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Benthic Invertebrates and Quality of Streambed Sediments in the White River and Selected Tributaries in and near Indianapolis, Indiana, 1994–96

Water-Resources Investigations Report 99-4276

Prepared in cooperation with the

Indianapolis Department of Public Works

U.S. Department of the Interior
U.S. Geological Survey

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By David C. Voelker and Danny E. Renn

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2000

U.S. Department of the Interior
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Conversion Factors and Abbreviations

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Concentrations of chemical constituents in sediment are given in metric units. Chemical concentrations are given in grams per kilogram (g/kg), milligrams per kilogram (mg/kg), micrograms per gram (µg/g), or micrograms per kilogram (µg/kg). Grams per kilogram is a unit expressing the concentration of chemical constituents as weight (grams) per unit weight (kilogram) of sediment.

Other abbreviations used in this report:

CSO	Combined-Sewer Outfall
DDD	Dichlorodiphenyl dichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DPW	Department of Public Works (Indianapolis)
EPT	Ephemeroptera, Plecoptera, and Trichoptera Biotic Index
HBI	Hilsenhoff Biotic Index
PCB’s	Polychlorinated biphenyls
PEL	Probable Effect Level
RUP	Restricted Use Pesticides
TEL	Threshold Effect Level
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
m^2	square meter
mm	millimeter
µm	micrometer

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Abstract

During this study, 369 benthic-invertebrate samples were collected at 21 sites and 33 streambed-sediment samples were collected at 14 sites to help develop and evaluate control strategies to mediate the impact of point and nonpoint sources of pollution on the White River and selected tributaries in and near Indianapolis, Indiana. Data analyses show that 124 taxa were identified and that most of the benthic invertebrates found belong to one of three taxa: the pollution-tolerant Diptera and the pollution-intolerant Ephemeroptera and Trichoptera. The Hilsenhoff Biotic Index, which was calculated from the number of arthropods and their tolerance to pollution, ranged from 4.4 (very good) to 9.4 (very poor) on the White River, and from 4.9 (good) to 9.1 (very poor) on the tributaries. The Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index, which was calculated from the number of taxa in pollution-intolerant species, ranged from 0 to 9 for the White River and from 0 to 9 for the tributaries. A high EPT Richness Index value reflects a great diversity of pollution-intolerant invertebrates at a site and generally indicates good water quality.

A comparison of data collected during the 1994 through 1996 study to data collected during a 1981 through 1987 study indicates that the proportion of pollution-tolerant taxa increased in the immediate vicinity of Indianapolis. This increase may be an indicator that the water quality in the immediate vicinity of Indianapolis has declined since the earlier study. Comparison of the Hilsenhoff Biotic Index values, however, indicates there has been no change since the previous study.

In the analysis of streambed sediments, small amounts of 12 metals were detected. Of those, only lead exceeded sediment-quality guidelines for the protection of aquatic life in three samples from two sites. Thirteen insecticides were detected in the streambed sediments, and of those only chlordane exceeded sediment-quality guidelines for the protection of aquatic life. Seventeen semivolatile organic compounds also were detected in streambed sediments at nine sites: four on the White River and five on the tributaries. Six of these compounds exceeded sediment-quality guidelines for the protection of aquatic life.

Introduction

The City of Indianapolis manages the combined-sewer system in Indianapolis, Ind., and is developing control strategies to mediate the impact of point- and nonpoint-pollution sources on the White River and its tributaries in and near the city. To develop and evaluate these control strategies, information is needed about the diversity and density of benthic invertebrates and the concentrations of metals, insecticides, herbicides, and semivolatile organic compounds sorbed on streambed sediments. To provide this information, the U.S. Geological Survey (USGS) in cooperation with the Indianapolis Department of Public Works (DPW) conducted a study from 1994 through 1996 to describe benthic-invertebrate communities and streambed-sediment quality for sites on the White River and selected tributaries in and near Indianapolis.

Discharges from combined-sewer systems, stormwater drains, municipal wastewater-treatment facilities, industrial sources, and surface-water runoff can degrade receiving waters by increasing the concentrations of metals, organic compounds, and nutrients (Crawford and others, 1992; Crawford and Wangsness, 1993; Martin and Craig, 1990; Martin, 1995; W.W. Stone, U.S. Geological Survey, written commun., 1997). In urban areas, this increase in concentrations can affect human health and instream biota, thereby limiting the use of these waters for municipal, industrial, and recreational purposes.

Benthic invertebrates were used as indicators of water quality to evaluate the effect of point- and nonpoint-source pollution on the White River and selected tributaries. Aquatic organisms act as natural monitors of their environment. During exposure to water of poor quality, organisms that cannot tolerate the stress may be destroyed and the aquatic-community structure changes (Cairns and others, 1973). The benthic-invertebrate community can be an extremely sensitive indicator of environmental changes. Even slight changes in environmental conditions, if persistent, can lead to changes in the benthic-invertebrate community (Gaufin, 1973). Discharges of municipal and industrial wastewaters in urban areas can increase the concentrations of organic compounds, metals, and nutrients in receiving waters. Increased organic and nutrient concentrations can substantially increase the growth of bacteria, which in turn increases the demand for oxygen and decreases concentrations of dissolved oxygen in the receiving waters. Organic enrichment also can cause oxygen depletion in the stream, resulting in adverse effects on biota.

Streambed and suspended sediments commonly contain substantially higher concentrations of trace elements than generally are found dissolved in water. From 50 percent to almost 100 percent of the total stream transport of metals can be associated with these sediments (Horowitz, 1991). In general, pesticides are hydrophobic compounds with extremely low solubility in water and strong sorption tendencies (Larson and others, 1997), making their association with streambed and suspended sediments very likely. Streambed sediments can act as reservoirs for many chemical constituents and can be re-suspended when disturbed. When compared to suspended sediments, streambed sediments have less spatial and temporal variability in their chemical and physical properties. Thus the concentrations of metals, organic compounds, and pesticides sorbed on streambed sediments can provide information on the chemistry, location, and source of point- and nonpoint-source pollution (Horowitz, 1991).

Purpose and Scope

For selected sites on the White River and its tributaries in and near Indianapolis, this report provides (1) information on the diversity and density of benthic invertebrates; (2) an evaluation of the water quality at each site, using the benthic-invertebrate data; (3) a comparison of the benthic-invertebrate data collected for this study to historical data; and (4) an evaluation of the concentrations of metals, insecticides, herbicides, and semivolatile organic compounds sorbed on streambed sediments.

The information and evaluations in this report are based on the analysis of 369 benthic-invertebrate samples collected at 21 sites during May, July, and September 1994 through 1996 and 33 streambed-sediment samples collected at 14 sites during the month of August from 1994 through 1996. All benthic-invertebrate and streambed-sediment samples were collected during low-flow, steady-state streamflow conditions. The Hilsenhoff Biotic Index (Hilsenhoff, 1987 and 1988) and the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index were used to evaluate the water quality at the sampling sites.

Description of Study Area and Sampling Sites

The study focuses on the White River and selected tributaries in and near Indianapolis, Ind. (fig. 1). Indianapolis is the capital of Indiana, the largest city in the State, and is incorporated with Marion County. Marion County has an area of 402 mi^2 (square miles) (Sturm and Gilbert, 1978) and in 1990 had a population of 783,042 (Bureau of the Census, 1990). The study area is in the central climate division in Indiana and has a continental-type climate characterized by hot, humid summers and cold, wet winters (Newman, 1966). The White River and its two largest tributaries, Fall Creek and Eagle Creek, are the major sources of water supply for Indianapolis (Duwelius, 1990).

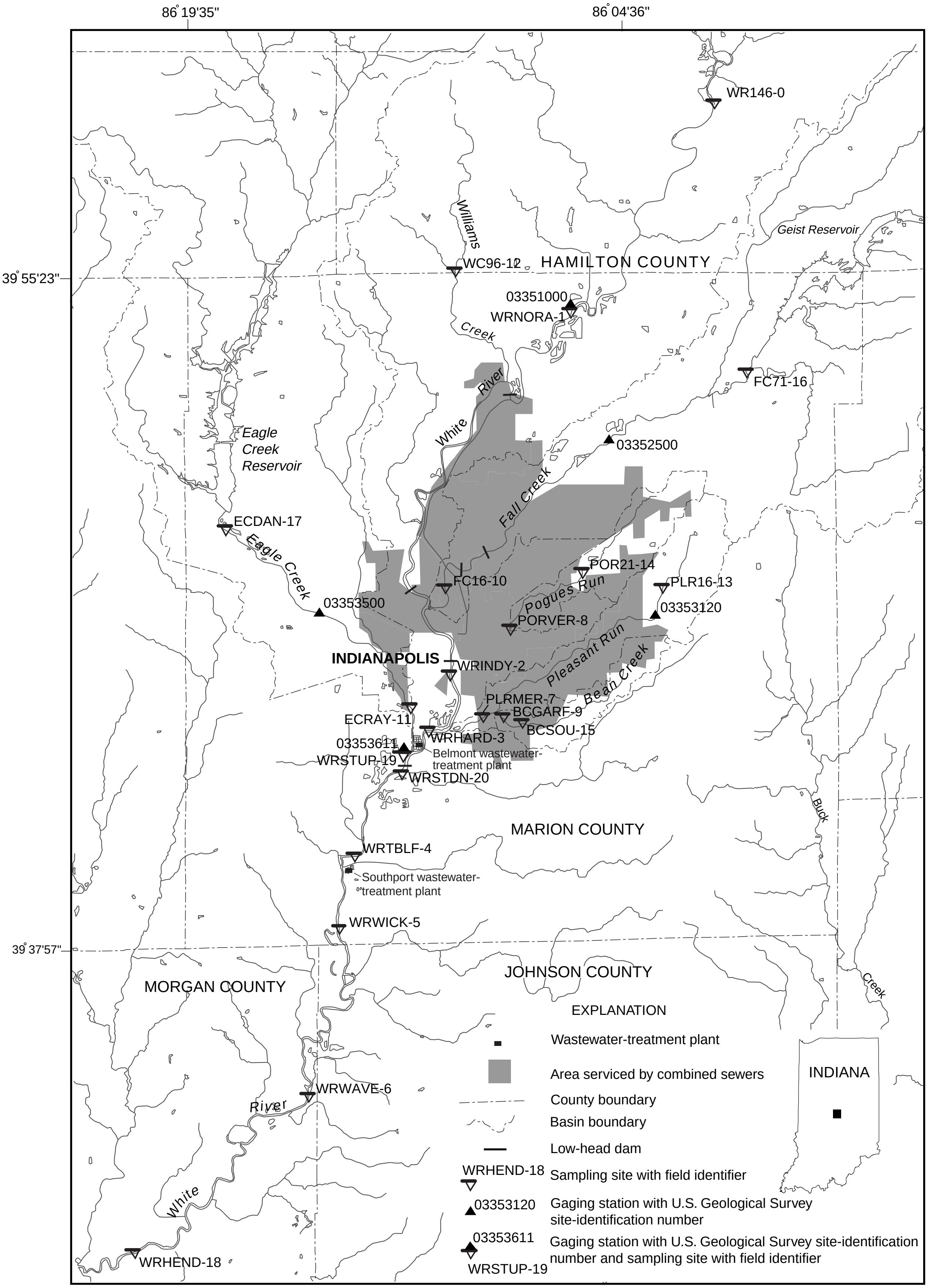
Approximately 40 mi^2 of the Indianapolis area is serviced by a combined-sewer system (fig. 1) (Howard Needles Tammen & Bergendoff, 1983). The combined-sewer system generally is located in the central section of Indianapolis. There are 137 combined-sewer outfalls (CSO's) that can discharge into the White River and its tributaries—29 outfalls discharge directly into the White River, 28 to Fall Creek, 6 to Eagle Creek, 49 to Pleasant Run, 4 to Bean Creek, and 21 to Pogues Run (Paul Werderitch, Indianapolis Department of Public Works, written commun., 1994).

Two large inputs to the White River are the discharges from the Belmont and Southport wastewater-treatment plants. The Belmont wastewater-treatment-plant outfall is about 0.5 mi (mile) upstream from the White River at Stout Generating Station (sample site WRSTUP-19 on fig. 1). The Southport wastewater-treatment plant is about 2 mi upstream from the White River at Wicker Road (sample site WRWICK-5).

Four low-head dams are located on the White River and two low-head dams are located on Fall Creek within the study area. These dams raise the water surface of the stream, thereby decreasing the streamflow velocities and causing increased sediment deposition. The low-head dam that is the farthest downstream on the White River in the study area is between sites WRSTUP-19 and WRSTDN-20. The site at White River at Stout Generating Station (WRSTUP-19) is 1,500 ft (feet) upstream from the dam, and the site at White River below Stout Generating Station (WRSTDN-20) is 50 ft downstream from the dam. Lick Creek, with a drainage area of 26.2 mi^2, also enters the White River between the two sites just upstream from the dam.

A total of 21 sampling sites were located on the White River and selected tributaries (table 1)—10 on the White River, 1 on Williams Creek, 2 on Fall Creek, 2 on Eagle Creek, 2 on Pleasant Run, 2 on Bean Creek, and 2 on Pogues Run. Of these, 18 sites were in Marion County, 1 in Hamilton County, and 2 in Morgan County (fig. 1). Sampling sites were selected to establish benthic-community descriptions in sections of the White River and its tributaries that may have been affected by urban activities in Indianapolis. These sites included locations upstream and downstream from CSO discharges and at sites where DPW has historical water-quality data.

Although affected by urban sources and runoff from agricultural areas upstream, the sites White River at 146th Street (WR146-0) in Hamilton County and White River near Nora (WRNORA-1), both identified as upstream sites, are in areas that are least affected by urban activities in Marion County. Six sampling sites in the immediate vicinity of Indianapolis—White River at Indianapolis (WRINDY-2), White River at Harding Street (WRHARD-3), White River at Stout Generating Station (WRSTUP-19), White River below Stout Generating Station (WRSTDN-20), White River at Tibbs-Banta Landfill (WRTBLF-4), and White River at Wicker Road (WRWICK-5)—represent sections of the river that may be most directly affected by urban activities. Downstream



Base from U.S. Geological Survey digital data, 1:100,000, 1983
Albers equal area projection
Standard parallels 29 30' and 45 30', central meridian -86

0 5 10 MILES
0 5 10 KILOMETERS

Figure 1. Map Showing location of the study area in Indiana and locations of sites on the White River and selected tributaries in and near Indianapolis where benthic invertebrates and streambed sediments were collected, 1994-96.

Table 1. Sites on the White River and selected tributaries in and near Indianapolis, Indiana, where benthic-invertebrate and streambed-sediment samples were collected, 1994–96

[USGS, U.S. Geological Survey; mi^2, square miles; BI, benthic invertebrate; SS, streambed sediment; -- no sample]

Field identifier	USGS site-identification number	Site name	Latitude	Longitude	Drainage area[a] (mi^2)	Number of samples	
						BI	SS
WR146-0	400001086012301	White River at 146th Street near Noblesville, IN	400001	860123	1,147	30	--
WRNORA-1	03351000	White River near Nora, IN (82nd Street)	395435	860620	1,219	21	4
WRINDY-2	03353000	White River at Indianapolis, IN (Morris Street)	394505	861030	1,635	18	4
WRHARD-3	03353193	White River at Harding Street, Indianapolis, IN	394337	861113	1,660	18	1
WRSTUP-19	03353611	White River at Stout Generating Station at Indianapolis, IN	394252	861202	1,872	12	2
WRSTDN-20	394234086120900	White River below Stout Generating Station at Indianapolis, IN	394234	861209	1,898	12	2
WRTBLF-4	394019086134601	White River at Tibbs-Banta Landfill near Southport, IN	394019	861346	1,920	15	1
WRWICK-5	393827086141701	White River at Wicker Road near Southport, IN	393827	861417	1,947	15	1
WRWAVE-6	03353660[b]	White River near Waverly, IN (State Road 144)	393402	861520	2,026	27	5
WRHEND-18	392956086212001	White River at Henderson Bridge near Adams, IN	392956	862120	2,126	9	--
WC96-12	03351072	Williams Creek at 96th Street at Indianapolis, IN	395537	861020	17.0	18	2
FC71-16	395259086001601	Fall Creek at 71st Street near Lawrence, IN	395259	860016	243	18	--
FC16-10	03352875	Fall Creek at 16th Street at Indianapolis, IN	394720	861040	317	15	3
ECDAN-17	394851086181301	Eagle Creek at Dandy Trail Road near Clermont, IN	394851	861813	164	21	--
ECRAY-11	394613086114700	Eagle Creek at Raymond Street at Indianapolis, IN	394411	861148	209	18	4
PLR16-13	394721086031001	Pleasant Run at East 16th Street at Indianapolis, IN	394721	860310	4.00	18	--
PLRMER-7	394358086092100	Pleasant Run near South Meridian Street at Indianapolis, IN	394358	860921	20.8	18	1
BCSOU-15	394349086080001	Bean Creek at Southern Avenue at Indianapolis, IN	394349	860800	5.00	18	--
BCGARF-9	394358086083901	Bean Creek at Garfield Park at Indianapolis, IN	394358	860839	5.30	18	2
POR21-14	394746086055601	Pogues Run at East 21st Street at Indianapolis, IN	394746	860556	4.40	18	--
PORVER-8	03352990	Pogues Run at Vermont Street at Indianapolis, IN	394617	860825	8.87	18	1

[a]Hoggatt, 1975.

[b]Station number was listed as 393402086152000 in Renn, 1998.

sampling sites in the study area, White River near Waverly (WRWAVE-6) and White River at Henderson Bridge (WRHEND-18), both in Morgan County, are away from the most urban areas yet are affected to some degree by urban activities in Indianapolis (Crawford and Wangsness, 1993).

The upstream sampling sites on selected tributaries to the White River were Williams Creek at 96th Street (WC96-12), Fall Creek at 71st Street (FC71-16), Eagle Creek at Dandy Trail Road (ECDAN-17), Pleasant Run at East 16th Street (PLR16-13), Bean Creek at Southern Avenue (BCSOU-15), and Pogues Run at East 21st Street (POR21-14) (table 1). These sites represent sections of the tributaries upstream from CSO's and, therefore, are less affected by urban activities. The upstream sampling sites were located as far upstream in Marion County as possible where flows are adequate to maintain a healthy benthic-invertebrate population even during low streamflow conditions. Williams Creek in the northern part of the study area has no CSO-discharge points along its length and was selected for comparison with other upstream sites. The downstream sampling sites are Fall Creek at 16th Street (FC16-10), Eagle Creek at Raymond Street, (ECRAY-11) Pleasant Run near South Meridian Street (PLRMER-7), Bean Creek at Garfield Park (BCGARF-9), and Pogues Run at Vermont Street (PORVER-8). These sites represent sections of the tributaries that are most subject to urban impacts, including possible CSO discharges.

Methods of Sample Collection and Analysis

Samples were collected during periods of low-flow, steady-state streamflow conditions as determined by review of monthly mean streamflows at USGS streamflow-gaging stations in the study area. Generally, the average monthly streamflows during 1994 and 1995 were lower than the long-term average monthly flow but, during 1996, they were greater than the long-term average monthly flow (fig. 2). USGS streamflow-gaging stations used to determine when low-flow, steady-state conditions were being met included Pleasant Run at Arlington Avenue (03353120), Eagle Creek at Indianapolis (03353500), Fall Creek at Millersville (03352500), White River near Nora (03351000), White River at Indianapolis (03353000), and White River at Stout Generating Station (03353611) (fig. 1).

Collection of Benthic Invertebrates and Streambed Sediments

Renn (1998) described the methods for sampling benthic invertebrates and streambed sediments for this study and lists the constituents analyzed. Three benthic-invertebrate samples were collected at each site. The samples were collected twice a year, once in May or July and again in September. Samples were collected with a Surber sampler with a 0.0929-m^2 grid and a collection-net-bag mesh opening of 210 µm (micrometers). The samples were preserved with a 10-percent Formalin solution and shipped to a contract laboratory for identification and analysis. Each organism was identified to the lowest possible taxonomic level.

Although a total of 21 benthic-invertebrate sites were sampled during the study, not all sites were sampled each year because of changes in site location based on review of the data, or because of changes in cooperator needs, or because a storm interrupted sampling (Renn, 1998). In 1994, 19 sites were sampled in May and September, and 20 sites were sampled in July and September 1995. Because of a storm in July 1996, only 16 sites were sampled; 20 sites were sampled in September 1996.

A total of 33 streambed-sediment samples were collected during the study. The samples were collected by scooping fine-grained sediments from the top inch of the streambed. The sediments then were sieved through a 2-mm (millimeter) mesh-screen sieve before being sent to a USGS laboratory for analysis. Samples were sieved further at the laboratory, and sediment sizes

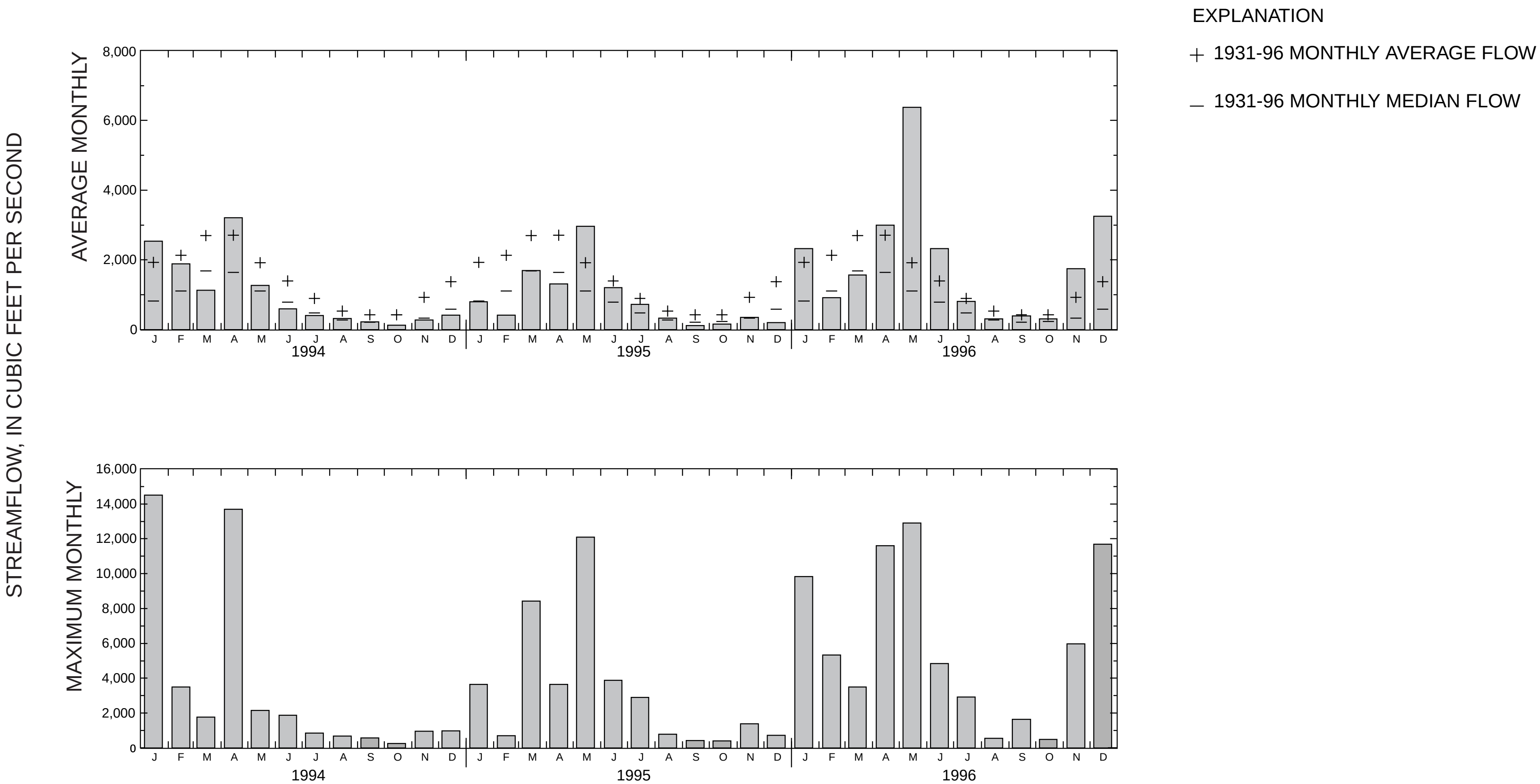


Figure 2. Average monthly and maximum monthly streamflow, White River at Indianapolis, U.S. Geological Survey streamflow-gaging station 03353000.

less than 63 μm were analyzed. A total of 14 streambed-sediment sites were sampled during the study (Renn, 1998). In 1994, 12 sites were sampled; 6 sites were sampled in 1995; and 5 sites were sampled in 1996.

Computation of Biotic Indices

The Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index and the Hilsenhoff Biotic Index (Hilsenhoff, 1987 and 1988) were used to evaluate water quality at the sampling sites. These indices are computed from the numbers and types of organisms in each sample. The number of distinct taxa identified; the density; and the percentage of taxa found that belong to the taxa Hirudinea, Oligochaeta, Coleoptera, Diptera, Ephemeroptera, Trichoptera, Gastropoda, Pelecypoda, and Tricladida were determined for each sample. Following the methods described by Crawford and others (1992), the data were used to describe the diversity and density of benthic invertebrates for this study.

Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index

The EPT Richness Index is computed as the total number of distinct taxa within the generally pollution-intolerant orders Ephemeroptera, Plecoptera, and Trichoptera. These organisms are more sensitive to low concentrations of dissolved oxygen and high concentrations of metals or natural organic compounds than many other types of benthic invertebrates. Thus, a high EPT Richness Index value, which reflects a great diversity of pollution-intolerant invertebrates at a site, generally indicates good water quality.

To determine the EPT Richness Index, the total number of distinct taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera were determined for the three benthic-invertebrate samples collected at each site during each sampling event. The EPT Richness Index for each site then was determined from the total number of distinct taxa among all the samples at that site for each sampling event.

Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (HBI) (Hilsenhoff, 1987 and 1988) uses the number of benthic invertebrates in the phylum Arthropoda at a site and their tolerance to pollution to evaluate the degree to which natural organic compounds are likely to be present. Each benthic invertebrate is assigned a tolerance value from 0 to 10, with 0 assigned to invertebrates least tolerant of organic pollution and 10 assigned to invertebrates most tolerant of organic pollution. Hilsenhoff (1987) determined tolerance values for benthic invertebrates identified to the species level; later, on the basis of his work in Wisconsin streams, he determined generalized tolerance values for invertebrates identified only to the family level (Hilsenhoff, 1988). Some of the organisms found in this study were not discussed by Hilsenhoff. Bode and others (1996) expanded on Hilsenhoff's work, and some tolerance values for organisms found in this study were taken from that work. A few organisms not listed in either investigator's work were assigned tolerance values based on similarly classified organisms. In general, benthic invertebrates identified during this study with the greatest intolerance to natural organic compounds are in the orders Ephemeroptera, Plecoptera, and Trichoptera, and the most tolerant benthic invertebrates are in the orders Diptera and Oligochaeta.

The HBI is divided into seven categories (table 2). A low HBI value indicates excellent water quality with little or no organic pollution, and a high HBI value indicates a poor water quality and higher organic pollution. To determine the HBI value, the three benthic-invertebrate samples collected at each site during each sampling event were summed; the summation of each taxon was multiplied by the tolerance value for that taxon. This product then was summed and divided by the total number of arthropods in the samples (Hilsenhoff, 1987 and 1988).

Table 2. Hilsenhoff Biotic Index as an evaluation of water quality (Hilsenhoff, 1987)

Biotic index	Water quality	Degree of organic pollution
0.00– 3.50	Excellent	No apparent organic pollution
3.51– 4.50	Very good	Possible slight organic pollution
4.51– 5.50	Good	Some organic pollution
5.51– 6.50	Fair	Fairly significant organic pollution
6.51– 7.50	Fairly poor	Significant organic pollution
7.51– 8.50	Poor	Very significant organic pollution
8.51–10.00	Very poor	Severe organic pollution

Analysis of Benthic Invertebrates

Analysis of the benthic-invertebrate samples collected in the study area identified 124 taxa. Of these, 28 were identified to the family level, 64 to genus, and 32 to species. Ninety-three of the 124 taxa were in the phylum Arthropoda. The majority of the taxa identified during this study belong to the generally pollution-tolerant Diptera (flies, midges, and mosquitoes) and the relatively pollution-intolerant Ephemeroptera (mayflies) and Trichoptera (caddisflies). A complete listing of benthic invertebrates collected during this study is found in Renn (1998).

White River Sites

Variations in the density and diversity of benthic-invertebrate taxa occur at sites along the White River as it moves through Indianapolis (table 3). The number of taxa identified in samples generally increased over the period of the study, with the highest number of taxa identified in the 1996 samples. In general, during each sample round, the number of taxa identified decreased in the downstream order, with the highest numbers at the two most upstream sites; however, the site at White River below Stout Generating Station (WRSTDN-20) also had high numbers of taxa.

The density of organisms also increased over time, with the highest densities found during the 1996 sampling periods, which was also when the highest average monthly streamflows occurred during the study. With the exception of the September 1995 sampling period, the lowest density of organisms generally was found at the White River at Harding Street (WRHARD-3) and White River at Stout Generating Station (WRSTUP-19) sampling sites. The sample indicating the lowest density of organisms was collected from the White River at Indianapolis (WRINDY-2) site in July 1995 (table 3).

Sites upstream and downstream from Indianapolis have a higher percentage of the pollution-intolerant Ephemeroptera and Trichoptera in their communities (table 4) than do the sites in the immediate vicinity of Indianapolis. The percentage of Ephemeroptera and Trichoptera at the sites in the vicinity of Indianapolis range from 0 to 16 percent and 0 to 75 percent, respectively; both have a median of 1 percent or less. The percentage of Ephemeroptera and Trichoptera at sites upstream and downstream from Indianapolis range from 0 to 35 percent and less than 1 to 86 percent, respectively. The median percentage of Ephemeroptera and Trichoptera found at sites upstream and downstream from Indianapolis was 10 percent and 31 percent, respectively.

Generally, Diptera were the highest percentage of taxa identified in the study area. The percentage of the total number of invertebrates of the pollution-tolerant Diptera at sites in the vicinity of Indianapolis ranges from 14 to 97 percent, with the median of all sample events being 75 percent. The range of percentages for Diptera at sites upstream and downstream from Indianapolis is 2 to 93 percent, with a median of 31 percent.

Table 3. Summary of the number of taxa; density of benthic invertebrates; and the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index and Hilsenhoff Biotic Index values for sites on the White River

[see table 1 for site names and descriptions; m^2, square meter; Sept, September; --, not sampled]

Field identifier	Sampling date	Number of taxa	Density (organisms/m^2)	EPT Richness Index	Hilsenhoff Biotic Index
Upstream sites:					
WR146-0	May 1994	19	5,200	7	5.8
	Sept 1994	20	3,100	7	5.1
	July 1995	20	1,300	9	5.0
	Sept 1995	19	1,200	6	5.8
	July 1996	27	15,000	8	5.4
	Sept 1996	27	13,000	7	5.8
WRNORA-1	May 1994	28	2,400	7	5.4
	Sept 1994	20	4,000	6	5.2
	July 1995	13	8,400	6	4.4
	Sept 1995	17	5,500	7	4.7
	July 1996	26	42,000	7	5.2
	Sept 1996	22	3,900	6	4.8
Sites in the immediate vicinity of Indianapolis:					
WRINDY-2	May 1994	17	1,800	5	5.9
	Sept 1994	13	4,000	0	7.9
	July 1995	8	290	0	7.4
	Sept 1995	18	5,000	3	6.9
	July 1996	26	18,000	7	9.0
	Sept 1996	19	7,800	4	9.2
WRHARD-3	May 1994	18	2,000	3	5.9
	Sept 1994	10	950	0	6.4
	July 1995	5	420	1	6.8
	Sept 1995	15	5,700	3	7.0
	July 1996	30	11,000	6	8.4
	Sept 1996	22	3,700	4	9.4
WRSTUP-19	May 1994	--	--	--	--
	Sept 1994	--	--	--	--
	July 1995	9	510	2	6.9
	Sept 1995	16	1,900	2	6.7
	July 1996	22	11,000	4	8.5
	Sept 1996	20	3,600	2	8.8
WRSTDN-20	May 1994	--	--	--	--
	Sept 1994	--	--	--	--
	July 1995	11	2,100	3	5.4
	Sept 1995	18	8,200	5	4.7
	July 1996	28	24,000	8	6.1
	Sept 1996	28	140,000	6	6.4

Table 3. Summary of the number of taxa; density of benthic invertebrates; and the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index and Hilsenhoff Biotic Index values for sites on the White River—Continued

Field identifier	Sampling date	Number of taxa	Density (organisms/m^2)	EPT Richness Index	Hilsenhoff Biotic Index
Sites in the immediate vicinity of Indianapolis—Continued:					
WRTBLF-4	May 1994	16	3,500	5	5.9
	Sept 1994	13	5,900	4	4.9
	July 1995	7	1,400	4	5.6
	Sept 1995	15	8,600	5	5.5
	July 1996	--	--	--	--
	Sept 1996	24	4,100	5	5.7
WRWICK-5	May 1994	11	3,300	2	6.0
	Sept 1994	19	2,000	6	5.8
	July 1995	5	540	2	6.3
	Sept 1995	15	3,800	4	6.8
	July 1996	--	--	--	--
	Sept 1996	19	1,200	4	6.3
Downstream sites:					
WRWAVE-6	May 1994	12	4,500	2	6.0
	Sept 1994	15	2,500	6	5.2
	July 1995	7	2,400	3	5.4
	Sept 1995	12	6,500	4	4.8
	July 1996	--	--	--	--
	Sept 1996	17	12,000	4	4.9
WRHEND-18	May 1994	13	3,400	3	5.9
	Sept 1994	16	1,800	5	4.7
	July 1995	--	--	--	--
	Sept 1995	--	--	--	--
	July 1996	--	--	--	--
	Sept 1996	--	--	--	--

The abundance of benthic invertebrates varies among sites and sampling events but is generally the same for sites upstream and downstream from Indianapolis and for sites in the immediate vicinity of Indianapolis. The median density for the White River sites upstream and downstream from Indianapolis was 4,050 organisms/m^2 (organisms per square meter) and 4,040 organisms/m^2 for sites in the immediate vicinity of Indianapolis. The diversity of taxa for the two groups, however, differs greatly. The percentages of taxa found belonging to the pollution-intolerant taxa Ephemeroptera and Trichoptera are higher at sites upstream and downstream from Indianapolis than at sites in the immediate vicinity of Indianapolis.

Besides water quality, a factor contributing to the decrease in macroinvertebrate diversity in the immediate vicinity of Indianapolis may be the different streamflow characteristics and substrate material at the sites (Renn, 1998). Sites on the White River upstream and downstream from Indianapolis had silt to gravel-size material with areas of cobble to boulder-size material that generally form run and riffle areas. Most White River sites in the immediate vicinity of Indianapolis had slow currents or pooled streamflow conditions, and the streambed contained fine-grained material in addition to gravel and cobbles.

Table 4. Summary of benthic-invertebrate data for the White River sites

[see table 1 for site names and descriptions; %, percent of total number of organisms; < , less than; Sept, September; -- , not sampled]

		Annelida		Insecta				Mollusca		Turbellaria
Field identifier	Date	Hirudinea %	Oligochaeta %	Coleoptera %	Diptera %	Ephemeroptera %	Trichoptera %	Gastropoda %	Pelecypoda %	Tricladida %
WR146-0 (upstream site)										
	May 1994	0	5	<1	86	5	1	0	<1	0
	Sept 1994	0	0	7	31	14	35	7	<1	2
	July 1995	0	<1	<1	19	32	4	0	0	<1
	Sept 1995	0	1	10	38	35	4	3	1	4
	July 1996	0	<1	<1	66	23	8	<1	0	0
	Sept 1996	0	0	3	58	19	13	2	<1	0
WRNORA-1 (upstream site)										
	May 1994	0	47	<1	28	21	<1	0	0	<1
	Sept 1994	0	6	21	18	9	31	7	3	3
	July 1995	<1	0	5	2	4	84	<1	<1	0
	Sept 1995	<1	<1	11	4	10	56	<1	<1	3
	July 1996	0	<1	<1	37	15	39	4	<1	1
	Sept 1996	<1	0	10	4	13	64	0	1	3
WRINDY-2 (site in the immediate vicinity of Indianapolis)										
	May 1994	<1	33	0	48	3	<1	0	0	11
	Sept 1994	4	5	1	24	0	0	1	1	62
	July 1995	10	2	0	85	0	0	0	0	0
	Sept 1995	<1	<1	<1	85	<1	<1	3	<1	9
	July 1996	0	<1	<1	80	3	2	9	<1	5
	Sept 1996	<1	<1	<1	79	<1	<1	2	<1	18

Table 4. Summary of benthic-invertebrate data for the White River sites—Continued

Field identifier	Date	Annelida		Insecta				Mollusca		Turbellaria
		Hirudinea %	Oligochaeta %	Coleoptera %	Diptera %	Ephemeroptera %	Trichoptera %	Gastropoda %	Pelecypoda %	Tricladida %
WRHARD-3 (site in the immediate vicinity of Indianapolis)										
	May 1994	<1	66	0	18	3	<1	2	0	8
	Sept 1994	2	37	0	42	0	0	2	0	16
	July 1995	3	0	0	92	3	0	0	0	<1
	Sept 1995	<1	<1	<1	97	<1	<1	<1	0	1
	July 1996	<1	2	<1	83	2	<1	2	<1	8
	Sept 1996	1	<1	0	88	<1	<1	2	0	6
WRSTUP-19 (site in the immediate vicinity of Indianapolis)										
	May 1994	--	--	--	--	--	--	--	--	--
	Sept 1994	--	--	--	--	--	--	--	--	--
	July 1995	<1	8	0	75	2	<1	0	0	12
	Sept 1995	2	1	2	76	6	<1	<1	<1	10
	July 1996	2	2	<1	93	<1	<1	<1	<1	2
	Sept 1996	3	4	2	87	<1	<1	<1	0	3
WRSTDN-20 (site in the immediate vicinity of Indianapolis)										
	May 1994	--	--	--	--	--	--	--	--	--
	Sept 1994	--	--	--	--	--	--	--	--	--
	July 1995	1	0	0	35	<1	45	1	16	1
	Sept 1995	2	<1	2	14	<1	75	3	<1	3
	July 1996	<1	3	<1	70	5	22	<1	<1	<1
	Sept 1996	<1	2	<1	74	<1	20	<1	<1	3

Table 4. Summary of benthic-invertebrate data for the White River sites—Continued

Field identifier	Date	Annelida		Insecta				Mollusca		Turbellaria
		Hirudinea %	Oligochaeta %	Coleoptera %	Diptera %	Ephemeroptera %	Trichoptera %	Gastropoda %	Pelecypoda %	Tricladida %
WRTBLF-4 (site in the immediate vicinity of Indianapolis)										
	May 1994	0	13	0	84	1	1	0	0	<1
	Sept 1994	0	<1	<1	29	6	60	4	<1	<1
	July 1995	0	<1	0	48	3	48	0	0	0
	Sept 1995	0	<1	2	43	4	50	<1	<1	<1
	July 1996	--	--	--	--	--	--	--	--	--
	Sept 1996	<1	<1	<1	49	10	38	<1	0	2
WRWICK-5 (site in the immediate vicinity of Indianapolis)										
	May 1994	0	13	0	85	<1	<1	0	0	<1
	Sept 1994	0	<1	<1	44	16	11	26	0	3
	July 1995	0	0	0	75	0	23	2	0	0
	Sept 1995	0	<1	2	89	1	4	3	<1	<1
	July 1996	--	--	--	--	--	--	--	--	--
	Sept 1996	<1	0	0	70	3	23	3	<1	<1
WRWAVE-6 (downstream site)										
	May 1994	0	2	<1	93	0	4	0	<1	0
	Sept 1994	0	<1	0	48	8	40	1	<1	2
	July 1995	<1	<1	0	43	<1	56	0	0	0
	Sept 1995	0	0	2	14	5	78	<1	0	0
	July 1996	--	--	--	--	--	--	--	--	--
	Sept 1996	0	<1	<1	12	2	86	<1	0	0
WRHEND-18 (downstream site)										
	May 1994	0	1	0	91	<1	7	0	0	0
	Sept 1994	<1	<1	<1	52	26	13	7	1	0
	July 1995	--	--	--	--	--	--	--	--	--
	Sept 1995	--	--	--	--	--	--	--	--	--
	July 1996	--	--	--	--	--	--	--	--	--
	Sept 1996	--	--	--	--	--	--	--	--	--

Tributary Sites

The numbers of distinct taxa and densities at the upstream and downstream tributary sites are shown in table 5. The densities of benthic invertebrates for the upstream sites ranged from 130 to 66,000 organisms/m^2, and the densities of benthic invertebrates for the downstream sites ranged from 130 to 15,000 organisms/m^2. Diversity and density varied greatly among the tributaries, with three tributaries—Fall Creek, Bean Creek, and Pogues Run—showing generally lower numbers of taxa at the downstream sites. The number of samples showing lower numbers of taxa at the downstream sites was about equal to those having a higher number of taxa. The density of organisms primarily was lower at the downstream sites, with only Pleasant Run showing overall increases in the number of taxa and density of organisms at the downstream site. Because of the consistency in habitat and streamflow conditions at the tributary sites, those conditions are not considered to be a factor in the changes in the diversity and density of benthic invertebrates observed between the upstream and downstream sites.

The diversity of benthic invertebrates at the upstream tributary sites is greater than that at the downstream tributary sites (table 6). The percentage of Diptera ranges from 22 to 94 percent of the total taxa found at the downstream sites, with a median of 84 percent. At the upstream sites, the percentage of Diptera ranges from 15 to 96 percent, with a median of 47 percent. The percentage of Ephemeroptera and Trichoptera at the downstream sites ranges, respectively, from 0 to 25 percent and 0 to 40 percent. The median percentage of Ephemeroptera and Trichoptera at the downstream sites is 2 percent and 3 percent, respectively. The upstream sites percentage of Ephemeroptera and Trichoptera ranges from 0 to 38 percent and 0 to 48 percent, respectively. At the upstream sites, the median percentage of Ephemeroptera and Trichoptera is 5 percent and 16 percent, respectively.

Median densities of organisms in the tributaries are almost one-fourth less than densities in the White River. Generally, the percentage of pollution-intolerant taxa (Ephemeroptera and Trichoptera) was higher at the upstream tributary sites than at the downstream tributary sites.

Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index

The EPT Richness Index values calculated for sites on the White River and selected tributaries in and near Indianapolis are presented in tables 3 and 5 and are displayed on figure 3. For the White River, the EPT Richness Index values ranged from 0 at the White River at Indianapolis (WRINDY-2) site during September 1994 and July 1995 and at the White River at Harding Street (WRHARD-3) site during September 1994 to 9 at the White River at 146th Street (WR146-0) and at the White River below Stout Generating Station (WRSTDN-20) sites during July 1996. The EPT values for sites upstream from Indianapolis were higher than the EPT values for sites located in the immediate vicinity of Indianapolis.

The EPT values for sites upstream from Indianapolis ranged from 6 to 9. At the White River at 146th Street (WR146-0) site, only one of the EPT values was less than 7; at the White River near Nora (WRNORA-1) site, all of the EPT values were 6 or 7. The EPT values for sites in the immediate vicinity of Indianapolis ranged from 0 to 8. At the White River at Indianapolis (WRINDY-2) site, half of the EPT values ranged from 4 to 7; at the White River at Harding Street (WRHARD-3) site, more than half of the EPT values ranged from 3 to 6; and at the White River at Stout Generating Station (WRSTUP-19) site, all of the EPT values were 2 or 4. At the White River below Stout Generating Station (WRSTDN-20) site, half of the EPT values were 6 or above; at the White River at the Tibbs-Banta Landfill (WRTBLF-4) site, half of the EPT values were 5; and at the White River at

Table 5. Summary of the number of taxa; density of benthic invertebrates; and the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index and Hilsenhoff Biotic Index values for sites on tributaries to the White River

[see table 1 for site names and descriptions; m^2, square meter; Sept, September; --, not sampled]

Field identifier	Sampling date	Number of taxa	Density (organisms/m^2)	EPT Richness Index	Hilsenhoff Biotic Index
Upstream sites:					
WC96-12	May 1994	25	6,200	9	5.4
	Sept 1994	16	6,500	4	5.3
	July 1995	12	600	4	5.0
	Sept 1995	--	--	--	--
	July 1996	21	12,000	5	5.6
	Sept 1996	29	2,400	5	5.2
FC71-16	May 1994	28	2,400	9	6.0
	Sept 1994	16	2,900	7	5.5
	July 1995	12	690	5	5.6
	Sept 1995	18	6,300	6	5.8
	July 1996	30	10,000	9	5.1
	Sept 1996	32	1,400	8	6.1
ECDAN-17	May 1994	13	3,100	3	5.9
	Sept 1994	14	6,800	3	5.4
	July 1995	6	1,300	2	6.1
	Sept 1995	15	2,000	4	5.2
	July 1996	27	66,000	7	5.8
	Sept 1996	20	4,100	5	5.2
PLR16-13	May 1994	10	2,100	2	6.0
	Sept 1994	18	1,400	4	6.3
	July 1995	10	180	3	5.0
	Sept 1995	14	1,300	5	6.2
	July 1996	27	4,000	6	5.8
	Sept 1996	19	1,100	5	6.1
BCSOU-15	May 1994	11	3,800	1	6.0
	Sept 1994	12	1,900	5	8.4
	July 1995	7	430	1	6.4
	Sept 1995	17	1,900	5	6.3
	July 1996	28	1,500	5	5.8
	Sept 1996	19	2,400	3	5.4
POR21-14	May 1994	17	8,100	4	6.0
	Sept 1994	15	2,300	4	6.2
	July 1995	7	130	2	6.0
	Sept 1995	13	610	3	5.8
	July 1996	24	1,700	6	5.8
	Sept 1996	17	2,000	3	5.4

Table 5. Summary of the number of taxa; density of benthic invertebrates; and the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index and Hilsenhoff Biotic Index values for sites on tributaries to the White River—Continued

Field identifier	Sampling date	Number of taxa	Density (organisms/m^2)	EPT Richness Index	Hilsenhoff Biotic Index
Downstream sites:					
FC16-10	May 1994	7	440	1	5.9
	Sept 1994	14	1,500	3	6.7
	July 1995	10	890	3	6.7
	Sept 1995	13	1,600	4	6.6
	July 1996	--	--	--	--
	Sept 1996	11	1,000	3	4.9
ECRAY-11	May 1994	19	2,400	7	6.0
	Sept 1994	26	1,300	4	6.8
	July 1995	12	620	5	6.6
	Sept 1995	18	1,600	5	6.7
	July 1996	29	15,000	6	6.1
	Sept 1996	29	3,500	5	6.2
PLRMER-7	May 1994	12	4,200	0	6.0
	Sept 1994	10	1,900	3	6.4
	July 1995	9	780	2	7.1
	Sept 1995	15	2,600	4	6.5
	July 1996	18	2,200	2	6.2
	Sept 1996	22	5,400	5	6.5
BCGARF-9	May 1994	10	490	0	5.8
	Sept 1994	9	1,400	3	9.1
	July 1995	7	400	2	6.9
	Sept 1995	17	6,600	4	6.6
	July 1996	32	4,900	5	5.6
	Sept 1996	17	1,600	2	6.0
PORVER-8	May 1994	9	620	0	6.4
	Sept 1994	10	690	1	7.8
	July 1995	6	130	0	7.0
	Sept 1995	15	610	2	6.4
	July 1996	19	5,300	3	6.1
	Sept 1996	13	700	3	6.6

Table 6. Summary of benthic-invertebrate data for sites on tributaries to the White River

[see table 1 for site names and descriptions; %, percent of total number of organisms;<, less than; Sept, September; --, not sampled]

		Annelida		Insecta				Mollusca		Turbellaria
Field identifier	Date	Hirudinea %	Oligochaeta %	Coleoptera %	Diptera %	Ephemeroptera %	Trichoptera %	Gastropoda %	Pelecypoda %	Tricladida %
WC96-12 (upstream site)										
	May 1994	0	5	1	73	13	1	<1	1	1
	Sept 1994	0	2	4	18	3	47	6	4	15
	July 1995	0	0	20	20	13	22	4	3	16
	Sept 1995	--	--	--	--	--	--	--	--	--
	July 1996	0	<1	2	68	2	24	2	<1	1
	Sept 1996	<1	<1	11	15	1	12	<1	17	41
FC71-16 (upstream site)										
	May 1994	0	9	<1	85	3	1	0	0	0
	Sept 1994	0	0	2	52	14	27	<1	0	0
	July 1995	0	2	6	42	11	37	<1	0	0
	Sept 1995	0	<1	3	51	4	29	<1	0	<1
	July 1996	0	0	4	32	17	45	<1	0	1
	Sept 1996	0	2	3	40	38	5	0	0	4
FC16-10 (downstream site)										
	May 1994	0	15	0	82	2	0	0	0	0
	Sept 1994	0	0	2	92	0	3	0	0	<1
	July 1995	<1	0	3	92	<1	2	0	0	0
	Sept 1995	0	<1	4	90	2	2	0	0	0
	July 1996	--	--	--	--	--	--	--	--	--
	Sept 1996	0	0	14	22	<1	40	0	0	0

Table 6. Summary of benthic-invertebrate data for sites on tributaries to the White River—Continued

Field identifier	Date	Annelida: Hirudinea %	Annelida: Oligochaeta %	Insecta: Coleoptera %	Insecta: Diptera %	Insecta: Ephemeroptera %	Insecta: Trichoptera %	Mollusca: Gastropoda %	Mollusca: Pelecypoda %	Turbellaria: Tricladida %
ECDAN-17 (upstream site)										
	May 1994	<1	6	0	90	<1	<1	0	0	1
	Sept 1994	0	<1	0	41	5	21	<1	0	13
	July 1995	0	0	0	41	<1	15	0	0	42
	Sept 1995	0	<1	5	29	5	39	<1	0	6
	July 1996	0	<1	<1	86	<1	12	<1	0	<1
	Sept 1996	0	0	0	29	2	43	0	0	25
ECRAY-11 (downstream site)										
	May 1994	<1	39	<1	48	6	6	0	0	0
	Sept 1994	2	9	1	50	22	<1	10	2	2
	July 1995	0	1	0	84	3	9	0	<1	0
	Sept 1995	<1	2	<1	76	4	7	4	1	1
	July 1996	<1	1	<1	92	1	3	2	<1	0
	Sept 1996	<1	0	<1	78	3	10	5	3	<1
PLR16-13 (upstream site)										
	May 1994	<1	<1	0	96	0	3	0	0	0
	Sept 1994	<1	2	0	81	6	8	2	0	<1
	July 1995	0	2	0	41	14	39	4	0	0
	Sept 1995	0	5	1	43	25	16	0	6	4
	July 1996	0	<1	<1	55	5	15	<1	<1	23
	Sept 1996	0	1	<1	82	5	6	0	2	2
PLRMER-7 (downstream site)										
	May 1994	0	6	0	93	0	0	0	0	0
	Sept 1994	<1	2	0	71	25	1	0	0	0
	July 1995	0	1	0	83	14	1	0	0	0
	Sept 1995	<1	0	0	87	5	4	3	0	<1
	July 1996	<1	3	0	92	<1	2	<1	0	0
	Sept 1996	1	<1	2	89	2	3	1	0	1

Table 6. Summary of benthic-invertebrate data for sites on tributaries to the White River—Continued

Field identifier	Date	Annelida: Hirudinea %	Annelida: Oligochaeta %	Insecta: Coleoptera %	Insecta: Diptera %	Insecta: Ephemeroptera %	Insecta: Trichoptera %	Mollusca: Gastropoda %	Mollusca: Pelecypoda %	Turbellaria: Tricladida %
BCSOU-15 (upstream site)										
	May 1994	0	43	<1	55	<1	0	0	0	0
	Sept 1994	2	<1	0	72	5	4	16	0	0
	July 1995	6	0	0	85	0	3	2	0	0
	Sept 1995	0	3	0	65	9	11	11	0	0
	July 1996	14	<1	<1	67	2	9	5	0	<1
	Sept 1996	<1	0	0	49	<1	48	2	0	0
BCGARF-9 (downstream site)										
	May 1994	0	34	0	64	0	0	0	0	0
	Sept 1994	0	0	<1	90	1	5	3	0	0
	July 1995	0	0	0	94	3	3	0	0	0
	Sept 1995	<1	<1	0	90	1	5	3	0	0
	July 1996	<1	4	<1	75	8	12	<1	<1	0
	Sept 1996	0	<1	0	80	0	14	5	0	0
POR21-14 (upstream site)										
	May 1994	<1	9	<1	89	<1	<1	0	0	<1
	Sept 1994	0	4	<1	47	4	24	19	0	<1
	July 1995	0	3	0	38	14	11	35	0	0
	Sept 1995	0	4	<1	27	9	4	54	0	0
	July 1996	<1	3	2	58	5	7	23	0	2
	Sept 1996	0	<1	4	47	<1	38	12	0	0
PORVER-8 (downstream site)										
	May 1994	<1	30	0	68	0	0	0	0	0
	Sept 1994	0	19	0	72	0	<1	9	0	0
	July 1995	0	27	0	73	0	0	0	0	0
	Sept 1995	0	18	<1	56	2	1	21	0	0
	July 1996	<1	3	0	70	0	2	25	0	0
	Sept 1996	2	4	0	90	1	2	2	0	0

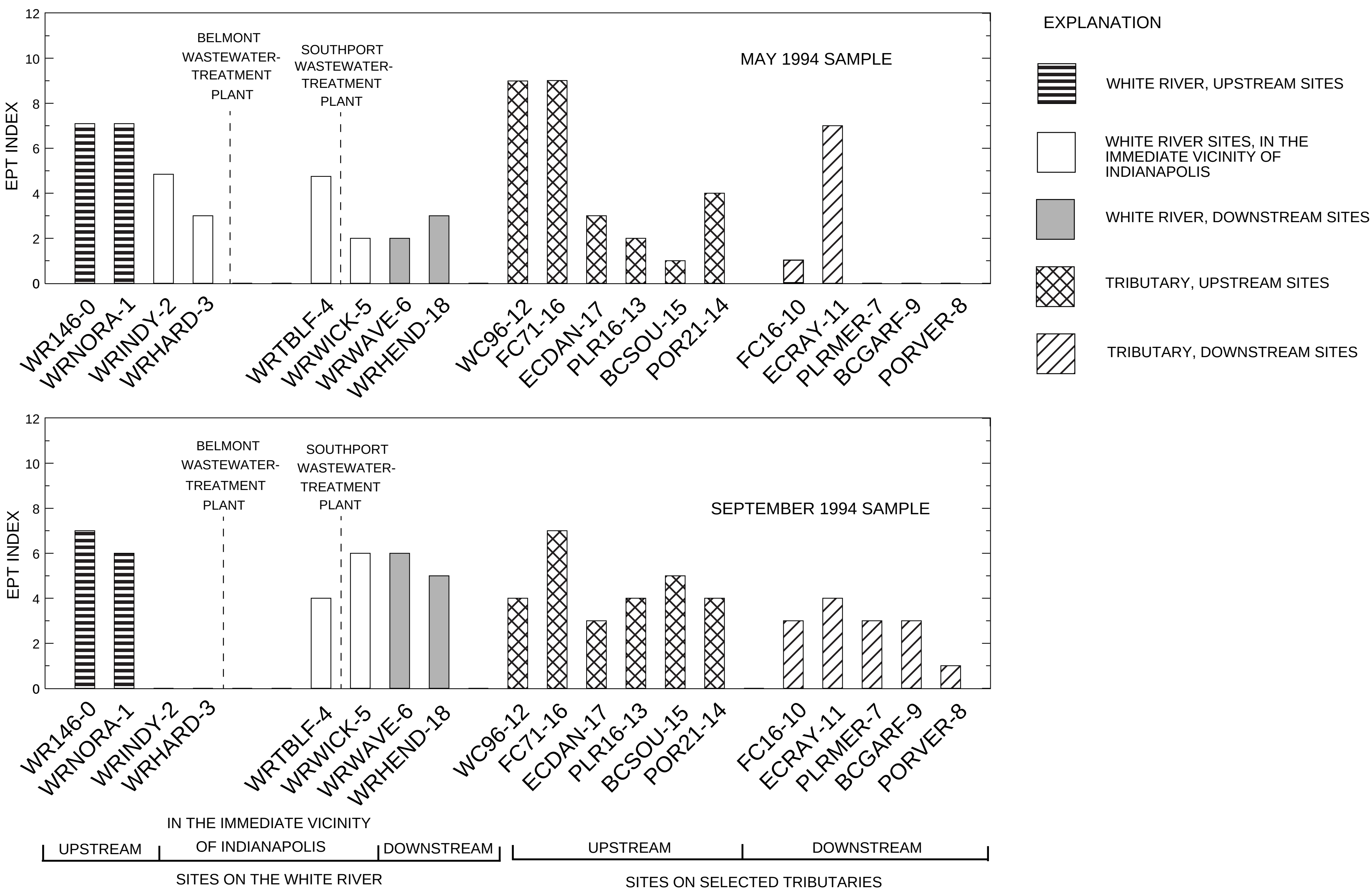


Figure 3. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index values for each sampling period, 1994-96, in the White River and selected tributaries.

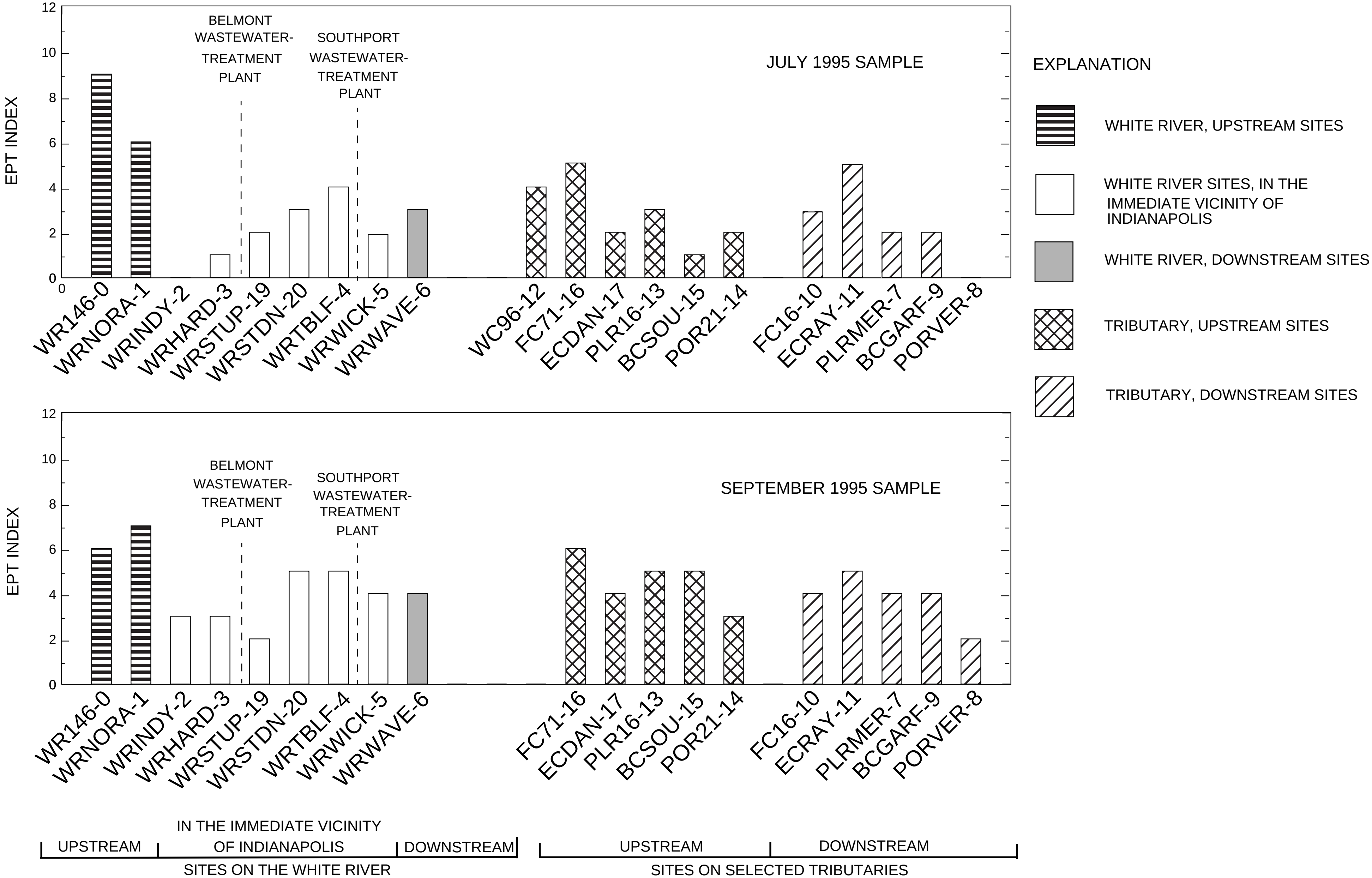


Figure 3. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index values for each sampling period, 1994-96, in the White River and selected tributaries—Continued.

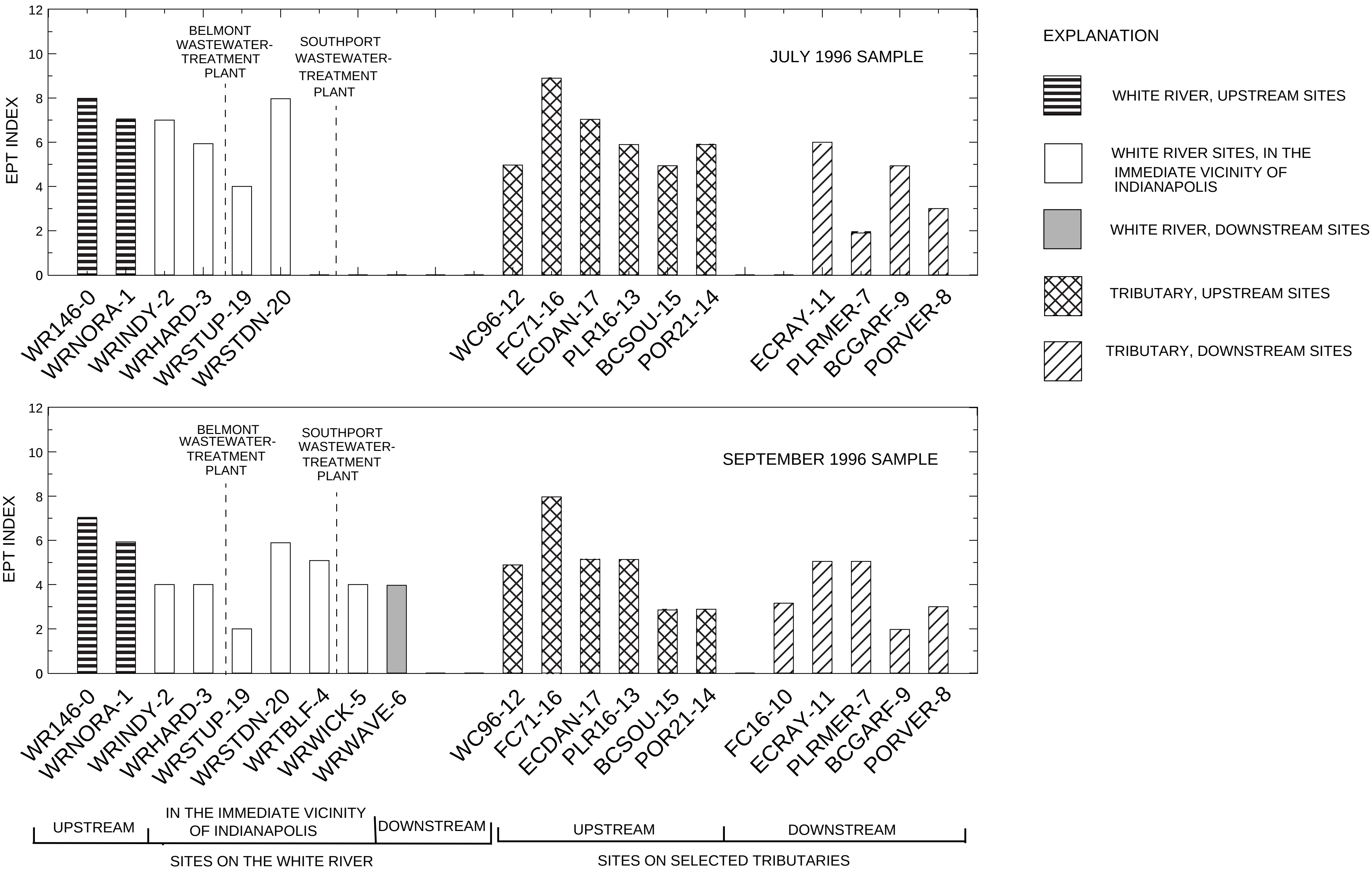


Figure 3. Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index values for each sampling period, 1994–96, in the White River and selected tributaries—Continued.

Wicker Road (WRWICK-5), half of the EPT values ranged from 4 to 6. These EPT values indicate that the diversity and density of pollution-intolerant invertebrates are higher in the upstream reaches than in the downstream reaches of the White River and selected tributaries.

The EPT values for sites downstream from Indianapolis were slightly higher than the EPT values for sites located in the immediate vicinity of Indianapolis but were lower than the EPT values for sites upstream from Indianapolis. The EPT values for sites downstream from Indianapolis ranged from 2 to 6. At the White River near Waverly (WRWAVE-6) site, the EPT values ranged from 2 to 6; at the White River at Henderson Bridge (WRHEND-18) site, the EPT values were 3 and 5. These EPT values support the analysis of benthic-invertebrate data showing that the diversity and density of pollution-intolerant invertebrates increase with distance downstream from Indianapolis. Similar to the HBI, contributing factors to the decreased EPT values in the immediate vicinity of Indianapolis could be the different streamflow characteristics and substrate materials among sites.

For the tributary sites (table 5), the EPT values ranged from 9 at Williams Creek at 96th Street (WC96-12) in May 1994 and at Fall Creek at 71st Street (FC71-16), which occurred in May 1994 and July 1996 (both of which are upstream sites), to 0 at Pleasant Run near South Meridian Street (PLMER-7) in May 1994, Bean Creek at Garfield Park (BCGARF-9) in May 1994, and Pogues Run at Vermont Street (PORVER-8) in May 1994 and July 1995 (all of which are downstream sites). For four of the five tributaries with upstream and downstream sites (with the exception of Eagle Creek), the EPT values for sites upstream generally were higher than the EPT values for the downstream sites. For these tributaries, the maximum difference between the upstream and downstream EPT values were 8 for Fall Creek during May 1994, 4 for Pleasant Run during July 1996, 2 for Bean Creek during September 1994, and 4 for Pogues Run during May 1994. For Eagle Creek, the upstream site almost always had lower EPT values than the downstream site (this may be because the upstream site is 4,000 ft downstream from the outlet of Eagle Creek Reservoir). In general, the EPT values support the HBI analysis discussed later in this report and indicate that the diversity and density of pollution-intolerant invertebrates are greater at the upstream sites compared to the downstream sites in the sampled tributaries. Williams Creek had some of the highest EPT values of the tributaries with EPT values ranging from 4 to 9, with more than half of the values being between 5 or 9. For the tributaries, stream conditions probably are not a contributing factor to the decreased EPT values observed at the downstream sites. All tributary sites had riffle to run streamflow conditions and gravel- and cobble-size substrate material (Renn, 1998).

The high EPT values for sites on the White River upstream from Indianapolis were similar to the high EPT values for the sites on Eagle Creek and the site on Williams Creek. The EPT values at the upstream site on Fall Creek were higher than or equal to values for the upstream sites on the White River. The EPT values for upstream sites on the other tributaries were lower than these values but similar to the EPT values for sites on the White River downstream from Indianapolis. The EPT values for the downstream sites on the tributaries were lower than the EPT values for the upstream tributary sites, while the EPT values for sites on the White River in the immediate vicinity of Indianapolis were the lowest. These values support the analysis of the benthic-invertebrate data that showed that the diversity of pollution-intolerant taxa is greater at the upstream tributary sites than at the downstream sites. Further analysis of the EPT values indicates that, in general, the spring and fall EPT values at each site are similar.

Hilsenhoff Biotic Index

The HBI values calculated for sites on the White River and selected tributaries in and near Indianapolis are presented in tables 3 and 5 and are displayed in figure 4. The data show that for sites on the White River, the HBI values ranged from

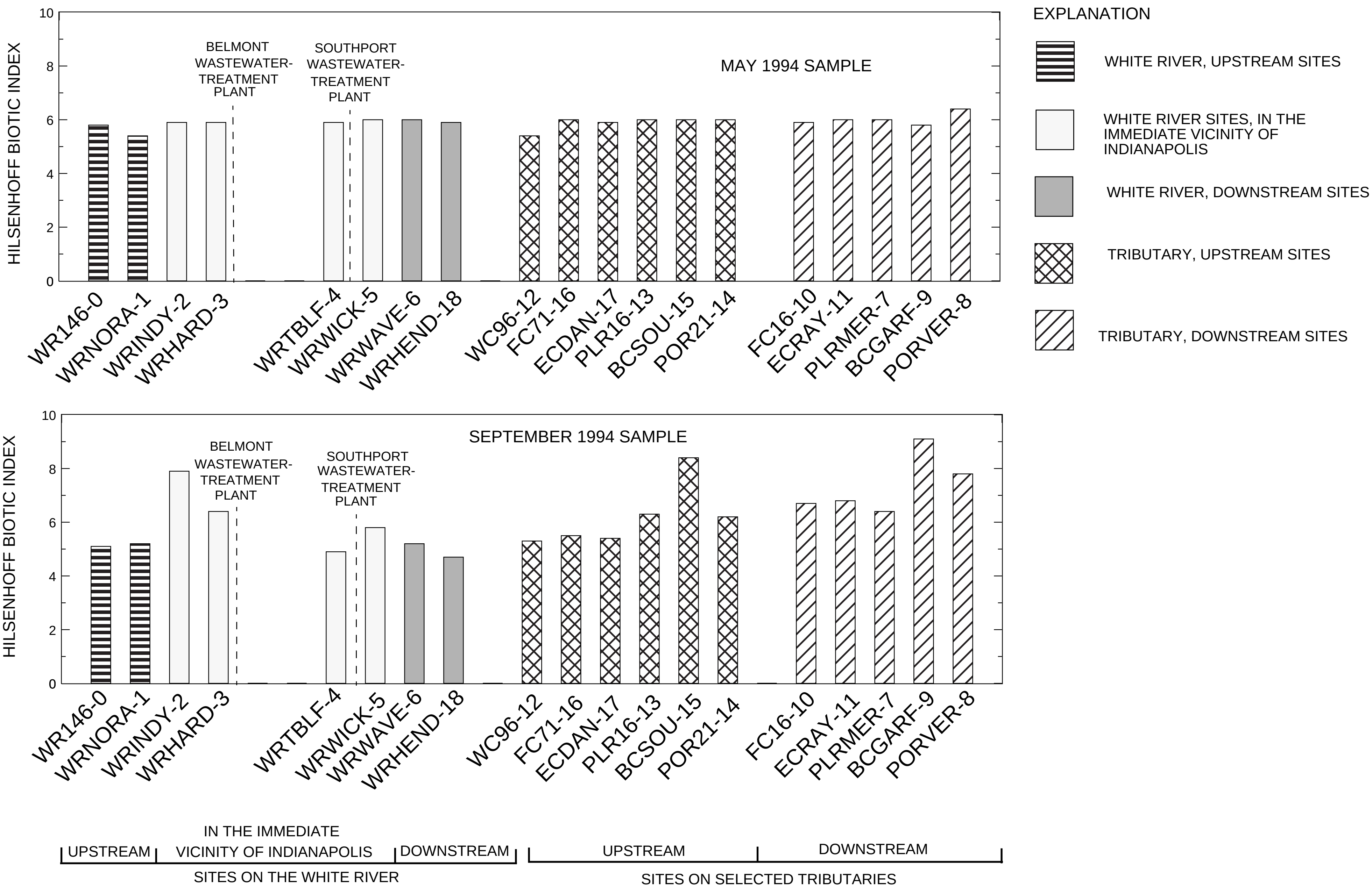


Figure 4. Hilsenhoff Biotic Index (HBI) values for each sampling period, 1994-96, in the White River and selected tributaries.

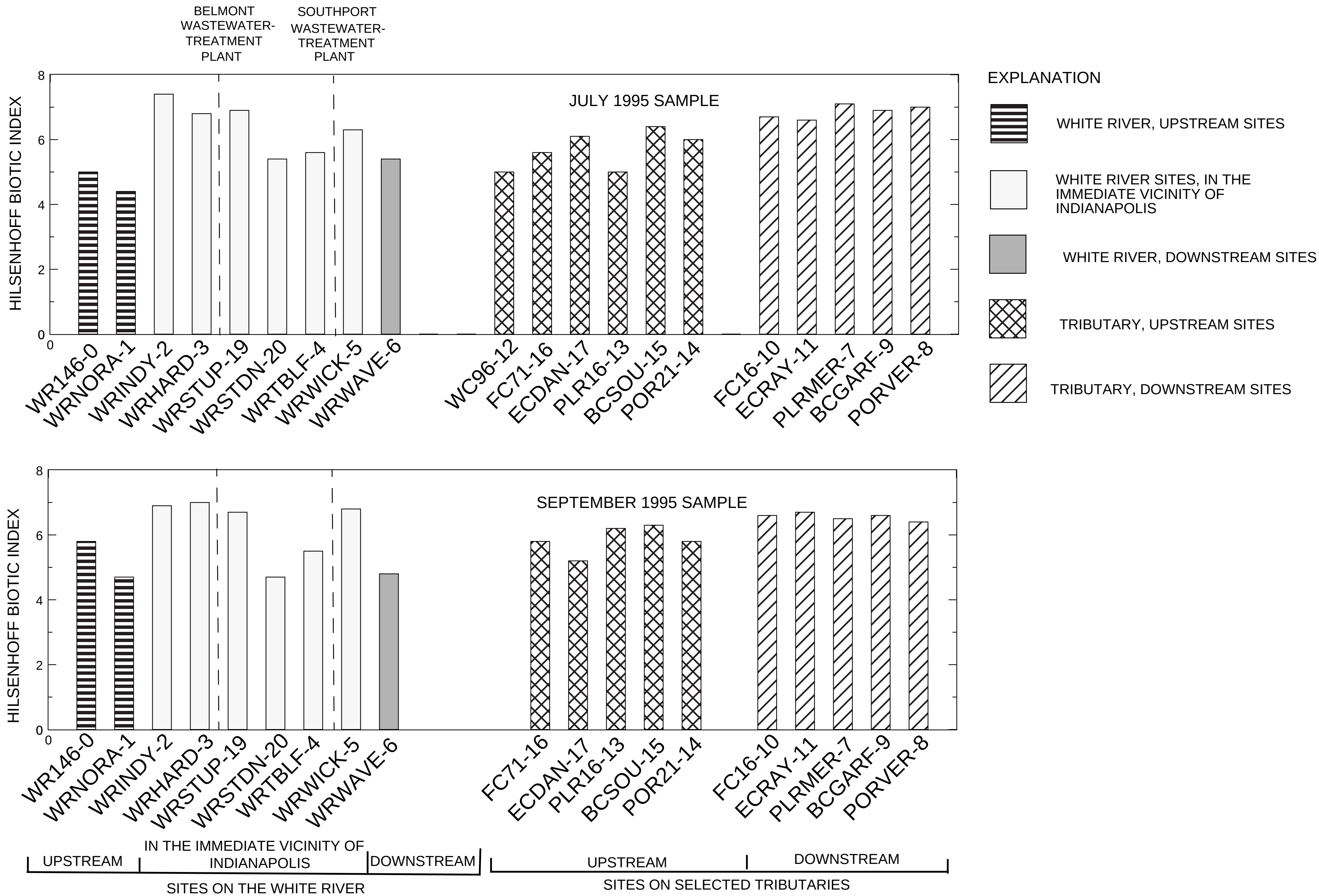


Figure 4. Hilsenhoff Biotic Index (HBI) values for each sampling period, 1994-96, in the White River and selected tributaries—Continued.

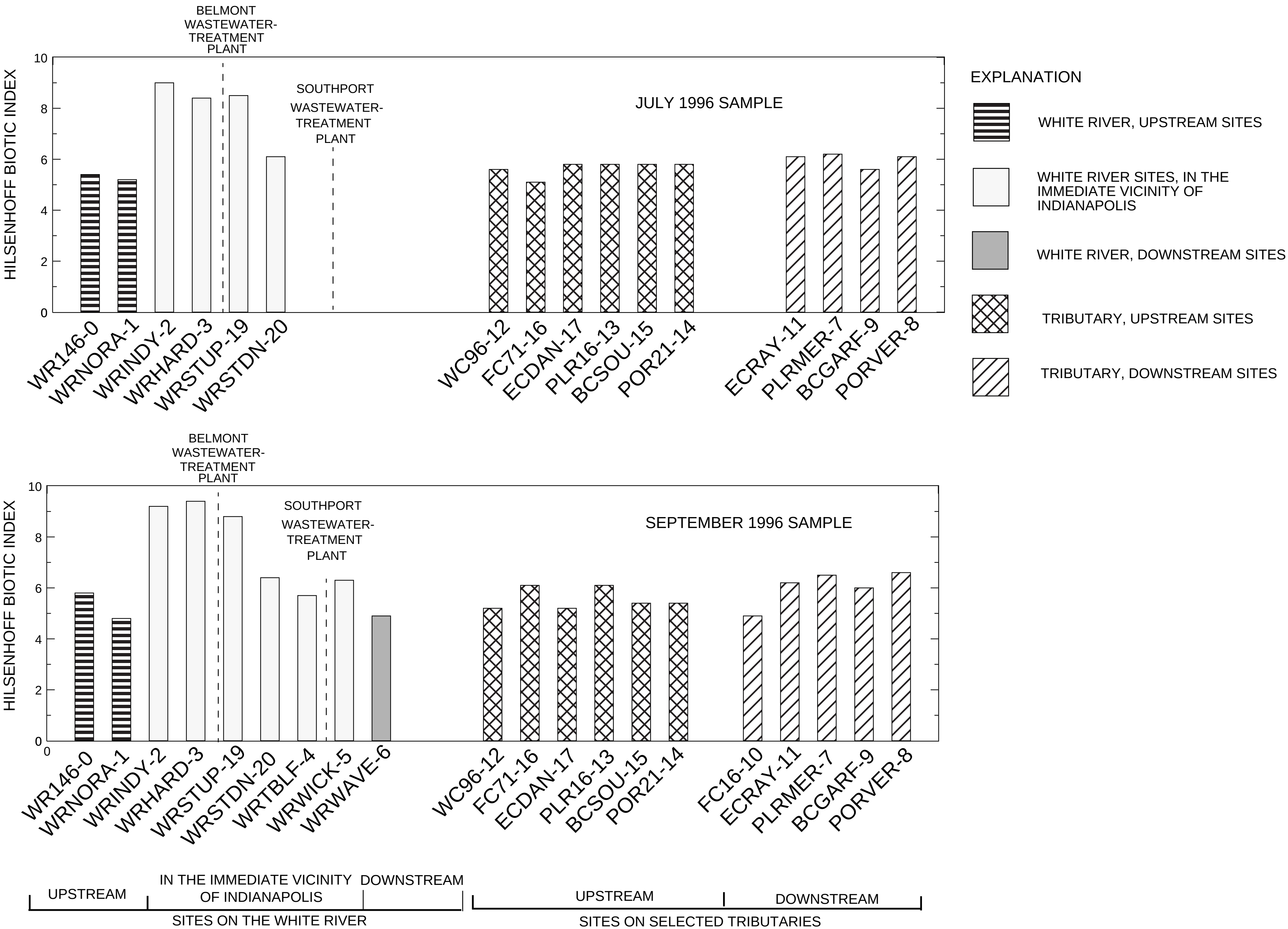


Figure 4. Hilsenhoff Biotic Index (HBI) values for each sampling period, 1994-96, in the White River and selected tributaries—Continued.

4.4 (very good water quality) at White River near Nora (WRNORA-1) to 9.4 (very poor water quality) at White River at Harding Street (WRHARD-3). The HBI values for sites upstream from Indianapolis, White River at 146th Street (WR146-0) and White River near Nora (WRNORA-1), ranged from 4.4 (very good) to 5.8 (fair); these values were lower than the HBI values for sites on the White River located in the immediate vicinity of Indianapolis, which ranged from 4.7 (good) to 9.4 (very poor). Data for May 1994 indicate no real difference in the HBI among the White River sites. The higher HBI values for sites in the immediate vicinity of Indianapolis, compared to sites upstream from Indianapolis, indicate increased effects from organic pollution in the White River as it flows through Indianapolis. Further analysis of the HBI values indicates that, in general, the two yearly HBI values at each site are similar.

The HBI values for sites downstream from Indianapolis—White River near Waverly (WRWAVE-6) and White River at Henderson Bridge (WRHEND-18)—ranged from 4.7 (good) to 6.0 (fair); these values were slightly lower than the HBI values for sites in the immediate vicinity of Indianapolis and similar to the values for sites upstream from Indianapolis. The lower HBI values for sites downstream from Indianapolis, compared to sites in the immediate vicinity of Indianapolis, suggest that the source of the pollution from natural organic compounds is associated with the urban areas of Indianapolis and that the effects of that organic pollution decrease downstream from the city.

Little variation occurred in the HBI for sites upstream and downstream from Indianapolis from 1994 through 1996. At the sites in the immediate vicinity of Indianapolis, however, a decrease in water quality for this period is indicated by the HBI (table 3 and fig. 4).

Although the sampling site White River at Stout Generating Station (WRSTUP-19) is only 1,550 ft upstream from the site White River below Stout Generating Station (WRSTDN-20), the changes in HBI values between the two sites are substantial. The HBI values at the White River at Stout Generating Station ranged from 6.7 (fairly poor) to 8.8 (very poor) water quality, and the values at the White River below Stout Generating Station ranged from 4.7 (good) to 6.4 (fair) water quality. Some of the variation in the benthic communities between these two sites may be related to substrate material sampled, aeration over the dam between the sites, and changes in streamflow characteristics between the pooled upstream site and the riffles downstream from the dam.

The HBI values for the most upstream site on the White River (White River at 146th Street, WR146-0) and the most downstream site with more than one year of data (White River at Waverly, WRWAVE-6) are similar. HBI values at 146th Street range from 5.0 (good) to 5.8 (fair) and from 4.8 (good) to 6.0 (fair) at Waverly. A higher number and diversity of taxa were identified at the White River at 146th Street site than at the White River at Waverly site. At the 146th Street site, the number of pollution-tolerant taxa found during the study is almost twice the number of the pollution-intolerant taxa. At Waverly, the combined number of pollution-intolerant taxa was about twice the number of the pollution-tolerant Diptera. While both sites have fair to good water quality, conditions at Waverly are more conducive to the pollution-intolerant taxa.

For the tributaries, the HBI values ranged from 4.9 (good) at Fall Creek at 16th Street (FC16-10) in September 1996 to 9.1 (very poor) at Bean Creek at Garfield Park (BCGARF-9) in September 1994. With a few exceptions, the HBI values for the upstream tributary sites were lower than the HBI values for the downstream tributary sites. In general, the water quality of the upstream sites was good to fair, with the exception of Bean Creek where the September 1994 sample indicated the upstream water quality was poor. The downstream site on Bean Creek also had a very poor HBI value for the September 1994 sample, which was different from the other samples at that site. The water quality at the downstream sites did not exceed fair, except for the September 1996 sample for Fall Creek which was good. The increased HBI values for the downstream sites indicate increased pollution from natural organic compounds may occur between the upstream and downstream sites. Williams Creek, which had only one sampling site, represents stream conditions not affected by urban activities of Indianapolis but may be affected by suburban activities in the basin. The HBI values at this site were some of the lowest for the tributaries, with values that ranged from 5.0 (good) to 5.6 (fair). For the tributaries, the habitat conditions are probably not a contributing factor to the increased HBI values observed at the downstream sites. All tributary sites had riffle to run streamflow conditions and gravel- and cobble-size substrate material (Renn, 1998).

The HBI values for sites on the White River upstream and downstream from Indianapolis are similar to the HBI values for the upstream sites on the tributaries. As previously mentioned, habitat may be one reason for the decrease in intolerant taxa in the White River in the immediate vicinity of Indianapolis. Another factor that may contribute to the increased HBI values observed at the sites on the White River in the immediate vicinity of Indianapolis is that the tributaries, with the exception of Williams Creek, enter the White River in this area. This area also is subject to the direct effects of urbanization, including urban runoff, CSO discharge, and industrial-municipal discharges.

Comparison to Previous USGS Study, 1981 through 1987

Crawford and others (1992) evaluated the effects of municipal wastewater on the quality of the White River near Indianapolis. In January 1983, the City of Indianapolis completed upgrades to its two wastewater-treatment plants, the Belmont Avenue and Southport Road wastewater-treatment plants. That upgrade of the treatment facilities included ozonation for disinfection of the effluents and, at the beginning of the 1994 disinfection season (April 1 through October 30), the facilities converted to chlorination of effluent. To evaluate the effects of the 1983 upgrades on streamwater quality, benthic-invertebrate samples were collected annually from 1981 through 1987, two times before and five times after the treatment facilities were upgraded, and during periods of relatively low flow in late summer or early fall. Benthic-invertebrate samples were collected at White River at Westfield Boulevard (upstream from the city), White River below Stout Generating Station (in the immediate vicinity of Indianapolis), and White River near Waverly (downstream from Indianapolis). The habitats at each site were similar at the time of sampling. During the 1981 through 1987 study, benthic invertebrates were collected, using a Surber sampler with a sampling area of 0.093 m^2. The mesh size (1,024 µm), however, was much larger than that used in the 1994 through 1996 study (210 µm). Small invertebrates may have been under represented in samples of the 1981 through 1987 study because of the use of a larger mesh size.

Crawford and others (1992) found that most of the benthic-invertebrate community belonged to one of six taxa: the pollution-intolerant taxa Ephemeroptera and Trichoptera and the more pollution-tolerant taxa Diptera, Gastropoda, Hirudinea, and Oligochaeta. The benthic communities found during the 1994 through 1996 study also belonged to the same six taxonomic groups, but the highest percentage of taxa belonged to three groups—Ephemeroptera, Trichoptera, and Diptera. Comparison of the pollution-intolerant and the pollution-tolerant taxa at the most upstream site during the 1981 through 1987 study (White River at Westfield Boulevard) and the most upstream site during the 1994 through 1996 study (White River near Nora) shows that, in general, the pollution-intolerant taxa were a higher percentage of the total taxa than the pollution-tolerant taxa during both studies (fig. 5). The two

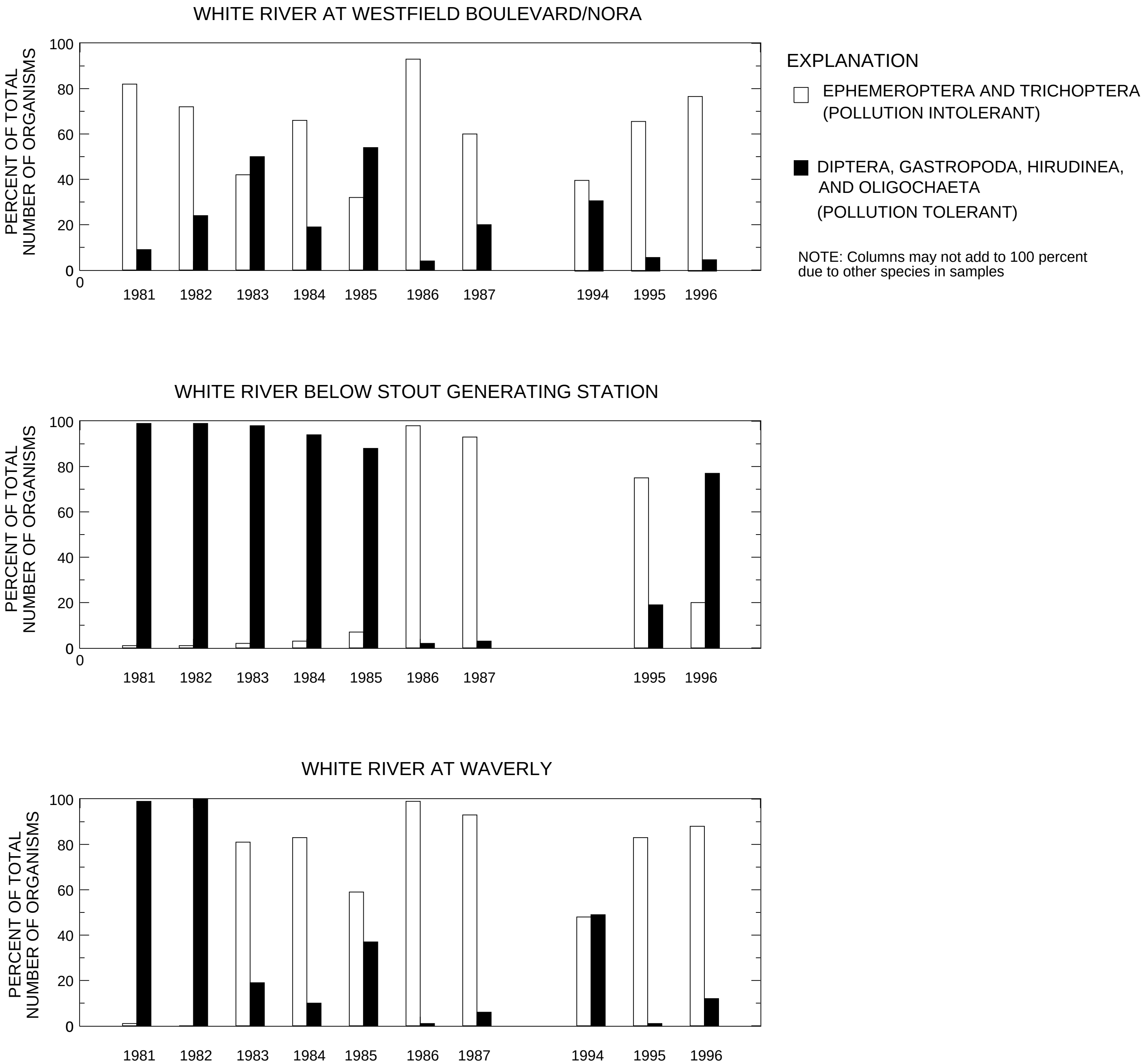


Figure 5. Changes in pollution-tolerant (Diptera, Gastropoda, Hirudinea, and Oligochaeta) and pollution-intolerant (Ephemeroptera and Trichoptera) organisms with time in the White River near Indianapolis, Indiana, 1981–87 and 1994–96.

sites are about 5 river miles apart, but both represent conditions upstream from the influences of urban Indianapolis. There was no significant difference in the percent of total number of pollution-tolerant and intolerant invertebrates between the 1981 through 1987 study and the data collected during the 1994 through 1996 study, indicating that there has been little or no change in the water quality above Indianapolis since 1987.

The HBI also can be used to compare the 1994 through 1996 water quality to historical water quality. Crawford and others (1992) calculated HBI values at each site for each annual sample. At the White River at Westfield Boulevard, the HBI values for 1981 to 1987 ranged from 5.03 to 6.69, indicating water quality that varied from good to fairly poor. This site can be compared to White River near Nora, where HBI values for 1994 through 1996 ranged from 4.4 to 5.4, indicating very good to good water quality. These results indicate that the water quality has improved slightly between the two sampling periods.

A plot of the data for the White River below Stout Generating Station (WRSTDN-20) indicates that the benthic-invertebrate community sampled during the 1994 through 1996 study differs somewhat from that present during the 1981 through 1987 study (fig. 5). The number of pollution-intolerant taxa increased significantly between 1983 to 1987 after the wastewater-treatment-plant improvements were completed. During the 1994 through 1996 study, the percentage of pollution-intolerant taxa is much higher than the percentage found during 1981 and 1982; the percentage of pollution-tolerant taxa, however, is a much higher percentage of the total taxa than during 1986 or 1987. This indicates that the 1994 through 1996 water quality may be better than during 1981 and 1982 but is of poorer quality than during 1986 and 1987. Also noteworthy is the reversal in communities from 1995 to 1996 at this site. Other than the significant increase in streamflow during 1996 (fig. 2), there is no apparent reason for the decrease in pollution-intolerant species in 1996. This reversal was not evident at other sites, indicating the possibility of a local change in water quality prior to the collection of samples in 1996.

During the 1981 through 1987 study, the HBI values for the White River below Stout Generating Station ranged from 5.06 to 8.41, reflecting good to poor water quality. During the 1994 through 1996 study, the HBI values at the White River below Stout Generating Station ranged from 4.7 to 6.4, or from good to fair water quality. These results indicate some improvement, with little change in the water quality at the White River below Stout Generating Station since 1987 (with the exception of the 1996 reversal in tolerant versus intolerant species) (fig. 5).

Crawford and others (1992) found that the number of pollution-intolerant taxa increased as a percentage of the total number of taxa at the White River at Waverly after the upgraded wastewater-treatment plants became operational in January 1983. The distribution of pollution-tolerant and intolerant taxa found during the 1994 through 1996 study is similar to the distribution Crawford and others (1992) found after the wastewater-treatment-plant improvements were made. In 1994, the number of pollution-tolerant taxa was about equal to the number of pollution-tolerant species, indicating at least a temporary change in water quality at the site.

The HBI values computed for 1981 through 1987 for the White River near Waverly ranged from 5.21 to 9.88, indicating water quality that varied from good to very poor (Crawford and others, 1992). During the 1994 through 1996 sampling, the HBI values at the White River near Waverly ranged from 4.8 to 6.0, indicating good to fair water quality. The later sampling indicates that the water quality at White River at Waverly compares favorably with the last 5 years of sampling during the 1981 through 1987 study. These results indicate little change in the water quality at White River at Waverly since 1987.

Results of the analyses of the 1994 through 1996 benthic-invertebrate data indicate that the water quality upstream and downstream from Indianapolis is similar to that found after the upgraded Indianapolis wastewater-treatment plants became operational. Comparison of the HBI values also indicates little or no change in water quality since the 1981 through 1987 study by Crawford and others (1992).

Analysis of Streambed Sediments

Thirty-three streambed-sediment samples, collected at 14 sites during 1994 through 1996, were analyzed for selected metals, pesticides, and semivolatile organic compounds (Renn, 1998). Five sites were sampled in 1994 and 1996, and four sites were sampled in 1995. Analytical results from the samples were examined to determine if temporal patterns exist in the streambed-sediment data. The highest concentrations of metals were detected in samples collected during 1996. These concentrations may be because of the above-average streamflows in spring 1996 prior to the sampling (fig. 2). No other temporal patterns were seen. Descriptive statistics for selected constituents are listed in table 7.

Sediment-quality guidelines for the protection of aquatic life (table 8) were used as criteria to determine if the concentrations of metals, pesticides, and semivolatile organic compounds detected in the streambed-sediment samples could affect receiving waters. The sediment-quality guidelines for freshwater sediments were developed in Canada (Canadian Council of Ministers of the Environment, 1995) by evaluating the sources of chemicals to the aquatic environment, their distribution in sediments, their behavior and persistence in sediments, their potential to bioaccumulate, and their effects on aquatic organisms that are exposed to the sediments. Two assessment values were calculated, the threshold effect level (TEL) and the probable effect level (PEL) for 23 compounds in freshwater environments. The TEL represents the concentrations below which effects on aquatic life occur rarely and the PEL represents the concentrations above which effects on aquatic life occur frequently. PEL's were used to determine if the chemical constituents detected during the study could have an adverse effect on aquatic life.

Metals

Twelve metals were detected in the streambed-sediment samples (Renn, 1998). These metals are aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese,

Table 8. Freshwater-sediment threshold effect and probable effect levels for the protection of aquatic life (Modified from Canadian Council of Ministers of the Environment, 1995)

[µg/g, microgram per gram; µg/kg, microgram per kilogram]

Chemical constituent	Threshold effect level[1]	Probable effect level[2]
Metals (µg/g)		
Arsenic	5.90	17
Cadmium	.596	3.53
Chromium	37.3	90
Copper	35.7	197
Lead	35.0	91.3
Mercury	.174	.486
Nickel	18.0	35.9
Zinc	123	315
Pesticides (µg/kg)		
Chlordane	4.5	8.9
DDT, total	6.98	4,450
p,p'-DDD	3.54	8.51
p,p'-DDE	1.42	6.75
Dieldrin	2.85	6.67
Endrin	2.67	62.4
Heptachlor epoxide	.60	2.74
Lindane	.94	1.38
Miscellaneous organics (µg/kg)		
PCB's, total	34.1	277
Semivolatile organic compounds (µg/kg)		
Benzo(a)anthracene	31.7	385
Benzo(a)pyrene	31.9	782
Chrysene	57.1	862
Fluoranthene	111	2,355
Phenanthrene	41.9	515
Pyrene	53.0	875

[1]Threshold effect level (TEL): the concentration below which adverse effects on aquatic life occur rarely.

[2]Probable effect level (PEL): the concentration above which adverse effects are predicted to occur frequently.

Table 7. Descriptive statistics for selected constituents for 33 streambed-sediment samples collected at sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96

[µg/g, microgram per gram; < , less than; mg/kg, milligram per kilograms; µg/kg, microgram per kilogram; Ins. Dat., insufficient data to compute statistics; g/kg, gram per kilogram; mm, millimeter]

Constituent	Median	Mean	Minimum	Maximum	Interquartile range	Number of samples below detection level
Metals						
Aluminum (µg/g)	1,300	1,780	150	4,800	1,445	0
Arsenic (µg/g)	3	3.33	2	9	2	0
Cadmium (µg/g)	1	1.07	<1	3	.117	8
Chromium (µg/g)	6	8.46	1	70	5.5	0
Copper (µg/g)	10	22.3	10	97	11	0
Iron (µg/g)	5,600	5,580	380	17,000	4,550	0
Lead (µg/g)	20	30.8	<10	140	20	2
Magnesium (mg/kg)	28,000	28,600	14,000	51,000	8,000	0
Manganese (µg/g)	230	258	86	840	110	0
Mercury (µg/g)	.02	.051	<.01	.34	.045	6
Nickel (µg/g)	10	14.6	<10	30	10	3
Zinc (µg/g)	30	39.8	5	190	25	0
Pesticides						
Chlordane (µg/kg)	5	10.7	1	40	15	0
DDT (µg/kg)	.10	.178	<.1	.7	.242	13
DDD (µg/kg)	.4	1.08	<.1	5.3	1.45	2
DDE (µg/kg)	.4	.636	.1	3.4	.7	0
Diazinon (µg/kg)	.4	.578	<.2	1.9	.65	2
Dieldrin (µg/kg)	.7	.883	<.1	2.8	.9	5
Endosulfan (µg/kg)	Ins. Dat.	Ins. Dat.	<.1	.1	Ins. Dat.	30
Endrin (µg/kg)	Ins. Dat.	Ins. Dat.	<.1	2	Ins. Dat.	31
Heptachlor (µg/kg)	Ins. Dat.	Ins. Dat.	<.1	.1	Ins. Dat.	32
Heptachlor epoxide (µg/kg)	.0858	.115	<.1	.4	.147	20
Lindane (µg/kg)	Ins. Dat.	Ins. Dat.	<.1	.1	Ins. Dat.	29
Malathion (µg/kg)	Ins. Dat.	Ins. Dat.	<.2	.3	Ins. Dat.	30
Miscellaneous organics						
PCB's (µg/kg)	15	30.1	<1	220	28.5	2

Table 7. Descriptive statistics for selected constituents for 33 streambed-sediment samples collected at sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96—Continued

Constituent	Median	Mean	Minimum	Maximum	Interquartile range	Number of samples below detection level
Semivolatile organic compounds						
Acenaphthylene (µg/kg)	Ins. Dat.	Ins. Dat.	<200	210	Ins. Dat.	32
Anthracene (µg/kg)	Ins. Dat.	Ins. Dat.	<200	550	Ins. Dat.	28
Benzo(a)pyrene (µg/kg)	238	360	<400	1,700	370	23
Benzo(b)fluoranthene (µg/kg)	311	415	<400	1,300	383	21
Benzo(k)fluoranthene (µg/kg)	207	314	<400	1,500	290	26
Benzo(a)anthracene (µg/kg)	136	342	<400	2,400	270	25
Benzo(ghi)perylene (µg/kg)	Ins. Dat.	Ins. Dat.	<400	930	Ins. Dat.	29
Bis(2-ethylhexyl)phthalate (µg/kg)	156	182	<200	490	129	23
Butyl benzyl phthalate (µg/kg)	Ins. Dat.	Ins. Dat.	<200	660	Ins. Dat.	32
Chrysene (µg/kg)	214	362	<400	2,000	370	25
Dibenz(a,h)anthracene (µg/kg)	Ins. Dat.	Ins. Dat.	<400	550	Ins. Dat.	32
Fluoranthene (µg/kg)	320	677	<200	3,600	830	15
Fluorene (µg/kg)	Ins. Dat.	Ins. Dat.	<200	270	Ins. Dat.	32
Indeno(1,2,3-cd)pyrene (µg/kg)	Ins. Dat.	Ins. Dat.	<400	810	Ins. Dat.	29
Naphthalene (µg/kg)	Ins. Dat.	Ins. Dat.	<200	320	Ins. Dat.	32
Phenanthrene (µg/kg)	152	396	<200	2,900	491	21
Pyrene (µg/kg)	280	588	<200	3,100	770	15
Inorganic and inorganic + organic carbon						
Carbon, inorganic (g/kg)	37	37.8	19	59	7	0
Carbon, inorganic+organic (g/kg)	44	45.5	26	78	12	0
Streambed sediment						
Percentage finer than 0.125 (mm)	2.1	3.04	.4	24.6	1.8	0
Percentage finer than 0.062 (mm)	.7	1.02	.2	6.4	.65	0

mercury, nickel, and zinc. Aluminum, arsenic, chromium, copper, iron, magnesium, manganese, and zinc were detected in all 33 samples, with aluminum, iron, magnesium, and manganese having the highest concentrations. Cadmium was detected in 25 samples from all 14 sites; lead was detected in 31 samples from all 14 sites; mercury was detected in 27 samples from all 14 sites; and nickel was detected in 30 samples from 13 sites (fig. 6). The samples also were analyzed for cyanide, but no sample had a concentration of cyanide above the detection limit.

Concentrations of copper, lead, mercury, and zinc are higher in the immediate vicinity of Indianapolis than they are upstream or downstream from the city (fig. 6), indicating that the source of these metals likely is related to urban activities within the immediate vicinity of the city.

Data collected in the White River Basin since 1991 as part of the USGS National Water-Quality Assessment (NAWQA) Program showed similar distributions of lead and mercury in fine-grained

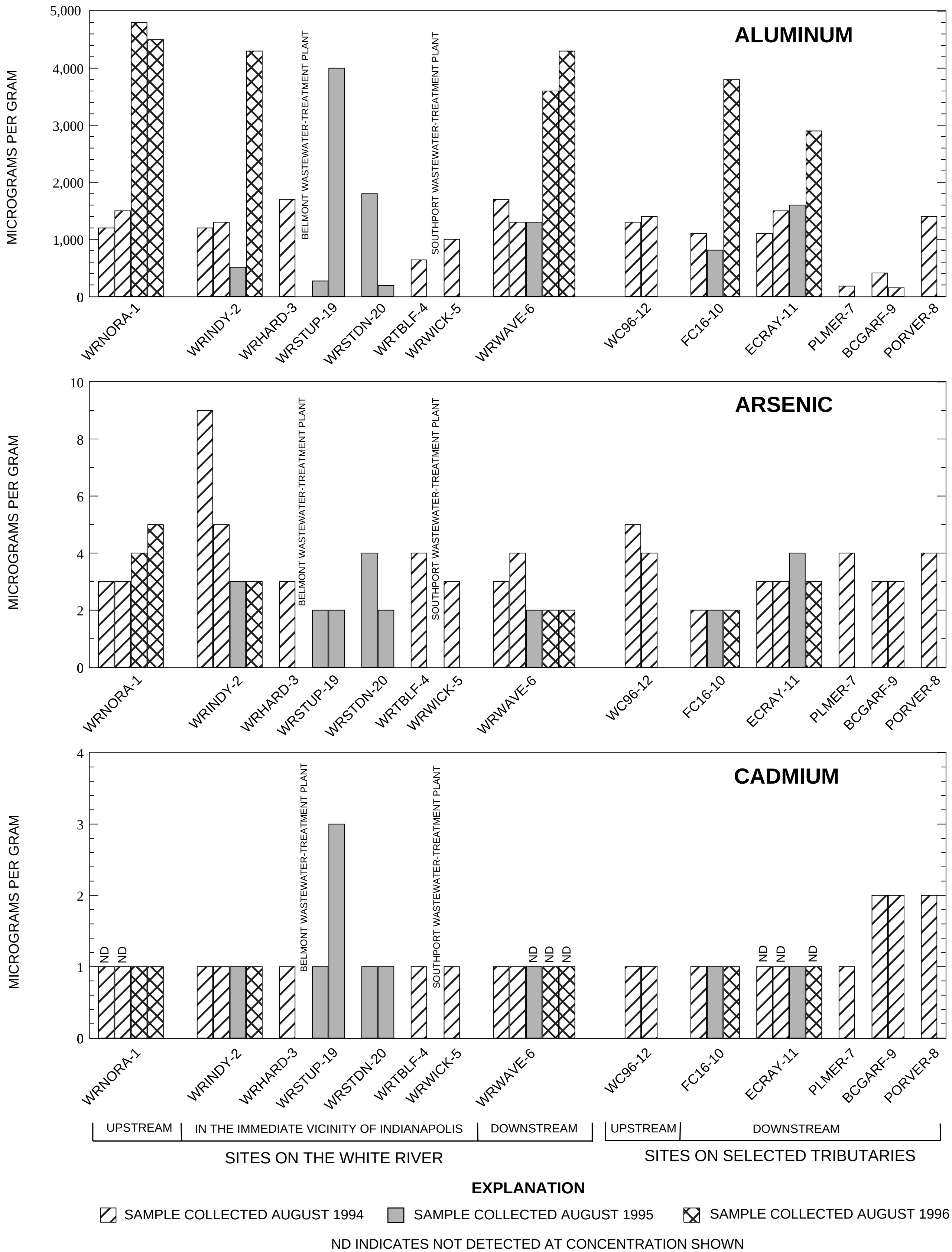


Figure 6. Concentrations of selected metals in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96.

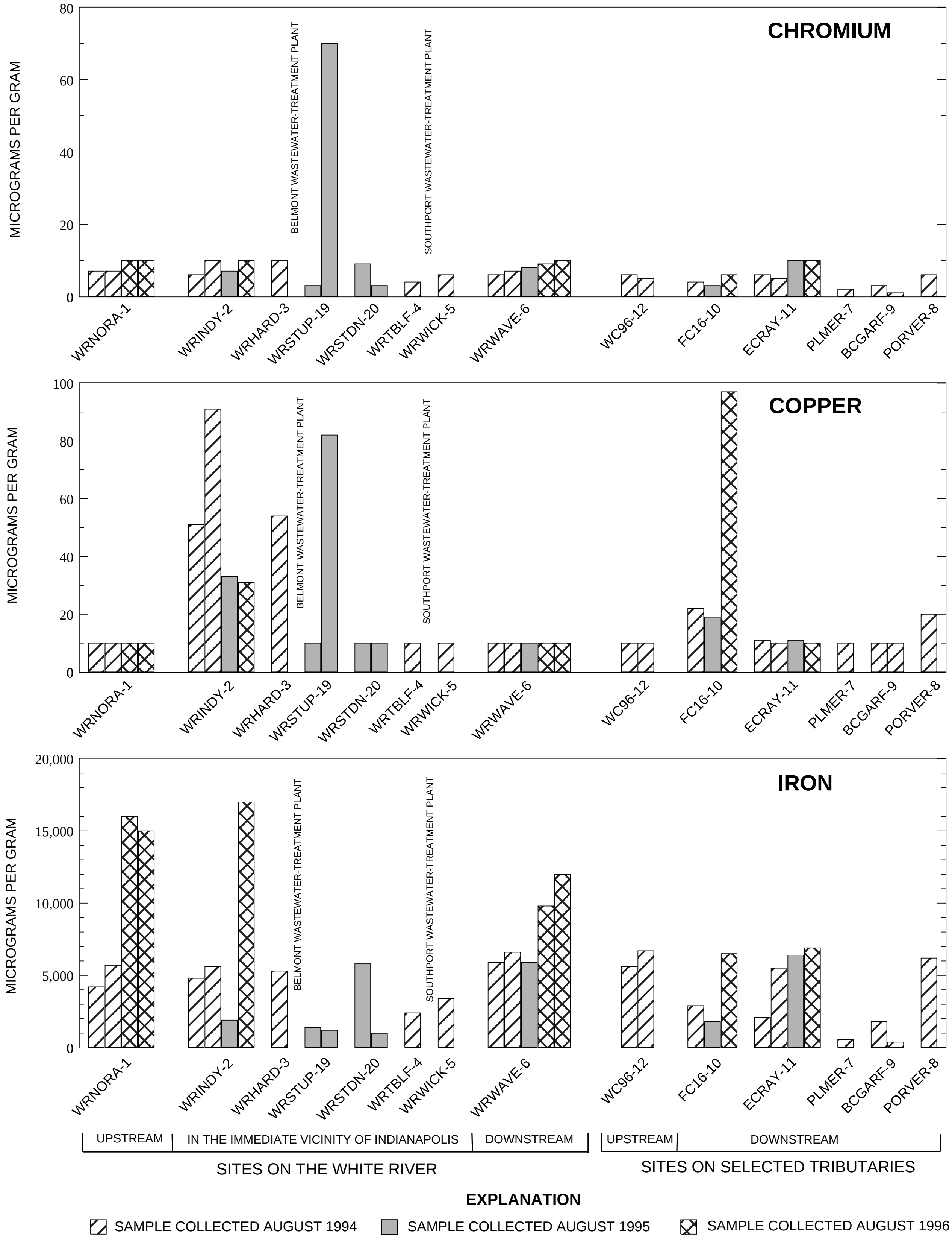


Figure 6. Concentrations of selected metals in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96—Continued.

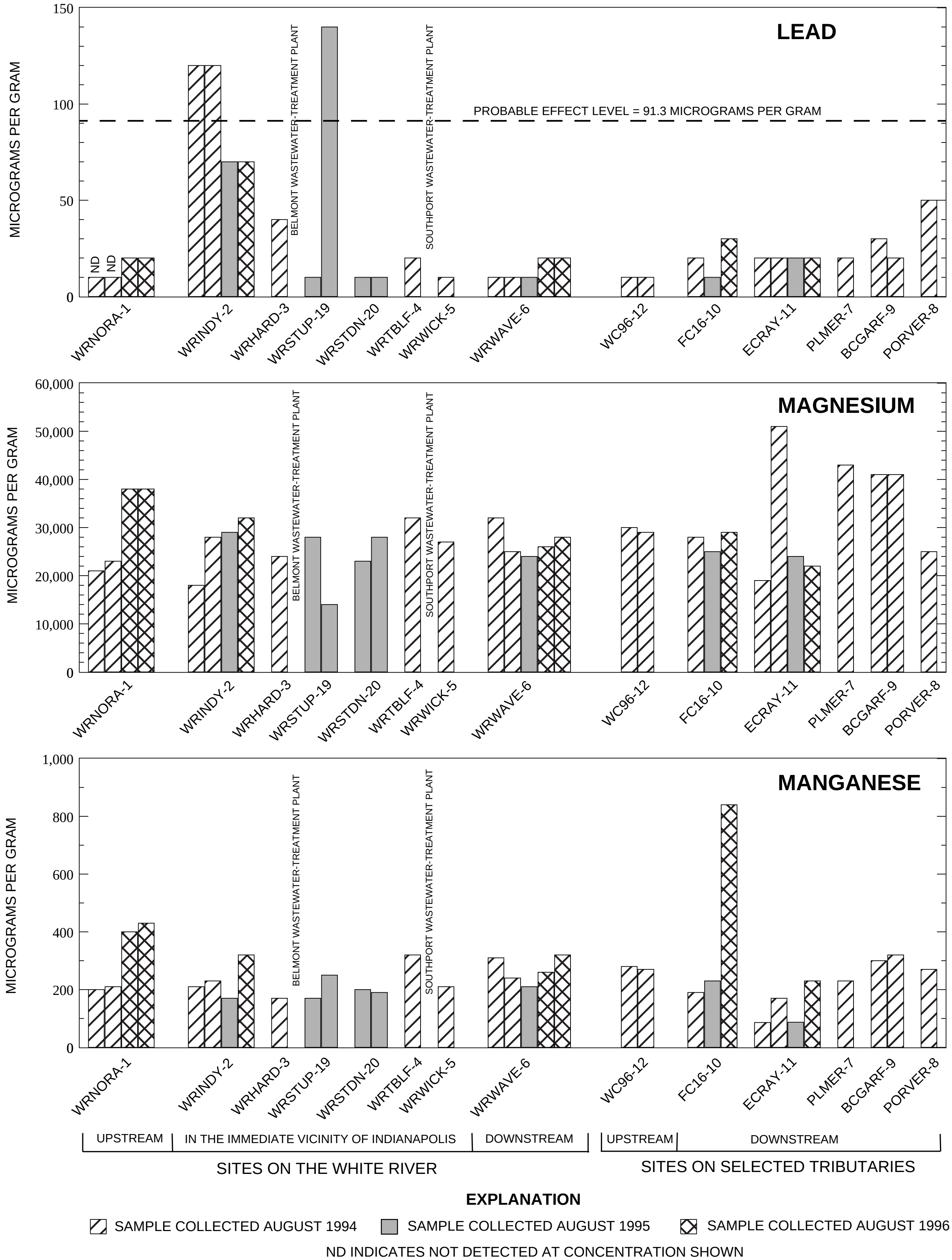


Figure 6. Concentrations of selected metals in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96—Continued.

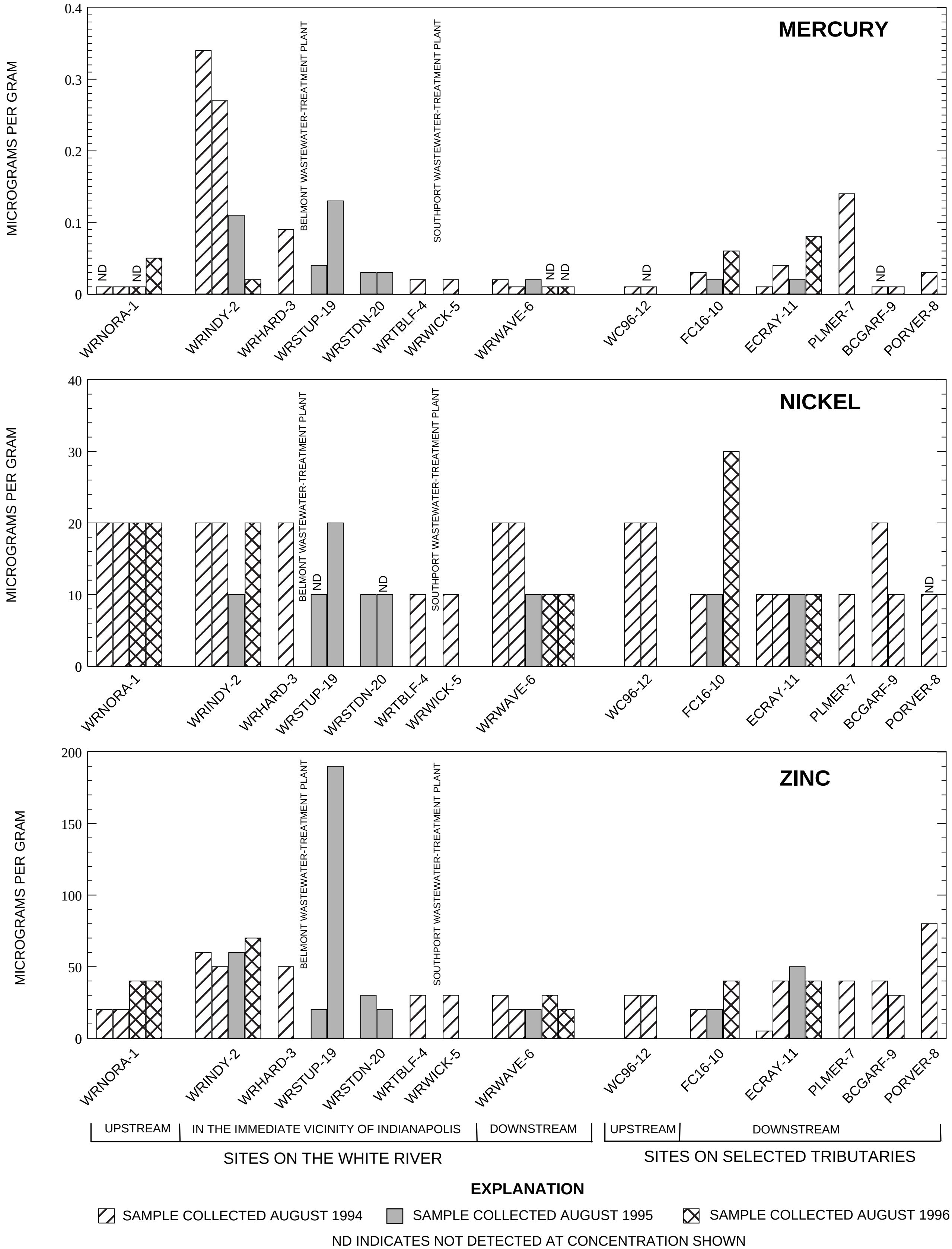


Figure 6. Concentrations of selected metals in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96—Continued.

sediments (<63 μm) throughout the basin, similar to those determined in this study. The highest concentrations of these metals were in the Indianapolis area, and the lowest concentrations were in rural areas (W.W. Stone, written commun., 1997).

The Canadian sediment-quality guidelines suggest PEL's for 8 of the 12 metals detected in the streambed sediments collected in this study—arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Of these, only lead exceeded the PEL of 91.3 μg/g (micrograms per gram) (table 8) in three samples from two sites (table 9). The maximum lead concentration detected was 140 μg/g at the White River above Stout Generating Station (WRSTUP-19). Lead also exceeded the PEL in two samples at the White River at Indianapolis (WRINDY-2), both with concentrations of 120 μg/g. Because the two sites that exceeded the PEL for lead are in the immediate vicinity of Indianapolis, the source of this lead may be related to urban activities.

Herbicides, Insecticides, and Polychlorinated Biphenyls

Streambed sediments were analyzed for 5 herbicides and 23 insecticides and polychlorinated biphenyls (PCB's). No herbicides were detected in the samples, but 12 insecticides were found in concentrations above detection limits. These are chlordane, DDT, DDD, DDE, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, and malathion. PCB's also were detected in 31 samples (table 9). Chlordane and DDE were detected in all samples from all sites; diazinon and dieldrin were detected in most samples at all sites; DDT, DDD, and PCB's were detected in most samples at 13 sites; heptachlor epoxide was detected in 13 samples at 9 sites; and endosulfan, endrin, heptachlor, lindane, and malathion had the lowest number of detections (table 9).

Chlordane, DDT, dieldrin, endosulfan, endrin, heptachlor, and lindane are organochlorine insecticides. DDD and DDE are degradation products of DDT, and heptachlor epoxide is the degradation product of heptachlor. Organochlorine insecticides are a class of organic insecticides that contain 50 percent or more chlorine. Organochlorine insecticides have extremely low water solubility and strong sorption tendencies and are characterized by their persistence in the environment. Routes of loss and degradation include runoff, volatilization, photolysis, and aerobic and anaerobic biodegradation (Larson and others, 1997). In general, these processes occur very slowly.

The use of organochlorine insecticides in the United States began in the 1940's and continued into the 1970's, with peak use occurring in the late 1950's and early 1960's (Larson and others, 1997). The use of most organochlorine insecticides in the United States was banned or severely restricted by the U.S. Environmental Protection Agency (USEPA) in the early to mid-1970's as potentially adverse human-health and ecological effects of these compounds became apparent.

The use of chlordane was banned in 1988; between 1983 and 1988, the only permitted use for chlordane was for control of subterranean termites (EXTOXNET, 1993). The range of concentrations of chlordane, 1 to 40 μg/kg (micrograms per kilogram), detected in the streambed-sediment samples is shown in table 7. Figure 7 shows that the highest concentrations of chlordane are found at sites in the immediate vicinity of Indianapolis, and the concentrations at these sites exceeded the 8.9 μg/kg PEL for chlordane (table 8). The maximum chlordane concentration detected was 40 μg/kg at Pogues Run at Vermont Street (PORVER-8). These concentrations likely are the remnants of efforts to control subterranean termites in the urban areas of Indianapolis or are from the movement of contaminated sediments upstream.

Table 9. Summary of detections for selected constituents for 33 streambed-sediment samples collected at sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96

[PEL, probable effect level; --, no PEL; µg/g, microgram per gram; mg/kg, milligram per kilogram; µg/kg, microgram per kilogram; g/kg, gram per kilogram]

Chemical constituent	Maximum concentration	Number of sites at which detected	Number of samples in which detected	Number of sites exceeding PEL	Number of samples exceeding PEL
Metals					
Aluminum (µg/g)	4,800	14	33	--	--
Arsenic (µg/g)	9	14	33	0	0
Cadmium (µg/g)	3	14	25	0	0
Chromium (µg/g)	70	14	33	0	0
Copper (µg/g)	97	14	33	0	0
Iron (µg/g)	1,700	14	33	--	--
Lead (µg/g)	140	14	31	2	3
Magnesium (µg/kg)	51,000	14	33	--	--
Manganese (µg/g)	840	14	33	--	--
Mercury (µg/g)	.34	14	27	0	0
Nickel (µg/g)	30	13	30	0	0
Zinc (µg/g)	190	14	33	0	0
Pesticides					
Chlordane (µg/kg)	40.0	14	33	8	15
DDT (µg/kg)	.70	13	20	0	0
DDD (µg/kg)	5.30	13	31	0	0
DDE (µg/kg)	3.40	14	33	0	0
Diazinon (µg/kg)	1.90	14	31	--	--
Dieldrin (µg/kg)	2.80	14	28	0	0
Endosulfan (µg/kg)	.10	3	3	--	--
Endrin (µg/kg)	2.00	2	2	0	0
Heptachlor (µg/kg)	.10	1	1	--	--
Heptachlor epoxide (µg/kg)	.40	9	13	0	0
Lindane (µg/kg)	.10	3	4	0	0
Malathion (µg/kg)	.30	2	3	--	--
Miscellaneous organics					
PCB's (µg/kg)	220	13	31	0	0

Table 9. Summary of detections for selected constituents for 33 streambed-sediment samples collected at sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96—Continued

Chemical constituent	Maximum concentration	Number of sites at which detected	Number of samples in which detected	Number of sites exceeding PEL	Number of samples exceeding PEL
Semivolatile organic compounds					
Acenaphthylene (µg/kg)	210	1	1	--	--
Anthracene (µg/kg)	550	4	5	--	--
Benzo(a)pyrene (µg/kg)	1,700	7	10	3	3
Benzo(b)fluoranthene (µg/kg)	1,300	8	12	--	--
Benzo(k)fluoranthene (µg/kg)	1,500	5	7	--	--
Benzo(a)anthracene (µg/kg)	2,400	5	8	5	8
Benzo(ghi)perylene (µg/kg)	930	4	4	--	--
Bis(2-ethylhexyl)phthalate (µg/kg)	490	6	10	--	--
Butyl benzyl phthalate (µg/kg)	660	1	1	--	--
Chrysene (µg/kg)	2,000	5	8	3	3
Dibenz(a,h)anthracene (µg/kg)	550	1	1	--	--
Fluoranthene (µg/kg)	3,600	9	18	2	2
Fluorene (µg/kg)	270	1	1	--	--
Indeno(1,2,3-cd)pyrene (µg/kg)	810	4	4	--	--
Naphthalene (µg/kg)	320	1	1	--	--
Phenanthrene (µg/kg)	2,900	7	12	5	9
Pyrene (µg/kg)	3,100	9	18	5	8
Inorganic and inorganic + organic carbon					
Carbon, inorganic (g/kg)	59	14	33	--	--
Carbon, inorganic+organic (g/kg)	78	14	33	--	--

The use of DDT was banned in the U.S. in 1972 (EXTOXNET, 1993). Table 7 shows the range of concentrations of DDT and the degradation products of DDT—DDD and DDE—detected in the streambed-sediment samples. All three constituents show higher concentrations at sampling sites on the White River in the immediate vicinity of Indianapolis than at sites upstream and downstream from Indianapolis. Figure 7 also shows that the concentrations of DDT and its degradation products are higher at sites on Fall Creek and Bean Creek. The highest concentrations of DDT (0.7 µg/kg) and DDD (5.3 µg/kg) were detected in samples from the White River at Indianapolis (WRINDY-2) site. The maximum concentration of DDE (3.4 µg/kg) was detected at the Bean Creek at Garfield Park (BCGARF-9) site. The PEL's for DDT, DDD, and DDE were not exceeded in samples from any site during this study.

Dieldrin was banned for use in the U.S. in 1985 except for subsurface termite control, dipping non-food roots and tops, and moth-proofing in a closed manufacturing process (EXTOXNET, 1993). Table 7 shows the range (0.3 to 2.8 µg/kg) of dieldrin concentrations for sites on the White River and its tributaries. Figure 7 shows that the

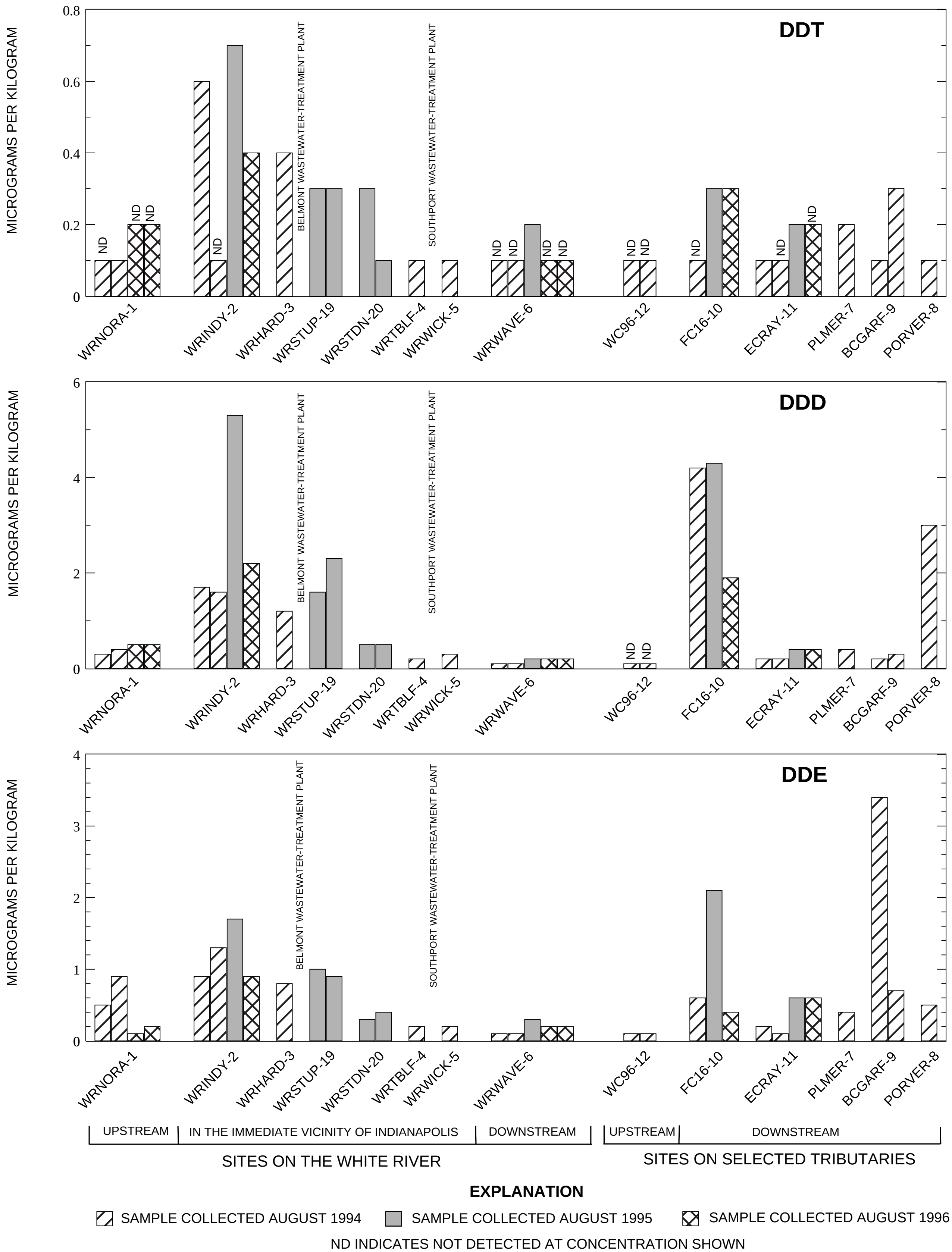


Figure 7. Concentrations of selected herbicides, insecticides, and PCB's in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96.

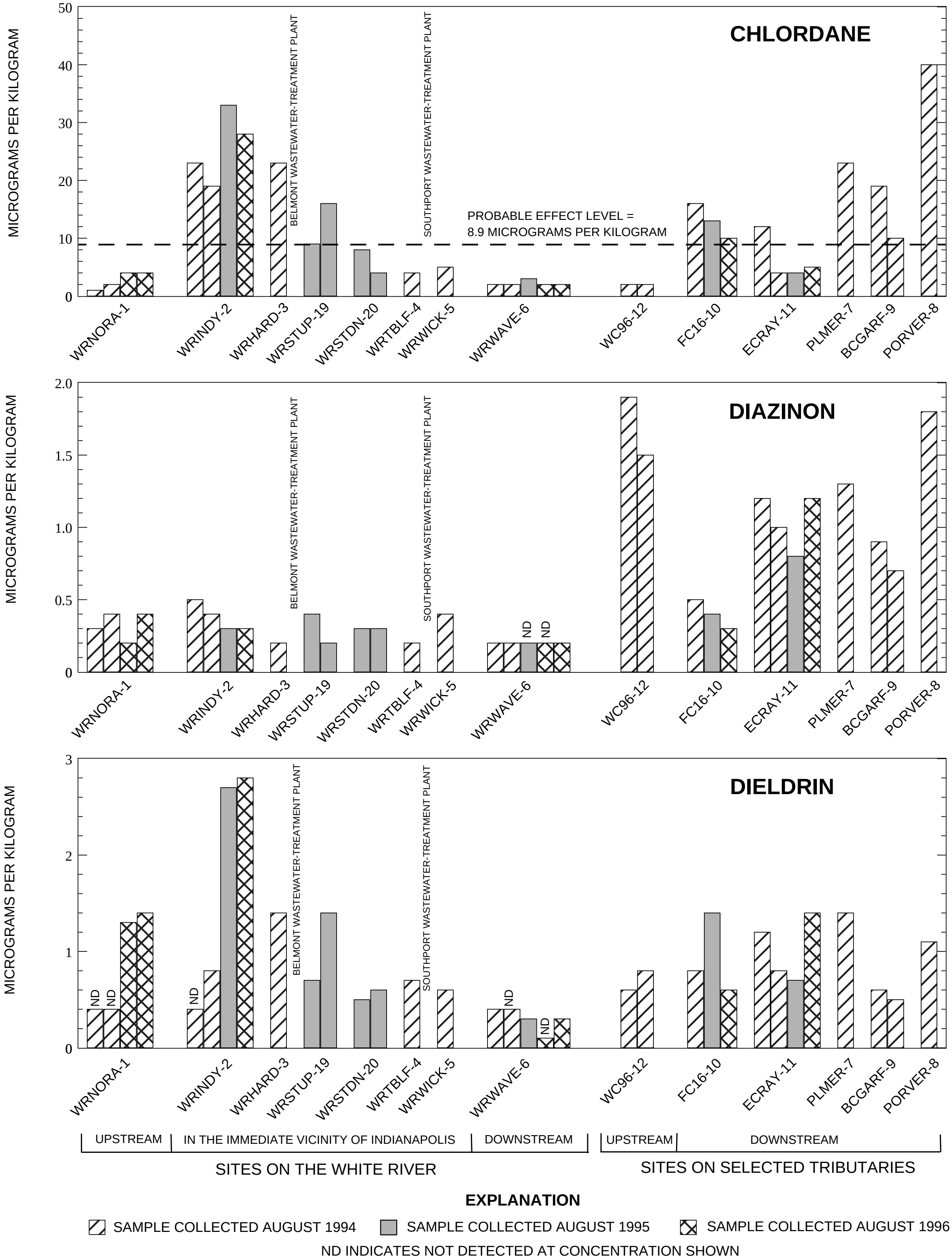


Figure 7. Concentrations of selected herbicides, insecticides, and PCB's in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96—Continued.

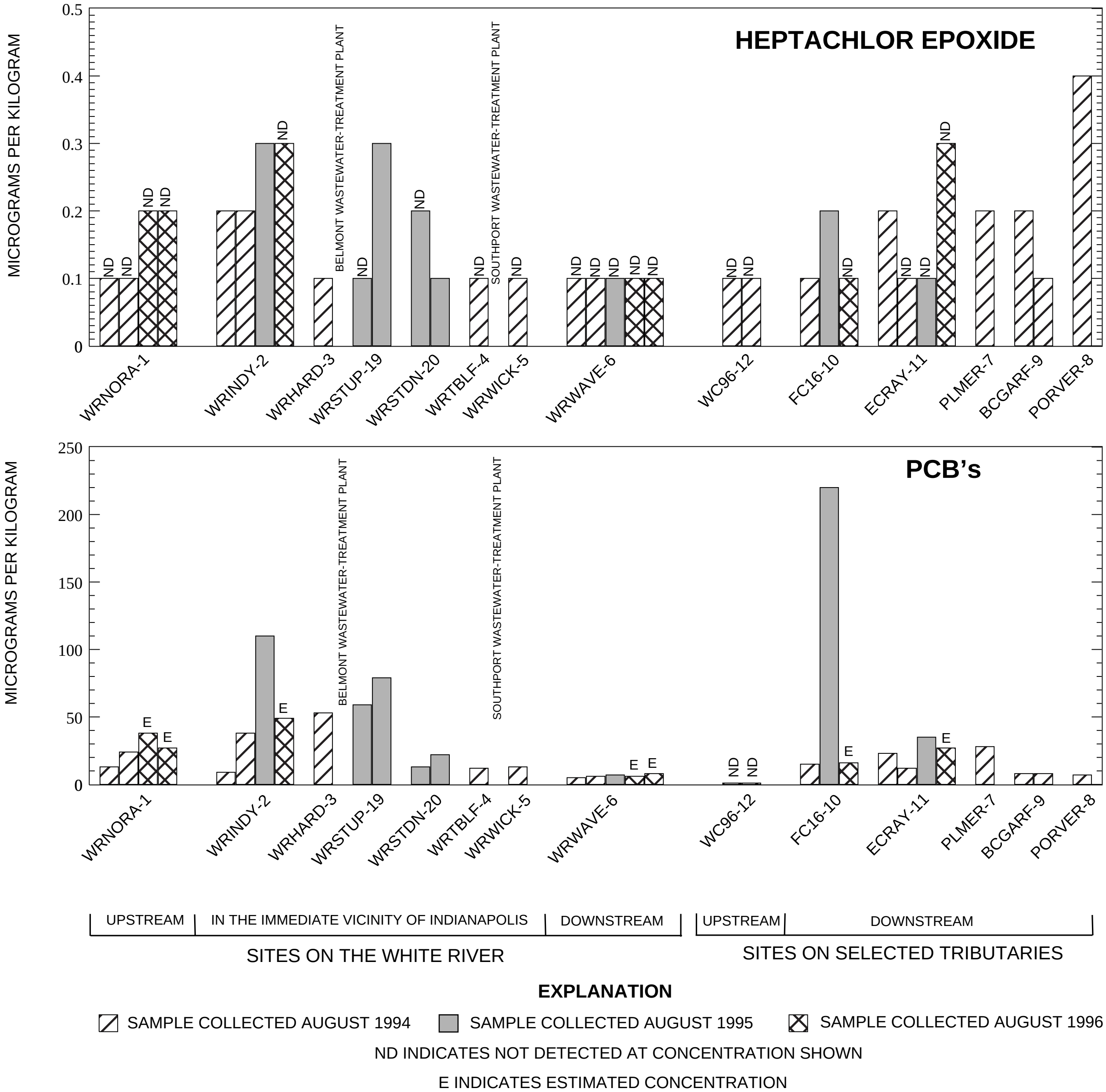


Figure 7. Concentrations of selected herbicides, insecticides, and PCB's in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96—Continued.

concentrations of dieldrin found in streambed sediments in the White River are highest in the immediate vicinity of Indianapolis. Similar distributions are seen in the tributary sediments sampled as part of this study. The maximum concentration of dieldrin, 2.8 μg/kg, was detected at the White River at Indianapolis (WRINDY-2) site and did not exceed the PEL of 6.67 μg/kg.

The registration of endrin for agricultural purposes was withdrawn in 1984 (EXTOXNET, 1993), but endrin was detected at the White River at Waverly (WRWAVE-6) and Fall Creek at 16^{th} Street (FC16-10) sites. One of these sites was in the immediate vicinity of Indianapolis, and one was downstream from Indianapolis. The PEL for endrin (62.4 μg/kg) was not exceeded at any site.

The use of heptachlor began to be phased out in 1978 and ultimately was banned in 1988 (EXTOXNET, 1993). Concentrations of heptachlor epoxide, a degradation product of heptachlor, were at or above the detection limit at nine sites on the White River and tributaries in the immediate vicinity of Indianapolis. The maximum concentration of heptachlor epoxide (0.4 μg/kg, which is less than the PEL) was detected at Pogues Run at Vermont Street (PORVER-8).

Of the organochlorine insecticides detected, only endosulfan and lindane still are used in the United States. Endosulfan and lindane are listed by the USEPA as Restricted Use Pesticides (RUP) (EXTOXNET, 1993) and, as such, may be purchased and used only by certified applicators. Endosulfan also is included in the USEPA's toxicity class I of highly toxic compounds, while lindane is included in the toxicity class II of moderately toxic compounds (EXTOXNET, 1993). Endosulfan was detected at three sites, all of which are in the immediate vicinity of Indianapolis. Lindane was detected at three sites, including sites throughout the study area. The PEL for lindane (1.38 μg/kg) was not exceeded in any of the samples; there is no PEL for endosulfan.

Diazinon and malathion are organophosphate insecticides with relatively high toxicities. Organophosphate insecticides came into wide-scale use in the U.S. in the late 1960's and 1970's as the use of organochlorine insecticides decreased. Organophosphate insecticides, as a group, vary considerably in chemical and environmental properties (Larson and others, 1997). The persistence of organophosphate insecticides in the aquatic environment is variable as well. The potential to be transported by runoff is low for diazinon and malathion.

Some formulations of diazinon are included in the USEPA's toxicity class II of moderately toxic compounds or toxicity class III of slightly toxic compounds, with some formulations also being listed by the USEPA as a RUP (EXTOXNET, 1993). In 1988, the USEPA canceled registration of diazinon for use on golf courses and sod farms because of the die-off of birds that often congregated in these areas. Malathion is listed by the USEPA as a General Use Pesticide and also is included in the USEPA's toxicity class III of slightly toxic compounds (EXTOXNET, 1993). Malathion, which was introduced in 1950, is a wide-spectrum insecticide that was one of the earliest organophosphate insecticides developed. Malathion is used for the control of harmful insects on fruits and vegetables and for the control of mosquitoes, flies, household insects, animal parasites, and head and body lice. It had been used for mosquito control in Marion County prior to 1994 (Terry Gallagher, Marion County Health Department, oral commun., 1999). Malathion was detected only at Bean Creek at Garfield Park (BCGARF-9) and Pogues Run at Vermont Street (PORVER-8), both of which are downstream tributary sites in the immediate vicinity of Indianapolis.

Table 7 shows the range (<0.2 to 1.9 μg/kg) of concentrations found for diazinon. Figure 7 shows that the concentrations of diazinon detected in the streambed sediments are substantially lower in the samples collected from the White River than in the samples collected from the tributaries, with the highest concentrations at the Williams Creek site. This spatial distribution may be the result of residential pest control. These data are supported by Crawford (1996), who reported substantially higher concentrations of diazinon in an urban stream in comparison with two agricultural streams.

PCB's are mixtures of chlorinated biphenyls. The use of PCB's was banned in 1979 by the USEPA because of human-health concerns when adverse ecological effects became apparent. PCB's were used primarily in capacitors and transformers but also in the formulation of pesticides, cutting oils, plastics, adhesives, sealants, inks, and paints. As with organochlorine insecticides, PCB's have extremely low water solubility and strong sorption tendencies and are characterized by their persistence in the environment (EXTOXNET, 1993).

Figure 7 shows the range of concentrations of PCB's. The figure shows that, generally, the highest concentrations were detected at the sites on the White River in the immediate vicinity of Indianapolis. The largest concentrations were detected in the sediments of Fall Creek; however, none exceeded the PEL of 277 µg/kg. The maximum concentration of PCB's was 220 µg/kg for Fall Creek at 16th Street (FC16-10). The maximum concentration at sites on the White River was 110 µg/kg at the White River at Indianapolis (WRINDY-2) site.

Semivolatile Organic Compounds

Seventeen of 54 semivolatile organic compounds were detected in the streambed-sediment samples (table 9 and Renn, 1998). Benzo(a)pyrene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, and pyrene were the most frequently detected, having been detected in 10 to 18 samples from six to nine sites (table 9). Acenaphthylene, anthracene, benzo(k)fluoranthene, benzo(a)anthracene, benzo(ghi)perylene, butyl benzyl phthalate, chrysene, dibenz(a,h)anthracene, fluorene, indeno(1,2,3-cd)pyrene, and naphthalene were detected in one to eight samples from one to five sites. The maximum concentration of semivolatile organic compounds ranged from 210 µg/kg for acenaphthylene to 3,600 µg/kg for fluoranthene. The median concentration for semivolatile organic compounds ranged from 136 µg/kg for benzo(a)anthracene to 320 µg/kg for fluoranthene.

Bis(2-ethylhexyl)phthalate and butyl benzyl phthalate are used as plasticizers in the manufacturing of plastic products (Verschueren, 1983). The remainder of the compounds detected are produced by the combustion of hydrocarbon fuels and organic material, such as gasoline in automobiles, diesel fuel in trucks, natural gas for heating, coal in electrical generating plants, coal in coke processing, and wood-burning fireplaces (Verschueren, 1983).

The occurrence of benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene was associated with sites in the immediate vicinity of Indianapolis. The highest concentrations generally were found at the Pleasant Run at Meridian Street (PLMER-7) site. The distribution patterns for benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene are shown in figure 8. None of the semivolatile organic compounds analyzed for were detected at White River near Nora (WRNORA-1), White River at Tibbs-Banta Landfill (WRTBLF-4), White River at Wicker Road (WRWICK-5), and Williams Creek at 96th Street (WC96-12). At the White River near Waverly (WRWAVE-6) site, a concentration of 2,400 µg/kg of benzo(a)anthracene was detected in the May 1994 sample. Benzo(a)anthracene was not detected in any of the four subsequent samples collected at this site during this study.

The NAWQA study conducted in the White River Basin during 1992 (W.W. Stone, written commun., 1997) showed the highest concentrations of benzo(a)pyrene and bis(2-ethylhexyl)phthalate in the Indianapolis area and the lowest concentrations in rural areas. In this study, these compounds showed a pattern of distribution in the White River of low concentrations upstream from Indianapolis, higher concentrations in the immediate vicinity of Indianapolis, and successively lower concentrations downstream from Indianapolis.

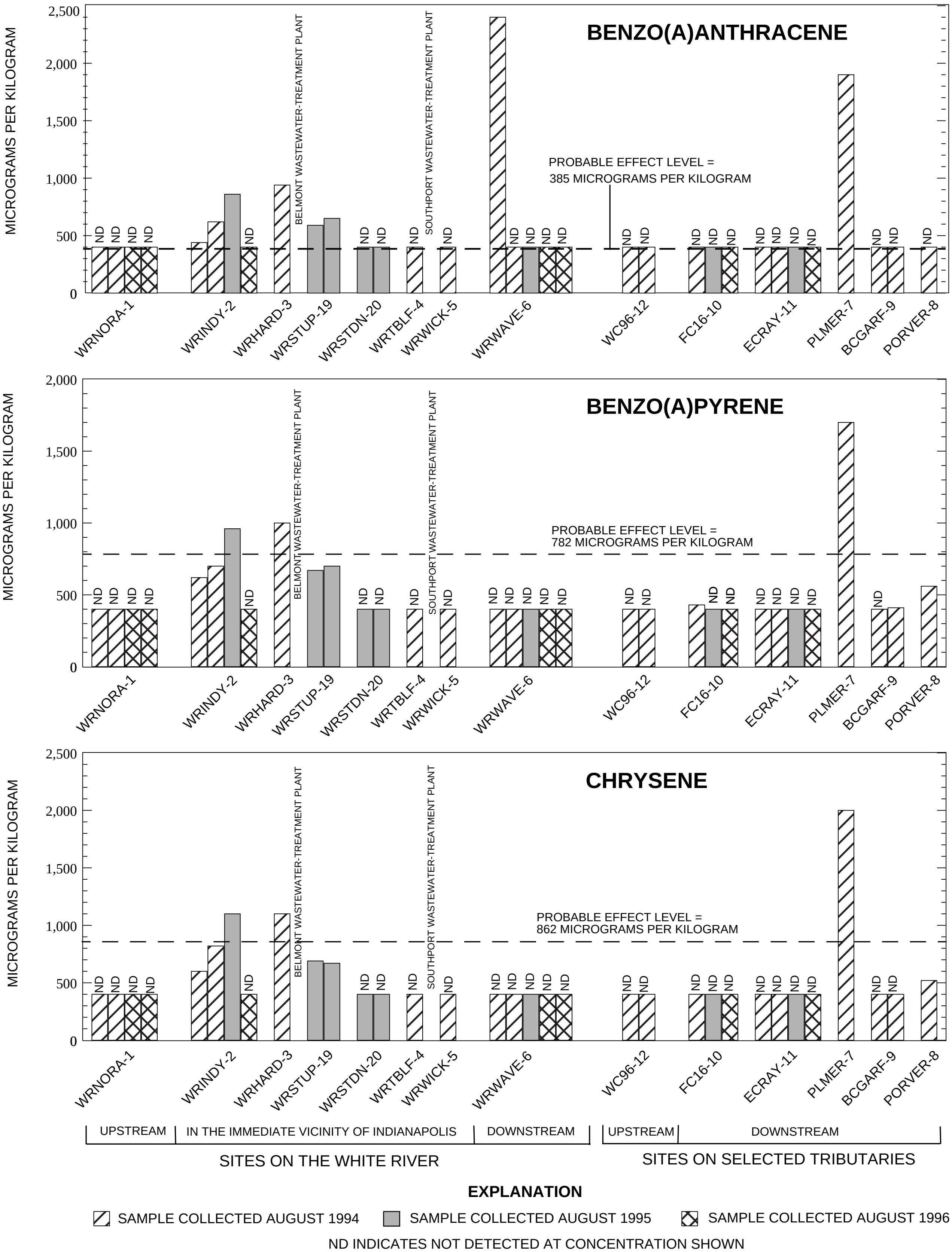


Figure 8. Concentrations of selected semivolatile organic compounds in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96.

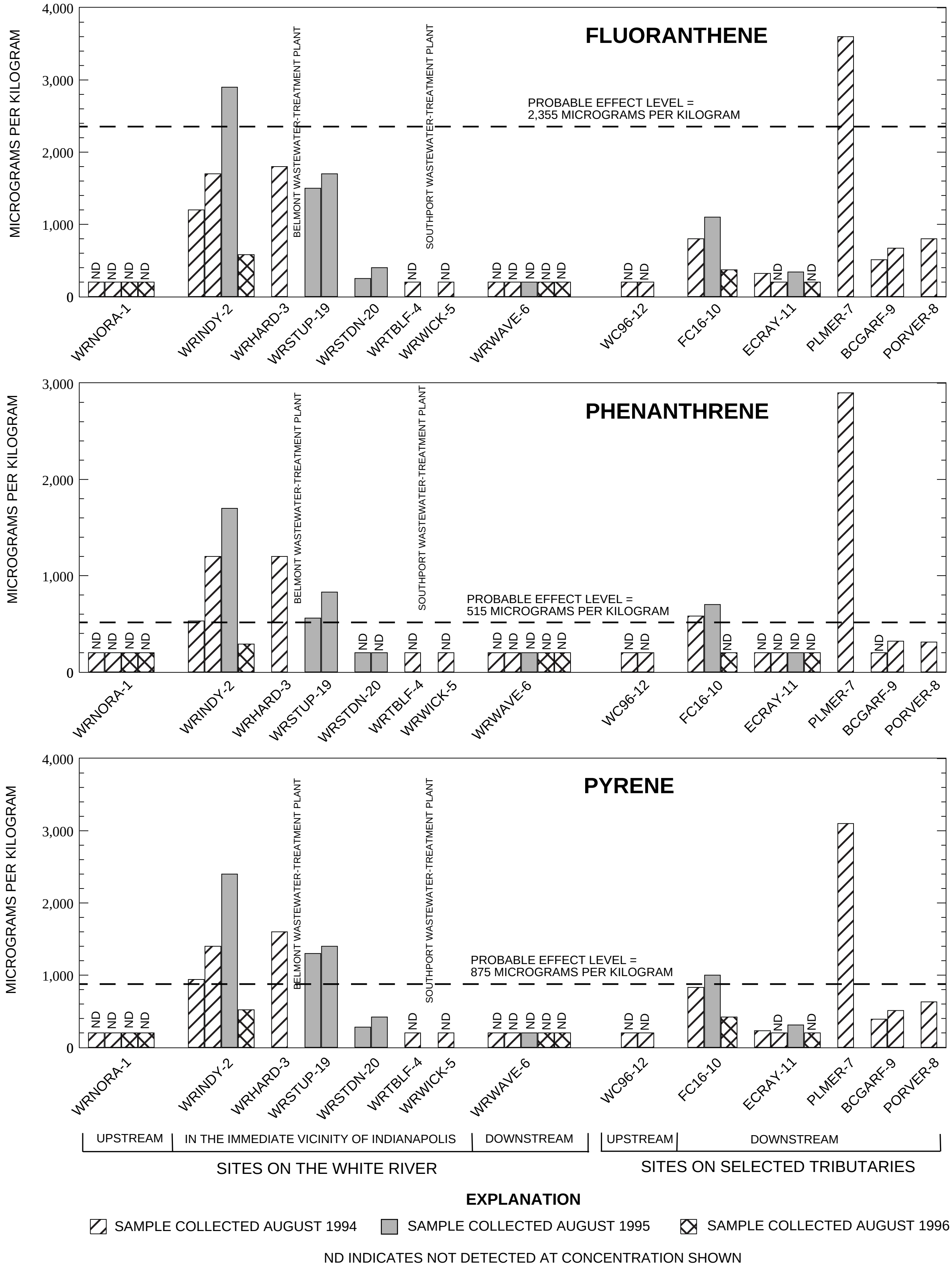


Figure 8. Concentrations of selected semivolatile organic compounds in streambed sediments for sites on the White River and selected tributaries in and near Indianapolis, Indiana, 1994–96.

Summary and Conclusions

The Indianapolis Department of Public Works and the U.S. Geological Survey completed a cooperative study on the White River and selected tributaries in and near Indianapolis, Indiana, from 1994 through 1996. The purpose of the study was to determine the diversity and density of benthic invertebrates and the concentrations of metals, insecticides, herbicides, PCB's, and semivolatile organic compounds sorbed on streambed sediments.

A total of 369 benthic-invertebrate samples were collected at 21 sites during May, June, and September 1994 through 1996 during low-flow, steady-state streamflow conditions. In the samples collected, 124 taxa were identified—28 to the family level, 64 to the genus level, and 32 to the species level. Ninety-three of the 124 taxa identified are in the phylum Arthropoda. The Hilsenhoff Biotic Index (HBI) (calculated from the number of arthropods and their tolerance to pollution) and the Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness Index (calculated from the number of taxa in three pollution-intolerant species) were used as indicators of water-quality conditions in the study area. The indices also were used to determine any changes between a study conducted from 1981 through 1987 and this study.

Analysis of the benthic data shows that a major part of the organisms identified belonged to three taxonomic groups—Diptera, Ephemeroptera, and Trichoptera. When comparing median percentages of the number of organisms found, analysis shows that the pollution-tolerant Diptera were more than twice as abundant at sites in the immediate vicinity of Indianapolis than at sites upstream or downstream from Indianapolis. Analysis showed diversity of organisms in the downstream tributary sites similar to the White River sites in the immediate vicinity of Indianapolis and diversity of organisms in the upstream tributary sites similar to the White River sites upstream and downstream from Indianapolis.

On the White River, the EPT Richness Index values ranged from 0 to 9. The EPT values for sites upstream from Indianapolis ranged from 6 to 8; the EPT values for sites in the immediate vicinity of Indianapolis ranged from 0 to 8; and the EPT values for sites downstream from Indianapolis ranged from 2 to 6. The decreased EPT values for sites in the immediate vicinity of Indianapolis, compared to sites upstream from Indianapolis, indicate increased natural organic and nutrient pollution. The increased EPT values for sites downstream from Indianapolis, compared to sites in the immediate vicinity of Indianapolis, indicate that the effects of natural organic and nutrient pollution have decreased. For the tributaries, the EPT values ranged from 0 to 9. For four of the five tributaries that had upstream and downstream sites, the EPT values for upstream sites, with few exceptions, were always higher than for downstream sites. The decreased EPT values for the downstream sites in these tributaries, compared to the upstream sites, indicate increased natural organic and nutrient pollution. Comparing EPT values for sites on the White River to sites on the tributaries, the sites on the White River upstream and downstream from Indianapolis had similar values to the upstream sites on the tributaries. The EPT values for the downstream sites on the tributaries were lower than the values on the White River sites upstream and downstream from Indianapolis and the upstream sites on the tributaries; the values for sites on the White River in the urban area of Indianapolis were lower than the downstream sites on tributaries.

For the White River, the HBI values indicated water quality that ranged from 4.4 (very good) to 9.4 (very poor). The HBI values for sites upstream from Indianapolis ranged from 4.4 (very good) to 5.8 (fair); the HBI values for sites in the immediate vicinity of Indianapolis ranged from 4.7 (good) to 9.4 (very poor); and the HBI values for sites downstream from Indianapolis ranged from 4.7 (good) to 6.0 (fair). Although streamflow and substrate conditions at some of the sites in the immediate vicinity of Indianapolis were different from other sites in the study area, the increased HBI values for those sites indicate increased pollution from natural organic compounds in the immediate vicinity of Indianapolis. The decreased HBI values for sites downstream from Indianapolis indicate that the effects of pollution from natural organic compounds decrease quickly.

The HBI values for the tributaries range from 4.9 (good) to 9.1 (very poor). For each of the five tributaries that had upstream and downstream sites, the HBI values for sites upstream, with few exceptions, were lower than for sites downstream. The increased HBI values for the downstream sites in the tributaries, compared to the upstream sites, indicate increased pollution from natural organic compounds. Comparing HBI values for sites on the White River to sites on the tributaries, the sites on the White River upstream and downstream from Indianapolis had similar values to the upstream sites on the tributaries. The HBI values for the downstream sites on the tributaries were higher than the sites upstream and downstream from Indianapolis, and the values for sites located on the White River in the immediate vicinity of Indianapolis were even higher.

Streambed sediments were collected at 14 sites and analyzed to determine the concentrations of 13 metals, 23 insecticides, 5 herbicides, and 54 semivolatile organic compounds. A total of 33 streambed-sediment samples were collected from 1994 through 1996 during low-flow, steady-state streamflow conditions. Of the 13 metals analyzed, aluminum, iron, magnesium, and manganese had the highest concentrations; arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc had lower concentrations. Only cyanide had concentrations that were below the detection limit for all samples. Copper, lead, mercury, and zinc concentrations were higher at sites on the White River in the immediate vicinity of Indianapolis. Lead was detected in 31 samples from all 14 sites; in three samples from two sites, lead was the only metal to exceed sediment-quality guidelines for the protection of aquatic life.

Streambed-sediment samples were analyzed for 23 insecticides and PCB's, of which 13 were detected—chlordane, DDT, DDD, DDE, diazinon, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, malathion, and PCB's. Chlordane, DDT, DDD, DDE, diazinon, dieldrin, and PCB's were detected at most sites for most samplings; endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, and malathion had the lowest number of detections. Distributions of chlordane, DDT, DDD, DDE, dieldrin, heptachlor epoxide, and PCB's were similar. In general, the highest concentrations for these constituents were detected in samples from sites in the immediate vicinity of Indianapolis. For diazinon, the highest concentrations were associated with sites on the tributaries. Endosulfan, heptachlor, and malathion were detected at sites in the immediate vicinity of Indianapolis; endrin and lindane were detected at sites in urban and non-urban areas. Although the last permitted use for any of these compounds was in 1988, chlordane, DDT and its degradation products DDD and DDE, dieldrin, heptachlor epoxide (the degradation product of heptachlor), and PCB's were detected at 14 sites in the study area. Heptachlor epoxide was detected at nine sites, and endrin was detected at two sites.

Seventeen semivolatile organic compounds were detected in the streambed sediments—acenaphthylene, anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)anthracene, benzo(ghi)perylene, bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. The maximum concentration of semivolatile organic compounds ranged from 210 μg/kg for acenaphthylene to 3,600 μg/kg for fluoranthene. The median concentration for semivolatile organic compounds ranged from 136 μg/kg for benzo(a)anthracene to 320 μg/kg for fluoranthene. Benzo(a)pyrene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, fluoranthene, phenanthrene, and pyrene were detected more frequently than the other compounds. Acenaphthylene, anthracene, benzo(k)fluoranthene, benzo(a) anthracene, benzo(ghi)perylene, butyl benzyl phthalate, chrysene, dibenz(a,h)anthracene, fluorene, indeno(1,2,3-cd)pyrene, and naphthalene were detected in one to eight samples from one to five sites. The semivolatile organic compounds detected were associated with sites in the immediate vicinity of Indianapolis.

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