Prepared in cooperation with The Nature Conservancy with generous support from the Nina Mason Pulliam Charitable Trust

Trends in Streamflow, Nutrients, and Total Suspended Solids in the Upper White River Basin, Indiana

Introduction

This fact sheet presents selected results from a study (Koltun, 2019) that was completed in partnership with The Nature Conservancy, with generous support from the Nina Mason Pulliam Charitable Trust. Existing water-quality and streamflow data were analyzed to statistically quantify changes in water quality over time and identify areas in the Upper White River Basin that demonstrated water-quality trends that may warrant conservation actions. Water-quality constituents linked to aquatic hypoxia (low oxygen conditions) and degraded instream habitat were chosen for analysis. The Nature Conservancy has an interest in reducing the contributions of these constituents to the White River, which connects to the Gulf of Mexico via the Wabash, Ohio, and Mississippi Rivers (not shown).

Streamflow data collected by the U.S. Geological Survey (USGS) on the Upper White River at Muncie, near Nora, and near Centerton, Indiana, and water-quality data collected by the USGS, Indiana Department of Environmental Management, Muncie Sanitary District, and Citizens Energy Group were used to complete the following:

1. estimate annual mean-daily concentrations and fluxes (rate of mass transport) of nutrients and total suspended solids (TSS) for analytical periods that include all or part of water years 1992–2017 (a water year is the period from October 1 to September 30 and is designated by the year in which it ends; the same analytical period was used for all locations for a given water-quality constituent) and

2. assess trends in streamflow and concentrations and fluxes of nutrients and TSS, including an evaluation of changes in "flow-normalized" concentrations and fluxes that occurred between water years 1997 and 2017.

Flow normalization is a process that attempts to remove the effects of year-to-year variation in streamflow on concentrations and fluxes without removing the effects associated with seasonal and long-term (multiyear) trends in streamflow. In this fact sheet, the term "load" refers to the total mass of a water-quality constituent that is transported to a given location in a stream, and "yield" refers to the load divided by the land area that drains to that location. The term "flux" refers to the rate at which the load is transported.

Estimated Mean Concentrations and Flux of Sediment and Nutrients

Annual mean-daily concentrations and fluxes of TSS and the nutrients total phosphorus as phosphorus (TP), nitrate plus nitrite as nitrogen (NO23), and total Kjeldahl nitrogen as nitrogen (TKN) were estimated for three USGS streamgages (the "study gages") on the Upper White River at Muncie, near Nora, and near Centerton, Ind. (USGS stations 03347000, 03351000, and 03354000, respectively; fig. 1), for water years 1992–2017 using the Weighted Regressions on Time, Discharge, and Season functions implemented in the Exploration and Graphics for RivEr Trends (EGRET) package (Hirsch and De Cicco, 2015). Drainage areas of the White River study gages at Muncie, near Nora, and near Centerton, Ind., are 241, 1,219, and 2,444 square miles, respectively. To facilitate trend assessment, Weighted Regressions on Time, Discharge, and Season was also used to estimate concentrations and fluxes that were flow normalized.

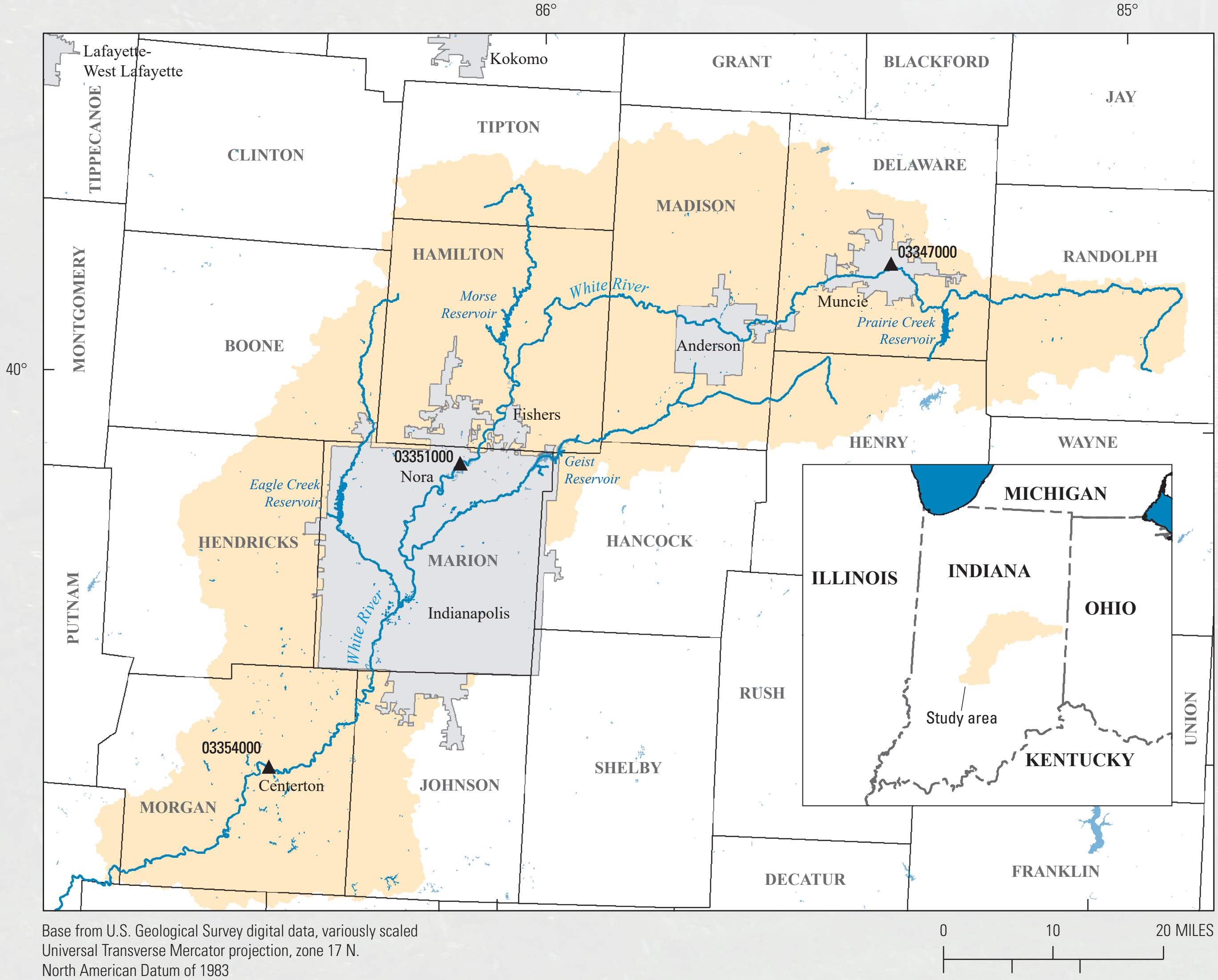
Analytical-period loads of each water-quality constituent increased in order from the most upstream study gage to the most downstream study gage; however, the same was not always true for yields (see fig. 2 for example). The highest yields of TSS, TP, and TKN occurred at the most upstream study gage (at Muncie); however, the highest yield of NO23 occurred at the most downstream study gage (near Centerton).

For the analytical period, TP yield was highest at the most upstream study gage at Muncie (fig. 1), whereas the NO23 yield at that same location was only about 70 percent of the yield at the most downstream study gage near Centerton. In addition, although the drainage area increased by a factor of about 10.1 between those two study gages, the analytical-period load (mass) increased by a factor of about 14.6 for TP and only 7.9 for NO23. Nearly one-half of the analytical-period TP load and about 58 percent of the NO23 load passing the study gage near Centerton came from the intervening drainage between the study gage near Nora (in northern Indianapolis) and the study gage near Centerton.

Trends in Streamflow

Trends in streamflow over time were assessed using time-series smoothing methods implemented in EGRET (Hirsch and DeCicco, 2015) and with Mann-Kendall tests (Mann, 1945). In the EGRET analyses, the annual maximum- and mean-daily streamflows and the annual minimum 7-day average streamflows at the study gages almost uniformly demonstrated net upward trends (increasing streamflows) from water years 1978 to 2017. Mann-Kendall tests also indicated that the average trend for the annual maximum-daily, annual mean-daily, and annual 7-day minimum streamflow statistics between water years 1978 and 2017 was upward at each of the study gages; however, only the trends in the annual mean-daily streamflows at the study gage at Muncie and the annual maximum-daily streamflows at the study gages near Nora and near Centerton were statistically significant at a 0.05 probability level (table 1).

According to Widhalm and others (2018), since 1895, mean-annual precipitation in Indiana has increased 5.6 inches with more rain falling in heavy downpours, and Indiana has warmed 1.2 degrees Fahrenheit (°F) with temperatures projected to rise about 5 to 6 °F above the 1971–2000 mean temperature (52.5 °F) by the mid-21st century. Höök and others (2018, p. 1) stated that “more frequent and intense precipitation, especially in the spring, will increase the risk of human-derived nutrients entering Indiana waterways as subsurface tile-drain flow and total runoff increases. Warming waters, combined with elevated nutrient levels, will lead to more algal blooms, reduced water clarity, and depleted oxygen levels.” The Nature Conservancy has expressed interest in pursuing measures that can increase water retention and infiltration on the landscape to help mitigate the increasing rainfall and run-off, and their potential detrimental effects on water quality.



EXPLANATION

03354000
▲ **U.S. Geological Survey streamgage and identifier**

Figure 1. Study area showing locations of study gages in the Upper White River watershed in central Indiana.

Changes in Flow-Normalized Concentration and Flux between Water Years 1997 and 2017

Bootstrap methods, based on repeated analyses using random samples (with replacement) of observed concentration data were used to assess the magnitude, direction, and likelihood of changes in annual flow-normalized mean-daily concentrations and fluxes of TSS, TP, NO23, and TKN at the study gages between water years 1997 and 2017. Although streamflows seemed to be increasing, the directions of change in flow-normalized TSS and nutrient concentrations and fluxes were most frequently downward (table 2), indicating decreasing concentrations and fluxes. Although the directions of change are promising, it is possible that positive effects on water quality from improvements in land-treatment practices and wastewater treatment will be diminished somewhat in the future by increasing streamflows such that landscape-based nutrient and sediment retention will have to be increased to reach water-quality improvement goals in the Upper White River.

Flow-normalized concentrations and fluxes of TSS and nutrients all decreased at the study gage near Nora, Ind., between water years 1997 and 2017 (table 2); however, there were some increases in flow-normalized concentrations and fluxes at the study gages at Muncie and near Centerton, Ind.

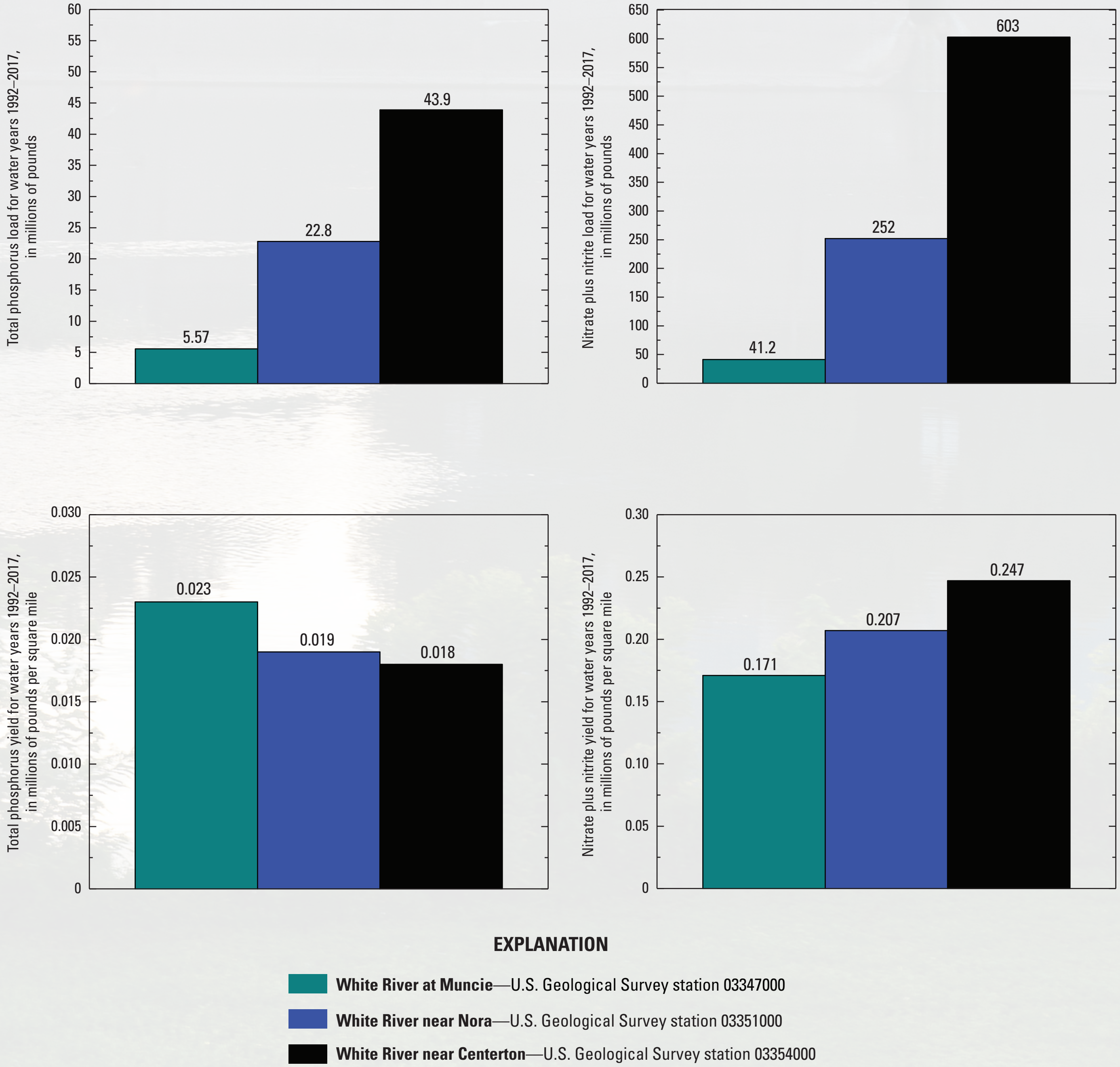


Figure 2. Loads and yields of total phosphorus and nitrate plus nitrite on the White River at Muncie, near Nora, and near Centerton, Indiana, for an analytical period including water years 1992 through 2017.

Table 1. Trends in annual streamflow statistics for water years 1978–2017 based on Mann-Kendall tests.

[Up arrow indicates upward trend (increasing streamflow), filled arrow indicates trend is statistically significant at 5-percent level]

Station number	Station name	Trend direction for: Annual 7-day minimum streamflow	Annual mean-daily streamflow	Annual maximum-daily streamflow
03347000	White River at Muncie, Indiana	⇧	⬆	⇧
03351000	White River near Nora, Indiana	⇧	⇧	⬆
03354000	White River near Centerton, Indiana	⇧	⇧	⬆

Table 2. Directions of change in flow-normalized concentrations and flux of nutrients and total suspended solids from water years 1997 to 2017.

[Up arrow indicates upward direction of change (increasing concentration or flux); down arrow indicates downward direction of change (decreasing concentration or flux); filled arrow indicates statistically significant change (at 5-percent level); TSS, total suspended solids; TP, total phosphorus as phosphorus, NO23, nitrate plus nitrite as nitrogen; TKN, total Kjeldahl nitrogen as nitrogen; L, likely; ALAN, as likely as not; HL, highly likely]

Constituent	Flow-normalized annual mean-daily concentration		Flow-normalized annual flux	
	Direction of change	Likelihood	Direction of change	Likelihood
03347000—White River at Muncie, Indiana				
TSS	⇧	L	⇧	L
TP	⇧	L	⇧	L
NO23	⇩	L	⇩	L
TKN	⇩	ALAN	⇧	ALAN
03351000—White River near Nora, Indiana				
TSS	⬇	HL	⬇	HL
TP	⬇	HL	⇩	L
NO23	⇩	L	⬇	HL
TKN	⬇	HL	⬇	HL
03354000—White River near Centerton, Indiana				
TSS	⬇	HL	⇩	L
TP	⬆	HL	⇧	L
NO23	⇧	L	⬇	HL
TKN	⬇	HL	⬇	HL

For example, increases were determined to be likely for flow-normalized concentrations and fluxes of TSS and TP at the Muncie study gage.

Flow-normalized NO23 concentrations likely increased at the study gage near Centerton between water years 1997 and 2017; however, it is highly likely that flow-normalized flux of nitrate plus nitrite decreased at that study gage. This unusual outcome is attributed to an increase in the frequency of occurrences and the amount of time that concentrations exceeded 4 milligrams per liter (mg/L) at daily mean flows less than about 1,500 cubic feet per second (ft^3/s). At the same time, the frequency of occurrences and the amount of time that concentrations exceeded 4 mg/L have decreased at daily mean flows greater than about 1,500 ft^3/s (fig. 3). The annual fluxes decreased over time because they are most heavily affected by concentrations during the relatively infrequent higher flow periods (where concentrations were decreasing over time), whereas mean concentrations, being time weighted, increased because they are more heavily affected by concentrations that occur during the more frequent lower flow periods (where concentrations were increasing over time). At the study gage near Centerton, daily mean streamflows were less than 1,500 ft^3/s more than 50 percent of the time during the 71-year historical period, whereas daily mean streamflows exceeded 3,000 ft^3/s only about 25 percent of the time. One possible explanation for this outcome is that the sporadic runoff-driven nonpoint-source contributions of NO23 decreased over time, while contributions of NO23 increased from more continuous sources such as wastewater treatment facilities and (or) tile drains.

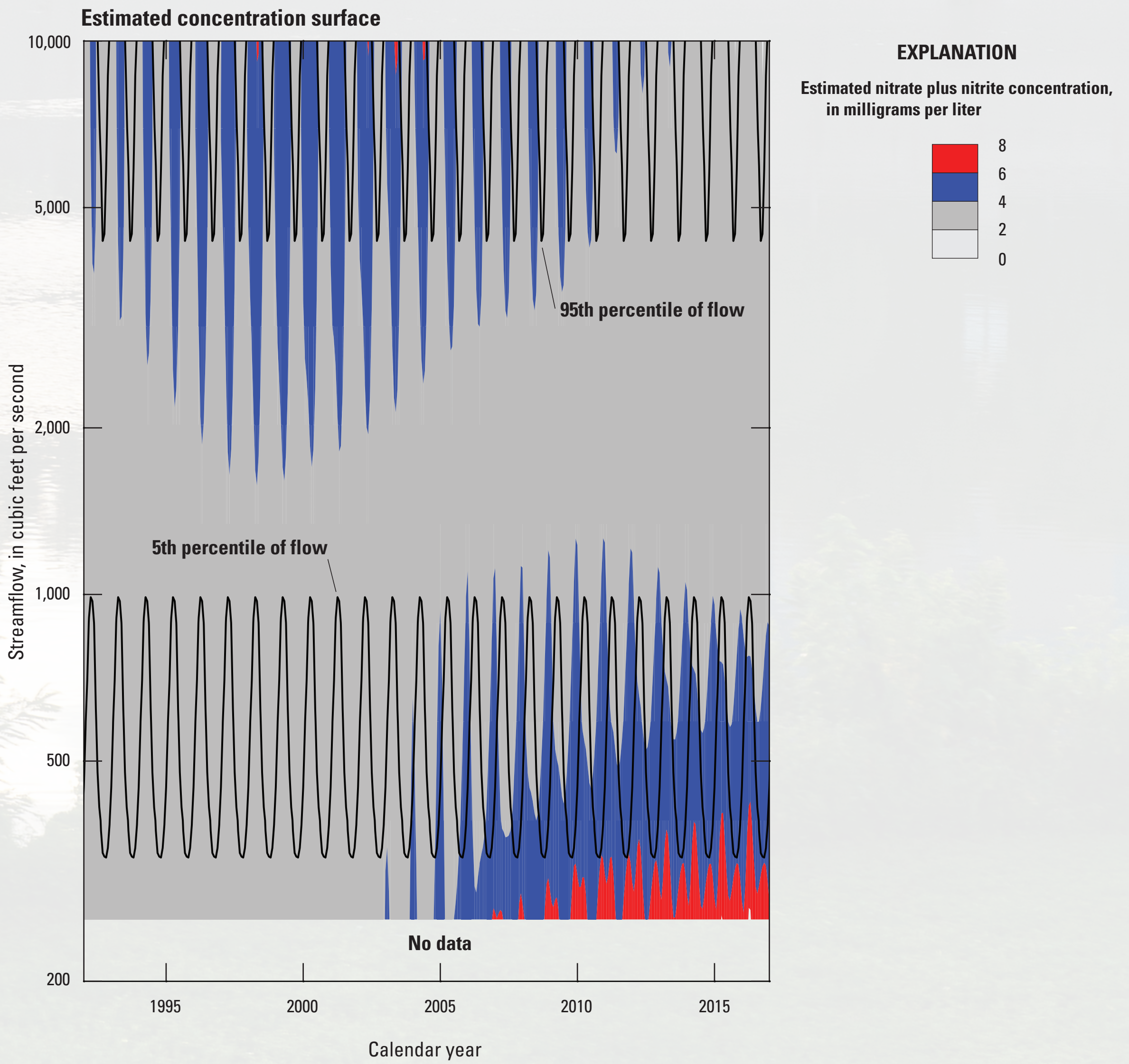


Figure 3. Relation between streamflow and the estimated concentration of nitrate plus nitrite as a function of time at the White River near Centerton, Indiana, streamgage (U.S. Geological Survey station 03354000), calendar years 1992 to 2017.

White River downstream from the White River Trail bridge, looking east toward White River State Park in downtown Indianapolis, Indiana. Photograph by Matt Williams, The Nature Conservancy.

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