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# National Water-Quality Assessment Program — Cycle II

## *Regional Assessments of Aquifers and Streams and Rivers*

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The U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program is planning regional assessments of water-quality conditions and trends in 19 aquifers and 8 river basins. These assessments build on NAWQA studies from 1991 to 2001 in 51 river basins and aquifers (known as "Study Units") that show how natural features, land use, and other human activities affect ground- and surface-water quality and aquatic ecosystems. (See map, p. 4, for locations of the Study Units. Summary reports for the individual studies are available online; see back page.)

The intent of these assessments is to summarize water-quality conditions in a regional context. These assessment will be useful for regional monitoring councils, States, and localities in addressing priority water-quality and drinking-water issues across broad regions that have similar hydrogeology, land use, and landscapes.

## Regional assessments of aquifers

A total of 62 principal aquifers underlie the United States (U.S. Geological Survey, 2003); the 19 aquifers selected for regional assessment account for about three-quarters of the estimated withdrawals of ground water for drinking-water supply (see map, p. 2).

Water quality within the different aquifers will be compared, and factors that affect ground-water quality and susceptibility to contamination will be assessed. These factors include natural features that affect the movement of water and associated chemicals into and through the aquifer material, such as soils, physiography, geology, mineralogy of aquifer materials, geochemical characteristics, and hydrogeology. For example, relatively rapid influx and vertical mixing of water throughout the aquifer system can occur in sand and gravel aquifers, alluvial fans, and carbonate (karst) settings with highly permeable sediment and open conduits in the bedrock.

Human activities that affect the movement of water and chemicals through the aquifers include pumping for irrigation and water supply, and applying fertilizers, pesticides, and other chemicals to areas that contribute recharge to aquifers.

Each of the NAWQA regional assessments focuses on water-quality issues of concern within a particular aquifer system, and addresses one or more of the following general issues:

- Chemical constituents and contaminants in aquifers
- Chemical quality of domestic and public ground-water supplies
- Chemical and hydrologic processes affecting ground-water quality and transport of contaminants
- Effects of agricultural and urban land use on water quality

The studies will vary in scope and complexity and will be implemented at different stages throughout the second decade of the NAWQA Program. As the studies progress, relative emphasis on topics may shift and new topics may be added.

### Summary of Cycle II regional assessments

In 2001, the National Water-Quality Assessment (NAWQA) Program began its second decade (or "Cycle II") of water-quality assessments. Forty-two of the 51 major river basins and aquifers assessed from 1991 to 2001 (referred to as "Study Units") will be revisited, and current conditions and trends in ground water and streams will be assessed (Gilliom and others, 2001).

Interagency coordination, data collection, modeling, and reporting of results during Cycle II will be generally organized at the regional scale rather than at the basin or Study-Unit scale as in Cycle I. This re-design extends our understanding of contaminant occurrence and allows more efficient coordination of an interdisciplinary USGS workforce that is needed to address NAWQA Program objectives over the long term. The Cycle I national assessments of pesticides, volatile organic compounds (VOCs), nutrients, and selected trace elements in streams and aquifers will continue, along with national topical studies on mercury, fate of agricultural chemicals, effects of urbanization on stream ecosystems, nutrient enrichment, and transport of contaminants to drinking-water wells.

Regional-scale analyses, models, and other scientific tools will provide a quantitative framework for understanding regional ground-water flow, analyzing ground- and surface-water quality conditions and trends, and extrapolating findings to unmonitored, comparable areas in other parts of the regions. Water-quality information in a regional context will be useful for regional monitoring councils, States, and localities in addressing priority water-quality and drinking-water issues and in assessing water resources in their areas.

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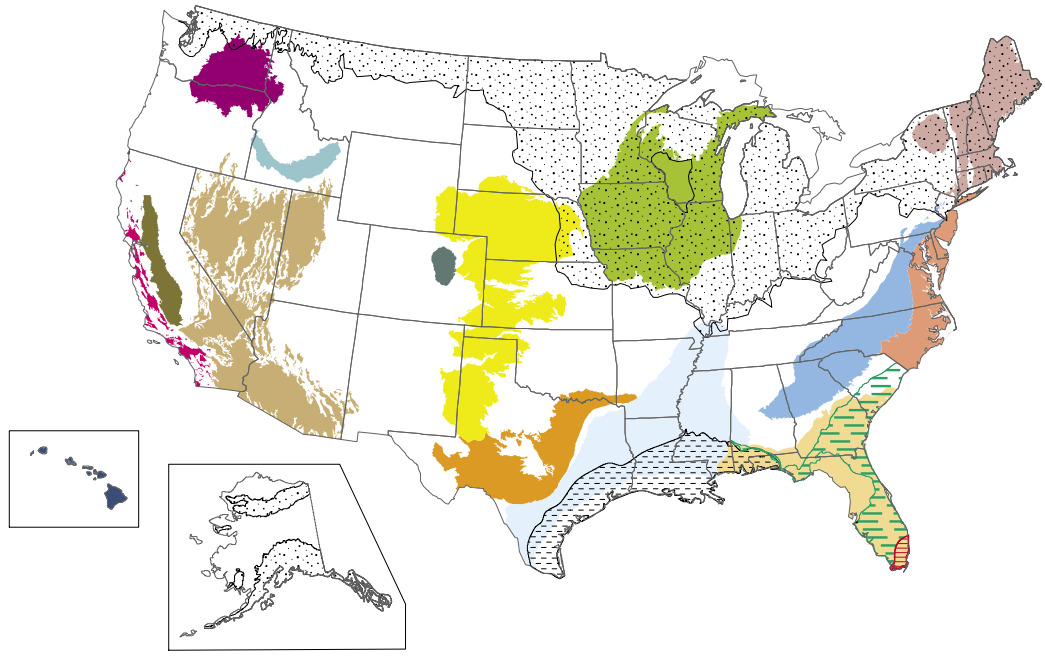
The study findings will be useful to resource managers and scientists in assessing ground-water vulnerability to contamination across different regions. By identifying natural and human factors and processes affecting contaminant occurrence and transport, the study will allow managers and scientists to apply findings to broader classes of contaminants and to newly identified contaminants. Models and other decision-support tools — which integrate aquifer characteristics, land use, and water-quality monitoring data — will help water managers assess the sustainability of water resources for future supply and develop cost-effective ground-water monitoring programs.

## Condition of the ambient ground-water resource

NAWQA studies from 1991 to 2001 indicated that contaminants in shallow ground water are widespread, often in mixtures but at low concentrations, in aquifer systems across a wide range of landscapes and land uses. Concentrations of contaminants generally were lower in water in the deeper parts of the aquifers than in shallow ground water underlying agricultural and urban areas. Water that replenishes the major aquifers is from a variety of sources and land-use settings, and includes high-quality water from undeveloped lands. In addition, deep aquifers generally are more protected than shallow aquifers by relatively impermeable materials. Contaminants are most prevalent in aquifers in geologic settings that allow rapid vertical movement of water from the shallow ground-water system.

Comprehensive analyses of a multitude of chemical constituents — nutrients, pesticides, volatile



Source: Modified from USGS, 2003

- Hawaiian volcanic-rock aquifers
- Aquifers composed of glacial deposits
- California Coastal Basin aquifers
- Central Valley aquifer system
- Columbia Plateau basin-fill and basaltic-rock aquifers[1]
- Snake River Plain basin-fill and basaltic-rock aquifers[1]
- Basin and Range basin-fill and carbonate-rock aquifers[1]
- Denver Basin aquifer system
- High Plains aquifer
- Edwards-Trinity aquifer system
- Cambrian-Ordovician aquifer system
- Mississippi embayment-Texas coastal uplands aquifer system[1]
- Coastal lowlands aquifer system
- Floridan aquifer system
- Surficial aquifer system
- Biscayne aquifer
- Piedmont and Blue Ridge crystalline-rock and carbonate-rock aquifers[1]
- Northern Atlantic Coastal Plain aquifer system
- New York and New England crystalline-rock aquifers[2]

[1] Combinations of principal aquifers.

[2] Not considered principal aquifers (defined as regionally extensive aquifers or aquifer systems that have the potential to be used as a source of potable water). The New York and New England crystalline rocks are, in general, minimally permeable but contain locally productive aquifers that serve domestic supplies.

Locations of 19 principal (or other) aquifers in which regional assessments are conducted.

organic compounds (VOCs), trace elements, and radionuclides — are planned in regional assessments of many of the aquifers, including, for example, the carbonate Biscayne and Floridan; the unconsolidated Surficial; the carbonate Basin and Range; the Piedmont; and volcanic aquifers underlying Hawaii.

Studies are also planned of contaminants of concern in particular aquifers, for example, arsenic, radon-222, uranium, and trace elements in the glacial deposits aquifers underlying the Northeast and upper Midwest; salinity in aquifers underlying the Basin and Range and California Coastal Basins; and nitrate and mixtures of urban pesticides in ground-water discharge from the glacial deposits aquifers, the Cambrian-Ordovician aquifer system in the upper Midwest, and the New York and New England crystalline-rock aquifers in the Northeast.

## Chemical quality of domestic and public ground-water supplies

Several regional analyses are planned on the occurrence of anthropogenic chemicals, such as fertilizers and pesticides, in domestic and public-supply wells. These assessments cover a large part of the Nation, including areas served by ground-water supplies derived from the Floridan aquifer system, Northern Atlantic Coastal Plain aquifer system, and the glacial deposits aquifers. Effects of long-term withdrawals (1950-2000) on ground-water quality in the Floridan aquifer system also will be assessed.

## Chemical and hydrologic processes affecting ground-water quality and transport of contaminants

Previous NAWQA studies indicated that natural features affect the transport of chemicals, and often result in different contaminant concentrations in different aquifer systems. Natural features include aquifer characteristics, such as geology, hydrology, mineral composition, and oxygen-reducing conditions, and the properties of the chemicals themselves, such as their tendency to dissolve, attach to sediment or bedrock, and persist in the environment.

Several regional assessments will focus on chemical and hydrologic processes that control the fate and transport of contaminants as water moves within principal aquifers, such as the Northern Atlantic Coastal Plain aquifer system and the glacial deposits, Basin and Range, and High Plains aquifers. In addition, several studies are planned to assess the effects of hydrologic alterations and controls — such as pumping, artificial recharge, and irrigation — on water quality in the High Plains, Hawaiian, Basin and Range, and California Coastal Basin aquifers, and the Central Valley aquifer system.

## Effects of agriculture and urban land use on water quality

Contaminants found in ground water underlying agricultural and urban lands are closely related to the chemicals that are applied to the land. In previous NAWQA studies, nitrate and selected herbicides were frequently detected in shallow ground water underlying agricultural land, and VOCs were frequently detected in shallow ground water underlying urban land. The regional assessments will examine relations between ground-water quality and land use in the Northern Atlantic Coastal Plain aquifer system; the arid and semi-arid western Basin and Range aquifers, the Central Valley aquifer system, and the California Coastal Basin aquifers; the High Plains aquifer; the glacial deposits aquifers; and the Piedmont aquifer. Selected topics include (1) effects of chemical use and agricultural practices in four agricultural settings in Florida and the southeastern Coastal Plain; (2) effects of urban development in the Mississippi embayment-Texas coastal uplands and Piedmont aquifers on the quality of ground water used for drinking; and (3) use of chloride as an indicator of urban influence on the glacial deposits aquifers used for drinking water.

### Regional assessment of water quality in the High Plains aquifer

The first NAWQA "pilot" regional aquifer assessment began in 1999 in the High Plains aquifer, which underlies an area of about 174,000 square miles in parts of eight western states and contains water recharged less than 10 to more than 10,000 years ago. A series of studies through 2004 assessed spatial and temporal variability in water quality in the aquifer, including concentrations of nutrients, volatile organic compounds, pesticides, trace elements, and radon. Besides providing a broad-scale assessment of water-quality conditions, the studies help with understanding the factors that control the vertical transport of chemicals. Tritium and radiocarbon concentrations were used to date the age of the ground water and help to assess timing of the recharge to the ground-water system, and therefore, the vulnerability of the water to contamination from recent human activities. A key finding was that chemical traveltimes through the thick unsaturated zone under irrigated farm fields ranged from about 50 to 375 years, which suggests that it could be many decades before improvements in water quality from implementation of best-management practices on land can be detected in the ground water. An assessment planned for 2005-06 will summarize conditions and transport using a USGS source-transport-receptor model of water quality. Many results from the High Plains studies are available on the Web at http://co.water.usgs.gov/nawqa/hpgw/HPGW_home.html

## Regional assessments of streams and rivers

Regional assessments of streams and rivers cover 8 river basins, which were delineated on the basis of 21 water-resource regions described in Seaber and others (1987). Each of the assessments focuses on chemicals and water-quality issues of concern in each region, and addresses one or more of the following general issues:

- Occurrence of nutrients and pesticides in relation to changes in chemical use
- Effects of urban development and agricultural practices on aquatic communities
- Sources and transport of nutrients to major rivers, lakes, estuaries, and coastal waters

Planned studies vary in scope and complexity, with some topics covering multiple regions. The studies will be implemented at different stages throughout the second decade of the NAWQA Program, and a series of reports is planned to document significant findings. As the assessments progress, relative emphasis on topics may shift and new topics may be added.

### Occurrence of nutrients and pesticides in relation to changes in chemical use

NAWQA studies indicate that contaminants are widespread, albeit often at low concentrations, in streams and rivers across a wide range of landscapes and land uses. Nationally, for example, at least one pesticide was found in about 95 percent of water samples and 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,


Locations of 8 river basins in which regional assessments are conducted.

and therefore, changes in water quality over time frequently are controlled by changes in chemical use. Regional assessments are planned for the following:

- The relation of pesticide occurrence in streams throughout the Corn Belt to changes in pesticide use, such as the increasing use of acetochlor and metolachlor to replace alachlor, and the increasing use of glyphosate (trade name "Roundup") — The assessment covers streams in parts of four river basins: the Great Lakes, Ohio, Upper Mississippi, and Souris-Red-Rainy; New England and Mid-Atlantic; Missouri; and Lower Mississippi, Arkansas-White-Red, and Texas-Gulf.

- Changes in the occurrence and concentrations of the pesticides diazinon, carbaryl, malathion, chlorpyrifos, and prometon in streams draining urban areas in the New England and Mid-Atlantic river basins — Changes in pesticide use and regulations, such as the phase-out of diazinon in 2001, may lead to changes in pesticide occurrence in urban streams. Study findings will be of particular interest to the pesticide industry and the agricultural community, as well as to regulators and managers involved with pesticide registration and resource management in agricultural and urban basins.

- Long-term trends in concentrations of nitrate in streams in California — Nitrate concentrations have decreased in some areas, such as in southern California, but have increased in others. Increased nitrate in the San Joaquin River Basin since the 1960s, for example, may be accounted for by increased fertilizer use, dairies, and artificial drainage. Information on long-term trends will be useful for resource managers developing nutrient criteria and total maximum daily loads (TMDLs) and in managing ecosystem restoration and drinking-water and wastewater systems.

## Effects of urban development and agricultural practices on aquatic communities

Previous NAWQA studies have documented the effects of urban development and agricultural practices on chemical, physical, and biological characteristics of streams. These effects include alterations in water quality and in physical characteristics of streams that disturb habitat and degrade fish, invertebrate, and algal communities. Degraded aquatic communities generally show reduced biological diversity and richness, and a dominance of species that are tolerant of disturbance, such as worms, midges, and omnivorous fish communities.

The most profound effects to biological, chemical, and physical conditions generally were observed in streams draining urban settings. Some of the NAWQA studies showed elevated contaminant levels, increased streamflows and transport of sediment, and physical disturbances such as deepened stream channels, degraded natural habitat, and altered substrates.

The NAWQA studies also showed, however, that the effects on aquatic communities can vary among land-use settings because of natural features, such as substrates, soils, geology, climate, basin characteristics, and hydrology — all of which can control the transport of water and contaminants over land and through the subsurface. In addition, the response of aquatic communities can vary because of different land-management practices in urban and agricultural settings, such as tile drains, grass buffer strips, and regulated streamflows.

Regional assessments in all eight river basins will describe effects of

Assessments will look at impacts on aquatic communities and stream habitat from variable streamflow, which is commonly associated with increased urban development, such as in and around the Boston and New England area. (Photo by K. W. Robinson, USGS.)

activities in urban and agricultural settings on water quality and/or stream health and aquatic communities. Each of the studies will emphasize an issue that is characteristic of the region, for example:

- New England and Mid-Atlantic — Variable streamflows associated with increased impervious surfaces, storm drains, and other artificial controls that affect runoff from residential and commercial development and dense road networks.
- Great Lakes, Ohio, Upper Mississippi, and Souris-Red-Rainy — Agricultural land-management practices, such as grassed waterways and riparian buffer strips; and suburban and urban development of large amounts of agricultural land (also will be studied in New England and Mid-Atlantic).
- Rio Grande, Colorado, and Great Basin; Pacific Northwest; California — Regulated streamflows to meet agricultural and urban needs, leading to altered flow regimes (typical of many of the drier climates in the West).
- South Atlantic-Gulf and Tennessee — Natural features, such as the substrate, soils, and basin characteristics affecting streams draining urban areas, including Birmingham, Alabama; Raleigh, North Carolina; and Atlanta, Georgia.

Study findings and models developed in these regional assessments will provide a better understanding of the effects of urbanization on aquatic ecosystems in a regional context and will be useful to managers and planners in monitoring, protecting, and restoring urban streams. An understanding of how chemical characteristics, hydrology, and basin features relate to ecosystem health will be useful to watershed managers in developing "smart-growth" strategies and reducing negative effects on urban aquatic communities. The findings also will be helpful to the agricultural community and water-resource managers who implement conservation programs, such as those administerd by the U.S. Department of Agriculture and state agricultural agencies. Finally, findings that incorporate the effects of human activities and natural factors will be useful in developing regional bioindicators of stream and landscape alterations and degradation, and in applying regional biomonitoring criteria.

### Sources and transport of nutrients to major rivers, lakes, estuaries, and coastal waters

The quantity of nutrients and sediment transported by streams and rivers can vary because of basin characteristics, hydrologic events, seasonal fluctuations in streamflow, land use, and contaminant sources. NAWQA will determine the relative significance of these factors on annual and seasonal loads and trends by using statistical tools and models. Findings will be extrapolated spatially, where possible, to unmeasured areas throughout the basins.

Sources and transport of nitrogen and phosphorus to rivers and coastal waters will be assessed in six river basins: New England and Mid-Atlantic; South Atlantic-Gulf and Tennessee; Great Lakes, Ohio, Upper Mississippi, and Souris-Red-Rainy; Missouri; Lower Mississippi, Arkansas-White-Red, and Texas-Gulf; and Pacific Northwest. Sediment will be assessed to the extent data are available.

Findings will help resource managers, planners, and scientists better understand the causes and sources that may lead to impaired conditions, such as annual or episodic algal blooms and hypoxia. Findings can also be used to develop nutrient criteria, prioritize conservation practices, manage nutrient enrichment in rivers, estuaries, and coastal waters, and track changes in watershed nutrients and suspended sediment.

## References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### For online information, reports, and data:

Summary assessments conducted during the first decade in the 51 Study Units are available at:
*http://water.usgs.gov/nawqa/nawqa_sumr.html*
All other reports, maps, and data are available at:
*http://water.usgs.gov/nawqa*