Water Quality in the Lower Illinois River Basin

Illinois, 1995–98

U.S. Department of the Interior
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Circular 1209

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Lower Illinois River Basin contact and Web site:

USGS State Representative
U.S. Geological Survey
Water Resources Division
221 N. Broadway Ave., Urbana, IL 61801
e-mail: dc_il@usgs.gov
http://il.water.usgs.gov/proj/lirb

National NAWQA Program:

Chief, NAWQA Program
U.S. Geological Survey
Water Resources Division
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Front cover: Summer wildflowers at Indian Creek near Wyoming, Ill. (photograph by David J. Fazio).

Back cover: Left, hydrologists collecting a water sample from Panther Creek near El Paso, Ill. (photograph by Paul J. Terrio); right, biologists collecting invertebrate samples from the Illinois River at Valley City, Ill. (photograph by David J. Fazio).

Water Quality in the Lower Illinois River Basin, Illinois, 1995–98

By George E. Groschen, Mitchell A. Harris, Robin B. King, Paul J. Terrio, *and* Kelly L. Warner

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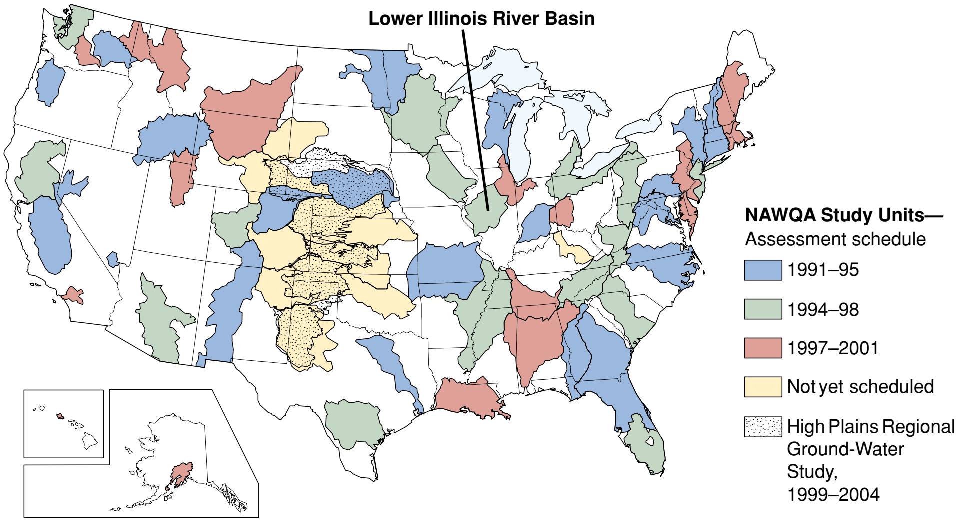
THIS REPORT summarizes major findings about water quality in the lower Illinois River Basin that emerged from an assessment conducted between 1995 and 1998 by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. Water quality is discussed in terms of local and regional issues and compared to conditions found in all 36 NAWQA study areas, called Study Units, assessed to date. Findings are also explained in the context of selected national benchmarks, such as those for drinking-water quality and the protection of aquatic organisms. The NAWQA Program was not intended to assess the quality of the Nation's drinking water, such as by monitoring water from household taps. Rather, the assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. The comparisons made in this report to drinking-water standards and guidelines are only in the context of the available untreated resource. Finally, this report includes information about the status of aquatic communities and the condition of in-stream habitats as elements of a complete water-quality assessment.

Many topics covered in this report reflect the concerns of officials of State and Federal agencies, water-resource managers, and members of stakeholder groups who provided advice and input during the lower Illinois River Basin assessment. Basin residents who wish to know more about water quality in the areas where they live will find this report informative as well.

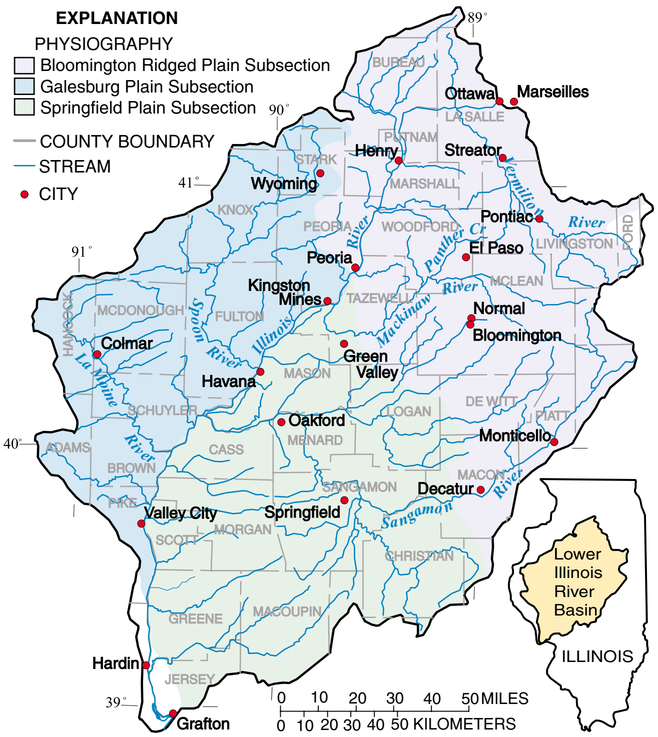


THE NAWQA PROGRAM seeks to improve scientific and public understanding of water quality in the Nation's major river basins and ground-water systems. Better understanding facilitates effective resource management, accurate identification of water-quality priorities, and successful development of strategies that protect and restore water quality. Guided by a nationally consistent study design and shaped by ongoing communication with local, State, and Federal agencies, NAWQA assessments support the investigation of local issues and trends while providing a firm foundation for understanding water quality at regional and national scales. The ability to integrate local and national scales of data collection and analysis is a unique feature of the USGS NAWQA program.

The lower Illinois River Basin is one of 51 water-quality assessments initiated since 1991, when the U.S. Congress appropriated funds for the USGS to begin the NAWQA Program. As indicated on the map, 36 assessments have been completed, and 15 more assessments will conclude in 2001. Collectively, these assessments cover about one-half of the land area of the United States and include water resources that are available to more than 60 percent of the U.S. population.

Stream and river highlights

During the past century, agricultural runoff, channel and drainage modifications, urbanization, and other activities have altered water quality, aquatic biological communities, and aquatic habitat in the lower Illinois River Basin. The water quality of large rivers, such as the Illinois and Sangamon Rivers, was more likely to meet drinking-water standards than water quality of small streams during 1995–98. In spring, concentrations of nitrate—especially in small streams—exceeded the Maximum Contaminant Level (MCL) of 10 mg/L (milligrams per liter) for drinking water. Some of these streams replenish drinking-water reservoirs. In samples collected during runoff from spring and early summer storms, concentrations of herbicides and a few insecticides exceeded drinking-water standards or guidelines, or guidelines to protect aquatic life. In a few samples from small streams, concentrations of commonly used agricultural pesticides were among the highest nationally. Although most concentrations were low with respect to existing drinking-water standards or guidelines, criteria for the protection of human health or wildlife have not been established for more than one-half of the chemicals detected.



The lower Illinois River Basin occupies approximately 18,000 square miles in central and west-central Illinois. The basin lies almost entirely within the Till Plains physiographic section. The glacial materials account for the flat prairie landscape and the thick, rich soils. The three physiographic subsections influence water quality indirectly by influencing the type and intensity of agricultural activities. [1]

- Nitrogen and phosphorus concentrations were among the highest in the Nation. The highest concentrations in the basin were found in small streams in agricultural areas. The MCL for nitrate was exceeded in 15 percent of samples from all streams and rivers. The concentration of total phosphorus in most samples (79 percent) from all streams and rivers exceeded the 0.1-mg/L guideline recommended by U.S. Environmental Protection Agency (USEPA) to prevent excess algal growth in streams. (See pages 6–8.)

- Nitrate concentrations in the Illinois River at the inflow to the basin (Ottawa) and outflow from the basin (Valley City) were similar; however, approximately twice the amount of nitrogen was transported out of the basin (124,000 tons per year) as was transported into the basin (66,000 tons per year). (See page 6.)

- During August 1997, concentrations of nitrate in streams were lower in the basin than in other NAWQA study-area streams of the upper Midwest. Algal communities may have incorporated much of the instream nitrogen, resulting in lower nitrate concentrations in the water during late summer. (See pages 7–10.)

- Three herbicides commonly used by farmers to protect corn and soybean crops—atrazine, metolachlor, and cyanazine—were detected in every sample collected during 1995–98. During periods of spring runoff, these herbicides exceeded drinking-water standards or guidelines or aquatic-life guidelines. Another herbicide, acetochlor, was detected in most samples (81 percent). (See pages 12–17.)

- Pesticide breakdown products were detected much more frequently than the parent compound, and generally at higher concentrations and for a longer period of time after application. (See pages 16–17.)

- Organochlorine compounds (including insecticides no longer used) were detected in fish tissue and sediment, and polycyclic aromatic hydrocarbons were detected in sediments at levels of concern. (See pages 17–22.)

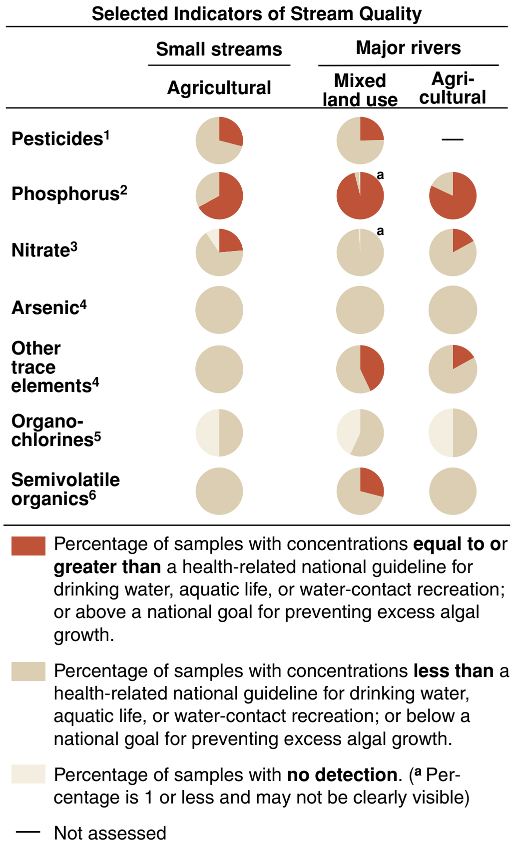
- The biological communities of streams in the basin comprised many organisms that are tolerant of poor water quality; however, some high-velocity streams had fairly diverse invertebrate communities. (See pages 20–21.)

Trends in stream-water quality

For decades, fertilizers and many pesticides have been applied to crops and land. The persistence of pesticides and breakdown products in the soil, water, and sediment within a watershed is not well understood. Concentrations of the herbicides alachlor and cyanazine, however, decreased from the 1991–92 period to the 1996–98 period in the Illinois River because of reduced application rates since the early 1990s. (See page 16.)

Major influences on streams and rivers

- Subsurface (tile) drainage from agricultural areas
- Agricultural and urban land-surface runoff
- Drainage modification to streams and channels



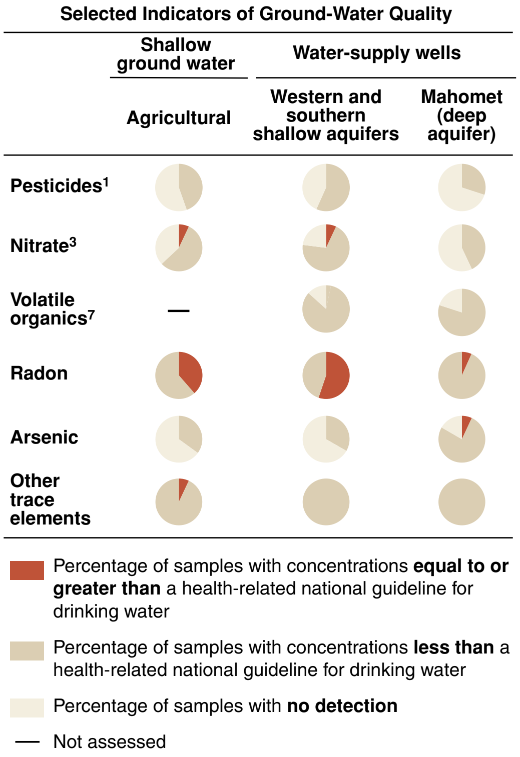
Ground-water highlights

In contrast to the water quality of streams and rivers in the basin and the quality of ground water in other areas across the Nation, agricultural chemicals in ground-water samples from shallow monitoring wells (generally less than 100 feet deep) and drinking-water wells only rarely exceeded the nitrate MCL. Except for radon and nitrate, shallow ground water in the lower Illinois River Basin generally met drinking-water standards or guidelines. Except for radon and arsenic, the water quality in the Mahomet aquifer (greater than 200 feet deep) meets all drinking-water standards or guidelines.

- Major corn and soybean herbicides were not as frequently detected in ground-water samples as they were in stream-water samples. No ground-water sample exceeded drinking-water standards or guidelines for pesticides. (See page 17.)
- Naturally occurring arsenic exceeded the current MCL of 50 µg/L (micrograms per liter) in 2 of 30 wells sampled in the Mahomet aquifer, a major drinking-water source. If the MCL is lowered to 5 µg/L, as proposed by the USEPA, samples from 60 percent (18 of 30) of the domestic (private household) and public-supply (publicly owned wells generally serving a community) wells sampled would probably exceed the lower standard. (See page 22.)
- Geologic materials underlying the basin indicate that it is an area of potentially high radon concentrations in ground water. In about one-half of the samples of shallow ground water, radon exceeded the proposed MCL of 300 pCi/L (picocuries per liter). Only 2 of 30 samples from the Mahomet aquifer exceeded the proposed radon MCL. (See pages 23–24.)
- Volatile organic compounds (VOCs) were detected in samples from 83 percent of shallow domestic and public-supply wells, but no samples exceeded drinking-water standards or guidelines. VOCs were detected in 80 percent of samples from the Mahomet aquifer but at concentrations near the method detection limit and well below drinking-water standards and guidelines. (See page 24.)

Major influences on ground water

- Agricultural and urban land uses
- Permeability of soil and aquifers
- Minerals in geological materials



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[1] Insecticides, herbicides, and pesticide breakdown products, sampled in water.
[2] Total phosphorus, sampled in water.
[3] Nitrate (as nitrogen), sampled in water.
[4] Arsenic, mercury, and trace metals, sampled in sediment.
[5] Organochlorine compounds including DDT and PCBs, sampled in sediment.
[6] Miscellaneous industrial chemicals and combustion by-products, sampled in sediment.
[7] Solvents, refrigerants, fumigants, and gasoline compounds, sampled in water.

INTRODUCTION TO THE LOWER ILLINOIS RIVER BASIN

The lower Illinois River Basin (the basin) encompasses 18,000 mi^2 (square miles) of central and west-central Illinois between the upper end at Ottawa and the confluence of the Illinois River with the Mississippi River near Grafton. The basin includes all of 22 counties and parts of 19 counties.

As of 1990, 1.3 million people lived in the basin. More than 50 percent of the population lived in the counties of Macon, McLean, Peoria, Sangamon, and Tazewell. The four most populated cities are Peoria, Springfield, Decatur, and Bloomington. The basin population decreased by 7 percent from 1980 to 1990 [2].

Land use

Agriculture is the predominant land use—typically corn and soybean row crops. Agriculture accounts for 88 percent of the overall land area, whereas forests account for 7 percent and urban areas account for about 2 percent (fig. 1). The remaining land use, about 3 percent, is mostly grassland, wetland, or water.

The small-stream basins that were sampled during 1995–98 have even higher percentages of land devoted to farming; for example, the Panther Creek Basin is 99 percent agricultural land (fig. 2). The lower Illinois River Basin has some of the most highly productive and intensively cultivated farmland in the world. As a result, application rates of farm-related chemicals are among the highest in the country in support of corn and soybean production. Runoff from these vast, flat farm areas carries relatively high concentrations of nutrients and pesticides into the

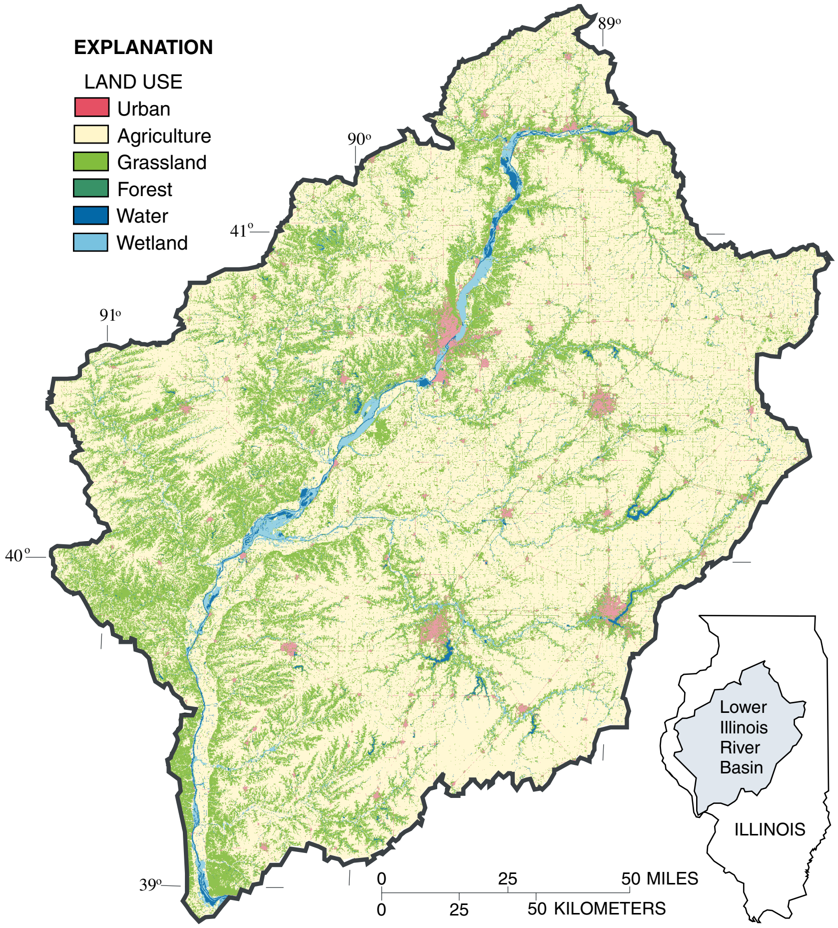


Figure 1. Land use in the lower Illinois River Basin is predominantly agriculture. Farming is most intensive in the part east of the Illinois River. Streambanks generally are steeper west of the Illinois River and are more forested than streambanks east of the river.

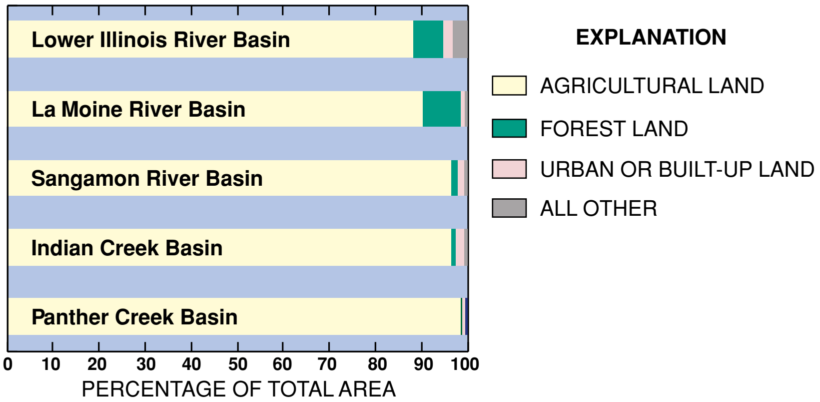


Figure 2. Proportion of land devoted to agriculture varies only slightly among basins—from 88 percent in the entire lower Illinois River Basin to 99 percent in the Panther Creek Basin.

small streams and major rivers of the basin.

Animal farming is also a significant industry in the basin [2], and runoff from manure spreading is a contributor to some of the highest levels of nitrate and total nitrogen found in the rivers and streams of the United States.

Study design in relation to land use

Chemical and biological samples were collected from a range of river and stream sizes in different landscape types and from shallow aquifers. A deep aquifer (Mahomet aquifer) was sampled to assess the overall water quality. A group of the shallow large-bore wells used for domestic (private household) supply was sampled, as well as other shallow domestic wells, to assess overall water quality and determine the occurrence of human-induced contaminants and the extent of land-use effects on recently recharged ground water.

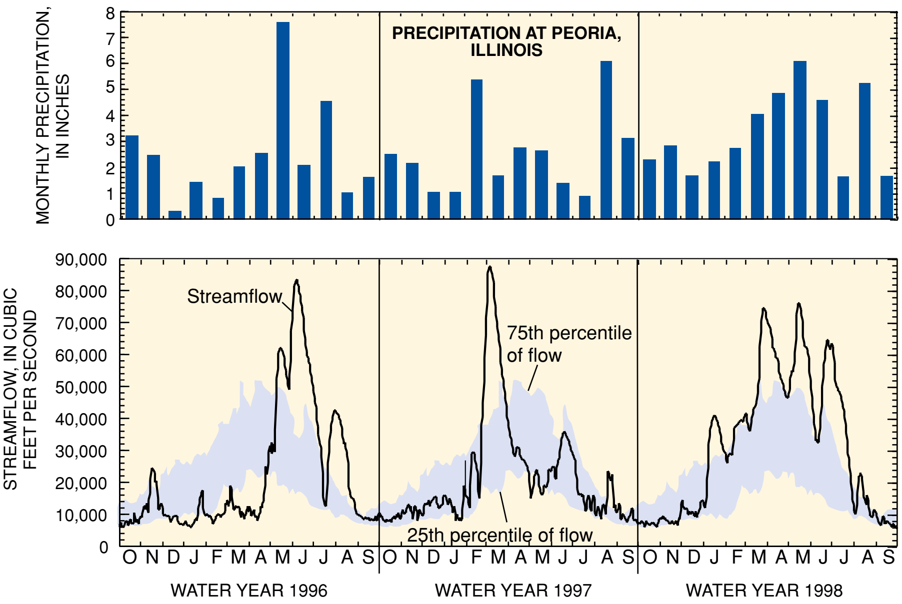


Figure 4. Hydrologic conditions during the data-collection period were near normal. Some relatively dry periods resulted in below-normal flow, and several wet periods resulted in above-normal flow on the Illinois River at Valley City.

Water use

In the lower Illinois River Basin, 48 percent of the public- or municipal-supply water is drawn from ground-water sources and 52 percent from surface-water sources (fig. 3). All private-supply water, usually for domestic use, is from ground water. Rural residents (about 25 percent of the population) generally are self-supplied from ground water [2]. In most of the western and southern parts of the basin, homeowners rely on cisterns or large-diameter dug or bored wells [3]. These large-diameter wells are highly susceptible to contamination from surface-water runoff and shallow ground water.

Irrigation, which is confined to sandy soils near the center of the basin, is entirely supplied by ground water.

Hydrologic conditions during the study period

Rainfall generally was near normal during the data-collection period (fig. 4). Typically, the largest rainstorms are during April to July. The generally normal rainfall had exceptions; in particular, water year 1997 (October 1996–September 1997) was slightly drier than

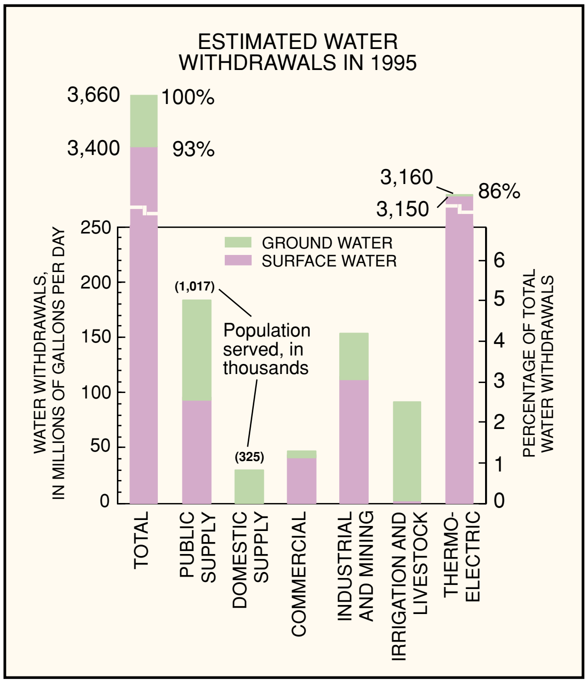


Figure 3. Water withdrawals in the lower Illinois River Basin are dominated by thermoelectric withdrawals (cooling water for power generation). Drinking water is supplied roughly equally from surface-water reservoirs and ground-water supplies.

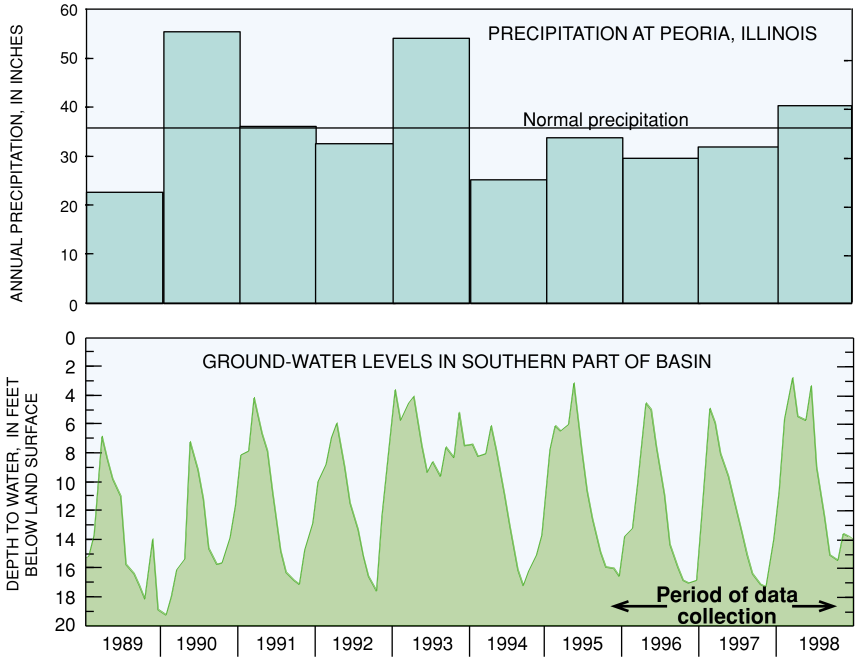


Figure 5. Ground-water conditions were near normal during 1989–98, including the data-collection period. In 1993, the observation-well water level shows the effect of the significant 1993 flood on the shallow ground water. (Data from K. Hlinka, Illinois State Water Survey, and National Weather Service.)

normal, and spring 1996 had fewer storms than normal.

Ground-water levels reflected the near-normal rainfall conditions, particularly in the southern part of the basin (fig. 5). Shallow ground water typically is recharged in late winter and early spring, then the level falls during the summer growing season. Water level in a representative well is shown in figure 5, along with 10 years of annual rainfall data collected near Peoria, which lies near the center of the basin.

The lower Illinois River

The Illinois River is a navigable waterway that connects the Mississippi River to Chicago and the Great Lakes. Barges carrying grain and other commodities are a significant influence on suspended sediment and water quality. The mean annual flow of the Illinois River increases from about 12,600 ft^3/s (cubic feet per second) at Ottawa to 22,600 ft^3/s at Valley City [2]. Five major tributaries—Vermilion River, Spoon River, Mackinaw River, La Moine River, and Sangamon River—and many smaller streams join the Illinois River (fig. 6). Flow gaging and sampling of the outflow from the basin is done at Valley City because the water level of the Mississippi River, at times, affects the flow of the Illinois River downstream from Valley City.

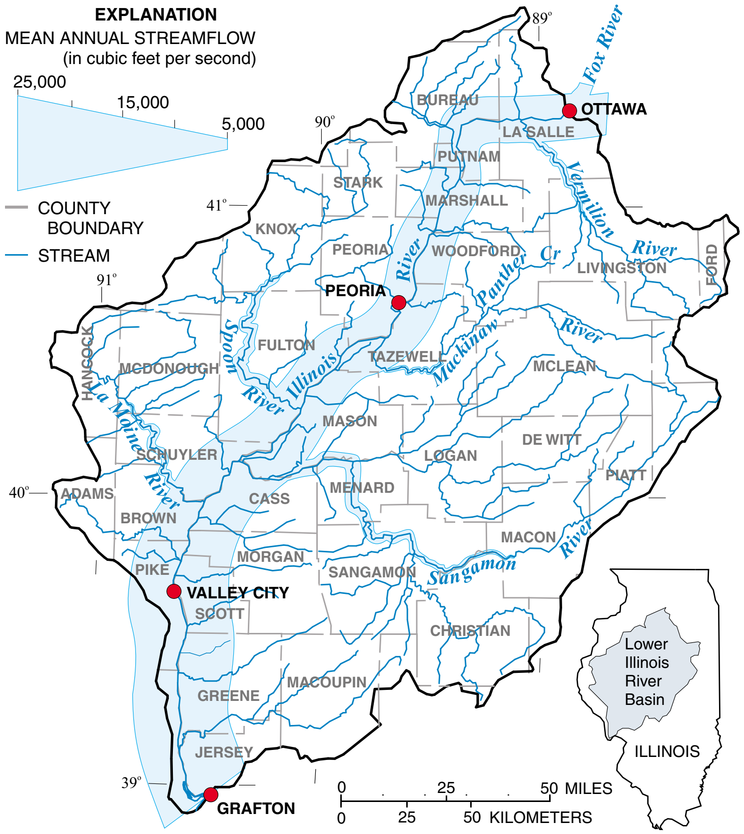


Figure 6. The lower Illinois River has five major tributaries. The inflow to the basin is at Ottawa, Ill., where the Fox River joins the Illinois River. Where the Illinois River leaves the basin and enters the Mississippi River near Grafton, Ill., the outflow is almost double that of the inflow.

Nutrient concentrations in streams and rivers are a major concern

Agriculture is the most important activity in the lower Illinois River Basin from an economic and water-quality perspective (fig. 7). Application rates of nitrogen and phosphorus in synthetic fertilizer and manure are among the highest in the Nation. The high application rates of agrichemicals in the basin were reflected by the kinds and amounts of contaminants found in streams, rivers, and ground water. Nevertheless, contaminants associated with urban or industrial activities also were detected in some streams, rivers, and wells.

Figure 7. Farming and related businesses are major activities in the lower Illinois River Basin. Agriculture has a significant effect on water quality and wildlife habitat. (Photograph by David J. Fazio, USGS.)

Flow-weighted concentrations of nitrate (nitrate as nitrogen) were generally highest in small streams in intensive agricultural areas and east of the Illinois River (fig. 8). The lowest flow-weighted mean concentration of nitrate was for the Illinois River at Valley City—the outflow from the basin. Concentrations of nutrients were similar at the basin inflow (Illinois River at Ottawa) and the basin outflow (Illinois River at Valley City). Urban sources, primarily wastewater effluent, however, were major contributors at the inflow [4], whereas agriculture provided most of the nutrient contribution to the water resources within the basin.

The nitrate load (amount of nitrate in water that moves past a location on the river) measured at the outflow from the basin, 124,000 ton/yr (tons per year), was nearly twice the load measured at the inflow, 66,000 ton/yr (fig. 9). Flow-weighted mean concentrations of nitrate are similar between the two Illinois River locations; therefore, the difference in loads is directly related to the difference in streamflow (fig. 6). The lower Illinois River Basin contributes roughly the same amount of nutrients to the Mississippi River as does the upper Illinois River Basin, which includes the

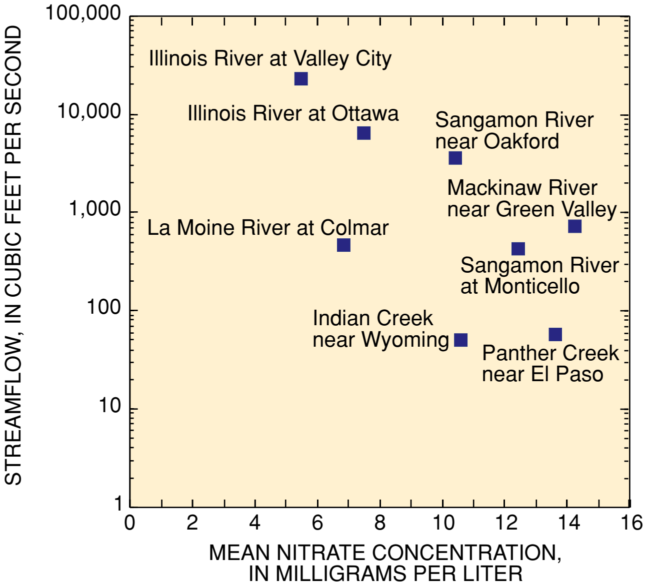


Figure 8. Mean nitrate concentrations generally are lowest in the Illinois River. Nitrate concentrations in the three largest rivers show a downward trend with increasing streamflow from the Sangamon River near Oakford to the Illinois River at Ottawa and to the Illinois River at Valley City. The La Moine River, which is the only river or stream sampled that lies entirely within the Galesburg Plain physiographic subsection, does not fit the general trend. The nitrate concentrations are flow-weighted means.

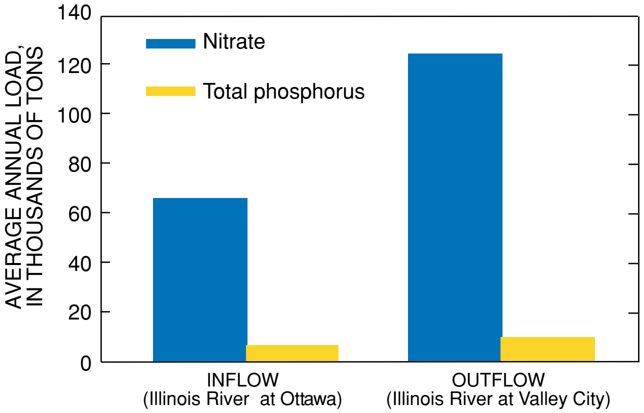


Figure 9. About twice as much nitrate and total phosphorus leaves the lower Illinois River as enters it. The loads for the upper Illinois River Basin—the basin upstream from Ottawa—are about one-half of the respective loads for the lower Illinois River Basin.

What Was Assessed?

The NAWQA Program was not intended to assess the quality of the Nation's drinking water, such as by monitoring water from household taps. Rather, NAWQA assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. Comparisons made in this report to drinking-water standards and guidelines are made only in the context of the available untreated resource.

Chicago urban area and rural areas in Illinois, Indiana, and Wisconsin.

The annual nitrogen yield (amount of nitrogen in water that flows out of the watershed divided by the area of the watershed) measured at the river and stream locations ranged from 4.6 to 12 (ton/mi^2)/yr (tons per square mile per year), the smallest yields being measured in the largest river and the largest yields measured in the smallest streams. The overall yield for the basin (Illinois River at Valley City) was 4.6 (ton/mi^2)/yr during 1995–98.

Substantial differences among nutrient concentrations in small agricultural basins and the lower nutrient concentrations in large rivers indicate that hydrological and biochemical processes reduce the nitrate concentration as nitrate moves through the basin and into the Mississippi River. Instantaneous concentrations of nutrients varied with season: nitrate concentrations were highest during the winter and spring and lowest in the late summer and fall.

Sites on the largest rivers—the Illinois River at Ottawa and Valley City and the Sangamon River near Oakford—had the highest flow-weighted mean concentrations of total organic nitrogen, ammonia nitrogen, and phosphorus; the latter two are indicators of urban wastewater effluent [4]. The Sangamon River near Oakford had the highest flow-weighted mean concentration of total organic nitrogen, ammonia nitrogen, and phosphorus. Samples from middle-sized La Moine River at Colmar generally had higher flow-weighted mean concentrations of most nutrients compared with samples from the Sangamon River at Monticello, which also is middle sized but is at the eastern edge of the basin. Flow-weighted mean concentrations of nitrate in samples from the Sangamon River at Monticello, however, were greater than those in samples from the La Moine River at Colmar. Panther Creek near El Paso, a small-basin site, generally had higher concentrations of most nutrients than did Indian Creek near Wyoming, another small-basin site.

Stream and river samples often exceeded the nitrate drinking-water standard and phosphorus guideline

Flow-weighted mean concentrations of nitrate for five of the eight sample locations in the basin, including two locations on the Sangamon River (used for public water supplies), were higher than the Maximum Contaminant Level (MCL) of 10 mg/L nitrate as nitrogen established for drinking water.

The concentration of total phosphorus in most samples (80 percent) from all streams and rivers exceeded the 0.1 mg/L guideline recommended by USEPA to prevent eutrophication in streams. Samples from Indian Creek near Wyoming had the highest concentrations of total phosphorus, and samples from Panther Creek near El Paso had the smallest. Indian Creek near Wyoming is downstream from a small wastewater-treatment plant, which is likely the reason for the higher total phosphorus at this site.

Streamflow-Weighted Concentrations

Drinking-water standards are generally based on the yearly average of samples collected quarterly. This is a legal definition of yearly average concentrations. Truly representative “average” water-quality conditions of a stream would require daily samples for some streams because of the variability in the concentration and in streamflow from day to day—especially over a period of storm runoff. During a storm, the levels of contaminants in a stream can vary 10 times or more from beginning to end. A method is needed to address this variability and “weigh” the concentrations found in individual “point” samples from a stream. A process is used to estimate the daily load or amount of a chemical that flows past a point. The daily loads are summed and then divided by the amount of streamflow to get an average for the period of interest. This flow weighting produces a more accurate mean concentration of a specific chemical for a period such as a year or, as for this report, for the 2–3 year period when samples were collected.

Nitrate concentrations were lower than in other areas of the Corn Belt during late summer

During August 1997, concentrations of dissolved nitrate and total nitrogen were found to be lower in streams and rivers of the lower Illinois River Basin than in some other areas of the Midwest. A synoptic study was done at 70 sites with drainage areas between 100 and 1,000 mi^2 in Illinois, Iowa, and Minnesota in August 1997, when streamflow had approximately reached the annual minimum [5]. Median concentrations of dissolved nitrate in streams generally increased northwestward, from Illinois (0.52 mg/L) to Iowa (1.5 mg/L) to Minnesota (3.5 mg/L). No significant relations between nitrate concentrations and streambank characteristics or soil permeability were identified. Streams that have formed on windblown glacial materials, however, generally had lower concentrations than streams formed on glacial till (unsorted material left behind by continental glaciers). The windblown materials typically have slightly higher permeability than the glacial till and are more likely to allow rainwater to infiltrate rather than run off to streams.

In Illinois, rainfall and thus runoff to streams was low before and during synoptic sampling; therefore, most streamflow was derived from ground-water seepage. Thus the low nutrient concentrations in ground water in the basin—much lower than those in streams and rivers—are a major reason why low nitrate concentrations were detected in the streams during August 1997 in the basin.

Differences in moisture conditions and precipitation during the 3-month period before the August sampling (wettest in Minnesota and driest in Illinois) probably also contributed to the differences in concentrations across the three-State region. The percentages of total nitrogen present as organic nitrogen and ammonia were higher in Illinois than in other parts of the study area. Nitrogen incorporation in algae also was a factor in the distribution of dissolved nitrate. Algal communities, particularly phytoplankton, were more stable and productive in Illinois than in other parts of the three-State synoptic study, and much of the nitrogen in the aquatic system was incorporated into these plant communities in the basin.

Nitrate concentrations differed upstream and downstream from water-supply reservoirs

Dissolved nitrate concentrations in samples from the Sangamon River (at Monticello) were found to be more variable upstream from several water-supply reservoirs than downstream from the reservoirs (fig. 10). From April through June, nitrate concentrations were frequently above the MCL of 10 mg/L (highest concentration, 17 mg/L) in the Sangamon River at Monticello, 29 mi upstream from Lake Decatur, the drinking-water source for the city of Decatur. The city of Decatur often must treat water for nitrate above the MCL during spring and early summer or mix the high-nitrate surface water with ground water to lower the nitrate concentration. Nitrate concentrations also were highest in the spring in the Sangamon River near Oakford, which is downstream from Lake Decatur and other water-supply reservoirs used by the city of Springfield. Concentrations in samples from the Sangamon River near Oakford, however, seldom exceeded the nitrate MCL.

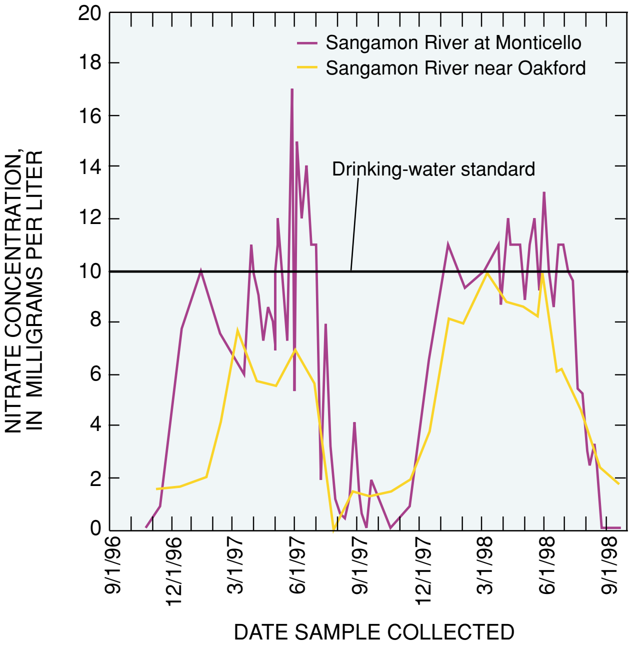
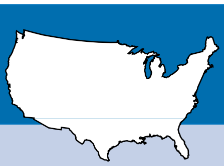


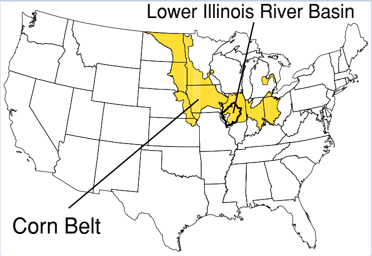
Figure 10. Nitrate concentration in the Sangamon River is affected by reservoirs and other factors. Monticello lies upstream from several water-supply reservoirs and the cities of Springfield and Decatur. Oakford lies downstream from the reservoirs. The reservoirs are for water supply, and during spring they are replenished by river water that exceeds the drinking-water standard for nitrate. Water leaving the reservoirs usually does not exceed the nitrate standard and has less variability in nitrate concentrations.

Conversely, concentrations of nitrate usually were less than 1 mg/L in the Sangamon River at Monticello from August through November, but typically remained higher than 1 mg/L at the Oakford site during the same period. Data from Scribner and others [6] indicate that nitrate concentrations of reservoirs in corn- and soybean-producing areas of the Midwest have nutrient concentrations and patterns similar to those in the Sangamon River near Oakford.



Algal index indicates comparatively poor water quality in Corn Belt

Small streams in the Corn Belt have both poorer water quality, as indicated by the algal status index, and higher nitrate concentrations than small streams in other parts of the Nation. The algal status index reflects a greater relative abundance of benthic algal species that are considered tolerant of poor water-quality conditions, including high nutrient concentrations. Results for this study are from data collected in 16 NAWQA Study Units from 1996 to 1998.

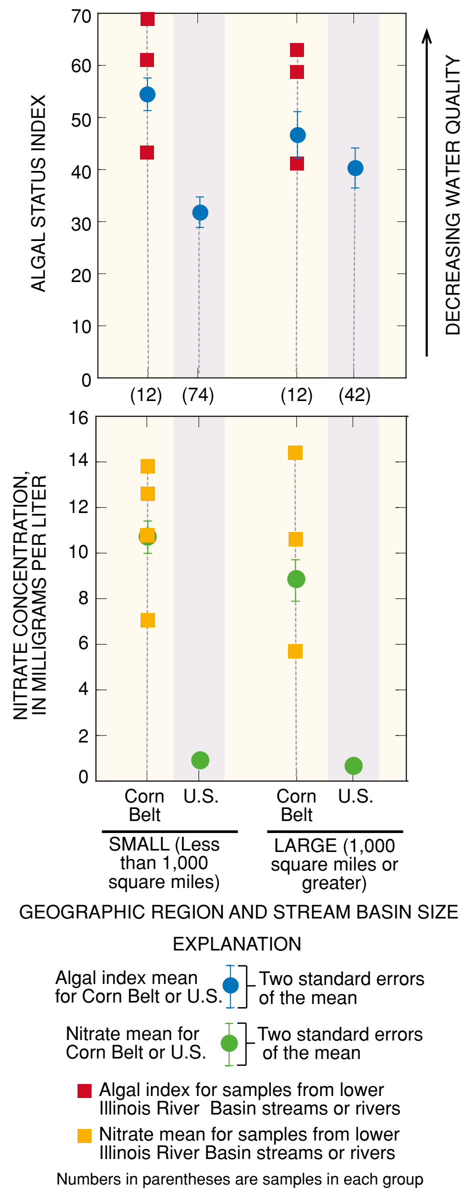


The lower Illinois River Basin lies within the eastern one-half of the Corn Belt.

Algae grow on virtually all stream surfaces receiving light. Algal communities are the foundation of the food web of many streams, serving as a food source for invertebrates and fish. Nuisance algal growth can result from excess nutrients and can lead to large variations in dissolved oxygen concentrations.

In large streams, flow-weighted mean concentrations of nitrate were also higher in the Corn Belt than in the rest of the Nation, but the algal status index was not significantly higher. The dynamics of the algal community change with stream size, and the importance of phytoplankton (floating algae) increases as streams get larger. The algal status index does not reflect the composition of the phytoplankton community, and this may explain the differences observed between small and large streams.

Chemical, physical, and biological factors all influence the algal community and local stream conditions. The algal status index at individual lower Illinois River Basin streams was similar to that at other streams in the Corn Belt.

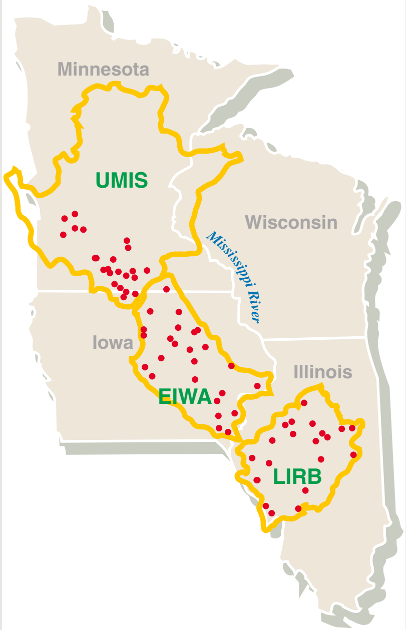


Algal status index values and nitrate concentrations for the lower Illinois River Basin, and for Study Units in the Corn Belt, are higher than mean values for Study Units in the Nation.

Excess nutrients often cause algal blooms that can be seen in streams and rivers in the basin. Algae reduce the amount of nutrients that remain in the water by converting nutrients into algal biomass. (Photograph by Paul J. Terrio, USGS.)

Riparian buffer zones influence the quality of midwestern streams and rivers

Despite similar land use throughout the Corn Belt region of the Midwest, streams flowing through cropland differ considerably in their ecological characteristics, in part because of differences in riparian buffer zones (see text boxes). This conclusion is based on an investigation of 70 streams and rivers within three NAWQA Study Units in the upper Midwest during August 1997 (figure at right) [5; 7]. Specifically, increases in tree cover in buffer zones were associated with aquatic biological communities indicative of good stream quality, reduced nuisance algal growths, and maintenance of sufficient dissolved oxygen concentrations to support diverse communities of aquatic organisms. For example, the number of aquatic insects indicative of good stream quality tended to increase with increases in percentage of tree cover, especially in sites where streamflow and dissolved oxygen conditions were favorable. Fish communities, sampled at 24 sites in the UMIS Study Unit, also indicated better overall conditions in streams with wooded riparian zones than those with more open canopy [8].



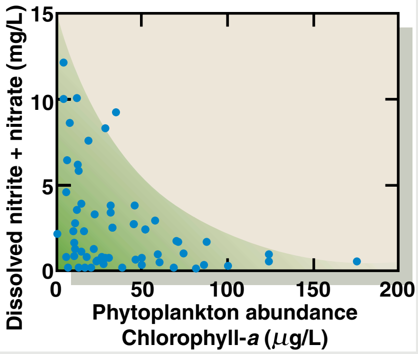
The influence of riparian buffer zones on the quality of 70 midwestern streams and rivers was evaluated in the Upper Mississippi River (UMIS), Eastern Iowa (EIWA), and lower Illinois River Basins (LIRB).

Streams with less tree cover, and thus less shading, contained relatively large growths of phytoplankton (algae suspended in the water) at levels considered indicative of eutrophication [9].

Digital images derived from USGS topographic maps were used to estimate the percentage of trees in a riparian buffer zone (a 100-meter width on each side of the stream) for 2- to 3-mile segments upstream from each sampling site, supplemented by vegetation surveys at the sampling site [5].

Organic enrichment resulting from excessive algal production in some midwestern streams may reduce dissolved oxygen concentrations and be detrimental to other requirements of aquatic organisms.

Shading from tree cover in riparian buffer zones may influence nutrient concentrations indirectly by reducing the growth of phytoplankton. In streams where phytoplankton were abundant (often where buffer zones were thin or lacking), dissolved nitrate concentrations were significantly lower (figure below) [9]. The lower nutrient concentrations may result from uptake by the abundant phytoplankton. Thus, assessments of eutrophication would benefit from consideration of biological communities and the riparian zone, rather than being based solely on nutrient concentrations in the water.



Dissolved nutrient concentrations decreased in eutrophic streams with excessive algal productivity. Rates of nutrient uptake by the algae can exceed rates at which nutrients are transported by streams during low-flow conditions.

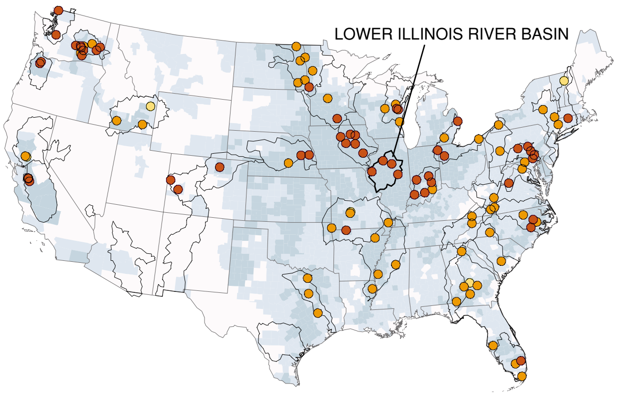
Resource agencies, including the U.S. Department of Agriculture, encourage maintenance of strips of trees or grass between cropland and streams as a best management practice. These “riparian buffer zones” are thought to intercept runoff of sediment and chemicals from fields, promote bank stability, and provide shading and habitat for aquatic life [10]. Riparian buffer zones should be considered along with other important factors that affect chemical and biological indicators of stream quality, such as soil drainage properties and stream hydrology [7].

Nutrient concentrations were among the highest in the Nation

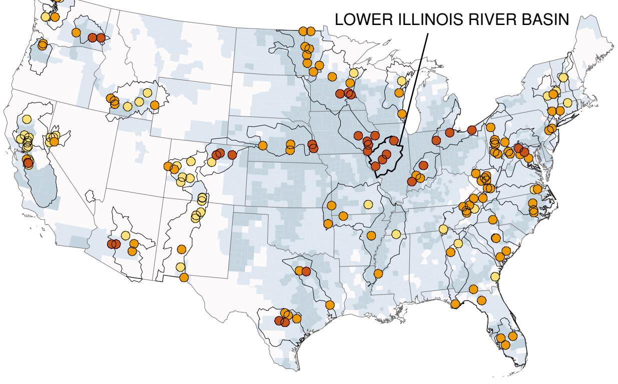
Concentrations, loads, and yields of nutrients in the lower Illinois River Basin were among the highest in the Nation. When compared with data from NAWQA studies nationwide, nitrate concentrations in the lower Illinois River Basin were in the highest 10 percent at every sampling location, and total phosphorus concentrations were in the highest 25 percent at seven of the eight locations.

TOTAL NITROGEN IN STREAMS

AGRICULTURAL AREAS



MIXED LAND USE AREAS



EXPLANATION

AVERAGE ANNUAL TOTAL NITROGEN INPUT, IN POUNDS PER ACRE, BY COUNTY, FOR 1995–98

INPUTS ARE FROM FERTILIZER, MANURE, AND THE ATMOSPHERE

- ▨ GREATER THAN 25 POUNDS PER ACRE
- ▨ 6 TO 25 POUNDS PER ACRE
- ☐ LESS THAN 6 POUNDS PER ACRE

AVERAGE ANNUAL CONCENTRATION OF TOTAL NITROGEN, IN MILLIGRAMS PER LITER

- ● HIGHEST (GREATER THAN 2.9)
- ● MEDIUM (0.64 TO 2.9)
- ● LOWEST (LESS THAN 0.64)

Soybeans, which are a major crop in the lower Illinois River Basin, are important for nutrient management and the nitrogen balance of agricultural watersheds. The roots of soybeans harbor bacteria that fix nitrogen from the atmosphere into the soil in a form that can be used by the plant, and by other crops the following year. (Photograph by Kelly L. Warner, USGS.)

Of the 10 largest rivers monitored by NAWQA (greater than 20,000 ft^3/s mean daily streamflow), the lower Illinois River Basin site at Valley City had the highest flow-weighted mean nitrate and total nitrogen concentrations (see “Streamflow-Weighted Concentrations,” p. 7). The concentrations were greater than twice the concentrations for both nitrate and total nitrogen of the next highest ranked location—Mississippi River at Hastings, Minnesota—and of a comparable-size river location—Mississippi River at Red Wing, Minnesota

Goolsby, Battaglin, and others [11, 12] concluded that the basin is one of the areas of highest nitrogen yield (amount of nitrogen runoff into streams per unit area) contributing to the Mississippi River. Alexander and others [13] estimated that 50 percent to greater than 90 percent of the nitrogen exported from much of the basin is transported to the Gulf of Mexico, where excess nutrients help create hypoxia—oxygen concentrations below the level required by most aquatic life in the Gulf. The Illinois River contributes from 15 to 20 percent of the total nitrogen that goes into the Gulf of Mexico from the Mississippi River [14, 12].

Roughly between 61,000 and 124,000 tons of nitrogen is transported annually from the lower Illinois River Basin to the Gulf of Mexico. More than one-half of the excess nitrogen entering the Gulf from the Mississippi River is thought to come from the upper Mississippi Basin—that portion upstream from St. Louis, Missouri. The Illinois River joins the Mississippi River just north of St. Louis.

Nitrate concentrations in some shallow wells exceeded the drinking-water standard

The 117-well network sampled in the basin consisted of 57 shallow monitoring wells installed for the study (fig. 11) and 60 water-supply wells of various types. Although the concentrations of nitrate in none of the 30 samples from the deep Mahomet aquifer exceeded the MCL (all concentrations were below 0.10 mg/L), nitrate concentrations in the shallow wells exceeded the MCL in 7 percent (6 of 87) of the shallow-well samples. Concentrations above the MCL ranged from 11 to 77 mg/L. All exceedances of the nitrate MCL were in samples from wells less than 50 feet deep.

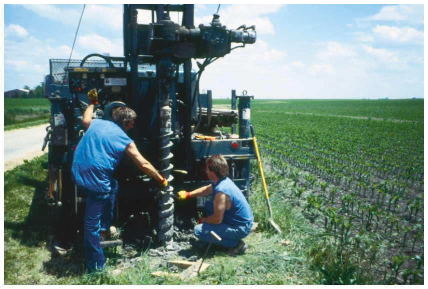


Figure 11. Study-Unit staff installed 57 wells to sample recently recharged ground water. Assistance and geological expertise was provided by the Illinois State Geological Survey. (Photograph by William S. Morrow, Jr., USGS.)

An important reason for fewer detections and much lower concentrations of nitrate and other agrichemicals in ground water is artificial drainage (where present) and the geological materials from which the soils developed. Most farmland in Illinois is artificially drained by ditches and subsurface drains (tile drains) because of the poor natural drainage of the soils and their parent materials (fig. 12). Artificial drainage short circuits infiltrating water to streams through the subsurface drains rather than allowing the water to move downward to the water table or to deeper aquifers [15]. Subsurface drainage also decreases the amount of potential runoff across land surface to streams because the soil is less saturated and ponding is less likely [15]. Another factor that helps prevent agrichemicals from reaching wells is that the fine-grained materials may be conducive to rapid breakdown of many of the chemicals.

One-half of the shallow wells installed for monitoring recently recharged ground water (28 of 57) were installed in the geological materials overlying the Mahomet aquifer. The shallow ground water in this area has a high potential for eventually recharging the underlying Mahomet aquifer [2]. Sampling results from these wells indicate the Mahomet aquifer is fairly well protected from contamination at land surface.

Some pesticides were always detected in streams and rivers

Herbicides are applied during spring planting to virtually all corn and soybean crops in the basin. Insecticides are applied during the summer to about 10 to 30 percent of the corn crop, depending on weather conditions. Approximately 6,000 to 6,700 tons of agricultural pesticides were applied annually in the lower Illinois River Basin during 1996–98 (data from [16–18]).

Figure 12. Subsurface drainage allows water with high concentrations of agrichemicals to be transported directly to ditches and streams. The outlet pipe from a subsurface drain at center of photograph is draining into the stream. (Photograph by Kelly L. Warner, USGS.)

Atrazine, which is commonly applied to corn in the basin, and its breakdown products (hydroxyatrazine, deisopropylatrazine, and deethylatrazine) were the most frequently detected pesticide and related compounds in streams throughout the basin and shallow ground water beneath cropland. Atrazine was detected in every stream sample collected from the basin, even during winter. Prometon, which is not used in appreciable amounts on cropland but commonly is applied for weed control in rights-of-way in the basin, was detected frequently in streams (93 percent of samples) and infrequently in shallow ground water (7 percent of samples).

In samples collected at Illinois River at Valley City (basin outflow), 40 pesticides or pesticide breakdown products were detected. Atrazine and metolachlor were always present, and cyanazine was detected in 97 percent of the samples.

Because the method detection limit varies widely from one pesticide or related compound to another, a common reporting level is used to compare detections of the pesticides and compounds on an equal basis. In figure 13, the frequency of detection of pesticides in stream and river samples and ground-water samples is shown at a common reporting level of 0.05 µg/L. Of the pesticides detected in 1 percent or more of samples, those shown in figure 13, only 2,4-D had a higher method detection limit than 0.05 µg/L; therefore the detection frequency of 2,4-D may be underestimated in figure 13. Even at the common reporting level, atrazine was detected in almost all stream and river samples.

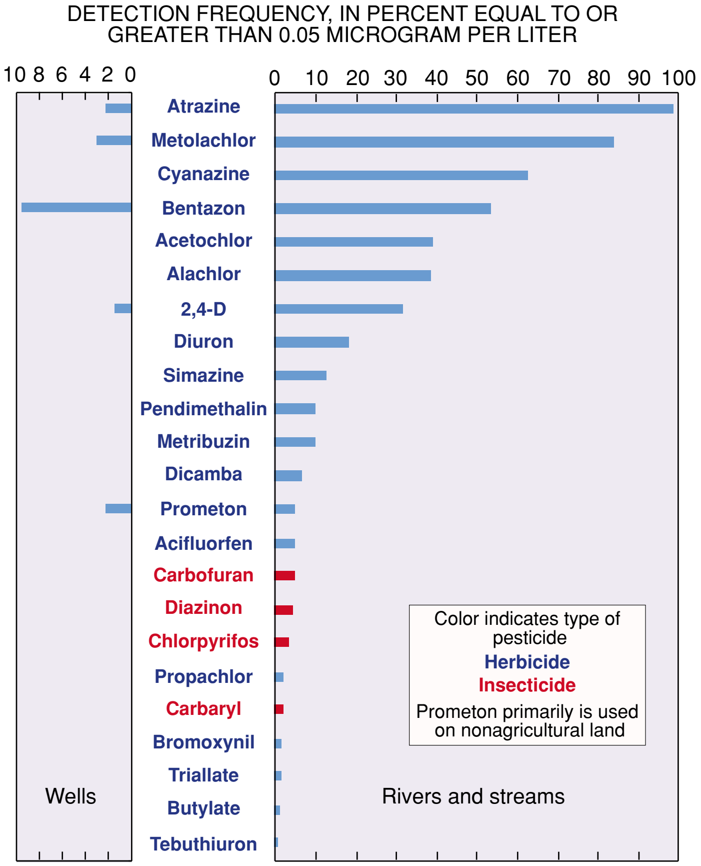


Figure 13. Many commonly applied pesticides were frequently detected in streams and rivers in the lower Illinois River Basin. Detections in ground water were far fewer, and some of the pesticides frequently detected in surface water (such as cyanazine, acetochlor, and alachlor) were not detected in shallow ground water at or above the common reporting level of 0.05 micrograms per liter.

Pesticide concentrations in streams periodically exceeded drinking-water standards

Concentrations of atrazine and cyanazine in some individual samples exceeded USEPA drinking-water standards or guidelines. Annual average concentrations of each compound in streams and rivers, however, were below their respective MCL (atrazine: 3 µg/L) or lifetime health advisory level (HAL) (cyanazine: 1 µg/L). Carbofuran, diazinon, chlorpyrifos, and carbaryl were the only insecticides detected. Diazinon concentration exceeded the Great Lakes water-quality objective (0.08 µg/L) [19] in one sample at Illinois River at Valley City during August 1998.

Some pesticide concentrations that exceeded human health standards or guidelines also were potentially toxic to aquatic life. For example, an atrazine concentration of 110 µg/L in a single sample from the La Moine River at Colmar (fig. 14) exceeded not only the USEPA MCL (3 µg/L) but also the Canadian guideline for the protection of freshwater aquatic life (1.8 µg/L) [20]. In samples from the Illinois River at Ottawa and at Valley City and the Sangamon River at Oakford, all exceedances of the cyanazine HAL and the metolachlor aquatic-life guideline (7.8 µg/L) were concurrent with an exceedance of the atrazine MCL. In contrast, diazinon concentrations twice exceeded the Great Lakes water-quality objective and one chlorpyrifos concentration exceeded the aquatic-life guideline (0.041 µg/L) independent of all other pesticide exceedances.

In samples from the La Moine River at Colmar and the Sangamon River at Monticello, for every pesticide other than atrazine, concentrations exceeded a drinking-water standard or guideline concurrent with an atrazine MCL exceedance. The lone exception was cyanazine, which exceeded the HAL independent of all other standard or guideline exceedances.

Currently (2000), drinking-water standards or guidelines and aquatic life guidelines have been established only for individual pesticides. Furthermore, USEPA drinking-water MCLs or HALs are established for only 25 of the 40 pesticides detected in the lower Illinois River Basin. Pesticides, however, commonly are found in mixtures of as many as 21 compounds in surface water (fig. 15). Although most samples of shallow ground water contained relatively few detectable concentrations of pesticides compared to samples from streams and rivers, two or more pesticides were detected in all samples where any of pesticides were detected at all. The health effects of such combinations of pesticides in drinking water, even in low concentrations, are not well understood.

Pesticide concentrations in streams have a seasonal pattern

Herbicide concentrations in stream and river samples are highest in late spring to early summer (fig. 16), and insecticide concentrations typically peak in midsummer. The highest pesticide concentrations typically occur during the first one or two periods of storm runoff after pesticide application. During seasonal peaks, concentrations of pesticides in samples of stream water exceeded drinking-water standards or guidelines or aquatic-life guidelines. For example, for about 6 weeks after herbicide application in the spring, concentrations of atrazine at Illinois River at Valley City were greater than the MCL of 3 µg/L. The annual mean atrazine concentration in the Illinois River at Valley City for 1996 through 1998, however, never exceeded the MCL. Peak concentrations of the insecticides diazinon and chlorpyrifos were measured during July or August of 1997 or 1998. Insecticides are often applied later in the growing season than herbicides.

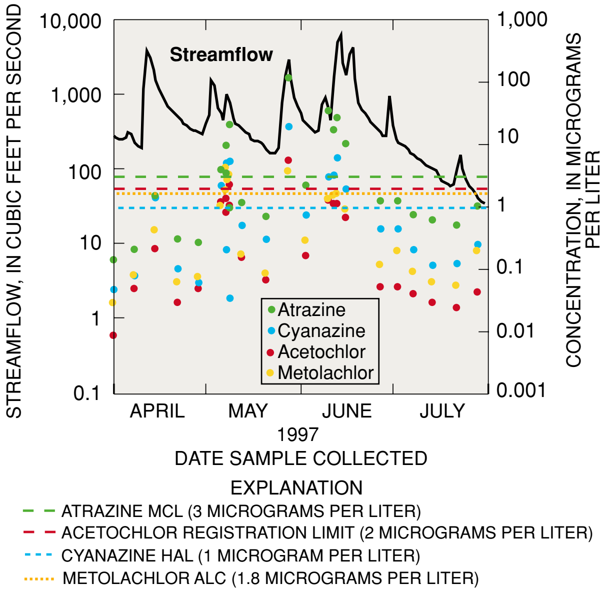


Figure 14. During late spring and early summer, many pesticides exceeded drinking-water standards or guidelines or aquatic-life guidelines. The graph shows concentrations of selected pesticides in the La Moine River at Colmar during part of 1997. (Registration limit for acetochlor is from [21]; ALC, Aquatic-Life Criterion from [20]; HAL, Health Advisory Level.)

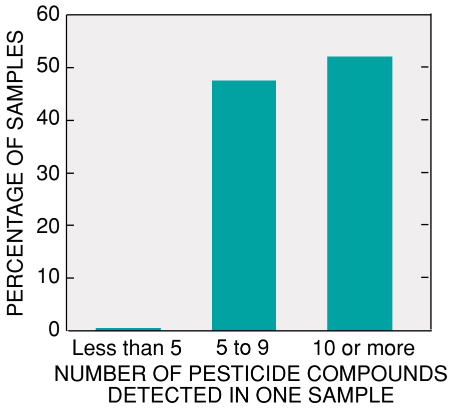


Figure 15. Most samples from streams and rivers contained multiple pesticides and related compounds. Five or more compounds were detected in more than 90 percent of samples. The maximum number of compounds detected at or above the method detection limit in one sample was 21.

Many factors affect the presence and concentration of pesticides in streams

The presence and concentration of pesticides in streams in the lower Illinois River Basin are influenced

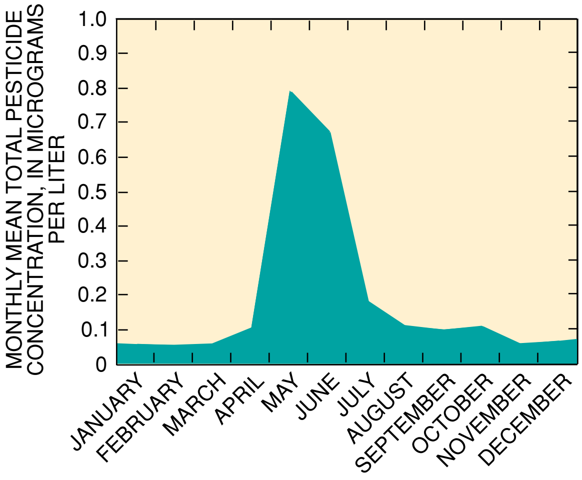


Figure 16. Pesticide concentrations vary seasonally. The sum of pesticide concentrations in samples peaks in late spring during runoff from rainstorms. Often, runoff from spring rains supplies reservoirs on some rivers and streams with a substantial amount of the water storage for the remainder of the year. Monthly mean totals are for all locations sampled for pesticides during October 1996–September 1998.

by land use and agricultural practices (fig. 17) such as pesticide application rate, drainage of crop land, and cropping methods. Natural factors, such as the size of the streams, type of terrain, and soil characteristics, also are important determinants. In addition, the distribution of individual pesticides in streams throughout a watershed depends on the physical and chemical properties of the pesticides that are in use—properties such as sorption (the ability of a pesticide to stick to soil particles), transformation (the ease with which a pesticide breaks down in the environment), and volatilization (the tendency of a pesticide to become gaseous and rise into the atmosphere).

Concentrations of agricultural chemicals generally reflect application rates

The most heavily applied pesticides (more than 1 million pounds of active ingredient per year; acetochlor, atrazine, cyanazine, and metolachlor) were generally the most frequently detected in streams and shallow aquifers. Herbicides such as alachlor and simazine, which are no longer applied as heavily as in previous decades, still are detected at relatively high rates. Bentazon is not applied as heavily as other herbicides, yet it is frequently detected in stream and well samples (fig. 18).

Figure 17. Pesticides are used to protect crops and increase production. Pesticides are often sprayed directly on the plants in the field. Other pesticides are incorporated into the soil, partly to limit the amount of chemical that leaves the field. (Photograph by Kelly L. Warner, USGS.)

Pesticide concentrations in water also were commonly related to drainage of water over and through agricultural soils, pesticide uptake by plants and microbes, and attachment to soil particles. Pesticide and nutrient persistence and regional differences in soils, geology, and climate govern the distribution of these water-quality indicators in the lower Illinois River Basin.

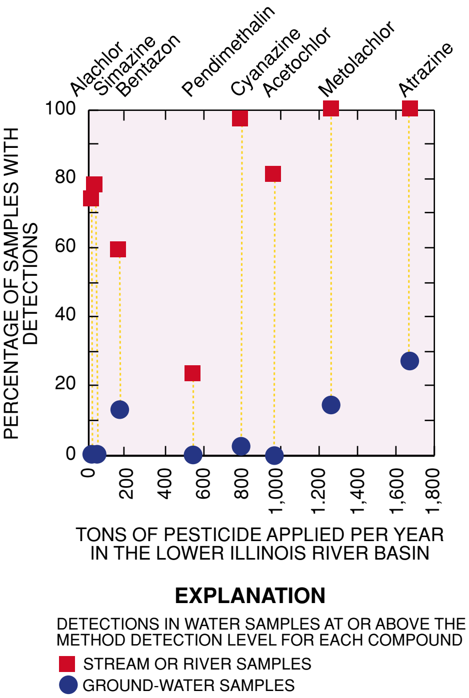


Figure 18. Detection rates in streams are mainly affected by the amount of pesticide applied in the basin. Detection rates in ground water, even for those pesticides that are heavily applied, are much lower.

The relatively infrequent detection of metolachlor in well samples may be related to the following factors:

1. Metolachlor is applied after weeds sprout and emerge, and it is taken up by plants and is converted to other compounds.
2. Soil microbes effectively degrade metolachlor.
3. Soils retain metolachlor instead of allowing it to run off or seep downward to ground water.

Stream size affects pesticide concentrations

In the lower Illinois River Basin, pesticide concentrations in small streams typically range from the highest to the lowest observed concentrations, whereas concentrations in large rivers are moderate and less variable. For example, during the period when most pesticides are washed into streams (May through July), the maximum concentration of atrazine measured in the Sangamon River at Monticello was about twice as high as that measured in the Illinois River. The highest concentrations of several pesticides, including atrazine (110 µg/L; May 1997), acetochlor (12 µg/L; May 1998), cyanazine (16 µg/L; May 1997), and 2,4-D (7.3 µg/L; May 1998) were detected in samples from the La Moine River at Colmar. In contrast, in months other than May or June, 70 percent (35 of 50) of samples from Sangamon River at Monticello had total pesticide concentrations that were less than 1 µg/L, as compared with 79 percent (26 of 33) of the samples from Illinois River at Valley City. Samples for analysis of pesticides were not collected from the smallest streams monitored.

Concentrations of alachlor and cyanazine in the Illinois River decreased

Application rates of cyanazine decreased during the 1996–98 sampling period in anticipation of its use being eliminated in 2003. Alachlor use has declined since the early 1990s—in fact, no use of alachlor was reported for 1998 in the basin. The use of alachlor, by voluntary agreement [21], is decreasing as acetochlor replaces it (fig. 19).

Cyanazine was detected in 97 percent of the river and stream samples and alachlor was detected in 74 percent of the samples during 1996–98. A comparison of mean monthly concentrations of those detections, however, shows a different story. During 1991–92, samples that were comparable to those collected as part of this NAWQA study were collected from the Illinois River at Valley City. The mean monthly concentrations for the two periods, separated by about 4–5 years or longer, indicate that concentrations of alachlor and cyanazine have substantially decreased (fig. 20).

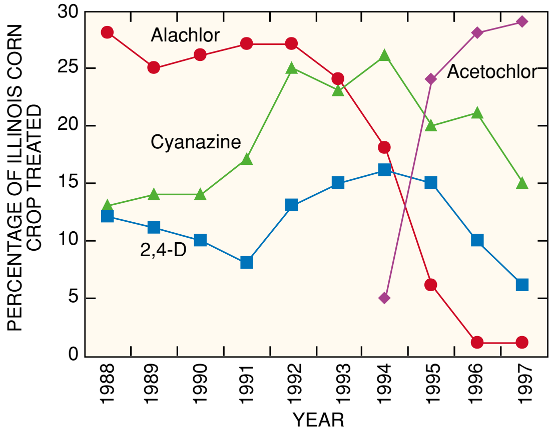


Figure 19. Use of herbicides on corn and soybeans in Illinois changed during 1988–97. Use of three common herbicides has declined from their peak use, but the use of acetochlor has increased substantially. (Data from [22].)

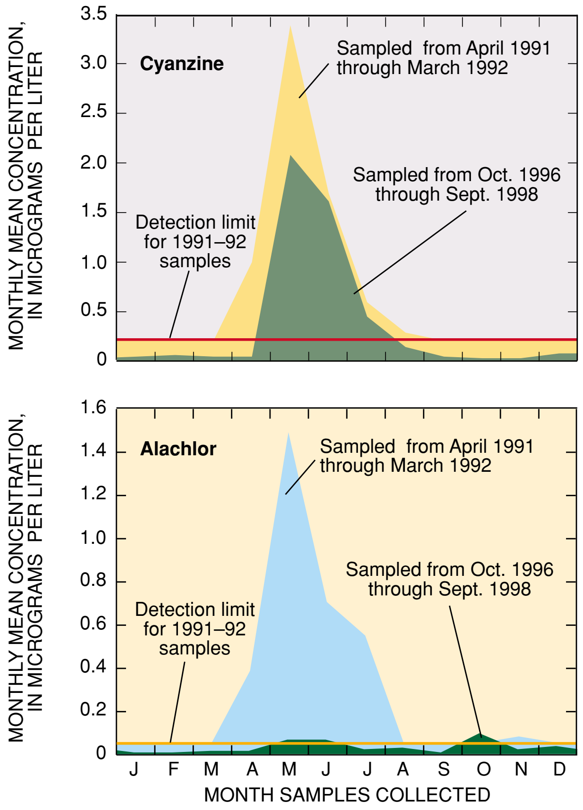


Figure 20. Monthly mean concentrations of cyanazine and alachlor declined substantially in water samples collected from the Illinois River at Valley City.

Pesticide breakdown products were detected more frequently than the parent compound

In stream and river samples (fig. 21) and groundwater samples (fig. 22), pesticide breakdown products, such as metolachlor ethanesulfonic acid (a breakdown product of metolachlor) and deethylatrazine (a breakdown product of atrazine) were detected more frequently at higher concentrations than their respective parent compounds. The toxicity of most of these breakdown products generally is unknown. Also unknown is the combined effect of parent compounds and the breakdown products. Drinking-water standards or guidelines or aquatic-life guidelines have been established for only a few pesticide breakdown products.

Most of the residue of metolachlor detected in ground water consisted of breakdown products (fig. 22). Metolachlor was frequently detected in streams and rivers. Because primarily breakdown products of metolachlor were found in ground water, metolachlor must break down before it can reach ground water.

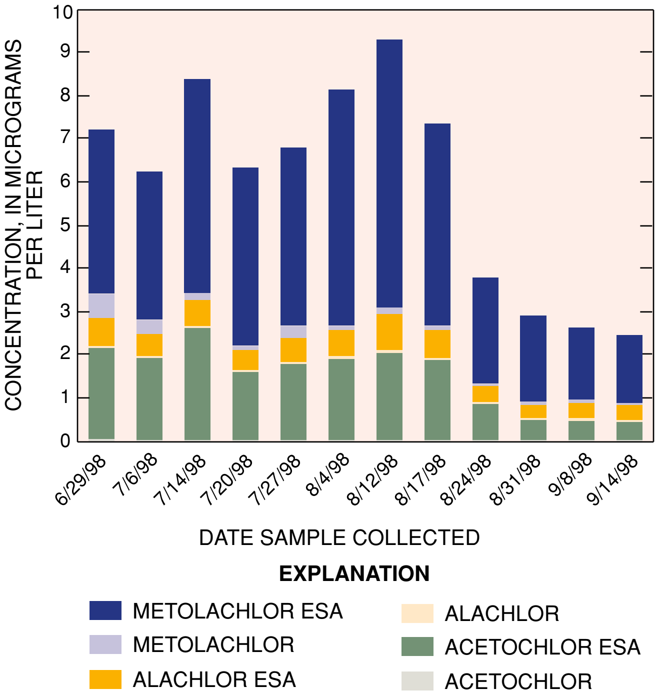


Figure 21. Breakdown products of common herbicides account for most of the analyzed herbicide residue in river water. Long after the parent compound drops below detection, breakdown products can still be detected. Earlier in the spring, acetochlor concentrations peaked at 9 micrograms per liter at this location, Sangamon River at Monticello. (ESA, ethanesulfonic acid)

Pesticides were not frequently detected in ground water

Pesticides are much less common in ground water than in streams. Six compounds, all herbicides (atrazine, metolachlor, prometon, bentazon, cyanazine, and dicamba), were detected in monitoring and water-supply wells. No insecticides were detected in ground-water samples. Only four of these pesticides were detected more than once. The maximum number of pesticides detected in a single well sample was four. Concentrations of all pesticides detected were very low (less than 0.44 µg/L). In ground-water samples, no pesticide came close to exceeding an existing drinking-water standard or guideline.

Insecticides discontinued in the 1970s were still detected in fish and sediment

Several organochlorine compounds (dieldrin, heptachlor epoxide, chlordane, and DDT) were commonly detected in fish tissue. Fish samples usually comprised 8 specimens of common carp, but at several locations

Standards for water, biota, and sediment quality

The USEPA [23–25] is responsible for setting drinking-water standards and guidelines to protect human health. Maximum Contaminant Level (MCL) is the maximum allowable concentration of a contaminant in water delivered to any user of public water systems. MCLs are enforceable standards based on an average annual concentration taken from four quarterly samples of finished drinking water. Health Advisory Level (HAL) is a nonenforceable, risk-based guideline. HALs indicate contaminant exposures below which no short- or long-term human-health effects are expected, based on drinking a specific amount of water for a specific period of time. Risk of illness increases with exposure time and concentration. Of 88 pesticides analyzed for in water, 14 have MCLs and 38 have HALs.

Guidelines to protect aquatic life have been set by several agencies including the USEPA, Environment Canada [26, 20], and the International Joint Commission (IJC) [19]. The aquatic-life guidelines developed by USEPA are based on 4-day average concentrations, are intended to protect 95 percent of the aquatic species, and should not be exceeded more than once in 3 years. The Canadian and IJC aquatic-life guidelines, which are more stringent than those of the USEPA, indicate a single maximum concentration that should never be exceeded. Aquatic-life guidelines have been established for only 18 pesticides.

Probable Effect Levels (PELs), are used to indicate contaminant concentrations in freshwater sediment associated with adverse effects on aquatic life for the Great Lakes region. The PEL is an estimate of the concentration above which adverse biological effects frequently occur [19, 27]. PELs are established for 18 of the 43 organochlorine and semivolatile organic compounds and 8 of 29 trace elements analyzed for this study.

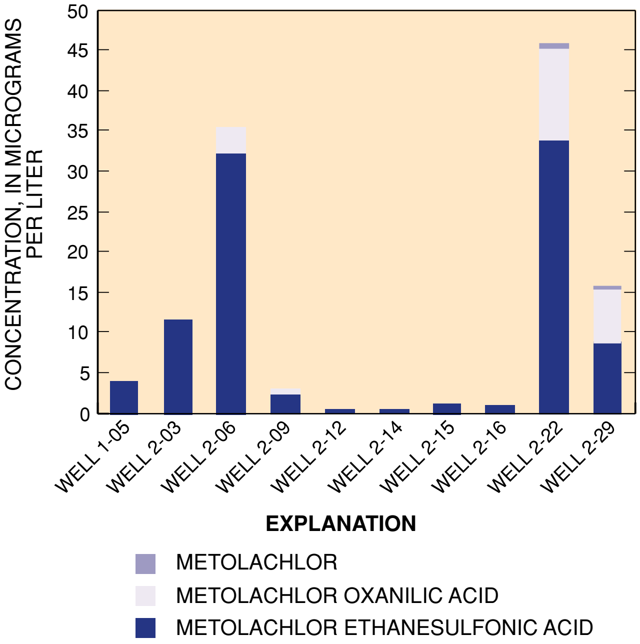


Figure 22. Breakdown products account for most of the residue of metolachlor in ground water. In these 10 shallow wells, metolachlor or its residue was detected. Metolachlor never exceeded the HAL (70 µg/L) in well samples; no drinking-water standards or guidelines have been established for the breakdown products.

white suckers were collected. These compounds are insecticides or insecticide breakdown products. Most of the organochlorine insecticides are no longer used because their registration was canceled by USEPA in the 1970s. Dieldrin, which was applied to corn and around buildings against termites, is a transformation product of aldrin, another insecticide that was applied to corn before use was discontinued during the early 1970s [28].

Dieldrin was detected in every tissue sample and one-third of the bed-sediment samples collected in the lower Illinois River Basin (table 1). The highest dieldrin concentration in fish tissue in the NAWQA Program across the Nation was detected in fish from the Sangamon River. Every concentration detected in the basin was in the highest 10 percent of the national NAWQA results. Aquatic-life guidelines were exceeded in 30 percent of the samples.

Heptachlor epoxide is a breakdown product of the insecticide heptachlor. The highest heptachlor epoxide concentration in fish tissue in the NAWQA Program nationally was detected in the La Moine River. Heptachlor epoxide was detected throughout the basin but at only one location in the Illinois River. The concentration of heptachlor epoxide in all fish tissue samples from the lower Illinois River Basin in which the compound was detected exceeded the concentration in more than 95 percent of all NAWQA samples. Heptachlor epoxide was not detected in any bed-sediment samples.

Table 1. Summary of total chlordane, total DDT, dieldrin, heptachlor epoxide, DDD, DDE, and total PCB concentrations in fish tissue (carp or white suckers) and bed sediment. The detections are compared to guidelines for the protection of fish-eating wildlife. DDD and DDE are breakdown products of DDT

[µg/kg, micrograms per kilogram (equivalent to parts per billion); NYSDEC, New York State Department of Environmental Conservation [27]; PEL, Probable Effect Level [26]; –, not applicable]

Fish Tissue

Compound detected in fish tissue	Number of sites with detections (20 sites sampled)	Minimum detected concentration (µg/kg)	Maximum detected concentration (µg/kg)	NYSDEC whole-fish non-carcinogenic criteria recommended for the protection of fish-eating wildlife (µg/kg)	Number of sites with concentrations in excess of NYSDEC criteria
Dieldrin	20	24	300	120	6
Heptachlor epoxide	13	13	44	200	0
Chlordane, total	20	20	310	500	0
DDT, total	20	11	550	200	1
PCBs, total	15	130	4,400	110	15

Bed Sediment

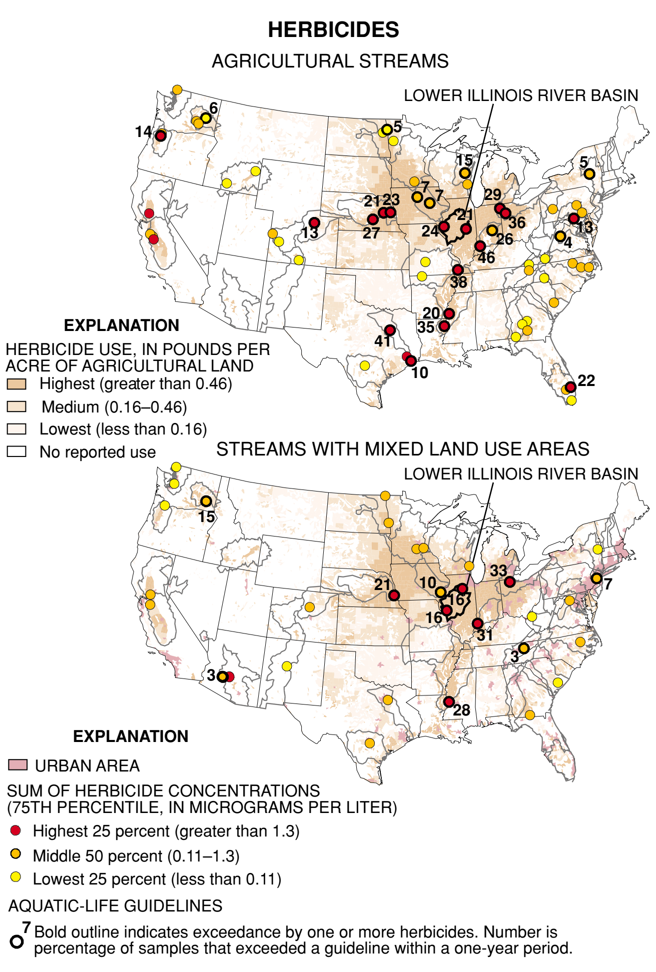
Compound detected in stream sediments	Number of sites with detections (21 sites sampled)	Minimum detected concentration (µg/kg)	Maximum detected concentration (µg/kg)	Canadian guidelines PEL (µg/kg)	Number of sites exceeding PEL
Dieldrin	7	1.4	5.5	6.7	0
Heptachlor epoxide	0	–	–	2.7	0
Chlordane, total	2	2.6	3.4	8.9	0
DDD	5	1.1	4.1	8.5	0
DDE	5	1.0	2.6	6.8	0
DDT	0	–	–	4.8	0
PCBs, total	1	57	57	277	0

Chlordane was found in every tissue sample and in two bed-sediment samples. No concentrations exceeded applicable guidelines. Total chlordane, as defined for this report, is the sum of five individual components of technical chlordane [28]. Among NAWQA studies nationwide, the highest concentration of oxychlordane (a breakdown product of chlordane) in fish tissue was found in fish from the Sangamon River at Monticello.

DDT was once a widely used insecticide in agricultural and urban areas of the United States. Legal use of DDT ended in 1972. Adverse effects of DDT on fish and wildlife include growth impairment, reproductive failure, and inhibition of thyroid activity, and recent studies have shown DDT to be disruptive of reproductive cycles in animals [28].

Breakdown products of DDT were detected in every fish-tissue sample and in almost one-half the bed-sediment samples. The highest total DDT concentrations in the basin in fish tissue and sediment were in samples from Illinois River locations. Concentrations in fish tissue also were high at two Sangamon River locations (in Monticello and downstream from Springfield) compared to national NAWQA data. In bed sediment, excluding

Basin and national results were similar for pesticides



HERBICIDES

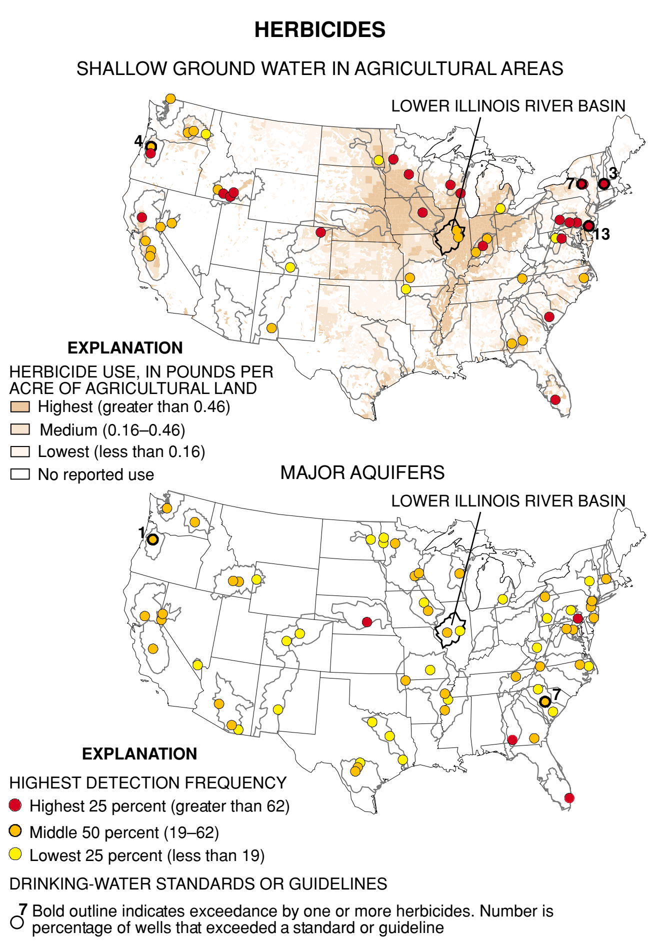
AGRICULTURAL STREAMS

STREAMS WITH MIXED LAND USE AREAS

National results from river and stream sampling reflect results found for pesticides in the lower Illinois River Basin [29]. Atrazine and metolachlor were the most frequently detected herbicides nationally and in the basin. Prometon and simazine were the next most frequently detected in the Nation, whereas cyanazine, prometon, and acetochlor were the next most frequently detected in the basin. Prometon has no listed agricultural use and is usually applied to roadways and rights-of-way.

The frequent detections of these herbicides in streams and rivers is due, at least in part, to their intensive application to crops and land areas. However, the major differences between the national results and the basin results were in that the frequencies of detections and levels of those detections were generally much higher in the basin than nationally (see Appendix). The Corn Belt, of which the basin is a part, has the highest rates of certain herbicide applications in the United States. Comparing only watersheds that are primarily agricultural, the results of the basin are similar to those from the rest of the Nation in frequency of detection.

For ground water, national and lower Illinois River Basin pesticide-sampling results also are similar. Nationally, detections of pesticides are less frequent and the concentrations are lower in wells than in streams. However, the detections of pesticides in ground water in the basin are even less frequent than in well samples for other agricultural areas in the United States. Most of the lower Illinois River Basin is underlain by glacially derived material that is poorly drained. Subsurface drainage diverts water to streams rather than allowing it to move downward (p. 12). The fine-grained, glacially derived material is conducive to rapid breakdown of many of the pesticides. These factors help prevent pesticides from reaching wells, thereby keeping the concentrations lower than those found in ground water in other parts of the Nation.



HERBICIDES

SHALLOW GROUND WATER IN AGRICULTURAL AREAS

MAJOR AQUIFERS

Illinois River locations, DDT breakdown products were detected only in a small stream in Decatur.

Other organochlorine compounds are persistent in sediments and fish

Polychlorinated biphenyls (PCBs) are a mixture of organochlorine compounds used in industrial processes. Even though production and use of PCBs was banned in the United States in 1979, PCBs commonly are found in fish and sediments because large amounts were produced, they degrade slowly, and they are transported in the atmosphere [28]. PCBs were detected in 75 percent of the fish-tissue samples in the basin, and these detections were geographically widespread. All detections in the basin exceeded the water-quality guidelines for the protection of fish-eating wildlife developed by the New York State Department of Environmental Conservation [27]. The highest PCB concentrations in fish tissue were in samples from Illinois River locations, with concentrations decreasing with increasing downstream distance from Chicago. PCBs were detected at only one location in the bed sediment.

In sufficiently high concentrations, most organochlorine compounds can be toxic to fish and other animals. These compounds bioaccumulate in animal tissue and may result in tumors, hormonal and behavioral problems, immune- and respiratory-system suppression, and abnormal development. Available evidence indicates that concentrations of these compounds have decreased over time and may be leveling off nationally [30, 28].

Common stream animals indicate poor water-quality conditions

Degradation of streams and habitat is caused by more than just chemical contamination. Biological community measures are used to assess water quality because the living components of stream ecosystems reflect the physical, chemical, and biological attributes of a stream. Measures of the algal, benthic-macroinvertebrate (fig. 23), and fish communities in streams each respond to different aspects of water quality over differing time periods and geographic areas.

Table 2. Selected biological indicators of water quality—comparison of lower Illinois River Basin sites to national network sites[1]

🟦 Lowest 25 percent nationally (least degraded locations)
⬜ Middle 50 percent nationally
🟧 Highest 25 percent nationally (most degraded locations)

Location sampled	Fish status	Invertebrate status	Algal status
Panther Creek near El Paso	🟦	⬜	⬜
Indian Creek near Wyoming	🟧	⬜	🟧
Sangamon River at Monticello	🟧	⬜	⬜
La Moine River at Colmar	🟧	⬜	🟧
Mackinaw River near Green Valley	⬜	⬜	⬜
Sangamon River near Oakford	🟧	🟧	🟧
Illinois River at Valley City	🟦	⬜	🟧

[1] Represents 140 sites in the NAWQA national network that have algal, invertebrate, and fish data.

Algal, benthic macroinvertebrate, and fish indices (table 2) were used to assess water quality as part of the NAWQA Program [32]. The higher the index, the more degraded the stream conditions. (See Appendix.) The algal status index reflects the relative abundance of benthic algal species that are considered tolerant of poor water-quality conditions, including high nutrient concentrations. In some regions, this index correlates with transport and deposition of silt.

Figure 23. Freshwater mussels are relatively long-lived animals that are indicators of long-term water quality. These mussels were from the North Fork Vermilion River in central Illinois. Mussels bury themselves in the bottom where they filter organic matter from the water. During the twentieth century, freshwater mussel populations declined drastically in the lower Illinois River Basin. (Photograph by David J. Fazio, USGS.)

Eleven community characteristics were used in the invertebrate community status index to assess water quality. The fish status indicator is the sum of scores of four fish-population characteristics (percent tolerant species, percent omnivorous fish, percent nonnative fish, and individuals with external anomalies) that increase in concert with water-quality degradation (fig. 24).

In relation to the rest of the Nation, the invertebrate status index in the lower Illinois River Basin was intermediate at all sites except one (table 2). Macroinvertebrate communities of streams in

Figure 24. Longnose gar from the Sangamon River in central Illinois. In the basin, the Longnose gar is the most common gar found in small rivers. Many fish were collected, measured, and released to determine the health of the fish communities in the streams and rivers sampled. (Photograph by David J. Fazio, USGS.)

Figure 25. Basin streams with fast current had the most diverse macroinvertebrate communities. (Photograph by David J. Fazio, USGS.)

the basin are dominated by many species that are widely distributed, most of which are tolerant of the effects of excess nutrients. Excessive quantities of nutrients in runoff to streams can be harmful to intolerant species by stimulating algal growth that may decrease dissolved-oxygen concentrations at night. The highest proportions of sensitive macroinvertebrate species were in streams with comparatively swift currents because increased water velocity can increase rates of stream aeration and thus maintain higher dissolved-oxygen concentrations (fig. 25).

Algae index values were either high or intermediate in relation to the entire Nation. The algal status index indicates that general algal conditions (as an indicator of water quality) in the Corn Belt are poor relative to the rest of the country. (See pages 9–10.)

One of the lowest fish-index scores in the country (indicating a healthy fish community) was at Panther Creek near El Paso. This small, shaded stream held a variety of habitats and a diverse fish population. All the biological index scores were high (degraded community) for the Sangamon River near Oakford. Little habitat diversity was found at this site, and concentrations of nutrients were high.

Highest concentrations of polycyclic aromatic hydrocarbons were in bed sediment near urban areas

Polycyclic aromatic hydrocarbons (PAHs) were detected in concentrations at or above a common reporting level of 50 µg/kg in as much as 50 percent of the bed-sediment samples (fig. 26). PAHs are byproducts of combustion; sources include fires, manufacturing, power generation, and vehicle emissions. With sufficient exposure, many PAHs are carcinogenic, causing tumors in fish and other animals, and many PAHs are toxic to some organisms [33]. In the basin, the highest PAH concentrations were in the bed sediment of the Illinois River at locations upstream from Peoria. The highest PAH concentrations at other sites in the basin were near urban areas: specifically, in

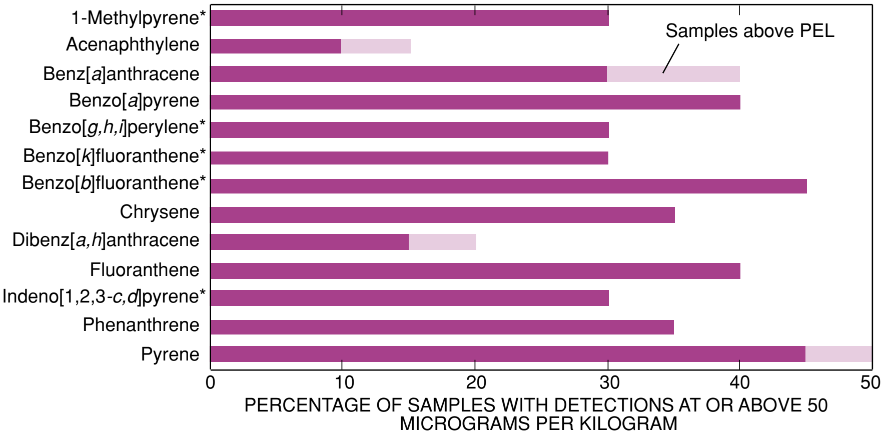
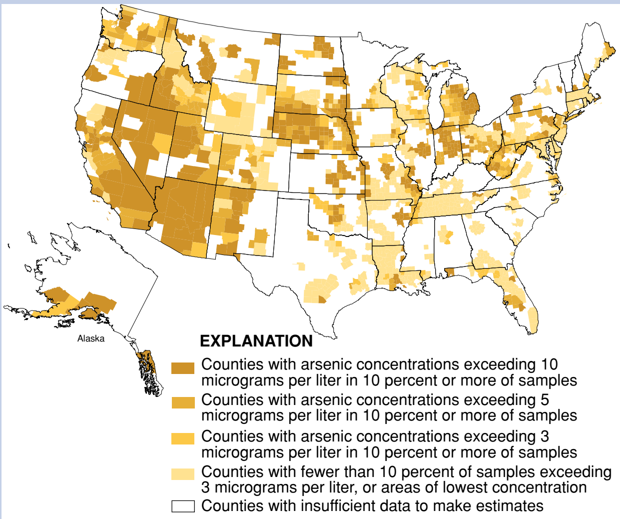


Figure 26. Four polycyclic aromatic hydrocarbons (PAHs) were detected at concentrations that may be detrimental to wildlife that live in bed sediments. Many PAHs are prevalent in sediments of the basin. Shown are percent detections at or above 50 micrograms per kilogram in bed-sediment samples and percent detections that exceed Canadian guidelines for protection of aquatic life [26]. [*, no guideline available; PEL, Probable Effect Level]

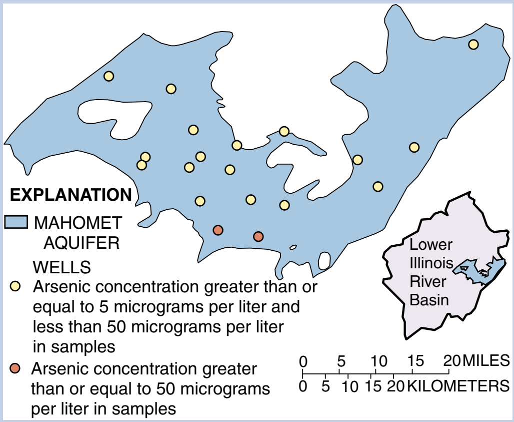
Arsenic in ground water is a national concern



Arsenic is a naturally occurring trace element in natural waters. With sufficient exposure, arsenic can cause skin, lung, bladder, liver, and kidney cancer in humans [34, 2]. It also has been reported to impair development and hearing; to adversely affect the vascular, gastrointestinal, and nervous systems; and to be associated with diabetes. The current (2000) arsenic MCL applies to the sum of all arsenic forms in finished drinking water. The USEPA has proposed a new MCL of 5 µg/L.

Areas in the Western United States and upper Midwest have relatively high arsenic concentrations in ground water. In Illinois, the dark areas on the map generally indicate the counties overlying the Mahomet aquifer, where water from about 7 percent of wells sampled (2 of 30) exceeded the current MCL (50 µg/L) and 60 percent would exceed the lower MCL. Only few a concentrations of arsenic above 5 µg/L and none above 50 µg/L in shallow wells (less than 100 feet deep) were found at wells in the western and southern shallow aquifers and other areas in the lower Illinois River Basin.

Nationally, water from 1 percent of wells sampled exceeded the current MCL [35], and only 13 percent would exceed the proposed new standard. In Illinois, if they do not treat the water for arsenic, people who draw water from the Mahomet aquifer have greater risk of drinking arsenic in water than ground-water users in the rest of the United States.



a small stream in the city of Decatur, in the Vermilion River near its confluence with the Illinois River (downstream from Streator and Pontiac), and in the Sangamon River downstream from Springfield. Four detections of PAH compounds exceeded the Canadian interim freshwater sediment-quality guidelines for the protection of aquatic life [26].

Arsenic exceeded the drinking-water standard in the Mahomet aquifer

The Mahomet aquifer is overlain by more than 100 feet of clay-rich glacial material. Contamination of this aquifer by human activities is minimal [31]. Although arsenic resulting from human activities can contaminate water, high concentrations of arsenic in the Mahomet aquifer are from natural sources. Arsenic concentrations in parts of the Mahomet aquifer exceeded the USEPA current MCL of 50 µg/L. In 1999, the National Academy of Science [34] concluded that this current standard does not sufficiently protect public health. The USEPA has proposed lowering the MCL to 5 µg/L. If the arsenic MCL were lowered to 5 µg/L, then water from more than 60 percent of the wells sampled (18 of 30) would exceed the new level.

Within the lower Illinois River Basin, the percentage of private-well samples with concentrations of arsenic above 50 µg/L was approximately the same as that of samples from public-supply wells. Statewide data from the Illinois Environmental Protection Agency [31], however, indicate the percentage of concentrations above 5 µg/L was different between the public wells and private wells statewide.

ILLINOIS RIVER: A history of degradation and recovery

In Illinois, 7 percent of the fish species have disappeared since about 1900, and many more species are in decline [36]. Smith [37] listed eight conditions responsible for the loss of many fish populations in Illinois streams. Some of these conditions can be found in the basin: siltation; drainage of natural lakes, swamps, and prairie marshes; desiccation during drought; species interactions, including competition from non-native fish; industrial, domestic, and agricultural pollution other than siltation; dams and reservoirs; and increased water temperature.

One of the most notable effects of human activity on stream life occurred between 1900 and 1920 in the Illinois River downstream from Chicago, after the Chicago Sanitary and Shipping Canal opened. The biological repercussions of industrial and domestic wastes being diverted to the Illinois River peaked in about 1920, when plants, benthic organisms, and fish practically were eliminated from the Illinois River downstream from Chicago to a point downstream from Peoria [38]. Since the 1920s, water quality in this reach of the Illinois River has gradually improved because of the improved wastewater-treatment practices upstream. Monitoring by the Illinois Natural History Survey (INHS) has documented partial recovery of fish communities. Between 1957 and 1992, common carp and goldfish dominated fish communities in the main stem of the upper Illinois River. **By 1993, however, native species had returned to the main stem, and the relative abundance of common carp and goldfish had declined significantly** [39]. In contrast, fish life in the bottomland lakes along the lower Illinois River has not increased to the degree anticipated from improvement in dissolved-oxygen conditions [40, 41].

Compared to urban areas upstream from the basin, streams in predominantly agricultural areas generally have higher biotic integrity and more diverse fish communities that commonly include various intolerant fish species [42, 43, and 37].

The Illinois River historically was an important wildlife resource. It is gradually recovering that status.

Radon exceeded the proposed drinking-water standard in almost one-half of shallow wells

The bedrock underlying the glacial materials in the lower Illinois River Basin and especially the glacial material itself contain a high concentration of the source elements that decay into radon. As a result, the potential for high concentrations of radon in ground water and soil gas in the basin is greater than the national average (W.S. Morrow, Jr., U.S. Geological Survey, written commun., 2000).

Radon was detected in all 30 water samples from the Mahomet aquifer (fig. 27). Concentrations of radon ranged from 110 to 730 picocuries per liter (pCi/L), and the mean concentration was 190 pCi/L.

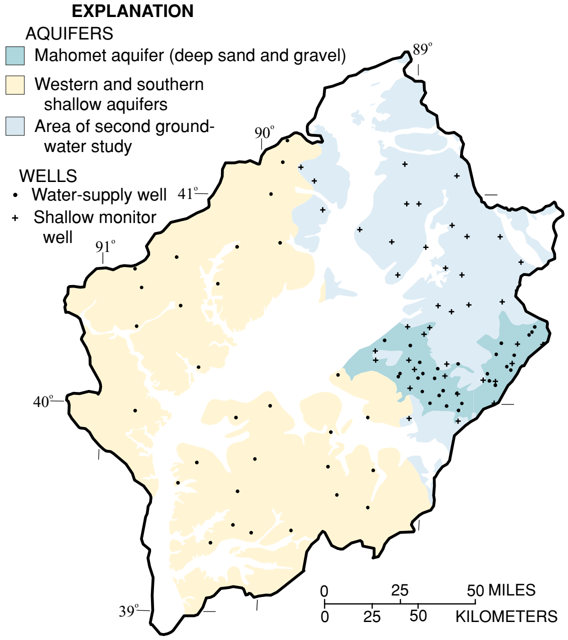


Figure 27. Ground-water studies encompassed most of the area of the lower Illinois River Basin. Two studies of water-supply wells and two studies of shallow, recently recharged ground water were completed. The first set of shallow monitor wells was drilled in the material overlying the Mahomet aquifer.

The samples from the Mahomet aquifer, however, had the lowest average radon concentrations of the four groups of study wells. (See pages 25–26.) Concentrations in 7 percent of Mahomet aquifer samples (2 of 30) exceeded the proposed USEPA radon MCL of 300 pCi/L. No sample concentrations exceeded the USEPA-proposed Alternative Maximum Contaminant Level (AMCL) for radon of 4,000 pCi/L. The MCL is proposed for drinking water where there is no other indoor-air radon-mitigation strategy. The AMCL is proposed for drinking water where a multimedia indoor-air mitigation strategy is used to reduce radon exposure.

Radon concentration was higher in samples from the 57 shallow monitoring wells and the 30 water-supply wells in the western and southern shallow aquifers than in the Mahomet aquifer. In the samples from the western and southern shallow aquifers, 55 percent (16 of 29) exceeded the proposed MCL, but none exceeded the proposed higher AMCL. Radon was highest in the samples from shallow monitoring wells in the glacial materials overlying the Mahomet aquifer (fig. 27). In the shallow monitoring wells, 38 percent (22 of 57) of the samples exceeded the radon MCL, although no sample exceeded the AMCL.

Volatile organic compounds were detected in ground water at low concentrations

Samples were collected from 60 private and public water-supply wells in the basin to determine the extent of contamination by volatile organic compounds (VOCs); 30 of the wells were in the Mahomet aquifer and the other 30 were in the western and southern shallow aquifers. Detections were similar in samples from wells in the western and southern shallow aquifers (83 percent) and in the Mahomet aquifer (80 percent). One sample from a well in the area of western and southern shallow aquifers contained 0.57 µg/L of methyl *tert*-butyl ether (MTBE)—well below the HAL for MTBE of 20 µg/L. The concentration of VOCs in almost all of the samples was at or near the method detection limit and was usually 10 to 100 times lower than applicable standards or guidelines for drinking water. The source of these VOCs—especially those in the Mahomet aquifer, which is largely protected from atmospheric or land-use contamination—is uncertain.

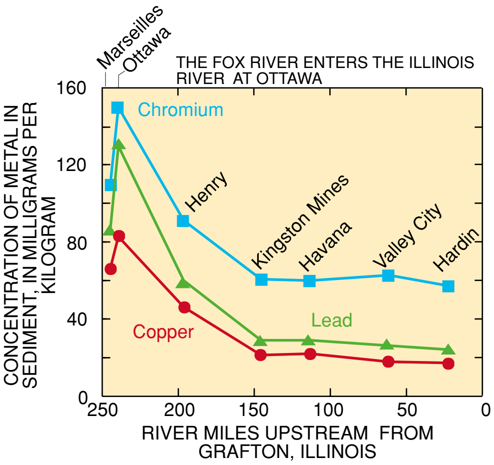


Figure 28. Concentrations of three metals in bed sediments decreased in the Illinois River from Ottawa, Ill., to Kingston Mines, Ill. The concentrations of metals were highest near the confluence of the Fox River and the Illinois River at Ottawa.

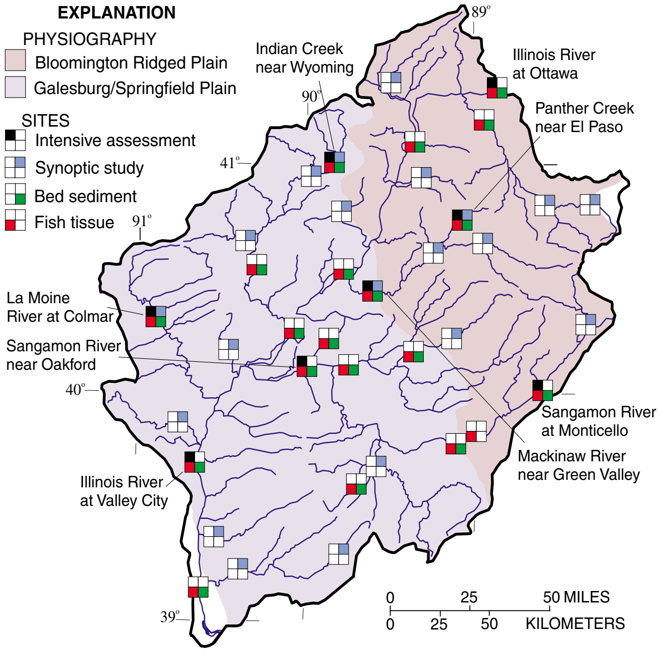
Fish and sediment in the Illinois River have high concentrations of trace elements

The Canadian interim freshwater sediment-quality guidelines for the protection of aquatic life [26] were exceeded at four locations for various trace elements. Three of these locations were on the Illinois River close to Chicago. In the Illinois River, bed-sediment concentrations of seven metals (chromium, copper, lead, mercury, nickel, selenium, and zinc) were highest near Ottawa and decreased downstream [44] (fig. 28).

In many samples of fish tissue collected in the lower Illinois River Basin, cadmium concentrations were high compared to those in all samples analyzed in the rest of the Nation. (See Appendix.) Concentrations of trace elements were examined in carp liver collected at 17 locations in the basin. The highest cadmium concentration in carp liver from across the Nation (52 milligrams per kilogram dry weight) was detected in the Vermilion River near its confluence with the Illinois River. Concentrations of cadmium in 10 carp-liver samples from the basin were in the upper one-third of the concentrations in all carp-liver samples collected in the Nation. Of those 10 samples, 6 were collected from the Illinois River main stem. Fitzpatrick and others [45] found cadmium at higher than background concentrations in sediment or biota at urban and agricultural locations in the upper Illinois River Basin. Long-term chronic exposure to cadmium can cause kidney and bone damage in humans. Mining and activities related to mining are the main sources of cadmium in the environment from human activities, but other sources include waste incineration, sewage sludge, fertilizers, batteries, tires, and many industrial processes [23].

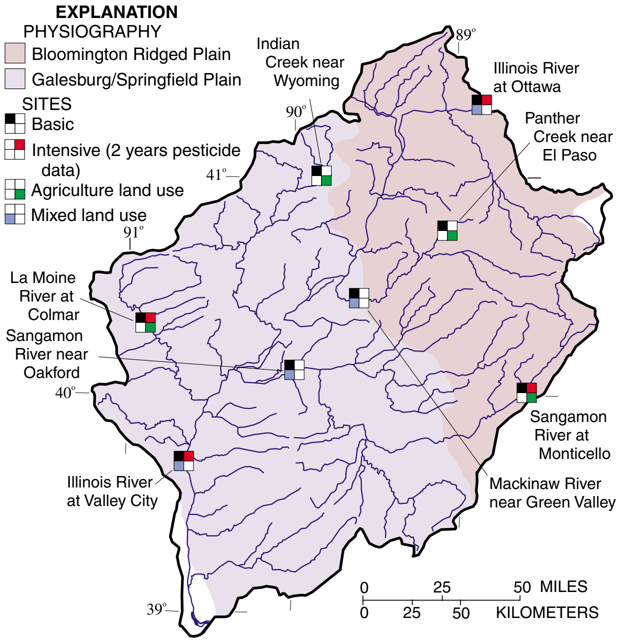
Stream chemistry

The main objective of the stream-chemistry component of the study was to assess the relation between agricultural land use and basin size and chemical constituents of surface water. Stream and river sampling locations were distributed among subbasins and on the Illinois River. Sampling locations included Basic and Intensive Fixed Sites—sampled at regular intervals for a period of 2 to 3 years—and Synoptic Sites that were sampled during a 2-week period in August 1997.



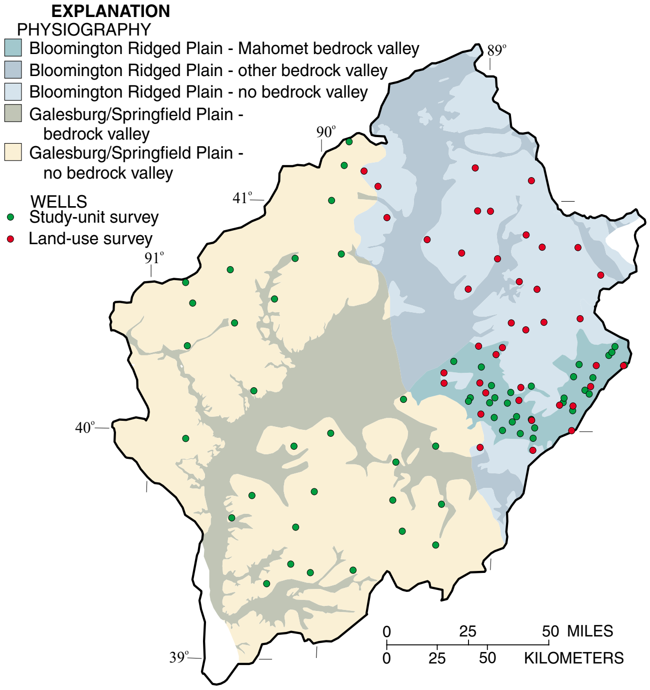
Ground-water chemistry

One objective of the ground-water chemistry component of the study was to determine whether chemical constituents of ground water were related to agricultural land uses (land-use surveys). Another objective in two surveys of domestic (household) and public-supply (municipal) wells (Study-Unit surveys) was to assess the overall water quality in selected drinking-water-source aquifers (Mahomet aquifer and the western and southern shallow aquifers) and to determine whether they are affected by land-use practices. The full extent of the Mahomet aquifer (in the Mahomet bedrock valley) is not shown. Results for the Mahomet aquifer are representative only for that part shown.



Stream ecology

The main objective of the ecology component of the study was to assess surface-water quality by integrating the physical, chemical, and biological factors. Ecology Sites were distributed at the basic fixed sites and at smaller subbasins that are all predominantly agricultural land. Sites were classified as either intensive or synoptic on the basis of the level and schedule of sampling effort.



Summary of data collection in the lower Illinois River Basin, 1995–98

Study component	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
Stream Chemistry				
Basic Sites—general water quality	Concentrations, seasonal variation, and annual loads. Data included streamflow, nutrients, major ions, organic carbon, suspended sediment, water temperature, specific conductance, alkalinity, pH, and dissolved oxygen.	Basic Fixed Sites: representative of common land uses, as well as major tributary and basin outflow sites.	8	Monthly plus storms; 2 years
Intensive Sites—pesticides	Concentrations and seasonal variations in pesticides and breakdown products. Data included 75 pesticides and 13 breakdown products of the most heavily applied herbicides.	Subset of Basic Sites: Two watersheds with greater than 90 percent row-crop agriculture and the basin inflow and outflow sites.	4	Weekly to monthly Jan. 1996–June 1998
Synoptic Sites—water chemistry and pesticides	Spatial distribution of nutrients, pesticides, and pesticide breakdown products. Data included nutrients and 24 pesticides and pesticide breakdown products.	Basic Sites Additional sites	4 17	Once in August 1997 during minimum flow
Contaminants in bed sediments	Occurrence and distribution of contaminants in bed sediment. Data included total PCBs, 32 organochlorine pesticides, 63 semivolatile organic compounds, and 44 trace elements.	Depositional zones of Basic Fixed Sites and some additional sites.	21	Once; June–October in 1996–97
Contaminants in fish	Occurrence and distribution of contaminants in biota. Data included total PCBs, 30 organochlorine pesticides in whole fish, and trace elements in fish livers.	Most stream sites also sampled for bed sediments.	20	Once; June–October in 1996–97
Stream Ecology				
Intensive assessments	Relations among biological communities and water chemistry, physical habitat, and land use. Includes spatial relations, along with spatial variation. Data included algae, invertebrates, fish communities, and physical habitat.	Basic Fixed Sites	8	1 reach, 1 year (1996) 1 reach, 3 years (1996–98) 3 reaches, 1 year (1996 or 1997)
Synoptic studies	Better spatial assessment. Data collected were same as above.	Synoptic Sites	21	Once in August 1997
Ground-Water Chemistry				
Aquifer survey—domestic and public-supply wells	Occurrence and distribution of chemicals in domestic and public-supply wells. Data included major ions, nutrients, 75 pesticides,13 pesticide breakdown products, 73 volatile organic compounds, dissolved organic carbon, trace elements, and radon.	Domestic and public supply wells across the subunit aquifers	2 public-supply wells and 58 domestic or private wells	Once; May–November in 1996–97
Resample selected aquifer survey wells	Confirmation of low-level or questionable detections of pesticides, breakdown products, and age-dating chemicals.	A subset of the wells above	19	Once in 1998
Resample selected aquifer survey wells	Confirmation of high-level detections of arsenic and to determine the chemical nature of the dissolved arsenic. Data included major ions and selected dissolved metals in addition to two chemical forms of arsenic.	A subset of wells from the deep aquifer survey with arsenic that exceeded the drinking-water standard.	10	Once in 1997
Land-use effects—corn and soybean row crops	Describe the effects of agricultural land use on shallow ground water in the area underlain by most recent glacial geologic material. Data included major ions, nutrients, 75 pesticides, 13 pesticide breakdown products, dissolved organic carbon, trace elements, and radon.	Very shallow monitoring wells installed for this study.	57	Once in 1997

GLOSSARY

Algae—Chlorophyll-bearing nonvascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.

Aquifer—A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Bed sediment—The material that temporarily is stationary in the bottom of a stream or other watercourse.

Benthic—Refers to plants or animals that live on the bottom of lakes, streams, or oceans.

Breakdown product—A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process that may result in a more toxic or a less toxic compound and a more persistent or less persistent compound.

Concentration—The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as microgram per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

Cubic foot per second (ft^3/s, or cfs)—Rate of water discharge representing a volume of 1 cubic foot passing a given point during 1 second, equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meter per second.

Ground water—In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat—The part of the physical environment where plants and animals live.

Herbicide—A chemical or other agent applied for the purpose of killing undesirable plants. See also Pesticide.

Insecticide—A substance or mixture of substances intended to destroy or repel insects. See also Pesticide.

Intolerant species—Those species that are not adaptable to human alterations to the environment and thus decline in numbers where human alterations occur. See also Tolerant species.

Invertebrate—An animal having no backbone or spinal column.

Load—General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Mean—The average of a set of observations, unless otherwise specified.

Median—The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.

Method detection limit—The minimum concentration of a substance that can be accurately identified and measured with present laboratory technologies.

Micrograms per liter (µg/L)—A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most stream water and ground water. One thousand micrograms per liter equals 1 milligram per liter.

Milligrams per liter (mg/L)—A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most stream water and ground water. One thousand micrograms per liter equals 1 milligram per liter.

Nitrate—An ion consisting of nitrogen and oxygen (NO_3^-). Nitrate is a plant nutrient and is very mobile in soils.

Organochlorine compound—Synthetic organic compounds containing chlorine. As generally used, this term refers to compounds containing mostly or exclusively carbon, hydrogen, and chlorine. Examples include organochlorine insecticides, polychlorinated biphenyls, and some solvents containing chlorine.

Periphyton—Organisms that grow on underwater surfaces; periphyton include algae, bacteria, fungi, protozoa, and other organisms.

Pesticide—A chemical applied to crops, rights-of-way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other "pests."

Phosphorus—A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.

Phytoplankton—See Plankton.

Picocurie (pCi)—One trillionth (10^{-12}) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7×10^{10} radioactive disintegrations per second (dps). A picocurie yields 2.22 disintegrations per minute (dpm) or 0.037 dps.

Plankton—Floating or weakly swimming organisms at the mercy of the waves and currents. Animals of the group are called zooplankton, and the plants are called phytoplankton.

Point source—A source at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.

Relative abundance—The number of organisms of a particular kind present in a sample relative to the total number of organisms in the sample.

Riparian—Areas adjacent to rivers and streams often with a high density, diversity, and productivity of plant and animal species relative to nearby uplands.

Semivolatile organic compound (SVOC)—Operationally defined as a group of synthetic organic compounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and polycyclic aromatic hydrocarbons (PAHs).

Sorption—General term for the interaction (binding or association) of a solute ion or molecule with a solid.

Subsurface drain—A shallow drain installed in an irrigated field to intercept the rising ground-water level and maintain the water table at an acceptable depth below the land surface.

Tolerant species—Those species that are adaptable to (tolerant of) human alterations to the environment and often increase in number when human alterations occur.

Trace element—An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

Volatile organic compounds (VOCs)—Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

Yield—The mass of material or constituent transported by a river in a specified period of time divided by the drainage area of the river basin.

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APPENDIX—WATER-QUALITY DATA FROM THE LOWER ILLINOIS RIVER BASIN IN A NATIONAL CONTEXT

For a complete view of lower Illinois River Basin data and for additional information about specific benchmarks used, visit our Web site at http://water.usgs.gov/nawqa/. Also visit the NAWQA Data Warehouse for access to NAWQA data sets at http://water.usgs.gov/nawqa/data.

This appendix is a summary of chemical concentrations and biological indicators assessed in the lower Illinois River Basin. Selected results for this basin are graphically compared to results from as many as 36 NAWQA Study Units investigated from 1991 to 1998 and to national water-quality benchmarks for human health, aquatic life, or fish-eating wildlife. The chemical and biological indicators shown were selected on the basis of frequent detection, detection at concentrations above a national benchmark, or regulatory or scientific importance. The graphs illustrate how conditions associated with each land use sampled in the lower Illinois River Basin compare to results from across the Nation, and how conditions compare among the several land uses. Graphs for chemicals show only detected concentrations and, thus, care must be taken to evaluate detection frequencies in addition to concentrations when comparing study-unit and national results. For example, acetochlor concentrations in lower Illinois River Basin agricultural streams were similar to the national distribution, but the detection frequency was much higher (83 percent compared to 33 percent).

CHEMICALS IN WATER

Concentrations and detection frequencies, lower Illinois River Basin, 1995–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals

◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

- - Not measured or sample size less than two

12 Study-unit sample size. For ground water, the number of samples is equal to the number of wells sampled

National ranges of detected concentrations, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

Streams in agricultural areas
Streams in urban areas
Streams and rivers draining mixed land uses
Shallow ground water in agricultural areas
Shallow ground water in urban areas
Major aquifers

Lowest 25 percent
Middle 50 percent
Highest 25 percent

National water-quality benchmarks

National benchmarks include standards and guidelines related to drinking-water quality, criteria for protecting the health of aquatic life, and a goal for preventing stream eutrophication due to phosphorus. Sources include the U.S. Environmental Protection Agency and the Canadian Council of Ministers of the Environment

| Drinking-water quality (applies to ground water and surface water)

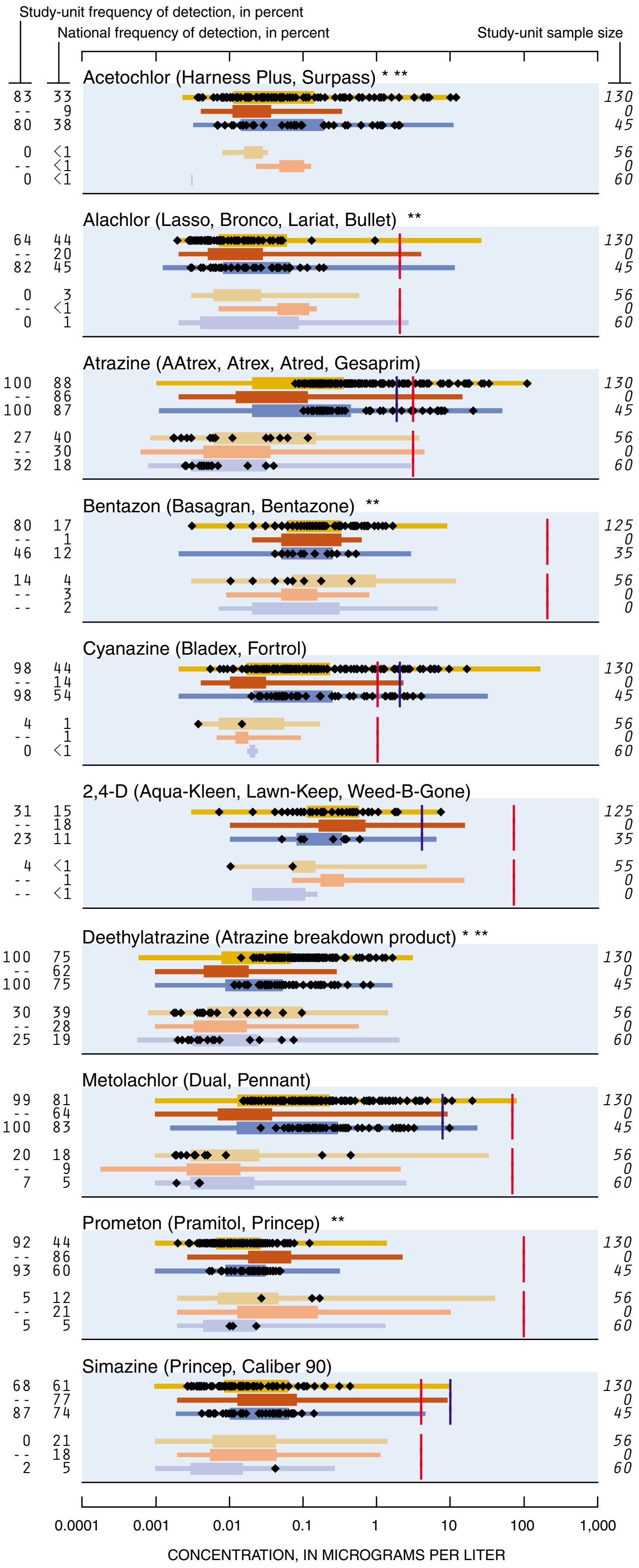
| Protection of aquatic life (applies to surface water only)

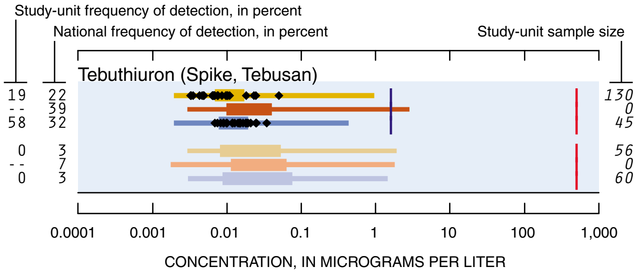
| Prevention of eutrophication in streams not flowing directly into lakes or impoundments

* No benchmark for drinking-water quality

** No benchmark for protection of aquatic life

Pesticides in water—Herbicides

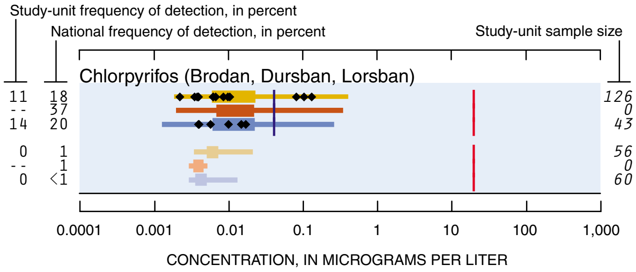


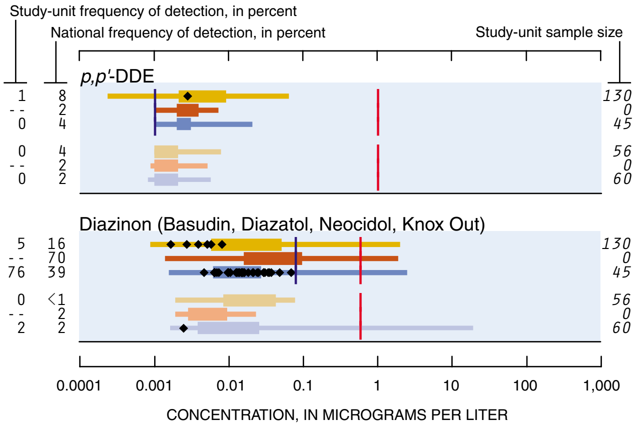


Other herbicides detected
Acifluorfen (Blazer, Tackle 2S) **
Benfluralin (Balan, Benefin, Bonalan) * **
Bromoxynil (Buctril, Brominal) *
Butylate (Sutan +, Genate Plus, Butilate) **
DCPA (Dacthal, chlorthal-dimethyl) * **
Dacthal mono-acid (Dacthal breakdown product) * **
Dicamba (Banvel, Dianat, Scotts Proturf)
2,6-Diethylaniline (Alachlor breakdown product) * **
Diuron (Crisuron, Karmex, Diurex) **
EPTC (Eptam, Farmarox, Alirox) * **
Linuron (Lorox, Linex, Sarclex, Linurex, Afalon) *
MCPA (Rhomene, Rhonox, Chiptox)
Metribuzin (Lexone, Sencor)
Molinate (Ordram) * **
Pendimethalin (Pre-M, Prowl, Stomp) * **
Propachlor (Ramrod, Satecid) **
Terbacil (Sinbar) **
Triallate (Far-Go, Avadex BW, Tri-allate) *
Triclopyr (Garlon, Grandstand, Redeem, Remedy) * **
Trifluralin (Treflan, Gowan, Tri-4, Trific)

Herbicides not detected
Bromacil (Hyvar X, Urox B, Bromax)
Chloramben (Amiben, Amilon-WP, Vegiben) **
Clopyralid (Stinger, Lontrel, Transline) * **
2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone) * **
Dichlorprop (2,4-DP, Seritox 50, Lentemul) * **
Dinoseb (Dinosebe)
Ethalfluralin (Sonalan, Curbit) * **
Fenuron (Fenulon, Fenidim) * **
Fluometuron (Flo-Met, Cotoran) **
MCPB (Thistrol) * **
Napropamide (Devrinol) * **
Neburon (Neburea, Neburyl, Noruben) * **
Norflurazon (Evital, Predict, Solicam, Zorial) * **
Oryzalin (Surflan, Dirimal) * **
Pebulate (Tillam, PEBC) * **
Picloram (Grazon, Tordon)
Pronamide (Kerb, Propyzamid) **
Propanil (Stam, Stampede, Wham) * **
Propham (Tuberite) **
2,4,5-T **
2,4,5-TP (Silvex, Fenoprop) **
Thiobencarb (Bolero, Saturn, Benthiocarb) * **

Pesticides in water—Insecticides



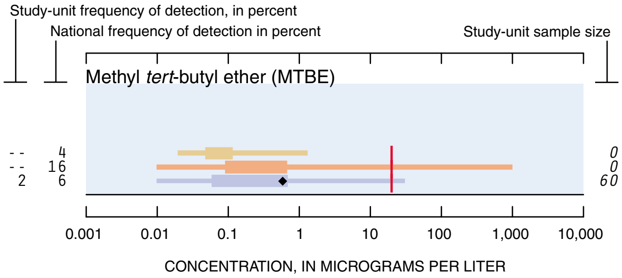


Other insecticides detected
Carbaryl (Carbamine, Denapon, Sevin)
Carbofuran (Furadan, Curaterr, Yaltox)
Dieldrin (Panoram D-31, Octalox, Compound 497)
Fonofos (Dyfonate, Capfos, Cudgel, Tycap) **
Malathion (Malathion)
Methyl parathion (Penncap-M, Folidol-M) **
Oxamyl (Vydate L, Pratt) **
Propargite (Comite, Omite, Ornamite) * **
Terbufos (Contraven, Counter, Pilarfox) **

Insecticides not detected
Aldicarb (Temik, Ambush, Pounce)
Aldicarb sulfone (Standak, aldoxycarb)
Aldicarb sulfoxide (Aldicarb breakdown product)
Azinphos-methyl (Guthion, Gusathion M) *
Disulfoton (Disyston, Di-Syston) **
Ethoprop (Mocap, Ethoprophos) * **
alpha-HCH (alpha-BHC, alpha-lindane) **
gamma-HCH (Lindane, gamma-BHC)
3-Hydroxycarbofuran (Carbofuran breakdown product) * **
Methiocarb (Slug-Geta, Grandslam, Mesurol) * **
Methomyl (Lanox, Lannate, Acinate) **
Parathion (Roethyl-P, Alkron, Panthion, Phoskil) *
cis-Permethrin (Ambush, Astro, Pounce) * **
Phorate (Thimet, Granutox, Geomet, Rampart) * **
Propoxur (Baygon, Blattanex, Unden, Proprotox) * **

Volatile organic compounds (VOCs) in ground water

These graphs represent data from 16 Study Units, sampled from 1996 to 1998

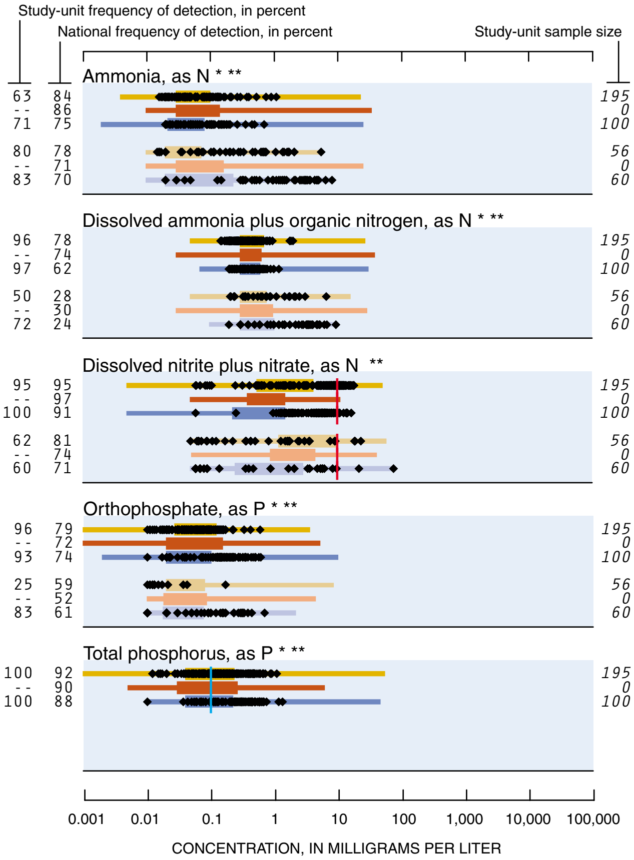


Other VOCs detected
Bromodichloromethane (Dichlorobromomethane)
2-Butanone (Methyl ethyl ketone (MEK)) *
Carbon disulfide *
Chlorobenzene (Monochlorobenzene)
Chlorodibromomethane (Dibromochloromethane)
Chloroethane (Ethyl chloride) *
Chloromethane (Methyl chloride)
Dichlorodifluoromethane (CFC 12, Freon 12)
Dichloromethane (Methylene chloride)

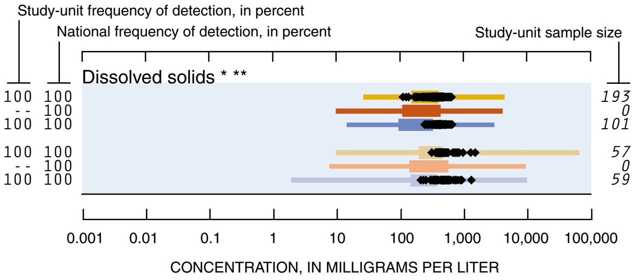
1,3 & 1,4-Dimethylbenzene (*m*-&*p*-Xylene)
1-4-Epoxy butane (Tetrahydrofuran, Diethylene oxide) *
1-Ethyl-2-methylbenzene (2-Ethyltoluene) *
Hexachlorobutadiene
Iodomethane (Methyl iodide) *
4-Methyl-2-pentanone (Methyl isobutyl ketone (MIBK)) *
Methylbenzene (Toluene)
2-Propanone (Acetone) *
Tetrachloroethene (Perchloroethene)
Tetrachloromethane (Carbon tetrachloride)
1,2,3,4-Tetramethylbenzene (Prehnitene) *
1,2,3,5-Tetramethylbenzene (Isodurene) *
Tribromomethane (Bromoform)
1,2,3-Trichlorobenzene *
1,1,1-Trichloroethane (Methylchloroform)
Trichloromethane (Chloroform)
1,2,3-Trimethylbenzene (Hemimellitene) *
1,2,4-Trimethylbenzene (Pseudocumene) *

VOCs not detected
tert-Amylmethylether (*tert*-amyl methyl ether (TAME)) *
Benzene
Bromobenzene (Phenyl bromide) *
Bromochloromethane (Methylene chlorobromide)
Bromoethene (Vinyl bromide) *
Bromomethane (Methyl bromide)
n-Butylbenzene (1-Phenylbutane) *
sec-Butylbenzene *
tert-Butylbenzene *
3-Chloro-1-propene (3-Chloropropene) *
1-Chloro-2-methylbenzene (*o*-Chlorotoluene)
1-Chloro-4-methylbenzene (*p*-Chlorotoluene)
Chloroethene (Vinyl chloride)
1,2-Dibromo-3-chloropropane (DBCP, Nemagon)
1,2-Dibromoethane (Ethylene dibromide, EDB)
Dibromomethane (Methylene dibromide) *
trans-1,4-Dichloro-2-butene ((Z)-1,4-Dichloro-2-butene) *
1,2-Dichlorobenzene (*o*-Dichlorobenzene)
1,3-Dichlorobenzene (*m*-Dichlorobenzene)
1,4-Dichlorobenzene (*p*-Dichlorobenzene)
1,2-Dichloroethane (Ethylene dichloride)
1,1-Dichloroethane (Ethylidene dichloride) *
1,1-Dichloroethene (Vinylidene chloride)
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)
cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)
1,2-Dichloropropane (Propylene dichloride)
2,2-Dichloropropane *
1,3-Dichloropropane (Trimethylene dichloride) *
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)
cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)
1,1-Dichloropropene *
Diethyl ether (Ethyl ether) *
Diisopropyl ether (Diisopropylether (DIPE)) *
1,2-Dimethylbenzene (*o*-Xylene)
Ethenylbenzene (Styrene)
Ethyl methacrylate *
Ethyl *tert*-butyl ether (Ethyl-*t*-butyl ether (ETBE)) *
Ethylbenzene (Phenylethane)
1,1,1,2,2,2-Hexachloroethane (Hexachloroethane)
2-Hexanone (Methyl butyl ketone (MBK)) *
Isopropylbenzene (Cumene) *
p-Isopropyltoluene (*p*-Cymene) *
Methyl acrylonitrile *
Methyl-2-methacrylate (Methyl methacrylate) *
Methyl-2-propenoate (Methyl acrylate) *
Naphthalene
2-Propenenitrile (Acrylonitrile)
n-Propylbenzene (Isocumene) *
1,1,2,2-Tetrachloroethane *
1,1,1,2-Tetrachloroethane
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113) *
1,2,4-Trichlorobenzene
1,1,2-Trichloroethane (Vinyl trichloride)
Trichloroethene (TCE)
Trichlorofluoromethane (CFC 11, Freon 11)
1,2,3-Trichloropropane (Allyl trichloride)
1,3,5-Trimethylbenzene (Mesitylene) *

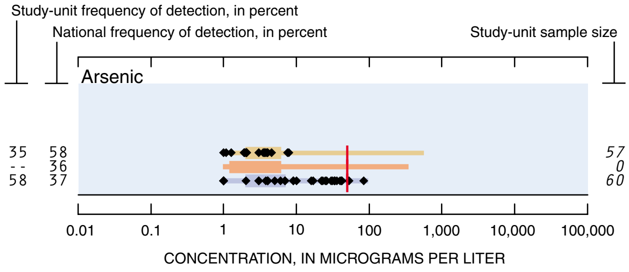
Nutrients in water

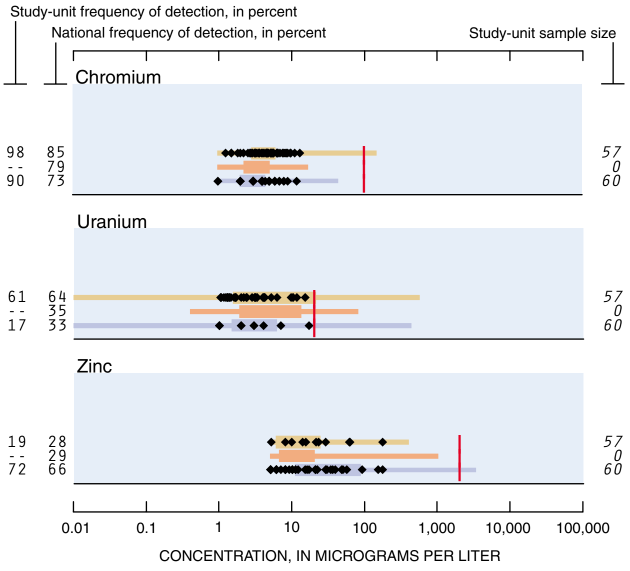


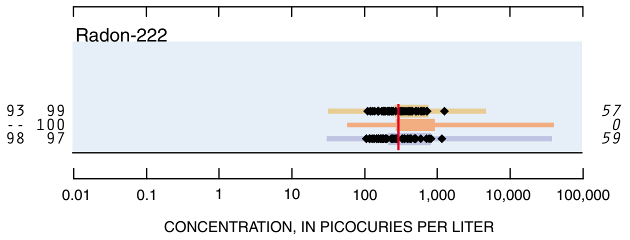
Dissolved solids in water



Trace elements in ground water







Other trace elements detected
Lead
Selenium

Trace elements not detected
Cadmium

CHEMICALS IN FISH TISSUE AND BED SEDIMENT

Concentrations and detection frequencies, lower Illinois River Basin, 1995–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals. Study-unit frequencies of detection are based on small sample sizes; the applicable sample size is specified in each graph

◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size

National range of concentrations detected, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

Fish tissue from streams in agricultural areas
Fish tissue from streams in urban areas
Fish tissue from streams draining mixed land uses

Sediment from streams in agricultural areas
Sediment from streams in urban areas
Sediment from streams draining mixed land uses

Lowest 25 percent | Middle 50 percent | Highest 25 percent

National benchmarks for fish tissue and bed sediment

National benchmarks include standards and guidelines related to criteria for protection of the health of fish-eating wildlife and aquatic organisms. Sources include the U.S. Environmental Protection Agency, other Federal and State agencies, and the Canadian Council of Ministers of the Environment

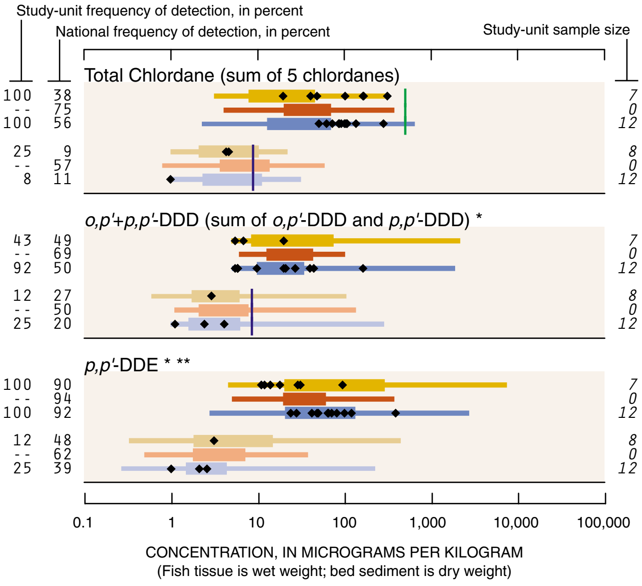
| Protection of fish-eating wildlife (applies to fish tissue)

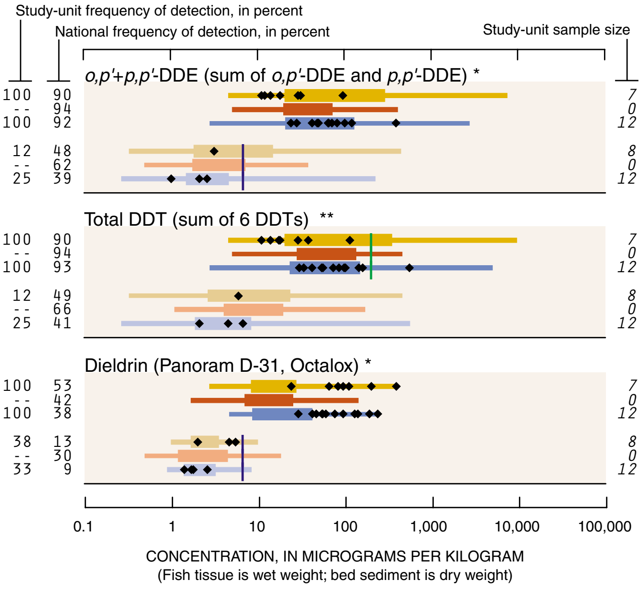
| Protection of aquatic life (applies to bed sediment)

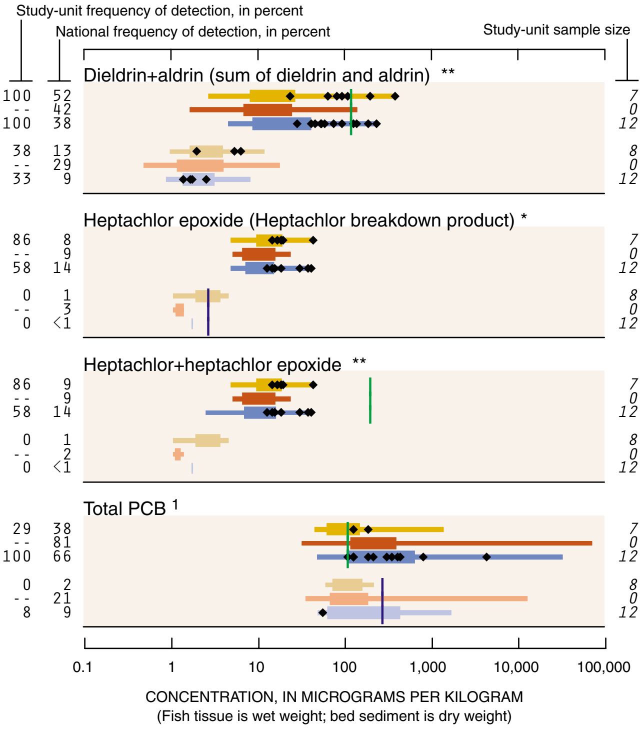
* No benchmark for protection of fish-eating wildlife

** No benchmark for protection of aquatic life

Organochlorines in fish tissue (whole body) and bed sediment





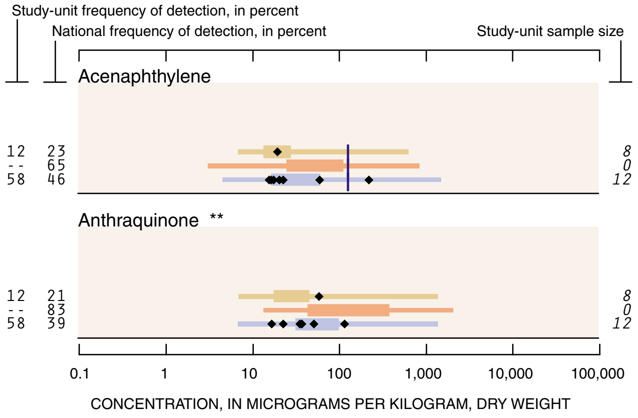


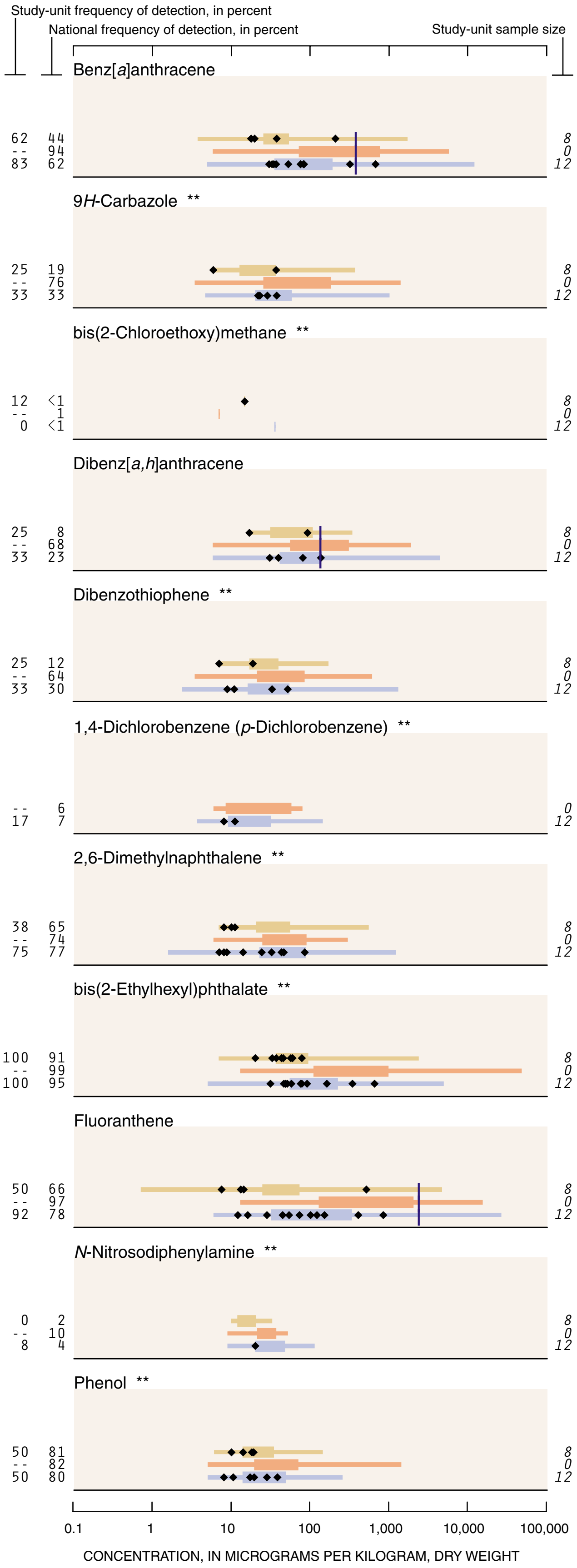
[1] The national detection frequencies for total PCB in sediment are biased low because about 30 percent of samples nationally had elevated detection levels compared to this Study Unit. See http://water.usgs.gov/nawqa/ for additional information.

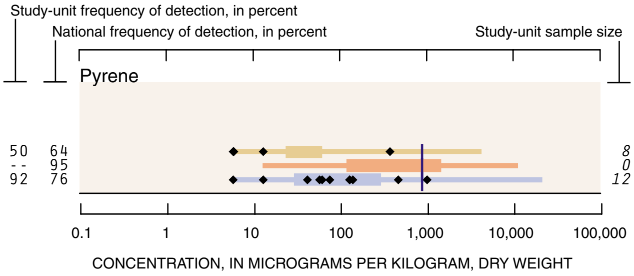
Other organochlorines detected
DCPA (Dacthal, chlorthal-dimethyl) * **
Hexachlorobenzene (HCB) **
Pentachloroanisole (PCA) * **

Organochlorines not detected
Chloroneb (Chloronebe, Demosan) * **
o,p'+*p,p'*-DDT (sum of *o,p'*-DDT and *p,p'*-DDT) *
Endosulfan I (alpha-Endosulfan, Thiodan) * **
Endrin (Endrine)
gamma-HCH (Lindane, gamma-BHC, Gammexane) *
Total-HCH (sum of alpha-HCH, beta-HCH, gamma-HCH, and delta-HCH) **
Isodrin (Isodrine, Compound 711) * **
p,p'-Methoxychlor (Marlate, methoxychlore) * **
o,p'-Methoxychlor * **
Mirex (Dechlorane) **
cis-Permethrin (Ambush, Astro, Pounce) * **
trans-Permethrin (Ambush, Astro, Pounce) * **
Toxaphene (Camphechlor, Hercules 3956) * **

Semivolatile organic compounds (SVOCs) in bed sediment



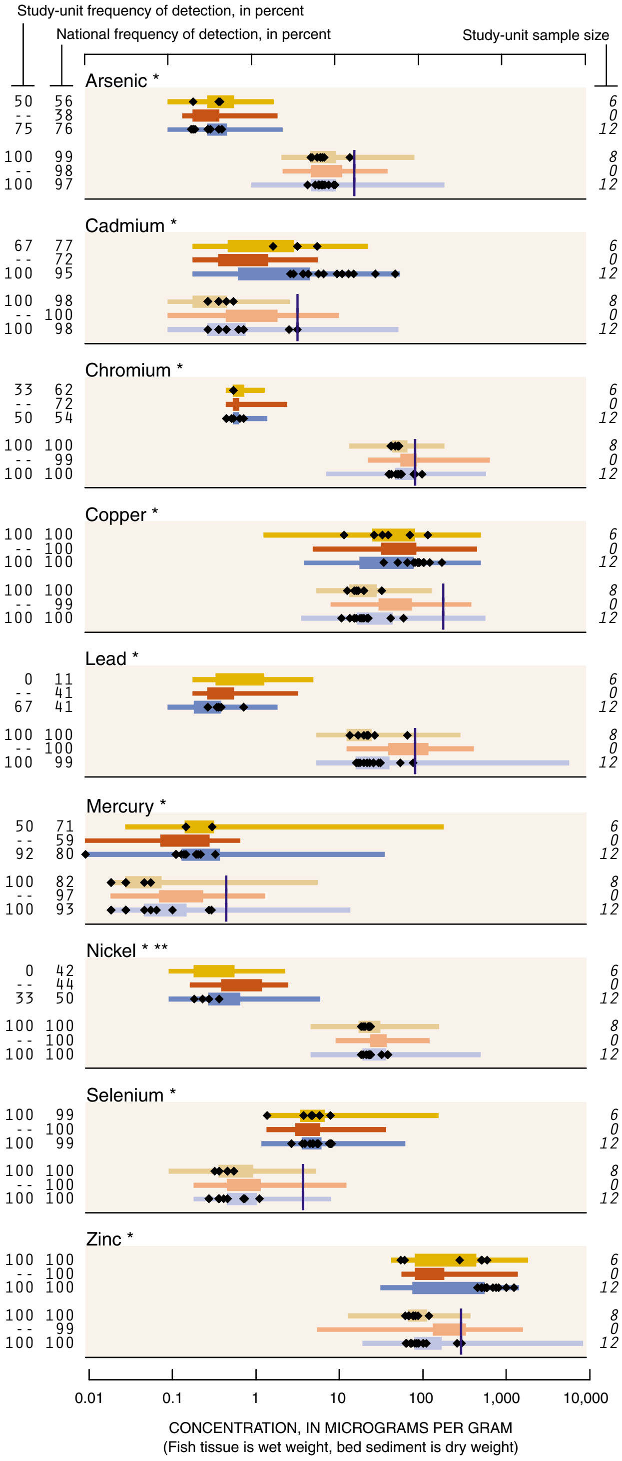




Other SVOCs detected
Acenaphthene
Acridine **
Anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene **
Benzo[*ghi*]perylene **
Benzo[*k*]fluoranthene **
Butylbenzylphthalate **
4-Chloro-3-methylphenol **
4-Chlorophenyl-phenylether **
Chrysene
p-Cresol **
Di-*n*-butylphthalate **
Di-*n*-octylphthalate **
1,3-Dichlorobenzene (*m*-Dichlorobenzene) **
Diethylphthalate **
1,2-Dimethylnaphthalene **
1,6-Dimethylnaphthalene **
3,5-Dimethylphenol **
Dimethylphthalate **
2-Ethylnaphthalene **
9*H*-Fluorene (Fluorene)
Indeno[1,2,3-*cd*]pyrene **
Isoquinoline **
1-Methyl-9*H*-fluorene **
2-Methylanthracene **
4,5-Methylenephenanthrene **
1-Methylphenanthrene **
1-Methylpyrene **
Naphthalene
Nitrobenzene **
Phenanthrene
Phenanthridine **
1,2,4-Trichlorobenzene **
2,3,6-Trimethylnaphthalene **

SVOCs not detected
C8-Alkylphenol **
Azobenzene **
Benzo[*c*]cinnoline **
2,2-Biquinoline **
4-Bromophenyl-phenylether **
2-Chloronaphthalene **
2-Chlorophenol **
1,2-Dichlorobenzene (*o*-Dichlorobenzene) **
2,4-Dinitrotoluene **
Isophorone **
N-Nitrosodi-*n*-propylamine **
Pentachloronitrobenzene **
Quinoline **

Trace elements in fish tissue (livers) and bed sediment



BIOLOGICAL INDICATORS

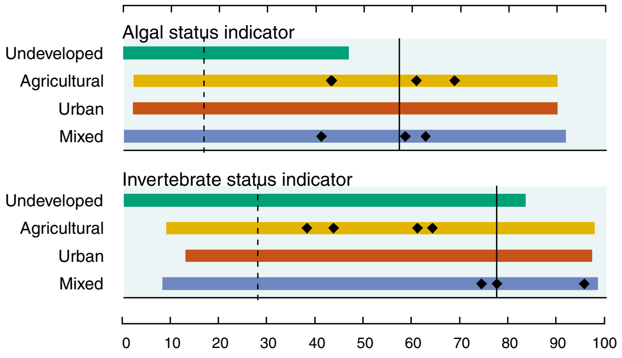
Higher national scores suggest habitat disturbance, water-quality degradation, or naturally harsh conditions. The status of algae, invertebrates (insects, worms, and clams), and fish provide a record of water-quality and stream conditions that water-chemistry indicators may not reveal. **Algal status** focuses on the changes in the percentage of certain algae in response to increasing siltation, and it often correlates with higher nutrient concentrations in some regions. **Invertebrate status** averages 11 metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. **Fish status** sums the scores of four fish metrics (percent tolerant, omnivorous, non-native individuals, and percent individuals with external anomalies) that increase in association with water-quality degradation

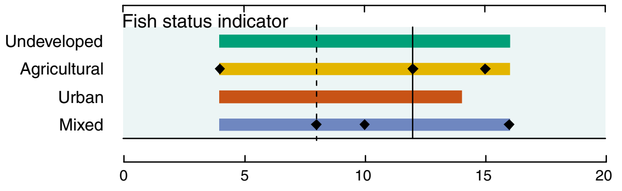
Biological indicator value, lower Illinois River Basin, by land use, 1995–98

◆ Biological status assessed at a site

National ranges of biological indicators, 16 NAWQA Study Units, 1994–98

🟩 Streams in undeveloped areas
🟨 Streams in agricultural areas
🟧 Streams in urban areas
🟦 Streams in mixed-land-use areas
—— 75th percentile
- - - 25th percentile





A COORDINATED EFFORT

Coordination with agencies and organizations in the lower Illinois River Basin was integral to the success of this water-quality assessment. We thank those who served as members of our liaison committee.

Federal Agencies
U.S. Environmental Protection Agency
Natural Resources Conservation Service
U.S. Fish and Wildlife Service

State Agencies
Illinois Environmental Protection Agency
Illinois Natural History Survey
Illinois Department of Natural Resources
Illinois Sate Geological Survey
Illinois State Water Survey
Illinois Department of Agriculture
Illinois Hazardous Waste Research Center
Illinois Abandoned Lands Council
Illinois Department of Public Health

Local Agencies
Bloomington and Normal Water Reclamation District
Metropolitan Water Reclamation District of Greater Chicago
Bloomington Water Department
Greater Peoria Sanitary District
City of Bloomington
Springfield City Water, Light, and Power
Mahomet Valley Water Authority
Peoria Health Department
Sanitary District of Decatur

Universities
University of Illinois
Water Resources Center, University of Illinois
Natural Resources and Environmental Sciences, University of Illinois
College of Agriculture, Consumer and Environmental Sciences, University of Illinois
College of Engineering, University of Illinois

Other public and private organizations
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The Nature Conservancy, Illinois Chapter
Heartland Water Resources

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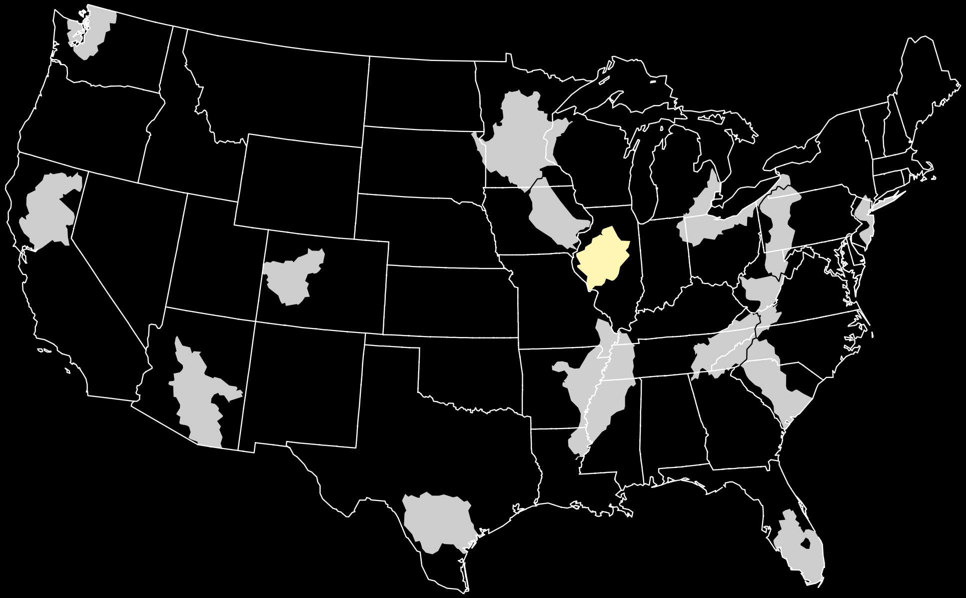
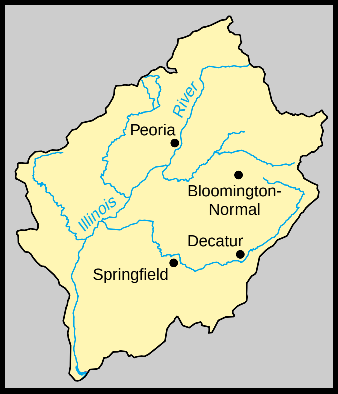
NAWQA

National Water-Quality Assessment (NAWQA) Program
Lower Illinois River Basin





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