resources within the watershed on the most serious issues."(Dennis W. Westcot, Environmental Program, California Regional Water Quality Control Board, August 6, 1998)

Coordination and Partnerships

It was recognized from the onset of the NAWQA Program that a national assessment by a single program could not possibly address or anticipate all current and future water-resource issues. Collaboration and coordination with numerous government, research, and interest-group partners, therefore, help to guide scientific efforts and ensure that NAWQA information will meet the needs of local, State, regional, and national stakeholders.

Partnerships and liaisons with environmental and natural resources managers, regulators, planners, and policy makers, from national to local, have involved over 1,500 organizations and individuals. Selected stakeholders are listed below.

- ***U.S. Environmental Protection Agency***—The U.S. Environmental Protection Agency (EPA) uses nationally consistent NAWQA data for their efforts related to GPRA performance measures; pesticide registration and regulations (resulting in

regulation of 17 compounds from 2003-2007); assessments of exposure and risk (such as related to the Food Quality Protection Act); source-water protection (as related to the 1996 Amendments to the Safe Drinking Water Act); aquatic life benchmarks (such as related to the Federal Insecticide, Fungicide, and Rodenticide Act); contaminant regulations (such as the Candidate Contaminant Listings); development of nutrient criteria; nutrient and pesticide management plans; stream protection and restoration; mercury emissions; fish consumption advisories; and monitoring strategies. Partnerships continue to be fostered with EPA regional offices and headquarter offices, including the Office of Pesticide Programs, Office of Wetlands, Oceans, and Watersheds, Office of Ground Water and Drinking Water, Office of Research and Development, and Office of Science and Technology. USGS continues to provide data to support the EPA *State of the Environment* Reports (2007 and 2012), as appropriate. For example, NAWQA national information contributes to indicators on nitrate and pesticides in streams and ground water in agricultural watersheds and on nitrogen and phosphorus discharges from large rivers to receiving waters.

> *"EPA has worked closely with the USGS NAWQA Program since it began in 1991, with the goal of advancing the scientific tools and data that are available to assess the potential risks posed by pesticides in surface water and ground water. Recently, EPA and USGS have collaborated in developing statistical models to predict concentrations of atrazine and other pesticides in streams around the country, including quantitative estimates of reliability. The models, developed by USGS from NAWQA data, increase EPA's capacity to estimate surface-water concentrations of pesticides. Model results are being used to identify locations where additional monitoring may be needed to evaluate the ecological condition of watersheds."* (Elizabeth Behl, Chief of Environmental Risk Branch, Office of Pesticide Programs, U.S. Environmental Protection Agency, 2006, USGS Circular 1291)

- ***The H. John Heinz III Center for Science, Economics, and the Environment (Heinz Center)***--The NAWQA Program continues its partnership with the Heinz Center to develop national indicators on nutrients (phosphorus and nitrogen), contaminants (including pesticides), and flow in streams and ground water. NAWQA data were used exclusively to develop 21 national indicators on nutrients (phosphorus and nitrogen) and contaminants (including pesticides) in streams and ground water, and were integrated in the development of 48 others in the 2007 analysis. This information is incorporated in the Heinz Center *State of the Nation's Ecosystems* Reports, periodically produced every 5 years (next anticipated in 2012). Building on the Heinz Center efforts, in 2009, NAWQA is developing National Environmental Status and Trends (NEST) water-quality and ecological indicators, an activity spearheaded by the U.S. Forest Service, Department of Interior (USGS), NOAA, and EPA.

> *"The Heinz Center depends heavily on NAWQA data to support our periodic report: "The State of the Nation's Ecosystems." NAWQA data provide the foundation of our description of chemical contamination—including pesticides and other compounds—both nationally and among different land uses, and for tracking how contaminant levels change over time. We appreciate NAWQA' strong commitment to making its information and data readily accessible to meet our organization's needs and to address the Nation's water-resource information needs."* (Robin O'Malley, Senior Fellow and Program Director, The H. John Heinz III Center for Science, Economics and the Environment, 2006, USGS Circular 1291)

- ***National Oceanic Atmospheric Administration (NOAA)***—The NAWQA Program works with NOAA's Integrated Ocean Observing System (IOOS), the National Ocean Service, and National Centers for Coastal Ocean Science in their efforts to protect estuarine and coastal waters, such as the Gulf of Mexico, by providing information on key sources, nutrient loadings, and watersheds that contribute to the transport of contaminants to receiving waters.

- ***Center for Disease Control (CDC))***—NAWQA collaborates with the CDC and provides chemical data to support its Environmental Public Health Tracking Network and overall efforts to relate environmental factors to cancer and other diseases.

> *"USGS provides local, State, and Federal agencies with top quality data and accurate reporting that both the farming community and environmental community can trust. NAWQA's ability to look at water quality over the long term helps to evaluate the effectiveness of water-management decisions, conservation activities, and certain farming practices that are used to reduce sediment and runoff of agricultural nutrients and chemicals from fields, such as related to conservation tillage, buffer strips along streams, manure management systems, and improved irrigation systems.* (Jeff Loser, USDA Natural Resources Conservation Service, June 2004, USGS Circular 1237)

- ***U.S. Department of Agriculture (USDA)***—NAWQA partners with USDA, including the Natural Resources Conservation Service (NRCS), Agricultural Research Service (ARS), Economic Research Service (ERS), NASS, and the Census of Agriculture, to enhance linkages between monitoring data and models with chemical use, sources of contaminants, land use, and conservation programs. The USDA pesticide

data program has adopted NAWQA's analytical chemical methods, which facilitates more consistent integration of data across agencies. In addition, NAWQA provides data and information to support the USDA Conservation Effects Assessment Project (CEAP) effort, for which USGS information and mass-budget approaches help to evaluate the role of hydrology and contaminant transport in evaluating the effectiveness of conservation and best-management practices on water quality in agricultural streams.

- ***State agencies***—Partnerships, in large part coordinated with the USGS Cooperative Water Programs, continue to develop with water-resource managers within State resource agencies who need information for the development of nutrient criteria, nutrient and pesticide management programs, implementation of Total Maximum Daily Loads (TMDLs), estuarine and coastal management, source-water protection, stream protection and restoration, fish consumption advisories, ground-water management, monitoring strategies, and development of water-quality benchmarks. NAWQA information is directly applicable to State needs (see inset). For example, in 2007, State regulatory agencies responsible for implementing the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requested the EPA to use NAWQA pesticide assessment and water-quality benchmarks for State pesticide regulations, which was agreed upon by EPA.

- ***Drinking-water community***—NAWQA continues to collaborate with the drinking-water community, which spans all levels of government and non-governmental organizations, utilities, universities, and the private sector, and which has an expressed need for information on relations between untreated water and human health and for practical indicators linking public supplies to the incidence of disease. NAWQA information helps water providers and other drinking-water practitioners, water managers, and those interested in drinking water policy to determine the vulnerability and sustainability of water resources for future supply, and to develop cost-effective monitoring programs. NAWQA continues its partnership and support of the national source-water collaborative—a group of about 20 governmental and non-governmental organizations striving towards improved dissemination of information and tools needed to protect source water and drinking-water supplies.

Addressing State Needs

"The U.S. Geological Survey's Willamette Basin NAWQA Program is a high quality, scientifically credible water quality assessment. The program took a comprehensive approach, which included ground water, surface water, land use, conventional pollutants, toxic pollutants, habitat, physical conditions, and biological components. The information obtained through this program complements our state monitoring efforts to provide a much more accurate and complete understanding of water quality conditions within the Willamette watershed. Such an understanding is essential to the wise and effective management of these treasured water resources and their protection for present and future generations." (Greg Pettit, Water Quality Monitoring, Oregon Department of Environmental Quality, 2001, USGS Circular 1161)

"The NAWQA program has shown itself to be capable of generating high quality data of direct benefit to State agencies. NAWQA has provided the model for how different programs should work together and benefit from each other's research." (Robert Bode, New York State Department of Environmental Conservation, 2001, USGS Circular 1165)

"The Central Nebraska NAWQA Study is an invaluable benchmark of water quality data. The facilitative approach between federal, state and local levels of government in data development lends undeniable credibility to the process, the data, and to programmatic applications." (Dayle E. Williamson, Nebraska Natural Resources Commission, 2001, USGS Circular 1163)

"Actual water-quality data shows us where our efforts to protect the environment are successful and what still needs to be done to prevent pollution. We depend on this valuable partnership with the U.S. Geological Survey, in cooperation with our communities, as we continue our work to protect and restore Pennsylvania's watersheds." (James M. Seif, Pennsylvania Department of Environmental Protection, 2001, USGS Circular 1168)

"The scientific and technical information contained in this [NAWQA] report provides valuable assistance in California's efforts to better understand and implement programs to address water resource issues—not only in the San Joaquin-Tulare Basins, but throughout the state." (Walt Pettit, California State Water Resources Control Board, 2001, USGS Circular 1159)

- ***Academia***—Partnerships continue with university researchers, the Academy of Natural Sciences, and the Consortium of Universities for the Advancement of Hydrologic Sciences (CUAHSI). For example, collaborative assessments with the Southern Illinois University Fisheries and Illinois Aquaculture Center and Department of Zoology continue on the potential effects of pesticide mixtures on aquatic organisms. Assessments of the relative importance and priorities for high-production volume chemicals; source-apportionment modeling of VOCs; and continued development of health-based screening levels (HBSLs) continue with the Oregon Health Sciences University.

- ***National Water-Quality Monitoring Council*** *(NWQMC)*—The NAWQA Program co-leads the NWQMC (composed of more than 50 representatives from other Federal, State, Tribal, and local agencies, non-governmental organizations, industry, and academia) in their effort to develop consistent methodology; common web services for data retrievals from

USGS and EPA in common formats; integrated water assessments based on data from multiple organizations and diverse sources; national water monitoring networks; and enhanced dissemination of information through periodic national conferences and workshops.

- ***National Liaison Committee*** – Since 1991, the NAWQA Program has included a National Liaison Committee, which is a subcommittee under the Advisory Council on Water Information. The Committee consists of about 100 representatives with water-resources responsibilities or interests from Federal, State, and regional organizations, academia, public interest groups, professional and trade associations, and the private industry, serving as a catalyst for scientifically informed examination of water quality issues and policy decisions. Specifically, the liaison committee meets about two times per year to 1) exchange information on findings and about water-resource issues of national and regional interest, 2) identify sources of data and information, and 3) provide feedback on any Program changes, design, and scope of products. In addition, this committee provides external reviews on prominent NAWQA documents and reports. Working groups and 1-1 collaborative efforts will continue to be developed as spin-offs from this committee to address specific issues of mutual interest, such as related to drinking water, water-quality benchmarks, and urban and agricultural issues.

- National Research Council—NAWQA seeks input from the National Academy of Sciences, National Research Council, which has conducted periodic reviews of the Program and makes recommendations to ensure the best use of current scientific methods and approaches in NAWQA assessments. To date, four favorable reviews (1986, 1990, 1994, and 2001) have been received. The last review identified NAWQA modeling capabilities integrated with monitoring as essential for understanding water-quality conditions and future water-resource management needs across the Nation.

Assessing Sources and Transport of Contaminants in Agricultural and Urban Areas

NAWQA studies indicate that contaminants are widespread, albeit often at low concentrations, in river basins and aquifer systems across a wide range of landscapes and land uses. Nationally, at least one pesticide was found in about 95 percent of water samples and in 90 percent of fish samples from streams, and in about 55 percent of shallow wells sampled in agricultural and urban areas.

The type and concentrations of contaminants that are found in urban and agricultural water resources are closely related to the chemicals that are used (such as fertilizers and pesticides) or that are released with waste products (such as sewage or manure). For example, phosphorus and many insecticides, such as diazinon, carbaryl, chlorpyrifos, and malathion, were detected more frequently and usually at higher concentrations in urban streams than in agricultural streams. Nationally, at least one pesticide guideline established to protect aquatic life was exceeded in nearly all (about 93 percent) urban streams sampled.

Nitrogen and many herbicides-most commonly atrazine and its breakdown product deethylatrazine (DEA), metolachlor, alachlor, and cyanazine—generally were detected more frequently and usually at higher concentrations in streams and shallow ground water in agricultural areas than in urban areas. Occurrence is linked to use; these herbicides rank in the top five used for agriculture. Concentrations of nitrate exceeded the EPA drinking-water standard of 10 milligrams per liter in samples collected from about 20 percent of shallow wells in agricultural areas (versus about 3 percent in urban areas).

VOCs were detected frequently in shallow ground water beneath urban areas (in about 90 percent of monitoring wells sampled) and less frequently in shallow ground water beneath agricultural areas (in 20 percent of monitoring wells). Some of the most common VOCs in urban areas were the solvents trichloroethene (TCE), tetrachloroethene (PCE), 1,1,1-trichloroethane (TCA), and trichloromethane (also known as chloroform), which is a disinfection by-product of water treatment; and the gasoline-related compounds benzene, toluene, xylene, and methyl *tert*-butyl ether (MTBE).

Predictive Modeling of Multiple Pesticides By Chemical Use – USGS and EPA have collaborated on expanding the USGS Watershed Regression Program (WARP) model, originally developed to predict concentrations of atrazine in watersheds across the Nation, to enable estimates for more than 100 additional pesticides for which information is available on chemical use and physical and chemical properties. The national-scale model increases EPA's capability to predict potential impacts of pesticide use on water quality, especially in areas where monitoring data are not available. In addition, the model helps to identify areas where additional monitoring is most needed to evaluate ecological condition of watersheds, and to provide estimates of potential exposure for implementation of the Food Quality Protection Act, which requires estimation of human exposure to pesticides in drinking water.

> *"For many years, EPA has worked closely with the USGS NAWQA Program to advance the scientific tools and data that are used to assess risks posed by pesticides in surface water and ground water. Recently, the two agencies have collaborated in developing an extrapolation model that will statistically relate pesticide concentrations to watershed characteristics. Using national data, this model, called WARP (Watershed Regression Program), estimates occurrence and exposure to atrazine for watersheds across the country, with calculated reliability. The model increases EPA's capability to predict potential impacts of pesticide use on water quality, especially in areas where monitoring data are not available and has been used to identify areas where additional monitoring is most needed to evaluate the ecological condition of watersheds."* (Elizabeth Behl, Environmental Risk Branch, U.S. Environmental Protection Agency, November 2004)

Upper Gunnison River Watershed, Colorado—A consortium of water, sanitation, and river districts, towns, counties, and the National Park Service in the Upper Gunnison River watershed, Colorado, use NAWQA findings to assess the occurrence and sources of contaminants in the developing areas and to determine the health of the watershed, given an urbanization rate of about 200 percent between 1970 and 1990. NAWQA findings on surface- and ground-water quality inform decisions related to wastewater facilities versus traditional septic systems, and help to implement annual septic-system monitoring to prevent further water-quality degradation.

State of New Jersey—The New Jersey Office of State Planning collaborates with USGS to develop a computer model that forecasts the effect of land-use development on freshwater quality. NAWQA findings and data are the foundation on which the model is based. The model helps to educate local planning boards about nonpoint source pollution and allows

municipalities and local planning officials to visualize the impacts of urban development on freshwater resources in their communities.

"Throughout the Floridan Aquifer, groundwater was contaminated by land-use practices. Sinkholes and streams serve as funnels down which contaminants pour directly into groundwater. USGS geologists Richard Marella and Marian Berndt found nitrates, as well as herbicides and pesticides, in springs and wells throughout North Florida. Nitrate concentrations in Manatee Springs near Gainesville, for example, had increased from 0.4 milligrams per liter in 1946 to more than 1.5 milligrams in the late 1990s." (Exerpt from the book "*Mirage-Florida and the Vanishing Water of the Eastern U.S.* by Cynthia Barnett, 2007, The University of Michigan Press)

"The Acadian-Pontchartrain Drainages NAWQA program has contributed valuable information to the U.S. EPA's Office of Pesticide Programs' (OPP) understanding of the occurrence of pesticides in ground and surface water in one of the Nation's major rice and sugarcane production areas. As a reliable source of comprehensive information, results from the USGS study unit have been used in pesticide exposure and risk assessments. The OPP has found the data useful in understanding the relationship between land use (e.g., agriculture) and the frequency and levels of pesticide detections in water." (Sid Abel, Environmental Fate and Effects Division, Office of Pesticide Programs, 2005, U.S. Environmental Protection Agency)

"The NAWQA approach of relating surface-water quality to land use will help us manage water resources in portions of the Missouri Ozarks now undergoing significant land-use change." (John Ford, Missouri Department of Natural Resources, 2001, USGS Circular 1158)

"The NAWQA Program provides a critical national focus that helps to quantify the condition of our water resources in a large number of places. Its approach to providing nationally consistent information allows us to make statements that simply could not be made otherwise. Using NAWQA data, we can describe nutrient and contaminant occurrence nationally and among different land uses, and track how those conditions change over time. We appreciate NAWQA's strong commitment to making its information and data readily accessible to meet our organization's needs and to address the Nation's water-resource information needs." (Robin O'Malley, The H. John Heinz III Center for Science, Economics and the Environment, November 2004)

Managing Chemical Use—Localities, states, and federal agencies recognize that chemical-use tracking is a critical first step to understanding and managing effects on water resources. Reducing chemical use and improving disposal practices can help reduce the contaminant concentrations in both urban and agricultural settings. More information about chemical use—data that are virtually unavailable in urban areas—is critical to linking contaminants to their sources, thus helping individuals, businesses, and industry as well as local, State, and Federal governments to improve water quality.

King County, Washington—USGS has worked with King County, Washington to better understand relations between pesticide use and occurrence in urban streams. In King County, 23 of 98 pesticides were found in streams in 10 urban and suburban watersheds. Homeowner use was indicated as the source of some insecticides, such as diazinon, and some herbicides, such as 2,4-D, which are commonly sold in home and garden stores. The county uses a USGS fact sheet ("Pesticides in Selected Small Streams in the Puget Sound Basin, 1987-1995," USGS FS-067-97) as an educational tool in an effort to encourage homeowners to use fewer pesticides on lawns and gardens. Almost half of the pesticides found in the streams had no retail sales within Seattle or the surrounding area, indicating that commercial applications, such as along road rights-of-way, are potential sources of these pesticides in streams. This information helps local officials to manage chemical use.

State of New Jersey—NAWQA findings showed that nitrate contamination of shallow ground water underlying areas of high nitrogen fertilizer use in southern New Jersey is expected to affect 100-foot-deep public drinking wells over the next 50 years. On the basis of this and other water-quality information, the New Jersey Department of Environmental Protection works with the agricultural community to minimize the use of fertilizers and pesticides and implement best management practices.

Improving land-management practices—Localities, states, and regions recognize that land-management practices can improve nonpoint pollution in agricultural and urban areas.

National Chloride Study (http://pubs.usgs.gov/sir/2009/5086/): NAWQA completed a comprehensive study in 2009 on chloride concentrations in the northern U.S. covering parts of 19 States showing elevated concentrations in many urban streams and groundwater. Chloride levels above the recommended federal criteria set to protect aquatic life were found in more than 40 percent of urban streams tested.

Elevated chloride can inhibit plant growth, impair reproduction, and reduce the diversity of organisms in streams. Use of salt for deicing roads and parking lots in the winter is a major source of chloride. Other sources include effluent from wastewater treatment facilities, septic systems, and runoff from farming operations.

NAWQA findings remind us of the unintended consequences that salt use for deicing may have on our waters; state and local transportation officials continue to implement innovative alternatives that reduce salt use without compromising human safety.

Salinity Decreases in Streams in the Southwest--Monitoring and modeling of streams and ground-water systems in parts of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming show that salinity has decreased in many streams in the Southwest in the last 20 years, in part because of the implementation of salinity-control projects that involve low water-use irrigation systems and re-direction of saline water away from streams (http://water.usgs.gov/nawqa/studies/mrb/salinity.html).

"The products and studies produced by the USGS are beyond reproach and represent an independent scientific voice that water planners look to for guidance…. I am continually impressed with the competence, dedication and professionalism that the USGS personnel possess and value and reliability of the data produced by this agency…The downward trends in salinity that the USGS have measured are significant and meaningful. We are avoiding costs due to damage that has been avoided based upon the investments of the Salinity Control Program."
(Dave Kanzer, Senior Water Resources Engineer, Colorado River Water Conservation District, in his remarks at a Congressional Briefing on Water Availability in Washington D.C., March 2008)

Dodge County, Nebraska—NAWQA data on ground-water flow and aquifer lithology near Maple Creek in Dodge County, Nebraska was used in a rezoning decision of agricultural to residential land. Specifically, NAWQA ground-water data helped County officials better evaluate the feasibility of installing septic tanks in newly proposed lots and partitioning existing farmland into small-acreage residential parcels.

Yakima River Basin, Washington—NAWQA findings show water-quality improvements from best-management practices in the Yakima River Basin, Washington. Irrigation Districts in the Yakima River Basin have implemented best management practices, such as shifting from furrow to sprinkler irrigation, to reduce water-quality degradation. NAWQA findings over the last decade show that these practices have reduced the loss of soil from irrigated cropland and have minimized the transport of contaminants that attach to soil particles, such as the insecticide DDT and phosphorus.

Rockingham County, Virginia—NAWQA findings on nutrients, pesticides, and bacteria levels in the Muddy Creek basin in Rockingham County, Virginia showed significant degradation because of dairy and poultry farming and intensive row cropping. The information was used by Rockingham County and other watershed organizations to implement fencing alternatives and other land-management practices to protect the basin's water resources. The county accelerated these changes when the information was placed in a national context, which ranked water quality in Muddy Creek among the most degraded of all agricultural streams (about 120) sampled by USGS.

Northwestern Ohio and northeastern Indiana—Conservation tillage, which is a reduced-cultivation method, has been implemented in about 50 percent of crop fields in the Maumee River Basin and in northwestern Ohio. NAWQA findings from 1993-98 in the Maumee and Auglaize River Basins showed significant decreases in the amounts of suspended sediment carried by the Maumee and Auglaize Rivers, which are large tributary sources to Lake Erie. These findings and trends will help the Ohio Lake Erie Commission and the U.S. Army Corps of Engineers to track progress towards their sediment-reduction goals of 15 and 67 percent from conditions in 1992.

An Agricultural Hazards Index in the Southwest—Scientists with the Center for Water Resources, University of California at Riverside, used NAWQA nutrients data and assessments on ground-water vulnerability to develop a Nitrate Groundwater Pollution Index. Index numbers are assigned for irrigated agricultural areas in the Southwest, based on overlays

of soils, crops, and irrigation information. The purpose of the index is to provide information for farmers to voluntarily target resources for management practices that will yield the greatest level of reduced nitrogen contamination potential for ground water by identifying the irrigated fields of highest intrinsic vulnerability.

Understanding Transport—Chemical-use tracking, source identification in agricultural and urban areas, and land-management practices are not enough to effectively manage nonpoint pollution. Decision makers and managers also need to understand the movement of water and the transport of contaminants through a watershed, which, in large part, is controlled by natural features and hydrologic connections between ground water and surface water. This would be relatively trivial if all watersheds responded similarly to sources of contamination, chemical use and land-management practices. However, NAWQA findings show that natural features, such as geology, climate, hydrology, and soils, control the transport of chemicals as they move from land to streams and then downstream to reservoirs and coastal waters, and they move from land to shallow ground water and underlying aquifers. For example, ground water is vulnerable to nitrate contamination in well-drained areas with permeable soils that are underlain by sand and gravel such as in the Platte River Valley in Colorado and Nebraska, or in karst (fractured carbonate rocks) in parts of Florida and the Susquehanna and Potomac River Basins in Pennsylvania, Maryland, and Virginia. These settings facilitate relatively rapid downward movement of water. In contrast, streams generally are most vulnerable to contamination in basins with poorly drained clay soils, steep slopes, or where sparse vegetation does not slow runoff.

NAWQA findings clearly show that differences in these natural features and hydrologic factors can result in very different degrees of vulnerability to contamination and different rates at which improved management can lead to improved water quality. Understanding these concepts determines the timing and success of appropriate management decisions and actions and helps to prioritize where improved treatment or management can have the greatest benefits. Because vulnerability to contamination can differ from place to place, a national strategy for managing nonpoint source pollution should consider local and regional differences in natural features.

Transport in Agricultural Watersheds Across the U.S.— A USGS study, released in 2009 as a series of articles published in the *Journal of Environmental Quality*, assesses agricultural chemicals in the environment in five agricultural areas across the U.S., providing a watershed approach to understanding the movement of chemicals and water through agricultural lands (http://jeq.scijournals.org/content/vol37/issue3/#SPECIAL_SUBMISSIONS). The five watersheds represent important agricultural practices in different environmental and hydrologic settings and, therefore, findings are relevant to agricultural areas throughout much of the Nation.

Approximately 40 percent of the land in the U.S. is used for agriculture. Often, natural hydrologic processes are modified toward optimizing agricultural production, such as in areas of extensive tile drains or irrigation, which can have unintended environmental impacts on water quantity and quality. Understanding the movement of water and chemicals in streams, ground water, and the atmosphere is critically important in evaluating and tracking effects of agricultural practices on water quantity and quality.

The study design focuses on the catchment scale and addresses several environmental compartments, including surface water, ground water, the unsaturated zone, the streambed, and the atmosphere. NAWQA findings in agricultural settings indicate that although nutrients (nitrogen and phosphorous) in agricultural streams are often elevated, alterations to stream habitat (turbidity, flow, and riparian cover) can inhibit nutrient transformations and result in large quantities of nutrients exported to downstream receiving waters. The information is used by water managers, land owners, and researchers to track and manage contaminants in agricultural areas (http://in.water.usgs.gov/NAWQA_ACT/).

High Plains Aquifer—NAWQA ground-water age-dating techniques and flow models were used to evaluate aquifer recharge, downward transport, and flow under various historic and current conditions in the High Plains Aquifer. Tritium and radiocarbon concentrations were used to assess ground-water ages and the timing of recharge to the ground-water system. A key finding was that travel times of recharge water through the thick unsaturated zones over much of the aquifer system ranged from about 50 to 375 years, indicating significantly slower recharge rates than previously thought. The High Plains aquifer system is a nationally important resource providing about 30 percent of the ground water used for irrigation in the Nation. This new information on ground-water recharge and transport was used by State and local agencies to evaluate the sustainability of the aquifer system to meet future water needs and to re-define water-conservation and resource management

plans in their efforts to reduce aquifer depletion. The full study on water quality of the High Plains aquifer for the period 1999–2004 can be accessed at http://pubs.usgs.gov/pp/1749 /.This effort represents the first systematic regional assessment of water quality in this nationally important aquifer. A stratified, nested group of studies was designed to assess linkages between the quality of water recharging the aquifer, the effect of transport through the hydrologic system on water quality, and the quality of the resource used for human consumption and agricultural applications. The stratified, nested design facilitated upscaling of monitoring results to unmonitored areas of the aquifer as well as upscaling of process understanding from local to regional scales.

Transport of Contaminants to a Public-Supply Well in York, Nebraska—NAWQA findings report on single, representative public-supply wells in nine different areas of the U.S. (http://oh.water.usgs.gov/tanc/NAWQATANC.htm). Findings for the public supply well in York, Nebraska, a high-capacity well that typically produces more than 720,000 gallons per day from the upper confined aquifer of the High Plains aquifer, show elevated concentrations of nitrate and pesticides in ground water, which is most likely due to intensive agriculture. In addition, sampling found low concentrations of the solvents trichloroethylene (TCE), tetrachloroethylene (PCE), and their degradation products, which may be linked to historical chemical use in urban and residential areas of York. Uranium and arsenic (which occur naturally in the sediments that make up the aquifers in the area) also were detected at concentrations less than drinking-water standards but still of concern. Overall, the current NAWQA study found that three primary factors affect the movement and fate of contaminants and the vulnerability of the public-supply well in York: (1) timing of water entry (recharge) to the aquifer, (2) short-circuiting of natural flow paths through inactive wells, and (3) natural geochemical conditions of the aquifer. (Full study can be accessed at: http://pubs.usgs.gov/fs/2008/3025/). Study findings are intended to help water managers, drinking-water suppliers, policymakers, and scientists to better understand how and why contamination of public-supply wells occurs and whether water quality may improve or degrade. Additionally, study findings may be used to evaluate various pumping, resource-development, and land-management scenarios.

Ogalla Aquifer, High Plains—Data demonstrating the occurrence of pesticides in ground water in the High Plains/Ogallala aquifer of northwestern Oklahoma has indicated that much of the water in the aquifer might have been recently recharged. Widespread detection of pesticides in the aquifer has refuted conventional wisdom that ground water takes hundreds or thousands of years to recharge the Ogalla Aquifer and has indicated greater vulnerability in parts of the aquifer to contamination than previously thought. Results from the NAWQA program have served as an impetus to increased monitoring of the effects of land-use practices, and in particular swine confined animal feeding operations (CAFOs) in the High Plains.

Island of Oahu, Hawaii—The deep volcanic-rock aquifer in central Oahu and Honolulu supplies more than 90 percent of the island's public-water supply and is a designated Sole Source Drinking-water Aquifer. The aquifer is highly permeable and unconfined except near the coast, and is vulnerable to contamination despite the deep water table (100 to 1,000 feet deep). Solvents were detected in the drinking-water aquifer throughout central Oahu, with highest concentrations beneath urban areas and military installations. Fumigants, herbicides, and elevated nutrients were prevalent in ground water beneath central Oahu agricultural lands. To the southeast in urban Honolulu, few contaminants were detected in drinking-water wells due to a century of urban planning and watershed protection that has directed intensive chemical use and storage away from upland recharge areas of Honolulu (Full study can be accessed at: http://pubs.usgs.gov/circ/2004/1239/).

Sussex County, Delaware—NAWQA studies in Sussex County, Delaware showed that ground water, which supplies more than half of the water to streams in this region, travels very slowly—about a foot a day—through this aquifer system. County officials now understand that improvements in ground water and stream quality can lag behind changes in fertilizer use and implementation of land-management practices by many years and even decades.

Understanding Interactions between Surface and Groundwater—Groundwater 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. Typically, ground-water inputs are not included in estimates of contaminant loads in streams. Section 303(d) of the Clean Water Act requires States to identify waters that are impaired by pollution and to establish a Total Maximum Daily Load (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. The TMDL process should include ground water in order for all pollution sources to be considered and for the process to be effective in protecting and restoring streams.

Similarly, surface water can be a major contributor to ground water, and can serve as a major nonpoint source of contamination to aquifers, particularly where high-capacity public-supply wells are located near streams and rivers. Ground water is generally thought to be safe for consumption without water treatment. However, ground water from wells near streams can host the same contaminants as the surface water recharging the well. Water managers should consider such connections in the design of source-water and well-head protection strategies.

Contaminants generally are more prevalent and detected at higher concentrations in streams than in ground water. This largely is determined by chemical properties of contaminants and flow conditions-ground water typically is not vulnerable to contamination by compounds that attach to soils or that are unstable in water, and relatively long residence times along groundwater flow paths allow many chemicals to degrade, disperse, or be diluted before reaching a well.

"The combined surface- and ground-water quality and ecological assessments of the Flint River Basin by the Lower Tennessee River Basin NAWQA Program have heightened our awareness of how vulnerable our water resources are due to karst features of the watershed. These technical, interdisciplinary assessments of watershed conditions have helped focus our watershed restoration efforts within the Flint River Basin."
(Susan Weber, Flint River Conservation Association, June 2004, USGS Circular 1233)

"The NAWQA Program synthesizes surface-water and ground water data in an accessible and objective way for a wide variety of decision makers across the Nation. Their water-quality assessments in more than 50 river basins across the Nation show the importance of recognizing connections between ground water and surface water, reminding us of the importance of protecting both waters as a single resource. Ground water and, more importantly, the interactions between ground water and surface water, are often not included in watershed monitoring and management strategies. And yet, ground water can be a major contributor to rivers and streams; quantifying the ground water contribution is therefore critical in developing water-quality standards and criteria, issuing permits, and meeting Clean Water Act goals. Similarly, surface water can be a major contributor to ground water, particularly where high-capacity public-supply wells are located near rivers and streams, and should be considered in the design of source-water and well-head protection strategies." (Paul Jehn, Technical Researcher, Ground Water Protection Council, Fall 2005)

San Antonio, Texas— NAWQA findings in San Antonio, Texas showed that major streams lose substantial amounts of water to the nearby highly permeable, faulted and fractured carbonate outcrop of the Edwards aquifer. The streams, in large part, originate in and flow through what is now mostly undeveloped rangeland; however, these streams also flow through northern San Antonio, which continues to be developed. Some contaminants that are typical of urban runoff are finding their way to the recharge zone and ultimately to the aquifers. For example, chloroform along with the herbicides atrazine, deethylatrazine, simazine and prometon were commonly detected in NAWQA samples from wells in the recharge zone. Findings on water quality in the Edwards aquifer and in the recharging streams point to a critical management issue for the region because the aquifer is the principal water supply for the greater San Antonio region.

Washington State - Historical mining in northern Idaho has resulted in elevated concentrations of some trace metals, particularly cadmium, lead, and zinc, in water and sediments in the Spokane River. These elevated trace-metal concentrations have raised the concern of residents and officials from the Washington Department of Ecology and Spokane County about their transport and potential contamination of the underlying Spokane Valley/Rathdrum Prairie aquifer, the primary source of drinking water for over 400,000 people in and around the city of Spokane. Hydrologic and chemical data collected as part of NAWQA indicate that the Spokane River recharges the aquifer between Coeur d'Alene Lake and Spokane. The data showed that although zinc concentrations in near-river wells were slightly elevated as a result of river recharge, all trace-metal concentrations were well below drinking- water standards.

"Understanding river and aquifer interaction often is critically linked to the consumptive needs of our citizenry, stream aquatic life, and riparian health, and ultimately our quality of life. Focused USGS scientific studies are assisting state and local government to protect water quality, manage water resources, and preserve natural systems, such as the Spokane River and Spokane Valley-Rathdrum Prairie Aquifer in Washington and Idaho." (John L. Roland, Washington State Department of Ecology, June 2004, USGS Circular 1235)

"Studies and research that we have directly co-sponsored with USGS and the NAWQA preliminary work has assisted us in setting up an early warning system for our well-field management plan." (Jerry Obrist, Lincoln Public Works & Utilities Department, October 2004)

City of Lincoln, Nebraska—NAWQA findings showed that ground-water withdrawals from the alluvial aquifer induces infiltration from the Platte River to the underlying aquifer where public-supply wells supply about 117 million gallons per day to Nebraska's large cities, Omaha, Lincoln, Grand Island, and Kearney. Of similar concern in the Central Nebraska Basins is the heavy agricultural use of fertilizers and herbicides, such as atrazine, alachlor, cyanazine, and metolachlor. For example, elevated concentrations of atrazine (at times exceeding the EPA drinking-water standard of 3 micrograms per liter) were detected in public-supply wells in the Ashland well field, the primary source of public supply for the City of Lincoln, which has a population of about 200,000. The USGS studies improved the City's understanding of the transport of pesticides from the Platte River through channel alluvium and into the ground water at the City of Lincoln well-field near the river. NAWQA findings are used by the City of Lincoln to update a well-field management plan.

Southern California—NAWQA findings showed that controlled and regulated water management can greatly affect transport of water between surface-water and groundwater systems, as demonstrated in southern California where flow of the Santa Ana River is used to recharge the ground-water system for public supply. Ground-water recharge facilities are located along rivers and streams draining the San Gabriel, San Bernardino, and San Jacinto Mountains, and along and adjacent to the Santa Ana River in the Coastal Basin. About 200 million gallons per day are recharged to the Coastal Plain aquifers to help balance the total amount of groundwater pumped from the aquifer used for public supply. The quality of water in aquifers in the Santa Ana Basin therefore reflects the quality of stream flow during the last 50 years, which is the average time that water remains in the groundwater system. NAWQA samples indicated elevated chloroform, a byproduct of water disinfection, widely distributed in the aquifer. MTBE also was commonly detected, although not as widespread as chloroform. The results indicate that yesterday's surface water is today's ground water and therefore remind us of the importance of protecting it as a single resource (http://pubs.usgs.gov/circ/2004/1238/)

Assessing Vulnerability to Help Prioritize Geographic Areas, Basins, and Aquifers for Management and Protection

NAWQA findings help to identify water resources and aquatic ecosystems that are most vulnerable to contamination and where improved treatment or management can have the greatest benefits.

Nitrate in Shallow Ground Water—A nitrate model, based on nationwide data, was developed to estimate the risk of nitrate contamination to shallow ground water across the Nation. The model highlights areas where nitrate more likely occurs, such as in the High Plains of northeastern Nebraska and northwestern Texas, and helps to explain why some areas are associated with higher probabilities of nitrate contamination. Specifically, the likelihood of nitrate contamination of shallow ground water is greatest in areas with high nitrogen input (associated with nitrogen fertilizer applications and high population densities) and well-drained soils that overlie unconsolidated sand and gravel aquifers. The national map is used by EPA and others involved in developing resource management strategies for prioritized monitoring, protection, and restoration. By targeting regions with the highest risk of nitrate contamination, resources can be directed to areas most likely to benefit from pollution-prevention programs and long-term monitoring. Use of risk guidelines to locate areas for prevention of contamination also can result in cost-effective management. Once ground water is contaminated, it is expensive and, in many cases, virtually impossible to clean up. Full study details can be found at http://water.usgs.gov/nawqa/home_maps/nitrate_shallow_gw.html

Atrazine in the Nation's Streams—NAWQA used national data to develop a watershed regression model, which estimates the occurrence and exposure to atrazine for watersheds across the country. Modeled findings showed that key factors affecting concentrations are atrazine use, the size of the watershed, overland flow, rainfall, and soil erodibility. These five factors help to explain about 80 percent of the variance in annual mean concentrations of atrazine among the sites across the Nation. Results indicate that only a few streams that have greater than a 50 percent probability that the actual average concentration of atrazine exceeds 3 micrograms per liter, which is the EPA drinking-water standard for atrazine. These streams are located in the Ohio and Mississippi Valleys and in southern Louisiana. Full study can be found at the Pesticides National Synthesis Project Website by accessing the USGS Circular 1291.

Atrazine in the Nation's Shallow Ground Water—NAWQA findings showed that the detection of atrazine in shallow ground water beneath agricultural areas can be estimated, in large part, by knowing the amount of agricultural land, the

amount of tiles or other subsurface drainage, water capacity of the soil, and vertical permeability of the soil. Atrazine use has an important influence on the occurrence of atrazine in shallow ground water, but not as important as for streams. Atrazine occurrence in shallow ground water is not necessarily highest in areas of greatest atrazine-use intensity. In fact, some of the Nation's highest use occurs in Iowa, Illinois, and Indiana, but soils in these areas tend to be poorly drained and, thus, artificial drainage by subsurface tile drains or trenches dewaters the agricultural fields. This practice tends to capture ground-water recharge and divert it to nearby streams. As a result, the detection of atrazine in ground water in these areas is less than it would otherwise be. Full study can be found at the Pesticides National Synthesis Project Website by accessing the USGS Circular 1291.

Dieldrin in Fish in Streams Across the Nation—Although dieldrin residues in fish have declined substantially since the 1960s, NAWQA data and extrapolation results suggest that residues are still present in many streams across the country at levels sufficient to be of potential human health concern. This finding is consistent with the fact that, in 2004, there were 23 fish consumption advisories active for dieldrin in the United States, covering 606 river miles and 625 lake-acres in seven states. The highest modeled predicted concentrations of dieldrin were mostly concentrated in the Corn Belt, with scattered patches in Texas, the southeast, urbanized parts of the northeast, and California. Concentrations of dieldrin in fish can be estimated, in large part, by knowing historical agricultural use, urban termite use, forested land in the basin, and fish lipid content. Together, these four variables explain nearly 60 percent of the variability in concentrations measured in fish in streams across the Nation. Full study can be found at the Pesticides National Synthesis Project Website by accessing the USGS Circular 1291.

North Atlantic Coastal Plain Indicators Model—EPA researchers have collaborated with NAWQA scientists in the North Atlantic Coastal Plain to develop logistic-regression models and maps that predict the occurrence of selected nutrients and pesticides in first-order streams during base flow conditions (which are comprised, in large part, from ground-water discharge). The models incorporate key landscape indicators, such as geology and soils that help to explain the transport of nutrients and pesticides from ground water to surface water and their effects on aquatic biota. The information is used to assess vulnerable areas of the Coastal Plain, and is useful for federal managers within the EPA Office of Pesticides and Office of Water who are charged in nutrient and pesticide management and protection, as well as in the EPA Chesapeake Bay Program who are charged with improved goal setting and management of water-quality conditions in the Chesapeake Bay estuary. In addition, the modeled findings are useful at the State level, such as in the development of State TMDLs, pesticide management plans, nutrient management criteria, and source-water protection.

> *"The insights and information that came from the NAWQA Mid-Atlantic Coastal Plain Synthesis Project served as the base for the design of the EPA 'Landscape Indicators for Pesticides' study. This study is the first time this particular stratified random design has been applied in a large monitoring study. The study has further benefited from the blending of expertise and talents from EPA and USGS scientists (with specialties in landscape ecology and hydrology, etc). This combination of expertise has enabled us to address the pesticide and nutrient issues in a comprehensive manner."* (Ann Pitchford, U.S. Environmental Protection Agency-Las Vegas, March 2001)

Understanding Trends and Whether Conditions are Better or Worse over Time

> *"The NAWQA Program is unique in its capability to answer whether the Nation's water quality is improving. This is a fundamental long-term issue that policymakers are seeking to address."* (Claudia Copeland, Resources and Environmental Policy, Congressional Research Service, November 2004)

NAWQA studies document the long-term presence of some contaminants, which in large part depends on their chemical properties. Not many, for example, would have anticipated the long-term persistence in some ground water of the fumigants 1,2-dibromomethane (EDB) and 1,2-dibromo-3-chloroproane (DBCP), nor the persistence in streams of certain organochlorine compounds, such as PCBs and the insecticides DDT, dieldrin, and chlordane. Concentrations of DDT and organochlorines have declined, but still persist at relatively elevated levels. For example, nationally, one or more organochlorine compounds were detected in sediment at about 60 and 80 percent of agricultural and urban stream sites, and concentrations exceeded sediment-quality guidelines at nearly 20 and 50 percent of those sites, respectively. Chlordane, in contrast to DDT, most commonly showed no significant change since 1970, and upward and

downward trends were evenly split. Chlordane use in agriculture was discontinued in 1978, but its urban use for termite control exceeded its use in agriculture and continued until at least 1988, and use of existing stocks by homeowners was permitted after 1988 and was common in a 1990 survey. The regulation of organochlorine pesticides clearly has resulted in decreased contaminant levels; however, the continuing high levels of chlordane, the slow rate of decreasing trends for DDT, and the continuing concern for human exposure indicate that organochlorine pesticides will remain a concern for many years to come.

Studies also show that changes in water quality over time frequently are controlled by changes in chemical use and land-management practices. For example, concentrations of modern, short-lived pesticides such as acetochlor change as chemical use changes. Concentrations of acetochlor increased and those of alachlor decreased in many streams in the Upper Illinois River Basin and other parts of the Upper Midwest, where acetochlor partly replaced alachlor for weed control in corn and soybeans beginning in 1994. The changes in chemical use were reflected in stream quality, generally within 1 to 2 years (http://pubs.usgs.gov/circ/2005/1291/). Contaminant concentrations also change with land-management practices. For example, conversion from rill (or "furrow") irrigation to sprinkler or drip irrigation in many parts of the Yakima River Basin, Washington since the early 1990s has reduced runoff from farm fields, resulting in decreases in suspended sediment, total phosphorus, dissolved nitrate, and organochlorine compounds in streams (http://pubs.usgs.gov/circ/2004/1237/).

Ground water quality also responds to changes in chemical use, but usually more slowly than surface water. In many aquifer systems ground water moves at rates within the range of tens to hundreds of feet per year and it may take decades or more for water to move from areas of recharge to areas of discharge, such as streams or supply wells. Improvements in ground-water quality can thereby lag behind land-management changes by decades because of the slow rate of ground-water flow. Long-term monitoring is critical to track the progress of our actions, such as reductions in chemical use and changes in land-management practices.

Corn Belt Trends in Pesticides—In November 2009, NAWQA released a regional study on trends in several major pesticides in rivers in the Corn Belt region, which generally includes Illinois, Indiana, Iowa, Nebraska and Ohio, as well as parts of adjoining States. Concentrations mostly declined or stayed the same between 1996 to2006, and declines in pesticide concentrations closely followed declines in their annual applications, indicating that reducing pesticide use is an effective and reliable strategy for reducing pesticide contamination in streams.

Declines in concentrations of the agricultural herbicides cyanazine, alachlor, and metolachlor show the effectiveness of EPA regulatory actions as well as the influence of new pesticide products. In addition, declines in concentrations of the insecticide diazinon from 2000 to 2006 correspond to the EPA's national phase-out of nonagricultural uses.

The USGS works closely with the EPA, which uses USGS findings on pesticide trends to track the effectiveness of changes in pesticide regulations and use across the Nation.

National and Regional Trends in Ground Water—In 2009, NAWQA scientists released a series of nine papers in the Journal of Environmental Quality in 2009 on national and regional trends in ground-water quality in the U.S. This series marks the first of many trends-studies to follow by NAWQA, which has collected consistent and comparable data for a large number of chemical constituents at wells across the Nation since its inception in 1991. Findings highlight national trends over the last 10-15 years, including increasing concentrations of nitrate in ground water in selected aquifers underlying agricultural areas associated with oxygenated conditions and well-drained soils. National analyses also show decreasing trends, overall, in selected agricultural pesticides, such as atrazine. Detailed studies in specific regions of the Nation, however, demonstrate that trends vary geographically and by aquifer, depending on many factors, including chemical use, aquifer type, age of the ground-water recharge, and geochemical conditions. (Papers can be accessed at http://jeq.scijournals.org/content/vol37/5_Supplement/ by scrolling down 17 citations in the Special Submissions.)

National Assessment of Metals and Hydrophobic Contaminants Using Lake Cores—Analysis of sediment cores (vertical tubes of mud) from reservoir and lake bottoms provides a quick snapshot of long-term water-quality changes that occur because of regulations and bans on chemical use (http://tx.usgs.gov/coring/). Runoff carries soil, debris, and attached contaminants to lakes and reservoirs, where they settle to the bottom; changes in water quality are thereby recorded in the

successive layers of sediment. NAWQA studies of nearly 50 reservoirs and lakes sampled in more than 30 rapidly urbanizing metropolitan areas show common patterns in quality, such as decreases in lead and increases in polycyclic aromatic hydrocarbons (PAHs) over several decades. For example, lead concentrations in Town Lake in Austin peaked in the late 1960s and then declined by about 70 percent, a direct response to the elimination of lead in gasoline. Concentrations of DDT generally followed its historical use in the United States, which peaked from the late 1950s to the mid-1960s and then declined substantially after its ban in 1972. Concentrations of PCBs, which were used primarily as insulation fluids in transformers and appliances peaked during the early 1960s and then declined by about 70 percent by 1998 (restrictions on PCBs were imposed in 1971). In contrast to trends in these regulated or banned contaminants, concentrations of total PAHs in Town Lake substantially increased. PAHs result from the burning of hydrocarbons. The increase in PAHs generally corresponded to roofing and increases in automobile use in the greater Austin area, which is evidence of the effect of non-industrial sources, such as vehicle emissions, road and tire wear, and engine oil leaks associated with growth on city fringes.

Diazinon in Northeastern Streams—NAWQA data from seven stream sites in the Northeast show decreases in concentrations of diazinon since 1998 (concentrations of diazinon decreased by about 15 to 40 percent). Until about 2001, diazinon was one of the most widely used insecticides in the U.S. for residential lawn and garden pest control (accounting for almost 70 percent of the 11 million pounds used each year). These improvements reflect management decisions by EPA and diazinon registrants beginning in 2000 to phase out the sale of diazinon for residential lawn and garden pest control, as well as for many agricultural uses. (Findings can be accessed at: http://pubs.usgs.gov/circ/2005/1291/).

"The Delmarva NAWQA study provides us with a timely report and assessment of water-quality trends for nutrients and pesticides in our ground-water and surface-water resources and reminds us all that much more needs to be done to protect and improve the water resources of Delaware." (Kevin C. Donnelly, Division of Water Resources, Delaware Department of Natural Resources and Environmental Control, June 2004, USGS Circular 1228)

Delmarva Peninsula, Delaware, Maryland, and Virginia—NAWQA findings showed that nitrate in ground water used for domestic supply (about 45 feet below land surface) on the Delmarva Peninsula increased by an average of 2 milligrams per liter between 1988 and 2001. The median concentration in 2001 exceeded the EPA drinking-water standard of 10 milligrams per liter. Increases in nitrate concentration most likely reflected an increased use of nitrogen fertilizers over the last 50 years. In contrast, the median concentration of nitrate in shallow ground water underlying agricultural areas (about 25 feet below land surface) did not change significantly over the same period, remaining below the drinking-water standard. Lower nitrate concentrations in the shallow groundwater may reflect positive effects of nutrient management practices on shallow ground-water quality, implemented by State and local water managers and farmers in many agricultural areas on the Delmarva Peninsula over the last 10 years. These improvements may not be apparent in the deeper parts of the aquifer because of the slow movement of ground water. Continued monitoring over the long term will show if trends continue and improvement from land-management practices occur.

Yakima River Basin, Central Washington—Previous NAWQA assessments (1988-1991) showed widespread detections of DDT and its breakdown products DDE and DDD (total DDT) in agricultural soils, stream water, suspended sediment, and fish in the Yakima River Basin in central Washington. Elevated concentrations of total DDT in bottom fish in the lower Yakima River were among the highest in the Nation. On the basis of these findings, the Washington Department of Health recommended that people eat no more than one meal per week of bottom fish from the lower Yakima River. Concentrations of total DDT in fish such as large-scale suckers, smallmouth bass, and carp from the lower Yakima River decreased by about half from the late 1980s to 1998, but still exceeded guidelines for the protection of fish-eating wildlife. Decreases also were noted in stream water—total DDT was detected frequently in unfiltered water samples from the Yakima River in 1989, but was not detected in the Yakima River samples one decade later (1999). Reduced concentrations of total DDT in the Yakima River Basin were attributed primarily to the implementation of best-management practices (BMPs) by farmers throughout much of the basin. The BMPs help to limit runoff of sediment and sorbed DDT, including drip and sprinkler irrigation systems, cover crops and ground cover, sediment retention basins, and the use of PAM (polyacrylamide, which causes soil particles to adhere to one another.(Full study is accessible at: http://pubs.usgs.gov/circ/2004/1237/).

Southwestern Florida—USGS works in partnership with the Florida Department of Agriculture and Consumer Services and the Southwest Florida Water Management District to evaluate trends in concentrations of agricultural chemicals in ground water. The herbicide bromacil was widely used in citrus production in central Florida until 1994 when its use in this region was replaced by alternative herbicides such as norflurazon and glyphosate. Its peak frequency of detection in ground water

occurred in 1996 after which its occurrence declined. The decline in bromacil coincided with an increase in norflurazon. Bromacil continued to be detected in samples from 25 percent of the monitoring wells 10 years after its discontinuance for use in citrus production. Thus, changes in chemical-use practices may not be immediately reflected in ground-water quality and, in fact, pesticide occurrence in shallow ground water may actually increase for some time following such changes in chemical use. These results from the Florida citrus region help water managers track ground-water quality over time as a result of changing farming practices and pesticide applications, and to better understand the timing, variability, and process for transport of agricultural chemicals to the subsurface.

Southern New Jersey—NAWQA scientists studied denitrification (conversion of nitrate to nitrogen gas) in southern New Jersey using a three dimensional model of ground-water flow that simulated the movement of nitrate through the shallow aquifer system to streams and public-supply wells. The model integrates hydrology with land use and nitrogen use over time and, therefore, is useful in predicting concentrations nitrate in unmeasured areas and into the future. Model simulations showed that concentrations of nitrate in streams and wells will not decline immediately, even with reductions in or stabilization of nitrogen use, primarily because of the amount of time required for water to move through the aquifer system and discharge to a stream or well. In fact, the model indicated that nitrate concentrations at 90-100 feet below land surface, which is a commonly completed depth of domestic wells in the Kirkwood-Cohansey aquifer in southern New Jersey, will continue to increase for several decades, and that ground water in areas of intensive nitrogen fertilizer use is likely to exceed the drinking-water standard for nitrate of 10 milligrams per liter by 2050. This model simulation assumes nitrate inputs remain unchanged from the year 2000. NAWQA modeled findings are used by water managers in the State of New Jersey to help manage nitrate in streams and ground water used for supply, to meet current and future projected use.

"The NAWQA program is generating water quality and ecological information that will be useful to the Oneida Environmental, Health and Safety Department in managing tribal water resources. As the Tribe engages in efforts to improve conditions of its watershed, NAWQA data and reports should serve as a reference against which future changes in water quality can be compared." (Patrick J. Pelky, Oneida Tribe of Indians of Wisconsin, Environmental, Health and Safety Department, 2001, USGS Circular 1156)

Assessing Source-Water Quality Used for Drinking

In 2001, NAWQA initiated several national assessments on source water used for drinking. The assessments build on the Program's resource characterizations of the occurrence of contaminants in ambient waters across the U.S., including streams and ground water. Findings show that the most commonly occurring contaminants in source water for community water systems and in domestic wells correspond to those detected most frequently in ambient stream water and groundwater sampled across the Nation by NAWQA during Cycle 1 and Cycle 2 assessments.

"The work that USGS does in monitoring contaminants in ambient and ground waters across the United States is very important to the EPA. The data that you provide are used in identifying possible drinking water contamination problems through our Contaminant Candidate List program and for the Six-Year Review of our regulations. We look forward to collaborating with you on future issues of interest to both of our agencies." (Benjamin H. Grumbles, former Assistant Administrator, USEPA, October 2005)

National assessments of source water and drinking water—In 2001, NAWQA initiated source-water-quality assessments to characterize water in selected drinking-water supply wells, stream intakes, and in finished drinking water associated with about 50 large community water systems. The source-water assessments complement drinking-water monitoring required by other Federal, State, and local programs, which focus primarily on post-treatment compliance monitoring. In 2009, NAWQA released its first assessment of the occurrence of about 260 anthropogenic organic compounds in source water (defined as stream water collected at a surface-water intake prior to water treatment) and finished water (defined as water that has passed through treatment processes but prior to distribution) at nine community water systems

"It is beyond the capability of an individual water utility to comprehensively evaluate the significance of potential source water compounds. That is why national-level research efforts by the United Status Geological Survey (USGS), and other public and private agencies, are so important in evaluating the occurrence, sources, and health effects of these compounds. The work ongoing by the USGS National Water Quality Assessment (NAWQA) Program will help the U.S. Environmental Protection Agency determine what, if any, human-health-based limits may need to be set. From that, water utilities will be able to develop and implement appropriate treatment." (Thomas P. Jacobus, Washington Aqueduct, December 2008)

across the Nation (http://water.usgs.gov/nawqa/swqa/), including the Washington Aqueduct on the Potomac River. The Washington Aqueduct, along with other water suppliers and governmental agencies in the Potomac River Basin Drinking Water Source Protection Partnership use NAWQA data and expertise on hydrology and water quality to assess natural and human influences on water supplies within the Potomac River Basin. This Partnership is a voluntary organization of water suppliers and local, State, and Federal agencies. NAWQA findings were used to help assess potential drinking-water issues related to contamination for the 3.6 million people in the Washington D.C. area where the Potomac River provides about 75 percent of the drinking water.

Also available is a compatible NAWQA assessment of the occurrence of about 260 anthropogenic organic compounds in source water at ground-water wells (prior to water treatment) and finished water (defined as water that has passed through treatment processes but prior to distribution) at over 20 community ground-water systems across the Nation (http://water.usgs.gov/nawqa/fsSWQ.pdf). NAWQA released a technical Scientific Investigations Report in 2009 on selected man-made compounds in water sampled from community water systems across the Nation. Source water (i.e. prior to water treatment), was sampled from 221 wells and analyzed for 258 manmade organic compounds, including pesticides and pesticide degradates, gasoline hydrocarbons, personal-care and domestic-use products, and solvents. Findings suggest relatively low concern for human health; relatively few compounds were detected at concentrations in source water greater than human-health benchmarks. The majority (84 percent) were at concentrations two or more orders of magnitude less than benchmarks. Similarly, concentrations in treated water, sampled at 94 systems, were always less than human-health benchmarks. USGS findings documented the occurrence of mixtures of organic compounds in the majority (greater than 70 percent) of source and treated water samples, which is an area for further consideration as the potential human-health significance from the low-level presence of multiple compounds in drinking water remains largely unknown.

National assessment on domestic wells—In 2009, NAWQA completed a comprehensive national-scale analysis on the quality of water in more than 2,100 private wells located in 48 States – a drinking-water resource relied upon by about 43 million people—or 15 percent of the Nation's population (http://water.usgs.gov/nawqa/studies/domestic_wells).

Private wells are not regulated by the Federal Safe Drinking Water Act. Private well owners are responsible or testing the quality of their well water and treating.

"The United State Geological Survey (USGS) report on the source water quality of domestic wells provides an important reminder to well owners of their responsibility to maintain their private well systems, including treatment equipment, if needed. The study also confirms the geographic, regional and even local variation that can occur in ground water and that water testing should be tailored to these local concerns. The research undertaken by the USGS has helped inform the association's educational programming so that NGWA professional members can serve their customers – private well owners – with science-based knowledge and tools." (Kevin McCray, CAE, executive director National Ground Water Association, March 2009)

USGS scientists sampled about 2,100 private wells in 48 states and found that more than 20 percent of private domestic wells sampled nationwide contain at least one contaminant at levels of potential health concern. The contaminants most frequently measured at concentrations of potential health concern were inorganic contaminants, including radon and arsenic. These contaminants are mostly derived from the natural geologic materials that make up the aquifers from which well water is drawn.

The study showed that the occurrence of selected contaminants varies across the country, often following distinct geographic patterns related to geology, geochemical conditions, and land use. For example, elevated concentrations of nitrate were largely associated with intensively farmed land, such as in parts of the Midwest Corn Belt and the Central Valley of California.

The results of this study are important because they show that a large number of people may be unknowingly affected. Greater attention to the quality of drinking water from private wells and continued public education are important steps toward the goal of protecting public health

In concert with the Water Environment Federation, NAWQA hosted a congressional briefing in Washington D.C., open to the public, on the quality of water in domestic wells. NAWQA findings on contamination and vulnerability of private wells in different regions of the Nation were presented with information on treatment options by the National Groundwater Association to help private well owners—currently not protected by the federal Safe Drinking Water Act—to better manage the quality of their drinking water. As stated by Kevin McCray, Executive Director of the National Ground Water Association and briefing panelist, "The U.S. Geological Survey study of water quality in household wells supports some old advice: Well owners should test their water regularly. USGS tested up to 219 substances or properties in water from household wells in 30 of the nation's

62 principal aquifers, and showed notable variations in what was found among geographic regions and even among wells in very close proximity to one another. This being true, a one-size-fits-all approach to water testing of private wells may not work. Whether it is this study-- *The Quality of Water from Domestic Wells in Principal Aquifers of the United States, 1991-2004*—or another, the well owner's response should be the same. Every drop of groundwater is unique to where it has been borrowed from the Earth. As a result, NGWA's message is succinct: Sample appropriately, test locally, and test annually."

Assessments on public wells— In 2010, NAWQA completed three assessments of the quality of water in, and transport of contaminants to, public wells. About 105 million people — or more than one-third of the nation's population — receive their drinking water from one of the 140,000 public water systems across the United States that rely on groundwater pumped from public wells. These wells can be vulnerable to naturally occurring contaminants such as radon, uranium, arsenic, and man-made compounds, including fertilizers, solvents and gasoline hydrocarbons.

(a) National occurrence (http://water.usgs.gov/nawqa/studies/public_wells/): Scientists tested water samples for 337 properties and chemical contaminants from nearly 1,000 public wells across the nation, including nutrients, radionuclides, trace elements, pesticides, solvents, gasoline hydrocarbons, disinfection by-products and manufacturing additives. The USGS study focused primarily on source (untreated) water collected from public wells before treatment or blending rather than the finished (treated) drinking water that water utilities deliver to their customers.

Findings showed that more than 20 percent of untreated water samples from public wells across the nation contained at least one contaminant at levels of potential health concern. Naturally occurring contaminants, such as radon and arsenic, accounted for about three-quarters of contaminant concentrations greater than human-health benchmarks in untreated source water. Naturally occurring contaminants are mostly derived from the natural geologic materials that make up the aquifers from which well water is withdrawn. Man-made contaminants were also found in untreated water sampled from the public wells, including herbicides, insecticides, solvents, disinfection by-products, nitrate, and gasoline chemicals. Man-made contaminants accounted for about one-quarter of contaminant concentrations greater than human-health benchmarks, but were detected in 64 percent of the samples, predominantly in samples from unconfined aquifers.

By focusing primarily on source-water quality, and by testing for many contaminants that are not regulated in drinking water, this USGS study complements the extensive monitoring of public water systems that is routinely conducted for regulatory and compliance purposes by federal, state and local drinking-water programs. Findings assist water utility managers and regulators in making decisions about future monitoring needs and drinking-water issues.

In concert with the Water Environment Federation and the Environmental and Energy Studies Institute, NAWQA hosted a congressional briefing in Washington D.C. to inform stakeholders and the public on the quality of water sampled from the high-production community water systems across the Nation. This briefing reflects NAWQA's increasing focus on assessing the quality of source water used for drinking; the role of the environmental factors affecting such quality; and placing NAWQA findings in a human-health context, all of which is in direct support for the Bureau's and DOI strategic plans for providing science relevant to human health.

b) Research on contaminant transport to public wells (http://oh.water.usgs.gov/tanc/NAWQATANC.htm): Since 2001, NAWQA has researched the vulnerability of public-supply wells in four aquifers in California, Connecticut, Nebraska and Florida. The USGS tracked the movement of contaminants in the aquifers, which help to explain what, when, and how contaminants may reach public-supply wells. Findings show that all wells are not equally vulnerable to contamination because of differences in three factors: the general chemistry of the aquifer, groundwater age, and direct paths within aquifer systems that allow water and contaminants to reach a well. The importance of each factor differs among the various aquifer settings, depending upon natural geology and local aquifer conditions, as well as human activities related to land use and well construction and operation. Findings in the four different aquifer systems can be applied to similar aquifer settings and wells throughout the nation.

USGS findings help public-supply well managers protect drinking water sources by prioritizing their monitoring programs and improving decisions related to land use planning, well modifications or changes in pumping scenarios that might help to reduce movement of contaminants to wells. In the Central Valley aquifer system near Modesto, California, for example, the USGS found that agricultural and urban development have enabled uranium to move from sediments to water in the upper part of the aquifer. This contaminated water drained down a public-supply well and entered the lower aquifer when it was not pumping. When pumping resumed, contaminant concentrations were temporarily elevated in water pumped from the well. As a result of USGS findings, public-supply well managers in Modesto have changed their pumping schedule, which has reduced the amount of contaminated water pumped from the well.

(c) Understanding geochemical processes (http://oh.water.usgs.gov/tanc/NAWQATANCRedox.htm): Geochemical processes related to reduction and oxidation can affect the quality of groundwater in all aquifer systems. Redox processes can alternately mobilize or immobilize potentially toxic metals associated with naturally occurring aquifer materials, contribute to the degradation or preservation of man-made contaminants, and generate undesirable byproducts, such as dissolved manganese, ferrous iron, hydrogen sulfide, and methane. This USGS study determines the kinds of redox processes that occur in an aquifer system, documents their spatial distribution, and evaluates how concentrations of natural or man-made contaminants are central to assessing and predicting the chemical quality of groundwater.

As part of this research, a decision support tool was developed by USGS scientists for water practitioners to analyze redox processes in aquifer systems using five chemical parameters that are relatively inexpensive and easy to measure (including dissolved oxygen, manganese, iron, nitrate, and sulfate). This information can cost-effectively help water managers to anticipate possible contamination issues in different settings and wells.

National assessment on bacteria—Microbiological data were collected from wells in 22 NAWQA study units during 1993–2004 representing 16 different principal aquifers. Samples of untreated ground water were analyzed for concentrations of fecal-indicator bacteria, which included the total-coliform bacteria, fecal-coliform bacteria, and *Escherichia coli,* and for the presence of somatic and male-specific coliphage viruses. Analyses of the samples showed that coliform bacteria occur relatively frequently—nearly 30 percent of all wells tested positive—and that domestic wells commonly are contaminated by total coliform bacteria, with 33 percent of these wells testing positive. The frequency of detections and concentrations of total coliform bacteria generally were higher in samples from domestic wells than in samples from public-supply wells; in fractured or porous rock materials (carbonate rocks) than in unconsolidated materials (mixtures of sand, gravel, clay); and in principal aquifers with median depths of sampled wells ranging from 100 to 200 feet than in principal aquifers with median depths of sampled wells less than 100 feet or greater than 200 feet. (Full study can be accessed at http://pubs.usgs.gov/sir/2006/5290).

Pesticide Study in the Lower Clackamas River Basin in Oregon—Pesticide occurrence and distribution in the lower Clackamas River basin was evaluated in 2000-2005. About 120 water samples were analyzed for a suite of dissolved pesticides. Sampling included the lower-basin tributaries and the Clackamas River main-stem, along with paired samples of pre- and post-treatment drinking water (source and finished water) from one of four drinking water-treatment plants that draw water from the lower river. Pesticides were detected in 9 (or 60 percent) of the 15 finished water samples collected from the water-treatment plant. These included 10 herbicides, 1 insecticide, 1 fungicide, 1 insect repellent, and 2 pesticide degradates. The herbicides diuron and simazine were the most frequently detected (four times each during the study), but at concentrations far below human-health benchmarks (USEPA Maximum Contaminant Levels or U.S. Geological Survey Health-Based Screening Levels (see page 25). The highest pesticide concentration in finished drinking water was 0.18 ug/L of diuron, which was 11 times lower than available human-health benchmarks.

"We appreciate the USGS' efforts in bringing this subject to the forefront of the environmental challenges we're all facing today in the Clackamas River watershed." (Andrew Swanson, Clackamas County Water Environment Services, 2008)

"Data from the study will help DEQ and other agencies gain a better understanding of the types of pesticides to focus stewardship efforts on." (Kevin Masterson, Oregon Department of Environmental Quality, 2008)

"Studies such as this provide us with the tools to identify where problems are and give us the opportunity to work with other stakeholders in the watershed to prevent pesticides from getting into the river to begin with." (Kim Swan, Clackamas River Water Providers, 2008)

Predicting pesticide contamination in sources of drinking water—NAWQA, in cooperation with EPA and industry representatives, has developed statistical models and a national database containing locations of drinking-water intakes, watershed boundaries, and pesticide use. The models are used to help estimate pesticide concentrations at unmonitored sites in streams and rivers used as sources of drinking water. The estimates are used by the EPA to implement the Food Quality Protection Act (FQPA), which requires estimation of human exposure to pesticides in drinking water.

"The NAWQA data are serving as a primary source of information for us in considering relative human exposure potential via water."

(Joseph J. Merenda, Jr. Office of Science Coordination and Policy Office of Prevention, Pesticides, and Toxic Substances, USEPA, September 2003)

Predicting arsenic in New England—USGS works collaboratively with the National Cancer Institute (NCI), Dartmouth College School of Medicine, Vermont Department of Health, and Colorado State University to model and predict the probability of arsenic occurrence in unmeasured areas in New England. Modeled findings help to fill in data gaps and to design and optimize ongoing data-collection activities where measurements of arsenic in wells can cost-effectively target areas of greatest importance. The model is based on NAWQA findings that relate arsenic occurrence to natural and human factors, including type of bedrock aquifer, geology, land use, and climate. NAWQA findings showed frequent detections of inorganic arsenic in wells drilled into the crystalline bedrock aquifer in northern New England, where deaths from bladder cancer have been elevated for the past 50 years. USGS findings are used by epidemiologists with NCI in their design of a concentration-based model used to estimate lifetime arsenic exposure for individuals living in New England, and in particular, to assess linkages between inorganic arsenic and bladder cancer in northern New England. USGS data on arsenic and other metals, radionuclides, nutrients, and VOCs, as well as spatial information on geology, land use, and water use, contribute to an NCI database used to design NCI water-sampling protocols and a large-scale epidemiological study.

Whatcom County, Washington—Elevated concentrations of 1,2-dichloropropane in ground water sampled by NAWQA scientists in the Puget Sound Basin renewed interest in determining the extent and source of drinking-water contamination in northern Whatcom County, Washington. The fumigant-derived compound was detected in ground water throughout the sampled area, sometimes at concentrations exceeding drinking-water standards. USGS works with Whatcom County to evaluate the occurrence and possible risk posed to the quality of drinking-water supplies by the use of 1,2-dichloropropane and other fumigants.

NAWQA assessments generally characterize the quality of the available, untreated ambient resource that can serve as sources for drinking and other uses. The information is used by local, State, regional, and federal partners to identify sources of safe drinking water, develop source-water protection plans, and to identify possible drinking-water contamination issues.

*"In southwest Ohio, the USGS NAWQA Program has tapped an extraordinary number of research sources to perform a water-quality assessment of the Great and Little Miami River Basins. NAWQA is developing a picture of water quality [in the Great and Little Miami River Basins] that did not previously exist. This is a service for many constituents who rely on the Basins' water resources, including the dozens of public water suppliers who must produce safe drinking water and the towns and cities whose histories and futures are linked to the health of the rivers and the aquifer." (*Jane Wittke, Water Quality Program, Ohio-Kentucky-Indiana Regional Council of Governments, June 2004, USGS Circular 1229)

"The South-Central Texas study conducted by the National Water Quality (NAWQA) Program in Austin, Texas has provided this region of Texas new data and a valuable insight to current water quality in both surface and groundwater. This region is one of the fastest growing in population in Texas and in the nation, thus emphasizing the need for water quality data gathering, assessment and evaluation by federal water resource agencies such as USGS. The information provided to the San Antonio Water System during the past three years has been widely used in our utility. Additionally, the assistance and information provided by the USGS Water Resources Division in Texas is invaluable to providing safe drinking water sources for the second most populous state and one of the fastest growing in America" (Mike Mecke, San Antonio Water System, March 2001)

State of Pennsylvania—NAWQA scientists work with the Pennsylvania Department of Environmental Protection and EPA to assess the occurrence and transport of viruses and fecal indicator bacteria in ground water used for non-community water supply. The results help state regulators and water suppliers make informed decisions about treatment options and screening techniques for viral contamination of ground water. The findings also support the State's Ground Water Rule, as required by EPA, for disinfection of ground water used for public-water supplies. In addition, NAWQA scientists work with the Pennsylvania Department of Environmental Protection to assess factors contributing to the reported high incidence of bacteria, total coliform, and E. coli in ground water used for domestic supply.

MTBE in the Nation's Shallow Ground Water—Scientific information is needed on the occurrence of new pesticides, VOCs, and other synthetic contaminants, as well as microbial, viral, and pharmaceutical contaminants in drinking-water supplies. The NAWQA Program works collaboratively with other agencies to better understand these "emerging contaminants." One of the most visible contaminants that emerged in the 1990s was MTBE, as described below.

The NAWQA Program measures compounds at very low concentrations, often 10 to 100 times lower than Federal or State standards and health advisories. Detection of compounds by NAWQA studies, therefore, does not necessarily translate to risks to human health or aquatic life. However, the findings are useful for identifying emerging issues and tracking contaminant concentrations over time. The prevalence of MTBE in shallow ground water is one such issue, identified by NAWQA studies in the 1990s. MTBE had been hailed in the 1970s as a compound that could help improve air quality in many urban areas by oxygenating gasoline and allowing it to burn cleaner. High solubility in water and persistence of MTBE in the subsurface were not considered. As a result, we are now confronted with the unintended consequence of widespread, albeit low, MTBE contamination in much of the shallow ground water in U.S. urban areas. In fact, MTBE was detected in more than 50 percent of shallow wells sampled in urban areas.

At the request of EPA and the White House Office of Science and Technology Policy, scientists with the NAWQA Program participated in an interagency assessment of the scientific basis and efficacy of the winter oxygenated gasoline program. This program mandates that compounds, such as MTBE, be added to gasoline in selected metropolitan areas to reduce the amount of atmospheric carbon monoxide in the winter. As part of the interagency assessment, NAWQA scientists reported on water-quality issues arising from the use of fuel oxygenates, including (1) occurrence of these compounds in drinking water, storm water, and streams; (2) environmental behavior and fate of fuel oxygenates (such as potential for biodegradation and remediation); and (3) recommendations on the types of monitoring and studies needed for improved exposure and risk assessment. On the basis of this input, along with studies and research by other federal agencies, universities, and the private sector, EPA recommended reducing or replacing MTBE with other oxygenates.

A preliminary analysis by USGS, in collaboration with the Metropolitan Water District of Southern California and Oregon Graduate Institute, showed potential sources of MTBE contamination near large number of community water supplies. Specifically, findings from about 36,000 community water supplies indicate that approximately 9,000 community water supply wells in 31 states are less than a mile from a leaking underground storage tank. Not all of these leaking tanks will be a significant source of MTBE to ground water and to the wells. However, the large number (9,000) suggests that the actual number of community water supply wells that may be affected should be identified.

New Hampshire public wells—USGS findings showed steady increases in of methyl tert-butyl ether (MTBE) in water from public wells in New Hampshire. About 40 percent of samples from public wells and twenty percent from private wells in southeast New Hampshire had measurable concentrations of MTBE (greater than a laboratory reporting level of 0.2 μg/L). MTBE concentrations strongly related to urban factors, such as population density. Surprisingly, MTBE concentrations increased with well depth for public supply wells. This finding is significant because deep bedrock wells are often considered to be less vulnerable to contamination than shallow wells, and in southeast New Hampshire, wells are being drilled deeper in search of increased supply.

New England—USGS conducted a study in 12 states in the Northeast in cooperation with EPA to better understand MTBE and other VOCs in drinking water supplied by more than 2,000 community-water systems. The study, including more than 21,000 samples collected during 1993-1998, found that MTBE was reported in nearly 9 percent of the community-water systems for which MTBE data were available (about 1,200). Detections were five times more likely in areas where MTBE-enriched, oxygenated or reformulated gasoline has been used. Chloroform was the most frequently detected VOC in the drinking water, reported in nearly 40 percent of the community water systems.

State of Iowa—NAWQA findings on the prevalence of MTBE in ground water beneath urban areas were used in the development of state legislation and to design a new water-quality network. The legislation (House File 772) (1) limits the amount of MTBE in motor vehicle fuels to less than 2 percent by volume; (2) established an interim committee to "study issues relating to the sale, use, and health and environmental effects of oxygenate enhancers contained in motor vehicle fuel,

including but not limited to ethanol and methyl tertiary butyl ether"; and, (3) requires analysis of MTBE in water and soil at leaking underground storage tank sites. In addition, as a result of NAWQA findings, Iowa began a statewide study to determine the impact of MTBE on municipal and public-water supplies by sampling all systems that use ground water as a source of drinking water.

State of Pennsylvania—The Pennsylvania Department of Environmental Protection works with USGS to assess the prevalence of MTBE in ground water and its potential to contaminate public drinking-water supplies. Through the partnership, consistent and quality-assured data are compiled to provide a qualitative vulnerability rating for MTBE based on different hydrogeologic settings throughout the State of Pennsylvania. The results help to prioritize areas where MTBE should be assessed; where public-supply wells should be tested; and where gasoline storage tanks should be inspected.

NAWQA Findings in a Human-Health Context

To place concentration data in a human-health context, concentrations of contaminants measured in NAWQA's source-water and resource assessments are compared to human-health benchmarks. Specifically, concentrations are compared to USEPA Maximum Contaminant Levels (MCLs) or USGS Health-Based Screening Levels (HBSLs). USEPA MCLs are legally enforceable standards for drinking water that specify the maximum permissible level of a contaminant that is delivered by public water systems. HBSLs are non-enforceable benchmark concentrations that were developed by USGS in collaboration with USEPA and others, using standard USEPA methods and the most current toxicity information, for many unregulated elements and compounds for which MCLs have not been established. HBSLs are equivalent to existing USEPA Lifetime Health Advisory and Cancer Risk Concentration values (when they exist), except for unregulated compounds for which more recent toxicity information has become available. It is important to note that the presence of contaminants at concentrations greater than benchmarks does not necessarily indicate that adverse effects are certain to occur. Conversely, concentrations less than benchmarks do not guarantee that adverse effects will not occur, but indicate that adverse effects are expected to be unlikely. MCLs or HBSLs are generally available for about half of the contaminants included in USGS assessments.

Comparison of the water-quality data to MCLs or HBSLs can provide an initial perspective on the potential significance of contaminant occurrence to human health and can help prioritize further studies. A screening-level assessment of this kind also provides a perspective on areas where adverse effects of contaminants are more likely to occur and the contaminants that may be responsible for such effects. A screening-level assessment is not designed to evaluate specific effects of contaminants in domestic well water on human health, nor is it a substitute for a comprehensive risk assessment, which generally includes many additional factors such as multiple avenues of exposure.

Assessing and Sustaining Aquatic Ecosystem Health

Activities associated with agriculture, urban areas, and (or) forests can affect overall ecosystem health by affecting stream-habitat conditions and fish, aquatic invertebrate, and algal communities. These can reflect introduction of chemical compounds. For example, the national assessment on pesticides (released in 2006) concluded that pesticides are seldom at concentrations likely to affect humans; however, of more concern, in many streams, particularly those draining urban and agricultural areas, pesticides were found at concentrations that may affect aquatic life or fish-eating wildlife. Degraded water and sediment, and physical alterations to streams that result in changes in stream flow, temperature, and channel morphology, commonly result in degraded stream habitat, reduced biological diversity, and an increase in the number of species tolerant of disturbance, such as worms, midges, and omnivorous fish communities.

The most profound effects can be seen in urbanizing areas. For example, NAWQA stream-ecology studies in the metropolitan areas of Anchorage, Birmingham, Boston, Chicago, Dayton-Cincinnati, Los Angeles, Philadelphia-Trenton, and Salt Lake City show that changes in aquatic communities are noticeable at low levels of urbanization within a basin. For example, in Anchorage, changes in aquatic communities are evident when watersheds reach about 5 percent impervious area, which in Anchorage correlates with a population density as low as 125 to 250 people per square mile. Findings also indicate that physical characteristics are altered with increasing urbanization, which can greatly affect aquatic communities. Specifically, increased residential and commercial development and road density often are associated with less tree canopy for shading, increased water temperatures, and more impervious surfaces, storm drains, and other artificial controls, all of which can increase the amount and rate of runoff during storms. As a result, increases in the magnitude and volume of peak stream flows can destroy fish-spawning beds, remove woody debris, transport large amounts of sediment, and remove natural substrates. These physical alterations are not typically tolerated by sensitive aquatic communities. Water temperatures often are increased in urban streams as a result of runoff flowing over impervious areas, such as parking lots and buildings. Many aquatic organisms can survive only within a narrow temperature range.

> *"Alaska's social and economic fabric is inextricably bound to the health of our salmon habitat and water quality. The NAWQA Program has played a critical role in helping policy makers, businesses and citizens better understand the complexities of our watersheds, and as a result, we now have better tools to manage our salmon and water resources for future generations." (*Bob Shavelson, Cook Inlet Keeper, Alaska, June 2004, USGS Circular 1240)

> *"Properly balancing competing water-resource demands while conserving our significant fish and wildlife resources for future generations is one of the most critical environmental management issues facing the Service today. The NAWQA Program provides an objective scientific foundation to assist resource agencies charged with making difficult management decisions. It synthesizes surface-water, ground-water, and biological data in an accessible and understandable way for a wide variety of readers. We find the NAWQA Program to be a valuable resource to our agency." (*Larry E. Goldman, U.S. Fish and Wildlife Service, June 2004, USGS Circular 1231)

Effects of urban development on stream ecosystem health in 9 metropolitan areas across the U.S. : A 2010 NAWQA study examines effects of urban development on stream ecosystem health (http://water.usgs.gov/nawqa/urban/). Findings show that the number of native fish and aquatic insects, especially those that are pollution sensitive, decline in urban and suburban streams at low levels of development — levels often considered protective for stream communities. For example, by the time a watershed reaches about 10 percent impervious cover in urban areas, aquatic insect communities are degraded by as much as 33 percent in comparison to aquatic insect communities in forested watersheds.

> "Stream protection and management are a top priority of state and local officials, and the USGS findings remind us of the unintended consequences that development can have on our aquatic resources. The USGS assessments of the effects of urbanization on stream ecosystems have been useful in helping us to predict and manage the future impacts of urban development and reinforces the importance of having green infrastructure to slow stream flows, control stormwater runoff, and protect aquatic life." (Tom Schueler, Chesapeake Stormwater Network Coordinator, June 2010)

The USGS determined the magnitude and pattern of the physical, chemical, and biological response of streams to increasing urbanization and how these responses vary throughout nine metropolitan areas, including Portland, OR; Salt Lake City, UT; Birmingham, AL; Atlanta, GA; Raleigh, NC; Boston, MA;

Denver, CO; Dallas, TX; and Milwaukee, WI. Comparisons among the nine metropolitan areas show that not all urban streams respond in a similar way. Land cover prior to urbanization can affect how aquatic insects and fish respond to urban development.

Findings are important to water managers and land-use planners in protecting and managing impacts of urban development and in setting realistic stream restoration goals in urban areas.

National Study on Mercury in Fish (http://water.usgs.gov/nawqa/mercury/): In August 2009, NAWQA released a national assessment on mercury contamination in fish, bed sediment and water from 291 streams across the nation, sampled from 1998 to 2005. Atmospheric mercury is the main source to most of these streams — coal-fired power plants are the largest source of mercury emissions in the United States — but 59 of the streams also were potentially affected by gold and mercury mining. The national assessment revealed mercury contamination in every fish sampled in the nearly 300 streams nationwide. Mercury, a neurotoxin, is one of the most serious contaminants threatening our Nation's waters. In un-mined areas, the main source to natural waters is mercury that is emitted to the atmosphere and deposited onto watersheds by precipitation.

> ***"This study shows just how widespread mercury pollution has become in our air, watersheds, and many of our fish in freshwater streams. This science sends a clear message that our country must continue to confront pollution, restore our nation's waterways, and protect the public from potential health dangers."*** (Secretary of the Interior Ken Salazar, August 2009)

The USGS information is used in current policy discussions within EPA related to controlling mercury sources in atmospheric deposition and setting mercury standards to protect the environment. All 50 states have mercury monitoring programs, and 48 states issued fish-consumption advisories for mercury in 2006, the most recent year of national-scale reporting to the EPA. The EPA regulates mercury emissions to air, land and water. In February 2009, the EPA announced that it intends to control air emissions of mercury from coal-fired power plants by issuing a rule under the Clean Air Act.

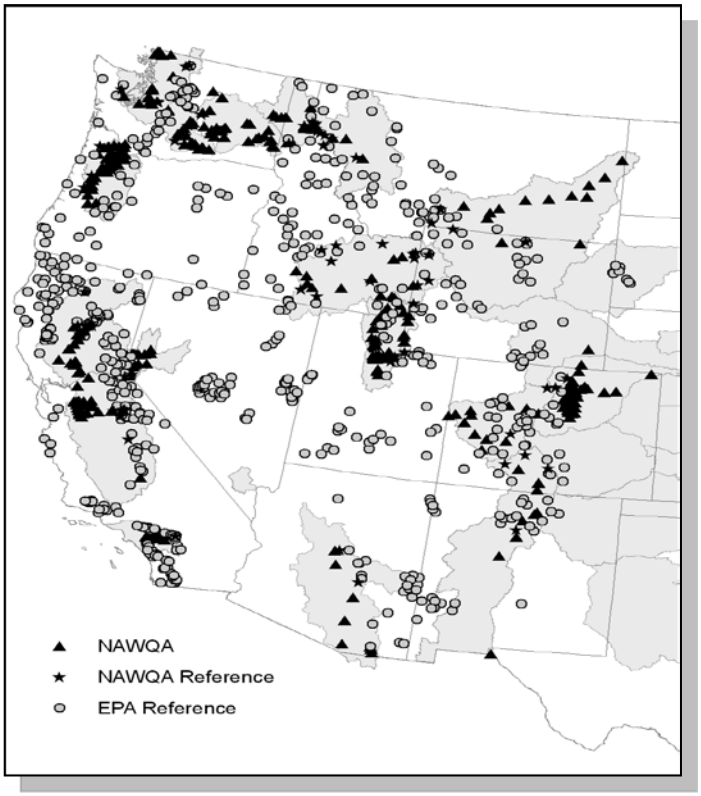
The findings also are critical for decision-makers to effectively manage mercury sources and to better anticipate concentrations of mercury and methylmercury in unstudied streams in comparable environmental settings.

Mercury in Streams Across the U.S.—In 2009, NAWQA scientists published a suite of papers in the Environmental Science and Technology journal that describes the availability of mercury in streams and how it makes its way into fish and other life-forms in these dynamic stream ecosystems. The three papers represent one of the most comprehensive studies of stream mercury dynamics. Findings identify watershed characteristics that make some streams more vulnerable to mercury deposition than others. Findings are relevant and timely to current policy discussions within the U.S. Environmental Protection Agency related to controlling mercury sources in atmospheric deposition and setting mercury standards to protect the environment. Full study can be accessed at http://water.usgs.gov/nawqa/mercury/pubs/ .

> *"The USGS scientists took a truly biogeochemical approach to seeing why certain streams have higher levels of mercury in them, where it is being produced, and how it's being accumulated in the food web. This kind of [research] has long been needed."* Vincent St. Louis, Biologist, University of Alberta (Canada) (cited in ES&T article by Naomi Nubick, March 2009)

Invertebrates in Western Streams—An integrated assessment of invertebrate communities in streams in the western U.S. is based on data from the U.S. Environmental Protection Agency (EPA) Wadeable Stream Assessment (WSA) and from the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. NAWQA data represent invertebrates sampled in approximately 400 streams within 16 large river basins (or study areas), including 87 reference sites (which are sites that represent the best possible stream ecological condition for a particular region). EPA data represent invertebrates sampled at more than 640 reference sites. Ecologists assessed comparability of the two sets of data and developed a modeling tool that allowed for quantification of bias due to any methodological differences and model uncertainty (or level of confidence) in assessing biological condition. The integrated assessment provides a regional context for NAWQA data and allows direct comparisons among the different NAWQA study areas, as well as an increased understanding of the

factors that can affect water quality and biological condition throughout the western region. The findings showed how land use has influenced the presence and abundance of native invertebrates, which, thereby, helps to anticipate the types of invertebrates expected in streams and the relative health of invertebrate communities. Similar integrated assessments of different types of data are also underway in the eastern U.S.



Polychlorinated Aromatic Hydrocarbons (PAHs) in Streams—NAWQA provided sound data and research that helped explain an important source—abraded seal coat from parking lots—of polycyclic aromatic hydrocarbons (PAHs) in urban streams and reservoirs. The study, done in 2005 in collaboration with the City of Austin, Texas reported that particles in runoff from parking lots treated with coal-tar sealcoat in Austin contained extremely high concentrations of PAHs. PAHs are potentially toxic to mammals (including humans), birds, fish, amphibians, invertebrates, and plants. Possible effects of PAHs on aquatic insects and other invertebrates include inhibited reproduction, delayed emergence, sediment avoidance, and mortality. Possible adverse effects on fish include fin erosion, liver abnormalities, cataracts, and immune system impairments. City of Austin scientists have reported toxicity and impaired aquatic communities related to sealcoat-contaminated sediment in local streams. Sealcoat is used by homeowners and commercial applicators across the nation. It is applied to residential driveways and to parking lots of shopping centers, apartment and condominium complexes, churches, schools, and office parks. The sealcoat wears off of the pavement relatively rapidly, especially in areas of high traffic, and many surfaces are resealed every two to three years. Sealcoat typically is not applied to streets, roads or highways. The City of Austin and Dane County, Wis., where Madison is located, have banned use of coal-tar based sealcoat. Full details can be accessed at http://tx.usgs.gov/coring/ .In 2009, USGS reported that dust collected from coal-tar sealcoated parking lots in Central and Eastern U.S. cities contains concentrations of polycyclic aromatic hydrocarbons (PAHs) that are about 1,000 times greater than levels found in Western cities where coal-tar sealcoat is less commonly used.

"The NAWQA staff in Austin has been instrumental in taking our findings related to pavement sealants to a much higher level, both in the recognition and exposure that the USGS carries, and in the quality of their science. The City of Austin has benefited greatly from collaboration with USGS/NAWQA staff over the last year and their professionalism and productivity has been exemplary for all of us involved with the sealant PAH source issue." (Mateo Scoggins, Researcher, Watershed Protection, City of Austin, Fall 2005)

U.S. Environmental Protection Agency—The EPA Office of Pesticides use NAWQA's extensive and nationally consistent pesticide data to assess the presence of toxic chemicals in areas where fish protected under the Endangered Species Act are present.

> *"The NAWQA study of urbanization and stream quality drew comparable conclusions to an Ohio EPA state-wide study of effects from urbanization, confirming the importance of maintaining riparian buffers and stream physical habitat. The finding has clear implications in drawing guidelines for suburban development. The NAWQA study was also able to confirm what Ohio EPA could only conclude inferentially, that a significant part of the cause of poor biological quality in urbanized catchments is due to loadings of contaminants. These findings are important because many researchers focus mainly on the consequences of hydrologic alteration affected by impervious surfaces and ignore water quality. The USGS NAWQA program helps Ohio EPA make informed water-resource management decisions by providing information from independent water-quality studies and advancing the science of water-quality monitoring, and through collaborative studies and sharing of technical expertise for the study of water-quality problems."* (Bob Miltner, Ohio Environmental Protection Agency, May 2004)

State of Nebraska—Continuous water-quality monitoring and monthly sampling by NAWQA at the Platte River near Louisville were used by the U.S. Fish and Wildlife Service in 2004 to help determine habitat requirements for re-establishment of the endangered pallid sturgeon fish in the Platte River. The Fish and Wildlife Service also used NAWQA monthly-sampling results as baseline information to assess potential exposure of sturgeon to endocrine-disrupting compounds.

State of New Jersey—On the basis of NAWQA findings in the Long Island-New Jersey Coastal Drainages, USGS works with the New Jersey Department of Environmental Protection to evaluate the effects of land use, hydrology, and pollution sources on biological indicators, including benthic macroinvertebrates and fish communities. Findings from the joint project are used to develop realistic stream management and restoration goals for urbanized streams.

State of North Carolina—NAWQA findings are used by the North Carolina Department of Environment and Natural Resources to help control excessive nutrients and resulting algal blooms, fish kills, and Pfiesteria incidents in the Neuse and Tar-Pamlico Rivers. For example, the findings led to the implementation of buffers in the Neuse River, which proved to effectively reduce nutrient runoff to the surface water. In addition, NAWQA research on the role of organic matter in streambed sediment in removing nitrate from ground water in some areas of the Coastal Plain has allowed the State to prioritize its efforts in streams where elevated nitrate is not as easily removed under natural conditions.

Upper Midwest—Biological data collected by NAWQA study units in the Upper Mississippi River Basin, Eastern Iowa River Basin, and Lower and Upper Illinois River Basins were used by the Nature Conservancy and NatureServe to set biological priorities in the Upper Midwest. NAWQA data were used by these two non-profit organizations to identify 47 sites in 7 States as the highest priority areas for conservation in the region and 22 significant areas for protection of freshwater biodiversity.

State of Utah—The NAWQA sampling strategy of integrating water chemistry, biology, and physical habitat as "multiple lines of evidence" was used in by a multi-agency taskforce that includes the U.S. Fish and Wildlife Service and Utah Department of Environmental Quality to assist in management of trace element contaminants in water, sediment, invertebrates, and fish resulting from mining operations.

State of California—Excessive mercury concentrations in water systems results in environmental concerns and identifying the source of the mercury is an important step in mitigating impacts. Unlike other areas of the United States where the atmosphere is generally the main source of mercury contamination, the major source of elevated mercury concentrations in the Sacramento River Basin has been from mercury mining and from the use of mercury in gold mining during the 19th century. Mining has resulted in streambed sediments that contain large mercury deposits that can contaminate water and fish. A recent USGS study found that colloidal suspended particulate matter plays an important role in downriver mercury transport, with greatest impact occurring during high flow or runoff events. The data provide water-resources managers with an improved understanding of the source and speciation of mercury occurrence in the Sacramento River.

State of Colorado—In the French Gulch watershed near Breckenridge, Colorado, metal mining has greatly impacted the watershed. NAWQA findings in the Upper Colorado River Basin on trace elements, streambed and suspended sediment, fish tissue, and macroinvertebrates helped a coalition of local agencies and organizations (French Gulch Remediation Opportunity Group) to determine realistic options for remediation. The coalition also gained support for continued monitoring at NAWQA sites as the remediation strategies were gradually implemented. Urbanization and increased recreation in and around the

Town of Vail, Colorado have impacted water quality in the Gore Creek watershed. Local water managers strive to maintain their gold-medal fisheries and, therefore, have conducted a mini-"NAWQA assessment" of the entire Gore Creek watershed using NAWQA protocols and sampling design. Integrated analyses of macroinvertebrates, fish, algae, surface- and ground-water chemistry, and bed-sediment chemistry have been completed. The NAWQA approach has helped the watershed group to understand the current health of the ecosystem, to make land-use decisions, such as those related to riparian buffer needs, and to implement best-management practices.

> *"The Mississippi River is one of the great rivers of the world and a vital component of the ecology and economy of Minnesota. We have consistently relied upon the NAWQA research on the Upper Mississippi for scientific data from which to assess the river's health. This is high quality data that play a key role in shaping river management policies and investment priorities."* (Mr. Whitney Clark, Friends of the Mississippi River, March 2001)

Linking Tributaries to Receiving Waters

The NAWQA design allows a multi-scale approach that helps to take into account both the needs of the local watersheds and basins and the larger water resource networks that connect them, such as the Mississippi River Basin, Great Lakes, South-Florida Everglades system, and the Chesapeake Bay watershed. This is critical because local decisions on the effects of land use or human actions in individual watersheds can contribute significantly to the cumulative or overall impact on the quality of the downstream resource and receiving water. For example, NAWQA studies show that a considerable amount of total nitrogen originates from watersheds in the Mississippi River Basin very distant from the Gulf of Mexico. The multi-scale information, as shown in the Mississippi River Basin, helps to contribute to successful solutions and actions at the local, state, interstate, and federal level—all of which are needed because of the interconnections of water resources, communities, and ecosystems across great distances, regardless of political boundaries that may govern jurisdiction over resource management and use.

Nutrients in the Long Island Sound --Results for nitrogen and phosphorus from the USGS statistical model (referred to as SPARROW for Spatially Referenced Regressions on Watershed Attributes) were used by the Long Island Sound Study, part of the EPA National Estuary Program, to assess dissolved oxygen conditions in the Long Island Sound. The information is used by the EPA Long Island Sound Study in their efforts to evaluate various levels of dissolved oxygen in the Sound related to nutrient loadings, standards, and exposure criteria.

> *"The information generated by the SPARROW modeling is very instrumental in understanding dissolved oxygen conditions in Long Island Sound, including those associated with relatively pristine, pre-colonial levels and those resulting from human activities. EPA uses the information in our efforts to manage future dissolved oxygen improvements in Long Island Sound associated with nitrogen and phosphorus inputs from major rivers and tributaries."* (Mark A. Tedesco, Director, Long Island Sound Office, USEPA, Fall 2005)

New England– USGS, in cooperation with EPA and New England Interstate Water Pollution Control Commission (NEIWPCC), developed a statistical SPARROW model to understand how and where the quality of New England's waterways is affected by nitrogen and phosphorus contamination. The model estimates the levels of total nitrogen and total phosphorus and the sources of these nutrients in 42,000 stream reaches throughout New England. Modeled findings revealed, for example, that half of the nitrogen found in New England streams comes from the atmosphere. The model is used by water-resource managers within the NEIWPCC and EPA to manage excess nutrients, which can stimulate damaging algal blooms downstream. The findings were incorporated in a regional long-term plan to reduce nitrogen entering Long Island Sound. EPA's Office of Research and Development uses modeled findings to help assess nitrogen inputs to coastal waters and to help explain results in their National Coastal Assessment in New England.

> *"The information generated by this modeling study is enormously valuable, and we're already using it to help us develop a long-term plan to reduce the amount of nitrogen that enters Long Island Sound."* (Ronald Poltak, New England Interstate Water Pollution Control Commission, Summer 2004)

Gulf of Mexico—In 2008 and continuing in 2009, NAWQA coordinates with the Gulf of Mexico Nutrient and Hypoxia Task Force to identify important sources and delivery of nitrogen and phosphorus to the northern Gulf of Mexico, which are the leading causes of oxygen loss (or "hypoxia"). NAWQA findings reveal important nonpoint and point sources of nitrogen and (for the first time) results for phosphorus, and demonstrate the importance of reservoirs, stream size, and other hydrologic factors that control nutrient delivery to the Gulf. In 2009, NAWQA provided new information to the 31 States in the basin and Federal agencies, such as the EPA and USDA, on the relative amounts of nitrogen and phosphorus delivered to the northern Gulf of Mexico from more than 800 watersheds in the Mississippi/Atchafalaya River Basins. Probabilistic rankings of nutrient yields, by watershed, help water managers, policy makers, and scientists to identify watersheds that deliver relatively large amounts of nutrients to the Gulf of Mexico, thereby providing information needed to develop cost-effective strategies for nutrient reduction in the Mississippi/Atchafalaya River Basin. In addition, the findings are used by the EPA Science Advisory Board and the Gulf of Mexico Task Force in their development of basin-wide recommendations and actions to reduce the nutrient burden flowing into the Gulf of Mexico.

"The Kansas Department of Health and Environment utilized the results of the SPARROW model for Mississippi watershed nitrogen transport as the unifying theme behind the state's Nutrient Reduction Plan. We look forward to continued refinement of the SPARROW modeling efforts to identify high priority watersheds for mitigation of nitrogen and other pollutants. We are unaware of any similar projects that have been as valuable in helping to identify nitrogen contributions to the Gulf of Mexico, and upstream states on a watershed-by-watershed basis." (Michael B. Tate, PE, Kansas Department of Health and Environment, 2009)

"The NAWQA Program is essential to understanding the impact of land-use changes on the quality of water flowing to the Great Lakes. Currently, there are two NAWQA study units in the Great Lakes, the Western Lake Michigan study unit and the Lake St. Clair-Lake Erie study unit. Findings are directly applicable to resource managers and planners and transferable throughout the Great Lakes Basin." (Quote was included in the "Legislative and Appropriations Priorities for the 106th Congress, Second Session" by the Great Lakes Commission. These priorities were formally endorsed by the eight-state Commission membership)

"NAWQA has been enormously helpful in synthesizing data and developing a better understanding of a key ecoregion of the Great Lakes. Contributions from this study will be useful for years to come as this region is managed as an integrated natural resource." (William C. Sonzogni, University of Wisconsin-Madison, State Laboratory of Hygiene, 2001, USGS Circular 1156)

"As the largest freshwater wetland in the continental US, and one identified as being critically endangered by farming, drought, development and drainage in its watershed, the Florida Everglades has the misfortune to exhibit some of the highest concentrations of mercury in its fish and wildlife…The contributions of the USGS NAWQA Project team have been of vital importance to the [South Florida Mercury Science] Program. The USGS has brought together scientists of many disciplines and enabled the South Florida Mercury Science Program to develop a deeper understanding of the scope, scale, status and trends of mercury problems in Florida. This has thereby greatly enhanced our ability to model and manage the factors that contribute to this problem." (Dr. Thomas Atkeson, Florida Department of Environmental Protection, April 2001)

"NAWQA studies are contributing valuable information on water quality/land use issues vital to effective management of the Chesapeake Bay ecosystem." (Dr. Emery Cleaves, Maryland Geological Survey, Baltimore, Maryland, 2001, USGS Circular 1166)

Support for the Development of Regulations, Standards, Guidelines, and Criteria for Contaminants

Regulations Based on the Reality of Occurrence—NAWQA studies document the prevalence of low levels of contaminants in streams and ground water throughout the Nation. Concentrations were almost always below current EPA drinking-water standards. Actual patterns of contamination, however, may differ from what is detected or regulated and, therefore, the risk to humans and the environment from low levels of exposure remains unclear. For example, current standards and guidelines do not account for contamination that occurs as mixtures of various parent compounds and breakdown products, or that is characterized by lengthy periods of low concentrations punctuated by brief, seasonal periods of higher concentrations. Specifically,

- Seasonality—In almost all 51 Study Units, contaminant exposure varied with seasons, with long periods of low or non-detectable concentrations punctuated by brief periods of much higher concentrations. Seasonal patterns were related primarily

to the timing and amount of chemical use, the frequency and magnitude of runoff from rainstorms or snowmelt, and land-management practices, such as tillage.

- Mixtures—Streams and ground water in basins with significant agriculture or urban development almost always contained mixtures of VOCs, nutrients, pesticides, and their chemical breakdown products. Nationally, for example, about 15 percent of samples collected from urban streams contained at least 10 VOCs. Similarly, about one-quarter of urban streams samples contained 10 or more pesticides. Possible cumulative effects on human and aquatic health from low concentrations of multiple compounds are unknown.

- Breakdown products—Breakdown products frequently were as common in the environment as the parent compounds. For example, atrazine, the most heavily used herbicide in the Nation, and its breakdown product deethylatrazine (DEA) were found together in about 75 percent of stream samples and about 40 percent of ground-water samples collected in agricultural areas across the Nation. Standards or guidelines to protect human health or aquatic life have not been established for breakdown products, yet they can be as toxic, or even more toxic, than parent compounds.

Effective water-resource management and watershed protection may require monitoring programs that analyze samples for breakdown products and multiple compounds, and that evaluate patterns related to seasons and storms when peak contaminant concentrations could possibly affect drinking-water supplies and critical life stages of aquatic organisms.

Cedar Rapids, Iowa— The NAWQA Program commonly detected elevated concentrations of nitrate and pesticides in the Cedar River and alluvium wells near Cedar Rapids, Iowa. The detections included pesticide breakdown products, which are mostly non-regulated and in some instances found at concentrations ten times the concentrations of parent compounds. On the basis of these findings, local officials in the city of Cedar Rapids, which obtains its water from the wells close to the Cedar River, has recommended monitoring and analysis of herbicide degradation products in city water supplies.

Potomac River, Washington D.C.—Sampling of nutrients and pesticides through a large storm event on the Potomac River in January 1996 showed that concentrations and total amounts of nutrients and atrazine can increase during localized large storms, sometimes with overwhelming effects on receiving waters, such as the Chesapeake Bay. In this case, concentrations of atrazine and other individual compounds exceeded EPA drinking-water standards during and following the extreme storm event. Such information helped water suppliers better understand the role of short-term and seasonal events, which affected timing of withdrawals, mixing, and storage to most effectively deliver high quality water at a minimum cost.

Pesticide registrations and regulations—The USPEA Office of Pesticides relies on USGS for high-quality, nationally consistent monitoring data for pesticide registration and for their assessments of pesticide exposure. For example, NAWQA data help to guide EPA's decisions on the commonly detected herbicides aldicarb, alachlor, and acetochlor, and the insecticides chlorpyrifos, diazinon, and carbofuran. In total, EPA has regulated 17 compounds through 2008 using NAWQA data. The EPA Office of Pesticides relies on USGS data to meet one of its performance goals, which states: "By 2010, detections of the 15 pesticides most frequently found in surface water in USGS 1994 NAWQA data will be reduced by 50 percent. Any new pesticides registered since 1996 found in USGS 2010 data for surface water will have a detection frequency no greater than 30 percent. By 2010, 50 percent of all pesticides with the potential to leach to ground water will be managed through labeling or other methods to prevent ground-water contamination."

State of Nevada—The Nevada Division of Agriculture, responsible for registering pesticides and protecting ground water, uses ground-water data collected by NAWQA in the Nevada Basin and Range to make decisions on registering pesticides. The agency historically used a network of deep supply wells for monitoring pesticides in agricultural areas of Nevada and no pesticides were detected by the State during 1993-1997 in these wells. However, the NAWQA Program reported the relatively frequent occurrence of pesticides, such as atrazine and simazine, on the basis of lower detection limits and shallower wells. These findings are incorporated in the Nevada registration process for pesticides.

"The NVBR NAWQA study detected pesticides in shallow ground water beneath urban and agricultural areas in Nevada. These results are being used by the Nevada Division of Agriculture to evaluate pesticide registrations in Nevada." (Charles Moses, Nevada Department of Business and Industry, Agricultural Division, 2001, USGS Circular 1170)

"The NAWQA Program helps the U.S. Environmental Protection Agency (USEPA) implement the new pesticide law… Food Quality Protection Act (FQPA), passed in August 1996. USEPA has been required to factor potential exposures to pesticides through drinking water into already complex procedures used to set pesticide "tolerance levels" in foods. Incorporating potential drinking-water exposures into the pesticide tolerance-setting process has presented USEPA with many scientific challenges including: 1) What reliable data are available on pesticide concentrations in surface and ground water in the U.S.? How do these concentrations vary with location and time? 2) How can USEPA account for the considerable geographic variability in geology, hydrology, land use, and agronomic practices in estimating profiles of pesticide drinking water exposures in various regions across the U.S.? 3) What "real world" data are available to evaluate and improve computational models that USEPA uses to estimate pesticide drinking-water residues for new pesticides entering the market? 4) What types of surface- and ground-water monitoring should USEPA require pesticide makers to conduct after new pesticides (or significant changes in use areas or practices) are approved to verify that actual pesticide levels do not exceed those estimated through USEPA's screening procedures? Building on many years of productive collaboration between USEPA and USGS, the NAWQA Program marshaled a wide range of its data and expertise to help USEPA address these and other questions. We do not have all of the answers yet by any means, but we in USEPA who are charged with implementing this part of the new FQPA are greatly impressed with the knowledge and expertise contributed by NAWQA Program scientists and managers to assist USEPA in addressing these questions. USEPA's Office of Pesticide Programs is a very satisfied "customer" of USGS and NAWQA water-resources programs." (Joseph J. Merenda, Office of Pesticide Programs, USEPA, 1998)

Implementation of FIFRA—NAWQA findings on more than 100 pesticides also show that pesticides are seldom present at concentrations likely to affect humans, but do occur in many streams, particularly those draining urban and agricultural areas, at concentrations that may affect aquatic life or fish-eating wildlife (http://water.usgs.gov/nawqa/pnsp/). The national assessment included a comprehensive evaluation of pesticide mixtures and concentrations in relation to aquatic-life benchmarks, which identified a number of pesticides, including diazinon, chlorpyrifos, and malathion as potential concerns for aquatic life (each of which exceeded aquatic-life benchmarks in more than 25 percent of urban streams studied). Results are heavily used by the USEPA and States in their implementation of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

"The Hudson River Basin NAWQA program has provided the Department with crucial information and a solid monitoring foundation to create our own statewide pesticide-monitoring program. It is our expectation that expansion of the NAWQA work to include other important areas of New York State will enable us to successfully meet all State and Federal monitoring requirements and provide the Department with the data we need to make responsible pesticide registration decisions." (Larry Rosenmann, New York State Department of Environmental Conservation, 2001,USGS Circular 1165)

Nutrient criteria

Nuisance plant growth is noted in streams across the nation because of elevated concentrations of nutrients. In fact, concentrations of phosphorus exceeded the EPA desired goal for phosphorus for preventing nuisance plant growth in streams (0.1 parts per million) in about 75 percent of agricultural and urban streams sampled by the NAWQA Program. It is difficult and premature, however, to attempt a national summary of the effects of eutrophication because methodologies are limited for deriving criteria based only on nutrient concentrations. In recognition of these limitations, EPA, in collaboration with USGS and other federal and state agencies, is developing a strategy to evaluate aquatic plant growth and to develop an understanding of stream nutrient dynamics, stream habitat, turbidity, and algal-growth processes.

"Today, EPA is encouraging all States, Territories and authorized Tribes to accelerate their efforts and give priority to adopting numeric nutrient standards or numeric translators for narrative standards for all waters in States and Territories that contribute nutrient loadings to our waterways. Incremental progress can be an effective way to accelerate progress. If a State needs to implement numeric nutrient criteria incrementally, EPA strongly recommends that States adopt numeric nutrient standards for their priority waters – i.e. waters at greatest risk of nutrient pollution (such as those identified through the EPA-USGS SPARROW modeling effort). (Mr. Ben H. Grumbles, former Assistant Administrator, EPA, May 25, 2007)

Phosphorus in the Nation's Streams—USGS developed and applied the USGS statistical model (referred to as SPARROW for Spatially Referenced Regressions on Watershed Attributes) model to predict concentrations of phosphorus in streams and rivers across the Nation that meet the EPA recommended goal to control excessive growth of algae and other nuisance plants. Findings indicated that only about 40 percent of U.S. stream miles meet the recommended goal, and that concentrations vary regionally. For example, about 20 percent of stream miles in the Upper Mississippi River Basin meet the goal versus nearly 85 percent in New England. Model findings help to identify regions that are most vulnerable to elevated concentrations of phosphorus and contribute scientifically defensible information to the development of regional water-quality criteria for nutrients.

"Water quality data and analysis for the Upper Illinois River Basin NAWQA study will be useful in developing Illinois nutrient standards and prioritizing the development of standards for other pollutants." (Richard Lanyon, Research and Development, Metropolitan Water Reclamation District of Greater Chicago, June 2004, USGS Circular 1230)

State of Louisiana—USGS works with the Louisiana Department of Environmental Quality to develop nutrient criteria using NAWQA information on chlorophyll a in the Acadian-Pontchartrain Basins. According to Louisiana Department officials, "The largest, most consistent source of chlorophyll a data for Louisiana comes from NAWQA sites."

State of Indiana—NAWQA scientists, in collaboration with the Indiana Department of Environmental Management (IDEM), monitor seasonal and annual trends of nutrient and algal concentrations and their potential effects on the biotic community. NAWQA findings were included in the EPA approved State of Indiana Nutrient Criteria Plan.

"The work that USGS is doing at NAWQA sites in Indiana provides a major contribution to Indiana's plan to develop nutrient criteria for the State. Indiana, like many States, is opting to try to develop nutrient criteria based on "cause and effect" relationships. NAWQA data provide valuable information on seasonal and annual trends, fate and transport of nutrients, and relations between biological, chemical, and physical data—all of which help to define cause-and-effect relationships between nutrients, algal responses, and biological condition." (Denny Clark, Indiana Department of Environmental Management, October 2004)

State of Oklahoma—The Oklahoma Water Resources Board recommended a limit of 0.037 milligrams per liter of total phosphorus for six of Oklahoma's highest-quality waterways. The 0.037 value came from a NAWQA Nutrient National Synthesis Report published in the Journal of the American Water Resources Association entitled "Nutrient Concentrations and Yield in Undeveloped Stream Basins of the United States" by, G.M. Clark, D.K. Mueller, and M.A. Mast. The streams drain areas of Arkansas heavily affected by poultry farming and as a result, the phosphorus limit faces stiff opposition from Arkansas.

St. Croix National Scenic Riverway, Minnesota—The St. Croix River Water Resources Planning Team, which is a multi-state-Federal cooperative organization, use NAWQA data to implement a protection strategy for the St Croix River in effort to reverse ecological degradation. In 2004, the Team announced a goal for a 20-percent reduction in phosphorus loading to the watershed. This recommendation was in large part based on NAWQA findings on nutrient loadings from tributaries.

"We are very fortunate to have the St. Croix National Scenic Riverway included in the NAWQA Program. The work done through NAWQA has proven to be invaluable and has provided a firm foundation and the momentum for additional studies. We have gained tremendous benefits from our association with NAWQA." (Randy Ferrin, St. Croix River Water Resources Planning Team, National Park Service, October 2004)

"The St. Croix National Scenic Riverway (NSR) was established in 1968 under the National Wild and Scenic Rivers Act. In the early 1990's continued development and usage of the St. Croix River concerned water resource managers about the impact on water quality. Research from the NAWQA Program provided evidence that nutrient loading from the tributaries was increasing the rate of eutrophication in Lake St. Croix, a sink of the St. Croix River Basin. In response to these threats, a cooperative agreement was signed in 1993 by the National Park Service, the Minnesota Department of Natural Resources, the Wisconsin Department of Natural Resources, and the Minnesota Pollution Control Agency. To date, the partnership that was formed (St. Croix Basin Water Resources Planning Team) has relied heavily on data from NAWQA to implement a protection strategy for the St. Croix River." (Pam Davis, St. Croix Basin Water Resource Planning Team, March 2001)

Contributions to State Assessments, Strategies, and Source-Water Protection

NAWQA findings are used to in State assessments of waters meeting beneficial uses and impaired waters (Total Maximum Daily Loads or TMDLS); in the development of strategies for source water protection and management and pesticide and nutrient management plans; and in setting fish-consumption advisories.

State assessments of water meeting beneficial uses and impaired waters—Consistent and comparable monitoring information is needed to effectively assess beneficial uses (as required in EPA 305(b) reporting) and impaired waters (as required in EPA 303(d) reporting), and to develop Total Maximum Discharge Loads (TMDLs). NAWQA information on the occurrence, sources, and transport of contaminants is used by States and Tribes to meet these requirements. An understanding of critical factors controlling sources and transport has proved critical in the accurate establishment of TMDLs in selected stream segments across the Nation.

State of Missouri—The Missouri Department of Natural Resources has incorporated NAWQA stream-quality data into their database for monitoring compliance with EPA 305(b) water-quality standards. The Department uses the data to describe attainment of beneficial uses, to identify and prioritize problems, to help develop Total Maximum Discharge Loads (TMDLs), and to assist in overall natural resource management.

State of New Jersey—The New Jersey Department of Environmental Protection use NAWQA findings in the preparation of their State Assessment 305(b) reports (beginning in 2000). Specifically, NAWQA information is used to report (1) the long-term nature of nitrate contamination; (2) improvements in stream conditions and fish communities in northern New Jersey due to improvements in waste water treatment; (3) relations between impaired biological communities in urban streams and impervious surfaces; and, (4) use of synthetic chemicals on biological health.

Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes, Wyoming—USGS assists the tribal Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes in sampling large river sites. NAWQA protocols are used for selected water-column and aquatic ecological sampling. The Commission uses this information in their State Assessment 305(b) report and to make management decisions on the surface-water resources.

State of Ohio—NAWQA findings showed elevated loadings of insecticides, polycyclic aromatic hydrocarbons (PAHs) and heavy metals in urban streams and rivers in the Great and Little Miami River Basins. The study was used by Ohio EPA in FY 2004 to assign with greater confidence the causes and sources of pollution to impaired waters appearing on their listing of impaired waters (EPA 303(d) listing). Results were timely with respect to several on-going Ohio EPA TMDL studies, particularly for Big Darby Creek, which was designated by American Rivers as one of the ten most imperiled rivers in the Nation because of suburban development. Scientific findings on nutrients and aquatic communities also supplied critical information for Ohio Environmental Protection Agency's Total Maximum Daily Load (TMDL) effort in the Stillwater River Basin in Ohio and continue to provide valuable data for future TMDLs in other sub-basins of the Great Miami River.

> "Data from the NAWQA [Program] supplied critical information for Ohio EPA's Total Maximum Daily Load (TMDL) effort in the Stillwater River Basin, and will continue to provide valuable data for future TMDLs in other sub-basins of the Great Miami River. Additionally, the NAWQA study has helped further our understanding of linkages between nutrients, land use, and impairment of aquatic life. The USGS has also been particularly generous in sharing scientific expertise developed by NAWQA with Ohio EPA, especially their expertise in sampling algal communities." (Robert Miltner, Ohio Environmental Protection Agency, June 2004, USGS Circular 1229)

San Joaquin Valley, California — NAWQA data were incorporated in the development of a TMDL for insecticides diazinon and chlorpyrifos in the San Joaquin River Basin in central California by the Central Valley Regional Water Quality Control Board. NAWQA data and assessments are unique in that they help to explain variations in concentrations over seasons, including during winter storms and periods of heavy irrigation. In addition, the NAWQA data and assessments help to explain

> "NAWQA monitoring and assessment in the San Joaquin River Basin has provided foundational information for the development of Total Maximum Daily Loads (TMDLs) for diazinon and chlorpyrifos in the San Joaquin River Basin. This information helps assure that the Central Valley Regional Water Quality Control Board makes informed water quality management decisions that are based on sound science."
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> (Leslie F. Grober, Senior Land and Water Use Scientist, California Regional Water Quality Control Board, Fall 2005)

atmospheric contributions, including both wet and dry deposition.

State of Oregon—Data on atmospheric mercury concentrations and loads to the Willamette Basin, Oregon were incorporated in an interim basin-wide, mercury TMDL by the Oregon Department of Environmental Quality (ODEQ). These atmospheric data are unique in that they are the first available for Oregon. NAWQA sampling efforts in the Willamette Basin continue to provide information to the ODEQ on mercury sources (especially in urban basins), mercury methylation rates, seasonal variability of mercury concentrations in streams, and bioaccumulation of mercury within the aquatic food web—all of which have been identified as areas needing additional research as ODEQ moves toward development of a final TMDL in 2009.

Yazoo River Basin in Mississippi – USGS data on biological indicators of water quality in streams draining the alluvial plan portion of the Yazoo River Basin (or the "Delta") were used by the Mississippi Department of Environmental Quality in support of the State of Mississippi's 305(b) process and development of TMDLs. USGS work continues to verify results from the initial project and to track trends in water-quality in Delta streams.

"USGS participation in the initial phase of the Delta Pilot project has helped MDEQ tremendously in moving forward with developing TMDLs for the Mississippi Delta. We appreciate their efforts and professionalism in persevering with this work through a spring flood, a summer drought, and 2 hurricanes to end the sampling season. We look forward to working with them on the next phase of the project in the spring of 2006." (Henry Folmar, Laboratory Director, Mississippi Department of Environmental Quality, Fall 2005)

State of North Carolina—An improved understanding of sources and transport via ground-water discharge has proved critical for accurate setting of TMDLs in North Carolina. NAWQA findings in the Albemarle-Pamlico Sound, North Carolina highlighted relatively significant sources of elevated phosphorus in discharging ground water to the Tar and Neuse Rivers, which likely originates from naturally occurring phosphate minerals in deep Cretaceous-age aquifer sands. The results are critical to fully account for all contributing phosphorus sources.

Minneapolis, Minnesota—NAWQA findings for Shingle Creek and other urban streams near the greater Minneapolis metropolitan area indicated a widespread chloride problem with significant implications regarding TMDL "course-of-actions." Chemical and biology samples collected by USGS in Shingle and Nine Mile creeks and 13 other major streams in the metropolitan area indicated clear relations between chloride concentrations and impervious surfaces and snowmelt (which is highly suggestive of salt applications for road-deicing). The data, placed in context with other NAWQA samples in urban streams throughout the Nation, showed that chloride concentrations significantly increase with increasing development. Prior to these USGS findings, the Shingle Creek Watershed Management Commission believed that chloride in Shingle Creek was a local, and solely a stockpile, issue. On the basis of USGS chloride results, the Commission recommended a metropolitan-wide approach to manage road salt use and to explore alternatives to sodium chloride (such as calcium magnesium acetate, which is higher in cost, but has a slower activation rate). The improved assessment of chloride sources led to improved strategies needed to meet Minnesota standards.

"As the TMDL (Total Maximum Discharge Loads) Coordinator for the Minnesota Pollution Control Agency (MPCA), the UMIS NAWQA study has been very valuable. The approach focuses on watershed health and the types of stressors that are important to the MPCA as we do our basin planning and TMDL restoration studies. NAWQA was flexible enough to include the St. Croix basin, further strengthening an already very active multi-state and federal study effort." (Dr. Howard Markus, Minnesota Pollution Control Agency, March 2001)

"Information provided by the Yellowstone NAWQA project has been very useful to our program. The Yellowstone River Basin periphyton study results are a fundamental aspect of Montana's Department of Environmental Quality's fish and aquatic use impairment determinations and a foundation for nutrient total maximum daily loads (TMDL) development. NAWQA Powder River data have been a critical part of trend analysis work. Without that data, we would have had very little recent information." (Pat Newby, Montana Department of Environmental Quality, June 2004, USGS Circular 1234)

State of Maryland—NAWQA findings on the movement of nutrients and sediment to surface water in the Potomac River Basin are incorporated in a watershed model that is used to evaluate TMDLs for nutrients and sediment in several tributaries and the main stem of the Potomac River.

State of Texas—USGS works with the Texas Natural Resource Conservation Commission and City of Fort Worth to better understand the occurrence, transport, and effects of legacy pollutants, such as DDT and PCBs, in urban streams and lakes in Fort Worth, Texas. The information is used by the State of Texas in their TMDL assessments of impaired urban waters. USGS is leading a comprehensive sediment coring and suspended-sediment sampling program, which is designed to determine if, and at what rates, these pollutants enter urban streams and lakes and how long it could take for these pollutants to naturally attenuate to safe levels.

State of Kansas—The Kansas Department of Health and Environment, Bureau of Water, used NAWQA modeling results in the development of their State's Nutrient Reduction Plan to address point and non-point sources of nutrients. The modeling results help to identify watersheds that have a high potential to transport nitrogen, and to target non-point source management funds and activities in watersheds that have the greatest potential to improve stream water quality. The modeling study also demonstrated the significance of point sources (wastewater treatment facilities) and their role in nitrogen transport, ultimately to the Gulf of Mexico. Many point sources in Kansas are now committed to upgrading treatment to address both nitrogen and phosphorus reduction.

State Strategies for Source-Water Protection –States, Tribes, and localities use NAWQA information to develop source-water protection strategies and statewide management plans, such as for pesticides, nutrients, and MTBE. Specifically, state environmental and natural resource agencies prioritize streams and ground-water areas for assessment of these constituents on the basis of vulnerability concepts, contaminant occurrence data, and quality-assurance protocols of the NAWQA Program.

"I coordinate the Upper Mississippi River Source Water Protection Initiative, an effort that will lead to the development of source-water protection plans for public water suppliers within the upper Mississippi River basin. The water quality data that have been generated and documented through NAWQA will figure prominently in the preparation of these plans. The information on certain contaminant levels in various settings within the basin, and the information describing the sources of contaminants provide documentation and solid rationale for identifying source water protection strategies, priorities, and protection measures for public water suppliers. In my opinion, more than any single information source, the Upper Mississippi River NAWQA provides an extremely valuable substantive basis for source water protection in the Upper Mississippi River basin." (Mr. David Brostrom, Upper Mississippi River Source Water Protection Initiative, March 2001)

State of Washington—The Washington State Department of Health, in concert with USGS, assessed the vulnerability of public water-supply wells to pesticide contamination based on statistical relations between levels of detection and geology, well characteristics, and land-use activities. NAWQA information on pesticide contamination enabled the health department to identify wells with low vulnerability to contamination and obtain waivers for quarterly monitoring required under the Federal Amendments to the Safe Drinking Water Act, 1996. By using the information to meet EPA requirements for safe drinking water, Washington State was able to protect their drinking-water source while saving at least $6 million in costly additional monitoring. This was an annual savings of as much as $70 per household on small public supply systems that were granted full monitoring waivers.

State of New Jersey – In collaboration with the New Jersey Department of Environmental Protection (NJDEP), the USGS collected data on contaminant occurrence in surface-water and ground-water resources, and related the results to geology, soils, land use, and other factors that affect vulnerability. Classification of almost 2,000 public supply wells according to their vulnerability to pesticides led to a substantial cost savings through monitoring waivers for water suppliers shown to be a low risk for contamination—specifically, the NJDEP estimated that because many wells and intakes were not vulnerable to contamination, waivers saved taxpayers at least $5.1 million annually for a one-time study cost of $1 million. The effort was done in response to the State Drinking-Water Act (SDWA) regulations (1996) that required the 626 large community water systems to monitor their 2,600 wells and 45 surface-water intakes quarterly for 23 pesticides. The monitoring would have increased consumers' water bills by $6.4 million each year (Full study accessible at: http://pubs.er.usgs.gov/usgspubs/fs/fs16596).

State of California—USGS works with the California State Water Resources Control Board and Department of Health Services to assess the vulnerability of public-supply wells to contamination. The State uses USGS ground-water-age-dating analyses as one indicator of vulnerability. In addition, on the basis of NAWQA findings on the occurrence of industry-related

and petroleum-based chemicals in ground water, the State has included the collection and analysis of VOCs in their vulnerability assessment. More than 200 wells have been sampled in southern California.

Pesticide and Nutrient Management Strategies

> *"The NAWQA Program has filled a tremendous void in the pesticide data that the State of Alabama must acquire in the development of the USEPA-mandated State Pesticide Management Plans. The scope of the data collected has made the decision-making process of writing the plan simpler because actual NAWQA data are used to make important determinations and the plan can target the areas of greatest importance."*
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> (Tony Cofer, Pesticide Division, Alabama Department of Agriculture and Industries, June 2004, USGS Circular 1231)

State of New York—NAWQA findings in the Hudson River Basin represented a broader array of analyses using lower detection limits than data previously available to the State. The New York State Department of Environmental Conservation applies the NAWQA pesticide information and protocols in its statewide pesticide monitoring, as required under the New York State Pesticide Reporting Law, to improve decisions regarding pesticide registration (Environmental Conservation Law Section 33-0714). A part of the monitoring program investigates the occurrence of pesticides and their breakdown products in public-water supply reservoirs, including the New York City network, the Finger Lakes-Great Lakes network, and the western New York reservoir network. Collaborative efforts with USGS were expanded beyond the Hudson River Basin to other parts of the State, sparked by public concerns over pesticides in New York State waters and their possible relation to the incidence of breast cancer. The project, which is based largely on NAWQA protocols and sampling, has resulted in a better understanding of the occurrence of pesticides throughout the state, such as the occurrence of dieldrin and other organochlorine compounds in the sole source aquifer on Long Island.

State of Kansas—NAWQA findings on elevated concentrations of atrazine (frequently approaching or exceeding the EPA drinking-water standard) in water-supply reservoirs in the Lower Kansas River Basin were used by the Kansas State Board of Agriculture as the basis for establishing a pesticide management area in northern Kansas (Delaware River Basin). Within this management area, the State of Kansas called for both voluntary and mandatory restrictions on pesticide usage on cropland to improve water quality. The management area was the first in the Nation to focus on reducing atrazine in runoff to streams and reservoirs.

State of Washington—The Washington State Department of Ecology created a Ground Water Management Area to protect ground water from nitrate contamination. The management area covers Grant, Franklin, and Adams counties, located in an intensive agricultural region of the Central Columbia Plateau. NAWQA information and communication of those findings in the USGS publication "Nitrate Concentrations in Ground Water of the Central Columbia Plateau" provided the scientific basis for implementing the management area. As follow-up to the NAWQA findings, USGS works with the Department of Ecology to (1) identify areas with lower nitrate concentrations, which could potentially serve as sources of future drinking-water supplies, (2) statistically correlate nitrate concentrations with natural features and human activities to better assess vulnerability; and, (3) design a long-term monitoring strategy for assessment of changes in nitrate concentrations over time.

Southeastern Idaho—As part of State Pesticide Management Plans for herbicides by the State Department of Agriculture, models and maps were developed by NAWQA to portray the potential for atrazine contamination in ground water in southeastern Idaho. Significant factors used to successfully predict atrazine concentrations in ground water were atrazine use, land use, precipitation, soil type, and depth to ground water.

State Fish Consumption Advisories

Potentially toxic compounds, such as DDT, chlordane, dieldrin, polychlorinated biphenyls (PCBs), and mercury, were commonly detected in fish in sampled streams, often at higher concentrations than in the sediment. Nationally, for example, one or more organochlorine compounds (including organochlorine pesticides and PCBS) were detected in about 95 percent of whole-fish samples collected at urban sites. Concentrations of organochlorine compounds in fish tissue exceeded guidelines to protect wildlife at nearly 75 percent of urban sites. (Full study is accessible at: http://pubs.usgs.gov/circ/2005/1291/).

NAWQA information on organochlorine compounds, mercury, and other trace elements in fish tissue is used by states to evaluate and establish fish consumption advisories.

State of South Carolina—NAWQA provided sound data on mercury concentrations to the South Carolina Department of Health and Environmental Control (SCDHEC) that helped explain elevated mercury in fish and the large number of fish consumption advisories in rivers and streams in and around the Santee River Basin. Comparisons to other NAWQA studies across the Nation showed that this basin has one of the highest rates of conversion of inorganic mercury to its more toxic form, methylmercury, which is the form readily available for uptake by fish and other aquatic communities. The findings were used by the SCDHEC and the National Park Service, in partnership with USGS, to assess natural factors controlling the mercury conversion, such as related to sediment microbial communities. The analysis is used to guide the State's continued management of stream health and fish advisories.

State of Washington— The Washington Department of Ecology issued fish-consumption advisories for rainbow trout and mountain whitefish caught in the Spokane River from Upriver Dam, Washington to the Idaho state line because of elevated levels of PCBs and lead. The first advisory was issued for lead in August 2000 following the release of NAWQA information on lead and other heavy metals. A second advisory was released in early 2001 for PCBs following a joint study by the State and USGS that looked at PCB occurrence and heavy metals downstream from Idaho's historic mining activities. NAWQA scientists, participating on a multi-agency team studying Lake Roosevelt, a popular fishing area in Washington State, collected several species of fish to evaluate mercury contamination. The results led to a site-specific health advisory for mercury by the Washington State Department of Health for consumption of walleye because possible adverse health effects from mercury. In the Yakima River Basin, the insecticide DDT was detected at elevated concentrations in water, streambed sediment, and fish tissue. These NAWQA findings suggested a potential health concern, especially to the local population of Native Americans who rely on fish as a major source of food, and a continued threat to fish-eating birds. The Washington State Department of Health recommended that people eat no more than one meal per week of bottom fish from the lower Yakima River.

"The Washington State Department of Health has determined that a human-health impact analysis should be conducted to determine if concentrations of DDT in fish in the Yakima River Basin pose a threat to human health. This determination was made on the basis of concentrations of total DDT reported from the analysis of fish tissues in the National Water-Quality Assessment study and results of preliminary risk-assessment calculations." (Glen Patrick, Washington State Department of Health, 2001, USGS Circular 1090)

State of New York—NAWQA findings documented the occurrence of PCBs in the Mohawk River in the vicinity of Utica and Little Falls, New York. These results contributed to decisions by the New York State Department of Health to issue fish consumption advisories on carp and selected game fishes, including largemouth bass and tiger muskellunge.

State of Pennsylvania—The Pennsylvania Department of Environmental Protection uses NAWQA data collected in game species to re-evaluate fish advisories on the Schuylkill and Delaware Rivers. PCB, chlordane, DDT, and dieldrin were the most frequently detected organochlorine compounds in fish tissue from 30 sites sampled throughout the Delaware River Basin. Among the four sites at which smallmouth bass fillets were analyzed for organochlorine compounds, three exceeded the Great Lakes consumption advisory level for PCBs.

State of Mississippi—In 2000, the State of Mississippi convened a Fish Advisory Task Force to develop procedures regarding fish consumption advisories for organochlorine compounds and other contaminants. NAWQA demonstrated that elevated organochlorine levels have persisted in fish in this part of the country longer than anticipated by most managers. Concentrations of total DDT collected from 30 of the 41 sites sampled in the Mississippi Embayment exceeded guidelines established to protect wildlife. In fact, fish collected in 1995 showed that the highest concentrations of total DDT in fish tissue throughout the entire Mississippi River drainage were in the Mississippi Embayment study area. Streams demonstrating elevated levels in fish by USGS, such as some in the Delta region in Mississippi, are included in the preliminary state fish-consumption advisories, minimizing necessary sampling by the State and, therefore, resulting in cost-effective and timely management decisions.

State of Texas—High levels of PCBs detected in fish in the Donna Canal in south Texas in the early 1990s led to a ban on possession and consumption of fish. Subsequent extensive sampling studies by the State of Texas continued to reveal high levels in fish but no information on potential sources. The Texas Natural Resource Conservation Commission approached the NAWQA Program in 1998 and requested suspended-sediment chemistry and coring methods to locate the PCB source. USGS sampling narrowed the potential source to a 90-meter stretch along the approximately 4 mile long Donna Canal. The State turned the results over to their Superfund Program to begin the process of assessment and clean up.

"For a period of four years following the discovery of high levels of PCBs in fish tissue in the Donna Canal by the USEPA, the Texas Natural Resource Conservation Commission, in cooperation with the Texas Department of Health and Texas Parks and Wildlife Department, conducted a series of investigations aimed at identifying the source of PCB contamination in the Donna Canal and associated reservoirs. Unfortunately, the subsequent (three) water, (two) fish and (three) bottom sediment sampling efforts brought us no closer to finding a source of the PCBs. Later (in 1998) after the first Superfund Site Discovery and Assessment investigation yielded equally empty results, we felt it was time to get help. Today, I am pleased to say that, not only have we been able to narrow the potential source of PCB contamination to an area of the canal approximately 90 meters long, the suspended sediment sampling results from [USGS] studies have enabled us to refocus our Superfund Site Discovery and Assessment investigation efforts and I am confident that this project will be in remediation mode by this Fall. Of course, the real benefactors of your work are the people of the Rio Grande Valley who will have one public health problem less to contend with." (Roger Miranda, Texas Natural Resource Conservation Commission, March 2001)

Improved Strategies and Protocols for Monitoring, Sampling, and Analysis

Local, State, tribal, and federal organizations recognize the value and application of the NAWQA Program's consistent and comparable monitoring designs and sampling methodology. Many have recognized that other available data have limited applicability because samples are not systematically collected as part of an inter-disciplinary and long-term evaluation of the total resource, but are biased to a specific geographic area, problem, or medium at a single point in time.

*"EPA is partnering with USGS and the States to support integrated monitoring designs that address multiple decision needs. Such designs include statistically valid (or "probabilistic") water-quality surveys, targeted and site-specific monitoring, landscape-based predictive models, and remote sensing. Multiple lines of monitoring are needed to answer the diverse array of water-resource questions. While the probabilistic designs provide a quantified estimate of, for example, percentage of streams impaired within a broad geographic region, a targeted design can address sources, seasonal differences, varying stream-flow and ground-water contributions, and processes that control the movement and quality of water. Imperative for future success is that data collection and monitoring are consistent and comparable so that the findings can be integrated. EPA and USGS are committed to increasing such comparability and integration of monitoring in order to enhance our ability to answer critical questions about our Nation's waters that no one program can answer alone." (*Mike Shapiro, Deputy Assistant Administrator, USEPA, Office of Water, February 2005)

"NAWQA data on benthic invertebrates is a major contribution to the State of Hawaii because the data have never been collected in Hawaiian streams and never before in conjunction with such a wealth of water-quality parameters. The information could provide the basis for an important new component in water-quality monitoring in Hawaii, which would be especially useful for volunteer monitors and educational groups." (Dr. Carl Evenson, University of Hawaii at Manoa, June 2004, USGS Circular 1239)

"The California State Water Resources Control Board has worked closely with the U.S. Geological Survey to develop a comprehensive monitoring and assessment program for California's groundwater basins. The approach, methods, and results from NAWQA studies have been fully integrated into California's plans to evaluate ground-water quality on a statewide basis." (Arthur G. Baggett, Jr., State Water Resources Control Board, June 2004, USGS Circular 1238)

"NAWQA's consistent methodology and quality assurance designs have been instrumental is increasing the validity of the District's monitoring program. We value our continued collaborative monitoring efforts with USGS." (Rick Wozniak, Water Resources Manager, Lower Elkhorn Natural Resources District, Fall 2005)

Lower Elkhorn Natural Resources District, Nebraska — The Lower Elkhorn Natural Resources District has modified their water-quality monitoring program on the basis of the NAWQA approach, methods, and quality assurance design. For example, the District has implemented the use of flow-through chambers in sampling, and included quality-assurance methodology for field spikes and replication samples.

Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI)—Hydrologic landscape regions, developed by NAWQA to integrate hydrologic, physiographic, ad geologic characteristics across large geographic areas, were used by the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) in their national design of hydrologic observatories. The hydrologic landscapes provide a framework for understanding the fate and transport of water and contaminants in diverse environmental settings across the Nation.

"The CUAHSI is committed to a national design of hydrologic observatories, dedicated to the collection of data on flow paths, fluxes, and residence times of water, sediment, nutrients, and other contaminants across a range of spatial and temporal scales. The observatories will promote collaborative research by providing multi-scale, multi-disciplinary, and consistent information from different hydrologic settings, and will allow comparisons across climatic and physiographic zones. Selection of possible observatory sites was based, in part, on NAWQA's spatial assessment of hydrologic landscapes because this classification is one of the first objective schemes that consider factors for both climatic drivers and hydrologic responses. This interpretive product, along with NAWQA data sets, helps to organize research in the hydrologic sciences—a major contribution of the USGS to our understanding of hydrologic processes in the United States." (Dr. Rick Hooper, Executive Director, Consortium of Universities for the Advancement of Hydrologic Science, Inc (CUAHSI), Fall 2005)

State of Colorado—At the request of the Colorado Department of Public Health and Environment, USGS compiled available data and reports on organic compounds in water, bed sediment, and fish tissue in Colorado streams. The compilation included information from the three NAWQA assessments in the South Platte, Rio Grande, and Upper Colorado River Basins in Colorado. This request was done in response to an EPA Audit Report of the Colorado Water Quality Standards, Monitoring, and Reporting Program, which found that "… although Colorado's monitoring program met statutory requirements, it had no systematic process to obtain organic-pollutant-monitoring data. Without these data, Colorado cannot identify water impaired by organic pollutants." USGS developed and implemented a monitoring plan for synthetic organic compounds in the South Platte River Basin in collaboration with the State of Colorado. The plan builds on NAWQA monitoring from 1992 to 1995 and on NAWQA monitoring sites established to assess changes in water quality over time.

State of Idaho—As follow-up to the NAWQA assessment in the Snake River Basin, USGS worked with the Idaho Department of Environmental Quality officials to develop a monitoring strategy for assessing trends in water-quality conditions and biological communities in the middle Snake River.

State of New Jersey—USGS works with the New Jersey Department of Environmental Protection and the New Jersey Geological Survey to develop surface- and ground-water-monitoring networks. The statewide networks are designed to measure the status of and trends in water quality, and to assess contaminant levels and pollutant loads in association with different land uses. The networks support the information needs of the State's watershed and TMDL programs. Both the surface- and ground-water networks follow the monitoring design of the NAWQA program.

Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes, Wyoming—The Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes designed an ambient ground-water-quality-monitoring network that is based on NAWQA randomization techniques and well selection criteria.

"The Yellowstone River Basin NAWQA program has been beneficial to the State of Wyoming, particularly to the Department of Environmental Quality's water-quality monitoring and assessment efforts. The ecological, bacteria, water quality, and streamflow data collected have provided DEQ with the ability to assess the water quality much more comprehensively than what would be possible with DEQ data alone." (Jeremy Zumberge, Monitoring Program, Wyoming Department of Environmental Quality, June 2004, USGS Circular 1234)

"The USGS Trinity NAWQA Program has been an invaluable resource for the Texas Natural Resource Conservation Commission [TNRCC] and the Texas Clean Rivers Program. Since 1993, NAWQA hydrologists and biologists have provided the TNRCC staff and Texas Clean Rivers Program partners with their technical expertise on data analysis procedures and monitoring and assessment protocols. As the challenges in data assessment and monitoring continue for the Texas Clean Rivers Program, the TNRCC will look to the USGS and the lessons learned from the Trinity NAWQA Program." (Sally C. Gutierrez, Water Quality Division, Texas Natural Resource Conservation Commission, 2001, USGS Circular 1171)

Local, State, tribal, and federal organizations also recognize the value and application of NAWQA's sampling methods and protocols for measuring water quality and biological health.

State of Wyoming—Selected NAWQA protocols for aquatic invertebrate and fish communities were adopted in 2004 by an interagency working group that includes the State of Wyoming, and Federal and other agencies, and incorporated in an aquatic ecology monitoring plan. This plan was prepared to document ecological conditions and to assess the effects of resource development, including coal-bed natural gas, in the Powder River Basin of northeastern Wyoming.

"Data collected via NAWQA on fish community composition has provided valuable information to the Wyoming Game and Fish Department, assisting in our effort to document native species distributions and their habitat preferences in northeast Wyoming." (Bob McDowell, Wyoming Game and Fish Department, Sheridan Region, Summer 2004)

State of Illinois—As part of their continuing program to update and maintain expertise in water-quality sampling, the Illinois Environmental Protection Agency (IEPA) compared NAWQA low-level water-quality sampling techniques with their own protocols for sampling public-water supplies. This combined effort between NAWQA scientists and IEPA was an evaluation that resulted *in modifications to the IEPA sampling strategy.*

State of Idaho—*NAWQA biological and habitat protocols were integrated into Idaho's statewide surface water-quality monitoring network. Previous network designs by the state focused primarily on water chemistry. The cooperative monitoring program between USGS and the Idaho Department of Environmental Quality, which consists of more than 50 USGS stream-gaged monitoring sites, allows the State to assess long-term trends in water quality, evaluate in-stream beneficial uses, such as aquatic life, recreation, and drinking water, determine contaminant levels in fish tissue, and estimate pollutant concentrations and loads (for use in the TMDL process).*

State of Montana*—The Montana Department of Environmental Quality used NAWQA protocols in its aquatic ecology sampling programs.*

State of Pennsylvania*—The Pennsylvania Fish and Boat Commission uses NAWQA procedures and data on fish communities from the Allegheny-Monongahela, Delaware River, and Lower Susquehanna River Basins in their statewide Index of Biotic Integrity.*

"The Montana Department of Environmental Quality has used NAWQA data for addressing TMDL issues within the Yellowstone and Clark Fork River watersheds. We have also worked together in the field with the NAWQA Program to develop Montana's statewide monitoring design and sampling protocols. Data that were collected side-by-side using both State and NAWQA protocols were compared. This helped refine the State of Montana's approach to biological monitoring. We also adopted NAWQA's approach for sampling sediment for trace metal analyses." (Randy Apfelbeck, Monitoring and Data Management Bureau, Montana Department of Environmental Quality, 2001)

State of Colorado—The Colorado Department of Public Health and Environment uses NAWQA sampling protocols to monitor water quality in the agricultural areas of the Grand Valley and Uncompahgre Valley. Because pesticides were frequently detected by the NAWQA Program, the State of Colorado has included the monitoring of pesticides for the first time.

City of New York, New York—NAWQA methods are used in a time-series monitoring project with the City of New York to assess the occurrence of urban and residential pesticides in the Croton Reservoir system. This reservoir system supplies about 10 percent of the New York City water supply.

States of Minnesota and North Dakota—The States of Minnesota and North Dakota use NAWQA findings and procedures to establish an Index of Biotic Integrity scoring system for use in the Red River of the North Basin. The procedures were adopted in 1997 to improve assessments of water quality.

State of Idaho—The Idaho Department of Environmental Quality uses NAWQA fishery information in their Index of Biotic Integrity to assess aquatic life conditions in large rivers of Idaho.

Pacific Northwest—NAWQA information on fish assemblages, along with other state and federal agency information, was used to complete a classification of 130 freshwater fish species in the Pacific Northwest. The classification included a

summary of attributes on origin, pollution tolerance, adult habitat, adult feeding, and temperature preference. The regional classification of fish species helps managers and researchers evaluate water conditions and recognize the importance of biological measures of water quality.

Communication of Findings for Policy and Management

USGS is committed to effective and timely communication of findings to managers, planners, and decision makers at all levels of government, environmental and conservation organizations, academia, industry, consulting and engineering firms, and the general public. The findings are presented in multiple formats in order to meet the diverse needs of the many different users—ranging from raw data, methodology, models, technical documents, and journal articles to concise, colorful, nontechnical forums, such as pamphlets and videos. The NAWQA Program has published more than 1,300 products since its inception in 1991. Direct access to summary assessments, technical publications, data, and maps can be accessed at http://water.usgs.gov/nawqa.

A USGS circular series is published by NAWQA on the quality of the Nation's waters. This series of products integrate and weave together complex information into key stories of interest to broad and varied audiences, including, for example, scientists in government, industry, and academia; water managers; public-health officials; utilities; regulators; elected officials; and watershed groups and others in the general public. The audience includes traditional USGS water stakeholders and cooperators, such as natural resource managers, academia, and the engineering community, as well as more non-traditional stakeholders, such as those in the health and recreation fields and those in policy-making roles. Information in this series is used for a basic understanding of water quality, resource management, regulation, conservation, monitoring strategies, and policy development.

> *"The synthesis reports produced under this [NAWQA] Program are highly valued as support for decision-making on restoration activities in the Everglades ecosystem, including those involving the Comprehensive Everglades Restoration Plan, an 8-billion dollar project being undertaken jointly by the U.S. Corps of Engineers and the South Florida Water Management District. Data from the NAWQA Program are also vital to supplement and interpret information from other water quality assessment activities, including major monitoring efforts conducted by the South Florida Water Management District, Everglades National Park and Biscayne Bay National Park. The NAWQA Program is successful because it combines technical excellence in data collection with scientific soundness and objectivity in reporting."* (Garth W. Redfield, Ph.D., Environmental Monitoring and Assessment Division, South Florida Water Management District, March 2001)

The reports highlight and explain "what was found" and "why it may be important" for water decisions and minimize attention to "what was done" and "how" (details on study design and analysis are in companion, foundation technical reports/articles that underpin these products). Consistent with the USGS mission for non-regulatory and unbiased science, the reports have no political agenda or specific policy recommendations, and yet directly connect scientific findings to critical water management and protection issues. The reports manage to engage and educate the non-technical reader while at the same time provide critical insights to those directly involved with water-resource decision making and point the more technical user to approropriate scientific reports, data, modeling, and methodology. Findings show where, when, and why specific contaminants occur, and yield science-based implications for assessing and managing the contaminants in our water resources. Also highlighted are current and emerging water issues and priorities and selected trends in water quality.

"Several federal agencies publish technical information in formats designed to meet the needs of various client groups. An excellent example of this tiered approach is the publishing strategy of the U.S. Geological Survey. This agency publishes fact sheets, circulars, and several forms of technical reports that are designed to communicate information to a diversity of potential users." (Cited in Journal of Ecological Applications, vol. 10 (4), p. 1001)

"As one involved in sharing information with both the public and other agencies addressing water resources issues in the Shenandoah River Basin, the Potomac NAWQA study has been quite helpful. This particular publication, summarizing a considerable amount of water quality data through informative graphics and excellent maps, should serve as a convenient reference to others interested in knowing more about our valuable water resources." (Mr. Thomas Mizell, Virginia Department of Environmental Quality, 2001, USGS Circular 1166)

"One of the best national studies I have seen on pesticides (and nutrients) in surface and ground waters is USGS Circular 1225 "The Quality of Our Nation's Waters: Nutrients and Pesticides." The report was developed as part of the excellent National Water-Quality Assessment (NAWQA) Program. It is posted on the web. A lot of other USGS pesticide information is [also] posted." (Barry Tonning, TetraTech, March 2001)

The Program anticipates the continued production and dissemination of technical and non-technical publications (about 350 anticipated through 2013). These include comprehensive summary reports (USGS Circulars) on the occurrence of nutrients in streams and ground water and aquatic ecological conditions in streams across the Nation. Additional products and communication include:

- Continued improvements to the NAWQA data-warehouse.
- Readily accessible and relevant information—including data, reports, maps, support tools, and methods—on the NAWQA website (http://water.usgs.gov/nawqa/). NAWQA will continue to expand (1) user-friendly, internet-accessible graphics, data sets, maps, tables, and interactive capabilities for extracting and displaying information; and, (2) interpretation of NAWQA data in a human-health and aquatic-health context.
- Public congressional briefings on key findings relevant to water-issues of national concern. Since 1998, the Program has co-hosted or participated in 25 congressional briefings, in large part supported by the Water Environment Federation. The NAWQA Program anticipates about two briefings per year, addressing topics such as mercury, water quality in domestic wells, and emerging contaminants.
- Collaborative efforts and support for multi-agency efforts, such as related to the Mississippi River Basin and hypoxia in the Gulf of Mexico.
- Co-leadership and continued support for the National Water Quality Monitoring Council
- Continued participation in other scientific and water-related conferences and workshops at all levels of the Program.
- Cyber seminars, training courses, and workshops through USGS web resources and other organization's webcasting sites
- Updated bibliographies and search engines for information by topic, environmental media, and geographic area.
- Continued development of the NAWQA stakeholder database, which, in 2009, maintains contact information and water requirements for about 1,800 stakeholders. The database is used to effectively track stakeholder needs and allows specialized, user-focused and targeted information delivery.
- Collaborative "spin off" projects and cultivation of new partnerships that expands NAWQA data collection and assessments beyond the program scope. These are cultivated through the state level USGS Cooperative Water Programs.

Examples of collaborative products for increased dissemination of information include:

State of Nevada—USGS, in cooperation with the Nevada Bureau of Mines and Geology, the Nevada Division of Environmental Protection, and the Nevada Bureau of Health Protection Services, published a pamphlet that describes (1) NAWQA findings on radon in ground water of western Nevada, and (2) recommendations by state agencies on how people can test their homes for radon and what actions to take if unhealthful levels are detected.

State of Washington—In collaboration with the Washington State Department of Health, USGS published a brochure that describes (1) NAWQA findings on elevated DDT concentrations in bottom fish in the Yakima River and tributaries, and (2) possible health effects and recommendations to reduce the exposure of this insecticide to the general public.

State of Kansas—In cooperation with the Kansas State Board of Agriculture, USGS published an educational video "Herbicides, Water Quality, and You" that describes factors affecting the occurrence of atrazine in streams and information to the farming community about ways to reduce transport of herbicides to streams.

State of Colorado—A USGS video "South Platte River—Lifeline of a Region" was developed to describe the many factors affecting water quality in the South Platte River, from its origins in the Rocky Mountains of Colorado, through the Front Range cities, and across the plains into Nebraska. The video includes interviews with individuals from the Denver Water Board, Colorado Department of Public Health and Environment, Colorado Division of Wildlife, USGS, and EPA. It is used as an educational tool by secondary schools, colleges, and universities, and as an outreach tool for citizens, non-governmental organizations, watershed groups, and state and federal agencies.

State of Arkansas—A USGS fact sheet summarizing NAWQA findings on water-quality conditions in the Ozark Plateaus was developed for Arkansas Stream Team water-quality workshops for citizens, sponsored and supported by the Arkansas Game and Fish Commission. The citizen-based Arkansas Stream Teams "adopt" sections of streams throughout Arkansas for stream bank rehabilitation and protection.

State of Georgia—Teachers and officials at all levels of government throughout Georgia use a USGS-NAWQA poster entitled "Everyone Lives Downstream" for education and outreach about water-quality issues related to urban development of the Atlanta Metropolitan area. About 15,000 posters were distributed. This poster was also the model for a poster developed jointly by USGS and Israeli, Jordanian, and Palestinian scientists working on the Middle East Peace Process.

Adirondack Mountains, New York—NAWQA scientists in the Hudson River Basin worked with the River Watch Network, the Adirondack Park Interpretive Centers, and the Adirondack Teacher's Center to help local high school teachers expand their earth-science curriculum. The program gives the schools the opportunity to measure chemical, physical, and biological characteristics of streams in their area and to interact with other schools and water-resource professionals in evaluating those data.

State of New Hampshire—USGS participates in a New Hampshire Consortium with other federal agencies, such as EPA, New Hampshire Departments of Environmental Services and Health and Human Services, and Dartmouth College, to help answer questions related to arsenic contamination in New Hampshire and its possible environmental and health effects. This consortium grew out of increased concern about arsenic in drinking water on the part of citizens and state officials. Outreach efforts by the consortium include a regional arsenic conference, a display at the New Hampshire Drinking Water Exposition, and a fact sheet.

Southern California—NAWQA scientists and researchers serve as technical advisors on local and state task forces and advisory committees throughout the Nation. As an example, USGS is represented on a task force in southern California concerned with elevated nitrogen and total dissolved solids in surface and ground water. This task force includes representatives of all the major water purveyors and wastewater dischargers in an area that serves the water-resource needs for more than 4 million people.

Contacts for additional information

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