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Monitoring the Water Quality of the Nation's Large Rivers

Mississippi River Basin NASQAN Program

The U.S. Geological Survey (USGS) has monitored water quality in the Mississippi River Basin as part of the National Stream Quality Accounting Network (NASQAN) since 1995, applying a basinwide perspective to understanding water quality on a regional scale (Hooper and others, 1997). The objectives of the Mississippi River Basin NASQAN Program are to provide an ongoing characterization of the concentrations and mass fluxes of sediment and chemicals at key locations in the basin, to determine regional source areas for these materials, and to assess the effect of human influences on observed concentrations and fluxes. NASQAN complements the ongoing USGS National Water-Quality Assessment (NAWQA) Program, which is performing a detailed assessment in 23 subbasins within the Mississippi River Basin (Hirsch and others, 1988). NASQAN monitors the large rivers in the Mississippi River Basin, downstream of NAWQA study units. NASQAN, in conjunction with NAWQA, can provide the data and information needed by other USGS programs, Federal and State agencies, other segments of the scientific community, and by the public to address the present and future status of water quality in the Mississippi River Basin.

Environmental Setting

The Mississippi River Basin, which drains about 41 percent of the conterminous United States, is the largest river basin in North America (fig.1). It is the third largest river basin in the world, smaller than only the Amazon River Basin in South America and the Congo River Basin in Africa. More than 72 million people reside in the Mississippi River Basin. In addition, the Mississippi River Basin contains one of the most productive farming regions in the world which produces the majority of the corn, soybeans, wheat, cattle, and hogs, as well as a significant amount of the cotton and rice grown in the United States. Furthermore, the majority of all pesticides and fertilizers used in the United States are applied to cropland in the Mississippi River Basin. As a result of rainfall runoff and ground-water discharge, streams in the Mississippi River Basin carry suspended sediment, naturally occurring chemicals weathered from the soil, and contaminants from human activities. These streams, and much of the dissolved and suspended material in them, eventually flow into the Mississippi River and ultimately are discharged to the Gulf of Mexico. The water quality of the Mississippi River and its tributaries is an important regional and national issue. The land use and cultural changes that have occurred in the Mississippi River Basin in the 1900's have had

Bridge sampling on Platte River near Louisville, Nebraska. (R.H. Coupe, photo)

Cableway sampling on Missouri River near Pierre, South Dakota. (R.H. Coupe, photo)

Boat sampling on Missouri River near Omaha, Nebraska. (R.H. Coupe, photo) measurable effects on the quality of water in the Mississippi River Basin. Because changes in land use and water quality likely will continue to occur in the Mississippi River Basin as agriculture production increases in response to the growing worldwide demand for food and fiber, it is important that a long-term program of monitoring, data analysis, interpretation, and reporting be implemented for the Mississippi River Basin.

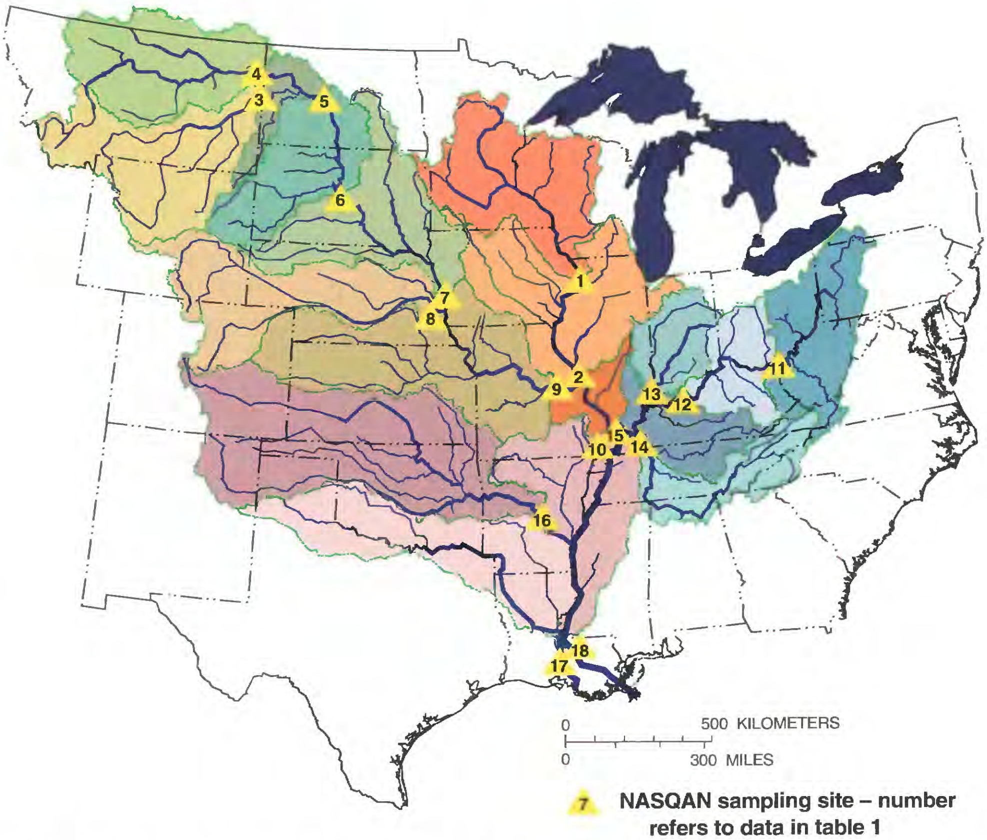

Figure 2. Subbasins defined by NASQAN stations.

Measuring Mass Flux

The choice of measuring mass flux (the amount of material that passes a set point) as the primary objective in the NASQAN program requires a relatively high sampling frequency. Additionally, the emphasis on flux characterization dictates that more samples must be collected during periods of higher streamflow.

The flux-based approach allows for the treatment of a river network as an integrated system. This approach provides data to describe and compare yields of non-point source contaminants across large regional basins, calculate loads to receiving waters, including off-continent flux, and test regional models of the influence of land use on water quality.

Station Selection

Eighteen NASQAN sampling stations (fig. 2, table 1) were selected at critical junctures within the Mississippi River Basin to provide the essential framework for understanding fluxes of materials within the basin and to the Gulf of Mexico. An important consideration for station selection was the influence of varying land use, and the presence of major reservoirs and input from major tributaries. Generally, stations were selected where significant changes in mass flux were expected, such as at confluences of major tributaries or at the downstream end of major reservoirs.

Sampling Strategy

The chemical constituents measured in the NASQAN Program (table 2) include 47 water-soluble pesticides, suspended and dissolved trace elements, major ions, nutrients, carbon, and suspended sediment. Samples are collected from 6 to 15 times per year. The number of samples

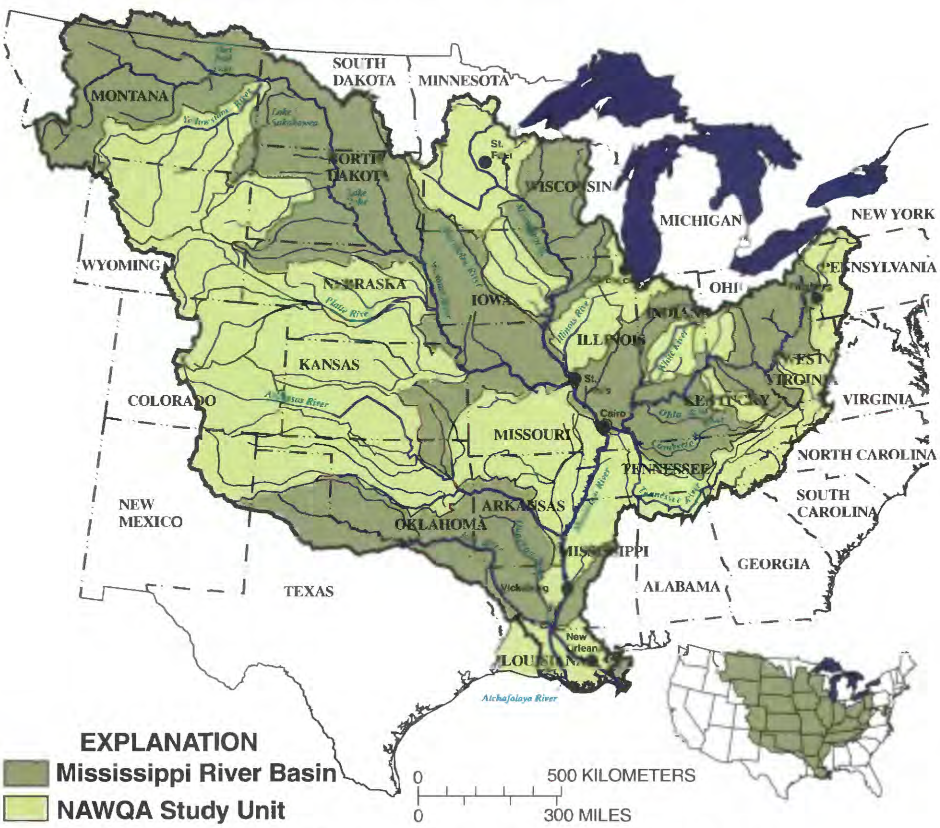

Figure 1. The Mississippi River Basin and the location of NAWQA study units.

subbasins most indicate trace-element enrichment, which trace elements are enriched, and what are potential sources or causes of the enrichment?

- What are the annual fluxes of dissolved material and suspended sediment from major subbasins within the Mississippi River Basin and what are the annual fluxes of these materials to the Gulf of Mexico? What fraction of the total mass of material transported from the major subbasins is in the dissolved phase? How much is in the suspended phase?

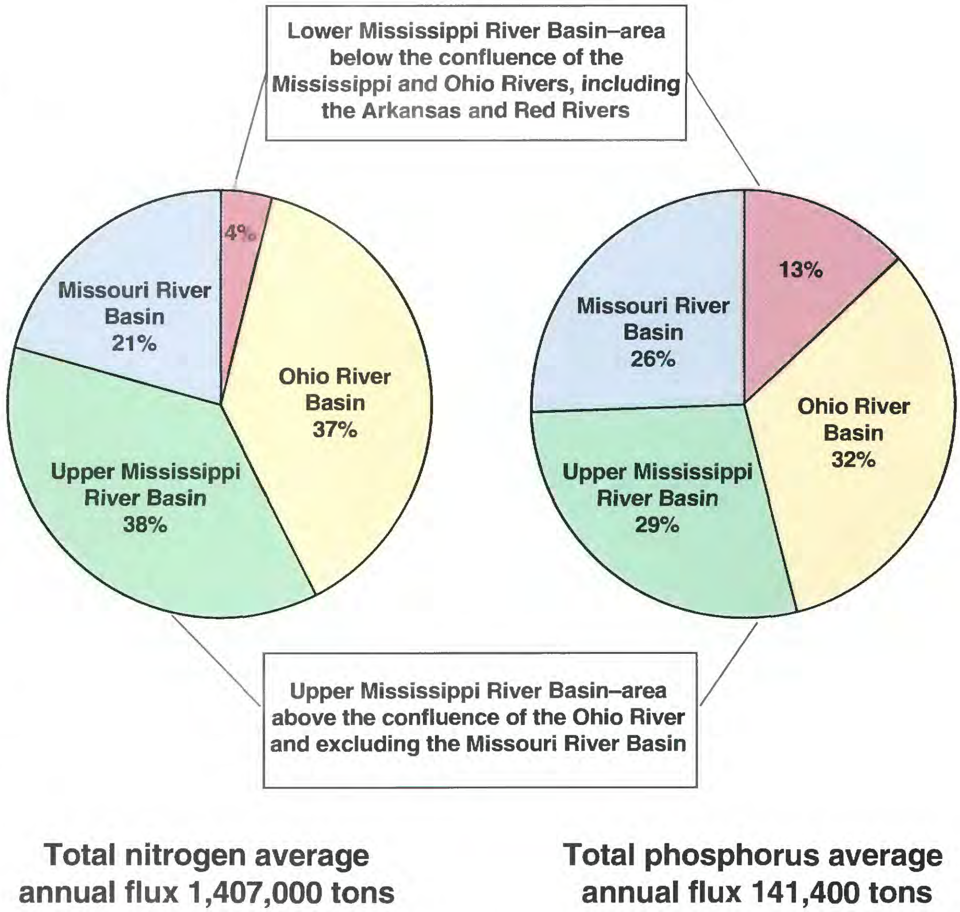

Figure 4. Percent flux of total nitrogen and total phosphorus into the Gulf of Mexico from the Mississippi and Atchafalaya Rivers by subbasin, 1995–96.

Preliminary Results

Fluxes of total nitrogen and total phosphorus for 1995 and 1996 from the Mississippi River Basin into the Gulf of Mexico show a distinct seasonality (fig. 3), corresponding with spring rains in the basin and the annual application of fertilizers to agricultural lands. The fluxes of total nitrogen and total phosphorus are similar in distribution, although the total nitrogen peaks are sharper, and are controlled by flow. Disproportionately large quantities of total nitrogen and total phosphorus discharging into the Gulf of Mexico originate in the Upper Mississippi and the Ohio River Basins. The two subbasins contribute approximately 75 percent of the annual total nitrogen flux and 61 percent of the annual total phosphorus flux to the Gulf of Mexico (fig. 4). Yet these two basins together only represent 32 percent of the drainage area in the Mississippi River Basin and 52 percent of the annual flow of the Mississippi River into the Gulf of Mexico. Further subdivision would be possible using data from all 18 NASQAN stations and would further identify source areas for these constituents.

National NASQAN Program

The Mississippi River Basin NASQAN Program is part of a national program that was redesigned in 1995 to focus on monitoring water quality in four of the Nation's largest rivers–the Mississippi (including the Missouri and Ohio), the Colorado, the Columbia, and the Rio Grande. In these four basins, the USGS currently operates a network of 40 NASQAN stations, and applies a consistent flux-based approach to characterize the transport of selected chemicals through the river systems.

Products of the NASQAN Program

Data from the NASQAN Program are published annually in USGS data reports issued by each State in the network. Additionally, NASQAN data are being released electronically on the World Wide Web (http://water.usgs.gov/nasqan), and flux estimates for selected constituents at NASQAN stations will be published periodically.

Selected References

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The Missouri River near Culbertson, Montana. (R.H. Coupe, photo)

Examples of questions NASQAN is addressing

Specific questions answered by NASQAN data in the Mississippi River Basin include:

- What is the annual transport of nitrogen and phosphorus from the Mississippi River Basin to the Gulf of Mexico? Which are the predominant subbasins that produce these nutrients and what is the relation between the yields of these nutrients and human influences such as type and intensity of agriculture and urbanization?
- What herbicides and insecticides currently in use are present in runoff from the major subbasins within the Mississippi River system? What are the concentrations of these chemicals and how are the concentrations and fluxes distributed in time and among subbasins?
- How do long-term increases in population, large-scale changes in land use and agricultural practices, and changes in the use of agricultural chemicals affect the concentrations and flux of nitrate and pesticides within the Mississippi River Basin and to the Gulf of Mexico?
- What are the dominant forms (organic or inorganic) and dominant chemical species in which carbon, nitrogen, and phosphorus are transported in the Mississippi River Basin? What is the predominant phase (dissolved or particulate) in which each of these elements is transported at key locations within the basin and into the Gulf of Mexico? Are significant in-stream transformations occurring among the forms of carbon and nitrogen as these elements are transported through the Mississippi River Basin to the Gulf of Mexico?
- How do long-term climatic cycles such as long dry periods (droughts) or long wet periods affect the annual flux of

Table 2. Constituents measured in the NASQAN program

Measurement class	Examples
Suspended sediment	Concentration of fine and coarse sediment particles
Pesticides	Common water-soluble pesticides, including atrazine and metolachlor
Suspended and dissolved trace elements	Lead, cadmium, copper, and zinc
Carbon	Dissolved and suspended organic carbon and dissolved inorganic carbon
Nutrients	Total and dissolved nitrogen and phosphorus
Major ions	Calcium, sulfate, and chloride
Support variables	Stream discharge, temperature, pH, dissolved oxygen, and specific conductance

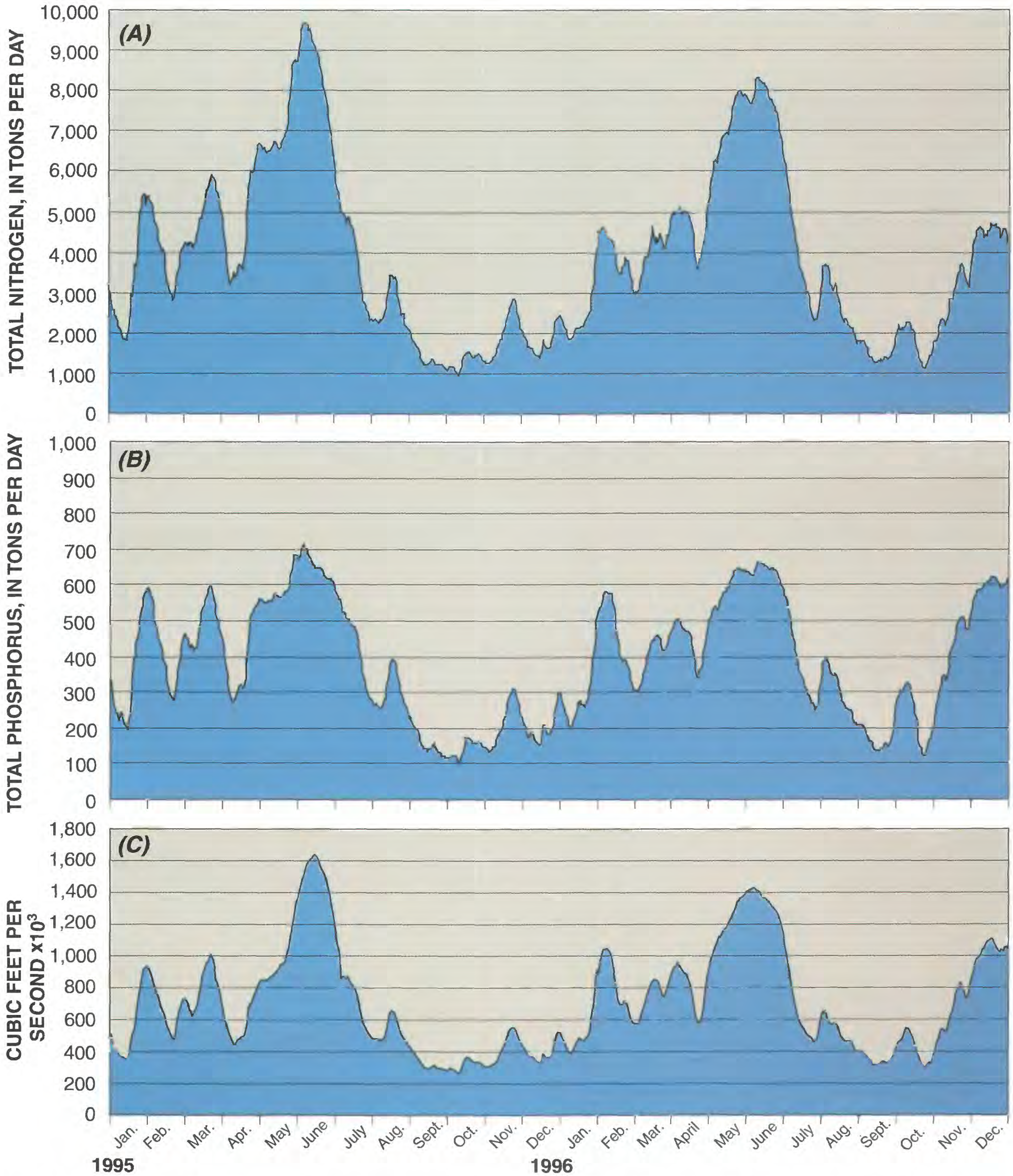

Figure 3. Total nitrogen *(A)*, total phosphorus *(B)*, and flow *(C)*, discharged to the Gulf of Mexico from the Mississippi and Atchafalaya Rivers in 1995 and 1996.

nutrients (carbon, nitrogen, phosphorus, silica) and other solutes?

- What is the yield of dissolved and suspended trace elements from major subbasins within the Mississippi River Basin? How do ratios of the fluxes of dissolved to suspended trace elements vary among subbasins, and do the flux ratios or trace element concentrations indicate enrichment attributable to human activities? Which major

Table 1. Description of NASQAN sampling stations in the Mississippi River Basin

[Mean discharge, from 1980 to 1996; mi^2, square miles; ft^3/s, cubic feet per second]

Map no.	Sampling station	Drainage area (mi^2)	Mean discharge (ft^3/s)	Incremental increase in drainage area (mi^2)	Incremental increase in streamflow (ft^3/s)
	Mississippi River Basin above the Missouri River				
1	Mississippi River at Clinton, IA	85,600	56,300	85,600	56,300
2	Mississippi River at Grafton, IL	171,300	130,200	85,700	73,900
	Missouri River Basin				
3	Yellowstone River near Sydney, MT	69,100	11,090	69,100	11,090
4	Missouri River near Culbertson, MT	91,600	9,500	91,600	9,500
5	Missouri River below Garrison Dam, ND	181,400	19,600	20,700	-990
6	Missouri River at Pierre, SD	243,500	23,700	62,100	4,100
7	Missouri River at Omaha, NE	322,800	35,800	79,300	12,100
8	Platte River at Louisville, NE	85,800	8,800	85,800	8,800
9	Missouri River at Hermann, MO	524,200	98,100	115,600	53,500
	Mississippi River Basin below the Missouri River and the Mississippi River at Grafton				
10	Mississippi River at Thebes, IL	713,200	243,400	17,700	15,100
	Ohio River Basin				
11	Ohio River at Greenup, KY	62,000	88,600	62,000	88,600
12	Ohio River at Cannelton Dam, KY	97,000	127,800	35,000	39,200
13	Wabash River at New Harmony, IN	29,200	[1]31,300	29,200	31,300
14	Tennessee River at Paducah, KY	40,300	60,400	40,300	60,400
15	Ohio River at Grand Chain, IL	203,000	295,900	37,100	76,400
	Lower Mississippi River				
16	Arkansas River at David Terry Dam, below Little Rock, AR	158,300	51,100	158,300	51,100
17	Atchafalaya River at Melville, LA	[2]93,300	[3]233,000	93,300	varies
18	Mississippi River near St. Francisville, LA	1,125,300	543,400	50,800	varies

[1] Discharge from the Wabash at Mt. Carmel, IN
[2] Excludes contribution from Mississippi River Basin.
[3] Includes Mississippi River Diversion.

collected at each station reflects the overall importance of that station to the flux or the predicated variability in water quality. For example, those stations downstream of major reservoirs are not sampled as often as others because the long residence times in the reservoirs result in the water being thoroughly mixed, thus dampening any seasonal effects.

Water Quality Issues

The climate, land use, soils, physiography, and population vary widely across the Mississippi River Basin. The annual runoff ranges from less than 2 inches per year in the western part of the basin to more than 50 inches per year in the southeastern part. Most of the fertilizer and pesticides used in the United States are applied to cropland in a 10-state area known as the corn belt (all or part of Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, South Dakota, and Wisconsin).This area is used primarily for cropland and produces most of the corn, soybeans, wheat, and sorghum grown in the United States. In some drainage basins, particularly in Iowa, Illinois, and Indiana, more than 50 percent of all land is used for growing crops. Large numbers of livestock and poultry also are produced in the central part of the basin (Battaglin and Goolsby, 1995). Furthermore, most of the basin's population of 72 million people reside in the eastern half of the basin. Contaminants, including sediment, nitrogen, phosphorus, pesticides, trace elements, industrial organic compounds, and sewage, originate from these many different uses of land and can have substantial effects on water quality in the Mississippi River Basin and the Gulf of Mexico (Goolsby and others, 1997; Meade, 1995).

Mississippi River at St. Louis on July 30, 1993. Lighter brown colors indicate areas of higher suspended sediment. (Strenco Photography, used with permission)

Wabash River flooding in the spring of 1997. (G.K. McCombs, photo)

Overflow of the Missouri River in 1997 on Route 19 near Hermann, Missouri. (R.R. Holmes, photo)