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Trends and Seasonal Patterns of Nitrogen and Phosphorus Concentrations and Loads in Two Mississippi Alluvial Plain Watersheds Following Nutrient Reduction Efforts During 2010–22



Scientific Investigations Report 2026–5057
Version 1.1, September 25, 2026

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

Front cover:

Background, Harris Bayou, looking upstream from the gaging station on June 25, 2025. Photograph by Stephen Devilbiss, U.S. Geological Survey (USGS).

Bottom right, Porter Bayou at Stephensville, looking upstream from the gaging station on February 28, 2025. Photograph by Stephen Devilbiss, USGS.

Back cover:

Top, An example of a tailwater recovery system using a portable surface re-lift pump, March 8, 2011. Photograph by Matthew Hicks, USGS.

Middle, An example of center-pivot irrigation in the study watershed, 2011. Photograph by Matthew Hicks, USGS.

Bottom, An example of precision-irrigation in the study watershed, 2011. Photograph by Matthew Hicks, USGS.

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By Stephen E. DeVilbiss, Matthew B. Hicks, Emily Gain, and Natalie Segrest

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
acre	0.004047	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
liter (L)	61.02	cubic inch (in^3)
	Load	
kilogram per day (kg/d)	2.205	pound avoirdupois per day (lb/d)
	Precipitation rate	
millimeter per day (mm/d)	0.03937	inch per day (in/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$°F = (1.8 \times °C) + 32$.

Datums

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Supplemental Information

Concentrations of chemical constituents in water are in milligrams per liter (mg/L).

A water year is the 12-month period from October 1 through September 30 of the following year and is designated by the calendar year in which it ends.

Abbreviations

BMP	best management practices
C-Q	concentration-discharge
EDF	effective degrees of freedom
EQIP	Environmental Quality Incentives Program
GAM	generalized additive model
MDEQ	Mississippi Department of Environmental Quality
NRCS	Natural Resources Conservation Service
Q	discharge
SSC	suspended sediment concentration
TN	total nitrogen
TP	total phosphorus
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WRTDS	weighted regression on time, discharge, and season

Trends and Seasonal Patterns of Nitrogen and Phosphorus Concentrations and Loads in Two Mississippi Alluvial Plain Watersheds Following Nutrient Reduction Efforts During 2010–22

By Stephen E. DeVilbiss,[1] Matthew B. Hicks,[1] Emily Gain,[1] and Natalie Segrest[2]

Abstract

The Mississippi Alluvial Plain ecoregion in Mississippi was historically part of the largest continuous wetland in North America but was clearcut and converted to row crop agriculture beginning in the late 1800s. To reduce the effects of agriculture on surface waters in the Mississippi Alluvial Plain, nutrient reduction best management practices have been implemented throughout the region, particularly in two small watersheds: Harris Bayou watershed (174.04 square kilometers) and Porter Bayou watershed (267.15 square kilometers). Since 2009, the U.S. Geological Survey, in cooperation with the Mississippi Department of Environmental Quality, has collected water-quality samples monthly and during high-flow runoff events, at three locations within each watershed to monitor and assess nutrient trends following best management practice implementation. Here, we have analyzed long-term and seasonal trends in discharge, total nitrogen (TN), and total phosphorus (TP) concentrations and loads using a combination of quantile-Kendall analysis, quantile regression, generalized additive models, and weighted regression on time, discharge, and season. In Harris Bayou watershed, discharge values at a ~0.4–0.5 daily nonexceedance probability increased by 15 percent per year at the uppermost monitoring site. Additionally, TN concentrations decreased throughout the watershed over time, particularly in the spring and winter months. Reductions in TP were less apparent and only observed at one sampling location in Harris Bayou watershed. Nutrient concentrations in Porter Bayou watershed remained consistent over time and increased at one sampling location. However, despite discrepancies in concentration trends, flow-normalized TN and TP loads consistently decreased over time in both watersheds. At the mouth of both watersheds, peak TN and TP loads decreased between 37.7 and 56.9 percent. Collectively, these results provide evidence that best management practices may help reduce the effect of agricultural practices in the region, particularly in Harris Bayou watershed. Additionally, management efforts resulted in greater reductions in TN concentrations than in TP concentrations.

Introduction

Human population growth drives the conversion of vast areas of natural landscapes to agricultural land use (Laurance and others, 2014; Potapov and others, 2022; Tilman, 1999), and large-scale agricultural expansion alters the Earth's aquatic resources. For example, land clearing and tillage practices enhance soil erosion and transport to surface waters (Issaka and Ashraf, 2017; Montgomery, 2007; Pimentel and others, 1987; Tong and Chen, 2002). Enhanced soil erosion, transport in runoff, and subsequent sedimentation in aquatic ecosystems can degrade benthic habitat, alter light availability for primary production, and drive hypoxic conditions (Burdon and others, 2013; Julian and others, 2008; Mallin and others, 2006). Excess nitrogen (N) and phosphorus (P) from fertilizer application can also be transported to surface and subsurface waters during irrigation or storm events, fundamentally alter key ecosystem processes such as metabolism, and fuel excessive biological production, including harmful algal blooms (Griffiths and others, 2013; Michalak and others, 2013). Effects of agriculture on aquatic resources are also evident beyond the watershed- and landscape-scales. For example, elevated nutrient loads from the Mississippi and Atchafalaya Rivers, largely attributed to agricultural practices, have been identified as a primary cause of the hypoxic zone or "dead zone" that forms in littoral waters beyond the river outflow (R.B. Alexander and others, 2008; Burkart and James, 1999). Collectively, agriculturally driven degradation of aquatic resources threatens many important ecosystem services, including drinking-water purification, aquatic food sources, and recreation (Gordon and others, 2010; Power, 2010). Thus, reducing the effects of agriculture on water quality is crucial for long-term ecosystem sustainability, productivity, and human health.

[1]U.S. Geological Survey.

[2]Mississippi Department of Environmental Quality.

Nutrient reduction best management practices (BMPs) are commonly implemented to reduce the effect of agriculture on aquatic ecosystem services (Lintern and others, 2020; Liu and others, 2017). Nutrient reduction BMPs range from more targeted and controlled applications of nutrient fertilizers on crop fields (Roberts, 2007) to hydrologic controls that reduce excess irrigation or promote biogeochemical removal of nutrients already in surface waters (such as N removal via denitrification). For example, advancements in soil moisture sensors, precision land leveling and irrigation, and tail-water recovery systems all reduce the amount of surface runoff and thus nutrients delivered from agricultural fields to surface waters (Abioye and others, 2020; Harun and others, 2015; Hedley, 2015; Omer and Baker, 2019). Vegetated drainage ditches, two-stage ditches, and low-grade weirs slow water velocity in streams, increasing hydraulic residence time and promoting the removal of nutrients through enhanced biogeochemical cycling and settling of suspended sediments (Faust and others, 2018; Littlejohn and others, 2014; Mahl and others, 2015).

The individual effectiveness of many BMPs at reducing nutrient loading in streams has been studied. Despite knowledge of the effects of individual BMPs on nutrient loading and water quality, detecting the cumulative effects of multiple BMPs at the watershed-scale has been difficult. Challenges in detecting watershed-scale water-quality improvements from BMPs can include improper water-quality monitoring strategies (Behmel and others, 2016), climate variability (Jayakody and others, 2014), landscape complexity (Kreiling and others, 2018), lack of landowner participation (Gao and Arbuckle, 2022), or improper BMP selection (D'Arcy and Frost, 2001). Another challenge associated with detecting watershed-scale improvements in water quality, even in the absence of the aforementioned challenges, is an often-observed temporal lag between BMP implementation and ecosystem response (McDowell and others, 2021; Meals and others, 2010). Specific to nutrient concentration or loads, temporal lags can be driven by the so-called legacy effect of N and P (Sharpley and others, 2013). For example, a substantial amount of N is stored in the root zone in agricultural fields, and even in the absence of N fertilizer application, this root zone N can continue to be a source of N in a watershed and cause lag times in observed N reductions of several decades (Van Meter and others, 2016). Phosphorus, conversely, can accumulate in surficial soils and sediments of waterbodies and either leach or be resuspended into the overlying water column, effectively masking any reductions at the edge-of-field (Jarvie and others, 2013; Sharpley and others, 2013). Collectively, legacy N and P contribute to often-observed minimal reductions in nutrients at the watershed scale, despite reductions in edge-of-field loading.

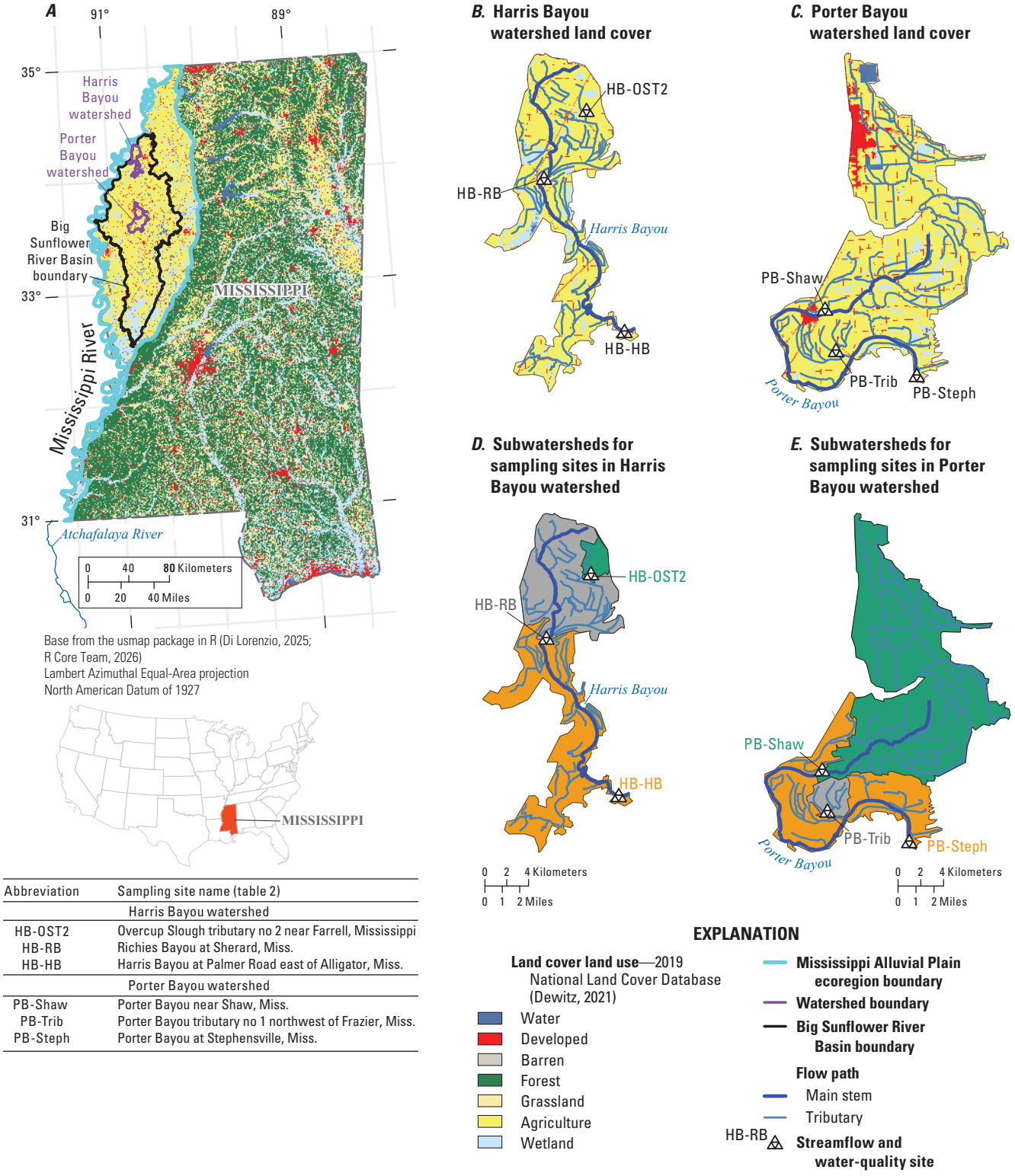
The objective of this study, conducted by the U.S. Geological Survey (USGS) in cooperation with the Mississippi Department of Environmental Quality, was to characterize long-term, post-restoration water-quality and discharge (Q) trends in two watersheds in the Mississippi Alluvial Plain level III ecoregion in Mississippi (Omernik and Griffith 2014, fig. 1). The watersheds have had numerous nutrient reduction BMPs implemented over the past 15 years (table 2.1). The Mississippi Alluvial Plain is an intensely cultivated region, with over 65 percent of the landcover committed to row crop agriculture (Taylor and others, 2023). Given the intensity of land alteration and agriculture in the region, identifying successful nutrient mitigation strategies has been challenging because of the degree of diffuse nutrient sources across the landscape. Starting in 2009, the Mississippi Department of Environmental Quality (MDEQ) began implementing BMPs in two pilot watersheds, Harris Bayou watershed and Porter Bayou watershed. The USGS subsequently started monitoring water quality throughout these watersheds in 2010.

Purpose and Scope

This report documents trends and seasonal patterns of nitrogen and phosphorus concentrations and loads in two Mississippi Alluvial Plain watersheds following nutrient reduction efforts. In each of the two study watersheds, continuous Q, routine monthly water-quality samples, and high-flow storm event samples have been collected at three locations representing the top, middle, and mouth of the watershed for the last 10–15 years, depending on monitoring location. Because no pre-restoration data were collected, no attempt has been made to attribute water-quality improvements or flow alterations directly to any specific BMP or combinations of BMPs. Rather, our goal was to identify statistically significant changes in nutrient concentrations and loads that can provide evidence that BMPs can improve water quality in the Mississippi Alluvial Plain. We hypothesized that, because of the degree of seasonality in nutrient concentrations caused by agriculture and weather patterns in the region (Shields and others, 2009; Taylor and others, 2023), any potential nutrient reductions from management efforts would be most obvious in the months surrounding the growing season (that is, early spring and late fall/winter).

Description of Study Area

The Harris Bayou watershed and Porter Bayou watershed are located within the Big Sunflower River Basin in the agriculturally dominated Mississippi Alluvial Plain ecoregion in Mississippi (fig. 1). The Mississippi Alluvial Plain represents the historical floodplain of the Mississippi River and was once part of the largest continuous wetland in North America (MacDonald and others, 1979). Prior to agriculture, the Mississippi Alluvial Plain was predominately hardwood bottomland forests consisting of cypress (*Taxodium*) and tupelo (*Nyssa*) species. However, as European settlers began to move into the region in the late 1800s, the value of the timber and agriculturally fertile soil drove the rapid deforestation of the region over approximately 100 years (Ochs and others, 2023). To prevent devastating flooding from the Mississippi



Abbreviation	Sampling site name (table 2)
	Harris Bayou watershed
HB-OST2	Overcup Slough tributary no 2 near Farrell, Mississippi
HB-RB	Richies Bayou at Sherard, Miss.
HB-HB	Harris Bayou at Palmer Road east of Alligator, Miss.
	Porter Bayou watershed
PB-Shaw	Porter Bayou near Shaw, Miss.
PB-Trib	Porter Bayou tributary no 1 northwest of Frazier, Miss.
PB-Steph	Porter Bayou at Stephensville, Miss.

Figure 1. (*A*) Land cover land use (Dewitz, 2021) and location of the Mississippi River and the two study watersheds, both within the larger Big Sunflower River Basin in the level III Mississippi Alluvial Plain ecoregion (Omernik and Griffith, 2014), the specific locations of sampling sites within (*B*) Harris Bayou watershed and (*C*) Porter Bayou watershed, and subwatersheds basins for (*D*) Harris Bayou watershed and (*E*) Porter Bayou watershed. Sites are described in the National Water Information System (NWIS) (U.S. Geological Survey [USGS], 2026a). NWIS site identifiers include HB-HB: USGS-07288068, HB-RB: USGS-07288048, HB-OST2: USGS-341550090391300, PB-Shaw: USGS-333601090450000, PB-Trib: USGS-333420090445900, PB-Steph: USGS-07288521.

River and protect crops, livestock, and human lives, a system of levees was constructed that has hydrologically disconnected the Mississippi Alluvial Plain from the Mississippi River (J. Alexander and others, 2012). Further hydrologic alterations in the region continue because of excessive groundwater pumping for irrigation that can disconnect surface water from groundwater, referred to as a "cone of depression," and cause historically gaining streams to become losing streams because of surface-water loss through the unsaturated zone into the aquifer (Barlow and Clark, 2011; Kresse and others, 2014; Yasarer and others, 2020). Consistent with the larger Mississippi Alluvial Plain region, both Harris Bayou watershed (174.04 square kilometers, 84.05 percent cultivated crops) and Porter Bayou watershed (267.15 square kilometers, 81.75 percent cultivated crops) are predominantly agricultural land (fig. 1). Dominant crop types in both watersheds consist of soybeans, cotton, rice, and corn. Although annual crop rotations drive year-to-year variability in crop type, there have been no substantial, unidirectional shifts in crop type in either watershed over the period of record (fig. 2) (Heintzman and others, 2024).

Beginning in 2008, the MDEQ began using funds from the U.S. Department of Agriculture–Natural Resources Conservation Service (USDA–NRCS) Environmental Quality Incentives Program (EQIP) to install nutrient reduction BMPs in Harris Bayou watershed and Porter Bayou watershed (FTN Associates, Ltd., 2012). The watersheds were chosen largely because of landowner buy-in and cooperation. General BMP categories and number implemented for BMPs that have documented coordinates are shown in figure 3 and listed in table 1 to provide some spatial context. A full list of all EQIP BMPs implemented during the period of record is provided in appendix 2; table 2.1. Importantly, certain landowners in Porter Bayou watershed discontinued their cooperation during the middle of the study period.

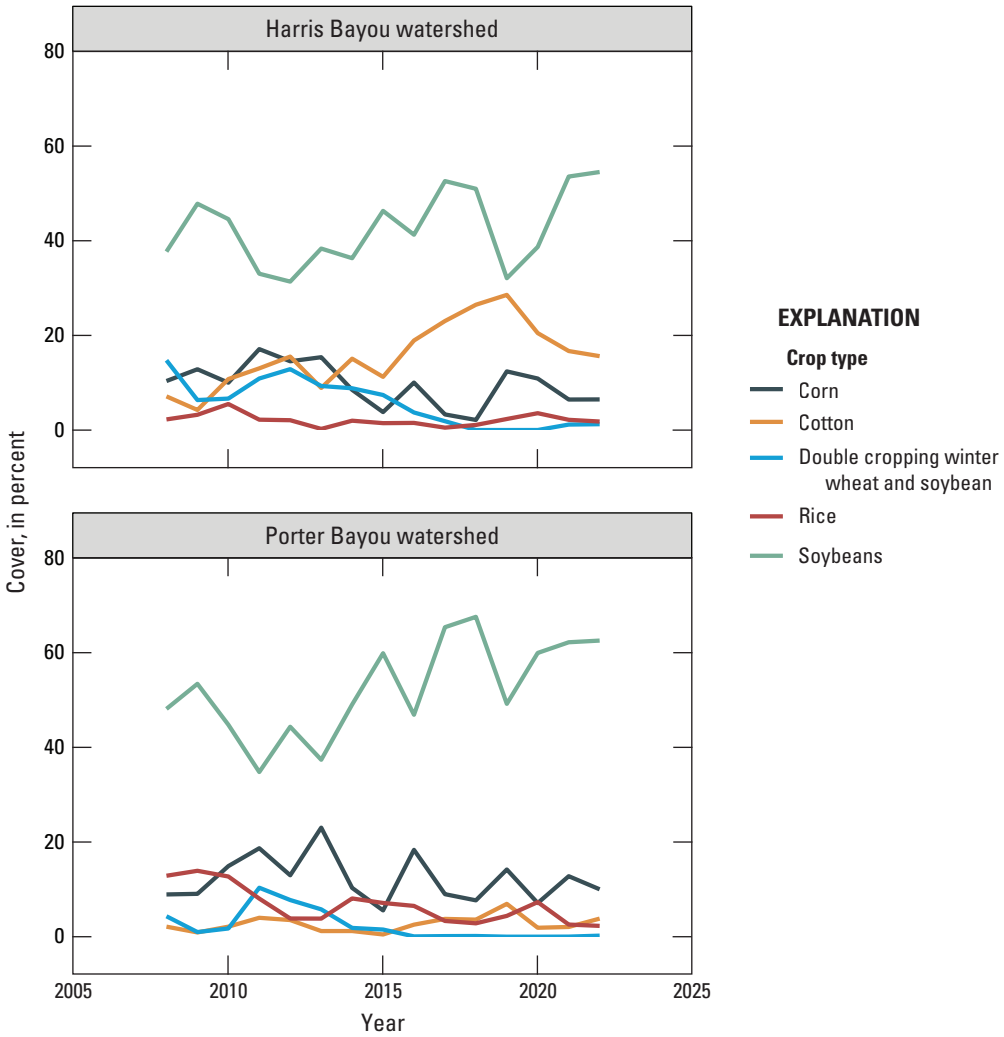


Figure 2. Temporal variability in the five most dominant crop types by land area in Harris Bayou watershed (top panel) and Porter Bayou watershed (bottom panel). Data are from the U.S. Department of Agriculture National Agricultural Statistics Service (2021) cropland data layer datasets.

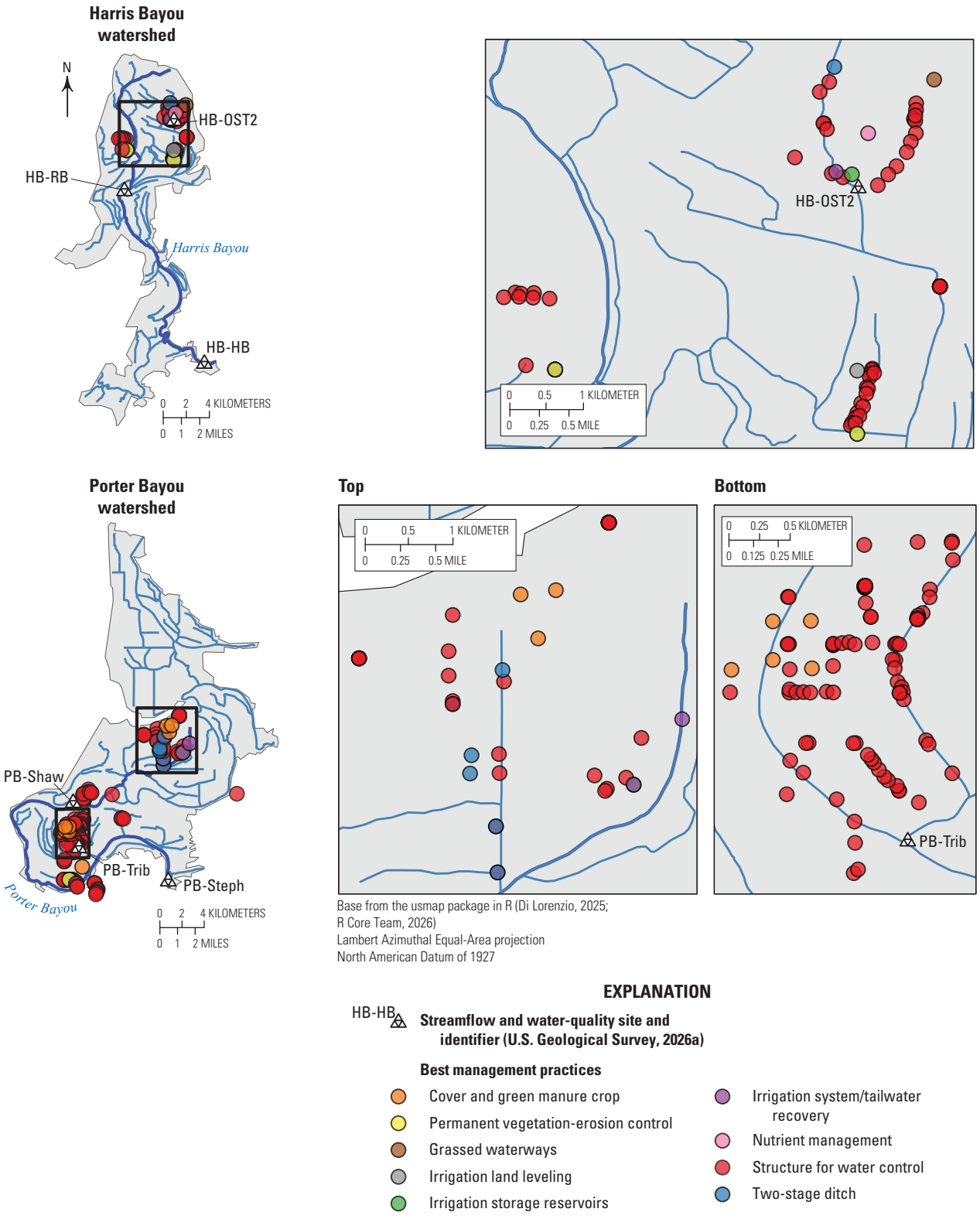


Figure 3. Location, broad classification, and summary of best management practices (BMPs) implemented in the two study watersheds: Harris Bayou watershed (top row) and Porter Bayou watershed (bottom row). These are only the BMPs for which the coordinates are known and do not represent all BMPs implemented in the study watersheds over the period of record. A complete list of BMPs is provided in table 2.1. Data provided by Natalie Seagrest (Mississippi Department of Environmental Quality, unpub. data, 2024).

Table 1. Summary of cumulative nutrient reduction best management practices (BMPs) implemented by the U.S. Department of Agriculture–Natural Resources Conservation Service's (USDA–NRCS's) Environmental Quality Incentives Program (EQIP) in Harris Bayou watershed and Porter Bayou watershed over the study period.

[These are only BMPs for which coordinates are available and correspond to the BMPs shown in figure 3. A complete list of EQIP BMPs implemented in Harris and Porter Bayou is provided in appendix 2; table 2.1]

BMP type	Number implemented in watershed	
	Harris Bayou	Porter Bayou
Permanent vegetation—erosion control	3	2
Grassed waterways	1	0
Irrigation land leveling	1	0
Irrigation storage reservoirs	1	1
Irrigation system, tail water recovery	1	2
Nutrient management	1	0
Structure for water control	55	177
Two-stage ditch	4	10
Cover and green manure crop	0	9
Total	67	201

Methods

Data Collection

All six monitoring stations collected continuous stage data for the Q computation. Water-surface elevation (stage) was continuously monitored at 15-minute intervals using a nonsubmersible pressure sensor near the center of the channel. Continuous stage data were used to estimate continuous streamflow using a stage-Q relation described by Turnipseed and Sauer (2010). Briefly, 10–15 stream profile measurements were collected every 8–12 weeks to establish stage-Q relations. Streamflow data associated with water-quality samples (table 2) were computed according to methods described in Rantz (1982).

Monthly water-quality grab samples were collected at each of the sites following standard protocols (USGS, 2006). Briefly, two 1-liter surface-water samples were collected from the thalweg in high-density polyethylene containers. Additionally, automatic storm samplers (Teledyne ISCO, Lincoln, Nebraska) were deployed to collect discrete samples across the hydrograph during high-flow events. The exact number of samples, frequency, and stage-discharge range of collection varied by site and over time as adjustments were made for variable storm intensities. For each sample collection, one high-density polyethylene sample container was preserved with sulfuric acid (H_2SO_4), and both containers were stored on ice until delivery to the MDEQ laboratory (Pearl, Mississippi) where they were kept at 4 degrees Celsius until analysis within 7 days of collection. Samples were analyzed for total nitrogen (TN) and total phosphorus (TP) in accordance with U.S. Environmental Protection Agency Methods for Chemical Analysis of Water and Wastes (U.S. Environmental Protection Agency, 1983). All data are publicly available from the National Water Information System (USGS, 2026a) and the Water Quality Portal (USGS, 2026b) and were accessed in R version 4.6.0 (R Core Team, 2026) using the dataRetrieval package (DeCicco and others, 2024). USGS site identifiers for each sample location are presented in table 3.

Specific subwatershed boundaries for each monitoring site are shown in figure 1, and drainage areas are listed in table 2.

Data Analysis

For statistical analyses, mean event analyte concentrations and Q values for all events were combined with routine samples to increase the number of observations.

Quantile-Kendall Discharge Analysis

Tests for increasing and decreasing trends in daily Q over the period of record were conducted for all six monitoring sites by means of a Quantile-Kendall analysis in R using the EGRET package (Hirsch and others, 2024). Quantile-Kendall analysis is an extension of the Mann-Kendall trend analysis, which is a nonparametric trend test that determines the magnitude, direction (that is, increasing or decreasing slope), and statistical significance of trends in time-series data. The Quantile-Kendall test analyzes trends over the full range

Table 2. Summary of discrete samples collected from sample locations and corresponding discharge (Q) measurements from the time of collection.

[Reported Q values here are only those paired with a water-quality observation and used in generalized additive models. km², square kilometer; min, minimum; max, maximum; n, number; MS, Mississippi; ft³/s, cubic foot per second; TN, total nitrogen; mg/L, milligram per liter; TP, total phosphorus; no, number; Rd, road; trib, tributary; NW, northwest; -, not applicable]

Area (km²)	Date range	Variable (unit of measure)	Sample no.	Min	Median	Mean	Max	Storms (n)
Harris Bayou watershed								
Overcup Slough tributary no 2 near Farrell, MS (HB-OST2)								
8.02	2010–22	Q (ft³/s)	123	0.03	10.25	27.73	112.29	-
8.02	2010–22	TN (mg/L)	114	0.78	1.9	3.09	16.18	55
8.02	2010–22	TP (mg/L)	117	0.05	0.52	0.62	3.75	60
Richies Bayou at Sherard, MS (HB-RB)								
83.86	2014–22	Q (ft³/s)	85	0.4	31.2	94.71	433.4	-
83.86	2014–22	TN (mg/L)	85	0.21	1.4	1.94	5.5	22
83.86	2014–22	TP (mg/L)	85	0.01	0.39	0.44	2.96	22
Harris Bayou at Palmer Rd east of Alligator, MS (HB-HB)								
174.04	2010–22	Q (ft³/s)	150	0.03	61.89	124.67	660.29	-
174.04	2010–22	TN (mg/L)	150	0.19	1.4	1.93	13	23
174.04	2010–22	TP (mg/L)	150	0.06	0.32	0.36	1.26	23
Porter Bayou watershed								
Porter Bayou near Shaw, MS (PB-Shaw)								
197.62	2014–22	Q (ft³/s)	73	0.09	29.5	93.82	780.94	-
197.62	2014–22	TN (mg/L)	72	0.28	1.2	1.78	9.9	15
197.62	2014–22	TP (mg/L)	71	0.01	0.3	0.33	1.93	15
Porter Bayou trib no 1 NW of Frazier, MS (PB-trib)								
10.01	2010–22	Q (ft³/s)	115	2.28	20.3	41.27	185.87	-
10.01	2010–22	TN (mg/L)	106	0.07	1.97	3.03	18.63	30
10.01	2010–22	TP (mg/L)	110	0.07	0.34	0.41	1.52	32
Porter Bayou at Stephensville, MS (PB-Steph)								
267.15	2010–22	Q (ft³/s)	161	0.56	50.8	146.11	1,119.77	-
267.15	2010–22	TN (mg/L)	160	0.16	1.4	2.04	16.46	36
267.15	2010–22	TP (mg/L)	158	0.01	0.38	0.44	2.24	35

of quantiles, from the daily minimum (first order statistic) to the daily maximum (365th order statistic). Data were not transformed prior to analyses because Mann-Kendall tests are nonparametric and rank-based, with no assumption of normality. Flow statistics in figures are presented as daily nonexceedance probabilities to provide better resolution at the tail-ends of the distribution.

Quantile Regression Nutrient Concentration Analysis

We used quantile regression to test for significant trends in TN and TP concentrations. Quantile regression is an extension of linear regression that allows for the analysis of specific quantiles of the data distribution and does not have the same assumptions of residual normalcy that a standard linear model requires. Specifically, we tested for significant ($\alpha = 0.05$) increasing or decreasing trends in nutrient concentrations at the 5th, 25th, 50th, 75th, and 95th quantiles of TN and TP concentrations. Standard errors were generated with bootstrapping. Analyses were performed in R using the quantreg package (Koenker, 2025).

Generalized Additive Modeling

We used GAMs to identify temporal and seasonal trends in TN and TP concentrations and related concentration-discharge (C-Q) slopes at all monitoring locations. All

Table 3. Identifiers, names, and abbreviations for sample locations used in this report (U.S. Geological Survey [USGS], 2026a).

[MS, Mississippi; Rd, road; no, number; trib, tributary; NW, northwest]

Site identifier	Site name	Abbreviation used in this report
	Harris Bayou watershed	
USGS-07288068	Harris Bayou at Palmer Rd east of Alligator, MS	HB-HB
USGS-07288048	Richies Bayou at Sherard, MS	HB-RB
USGS-341550090391300	Overcup Slough tributary no 2 near Farrell, MS	HB-OST2
	Porter Bayou watershed	
USGS-07288521	Porter Bayou at Stephensville, MS	PB-Steph
USGS-333420090445900	Porter Bayou trib no 1 NW of Frazier, MS	PB-Trib
USGS-333601090450000	Porter Bayou near Shaw, MS	PB-Shaw

modeling was performed in R using the mgcv package (Wood, 2017). To evaluate seasonality across the period of record, we used a time-varying and seasonal modeling approach that incorporated year, continuous month, and C-Q relations based on equation 1 (von Brömssen and others, 2023):

$$c = a + f1(\text{year, month}) + f2(\text{year, month} * q) + \varepsilon \; \varepsilon \sim N(0, \Lambda), \quad (1)$$

where

c is concentration;
a is the intercept;
$f1$(year, month) is a smooth function representing the concentration trend across year and month;
$f2$(year, month * q) is a smooth function representing the C-Q trend across year and month;
q is discharge;
ε is the error term; and
$\varepsilon \sim N(0, \Lambda)$ is the distribution of error term, which is normally distributed, has a mean of 0, and an autoregressive process of lag 1 variance-covariance matrix Λ.

A concentration trend was included because it has been shown to improve the model fit and estimates of C-Q slopes (von Brömssen and others, 2023). A time-varying and seasonal modeling approach was used to provide more detail on seasonal patterns in both concentrations and C-Q relations. This approach was used because BMPs may have altered C-Q relations over time due to reductions in loading or altered nutrient processing efficiencies and because agricultural practices and seasonal weather patterns are expected to drive substantial seasonal variability in nutrient transport dynamics throughout a year. Prior to modeling, nutrient and Q values were log-transformed. Because the model represents mean concentration values when log-transformed Q is equal to 1 (that is, the intercept indicates the concentration when Q is equal to 0), Q values were mean-centered to adjust model outputs to estimate the overall concentration mean (as opposed to the concentration when Q = 0). Lastly, temporal autocorrelation was accounted for using an autoregressive process of lag 1. Summaries of data used in GAMs are presented in table 2 and appendix 1; figure 1.1. Positive C-Q values indicate that concentrations increase with increasing Q and are commonly referred to as "flushing behavior." Conversely, negative C-Q values indicate that concentrations decrease with increasing Q, referred to as "diluting behavior" (Rose and others, 2018). A C-Q slope of zero indicates that concentration does not change with changing Q and is referred to as "chemostatic."

Load Estimations

TN and TP loads and flow-normalized loads were estimated using weighted regression on time, discharge, and season (WRTDS). Modeling was performed in the R statistical software platform using the EGRET package (Hirsch and others, 2024). The mean daily Q records obtained from the National Water Information System contained substantial gaps that required estimation prior to their use in load calculation. The general approach to completing a mean daily Q record was to first complete the "unit value" record (streamgage data reported at 15-minute intervals) as much as possible, then use the unit

values to supplement the mean daily record. Missing unit values were estimated as the lowest recorded Q when the gage height was at or below the lowest height for which Q was reported (threshold of suppression). Where gaps did not exceed 4 days in length, unit values were estimated by linear interpolation with the R package imputeTS (Moritz and Bartz-Beielstein, 2017).

Remaining missing values in the daily record were estimated using the Maintenance of Variance Extension Type 1 (MOVE.1; Hirsch, 1982) method with the smwrStats R package version 0.7.6 (Lorenz and De Cicco, 2017) and nearby reference streamgages. An exception to this process was made for HB-OST2, which was completed by substituting all missing unit values with the lowest recorded Q and calculating the missing daily mean values from the unit values. WRTDS was then computed using default parameters. Modeled loads can be accessed at Crowley-Ornleas and others (2026).

Results

Discharge Trends

Seasonal Trends

Generally, average monthly Q tended to be highest in the spring months of March and April and lowest in the summer months of August and September during peak growing season (fig. 4). This seasonal trend, which results from precipitation in the region (appendix 1; fig. 1.2*A*, *C*), is apparent at all monitoring sites in Harris Bayou watershed, including HB-OST2, HB-RB, and HB-HB. Q increased from the top of the watershed at HB-OST2 (mean Q = 10.1 ft^3/s) through the midpoint at HB-RB (mean Q = 66.5 ft^3/s) to the mouth of the watershed at HB-HB (mean Q = 133.7 ft^3/s). Seasonal patterns that result from precipitation (refer to appendix 1; fig. 1.2*B*, *D*) were also apparent in Porter Bayou watershed, with the highest monthly average Q observed in the spring and lowest flows observed in September and October. Similar to Harris Bayou watershed, in Porter Bayou watershed, the highest average Q was observed at the mouth, at PB-Steph (mean Q = 124.5 ft^3/s). The second highest flows were observed at the top of the watershed at PB-Shaw (mean Q = 85.6 ft^3/s), whereas the lowest flows in Porter Bayou watershed were observed at PB-Trib (mean Q = 27.6 ft^3/s). The PB-Trib site is on a tributary to Porter Bayou rather than Porter Bayou proper, which explains why Q is lower at PB-Trib than upstream at PB-Shaw.

Long-Term Trends

Overall, little change in Q was observed over the period of record, except at HB-OST2 in Harris Bayou watershed. Specifically, flows within a ~0.4 and 0.5 daily nonexceedance probability range increased by as much as 15 percent per year, and higher flows at a daily nonexceedance probability of 0.98 increased by ~5 percent per year (fig. 5*A*). Less pronounced changes in Q were observed at HB-RB and HB-HB. At HB-RB, only flows between 0.91 and 0.93 daily nonexceedance probabilities significantly changed over the period of record, decreasing by ~9–10 percent per year (fig. 5*C*). At HB-HB, slight increases in flow between 2 and 5 percent per year were observed between 0.85 and 0.99 daily nonexceedance probabilities (fig. 5*E*). Compared to Harris Bayou watershed, observed changes in Q were less significant in Porter Bayou watershed, where only PB-Steph had significant changes in Q over the period of record. Specifically, Q between ~0.2 and 0.45 daily nonexceedance probabilities increased between ~8 and 11 percent per year (fig. 5*F*). No significant changes in Q were observed at PB-Shaw or PB-Trib (fig. 5*B*, *D*).

Temporal Trends in Nutrient Concentrations

Harris Bayou Watershed

Quantile regression identified significant decreases in concentrations of TN and TP throughout Harris Bayou watershed. Specifically, at HB-OST2, significant decreases in TN were observed for the 50th, 75th, and 95th quantiles (all $p < 0.05$) (fig. 6*A*, table 4). At HB-OST2, however, significant increases in TP were observed for the 25th percentile (fig. 6*D*, table 4). At HB-RB, significant decreases in TN were also observed for the 50th, 75th, and 95th quantiles (all $p < 0.05$, fig. 6*B*, table 4) and significant reductions in TP were observed for the 5th, 25th, and 75th quantiles (all $p < 0.05$, fig. 6*E*, table 4), but reductions were not apparent at median or 95th quantile concentrations. Lastly, at the mouth of Harris Bayou watershed at HB-HB, significant reductions in TN were observed at the 50th and 75th quantiles (both $p < 0.05$, fig. 6*C*, table 4), whereas reductions in TP were observed at the 95th quantile ($p < 0.05$, fig. 6*F*, table 4).

Porter Bayou Watershed

Reductions in concentrations of TN and TP were less apparent in Porter Bayou watershed than in Harris Bayou watershed. At PB-Shaw, reductions in TN were only observed at the 95th percentile ($p < 0.05$, fig. 7*A*, table 4), whereas reductions in lower TP concentrations were observed at the 25th quantile ($p < 0.05$, fig. 7*D*, table 4). At PB-Trib, significant increases in TN and TP were observed for 50th and 75th quantile concentrations (all $p < 0.05$, fig. 7*B*, *E*, table 4). At PB-Steph, the lowest concentrations of TN at the 5th quantile increased, but TP did not change significantly ($p < 0.05$, fig. 7*C*, *F*, table 4).

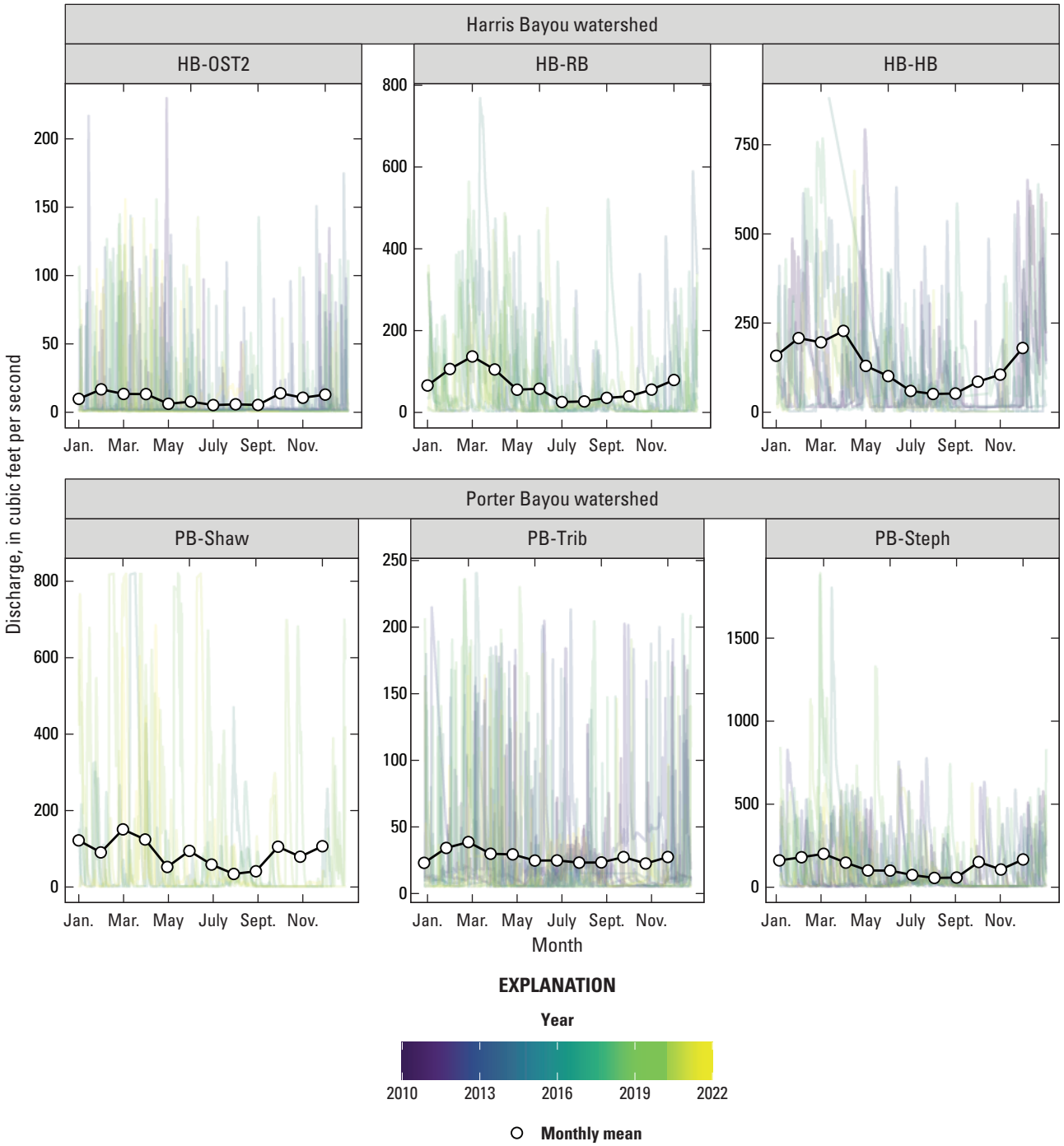


Figure 4. Seasonal patterns in daily discharge at sites in Harris Bayou watershed (top row) and Porter Bayou watershed (bottom row). The y-axis ranges are different for each panel. HB-OST2, Overcup Slough tributary no. 2 near Farrell, Mississippi; HB-RB, Richies Bayou at Sherard, Miss.; HB-HB, Harris Bayou at Palmer Road east of Alligator, Miss.; PB-Shaw, Porter Bayou near Shaw, Miss.; PB-Trib, Porter Bayou trib no. 1 northwest of Frazier, Miss.; PB-Steph, Porter Bayou at Stephensville, Miss. Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

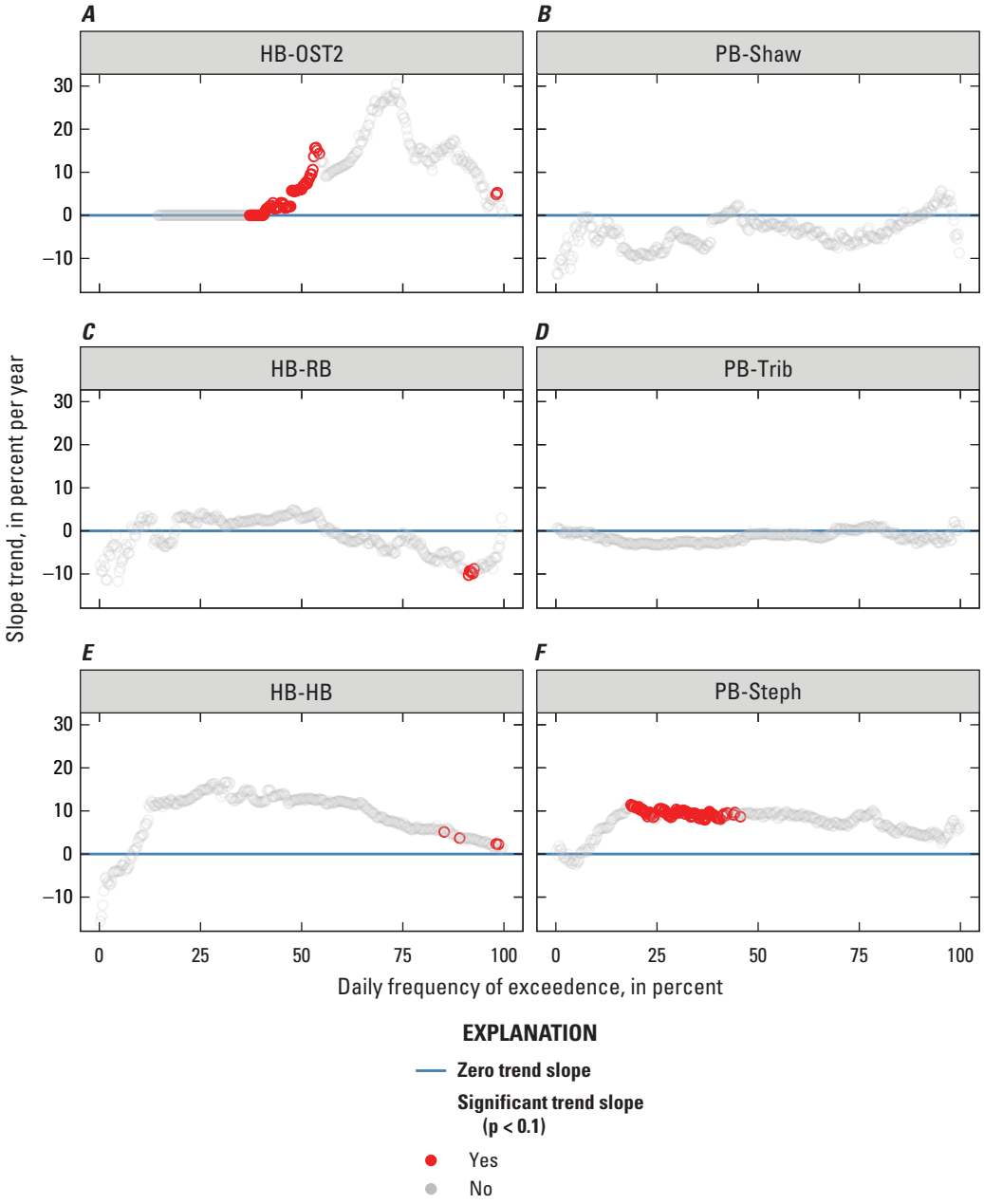


Figure 5. Quantile-Kendall analyses of daily discharge values at (*A*) Overcup Slough tributary no. 2 near Farrell, Mississippi (HB-OST2); (*B*) Porter Bayou near Shaw, Miss. (PB-Shaw); (*C*) Richies Bayou at Sherard, Miss. (HB-RB); (*D*) Porter Bayou trib no. 1 northwest of Frazier, Miss. (PB-Trib); (*E*) Harris Bayou at Palmer Road east of Alligator, Miss. (HB-HB); and (*F*) Porter Bayou at Stephensville, Miss. (PB-Steph). Each point on the plot represents a trend slope indicating how much discharge has increased (positive trend slope) or decreased (negative trend slope) over the period of record. Points are ordered along the x-axis per the order of their statistic. For example, the point farthest to the left is the first order statistic and represents the annual minimum daily discharge. The point farthest to the right is the 365th order statistic and represents the annual maximum daily discharge. Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

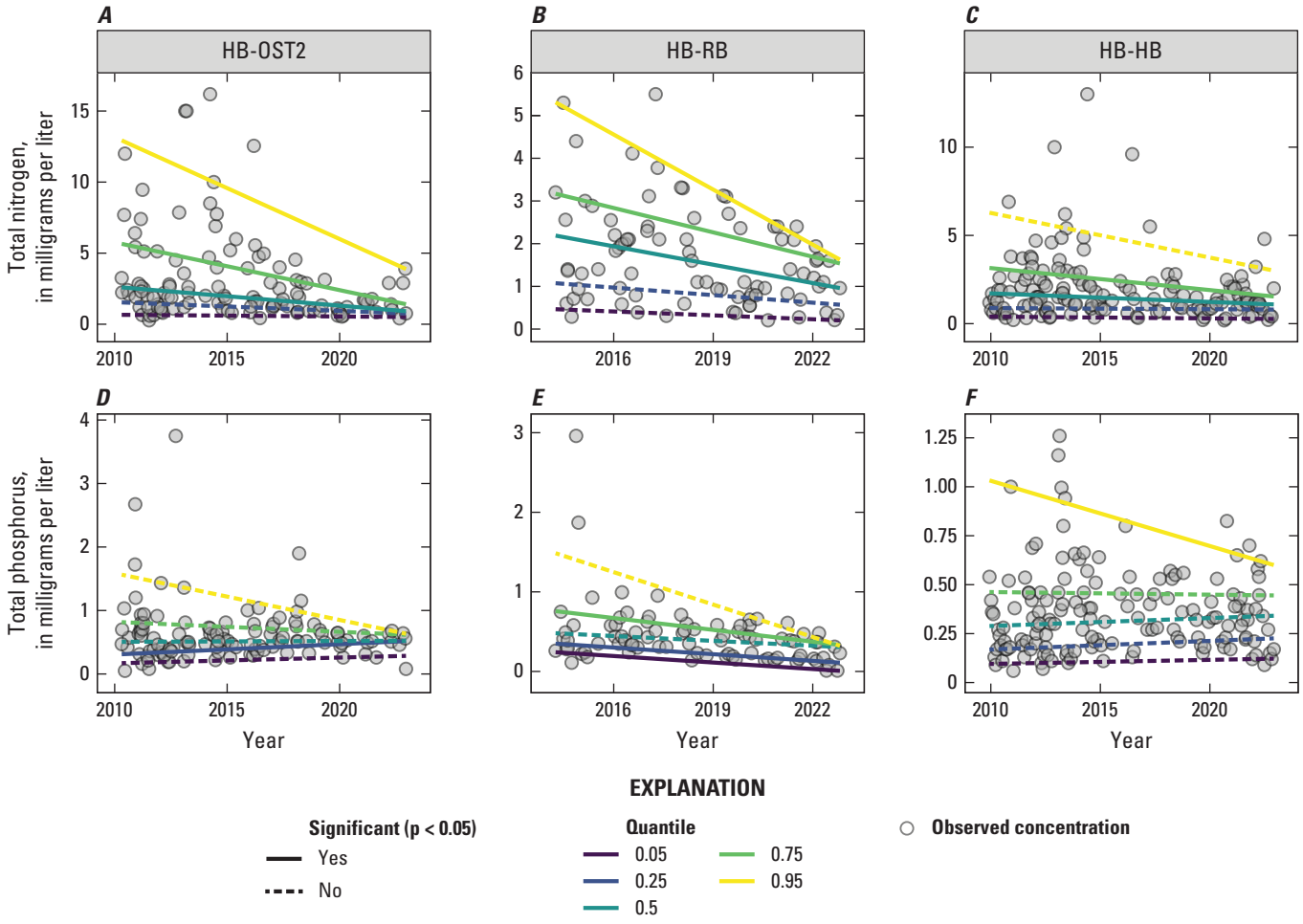


Figure 6. Quantile regression of total nitrogen (*A*–*C*) and total phosphorus (*D*–*F*) at Overcup Slough tributary no. 2 near Farrell, Mississippi (HB-OST2, left column); Richies Bayou at Sherard, Miss. (HB-RB, middle column); and Harris Bayou at Palmer Road east of Alligator, Miss. (HB-HB, right column). Regression was performed on the 5th, 25th, 50th, 75th, and 95th quantiles. Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

Seasonal Trends in Nutrient Concentrations

Generalized additive modeling provided a more detailed description of seasonal patterns of nutrient concentrations over time than quantile regression. Effective degrees of freedom (EDF) represent the degree of nonlinearity in nutrient dynamics and can be used to infer the degree of seasonality. Specifically, EDF = 1 represents a linear relation and thus no seasonality, $1 < \text{EDF} \leq 2$ is considered slightly nonlinear and thus weakly seasonal, and EDF > 2 indicates a high degree of nonlinearity and high seasonality (Zuur and others, 2009).

Harris Bayou Watershed

At HB-OST2, GAMs indicated significant reductions in modeled TN concentrations ($p < 0.001$), but no seasonality was detected, as depicted by all vertical contour lines (fig. 8*A*; EDF = 0.94, table 5). No apparent reductions in TP occurred over time at HB-OST2; however, seasonal patterns were detected, with the highest modeled concentrations occurring in late fall around November (fig. 8*B*; $p < 0.001$; EDF = 11.35, table 5). Significant temporal and seasonal trends in TN and TP were also observed at HB-RB (both $p < 0.001$; EDF = 10.73 and 8.42, respectively, table 5). For TN, modeled concentrations at HB-RB were the highest at the beginning of the period of record pre-growing season during the spring but were consistently predicted to decline over time, reaching modeled concentrations similar to those during the summer growing season by the end of the period of record (figs. 8*C* and 9*B*). Similarly, modeled TP concentrations were highest in the months bracketing the growing season (late spring and late fall) and were consistently predicted to decline over time (figs. 8*D* and 9*C*). Similar to HB-RB, seasonal patterns in predicted TN concentrations that result from the growing season were observed at HB-HB. Predicted TN concentrations at HB-HB were highest at the beginning of the period of record during spring and late fall and declined consistently over time in both periods (figs. 8*E* and 9*A*; $p < 0.001$;

Table 4. Summary statistics for quantile regression of total nitrogen (TN) and total phosphorus (TP) over the period of record.

[Refer to table 3 for additional site information. no., number; Rd, road; MS, Mississippi; NW, northwest; coeff, coefficient; SE, standard error; P, p-value]

Quantile	Statistic	Harris Bayou watershed						Porter Bayou watershed					
		Overcup Slough tributary no 2 near Farrell, MS (HB-OST2)		Richies Bayou at Sherard, MS (HB-RB)		Harris Bayou at Palmer Rd east of Alligator, MS (HB-HB)		Porter Bayou near Shaw, MS (PB-Shaw)		Porter Bayou trib no 1 NW of Frazier, MS (PB-Trib)		Porter Bayou at Stephensville, MS (PB-Steph)	
		TN	TP	TN	TP	TN	TP	TN	TP	TN	TP	TN	TP
0.05	Coeff	−0.01	0.01	−0.03	−0.03[a]	−0.01	0.002	0.001	−0.01	0.004	0.003	0.02[a]	−0.004
0.05	SE	0.02	0.01	0.03	0.01[a]	0.01	0.002	0.01	0.01	0.03	0.007	0.01[a]	0.004
0.05	P	0.59	0.43	0.26	0.002[a]	0.41	0.40	0.95	0.15	0.92	0.67	0.04[a]	0.35
0.25	Coeff	−0.06	0.02[a]	−0.06	−0.03[a]	−0.01	0.004	−0.04	−0.02[a]	0.06	0.004	0.02	0.00
0.25	SE	0.04	0.01[a]	−0.05	0.01[a]	0.02	0.003	0.04	0.01[a]	0.07	0.01	0.03	0.01
0.25	P	0.14	0.04[a]	0.29	0.004[a]	0.77	0.18	0.26	0.01[a]	0.39	0.70	0.49	1.00
0.50	Coeff	−0.13[a]	0.001	−0.14[a]	−0.02	−0.05[a]	0.004	−0.02	−0.01	0.17[a]	0.03[a]	0.00	0.01
0.50	SE	0.04[a]	0.008	0.08[a]	0.02	0.02[a]	0.01	0.07	0.01	0.09[a]	0.01[a]	0.03	0.01
0.50	P	0.002[a]	0.86	0.05[a]	0.23	0.02[a]	0.44	0.75	0.25	0.05[a]	0.002[a]	1.00	0.30
0.75	Coeff	−0.34[a]	−0.02	−0.19[a]	−0.05[a]	−0.12[a]	−0.001	−0.08	0.00	0.46[a]	0.04[a]	0.01	0.01
0.75	SE	0.13[a]	0.01	0.09[a]	0.02[a]	0.05[a]	0.008	0.14	0.01	0.23[a]	0.02[a]	0.07	0.01
0.75	P	0.01[a]	0.10	0.03[a]	0.01[a]	0.01[a]	0.87	0.54	0.99	0.05[a]	0.03[a]	0.89	0.36
0.95	Coeff	−0.72[a]	−0.07	−0.43[a]	−0.14	−0.25	−0.03[a]	−0.80[a]	−0.03	0.69	−0.02	0.14	0.02
0.95	SE	0.31[a]	0.06	0.09[a]	0.09	0.16	0.02[a]	0.38[a]	0.07	0.58	0.03	0.50	0.04
0.95	P	0.02[a]	0.23	<0.001[a]	0.12	0.11	0.05[a]	0.04[a]	0.69	0.23	0.56	0.78	0.61

[a]Statistically significant relation ($p \leq 0.05$).

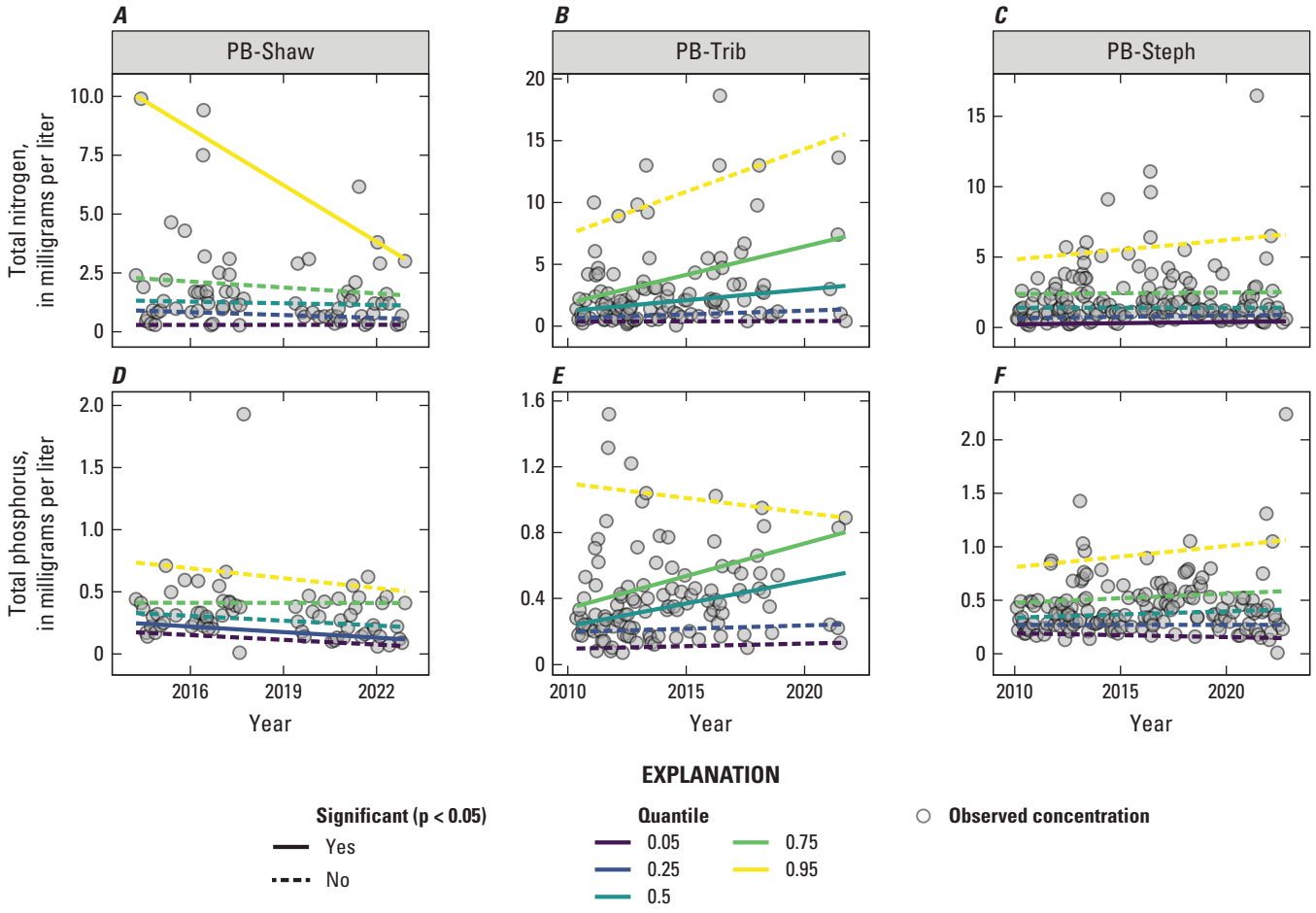


Figure 7. Quantile regression of total nitrogen (*A*–*C*) and total phosphorus (*D*–*F*) at Porter Bayou near Shaw, Mississippi (PB-Shaw, left column); Porter Bayou trib no. 1 northwest of Frazier, Miss. (PB-Trib, middle column); and Porter Bayou at Stephensville, Miss. (PB-Steph, right column). Regression was performed on the 5th, 25th, 50th, 75th and 95th quantiles. Refer to table 3 for additional site information.

EDF = 13.7, table 5). Predicted TP concentrations were lower at HB-HB than at HB-OST2 and HB-RB but showed signs of seasonality, with slightly higher modeled concentrations occurring in the spring and fall (fig. 8*F*; $p < 0.001$, EDF = 9.01, table 5). Unlike TN, however, predicted TP concentration spikes remained consistent over the period of record in the fall and increased in the spring.

Porter Bayou Watershed

In Porter Bayou watershed, seasonal trends in modeled nutrient concentrations were also apparent but differed among sites. Specifically, at PB-Shaw, significant seasonality in predicted TN concentrations was observed, with higher modeled concentrations predicted in late spring around June, which, contrary to quantile regression, decreased over the period of record (figs. 10*A* and 11*A*; $p < 0.001$, EDF = 9.22, table 5). No significant seasonal or annual trend was detected for TP at PB-Shaw (fig. 10*B*, $p = 0.56$, table 5). Conversely, at PB-Trib, modeled TN concentrations increased in June over the period of record (figs. 10*C* and 11*B*; $p < 0.001$, EDF = 11.08, table 5), whereas TP concentrations tended to increase in spring and fall/winter months (fig. 10*D*; $p = 0.029$, EDF = 5.24, table 5). At PB-Steph, TN and TP showed significant seasonality (both $p < 0.001$, EDF = 12.99 and 10.73, respectively, table 5). The highest modeled TN concentrations at PB-Steph were predicted for late May at the beginning of the record and shifted to early June by the end of the record, whereas the lowest concentrations were predicted for the growing season between August and October (fig. 10*E*). The highest modeled TP concentrations at PB-Steph were observed in spring and fall and were also lowest during the growing season (fig. 10*F*). However, concentration spikes bracketing the growing season did not decrease over the period of record at PB-Steph.

Table 5. Summary statistics for the time-varying and seasonal generalized additive models.

[Refer to table 3 for additional site information. est, estimated intercept; SE, standard error, t, t-value; p, p-value; EDF, effective degrees of freedom; F, F-statistic; r^2, coefficient of determination; HB-OST2, Overcup Slough tributary no 2 near Farrell, Mississippi; TN, total nitrogen; TP, total phosphorus; HB-RB, Richies Bayou at Sherard, Miss.; HB-HB, Harris Bayou at Palmer Road east of Alligator, Miss.; PB-Shaw, Porter Bayou near Shaw, Miss.; PB-Trib, Porter Bayou trib no 1 northwest of Frazier, Miss.; PB-Steph, Porter Bayou at Stephensville, Miss.; *f*1(year, month) represents the concentration trend, whereas *f*2(year, month * *q*) represents the concentration-discharge (C-Q) slope trend; <, less than]

Site	Nutrient	Parametric coefficients (intercept)				Smooth terms				Adjusted r^2
		Est	SE	t	p	Term	EDF	F	p	
HB-OST2	TN	0.35	0.038	9.26	<0.001	*f*1(year, month)	0.94	0.13	<0.001	0.17
HB-OST2	TN	0.35	0.038	9.26	<0.001	*f*2(year, month * *q*)	4.35	0.26	<0.001	0.17
HB-OST2	TP	−0.27	0.021	−12.76	<0.001	*f*1(year, month)	11.35	0.24	0.001	0.47
HB-OST2	TP	−0.27	0.021	−12.76	<0.001	*f*2(year, month * *q*)	13.79	0.79	<0.001	0.47
HB-RB	TN	0.12	0.028	4.36	<0.001	*f*1(year, month)	10.73	0.97	<0.001	0.43
HB-RB	TN	0.12	0.028	4.36	<0.001	*f*2(year, month * *q*)	$1.8e^{-5}$	0.00	0.62	0.43
HB-RB	TP	−0.48	0.031	−15.25	<0.001	*f*1(year, month)	8.42	0.53	<0.001	0.44
HB-RB	TP	−0.48	0.031	−15.25	<0.001	*f*2(year, month * *q*)	1.67	0.36	0.002	0.44
HB-HB	TN	0.15	0.024	6.15	<0.001	*f*1(year, month)	13.7	0.55	<0.001	0.45
HB-HB	TN	0.15	0.024	6.15	<0.001	*f*2(year, month * *q*)	4.3	0.16	<0.001	0.45
HB-HB	TP	−0.53	0.018	−30.02	<0.001	*f*1(year, month)	9.01	0.20	<0.001	0.48
HB-HB	TP	−0.53	0.018	−30.02	<0.001	*f*2(year, month * *q*)	6.02	0.83	<0.001	0.48
PB-Shaw	TN	0.061	0.035	1.73	0.09	*f*1(year, month)	9.22	0.79	<0.001	0.57
PB-Shaw	TN	0.061	0.035	1.73	0.09	*f*2(year, month * *q*)	3.02	0.30	<0.001	0.57
PB-Shaw	TP	−0.56	0.034	−16.53	<0.001	*f*1(year, month)	$7.6e^{-6}$	0.00	0.56	0.24
PB-Shaw	TP	−0.56	0.034	−16.53	<0.001	*f*2(year, month * *q*)	1.79	0.41	<0.001	0.24
PB-Trib	TN	0.29	0.041	7.08	<0.001	*f*1(year, month)	11.08	0.68	<0.001	0.51
PB-Trib	TN	0.29	0.041	7.08	<0.001	*f*2(year, month * *q*)	8.33	0.64	<0.001	0.51
PB-Trib	TP	−0.48	0.027	−17.76	<0.001	*f*1(year, month)	5.24	0.15	0.029	0.26
PB-Trib	TP	−0.48	0.027	−17.76	<0.001	*f*2(year, month * *q*)	3.31	0.32	<0.001	0.26
PB-Steph	TN	0.15	0.023	6.48	<0.001	*f*1(year, month)	12.99	0.64	<0.001	0.56
PB-Steph	TN	0.15	0.023	6.48	<0.001	*f*2(year, month * *q*)	5.63	0.57	<0.001	0.56
PB-Steph	TP	−0.44	0.021	−21.13	<0.001	*f*1(year, month)	10.73	0.30	<0.001	0.36
PB-Steph	TP	−0.44	0.021	−21.13	<0.001	*f*2(year, month * *q*)	10.92	0.57	<0.001	0.36

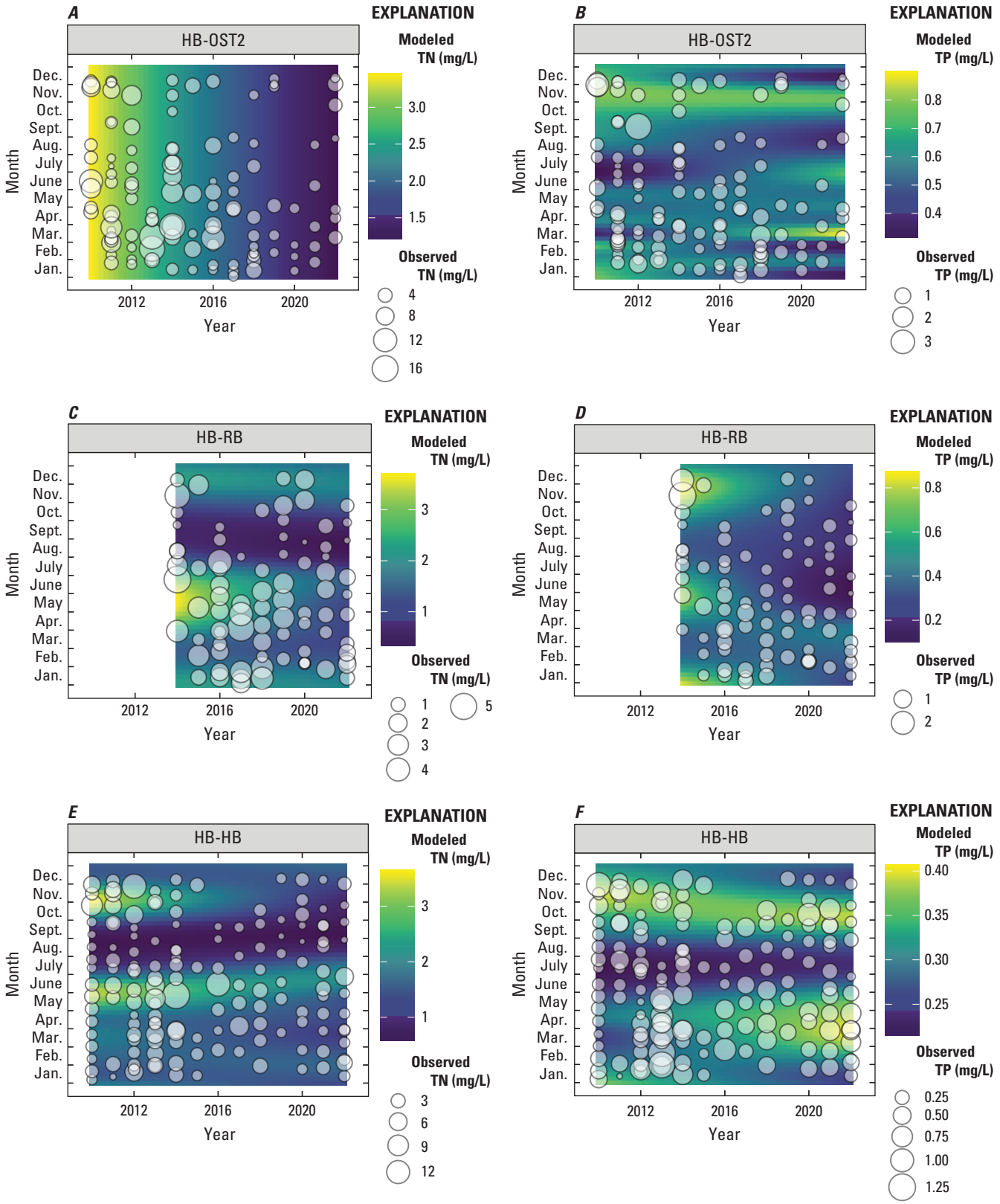


Figure 8. Generalized additive model predictions and observed concentrations of total nitrogen (TN, left column) and total phosphorus (TP, right column) concentrations across years and months for Harris Bayou watershed. *A*, *B*, Overcup Slough tributary no. 2 near Farrell, Mississippi (HB-OST2); *C*, *D*, Richies Bayou at Sherard, Miss. (HB-RB); and *E*, *F*, Harris Bayou at Palmer Road east of Alligator, Miss. (HB-HB). Refer to table 3 for additional site information (U.S. Geological Survey, 2026a). mg/L, milligram per liter

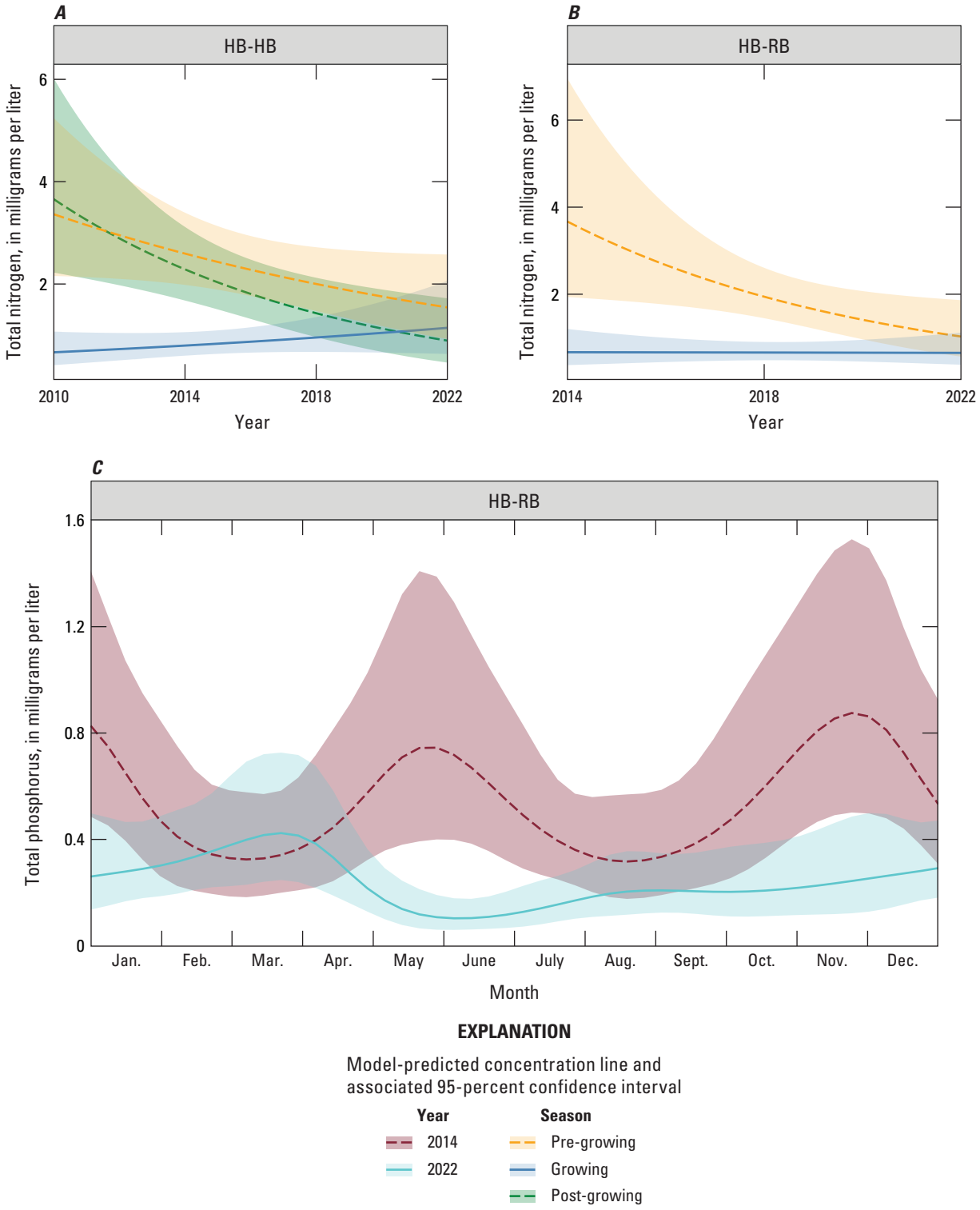


Figure 9. Examples of generalized additive model predictions showing seasonal decreases in nutrient concentrations over the period of record. *A*, Predicted total nitrogen (TN) concentrations at Harris Bayou at Palmer Road east of Alligator, Mississippi (HB-HB) pre-growing season, post-growing season, and during the growing season. *B*, Modeled TN concentrations at Richies Bayou at Sherard, Miss. (HB-RB) pre-growing season and during the growing season. *C*, Seasonal variability in predicted total phosphorus concentrations (TP) at HB-RB across months during the first and last year of record. Predictions are from the same model represented in figure 8. Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

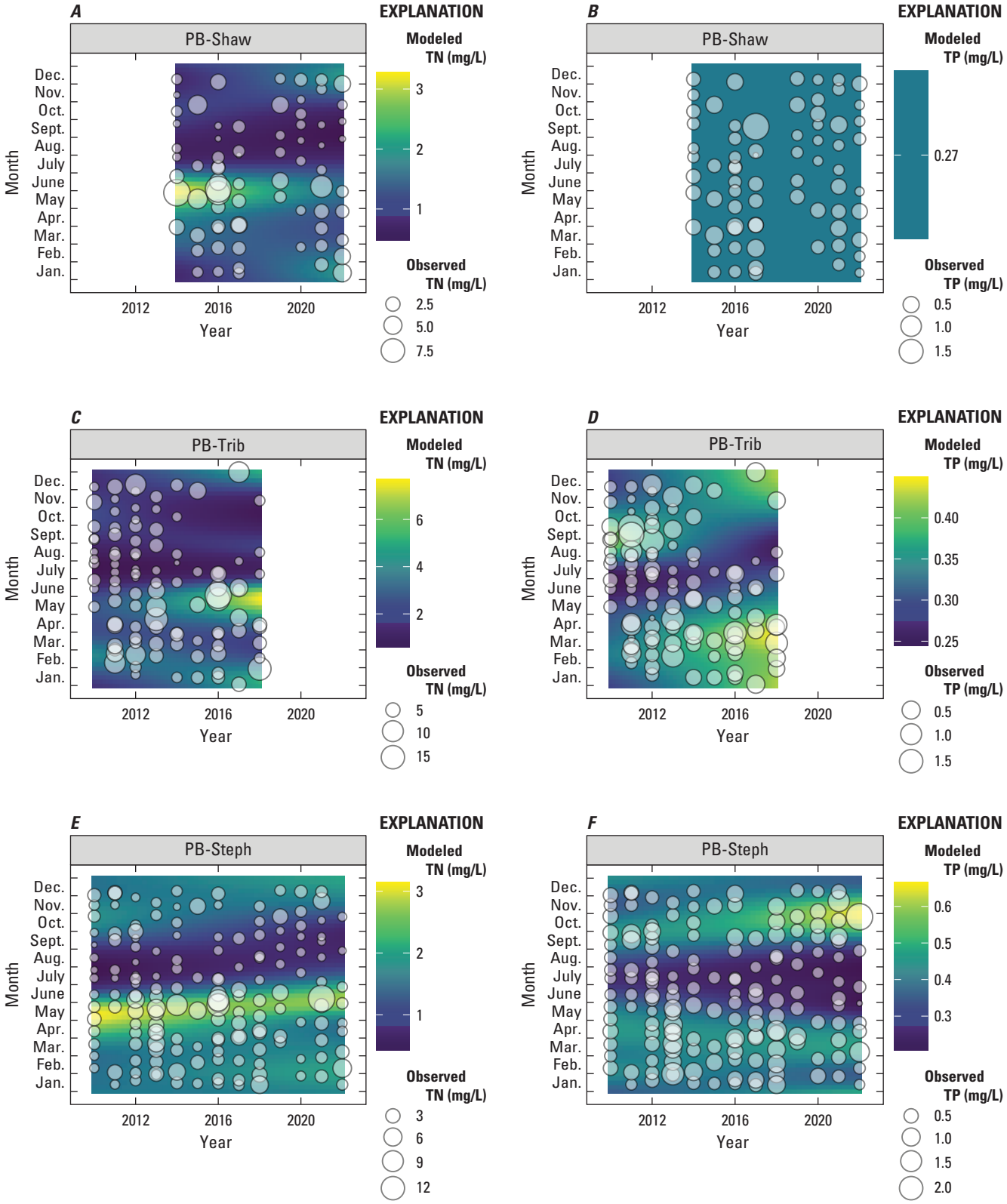


Figure 10. Generalized additive model predictions of total nitrogen (TN, left column) and total phosphorus (TP, right column) concentrations across years and months for Porter Bayou watershed. *A*, *B*, Porter Bayou near Shaw, Mississippi (PB-Shaw); *C*, *D*, Porter Bayou trib no. 1 northwest of Frazier, Miss. (PB-Trib); *E*, *F*, Porter Bayou at Stephensville, Miss. (PB-Steph). Refer to table 3 for additional site information (U.S. Geological Survey, 2026a). mg/L, milligram per liter

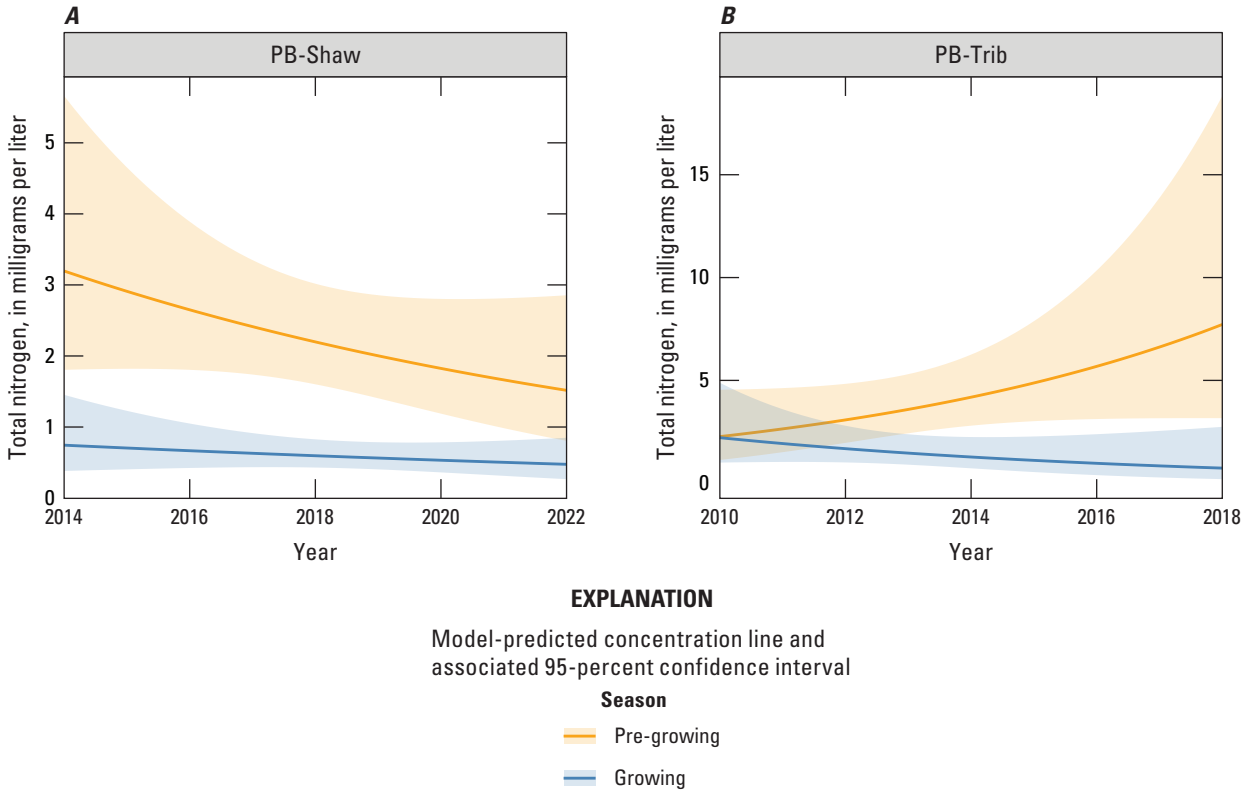


Figure 11. Predicted total nitrogen concentrations highlighting concentration differences between pre-growing and growing seasons over the period of record at (*A*) Porter Bayou near Shaw, Miss. (PB-Shaw); and (*B*) Porter Bayou trib no. 1 northwest of Frazier, Miss. (PB-Trib). Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

Seasonal Trends in Concentration-Discharge Relations

Harris Bayou Watershed

Significant seasonal trends in C-Q relations were observed at all sites in Harris Bayou watershed for TN and TP ($p < 0.001$, table 4), except for TN at HB-RB (fig. 12*C*; $p = 0.62$, table 5). The most pronounced changes in C-Q relations for Harris Bayou watershed occurred at HB-OST2, where TN and TP C-Q slopes shifted from flushing (slope > 0) to diluting (slope < 0) in certain seasons over the period of record (fig. 12*A*, *B*; EDF = 4.35 and 13.79, respectively). At the beginning of the period of record in 2010, TN C-Q slopes at HB-OST2 were highest in winter during January and late fall during November but decreased to negative values by the end of the period of record in 2022 (fig. 13*A*). In 2010, the highest TP C-Q slopes at HB-OST2 occurred in winter in late January and in summer in June. By 2022, C-Q slopes in June were negative, indicating diluting behavior, and slopes were near zero in January, indicating chemostatic behavior. Despite TN C-Q slopes shifting from flushing to diluting in the fall, TP C-Q slopes at HB-OST2 remained negative over the period of record during the fall growing season in September (fig. 13*B*), consistent with lower suspended sediment concentrations (SSCs) in the late summer and early fall (appendix 1; fig. 1.2*E*). Although there was no significant change in TN C-Q slopes at HB-RB, TP C-Q slopes consistently increased over the period of record (fig. 12*D*; $p = 0.002$, EDF = 1.67, table 5). At HB-HB, TN C-Q slopes were highest in July at the beginning of the period of record and decreased to near-zero values by 2022 (fig. 12*E*; EDF = 4.3, table 5). TP C-Q slopes were highest in late April at HB-HB in 2010 and also decreased to near-zero values over the period of record (fig. 12*F*; EDF = 6.02, table 5). For TN and TP, however, C-Q slope confidence bands overlap across years and seasons.

Porter Bayou Watershed

Significant seasonal C-Q relations were observed at all sites in Porter Bayou watershed for TN and TP (all $p < 0.001$, table 4). Trends in TN-CQ slopes at PB-Shaw were similar to those at HB-OST2 in Harris Bayou watershed, with steeper slopes occurring in the winter at the beginning of the period of record but decreasing to near zero by 2022 (fig. 14*A*; EDF = 3.02, table 5). The highest C-Q slopes for any site in Harris Bayou watershed and Porter Bayou watershed were detected at PB-Trib for TN, but seasonal variability was inconsistent over the period of record (fig. 14*C*; EDF = 8.33, table 5).

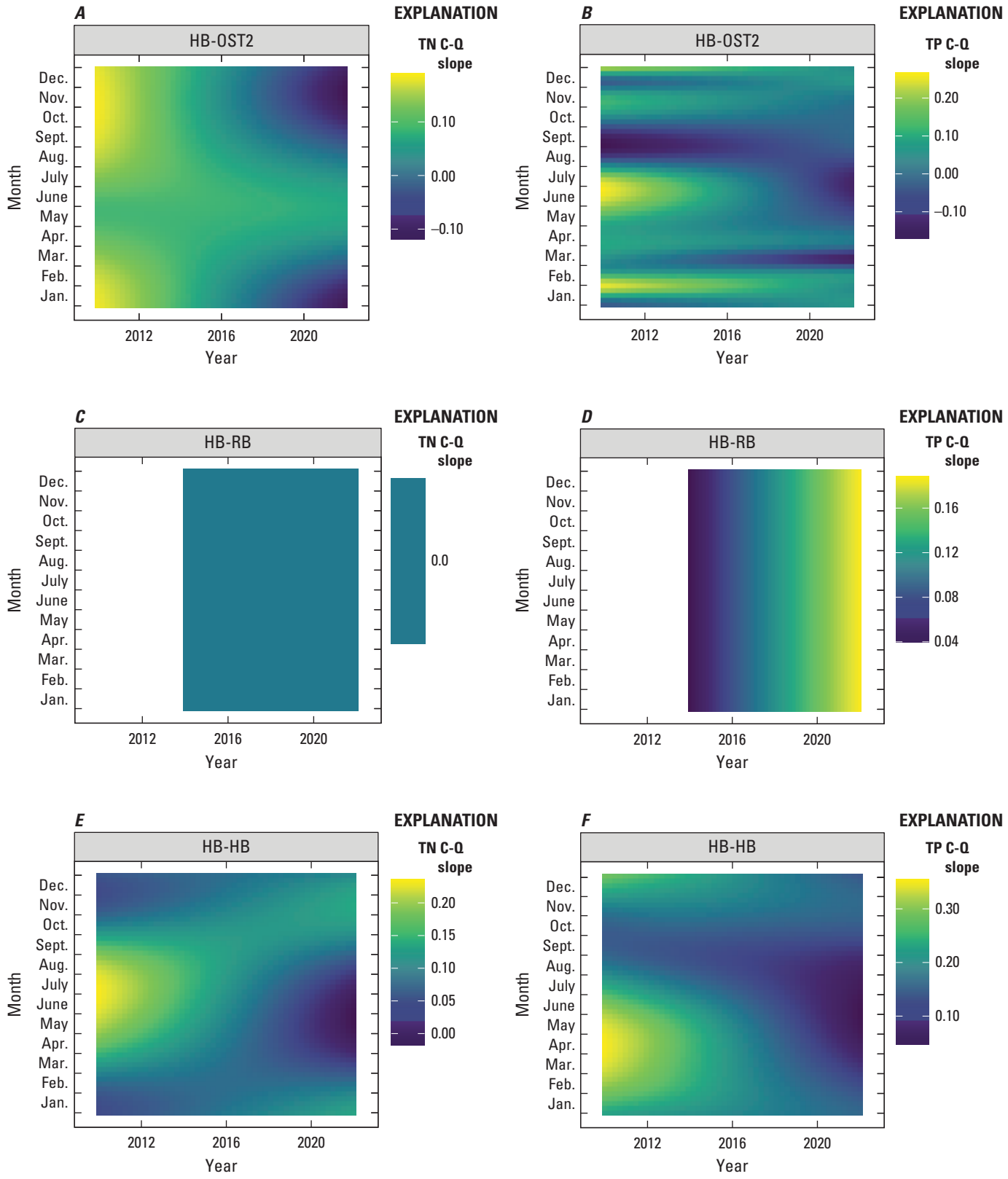


Figure 12. Modeled total nitrogen (TN, left column) and total phosphorus (TP, right column) concentration-discharge slopes (C-Q slopes) across seasons over the period of record for Harris Bayou watershed. *A*, *B*, Overcup Slough tributary no. 2 near Farrell, Mississippi (HB-OST2); *C*, *D*, Richies Bayou at Sherard, Miss. (HB-RB); *E*, *F*, Harris Bayou at Palmer Road east of Alligator, Miss. (HB-HB). Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

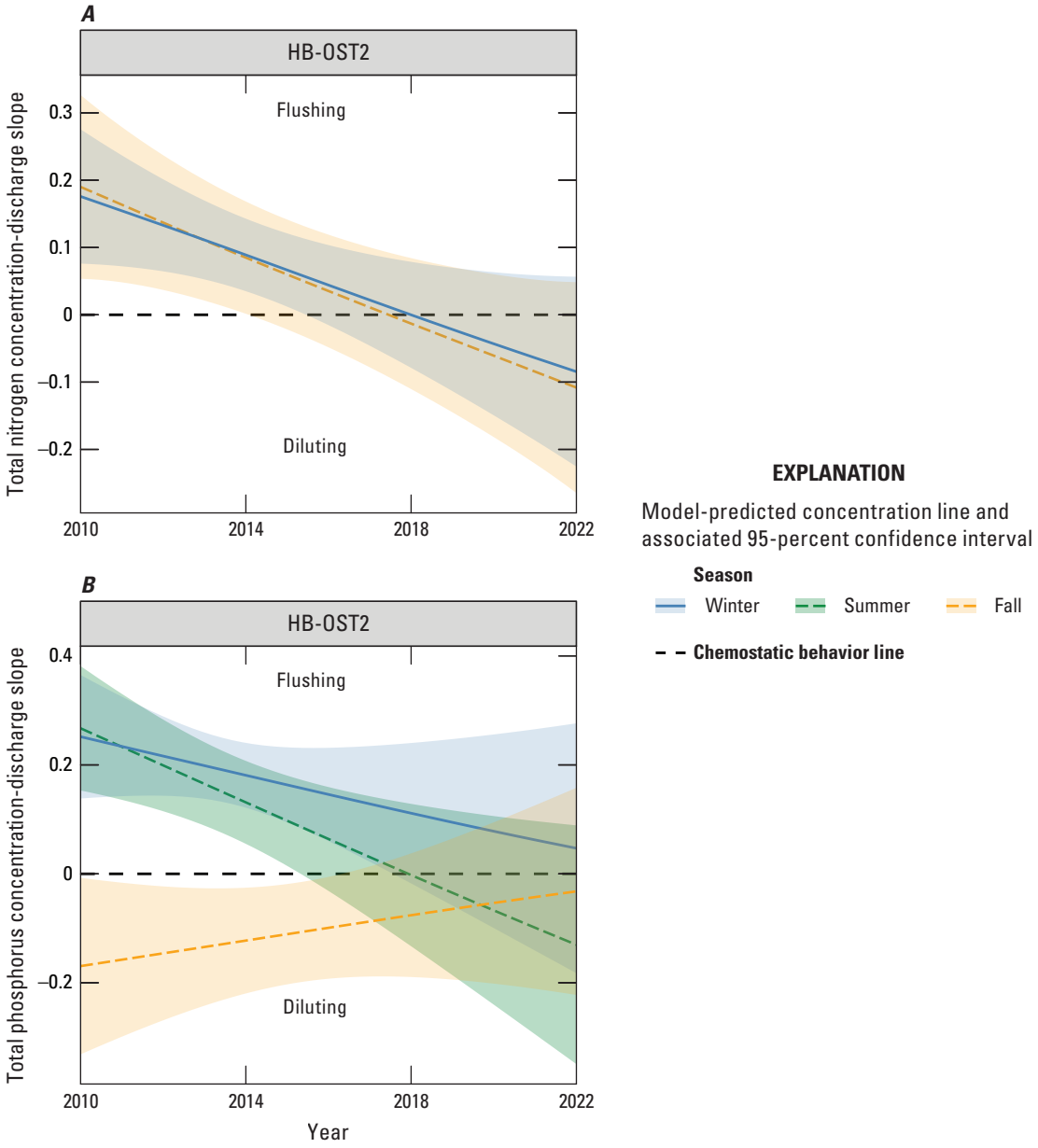


Figure 13. Examples of (*A*) total nitrogen and (*B*) total phosphorus concentration-discharge slopes at Overcup Slough tributary no. 2 near Farrell, Mississippi (HB-OST2). Refer to table 3 for additional site information. The chemostatic behavior line indicates no concentration change with changing discharge. Positive values above the line indicate flushing behavior, whereby concentrations increase with discharge. Negative values below the dashed line indicate diluting behavior, whereby concentrations decrease with increasing discharge. Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

TP C-Q slopes consistently increased over the period of record at PB-Trib, particularly during the summer months between July and September (fig. 14*D*; EDF = 3.31, table 5). At PB-Steph, TN C-Q slopes were also highest in winter months at the beginning of the period of record and steadily decreased to near-zero values by 2022 (fig. 14*E*; EDF = 5.63, table 5). TP C-Q slopes showed considerable seasonal variability at PB-Steph and were generally highest in winter and lowest during the fall growing-season months (fig. 14*F*; EDF = 10.92, table 5).

WRTDS Load Estimates

Across all monitoring sites in Harris Bayou watershed and Porter Bayou watershed, flow-normalized (Q-norm) daily load estimates for TN and TP indicate that throughout a given year, loads were consistently highest in the spring between March and April and lowest in the fall between September and November (fig. 15). Further, the largest reductions in loads also occurred during spring months, particularly at the mouths of each watershed at HB-HB and PB-Steph. In Harris Bayou

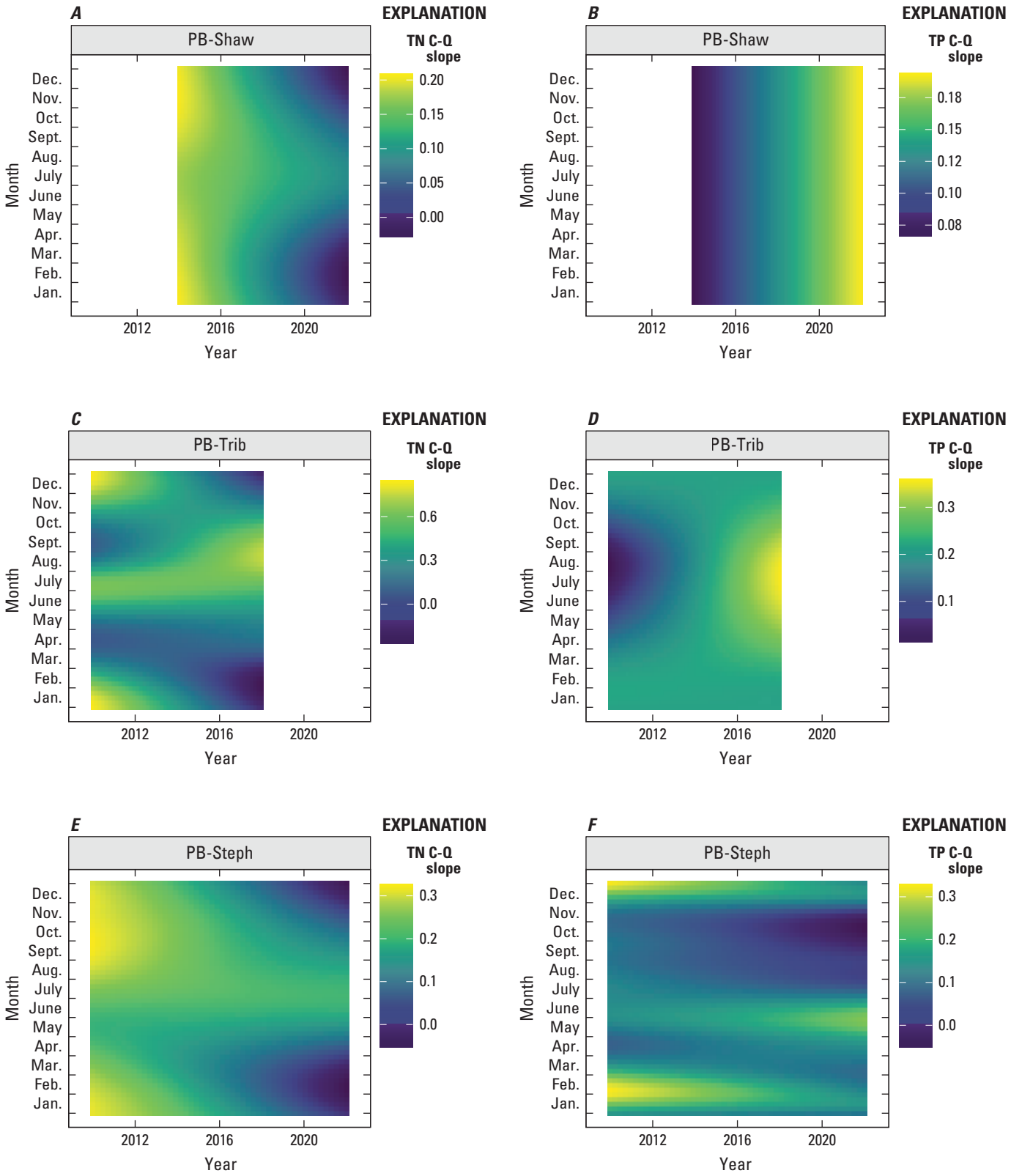


Figure 14. Modeled total nitrogen (TN, left column) and total phosphorus (TP, right column) concentration-discharge slopes (C-Q slopes) across seasons over the period of record for Porter Bayou watershed. *A*, *B*, Porter Bayou near Shaw, Mississippi (PB-Shaw); *C*, *D*, Porter Bayou trib no. 1 northwest of Frazier, Miss. (PB-Trib); *E*, *F*, Porter Bayou at Stephensville, Miss. (PB-Steph). Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

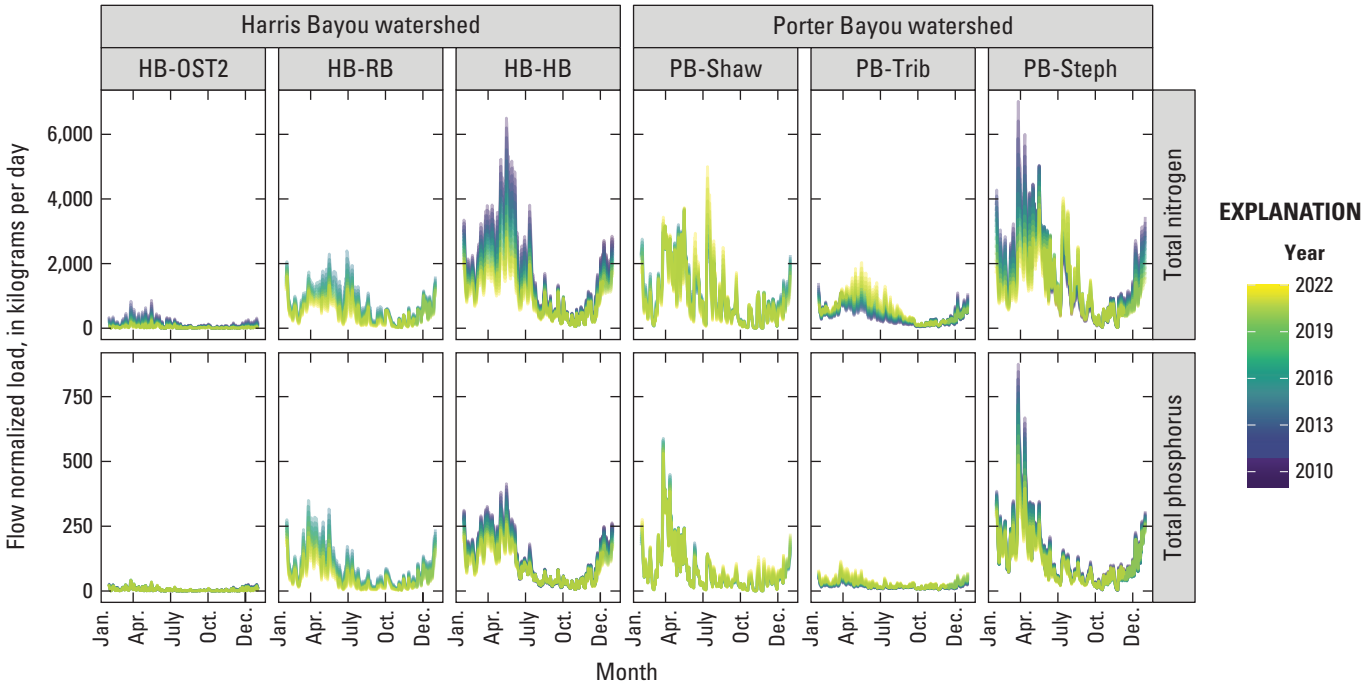


Figure 15. Seasonal patterns in flow-normalized load estimates for total nitrogen (TN) and total phosphorus (TP) at study sites in Harris Bayou watershed and Porter Bayou watershed. HB-OST2, Overcup Slough tributary no. 2 near Farrell, Mississippi; HB-RB, Richies Bayou at Sherard, Miss.; HB-HB, Harris Bayou at Palmer Road east of Alligator, Miss.; PB-Shaw, Porter Bayou near Shaw, Miss.; PB-Trib, Porter Bayou trib no. 1 northwest of Frazier, Miss.; PB-Steph, Porter Bayou at Stephensville, Miss. Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

watershed, peak Q-norm daily load estimates at the watershed mouth decreased over the period of record from 6,502 to 2,803 kilograms per day (kg/d) (56.9 percent reduction in peak loads) for TN and from 414 to 258 kg/d (37.7 percent reduction in peak loads) for TP, both occurring in the spring (fig. 15). In Porter Bayou watershed, peak Q-norm load estimates at the watershed mouth decreased over the period of record from 7,021 to 4,035 kg/d (42.5 percent reduction in peak loads) for TN and from 875 to 487 kg/d (44.3 percent reduction in peak loads) for TP, again both occurring in the spring (fig. 15). Consistent declines in estimated Q-norm spring nutrient loads were also observed at HB-OST2 and HB-RB in Harris Bayou watershed. In Porter Bayou watershed, load reductions were not observed for TN or TP at PB-Shaw, and load estimates increased at PB-Trib (fig. 15).

Collectively across the period of record, mean daily load estimates (non-Q-norm) were highly variable across years, but Q-norm mean daily loads for each year consistently decreased for TN and TP at every monitoring site in Harris Bayou watershed (fig. 16). At HB-OST2, mean daily Q-norm TN load estimates decreased from 112 to 29 kg/d, a decrease of 76.4 percent. Estimated mean daily TP loads decreased from 6.2 to 5.2 kg/d, a reduction of 16.2 percent. At HB-RB, mean daily Q-norm TN loads decreased from 754.2 to 447.1 kg/d, a decrease of 40.7 percent. The greatest reduction in mean daily TP loads was observed at HB-RB, decreasing 43.9 percent from 86.7 to 48.6 kg/d. At HB-HB, mean daily Q-norm TN loads decreased 43.2 percent, from 1,705 to 969.1 kg/d, while mean TP loads decreased from 121.4 to 92.3 kg/d, or 24.0 percent.

Reductions in mean daily load estimates were not as evident throughout Porter Bayou watershed, but similar to Harris Bayou watershed, non-Q-norm mean daily loads were highly variable across years (fig. 16). Q-norm mean daily estimates of TN loads actually increased over the period of record at PB-Trib, and TP loads increased at PB-Shaw and PB-Trib. At PB-Shaw, mean TN loads decreased from 1,036 to 982.4 kg/d, a decrease of 5.3 percent. Conversely, mean TP loads increased from 79.0 to 84.8 kg/d, an increase of 7.3 percent. The greatest percentage increases in loads were observed at PB-Trib. Mean Q-norm TN loads increased from 365.5 to 607.6 kg/d, representing an increase of 66.2 percent. Percent increases of mean Q-norm TP loads were similar to TN, and increased by 59.4 percent from 19.2 to 30.6 kg/d. Despite increases in mean daily loads at upstream and tributary locations, load estimates at the mouth at PB-Steph consistently decreased over time, at a rate similar to HB-HB (appendix 1; fig. 1.3). Mean daily TN load estimates decreased from 1,633 to 1,201 kg/d, or 26.5 percent. TP loads decreased from 137.8 to 112.0 kg/d, a decrease of 18.7 percent.

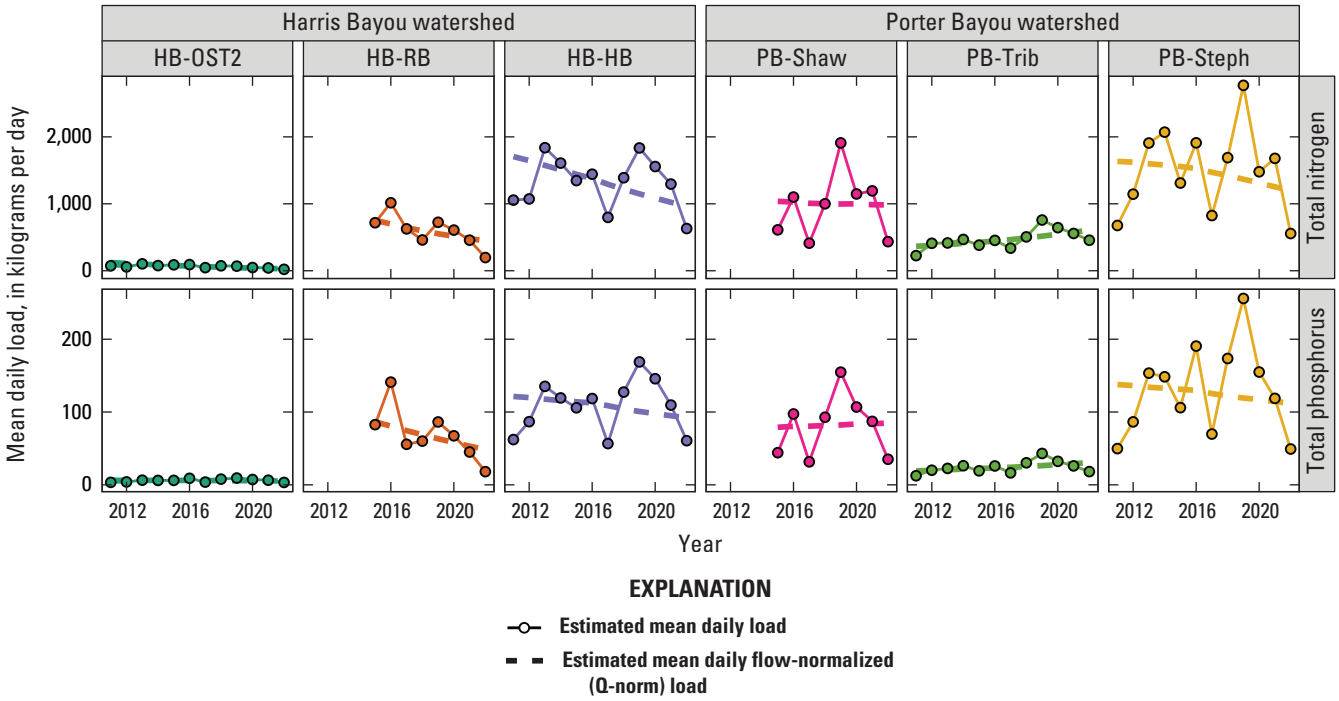


Figure 16. Weighted regression on time, discharge, and season (WRTDS) mean daily load estimates and mean daily flow-normalized (Q-norm) load estimates for each year for total nitrogen and total phosphorus at sites in Harris Bayou watershed and Porter Bayou watershed. HB-OST2, Overcup Slough tributary no. 2 near Farrell, Mississippi; HB-RB, Richies Bayou at Sherard, Miss.; HB-HB, Harris Bayou at Palmer Road east of Alligator, Miss.; PB-Shaw, Porter Bayou near Shaw, Miss.; PB-Trib, Porter Bayou trib no. 1 northwest of Frazier, Miss.; PB-Steph, Porter Bayou at Stephensville, Miss. Refer to table 3 for additional site information (U.S. Geological Survey, 2026a).

Discussion

Primary Observations in Harris Bayou Watershed and Porter Bayou Watershed

Overall, there is substantial evidence that TN concentrations have declined since BMP implementation in Harris Bayou watershed, while TP concentrations have remained largely consistent. Seasonal patterns of TN and TP concentrations were evident in both watersheds. In general, nutrient concentrations were highest in the spring and winter months and lowest during the summer and fall growing months, and decreases in seasonal TN concentration spikes drove long-term TN reductions. C-Q relations indicate that at certain sites, TN and TP concentrations have become less driven by Q over time. However, significant reductions in concentrations were only observed with TN, not TP, indicating either (1) BMPs may be more effective at reducing N than P or (2) in-stream processing or sources such as legacy streambank P are providing in-stream sources of P despite reductions in internal loading (Sharpley and others, 2013). There was little evidence that nutrient concentrations have decreased in Porter Bayou watershed over the period of record. This finding may either be attributed to landowner participation or to specific BMPs that were installed in Harris Bayou watershed but not Porter Bayou watershed. However, despite a lack of clear evidence that nutrient concentrations have declined in Porter Bayou watershed, Q-normalized TN and TP loads have decreased at a similar rate at the mouth of both watersheds since BMP implementation. Potential mechanistic explanations for these observations are provided in the following sections.

Agriculture, Weather, and Sediment Patterns Explain Seasonal Nutrient Dynamics

Seasonal patterns of TN and TP concentrations and loads were observed in Harris Bayou watershed and Porter Bayou watershed. In general, TN and TP concentrations and loads tended to be highest during the spring and winter months, and lowest during the summer growing season. This pattern has previously been observed across multiple streams in the Mississippi Alluvial Plain (Shields and others, 2009; Taylor and others, 2023) and can be explained by a combination of weather patterns and agricultural practices. In the Mississippi Alluvial Plain, nitrogen fertilizers are commonly applied to fields pre-growing season, in the spring near the time of planting, to increase crop yield (Oldham, 2012). However, prior to plant growth and biological uptake that sequesters nutrients, fertilizer-N is susceptible to loss via runoff while

the field is still bare. The degree of N runoff and speciation of N lost (nitrate [NO_3^-] versus ammonium nitrogen [NH_4-N] versus organic N) post-fertilization can be greatly affected by the type of fertilizer applied and the duration between application and the first runoff event (King and Torbert, 2007; Smith and others, 2007). Long-term sequestration of N fertilizers can also increase soil-N concentrations over time, thereby increasing the likelihood of N runoff or leaching, even in the absence of fertilizer application (Basu and others, 2022; McDowell and others, 2021; Van Meter and others, 2016). Post-growing season TN spikes were also observed, particularly at HB-HB and to a lesser degree at PB-Steph. After harvest, crop residues high in carbon (C), N, and P are often left on the field and can readily leach into surface waters (Agneessens and others, 2014; de Neve and Hofman, 1998). Additionally, some farmers till their fields post-harvest, which can also increase the likelihood of nutrient loss via erosion. Collectively, these seasonal agricultural practices can explain seasonal patterns in TN concentrations in Harris Bayou watershed and Porter Bayou watershed. Seasonal patterns in N concentrations coincide with patterns of precipitation and Q (refer to appendix 1; fig. 1.2*A–D*), resulting in even more pronounced seasonal patterns in TN loads that peak in the spring.

Similar seasonal patterns were also observed for TP concentrations, with higher concentrations typically observed during the pre- and post-growing seasons in the spring and winter and lower concentrations observed during the summer-fall growing season. However, Mississippi Alluvial Plain soils have high concentrations of bioavailable P from geologic sources, and P fertilizers are generally not applied in the region (Oldham, 2012). Thus, seasonal P dynamics may be more related to weather and associated effects on suspended sediments. Precipitation has a seasonal pattern in the Mississippi Alluvial Plain, with the highest rainfall occurring in spring and winter and lowest rainfall during the summer-fall growing season (refer to appendix 1; fig. 1.2*A–D*). Elevated rainfall intensity outside of the growing season can greatly increase the overland transport of soil and associated P from agricultural fields to surface waters (Ross and others, 2022), especially when BMPs like winter cover crops are not used and fields are left bare (De Baets and others, 2011; Kaspar and Singer, 2011). Discharge is also highest in spring and winter months. At HB-HB and particularly at PB-Steph, patterns of SSC align with precipitation and Q patterns, increasing in spring and winter, and decreasing during the growing season (refer to appendix 1; fig. 1.2*E*, *F*). Stream sediments in Harris Bayou watershed and Porter Bayou watershed consist largely of smaller, easily resuspended clay and silt particles (between 48 and 51 percent clay and 38 and 42 percent silt) that contain relatively high P concentrations between 2.25 and 2.69 parts per million (DeVilbiss and others, 2023). Unlike TN, TP concentrations were positively related to SSC concentrations, particularly at PB-Steph (refer to appendix 1; fig. 1.2*G–J*), which has been observed in other agricultural watersheds (Kronvang, 1992; Sandström and others, 2020). Thus, entrainment of resuspended sediments may also increase with increasing Q, further elevating TP but not TN concentrations during the spring and winter months (Kleeberg and others, 2008; Peterson and others, 2008). Additionally, as with N, crop residues can also contain substantial amounts of bioavailable P that can contribute to stream P concentrations post-harvest via runoff (Noack and others, 2012). Given the strong link between Q, SSC, and TP, it is unsurprising that TP loads also display the same seasonal patterns related to both agriculture and weather patterns.

Although concentrations of TN and TP were lowest during the fall growing season, seasonal patterns of molar N:P demonstrate that TN concentrations are lower relative to TP concentrations. Across all sites, a general seasonal pattern of N:P was observed, with higher ratios observed in the spring, following fertilizer application (indicating more TN relative to TP) and the lower N:P observed in the fall (indicating relatively higher TP) (appendix 1; fig. 1.4). Groundwater used for irrigation in the Mississippi Alluvial Plain contains high concentrations of P (0.12–1.2 mg/L; median = 0.62 mg/L, Welch and others, 2010), which has the potential to contribute substantial concentrations to surface waters during the growing season while fields are being irrigated because furrow irrigation is the predominant method in the Mississippi Alluvial Plain (Welch and others, 2009; Yasarer and others, 2020). Increased P from irrigation water, in combination with N-sequestration in crops and the enhanced capacity for N-removal via denitrification in the hot summer months, could explain this consistent decline in N:P during the growing season across sites (Christensen and others, 1990). Seasonal patterns of molar N:P were consistently low at all sites across months, with site averages ranging from 12.5 to 17.7, suggesting the potential for N-limitation almost year-round. However, concentrations are generally greater than the proposed concentration limits needed to alleviate nutrient limitation (0.003–0.010 mg/L for P and 0.10–0.13 mg L for N) (Chorus and Spijkerman, 2021). Future research investigating the role of nutrient stoichiometry on ecosystem processes in Mississippi Alluvial Plain streams, like denitrification and N-fixation, which can co-occur, could improve our ability to predict how stream ecosystems will respond to variability in resource availability (Eberhard and others, 2018; Keck and Lepori, 2012).

BMPs May Affect Long-Term N and P Trends Differently

Although similar seasonal patterns were observed between TN and TP, long-term trends differed. Although there was considerable evidence for reductions in TN concentrations in Harris Bayou watershed, there was little evidence suggesting that TP concentrations have decreased over the period of record. In Harris Bayou watershed, decreasing TN trends were largely driven by reductions in pre- and post-growing season spikes, except at HB-OST2,

where consistent declines were observed across all seasons. Numerous structures for water control, like low-grade weirs, were installed in Harris Bayou watershed, particularly in close proximity to HB-OST2. These low-grade weirs are specifically designed to hold water in multiple locations to increase hydraulic residence time, in turn increasing deposition of suspended sediments and enhancing biogeochemical removal of nutrients (Kröger and others, 2008). Low-grade weirs have demonstrated some ability to reduce nutrient and sediment loads during storm events at other locations throughout the Mississippi Alluvial Plain (Faust and others, 2018; Kröger and others, 2011; Littlejohn and others, 2014). In Harris Bayou watershed, consistent declines in TN concentrations may be explained by increased rates of denitrification caused by increased hydraulic residence time. This explanation is supported by substantial increases in low flows at HB-OST2 by as much as 20–30 percent, which has also decreased the amount of time the tributary is dry. Grassed waterways are another BMP implemented in Harris Bayou watershed by HB-OST2 that can effectively remove sediments and nitrogen via denitrification and (or) N-uptake by vegetation (Neilen and others, 2017). Collectively, these additional BMPs in Harris Bayou watershed may have contributed to reductions in TN. Increased hydraulic residence time can promote denitrification but may affect TP differently.

Increased hydraulic residence time and associated sediment deposition can create conditions that promote hypoxic or anoxic conditions at the water-sediment interface (Briggs and others, 2013; Carter and others, 2021; Hall and Ulseth, 2020). Although hypoxic conditions promote denitrification, reductive dissolution of iron-bound P can increase water-column concentrations and drive similar dynamics as point sources of P (Smolders and others, 2017). Iron-bound P is likely high in Mississippi Alluvial Plain sediments and streambanks because of irrigation with iron-rich groundwater from the lower Mississippi River Valley alluvial aquifer (Borrok and others, 2018). Reductive dissolution of iron-bound P may also be occurring in streams in the Mississippi Alluvial Plain, where significant relations between sediment and water-column TP concentrations indicate a dynamic equilibrium between sediment and water-column P (DeVilbiss and others, 2023). Thus, low-grade weirs promote N removal but may also promote internal P cycling, which has been observed in other aquatic environments in the Mississippi Alluvial Plain (Dubose and others, 2022). Overall, several scenarios could potentially explain the lack of reductions in P concentrations: (1) overland transport of soil-bound P to surface waters has not decreased over time and provides a consistent source of P to Harris Bayou and Porter Bayou; (2) resuspension of sediment-bound legacy P stored in stream sediments during high-flow events is contributing a significant source of P to the overlying water column; (3) reductions in external P loading are masked by the leaching of sediment-bound legacy P to the overlying water column; (4) a combination of surface runoff, resuspension of legacy P, or leaching of legacy P are preventing detectable decreases in P concentrations. Patterns of C-Q slopes can provide additional insight into mechanisms controlling nutrient dynamics over the period of record.

C-Q relations play a critical role in how nutrients and water quality respond to streamflow (Bieroza and others, 2018; Rose and others, 2018; von Brömssen and others, 2023); however, C-Q relations have been shown to differ at temporal scales. For example, NO_3^- C-Q slopes can be positive at the seasonal scale representing base-flow conditions but become negative at the individual event-scale. Conversely, seasonal TP C-Q slopes can be negative at the seasonal scale and become positive during individual events, and these differences can be attributed to differences in diffuse versus point sources (Minaudo and others, 2019). The present study assesses seasonal C-Q dynamics over more than a decade primarily with routine monitoring samples, but importantly, mean high-flow event concentrations from storm sampling were included to increase sample size and represent between 15 and 51 percent of total observations, depending on the site. Thus, observations do contain flows substantially higher than base flow.

At all sites, C-Q slopes were positive for TN and TP at the beginning of the record, indicating that both TN and TP increased in concentration as Q increased. In most instances, C-Q slopes remained positive over the period of record, demonstrating little long-term change in the relation between nutrient concentrations and Q. However, most sites had substantial seasonal patterns in C-Q slopes. TN C-Q slopes remained consistent in the summer months during lower flows, ranging from flushing to chemostatic. Similar seasonal patterns for N have been observed in other river systems (Zimmer and others, 2019). Although concentrations are lower in the summer months, primary sources of N could come from irrigation water, resulting in a positive correlation of flow and N (Causapé and others, 2004; Lassaletta and others, 2009). Irrigation water also has higher salinity (Borrok and others, 2018), which has been shown to promote microbial activity and biological processing of N, and may contribute to increased concentrations during irrigation-driven flow events depending on the balance of N fixation, denitrification, organic N breakdown, nitrification, microbial uptake, or other N-cycling pathways (DeVilbiss and others, 2024).

TP C-Q slopes were seasonally variable among sites and tended to be higher in summer but were also high in winter and spring when flows and SSC were higher (for example, HB-OST2, HB-HB, PB-Steph). At HB-OST2, however, C-Q slopes for TN and TP shifted from positive to negative over the period of record, indicating a shift from flushing to diluting behavior. Yet, despite evidence that TP and TN became decoupled from flow dynamics over time, only TN concentrations decreased. Although TN C-Q slopes shifted from flushing to diluting in the fall growing season, TP C-Q slopes were consistently negative, which coincides with consistently low SSC during fall months and provides evidence that TP dynamics are controlled by sediment dynamics. Given the lack of strong relations between SSC

and TN, reductions in TN C-Q slopes during the fall may be explained by enhanced biogeochemical cycling, which is likely high in fall as water temperatures are still high. Mechanisms behind reductions in TN C-Q slopes in winter months are less clear but could be explained by reduced TN concentrations as a result of enhanced denitrification in warmer months. C-Q slopes may also provide insight into the discrepancy between nutrient concentration trends and load trends at the mouth of Porter Bayou watershed. Although clear reductions in concentration were not observed, results of temporal and seasonal C-Q analyses indicate that C-Q slopes have decreased over time, approaching near chemostatic behavior, which may explain load reductions in Porter Bayou watershed.

Discrepancies Between Harris Bayou Watershed and Porter Bayou Watershed and Potential Linkages to BMPs

Water-quality samples were not collected prior to the implementation of BMPs in either Harris Bayou watershed or Porter Bayou watershed, nor was a control watershed established in the region. Thus, direct linkages between specific BMPs and changes in water quality over the period of record cannot be evaluated, which also was not the objective of the study. However, differences in water quality and specific BMPs implemented between Harris Bayou watershed and Porter Bayou watershed may provide some insights. For example, TN concentrations decreased significantly over the period of record in Harris Bayou watershed but not Porter Bayou watershed, despite substantially more water control structures installed in Porter Bayou watershed (177) versus Harris Bayou watershed (55). However, there were three additional BMP categories used in Harris Bayou watershed that were not used in Porter Bayou watershed: (1) grassed waterways; (2) precision irrigation land leveling; and (3) nutrient management (that is, manage for rate, source, placement, and timing of nutrient additions, per USDA Code 590) (USDA, 2019). Based on the differences in temporal changes of nutrient concentrations between Harris Bayou watershed and Porter Bayou watershed, grassed waterways and irrigation land leveling may have a larger effect on nutrient reductions at the watershed scale than water control structures like low grade weirs. Future research could focus on evaluating the effects of these specific BMPs on water quality in the Mississippi Alluvial Plain.

Conclusions

Nutrient reduction BMPs demonstrate some ability to help reduce nutrient concentrations and loads in Mississippi Alluvial Plain watersheds. In this study, we identified changes in Q, nutrient concentrations, and nutrient loads in Harris Bayou watershed and Porter Bayou watershed following BMP implementation. Low flows at HB-OST2 increased by as much as 15 percent, which may be attributed to the numerous low-grade weirs installed throughout the watershed. Further, seasonal spikes in TN and TP concentrations were observed throughout Harris Bayou watershed but were not as apparent in Porter Bayou watershed. Additionally, there was some evidence of reduced TP concentrations, particularly in Harris Bayou watershed; however, reductions in TN concentrations were much more apparent. Reduced changes in TP relative to TN could be attributed to legacy P stored in the sediments. Despite discrepancies between nutrients and watersheds, TN and TP loads decreased consistently over the period of record at the mouth of Harris Bayou watershed and Porter Bayou watershed. Our results highlight that detecting water-quality or ecosystem-level responses to BMPs is challenging and requires substantial data collection and consideration of seasonality.

Although our study results indicate that BMPs may help reduce N concentrations and loads, direct linkages to management practices are outside the scope of this work. Further research would be needed to fully understand the mechanisms driving reductions. A better understanding of N sources and in-stream dynamics may also help identify discrepancies in N reductions between study watersheds. Additional research focused on internal P loading and cycling pathways could help further explain the lack of P reductions in both study watersheds. For example, studies examining P accumulation and release behind low-grade weirs in addition to denitrification rates may help explain the lack of TP reductions and inform important management actions like BMP refresh rates. Understanding how BMPs affect the relative proportions of external versus internal P loading could help constrain estimated lag times between BMP implementation and observable P reductions and inform realistic expectations for ecosystem responses. The addition of high-frequency sensor data could also increase our understanding of how N and P respond to flow events on shorter time scales. Lastly, incorporation of additional monitoring techniques like biomonitoring (for example, DeVilbiss and others, 2025) could help provide additional evidence to support ecosystem responses to BMPs in the Mississippi Alluvial Plain.

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Appendix 1.

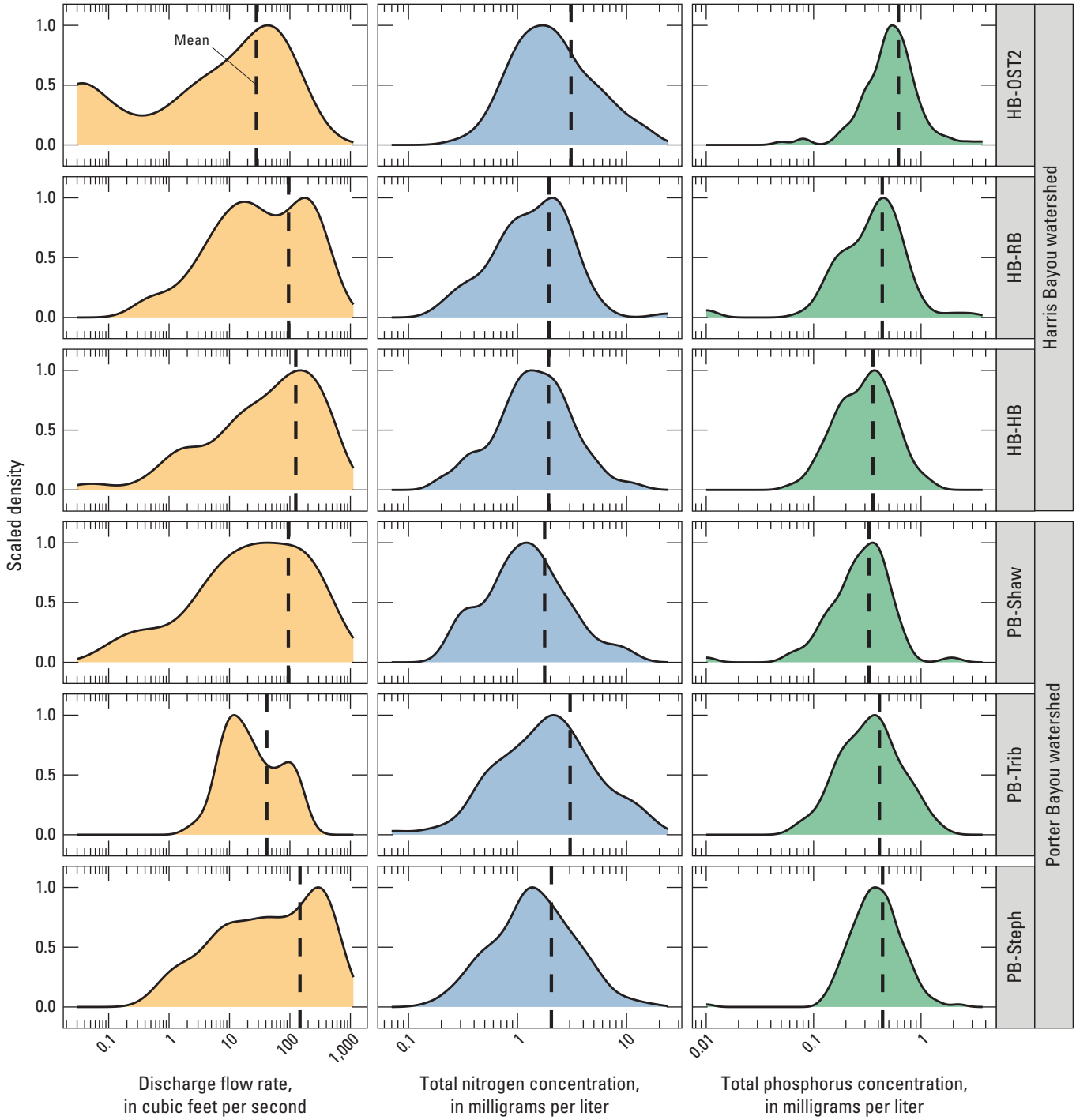


Figure 1.1. Scaled density plots showing the distribution of discharge, total nitrogen, and total phosphorus at each monitoring location. The discharge values are only those that were recorded at the time of a discrete water-quality sample collection. HB-OST2, Overcup Slough tributary no. 2 near Farrell, Mississippi; HB-RB, Richies Bayou at Sherard, Miss.; HB-HB, Harris Bayou at Palmer Road east of Alligator, Miss.; PB-Shaw, Porter Bayou near Shaw, Miss.; PB-Trib, Porter Bayou trib no. 1 northwest of Frazier, Miss.; PB-Steph, Porter Bayou at Stephensville, Miss. Refer to table 3 for additional site information.

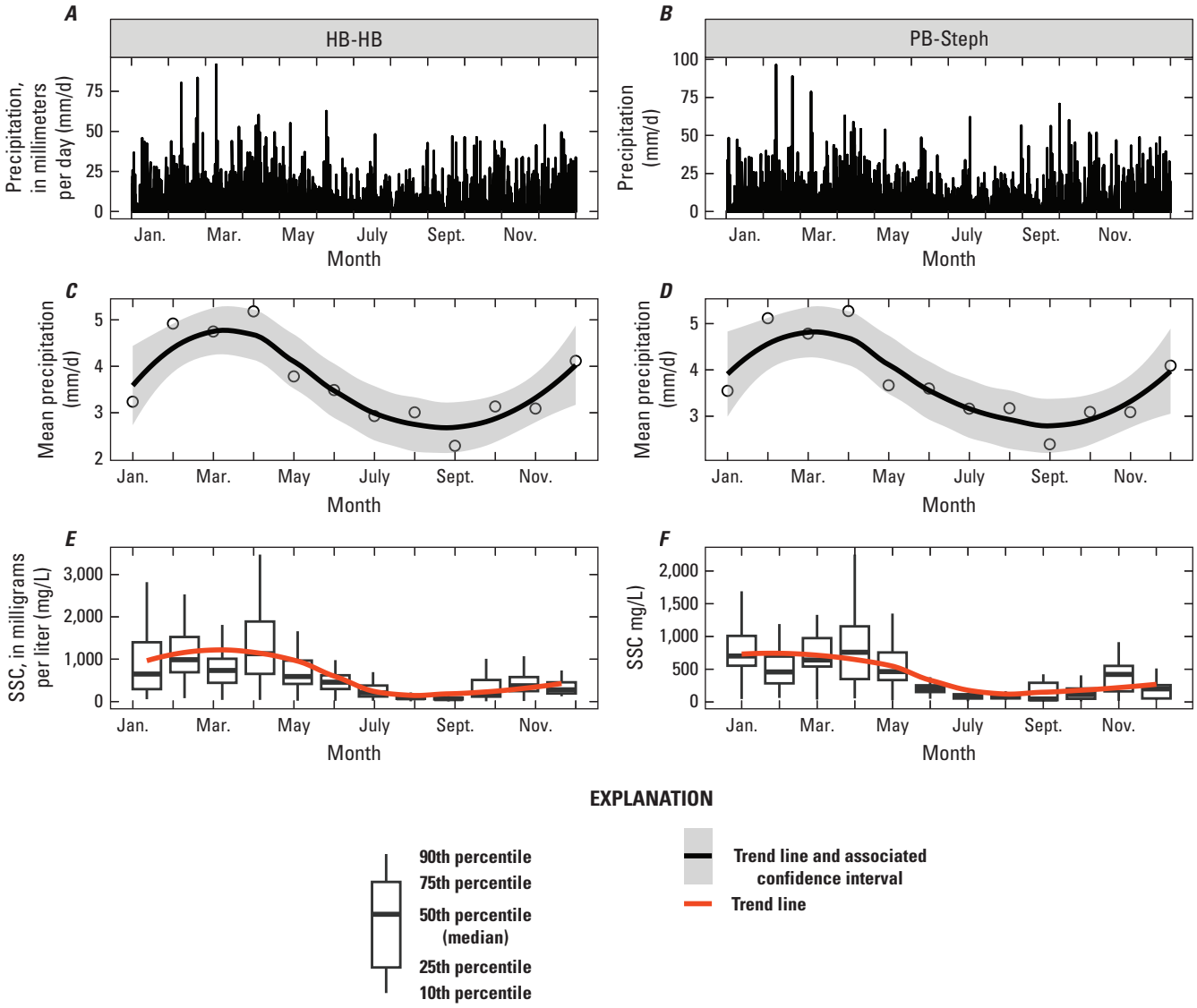


Figure 1.2. Seasonal patterns in daily precipitation (*A*, *B*), mean-daily precipitation for each month (*C*, *D*), total suspended solids concentrations (SSC; *E*, *F*), the relations between SSC and total phosphorus (TP; *G*, *H*), and the relation between SSC and total nitrogen (TN; *I*, *J*), at two study sites: Harris Bayou at Palmer Road east of Alligator, Miss. (HB-HB) in Harris Bayou watershed (left column) and Porter Bayou at Stephensville, Miss. (PB-Steph) in Porter Bayou watershed (right column). Refer to table 3 for additional site information.

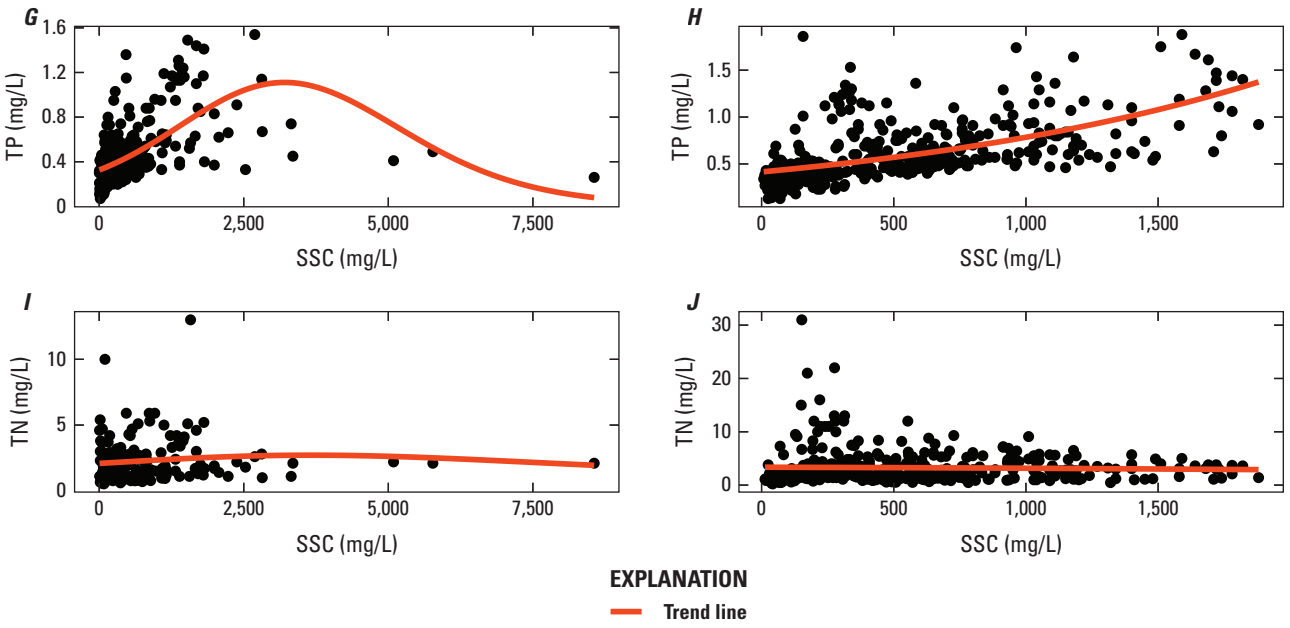


Figure 1.2.—Continued

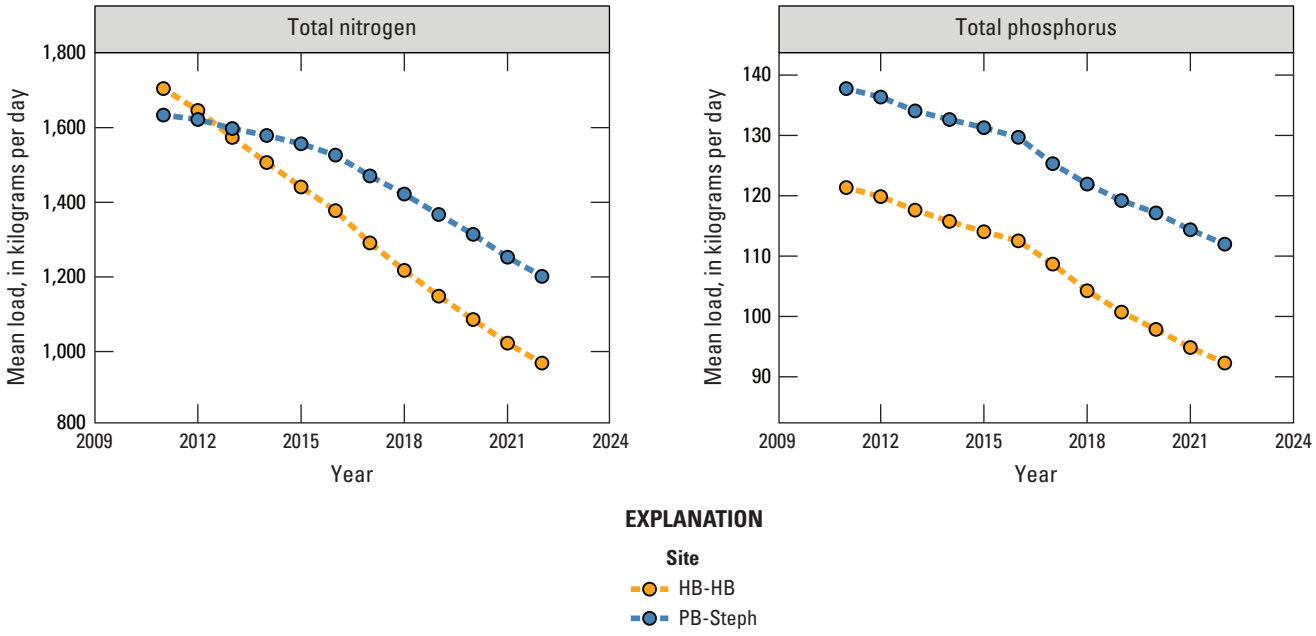


Figure 1.3. A comparison of flow-normalized total nitrogen and total phosphorus loads from weighted regression on time, discharge, and season (WRTDS; Hirsch and others, 2010) at the mouth of both study watersheds. PB-Shaw, Porter Bayou near Shaw, Mississippi; PB-Trib, Porter Bayou trib no. 1 northwest of Frazier, Miss.; PB-Steph, Porter Bayou at Stephensville, Miss. Refer to table 3 for additional site information.

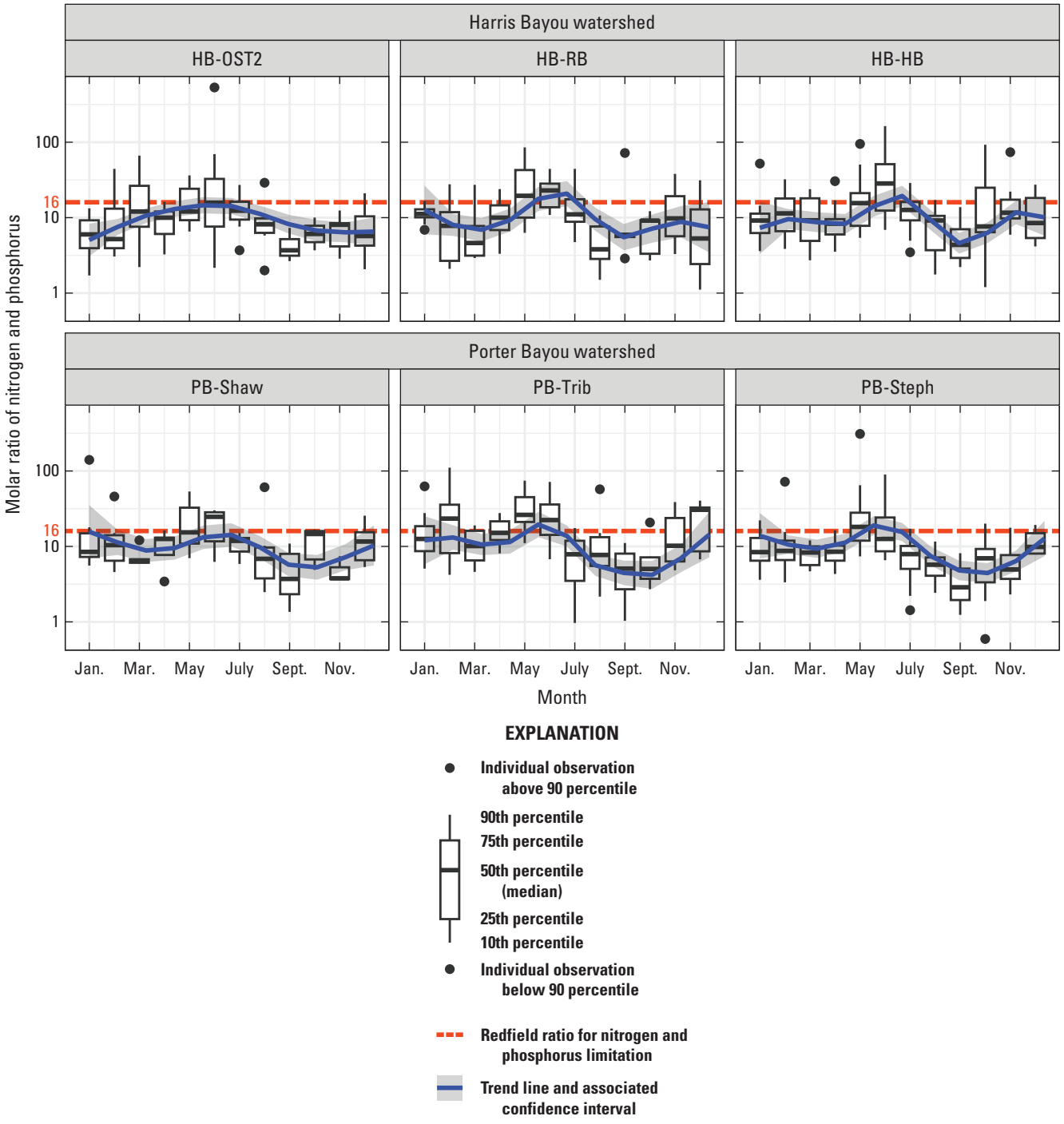


Figure 1.4. Seasonal patterns in the molar ratio of nitrogen and phosphorus (N:P). Trend lines are fit with generalized additive models. HB-OST2, Overcup Slough tributary no. 2 near Farrell, Mississippi; HB-RB, Richies Bayou at Sherard, Miss.; HB-HB, Harris Bayou at Palmer Road east of Alligator, Miss.; PB-Shaw, Porter Bayou near Shaw, Miss.; PB-Trib, Porter Bayou trib no. 1 northwest of Frazier, Miss.; PB-Steph, Porter Bayou at Stephensville, Miss. Refer to table 3 for additional site information.

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Appendix 2.

Table 2.1. Complete list of U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Environmental Quality Incentives Program (EQIP) best management practices (BMPs) implemented in Harris and Borter Bayou watersheds during the period of study (FTN Associates, Ltd., 2012).

[Data provided by Natalie Seagrest (Mississippi Department of Environmental Quality, unpub. data, 2024). List includes BMPs that are not specific to nutrient reduction. no., number; ft, foot; ft^2, square foot; acre-ft, acre-foot]

Watershed	EQIP code	Name	Amount	Unit	Year range
Harris Bayou	132	Soil resources planning - written	6	no.	2019
Harris Bayou	325	High tunnel system	2,133	ft^2	2018–18
Harris Bayou	328	Conservation crop rotation	1,245.6	acre	2022–22
Harris Bayou	340	Cover crop	6,957.5	acre	2015–22
Harris Bayou	342	Critical area planting	2	acre	2010–10
Harris Bayou	345	Residue and tillage management, reduced till	1,573.8	acre	2021–22
Harris Bayou	356	Dike	599,110.4	ft	2008–20
Harris Bayou	362	Diversion	7,163	ft	2010–21
Harris Bayou	382	Fence	12,635	ft	2016–22
Harris Bayou	410	Grade stabilization structure	19	no.	2010–21
Harris Bayou	430	Irrigation pipeline	100,721.1	ft	2012–22
Harris Bayou	430EE	Irrigation water conveyance, pipeline	106,111	ft	2008–13
Harris Bayou	436	Irrigation reservoir	60,012	acre-ft	2011–14
Harris Bayou	441	Irrigation system, microirrigation	0.4	acre	2015–16
Harris Bayou	442	Irrigation system, sprinkler	838.2	acre	2015–20
Harris Bayou	443	Irrigation system, surface and subsurface	4,897.1	acre	2012–18
Harris Bayou	447	Irrigation system, tail water recovery	11	no.	2008–13
Harris Bayou	449	Irrigation water management	55,786.5	acre	2008–22
Harris Bayou	460	Land clearing	2	acre	2017–20
Harris Bayou	516	Livestock pipeline	300	ft	2021
Harris Bayou	533	Pumping plant	135	no.	2010–21
Harris Bayou	561	Heavy use area protection	0.039	acre	2021–21
Harris Bayou	587	Structure for water control	400.7	no.	2008–21
Harris Bayou	590	Nutrient management	6,478.4	acre	2008–22
Harris Bayou	595	Pest management conservation system	1,245.6	acre	2022–22
Harris Bayou	614	Watering facility	1	no.	2021
Harris Bayou	642	Water well	6	no.	2010–18
Harris Bayou	644	Wetland wildlife habitat management	11.4	acre	2020
Harris Bayou	646	Shallow water development and management	334.5	acre	2008–22
Harris Bayou	798	Seasonal high tunnel for crops	2,172	ft^2	2016
Harris Bayou	B000MRB2	Mrbi bundle#2 - non-irrigated cropland #1	251.9	acre	2019–20
Harris Bayou	CROP	Cropland annual payment	26,823.34	acre	2018–22
Harris Bayou	E300EAP1	Existing activity payment-land use	1,590.6	acre	2022
Harris Bayou	E300EAP2	Existing activity payment-resource concern	6.	no.	2022
Harris Bayou	E328106R	Resource conserving crop rotation for soil organic matter improvement	5,659.1	acre	2019–22
Harris Bayou	E328136Z	Leave standing grain crops unharvested to benefit wildlife food sources	10.8	acre	2019–21
Harris Bayou	E328137Z	Leave standing grain crops unharvested to benefit wildlife cover and shelter	1	acre	2019
Harris Bayou	E340101Z	Cover crop to reduce water erosion	276.6	acre	2019–20

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[Data provided by Natalie Seagrest (Mississippi Department of Environmental Quality, unpub. data, 2024). List includes BMPs that are not specific to nutrient reduction. no., number; ft, foot; ft^2, square foot; acre-ft, acre-foot]

Watershed	EQIP code	Name	Amount	Unit	Year range
Harris Bayou	E340107Z	Cover crop to minimize soil compaction	310.2	acre	2019–20
Harris Bayou	E340134Z	Cover crop to suppress excessive weed pressures and break pest cycles	3,421.7	acre	2019–22
Harris Bayou	E345101Z	Reduced tillage to reduce water erosion	7.7	acre	2019
Harris Bayou	E345106Z	Reduced tillage to increase soil health and soil organic matter content	8,389.3	acre	2019–22
Harris Bayou	E345114Z	Reduced tillage to increase plant-available moisture: irrigation water	498.9	acre	2019–21
Harris Bayou	E345115Z	Reduced tillage to increase plant-available moisture: moisture management	3,392.3	acre	2019–22
Harris Bayou	E345144Z	Reduced tillage to reduce energy use	229.2	acre	2019
Harris Bayou	E386137Z	Enhanced field border to provide wildlife cover or shelter along the edge(s) of a field	2	acre	2019–20
Harris Bayou	E590118X	Reduce risks of nutrient losses to surface water by utilizing precision ag technologies	26,789.2	acre	2019–22
Harris Bayou	E590118Z	Improving nutrient uptake efficiency and reducing risk of nutrient losses to surface water	4,070.6	acre	2019–22
Harris Bayou	E590119X	Reduce risks of nutrient losses to groundwater by utilizing precision agriculture technologies	5,520	acre	2019–21
Harris Bayou	E590119Z	Improving nutrient uptake efficiency and reducing risk of nutrient losses to groundwater	10,456.8	acre	2019–22
Harris Bayou	E590A	Improving nutrient uptake efficiency and reducing risk of nutrient losses	345	acre	2022
Harris Bayou	E595116X	Reduce risk of pesticides in surface water by utilizing precision pesticide application techniques	50,070.4	acre	2019–22
Harris Bayou	E595116Z	Reduce risk of pesticides in surface water by utilizing IPM PAMS techniques	15,739.8	acre	2019–22
Harris Bayou	E595129Z	Reduce ozone precursor emissions related to pesticides by utilizing IPM PAMS techniques	30,373.6	acre	2019–22
Harris Bayou	E595B	Reduce risk of pesticides in water and air by utilizing IPM PAMS techniques	1,590.6	acre	2022
Harris Bayou	E646136Z1	Close structures to capture/retain rainfall to improve food for waterfowl/wading birds during winter	151.1	acre	2019–20
Harris Bayou	E646137Z1	Close structures to capture and retain rainfall to improve cover and shelter for birds during winter	10.4	acre	2020
Harris Bayou	E646138Z1	Close structures to capture and retain rainfall to provide water for birds during winter	151.8	acre	2019–20
Harris Bayou	EUP	Erroneous underpayment	1	no.	2019
Porter Bayou	104	Nutrient management plan - written	3	no.	2019

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[Data provided by Natalie Seagrest (Mississippi Department of Environmental Quality, unpub. data, 2024). List includes BMPs that are not specific to nutrient reduction. no., number; ft, foot; ft^2, square foot; acre-ft, acre-foot]

Watershed	EQIP code	Name	Amount	Unit	Year range
Porter Bayou	114	Integrated pest management plan - written	5	no.	2018–19
Porter Bayou	118	Irrigation water management plan - written	2	no.	2021
Porter Bayou	309	Agrichemical handling facility	1	no.	2022
Porter Bayou	314	Brush management	24.4	acre	2015–21
Porter Bayou	315	Herbaceous weed treatment	599.3	acre	2019–22
Porter Bayou	319	On-farm secondary containment facility	2	no.	2016
Porter Bayou	327	Conservation cover	20.5	acre	2015–22
Porter Bayou	328	Conservation crop rotation	8,909.4	acre	2021
Porter Bayou	329	Residue and tillage management, no till	187.2	acre	2020–21
Porter Bayou	340	Cover crop	17,672.9	acre	2013–22
Porter Bayou	342	Critical area planting	89.6	acre	2009–22
Porter Bayou	345	Residue and tillage management, reduced till	12,538.5	acre	2019–21
Porter Bayou	351	Well decommissioning	1	no.	2013
Porter Bayou	356	Dike	2,057,617.9	ft	2008–22
Porter Bayou	382	Fence	73,948.3	ft	2015–21
Porter Bayou	386	Field border	0.7	acre	2014–21
Porter Bayou	390	Riparian herbaceous cover	0.2	acre	2021
Porter Bayou	391	Riparian forest buffer	0.3	acre	2021
Porter Bayou	393	Filter strip	8.8	acre	2013–21
Porter Bayou	410	Grade stabilization structure	189	no.	2008–22
Porter Bayou	430	Irrigation pipeline	261,151.1	ft	2012–22
Porter Bayou	430EE	Irrigation water conveyance, pipeline	55,381.8	ft	2008–13
Porter Bayou	430FF	Irrigation water conveyance, pipeline	275	ft	2012
Porter Bayou	436	Irrigation reservoir	2,163.7	acre-ft	2010–22
Porter Bayou	441	Irrigation system, microirrigation	16.2	acre	2008–14
Porter Bayou	442	Irrigation system, sprinkler	6,785	acre	2008–21
Porter Bayou	443	Irrigation system, surface and subsurface	4,859.7	acre	2008–20
Porter Bayou	447	Irrigation system, tailwater recovery	10	no.	2011–13
Porter Bayou	449	Irrigation water management	48,117.8	acre	2008–22
Porter Bayou	460	Land clearing	1	acre	2019
Porter Bayou	462	Precision land forming	4,870.2	acre	2017–22
Porter Bayou	464	Irrigation land leveling	4,631.9	acre	2008–19
Porter Bayou	484	Mulching	0.2	acre	2021–21
Porter Bayou	512	Forage and biomass planting	21.4	acre	2015–18
Porter Bayou	516	Livestock pipeline	1,549.3	ft	2015–20
Porter Bayou	528	Prescribed grazing	11.8	acre	2018–19
Porter Bayou	533	Pumping plant	291	no.	2010–22
Porter Bayou	554	Drainage water management	3,671.8	acre	2012–21
Porter Bayou	561	Heavy use area protection	1.813	acre	2015–20
Porter Bayou	576	Livestock shelter structure	2	no.	2017–18
Porter Bayou	580	Streambank and shoreline protection	150	ft	2019

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Watershed	EQIP code	Name	Amount	Unit	Year range
Porter Bayou	587	Structure for water control	5,907	no.	2008–22
Porter Bayou	590	Nutrient management	25,783.7	acre	2008–22
Porter Bayou	595	Pest management conservation system	9,624.2	acre	2019–22
Porter Bayou	601	Vegetative barriers	13,633.3	ft	2013–14
Porter Bayou	607	Surface drainage, field ditch	4,540.2	ft	2013–17
Porter Bayou	612	Tree/shrub establishment	0.6	acre	2020–21
Porter Bayou	614	Watering facility	7	no.	2015–20
Porter Bayou	642	Water well	22	no.	2010–20
Porter Bayou	644	Wetland wildlife habitat management	916.7	acre	2015–22
Porter Bayou	646	Shallow water development and management	985.1	acre	2010–21
Porter Bayou	647	Early successional habitat management	9.4	acre	2013–14
Porter Bayou	656	Constructed wetland	7.4	acre	2015–15
Porter Bayou	666	Forest stand improvement	301.1	acre	2019–22
Porter Bayou	798	Seasonal high tunnel for crops	4,356	ft^2	2011–14
Porter Bayou	AGLAND	Associated ag land	1,900.6	acre	2020–21
Porter Bayou	B000CPL12	Non-irrigated precision ag (mrbi)	751.8	acre	2020
Porter Bayou	B000CPL13	Non-irrigated cropland (mrbi)	114	acre	2021
Porter Bayou	B000CPL18	Crop bundle #18 - precision ag	54.1	acre	2020–21
Porter Bayou	B000CPL19	Crop bundle #19 - soil health precision ag	397.1	acre	2020–21
Porter Bayou	B000FST1	Forest bundle#1	30.2	acre	2020
Porter Bayou	B000MRB2	Mrbi bundle#2 - non-irrigated cropland #1	287.2	acre	2019
Porter Bayou	CROP	Cropland annual payment	158,662.59	acre	2018–22
Porter Bayou	E300EAP1	Existing activity payment-land use	38,462.8	acre	2020–22
Porter Bayou	E300EAP2	Existing activity payment-resource concern	64	no.	2020–22
Porter Bayou	E315132Z	Herbaceous weed control for desired plant communities/habitats consistent with the ecological site	293.1	acre	2019–21
Porter Bayou	E315A	Herbaceous weed treatment to create plant communities consistent with the ecological site	151.7	acre	2020
Porter Bayou	E327136Z1	Conservation cover to provide food habitat for pollinators and beneficial insects	10.9	acre	2019–20
Porter Bayou	E327136Z2	Establish monarch butterfly habitat	187.1	acre	2019–21
Porter Bayou	E327B	Establish monarch butterfly habitat	20.1	acre	2020–22
Porter Bayou	E328101R	Resource conserving crop rotation to reduce water erosion	51,285.1	acre	2020–21
Porter Bayou	E328106Z1	Soil health crop rotation	247.7	acre	2020
Porter Bayou	E328136Z	Leave standing grain crops unharvested to benefit wildlife food sources	206.1	acre	2018–21
Porter Bayou	E328137Z	Leave standing grain crops unharvested to benefit wildlife cover and shelter	12	acre	2018–21
Porter Bayou	E328A	Resource conserving crop rotation	80.9	acre	2020

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Watershed	EQIP code	Name	Amount	Unit	Year range
Porter Bayou	E328B	Improved resource conserving crop rotation	71.4	acre	2020
Porter Bayou	E328D	Leave standing grain crops unharvested to benefit wildlife	126.9	acre	2020–21
Porter Bayou	E328F	Modifications to improve soil health and increase soil organic matter	125.4	acre	2020–21
Porter Bayou	E329106Z	No till system to increase soil health and soil organic matter content	291.3	acre	2019–21
Porter Bayou	E329C	No till to increase plant-available moisture	28.7	acre	2020–21
Porter Bayou	E329D	No till system to increase soil health and soil organic matter content	114	acre	2021–21
Porter Bayou	E340101Z	Cover crop to reduce water erosion	1,284.6	acre	2018–21
Porter Bayou	E340107Z	Cover crop to minimize soil compaction	992.4	acre	2019–21
Porter Bayou	E340118Z	Cover crop to reduce water quality degradation by utilizing excess soil nutrients-surface water	183.5	acre	2019–21
Porter Bayou	E340119Z	Cover crop to reduce water quality degradation by utilizing excess soil nutrients-groundwater	38.2	acre	2019
Porter Bayou	E340134Z	Cover crop to suppress excessive weed pressures and break pest cycles	914.7	acre	2019
Porter Bayou	E340A	Cover crop to reduce soil erosion	193.3	acre	2021
Porter Bayou	E340B	Intensive cover cropping to increase soil health and soil organic matter content	159	acre	2020–21
Porter Bayou	E340C	Use of multi-species cover crops to improve soil health and increase soil organic matter	40.4	acre	2020
Porter Bayou	E340E	Use of soil health assessment to assist with development of cover crop mix to improve soil health	23.7	acre	2020
Porter Bayou	E340F	Cover crop to minimize soil compaction	114.9	acre	2021
Porter Bayou	E340G	Cover crop to reduce water quality degradation by utilizing excess soil nutrients	138.4	acre	2020–21
Porter Bayou	E340H	Cover crop to suppress excessive weed pressures and break pest cycles	154.2	acre	2020–21
Porter Bayou	E345101Z	Reduced tillage to reduce water erosion	3,177.1	acre	2019–21
Porter Bayou	E345106Z	Reduced tillage to increase soil health and soil organic matter content	98,841.5	acre	2019–22
Porter Bayou	E345114Z	Reduced tillage to increase plant-available moisture: irrigation water	1,254.8	acre	2019–21
Porter Bayou	E345115Z	Reduced tillage to increase plant-available moisture: moisture management	3,443.2	acre	2018–21
Porter Bayou	E345128Z	Reduced tillage to reduce tillage induced particulate matter	431.7	acre	2019–21
Porter Bayou	E345144Z	Reduced tillage to reduce energy use	569.9	acre	2019–20
Porter Bayou	E345A	Reduced tillage to reduce soil erosion	16,168.6	acre	2020–22

Table 2.1. Complete list of U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Environmental Quality Incentives Program (EQIP) best management practices (BMPs) implemented in Harris and Borter Bayou watersheds during the period of study (FTN Associates, Ltd., 2012).—Continued

[Data provided by Natalie Seagrest (Mississippi Department of Environmental Quality, unpub. data, 2024). List includes BMPs that are not specific to nutrient reduction. no., number; ft, foot; ft^2, square foot; acre-ft, acre-foot]

Watershed	EQIP code	Name	Amount	Unit	Year range
Porter Bayou	E345B	Reduced tillage to reduce tillage induced particulate matter	222.3	acre	2020–22
Porter Bayou	E345C	Reduced tillage to increase plant-available moisture	4,312.7	acre	2020–22
Porter Bayou	E345D	Reduced tillage to increase soil health and soil organic matter content	210.7	acre	2020–22
Porter Bayou	E345E	Reduced tillage to reduce energy use	213.2	acre	2020–22
Porter Bayou	E382136Z	Incorporating “wildlife friendly” fencing for connectivity of wildlife food resources	571	ft	2019–20
Porter Bayou	E386106Z	Enhanced field borders to increase carbon storage along the edge(s) of the field	5	acre	2018
Porter Bayou	E391127Z	Increase stream shading for stream temperature reduction	1	acre	2018
Porter Bayou	E449114Z1	Advanced IWM--Soil moisture is monitored, recorded, and used in decision making	81	acre	2018
Porter Bayou	E449114Z4	Intermittent flooding of rice fields	1,026.4	acre	2018–21
Porter Bayou	E449114Z6	Automated intermittent flood irrigation of rice fields, Year 2-5	962.4	acre	2019–21
Porter Bayou	E449114Z8	Advanced Automated IWM - Year 1 - Equipment and soil moisture is monitored, recorded and used in dec	320.8	acre	2018
Porter Bayou	E512106Z2	Forage plantings that can help increase organic matter in depleted soils	0.2	acre	2020
Porter Bayou	E512136Z2	Native grass or legumes in forage base to provide wildlife food	0.5	acre	2020
Porter Bayou	E528104Z	Grazing management that protects sensitive areas from gully erosion	0.2	acre	2020
Porter Bayou	E528105Z	Prescribed grazing that improves or maintains riparian and watershed function-erosion	0.4	acre	2020
Porter Bayou	E528107Z1	Improved grazing management for soil compaction through monitoring activities	0.5	acre	2020
Porter Bayou	E528122Z	Prescribed grazing that maintains/improves riparian/watershed function-pathogens/ chemicals	262.5	acre	2019–21
Porter Bayou	E528126Z	Prescribed grazing that maintains/improves riparian/watershed function-min sediment in surface water	0.4	acre	2020
Porter Bayou	E528140Z1	Maintaining quantity and quality of forage for animal health and productivity	2.5	acre	2019–20
Porter Bayou	E590118X	Reduce risks of nutrient losses to surface water by utilizing precision ag technologies	105,937.2	acre	2018–22
Porter Bayou	E590118Z	Improving nutrient uptake efficiency and reducing risk of nutrient losses to surface water	41,559.2	acre	2018–22

Table 2.1. Complete list of U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Environmental Quality Incentives Program (EQIP) best management practices (BMPs) implemented in Harris and Borter Bayou watersheds during the period of study (FTN Associates, Ltd., 2012).—Continued

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Watershed	EQIP code	Name	Amount	Unit	Year range
Porter Bayou	E590119Z	Improving nutrient uptake efficiency and reducing risk of nutrient losses to groundwater	662.7	acre	2020
Porter Bayou	E590130Z	Improving nutrient uptake efficiency and reducing risks to air quality - emissions of ghgs	1,620.9	acre	2019–21
Porter Bayou	E590A	Improving nutrient uptake efficiency and reducing risk of nutrient losses	4,687.2	acre	2021–22
Porter Bayou	E590B	Reduce risks of nutrient loss to surface water by utilizing precision agriculture technologies	21,338.7	acre	2020–22
Porter Bayou	E595116X	Reduce risk of pesticides in surface water by utilizing precision pesticide application techniques	171,757.4	acre	2018–22
Porter Bayou	E595116Z	Reduce risk of pesticides in surface water by utilizing IPM PAMS techniques	733	acre	2019–21
Porter Bayou	E595129Z	Reduce ozone precursor emissions related to pesticides by utilizing IPM PAMS techniques	90,294.7	acre	2019–21
Porter Bayou	E595A	Reduce risk of pesticides in surface water by utilizing precision pesticide application techniques	23,340.3	acre	2020–22
Porter Bayou	E595B	Reduce risk of pesticides in water and air by utilizing IPM PAMS techniques	26,025.9	acre	2020–22
Porter Bayou	E612137Z	Tree/shrub planting for wildlife cover	17.7	acre	2020
Porter Bayou	E612A	Cropland conversion to trees or shrubs for long term improvement of water quality	3.9	acre	2020–21
Porter Bayou	E612C	Establishing tree/shrub species to restore native plant communities	4	acre	2020–21
Porter Bayou	E645A	Reduction of attractants to human-subsidized predators in sensitive wildlife species habitat	1	no.	2020–20
Porter Bayou	E646136Z1	Close structures to capture/retain rainfall to improve food for waterfowl/wading birds during winter	1,401.1	acre	2018–22
Porter Bayou	E646136Z2	Extend retention of rainfall to provide food for late winter habitat	10	acre	2020
Porter Bayou	E646137Z1	Close structures to capture and retain rainfall to improve cover and shelter for birds during winter	183.2	acre	2019–21
Porter Bayou	E646138Z1	Close structures to capture and retain rainfall to provide water for birds during winter	128	acre	2018
Porter Bayou	E646139Z1	Close structures to capture and retain rainfall for birds to improve habitat continuity	45.5	acre	2019
Porter Bayou	E646A	Close structures to capture and retain rainfall for waterfowl and wading bird winter habitat	58.2	acre	2020

Table 2.1. Complete list of U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Environmental Quality Incentives Program (EQIP) best management practices (BMPs) implemented in Harris and Borter Bayou watersheds during the period of study (FTN Associates, Ltd., 2012).—Continued

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Watershed	EQIP code	Name	Amount	Unit	Year range
Porter Bayou	E666106Z2	Maintaining and improving forest soil quality	1,611.7	acre	2019–21
Porter Bayou	E666107Z	Maintaining and improving forest soil quality by limiting compaction	167.6	acre	2019–21
Porter Bayou	E666115Z2	Enhance development of the forest understory to improve site moisture	25.4	acre	2020
Porter Bayou	E666118Z	Enhance development of the forest understory to capture nutrients in surface water	24.4	acre	2020
Porter Bayou	E666119Z	Enhance development of the forest understory to capture nutrients -groundwater	21	acre	2020
Porter Bayou	E666130Z	Increase on-site carbon storage	1,616.9	acre	2020–21
Porter Bayou	E666132Z1	Crop tree management for mast production	21.2	acre	2020
Porter Bayou	E666137Z1	Snags, den trees, and coarse woody debris for wildlife habitat	2,599.7	acre	2019–21
Porter Bayou	E666137Z2	Summer roosting habitat for native forest-dwelling bat species	2,599.7	acre	2019–21
Porter Bayou	E666A	Maintaining and improving forest soil quality	265.9	acre	2022
Porter Bayou	E666H	Increase on-site carbon storage	265.9	acre	2022
Porter Bayou	E666O	Snags, den trees, and coarse woody debris for wildlife habitat	1,069.3	acre	2021–22
Porter Bayou	E666P	Summer roosting habitat for native forest-dwelling bat species	1,069.4	acre	2021–22
Porter Bayou	FARM	Farmstead	408.8	acre	2020–21
Porter Bayou	MINPAY	Minimum payment adjustment	2	no.	2020–21
Porter Bayou	NIPF	Non-industrial private forest land annual payment	6,928	acre	2020–21
Porter Bayou	PAST	Pasture annual payment	169	acre	2020–21

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