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Water Quality Monitoring in the Upper Poteau River Watershed

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EXECUTIVE SUMMARY

The Upper Poteau River Watershed (UPRW) has been listed as a priority watershed in Arkansas since 1998 due to nutrient and sediment enrichment from point and nonpoint sources (NPS). According to the Arkansas NPS pollution management plan, the goals for the UPRW are to reduce pollutant levels that will restore all designates uses and target subwatersheds where implementation of management practices can have the greatest impact. Over the last several years, many 319(h) projects have been implemented and point sources have been reduced in order to improve water quality in the UPRW. The purpose of this study was to monitor 15 sites in the UPRW, three on existing U.S. Geological Survey (USGS) monitoring sites and 12 additional sites on the HUC-12 scale, for streamflow, nutrients, and sediments to add to the water quality database used by policy and decision makers of Arkansas.

This project successfully collected water samples across a range of flows at 15 sites over three years, collected stage and discharge measurements at 8 of the 12 HUC-12 sites, developed rating curves for sites with stage and discharge measurements, estimated monthly and annual constituent loads for sites with discharge measurements, conducted water quality trend analyses at the three USGS sites, and analyzed the relationship between nutrient concentrations and land use. At the three USGS sites, constituent loads were generally greatest in the 2019 project year, and long term trend analyses suggested flow-adjusted sediments were decreasing over time. However, flow adjusted N was increasing at both the Poteau River and James Fork, and flow-adjusted SRP was increasing only at the James Fork. At the HUC-12 sites, constituent loads were generally greatest in 2020, and the largest magnitude of loads occurred from the Lower Poteau river site which is just downstream of the waste water treatment plant in Waldron, Arkansas. Finally, average and flow-weighted concentrations increased with increasing human development (which mostly consists of agricultural land use in the UPRW) across sites (with the exclusion of sites 3 and 9). Ultimately, the data collected in this project is important for understanding small-watershed pollutant sources and long-term trends in water quality at the UPRW.

INTRODUCTION

Excess pollutants entering waterbodies can lead to an array of environmental health concerns (e.g. reduced water clarity and increased algal and plant growth), and cause waterbodies to not meet their designated use(s) (Correll 1998; Jonge et al. 2002; Paerl et al. 2016). With increasing population and land use changes, non-point source (NPS) pollutants have jeopardized aquatic ecosystems, mainly through rainfall and runoff from agricultural and urban landscapes. Therefore, it is important to identify diffuse pollution sources to develop total maximum daily loads (TMDLs) and implement best management practices (BMPs) and improve water quality.

In Arkansas, the NPS Pollution Manage-ment Plan seeks to reduce, manage, control, or abate NPS pollution through watershed prioritization, TMDL development, management practices and stakeholder involvement (ANRC 2018). The Upper Poteau River Watershed (UPRW) has been listed as a priority watershed in Arkansas since 1998 due to nutrient and sediment enrichment from point and nonpoint sources. According to the NPS pollution plan, the long term goal for the UPRW is to reduce pollutant levels that will restore all designated uses. The short term goal is to reduce pollutants of concern and target subwatersheds where implementation of management practices can have the greatest impact.

Several U.S. Environmental Protection Agency (EPA) 319(h) projects have been completed in the UPRW including the Poteau River Agricultural Watershed Project (06-300), Arkansas Forestry Commission Silviculture Project (05-300), the Litter Transport from designated Nutrient Surplus Area (NSA) in Arkansas (05-1600), NPS Pollution BMP E-Education (09-1700), and Water Quality Monitoring for Selected Priority Watersheds in Arkansas: Upper Saline, Poteau, and Strawberry (11-800). Additionally, municipal and industrial point source reductions have occurred in the past decade (ANRC 2018). These efforts may lead to improvement in water quality at the aggregate or larger watershed level. Therefore, the purpose of this study was to aid in documentation of water quality improvements or impairments in this watershed, by monitoring 15 sites within the watershed, three of these existing at U.S. Geological Survey (USGS) discharge monitoring sites, and the remaining 12 sites on the hydrologic unit code (HUC) 12 scale. This monitoring project sought to estimate monthly and annual loads which can be used for future watershed modelling efforts, analyze water quality trends at the USGS sites, contribute data to the historical water quality databases, and collect data that will aid in future developments or updates to watershed management plans in the area.

METHODS

Study Site Description

The UPRW (HUC 11110105) occupies an area of 1,400 km^2 in Arkansas (Figure 1, Table 1). In 2001, land use in the area was 60.0% forested, 6.3% urban, 25.9% agriculture, 3.7% grassland, and 0.8% open water (USGS 2001). In 2016, forested area increased to 65.3%, agriculture area decreased to 21.9%, and urban area was 6.4%, grassland was 4.0%, and open water was 0.9% (USGS 2016). The headwaters of the Poteau River begin near Waldron, Arkansas, and flow west into Oklahoma. The two main tributaries to the Poteau River within the UPRW

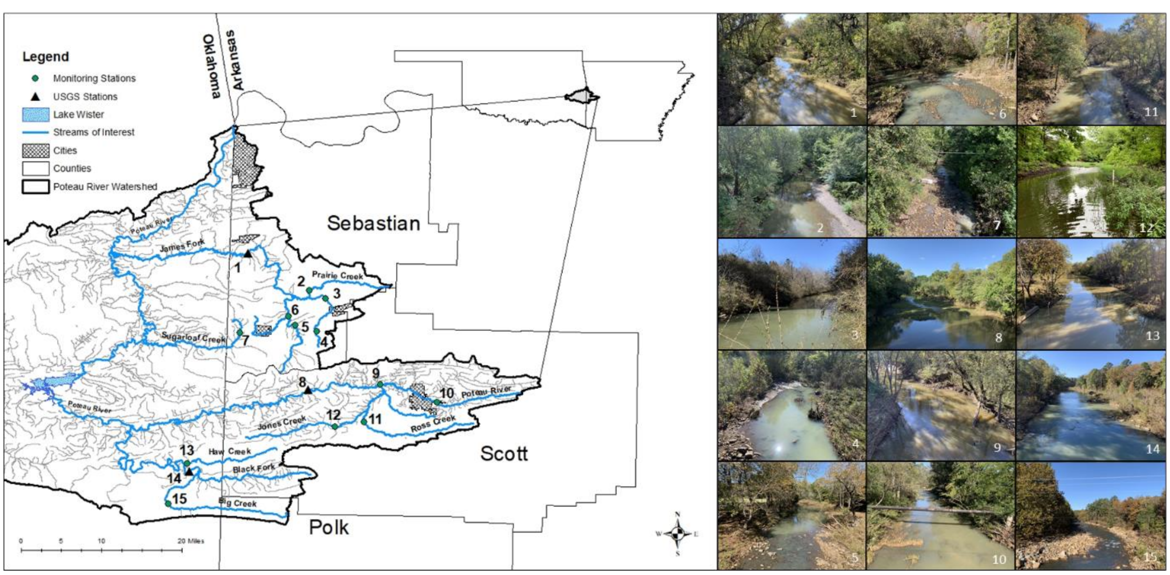


Figure 1: Upper Poteau River Watershed in Arkansas. Monitoring site numbers on map and images correspond to site numbers on in Table 1.

in Arkansas are the Black Fork and the James Fork.

The UPRW is listed as a priority watershed within the Arkansas Nonpoint Source Pollution Plan, and has been a focus of trans-boundary water quality issues for the last several decades (ANRC 2018). In 2012, this 1,400 km^2 watershed contained over 350 poultry farms and produced nearly 100 million birds (USDA 2012). Portions of the Poteau River are listed on the Arkansas 303 (d) list for dissolved oxygen, turbidity, chlorides, sulfates and total dissolved solids (ADEQ 2018). A TMDL was developed in 2006 for the Poteau River, which concluded a 35% reduction in total phosphorus (TP) from non-point sources was necessary for water quality protection (USEPA 2006).

Three USGS discharge monitoring sites exist in the UPRW on the James Fork, Poteau River, and Black Fork (Figure 1, Table 1), and these were monitored in this study. Catchment land use across the USGS sites ranged from 50 to 88% forested, 3.5 to 5.6% urban, and 10 to 41 % agriculture (Table 1). An additional 12 sites were selected at bridge crossings near the outflow of HUC-12 subwatersheds within the UPRW (Figure 1, Table 1). Sites were selected to represent a range of land use and baseflow water quality conditions. Catchment land use across these sites ranged from 23 to 92.3% forested, 1.1 to 7.7% urban, and 0 to 61.4% agriculture (mostly pasture). Barren land represented less than 1% of catchment area for all watersheds, and the remainder of the watershed areas were open water, shrubs, and grasslands (USGS 2016). The catchment area ranged from 7 to 381 km^2 across all sites, including the USGS sites (Table 1).

Data Collection

At the HUC-12 sites, a HOBO water level logger (i.e., pressure transducer; Onset Com-

Table 1: Monitoring site ID's (corresponding to Figure 1), locations, watershed areas, and land use in the Upper Poteau River Watershed.

Site ID	Site Name	Lat N	Long W	Watershed Area (km^2)	%F[1]	%U[2]	%AG[3]
	James Fork Watershed - HUC 1111010508						
1	USGS 07249400 - James Fork	35 09.755	94 24.424	381	50.3	4.8	40.8
2	Prairie Creek	35 05.709	94 17.776	70	23.0	5.1	61.4
3	Lower Cherokee Creek	35 04.839	94 16.013	80	45.1	6.0	46.4
4	Cherokee Creek Headwaters*	35 01.379	94 16.985	14	84.5	1.1	9.4
5	James Fork Headwaters*	35 01.984	94 19.315	39	84.7	1.2	8.9
6	Lower James Fork*	35 02.820	94 20.302	95	69.9	3.5	18.3
	Lower Poteau River Watershed - HUC 1111010506						
7	Upper Sugar Loaf Creek	35 01.177	94 25.285	7	88.6	1.6	1.3
	Headwaters Poteau River Watershed - HUC 1111010501						
8	USGS 07247000 - Poteau River	34 55.129	94 17.918	527	63.7	5.6	21.3
9	Lower Poteau River*	34 55.666	94 10.124	193	51.6	7.7	32.0
10	Poteau River Headwaters*	34 53.769	94 03.975	39	52.7	5.5	33.1
11	Ross Creek*	34 51.647	94 11.910	77	71.8	4.6	13.9
12	Upper Jones Creek*	34 51.895	94 12.835	73	84.8	2.7	2.2
	Black Fork Watershed - HUC 1111010502						
13	Haw Creek	34 47.257	94 30.924	62	90.3	1.8	1.1
14	USGS 07247250 - Black Fork	34 46.428	94 30.748	245	88.3	3.5	9.8
15	Big Creek*	34 42.970	94 33.006	60	92.3	6.2	0.0

puter Corporation, Bourne, Massachusetts) was deployed at each site in December 2017 or January 2018 to obtain continuous stage records, and HOBO barometric pressure transducers were installed within 16 km of each sample site to account for fluctuations in atmospheric pressure. The HOBOs were installed and maintained according to standard operating procedures (OCC 2018), where the HOBO water level loggers were typically suspended within a polyvinyl chloride (PVC) pipe attached to a bridge post, and atmospheric HOBOs were bound to trees outside of the stream channel (Figure 2A and 2B, respectively). Sensors were set to record measurements on 15-minute intervals, and data were downloaded from the HOBOs on a monthly basis.

SonTek-IQ acoustic Doppler instruments (SonTek/Xylem Inc., San Diego, California), were rotated among eight of the HUC-12 sites to measure discharge during high flow events. SonTek-IQs measure the velocity of water using the Doppler shift and internally calculate discharge once calibrated to the stream channel geometry. Roving discharge monitoring stations were installed at each site to allow for easy rotation of the SonTek-IQs among sites between flood events. Roving discharge monitoring stations include a concrete base staked into the streambed, a container to store the battery and wiring (e.g. an ammo can), and PVC pipe from the concrete base up the stream bank and to the battery container (Figure 2 C-E). The battery container is attached to a tree outside of the floodplain (Figure 2E).

Rating Curve Development

Rating curves were developed for the eight HUC-12 sites using the high-flow data captured during SonTek-IQ deployment, and baseflow discharge measurements collected on a monthly basis using velocity-area methods, since the SonTek-IQ flow measurements are not reliable when water depths are less than 0.45 m (SonTek-IQ 2017). Since all instantaneous flow measurements obtained by the SonTek-IQ were not necessary for rating curve development, we

Figure 2: A) Pressure transducer installation on a bridge post, B) atmospheric pressure transducer attached to a tree outside of floodplain, C) SonTek-IQ attached to concrete block in stream channel, D) SonTek-IQ in stream channel, and E) ammo can attached to tree outside of the flood plain to store battery.

selected various points along the hydrograph to use in the rating curve. Therefore, the final rating curves consisted of the averages (i.e., five values on 15 minute intervals) around the peak flows, 75% of the peak flows, and 50% of the peak flows from the SonTek-IQ, averages around the corresponding stages, and baseflow measurements.

Rating curves were developed using simple linear regression, locally weighted regression (LOESS), and Manning's equation. Below the range of measured flow data, 2-point regression was applied to estimate low flows, and nonparametric LOESS regression was used to fit the range of measured flow and stage data with a sampling proportion of 0.5. Manning's equation was used for flow estimations above of the range of measured data (Equation 1):

$$Q = \left(\frac{K}{n}\right) AR^{\frac{2}{3}}\sqrt{S}$$

where Q is the flow (ft^3/s), K is a constant equal to 1.49 $ft^{1/3}/s$, *n* is the surface roughness ($s/ft^{1/3}$), A is the cross-sectional area of flow (ft^2), R is the hydraulic radius (ft), and S is the slope of the channel (ft/ft).

To estimate A and R from Manning's equation, an unsteady flow analysis was conducted in the Hydrologic Engineering Center's River Analysis System (HEC-RAS) (USACE 2016). With inputs including the stream channel survey, LOESS rating curve data, and a stage hydrograph, the unsteady flow analysis computes the A and the wetted perimeter (WP) for a range of user defined depths. The R at each depth is then computed as A divided by the WP. The final rating curves were analyzed using Nash-Sutcliffe Efficiency (NSE), and are shown for each site in the results section. The rating curves were then used to develop a record of continuous, instantaneous flow on a 15-minute time interval.

At the three USGS discharge monitoring sites, instantaneous flow was available through the USGS National Water Information Systems (USGS 2020). Discharge was downloaded for each site at the end of the project period to use in constituent load estimations.

Constituent Load Estimations

Water samples were collected across the range of discharge measurements (i.e., baseflow and stormflow) at all 15 sites to estimate constituent loads. Sample collection began in October 2017, and continued through the end of the project period in September 2020. Water samples were analyzed at the Arkansas Water Resources Center Water Quality Lab (AWRC WQL) for nitrate plus nitrite (NN), chloride (Cl), fluoride (Fl), soluble reactive P (SRP), TP, total nitrogen (TN), total suspended solids (TSS), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC). The equipment, methods and method detection limits for the certified AWRC lab are available online (AWRC 2020).

Constituent loads (L_i) were estimated by multiplying constituent concentrations (C_i) by instantaneous flow (Q_i). A generalized additive model (GAM), in the mgcv package in R (R Core Team 2016; Wood 2017), was applied to predict constituent loads using a spine based smooth function (s) of each predictor variable, log transformed instantaneous flow and day of year (DOY, to capture seasonality) (Equation 2):

$$\log_{10} L_i = s(\log_{10} Q_i) + s(DOY)$$

The performance of the GAM models were evaluated using R^2 and NSE. A continuous record of constituent loads with 95% confidence intervals was developed using each GAM. Daily constituent loads were estimated by integrating continuous loads over time, and daily loads were then summed to estimate monthly and annual loads.

Trend Analyses

The long-term data used to evaluate trends at the USGS sites come from the USGS NWIS, which includes flow, stage, and various water quality parameters. Constituents of interest at each site were instantaneous dis-charge (Q_i), TN, NN, TP, SRP, and SS (Table 2). These data were available from the 1970s to 2020 depending on site and parameter (Table 2).

Raw data from the USGS contained censored and estimated values. Estimated values were assumed sufficient, and these values were used in analysis. Less than 15% of the data were censored across all sites and constituents, except for TN and SRP at the Black Fork, where 16% and 39% of the data was censored, respectively (Table 2). Censored values were replaced with the average of the censored values for each parameter to reduce the potential influence of changing reporting limits. The U.S. Environmental Protection Agency suggested using simple substitution methods with data sets less than 15% censored (USEPA 2000). Since less than 15% of the data here was censored for the majority of constituents (except for TN and SRP at Black Fork), this method is likely adequate for our data set.

The database covers several decades where processing and analyses changes occurred for some constituents. Some data were combined to account for changing methods (e.g. switching from filtered to unfiltered samples or for gaps in data availability). At all sites, we combined the mean daily discharge (Q_d, P00060) with the instantaneous discharge (Q_i, P00061) to account for missing Q_i values (< 10 % of data). For the James Fork, we combined the filtered NN (p00631) with the unfiltered nitrate plus nitrite (p00630). There were a few sample dates with both filtered and unfiltered data. The values were within 10% of each other, so an average of the values was used. At the Poteau and Black Fork, full data sets were available for the filtered nitrate plus nitrite, so no combination was necessary.

Constituent concentrations were used to evaluate long-term water quality trends, using the following three-step procedure (White et al. 2004):

Table 2: USGS parameter codes, constituents, percentage of censored values, and data availability for the James Fork (USGS 07247250, Site 1), Poteau River (USGS 07247000, Site 8), and Black Fork (USGS 0729400, Site 14) in the Upper Poteau River Watershed.

USGS parameter code	Constituent	% Censored			Data availability		
		James Fork	Poteau River	Black Fork	James Fork	Poteau River	Black Fork
p00600	Total nitrogen, unfiltered, mg L^{-1} as N	9.2%	11.5%	16.4%	1975-1981, 1995-2020	1995-2020	1991-2018
p00630	Nitrate plus nitrite, unfiltered, mg L^{-1} as N	0.0%	NA	NA	1977-1994	NA	NA
p00631	Nitrate plus nitrite, filtered, mg L^{-1} as N	10.8%	11.5%	1.4%	1976-1981, 1994-2020	1995-2020	1991-2018
p00665	Phosphorus, water, unfiltered, mg L^{-1} as P	9.6%	0.3%	9.3%	1972-1981, 1983-2020	1995-2020	1992-2018
p00671	Orthophosphate, water, filtered, mg L^{-1} as P	13.9%	6.2%	38.7%	1995-2020	1995-2020	1991-2018
p80154	Suspended sediment concentration, mg L^{-1}	0.0%	0.0%	1.0%	1978-1981, 1995-2020	1995-2020	1991-2018

- Discharge and constituent concentrations were log transformed in order to reduce effects of outliers (Helsel and Hirsch 1991).

- Constituent concentrations were flow adjusted using a locally weighted regression (LOESS) smoothing technique. LOESS spans were manually inspected, in order to minimize error from the LOESS regression while maximizing the regression's predictive power (Simpson and Haggard 2018). A range of spans between 0.3 and 0.7 for all constituents was chosen, based on the root mean square errors (RMSE) and visual inspection of the LOESS fits.

- Residuals from the LOESS fit (i.e. the flow-adjusted concentrations, FACs) were analyzed over time in order to evaluate trends, changes in residuals represent a change in constituent concentration over time unrelated to flow. Monotonic trends were examined using linear regression and the nonparamtetric Seasonal Kendall Test (SKT) based on quarterly data or the median FAC during that quarter. The slopes from these tests were used to estimate the magnitude (% yr^{-1}) of any trends (Sen 1968; Hirsch et al. 1982). Trends with p-values less than 0.05 were considered "extremely likely" to increase or decrease, p-values between 0.05 and 0.20 were considered "likely" to increase or decrease, and p-values greater than 0.20 were considered "likely not changing".

Trend analysis was then repeated by removing all censored values to see if the reporting limits influence our trends interpretation. The results from linear regression and the SKT were not different across most of the data, so the results section focuses on the linear model slopes and p-values.

A nonparametric change point analysis (nCPA) was implemented for all FACs over time, to detect any changes in the time series of data (King and Richardson 2003; Qian et al. 2003). If one or more change point was identified, then the three-step trend analysis was conducted on the time series to the left and right of the point. Additionally, for constituents with gaps in the data sets, a simple t-test or analysis of variance (ANOVA) was used to analyze the difference between means FACs across the groups of data. All data analysis was completed using R.

RESULTS

USGS 07249400- James Fork (Site 1)

Constituent Loads

The USGS gaging station on the James Fork (Figure 3) is near Hackett, Arkansas, and its watershed covers an area of 381 km^2 that is 50.3% forest, 4.8% urban and 40.8% agriculture. Flow measurements for the project period of October, 2017 through September, 2020 ranged from 0.0 and 11,400 cfs. A total of 114 water samples were collected during the project period, with 71 during baseflow conditions and 43 during storm flow. Water samples were collected across 99.9% of all flow measurements, with no flow measurements falling below where water samples were collected, and 0.1% of flow measurements falling above.

Constituent concentrations were gen-erally greater in the 2017 project year (i.e., October, 2017 – September, 2018) compared to 2018 and 2019 (Table 3), except for NN and Fl which were greatest in 2019. Additionally, con-stituent concentrations were generally greatest in the winter months (i.e., December, January, and February), and least in spring months (i.e., March, April and May).

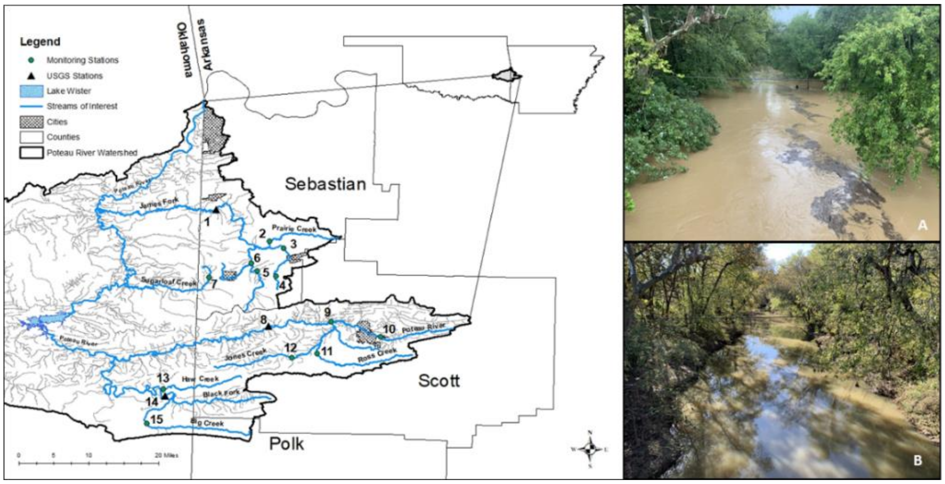


Figure 3: Upper Poteau River Watershed site map (left) and images of the James Fork (Site 1) during storm flow (A) and baseflow conditions (B).

Measured concentrations were multiplied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The R^2 and NSE values for each constituent's GAM were greater than 0.90, and all constituents but Fl were greater than 0.96 (Table 4). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 4). Nutrient and sediment loads were greater in the 2019 project year compared to 2017 and 2018, while anions (i.e., Fl, Cl and SO_4^{2-}) were greater in the 2018 project year. NN loads generally made up about 25% of TN loads, and SRP loads made about 23% of TP loads. Slightly higher percentages were observed for mean concentrations each year, with NN making up about 29% of TN concentrations and SRP making up about 26% of TP concentrations (Table 3).

Trend Analysis

Trend analysis was conducted using over 40 years of available flow and water quality data from the USGS at the James Fork. Sediments, P and TN generally increased with discharge, while NN was more variable at higher flows. LOESS was fit to each concentration and discharge

Table 3: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the James Fork (USGS 07249400, Site 1).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	mg L^{-1}								NTU	µS cm^{-1}
2017	0.92	0.223	0.21	0.055	97.43	0.120	5.023	31.544	122.41	205.44
2018	0.76	0.236	0.14	0.035	62.22	0.115	3.952	24.795	77.15	141.29
2019	0.76	0.252	0.15	0.044	72.47	0.153	4.039	29.241	71.88	160.16
Fall	0.82	0.248	0.16	0.055	50.81	0.124	4.438	25.401	61.62	170.02
Winter	0.91	0.298	0.21	0.039	105.83	0.119	5.159	31.588	128.23	168.29
Spring	0.76	0.209	0.13	0.035	56.24	0.120	3.979	24.997	64.33	141.64
Summer	0.77	0.188	0.18	0.052	96.21	0.155	3.828	32.245	107.21	198.42

Table 4: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the James Fork (USGS 07249400, Site 1). Additionally, the mean daily flow (Q_d) for each project year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2017	2018	2019
Q_d	--	--	--	141	330	335
TN	0.993	0.993	648 (558-753)	126,036	290,341	296,487
NN	0.964	0.967	157 (98-254)	31,037	71,098	72,669
TP	0.981	0.983	164 (120-226)	34,341	70,060	76,102
SRP	0.962	0.964	38 (24-63)	8,030	16,075	17,901
TSS	0.980	0.982	75,690 (49,549-116,380)	18,763,463	28,936,749	35,628,019
Fl	0.910	0.917	66 (37-119)	11,972	30,558	29,882
Cl	0.994	0.994	2,100 (1,842-2,395)	389,338	970,448	947,803
SO_4^{2-}	0.983	0.984	11,984 (9,394-15,326)	2,274,660	5,467,050	5,395,922

relationship with sampling propor-tions of 0.4 – 0.7 (Table 5), and LOESS RMSEs were relatively low (< 0.36).

The trends in flow-adjusted concen-trations over time (i.e., 1995 – 2020) were variable across constituents. The specific changes include:

- TN likely increased ($0.05 < p < 0.20$) at 0.29 % yr^{-1}, with no change points identified (Figure 4, A); however, the average flow-adjusted TN was 20% greater between 1976 and 1981 compared to 1995 to 2020 ($p < 0.05$).
- NN extremely likely increased from 1995 to 2020 (where the data was completely filtered, Table 1) by 1.25 % yr^{-1} ($p < 0.05$); however, with the combined dataset of filtered and unfiltered NN, the average flow adjusted NN was 34% greater from 1979 to 1981 compared to after 1995 ($p < 0.05$, Figure 4, B). One change point occurred for NN in April 1998, where flow-adjusted NN was 27% greater after 1998 compared to before.
- TP was likely not changing between 1995 and 2020 ($p = 0.28$); two significant change points occurred in the FACs, one

Table 5: Optimal LOESS Sampling Proportion, LOESS RMSE, Linear Model Slope, Linear Model p-Value, Seasonal Kendall's Test (SKT) Sen's Slope, and Seasonal Kendall's Test p-Value for Trends in Flow Adjusted Concentrations (FACS) for each Parameter the James Fork (USGS 07249400, Site 1).

Parameter	LOESS Sampling Proportion	LOESS RMSE	Linear Model Slope (%/yr)	Linear Model p-Value	SKT Sen's Slope (%/yr)	SKT p-Value
TN	0.40	0.16	0.29	0.15	0.28	0.12
NN	0.70	0.36	1.25	<0.01	0.99	<0.01
TP	0.70	0.26	0.12	0.28	0.04	0.55
SRP	0.70	0.25	0.44	0.15	0.12	0.42
SS	0.50	0.3	-2.27	<0.01	-2.18	<0.01

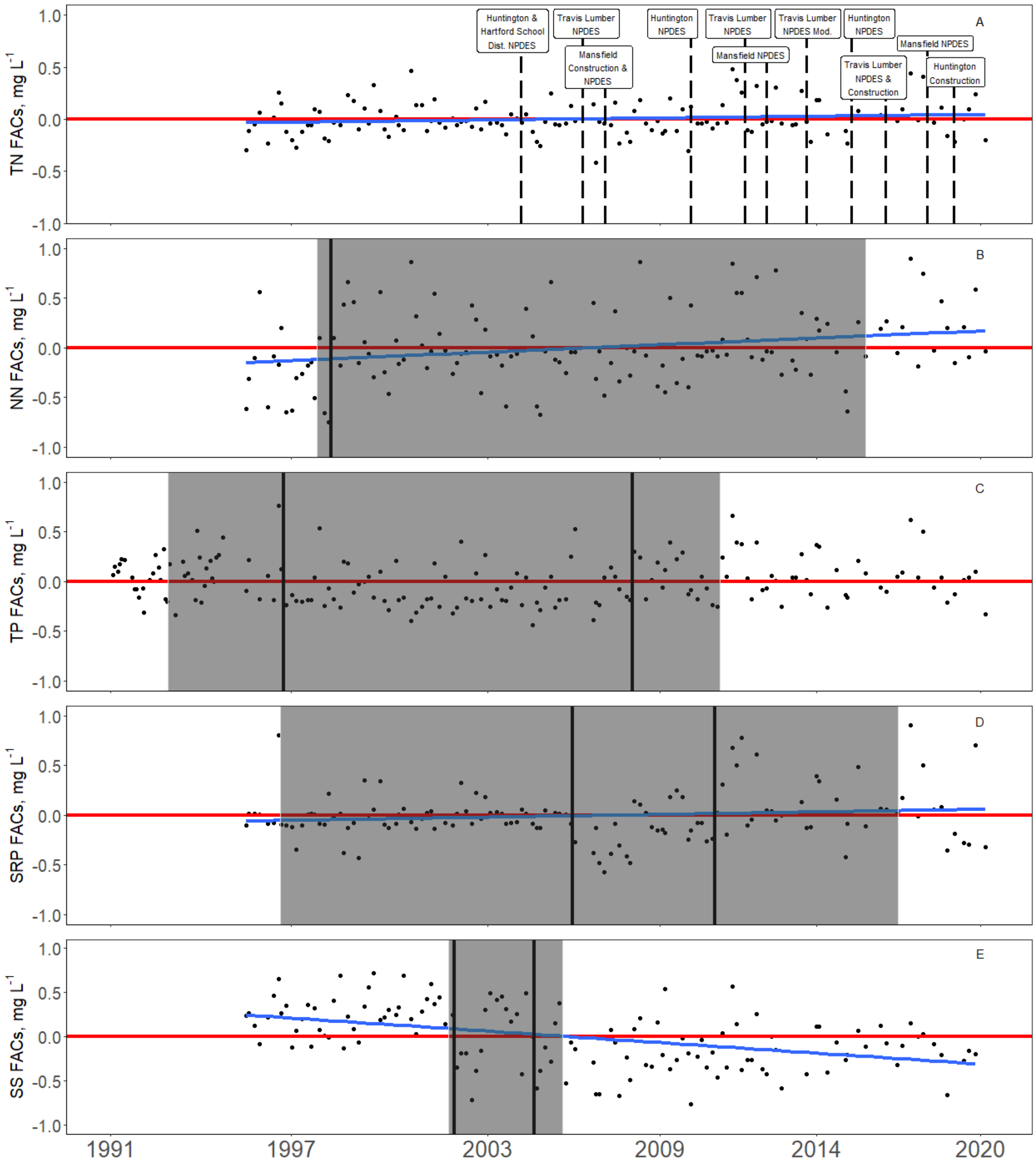


Figure 4: Trends in Flow Adjusted Concentrations (FACs) of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediments (SS), Nitrate+Nitrite (NN), and Soluble Reactive Phosphorus (SRP) at the James Fork. The FACs were truncated from -1 to 1 for consistency. This may cause a few data points to be missing from the figure, but all data were included in trend analysis. Significant change points are identified by solid vertical lines, the grey areas are the 95% confidence intervals around the change points, and significant linear model slopes are identified by solid blue lines. A timeline of events related to Nonpoint Source Discharge Elimination System (NPDES) permits and other significant milestones for the point sources on the James Fork (Site 1) is shown in Figure 4,A.

in September 1996 and one in April 2008 (Figure 4, C), but no monotonic changes occurred before or after the change points.

- SRP likely increased ($0.05 < p < 0.20$) by a magnitude of 0.44 % yr^{-1}; two change points occurred in flow-adjusted SRP, one in June 2006 and the other in April 2011, and average SRP FACs were 21% greater after 2011 and 24% less before 2006 compared to between 2006 and 2011 (Figure 4, D).

- SS extremely likely decreased at a rate of 2.27% yr^{-1} ($p < 0.05$, Figure 4, E), but the average flow-adjusted SS after 1995 was not significantly different than the average flow adjusted SS before 1981 ($p > 0.05$); two change points were identified relatively close in time, one in June 2002 and the other in January 2005.

Prairie Creek (Site 2)

The Prairie Creek monitoring site (Figure 5) is near Huntington, Arkansas, and its watershed covers an area of 70 km^2 that is 23.0% forest, 5.1% urban and 61.4% agriculture. A pressure transducer was installed at site 2 on December 21, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 0.05 and 13.6 ft. Due to equipment malfunction, stage measurements were not collected for 18 days in January 2019 (i.e., January 8 – 18, 2019). Baseflow discharge measurements were collected on 12 occasions throughout the project period, with baseflows ranging from 0.4 to 32.3 cfs. Due to time constraints, a SonTek-IQ was not deployed at this site.

A total of 65 water samples were collected from site 2, with 35 during baseflow conditions and 30 during storm flow between October 2017 and September 2020. Water samples were collected across 97.9% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 2% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 6). Additionally, constituent concentrations were generally greatest in the summer months (i.e., June, July, and August), and least in spring months (i.e., March, April, and May).

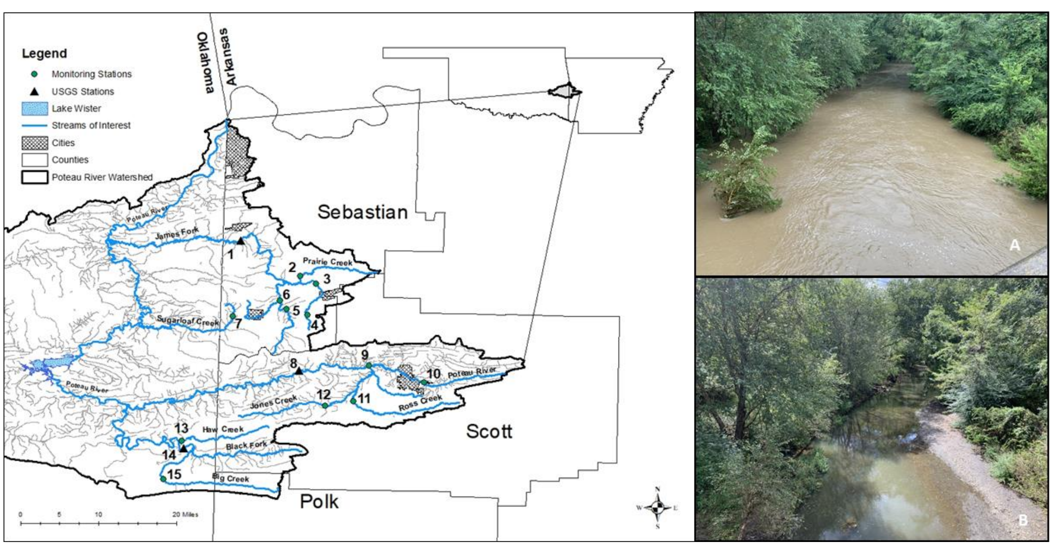


Figure 5: Upper Poteau River Watershed site map (left) and images of Prairie Creek (Site 2) during storm flow (A) and baseflow conditions (B).

Table 6: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at Prairie Creek (Site 2).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	----------	----------	----------	----------	mg L^{-1}	----------	----------	----------	NTU	µS cm^{-1}
2017	0.99	0.277	0.24	0.119	54.84	0.123	5.502	20.102	82.18	133.73
2018	0.89	0.245	0.19	0.085	53.15	0.106	4.133	12.531	71.81	91.83
2019	0.94	0.283	0.22	0.117	53.13	0.134	4.397	13.642	59.29	99.71
Fall	0.97	0.304	0.22	0.146	36.48	0.120	5.121	15.465	53.57	107.97
Winter	0.98	0.338	0.19	0.082	39.24	0.088	5.534	16.348	65.94	111.33
Spring	0.77	0.128	0.14	0.056	35.01	0.104	3.983	12.584	48.13	96.03
Summer	1.03	0.302	0.29	0.130	95.16	0.161	3.986	15.682	105.73	109.54

However, NN, Cl and $SO_4^{2`}$ concentrations were greatest in the winter months (December, January, and February) and least in spring months.

Lower Cherokee Creek (Site 3)

The Lower Cherokee Creek monitoring site (Figure 6) is near Huntington, Arkansas, and its watershed covers an area of 80 km^2 that is 45.1% forest, 6.0% urban and 46.4% agriculture. A pressure transducer was installed at site 3 on December 21, 2017, but the pressure transducer was lost in a storm event on June 10, 2019. Stage measurements were not continued past this point, since this site was also too deep for manual discharge measurements and SonTek-IQ installation. From December 2017 to June 2019, stage measurements ranged between 0.0 and 7.9 ft.

A total of 41 water samples were collected from site 3, with 20 during baseflow conditions and 21 during storm flow between October 2017 and June 2019. Water samples were collected across 94.0% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and

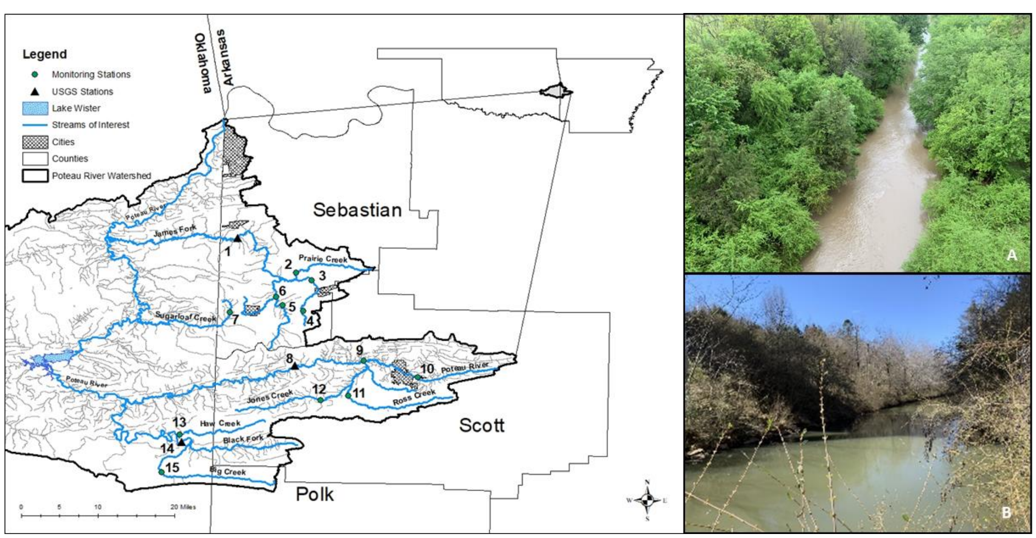


Figure 6: Upper Poteau River Watershed site map (left) and images of Lower Cherokee Creek (Site 3) during storm flow (A) and baseflow conditions (B).

Table 7: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the Lower Cherokee Creek (Site 3).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	mg L^{-1}								NTU	µS cm^{-1}
2017	2.46	0.725	0.33	0.169	45.06	0.183	8.095	16.985	76.28	186.19
2018	0.84	0.227	0.14	0.053	26.37	0.096	3.466	10.211	44.55	74.88
2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fall	1.12	0.300	0.22	0.122	18.50	0.093	8.090	14.985	31.91	137.00
Winter	2.93	0.420	0.26	0.121	33.93	0.099	6.792	14.405	62.20	146.33
Spring	0.78	0.193	0.11	0.050	18.74	0.120	4.520	12.148	28.53	99.72
Summer	1.65	0.869	0.32	0.140	63.48	0.207	4.064	12.812	105.55	133.56

5.9% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 (Table 7). Additionally, constituent concentrations were generally greatest in the summer months (i.e., June, July, and August), and least in spring months (i.e., March, April, and May), except TN and EC concentrations were greatest in the winter, and Cl and $SO_4^{2`}$ concentrations were greatest in the fall months (September, October, and November). However, only about a year and a half of water quality data is available for this site compared to 3 years at other sites.

Cherokee Creek Headwaters (Site 4)

The Cherokee Creek Headwaters monitoring site (Figure 7) lies between Hartford and Mansfield, Arkansas, and its watershed covers an area of 14 km^2 that is 84.5% forest, 1.1% urban and 9.4% agriculture. A pressure transducer was installed at site 4 on December 19, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 0.1 and 7.6 ft. Due to equipment malfunction, stage measurements were not collected for 19 days in January 2019 (i.e., January 8 – 26 2019). Baseflow discharge

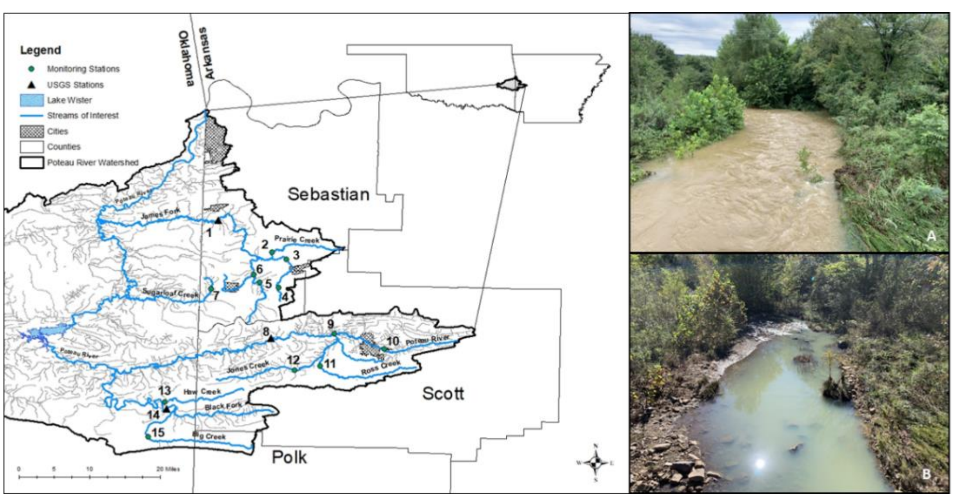


Figure 7: Upper Poteau River Watershed site map (left) and images of the Cherokee Creek Headwaters (Site 4) during storm flow (A) and baseflow conditions (B).

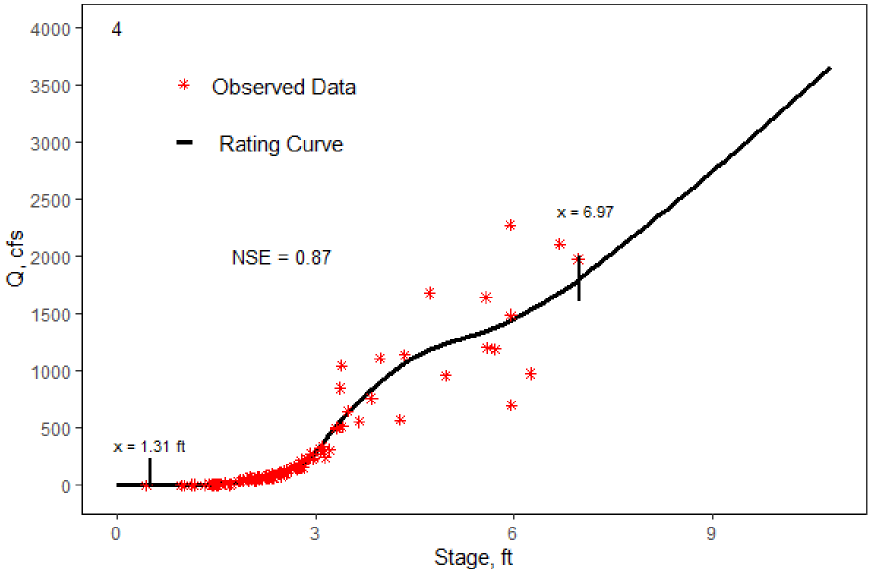


Figure 8: Rating curve for the Cherokee Creek Headwaters (Site 4). Two-point regression was used for stages below 1.31 ft, LOESS regression for stages between 1.31 and 6.97 ft, and Manning's equations for stages above 6.97 ft.

measurements were collected on 19 occasions throughout the project period, with baseflows ranging from 0.0 to 18.6 cfs. A SonTek-IQ was deployed between December 2018, and April 2019, and again from October 2019, to June 2020. Flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 35 and 2,300 cfs. Between SonTek-IQ and manual discharge measurements, 98.7% of all stage measurements were captured by flow measurements, (i.e., less than 2% of all stage measurements fell outside the range of measured flow).

A total of 80 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. For the final rating curve (Figure 8), a two-point regression, with a slope of 0.04 ft^2/s, was used for stage values less than 1.31 ft. LOESS regression was used between 1.31 and 6.97 ft, where measured flow data exists, and Manning's

Table 8: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the Cherokee Creek Headwaters (Site 4).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	mg L^{-1}								NTU	µS cm^{-1}
2017	0.73	0.235	0.16	0.087	18.05	0.088	7.969	14.684	48.39	94.24
2018	0.35	0.032	0.05	0.010	8.50	0.084	3.230	10.023	27.32	55.38
2019	0.41	0.081	0.06	0.026	8.03	0.096	4.083	12.168	25.44	68.79
Fall	0.49	0.097	0.09	0.045	9.10	0.091	5.129	11.658	27.61	74.16
Winter	0.42	0.088	0.06	0.017	6.22	0.060	6.135	12.848	25.54	73.52
Spring	0.38	0.052	0.05	0.012	7.53	0.080	3.539	10.879	27.13	59.13
Summer	0.59	0.174	0.13	0.066	19.53	0.121	4.687	12.975	47.06	76.22

equation was used to predict flows above 6.97 ft, with a Manning's n of 0.05. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020 (except for the missing days of stage in January 2019).

A total of 68 water samples were collected from site 4, with 36 during baseflow conditions and 32 during storm flow between October 2017 and September 2020. Water samples were collected across 97.6% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 2.3% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 8). Additionally, constituent concentrations were generally greatest in the summer months (i.e., June, July, and August), and least in spring months (i.e., March, April, and May). However, TSS, turbidity, and Fl concentrations were least and Cl concentrations were greatest in the winter months (i.e., December, January, and February).

Measured concentrations were multiplied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020 (except for the missing days of stage in January 2019). The R^2 and NSE values for each constituent's GAM were greater than 0.80, and all constituents but NN were greater than 0.90 (Table 9). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 9). Constituent loads in January 2019 may be underestimated due to 19 days of missing stage data. However, the USGS monitoring station in this watershed (James Fork- USGS 07249400) expressed mostly baseflow conditions during this time period, with two small storm event raising the stage by less than 5 ft each. Therefore, constituent loads during this time were likely small. Most constituent loads were greater in 2020 compared to 2018 and 2019, except for SRP and Cl, which were greatest in

Table 9: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the Cherokee Creek Headwaters (Site 4). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	9	13	13
TN	0.976	0.978	13 (8-23)	3,863	4,401	6,034
NN	0.873	0.882	1 (0-3)	353	399	490
TP	0.967	0.975	2 (1-4)	726	569	814
SRP	0.936	0.954	1 (0-2)	251	124	211
TSS	0.962	0.958	459 (157-1,421)	105,398	122,487	267,712
Fl	0.952	0.954	2 (1-3)	599	794	892
Cl	0.990	0.991	59 (48-75)	18,332	24,789	20,889
SO_4^{2-}	0.993	0.994	232 (191-285)	66,618	95,791	87,947

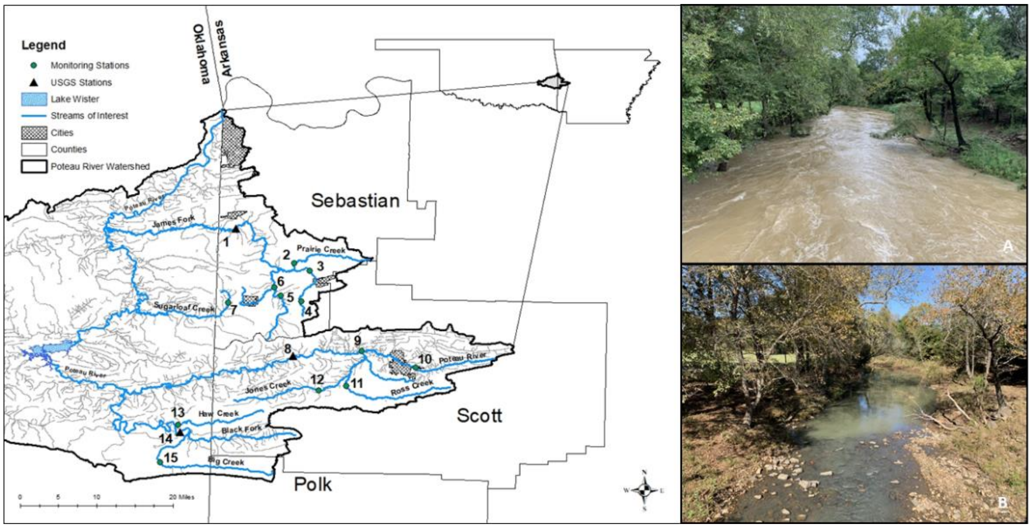


Figure 9: Upper Poteau River Watershed site map (left) and images of the James Fork Headwaters (Site 5) during storm flow (A) and baseflow conditions (B).

2018. NN loads generally made up about 10% of TN loads, while SRP loads made up closer to 25% of TP loads. However, NN made up about 20% of TN concentrations and SRP made up about 38% of TP concentrations each year.

James Fork Headwaters (Site 5)

The James Fork Headwaters monitoring site (Figure 9) lies near Hartford, Arkansas, and its watershed covers an area of 39 km^2 that is 84.7% forest, 1.2% urban and 8.9% agriculture. A pressure transducer was installed at site 5 on December 19, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 0.0 and 9.3 ft. Due to

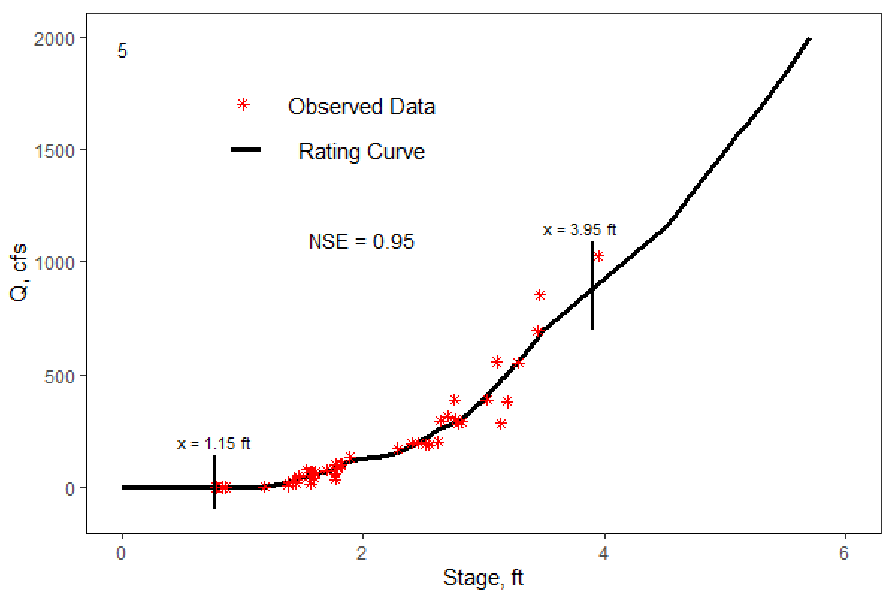


Figure 10: Rating curve for the James Fork Headwaters (Site 5). Two-point regression was used for stages below 1.15 ft, LOESS regression for stages between 1.15 and 3.95 ft, and Manning's equations for stages above 3.95 ft.

Table 10: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the James Fork Headwaters (Site 5).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	---------- mg L^{-1} ----------								NTU	µS cm^{-1}
2017	0.76	0.173	0.20	0.081	43.69	0.054	4.031	38.998	42.78	151.33
2018	0.38	0.108	0.08	0.005	47.93	0.087	2.404	20.341	56.53	80.00
2019	0.44	0.105	0.09	0.038	25.58	0.090	3.157	24.911	33.46	105.91
Fall	0.60	0.180	0.15	0.091	32.03	0.074	3.944	31.803	32.48	132.92
Winter	0.55	0.144	0.12	0.034	30.19	0.063	3.366	20.611	43.71	88.94
Spring	0.27	0.066	0.03	0.004	13.16	0.069	2.628	24.080	21.60	93.53
Summer	0.63	0.113	0.17	0.035	75.68	0.100	2.841	37.172	73.16	138.23

equipment malfunction, stage measurements were not collected for 19 days in January 2019 (i.e., January 8 – 26 2019). Baseflow discharge measurements were collected on 15 occasions throughout the project period, with baseflows ranging from 0.2 to 63.6 cfs. A SonTek-IQ was deployed between January and June 2018, and flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 55 and 1,100 cfs. Between SonTek-IQ and manual discharge measurements, 92.9% of all stage measurements were captured by flow measurements, (i.e., less than 8% of all stage measurements fell outside the range of measured flow).

A total of 35 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. For the final rating curve (Figure 10), a two-point regression with a slope of 0.95 ft^2/s was used for stage values less than 1.15 ft. LOESS regression was used between 1.15 and 3.95 ft, where measured flow data exists, and Manning's equation was used to predict flows above 3.95 ft, with a Manning's n of 0.022. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020 (except for the missing days of stage in January 2019).

A total of 78 water samples were collected from site 5, with 38 during baseflow conditions and 40 during storm flow between October 2017 and September 2020. Water samples were collected across 98.3% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 1.6% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 10). Additionally, constituent concentrations were generally greatest in the summer months (i.e., June, July, and August), and least in spring months (i.e., March, April, and May). However, NN, SRP and Cl concentrations were greatest in the fall months (i.e., September, October, and November), and Fl and SO_4^{2-} were least in the winter months (i.e., December, January, and February).

Measured concentrations were multi-plied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020 (except for the missing days of stage in January 2019). The R^2 and NSE values for each constituent's GAM were greater than

Table 11: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the James Fork Headwaters (Site 5). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	32	47	42
TN	0.964	0.969	47 (28-79)	15,875	15,863	18,871
NN	0.920	0.933	7 (3-14)	3,043	2,313	1,837
TP	0.937	0.944	14 (6-34)	3,489	3,714	8,241
SRP	0.897	0.929	1 (0-5)	558	283	333
TSS	0.964	0.971	6,355 (2,584-15,969)	1,140,686	2,397,216	3,320,140
Fl	0.941	0.944	7 (5-10)	1,939	2,620	2,738
Cl	0.990	0.994	199 (141-280)	69,158	80,204	64,895
SO_4^{2-}	0.963	0.966	1,019 (803-1,300)	337,472	419,069	344,028

0.80, and all constituents but SRP were greater than 0.90 (Table 11). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 11). Constituent loads in January 2019 may be underestimated due to 19 days of missing stage data. However, the USGS monitoring station in this watershed (James Fork- USGS 07249400) expressed mostly baseflow conditions during this time period, with two small storm event raising the stage by less than 5 ft each. Therefore, constituent loads during this time were likely small. Most constituent loads were greatest in the 2020, except for NN and SRP, which were greatest in 2018, and Cl and SO_4^{2-}, which were greatest in 2019. NN loads generally made up about 16% of TN loads, while SRP loads made up about 11% of TP loads. However, NN made up about 15% of TN concentrations and SRP made up about 10% of TP concentrations each year.

Lower James Fork (Site 6)

The Lower James Fork monitoring site (Figure 11) lies near Hartford, Arkansas, and its watershed covers an area of 95 km^2 that is 69.9% forest, 3.5% urban and 18.3% agriculture. A pressure transducer was installed at site 6 on December 20, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 1.1 and 13.9 ft. Due to equipment malfunction, stage measurements were not collected for 19 days in January 2019 (i.e., January 8 – 26, 2019). Baseflow discharge measurements were collected on 12 occasions throughout the project period, with baseflows ranging from 0.0 to 29.4 cfs. A SonTek-IQ was deployed between February and June 2018, and flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 7.8 and 3,100 cfs. Between SonTek-IQ and manual discharge measurements, 95.6% of all stage measurements were captured by flow measurements, (i.e., less than 5% of all stage measurements fell outside the range of measured flow).

A total of 45 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. For the final rating curve (Figure 12), a two-point regression with a slope of 0.21 ft^2/s was used for stage values less than 1.69 ft. LOESS regression was used between 1.69 and 9.06 ft, where measured flow data exists, and Manning's

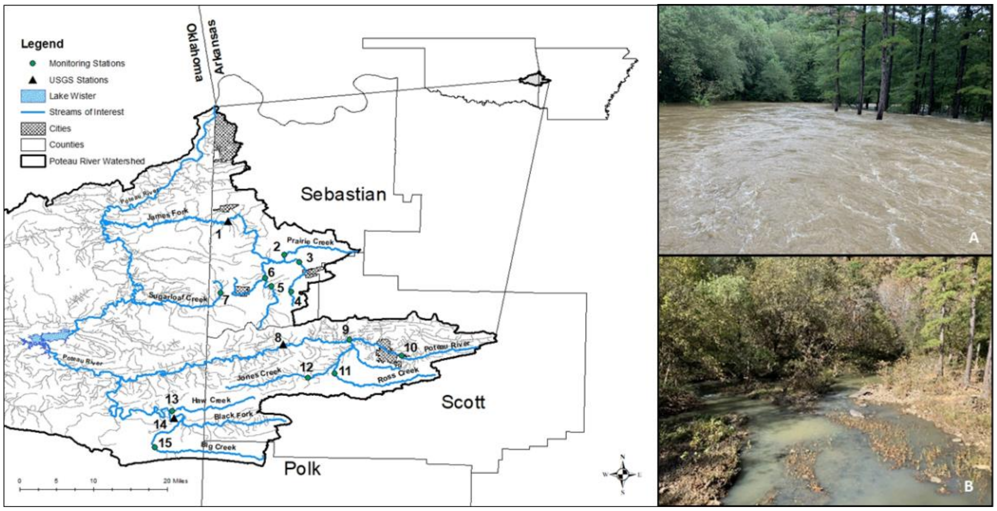


Figure 11: Upper Poteau River Watershed site map (left) and images of the Lower James Fork (Site 6) during storm flow (A) and baseflow conditions (B).

equation was used to predict flows above 9.06 ft, with a Manning's n of 0.03. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020 (except for the missing days of stage in January 2019).

A total of 76 water samples were collected from site 6, with 37 during baseflow conditions and 39 during storm flow between October 2017 and September 2020. Water samples were collected across 98.3% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 1.6% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019

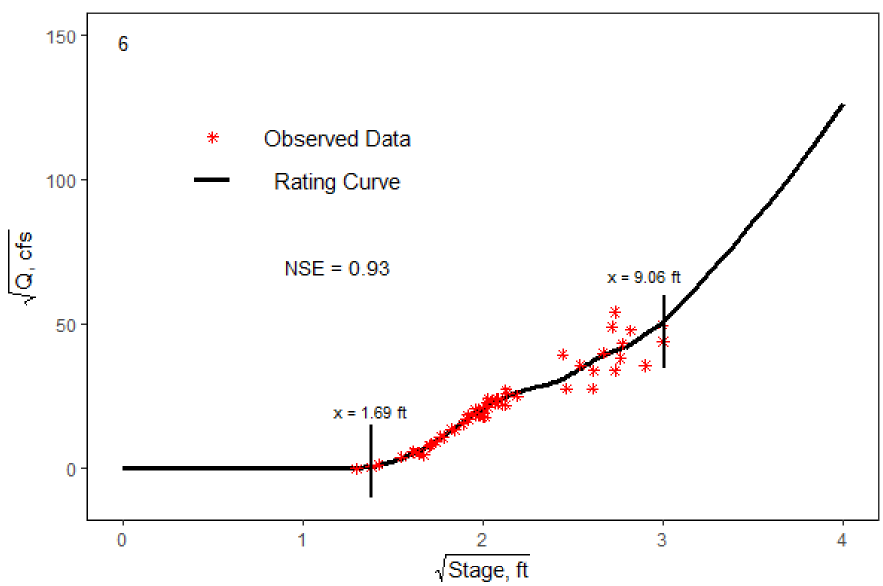


Figure 12: Rating curve for the Lower James Fork (Site 6). Two-point regression was used for stages below 1.69 ft, LOESS regression for stages between 1.69 and 9.06 ft, and Manning's equations for stages above 9.06 ft.

Table 12: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the Lower James Fork (Site 6).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	----------	----------	----------	----------	mg L^{-1}	----------	----------	----------	NTU	µS cm^{-1}
2017	0.99	0.258	0.26	0.115	113.02	0.082	3.827	32.725	117.50	140.03
2018	0.58	0.094	0.14	0.040	45.50	0.092	2.859	21.990	66.63	95.61
2019	0.71	0.178	0.22	0.125	57.90	0.117	3.394	25.595	60.09	112.49
Fall	0.81	0.202	0.27	0.187	44.46	0.118	4.044	28.068	52.67	124.09
Winter	0.92	0.246	0.25	0.098	61.64	0.068	4.092	29.255	100.03	122.94
Spring	0.52	0.070	0.10	0.031	26.64	0.085	2.721	23.323	40.22	97.46
Summer	0.78	0.191	0.20	0.069	141.55	0.116	2.793	27.345	123.18	121.50

(Table 12). Additionally, constituent concentrations were generally the least in spring months (i.e., March, April, and May), except for Fl which was the least in the winter (i.e., December, January, and February). The seasons with the greatest concentrations were more variable across constituents, with TN, NN, Cl and SO_4^{2-} being the greatest in the winter, TP, SRP, Fl and EC in the fall (i.e., September, October, and November), and TSS and turbidity in the summer (i.e., June, July and August).

Measured concentrations were multiplied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020 (except for the missing days of stage in January 2019). The R^2 and NSE values for each constituent's GAM were greater than 0.80, and all constituents but SRP were greater than 0.90 (Table 13). Daily constituent loads

Table 13: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the Lower James Fork (Site 6). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	64	79	93
TN	0.978	0.980	158 (107-239)	47,258	52,343	71,105
NN	0.881	0.889	28 (13-65)	7,396	9,616	13,162
TP	0.966	0.969	52 (30-93)	15,038	14,732	19,602
SRP	0.929	0.937	19 (7-53)	5,249	4,493	10,253
TSS	0.974	0.978	17,578 (8,047-40,371)	3,595,372	6,044,117	9,128,486
Fl	0.980	0.983	16 (12-25)	5,228	5,704	7,019
Cl	0.994	0.996	474 (366-617)	165,545	165,520	187,345
SO_4^{2-}	0.993	0.995	3,266 (2,377-4,513)	1,123,983	1,120,377	1,280,245

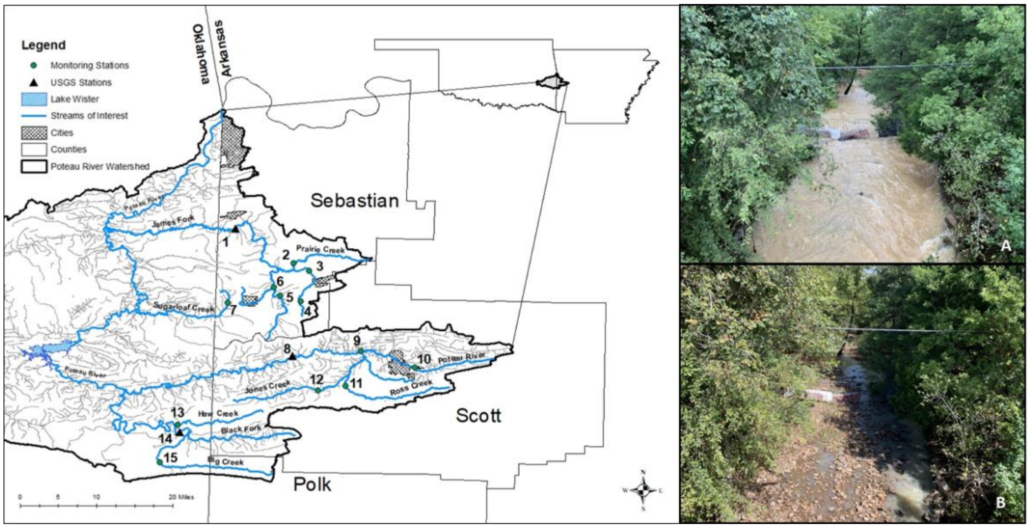


Figure 13: Upper Poteau River Watershed site map (left) and images of Upper Sugar Loaf Creek (Site 7) during storm flow (A) and baseflow conditions (B).

were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 13). Constituent loads in January 2019 may be underestimated due to 19 days of missing stage data. However, the USGS monitoring station in this watershed (James Fork- USGS 07249400) expressed mostly baseflow conditions during this time period, with two small storm event raising the stage by less than 5 ft each. Therefore, constituent loads during this time were likely small. Constituent loads were greatest in 2020 compared to 2018 and 2019. NN loads generally made up about 17% of TN loads, while SRP loads made up about 33% of TP loads. However, NN made up about 23% of TN concentrations and SRP made up about 44% of TP concentrations each year.

Upper Sugar Loaf Creek (Site 7)

The Upper Sugar Loaf Creek monitoring site (Figure 13) is near Hartford, Arkansas, and its watershed covers an area of 7 km^2 that is 88.6% forest, 1.6% urban and 1.3% agriculture. A pressure transducer was installed at site 7 on December 20, 2017, and stage measurements

Table 14: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at Upper Sugar Loaf Creek (Site 7).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	mg L^{-1}								NTU	µS cm^{-1}
2017	0.79	0.530	0.08	0.006	51.06	0.074	6.617	12.531	94.77	79.63
2018	0.30	0.082	0.06	0.004	13.98	0.097	4.115	12.904	59.48	63.78
2019	0.30	0.094	0.05	0.005	11.18	0.117	4.843	12.842	49.28	71.42
Fall	0.34	0.130	0.05	0.005	7.81	0.107	5.016	12.663	50.28	68.30
Winter	0.69	0.509	0.05	0.004	9.24	0.067	5.589	13.307	44.76	74.80
Spring	0.34	0.131	0.05	0.005	8.11	0.101	4.163	13.810	50.87	68.69
Summer	0.41	0.121	0.09	0.005	60.06	0.114	5.440	11.613	106.69	72.10

throughout the study (January 2018 – December 2020) ranged between 0.0 and 5.8 ft. Due to equipment malfunction, stage measurements were not collected for 18 days in January 2019 (i.e., January 8 – 18 2019). Baseflow discharge measurements were collected on 12 occasions throughout the project period, with baseflows ranging from 0 to 6.0 cfs. Due to time constraints, a SonTek-IQ was not deployed at this site.

A total of 66 water samples were collected from site 2, with 35 during baseflow conditions and 31 during storm flow between October 2017 and September 2020. Water samples were collected across 97.0% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 2.9% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 14). TN, NN, Cl, and EC were greatest in the winter months (i.e., December, January, and February), and generally the least in the fall months (i.e., September, October, and November. However, TP, SRP, TSS, Fl and turbidity were greatest in the summer months (i.e., June, July, and August), and generally the least in the winter months.

USGS 07247000- Poteau River (Site 8)

Constituent Loads

The USGS gaging station on the Poteau River (Figure 14) is near Cauthron, Arkansas, and its watershed covers an area of 527 km^2 that is 63.7% forest, 5.6% urban and 21.3% agriculture. Flow measurements for the project period of October, 2017 and September, 2020 ranged from 0.01 and 20,200 cfs. A total of 115 water samples were collected during the project period, with 75 during baseflow conditions and 40 during storm flow. Water samples were collected across 98.8% of all flow measurements, with 0.1% flow measurements falling above where water samples were collected, and 1.1% of flow measurements falling below.

Constituent concentrations of TP, SRP, TSS, Fl and turbidity were greatest in the 2018 project year (i.e., October, 2018 – September, 2019), while TN and NN were greatest in the 2019 project year, and Cl SO_4^{2-}, and EC were greatest in the 2017 project year (Table 15). Additionally, constituent concentrations were generally greatest in the winter months (i.e., December, January and February), and least in spring months (i.e., March, April, and May).

Measured concentrations were multi-plied by instantaneous flow (Q_i) to estimate

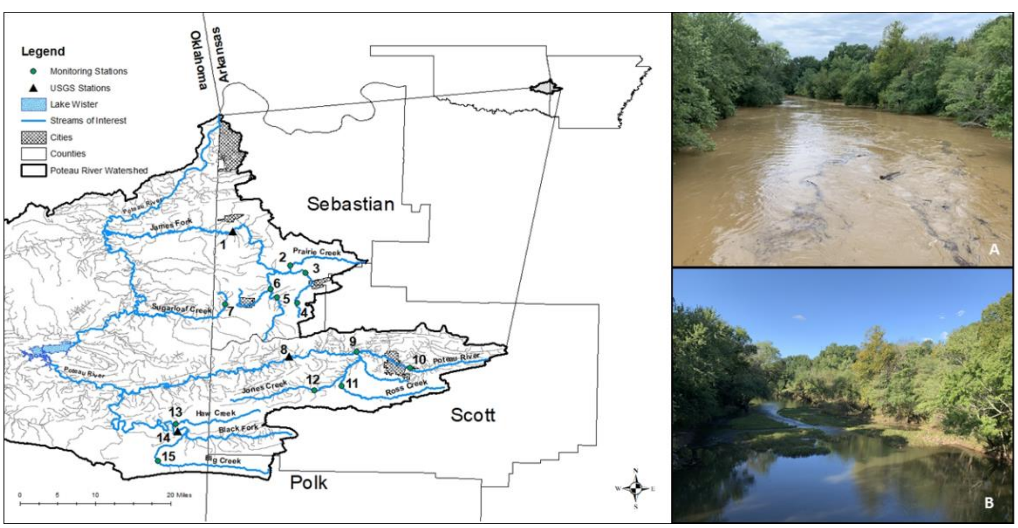


Figure 14: Upper Poteau River Watershed site map (left) and images of the Poteau River (Site 8) during storm flow (A) and baseflow conditions (B).

Table 15: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the Poteau River (USGS 07247000, Site 8).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	mg L^{-1}								NTU	µS cm^{-1}
2017	0.95	0.267	0.15	0.046	39.06	0.057	13.720	9.019	44.76	144.26
2018	0.88	0.243	0.17	0.054	43.87	0.076	5.596	7.265	53.93	71.98
2019	0.99	0.388	0.14	0.051	35.40	0.072	7.086	6.782	34.44	89.78
Fall	0.95	0.356	0.11	0.046	18.05	0.062	13.375	7.570	24.47	128.71
Winter	1.04	0.378	0.20	0.071	54.69	0.053	7.531	8.896	62.71	101.76
Spring	0.78	0.188	0.14	0.042	42.31	0.073	3.945	7.001	47.19	61.97
Summer	0.98	0.285	0.14	0.045	41.34	0.083	10.430	7.226	41.48	114.89

constituent loads (L_i). The R^2 and NSE values for each constituent's GAM were greater than 0.80, and all constituents but Fl were greater than 0.90 (Table 16). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 16). Constituent loads were greatest in the 2019 project year. NN loads generally made up about 26% of TN loads, while SRP loads made about 33% of TP loads. SRP concentrations also made up about 33% of TP concentrations each year, but NN made up about 32% of TN concentrations each year.

Trend Analysis

Trend analysis at the Poteau River was conducted using over 20 years of available flow and water quality data from the USGS. Sediments, P and TN generally increased with discharge, while NN was more variable at higher flows. LOESS was fit to each concentration and discharge relationship with sampling proportions of 0.4 – 0.7 (Table 17), and LOESS had relatively low RMSEs (< 0.35).

Table 16: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the Poteau River (USGS 07247000, Site 8). Additionally, the mean daily flow (Q_d) for each project year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2017	2018	2019
Q_d	--	--	--	205	505	651
TN	0.986	0.987	953 (783-1,164)	161,319	352,837	532,860
NN	0.946	0.951	254 (123-537)	39,623	98,198	140,243
TP	0.961	0.964	202 (148-279)	35,134	68,911	118,419
SRP	0.939	0.949	71 (34-149)	10,631	21,933	43,841
TSS	0.970	0.973	59,810 (41,276-87,241)	10,018,000	19,291,781	36,362,334
Fl	0.877	0.892	66 (38-114)	8,894	25,460	38,233
Cl	0.992	0.993	3,056 (2,342-4,004)	520,743	1,244,752	1,657,654
SO_4^{2-}	0.981	0.983	6,944 (5,247-9,217)	1,113,634	2,762,150	3,720,429

Table 17: Optimal LOESS Sampling Proportion, LOESS RMSE, Linear Model Slope, Linear Model p-Value, Seasonal Kendall's Test (SKT) Sen's Slope, and Seasonal Kendall's Test p-Value for Trends in Flow Adjusted Concentrations (FACS) for each Parameter the Poteau River (USGS 07247000, Site 8).

Parameter	LOESS Sampling Proportion	LOESS RMSE	Linear Model Slope (%/yr)	Linear Model p-Value	SKT Sen's Slope (%/yr)	SKT p-Value
TN	0.7	0.14	0.44	0.019	0.30	0.010
NN	0.7	0.36	1.23	0.015	0.62	0.045
TP	0.5	0.28	-1.53	<0.01	-1.37	<0.01
SRP	0.5	0.46	-2.55	<0.01	-2.71	<0.01
SS	0.6	0.3	-2.15	<0.01	-2.16	<0.01

Trends were identified in all flow-adjusted concentrations over time (i.e., 1995 – 2020), but the direction varied by constituent. The specific changes include:

- TN likely increased ($0.05 < p < 0.20$) at 0.44 % yr^{-1}, showing a change point in May 2007 (Figure 15, A); average TN FACs were 9% greater after 2007 compared to before 2007.
- NN extremely likely increased ($p < 0.05$, Figure 15, B) at a rate of 1.23 % yr^{-1}, but no change point in NN FACs occurred over time.
- TP extremely likely decreased ($p < 0.05$) at -1.53 % yr^{-1}, with a change point in August 2002, resulting in a 22% decrease in mean FACs (Figure 15, C).
- SRP extremely likely decreased ($p < 0.05$) with the greatest magnitude of change compared to other constituents (-2.55 % yr^{-1}), and one change point in SRP FACs occurred in October 2003 (Figure 15, D) where mean FACs were 32% less after 2003.
- SS extremely likely decreased ($p < 0.05$) at -2.15 % yr^{-1}, and one change point occurred in October 2002 (Figure 15, E) resulting in a 32% decrease in mean FACs.

Lower Poteau River (Site 9)

The Lower Poteau River monitoring site (Figure 16) lies just downstream of Waldron, Arkansas, and its watershed covers an area of 193 km^2 that is 51.6% forest, 7.7% urban and 32.0% agriculture. A pressure transducer was installed at site 9 on December 19, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 1.3 and 22.9 ft. Baseflow discharge measurements were collected on 14 occasions throughout the project period, with baseflows ranging from 1.5 to 108.9 cfs. A SonTek-IQ was deployed between October 2019 and June 2020, and flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 200 and 7,500 cfs. Between SonTek-IQ and manual discharge measurements, 99.9% of all stage measurements were captured by flow measurements, (i.e., less than 1% of all stage measurements fell outside the range of measured flow).

A total of 132 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. For the final rating curve (Figure 17), a two-point regression with a slope of 0.31 ft^2/s for stage values less than 1.70 foot. LOESS regression was used between 1.70 and 21.72 ft, where measured flow data exists, and Manning's equation was used to predict flows above 21.72 ft, with a Manning's n of 0.07. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020.

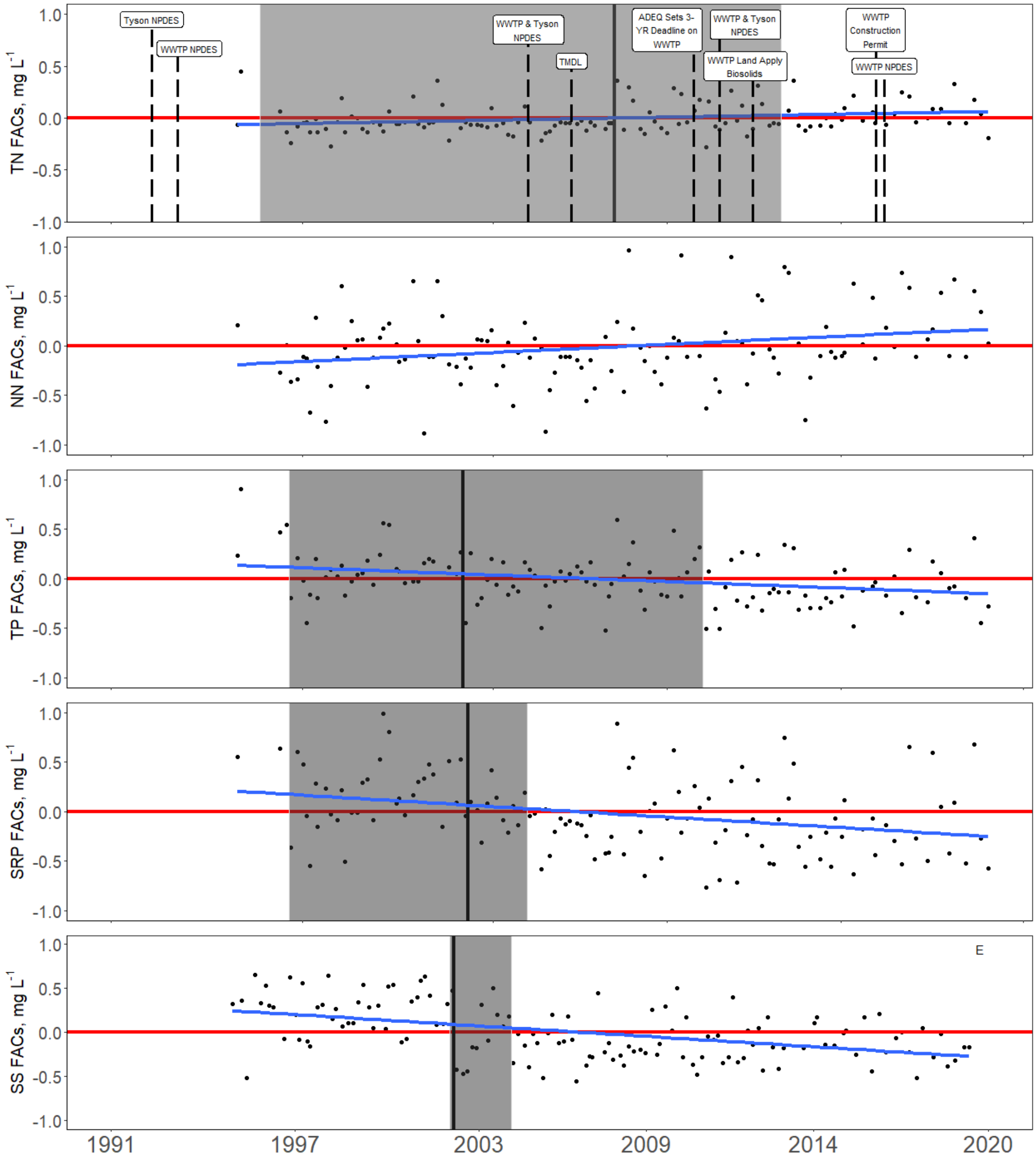


Figure 15: Trends in Flow Adjusted Concentrations (FACs) of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediments (SS), Nitrate+Nitrite (NN), and Soluble Reactive Phosphorus (SRP) at the Poteau River. The FACs were truncated from -1 to 1 for consistency. This may cause a few data points to be missing from the figure, but all data were included in trend analysis. Significant change points are identified by solid vertical lines, the grey areas are the 95% confidence intervals around the change points, and significant linear model slopes are identified by solid blue lines. A timeline of events related to Nonpoint Source Discharge Elimination System (NPDES) permits and other significant milestones for the point sources on the Poteau River is shown in Figure A.

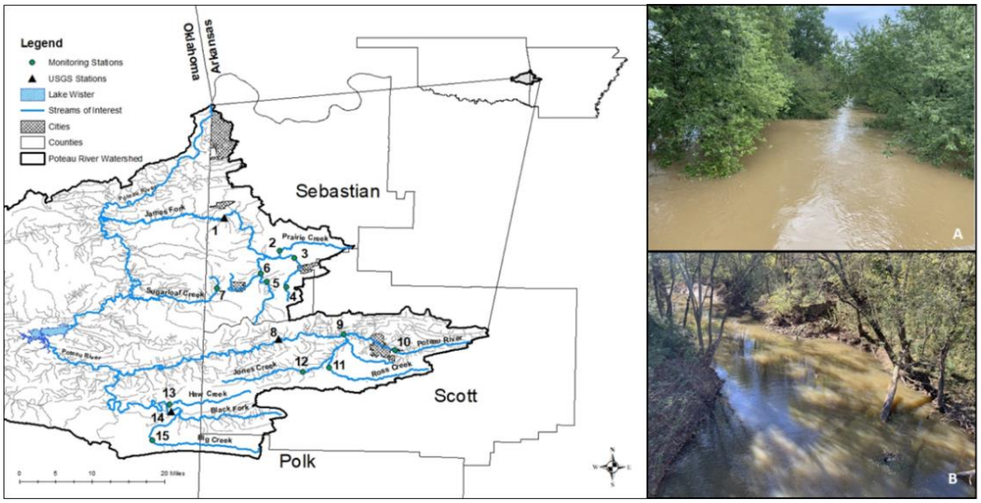


Figure 16: Upper Poteau River Watershed site map (left) and images of the Lower Poteau River (Site 9) during storm flow (A) and baseflow conditions (B).

A total of 72 water samples were collected from site 9, with 39 during baseflow conditions and 33 during storm flow between October 2017 and September 2020. Water samples were collected across 99.7% of all stage measurements, with less than 1% of stage measurements falling above and below where water samples were collected. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 18), except for TN, NN and Fl, which were greatest in the 2019 project year. Additionally, constituent concentrations were generally greatest in the summer months (i.e., June, July, and August), and least in spring months (i.e., March, April, and May). However, Cl, EC and SO_4^{2-} concentrations were greatest in the fall months (i.e., September, October, and November) and least in spring months.

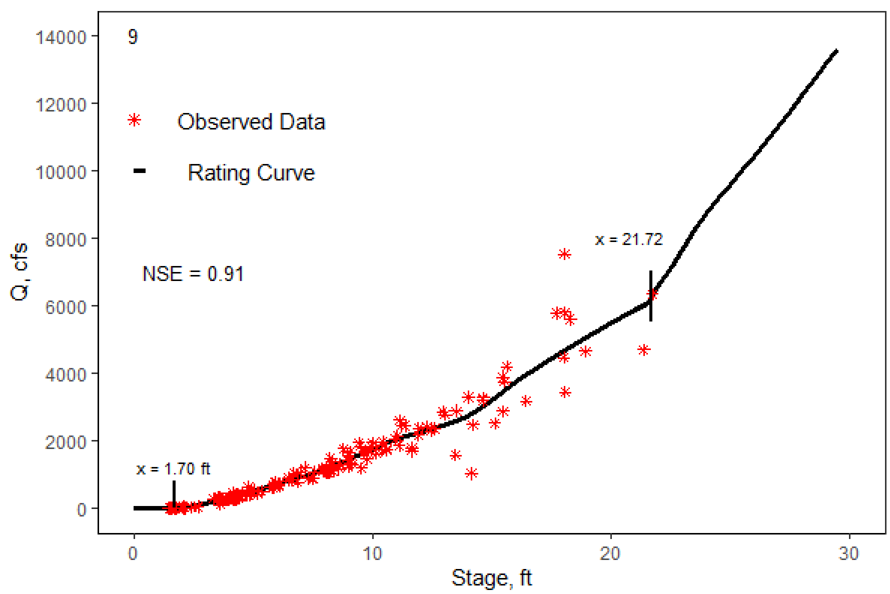


Figure 17: Rating curve for the Lower Poteau River (Site 9). Two-point regression was used for stages below 1.7 ft, LOESS regression for stages between 1.7 and 21.72 ft, and Manning's equations for stages above 21.72 ft.

Table 18: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the Lower Poteau River (Site 9).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	------	------	------	------	mg L^{-1}	------	------	------	NTU	µS cm^{-1}
2017	2.50	1.533	0.39	0.230	71.93	0.070	35.879	17.829	75.61	300.21
2018	1.39	0.484	0.25	0.128	44.32	0.074	7.329	8.591	58.31	86.77
2019	3.14	2.356	0.33	0.210	48.56	0.079	12.535	9.986	46.03	168.45
Fall	2.57	1.580	0.31	0.207	28.33	0.069	26.532	15.453	34.01	270.68
Winter	1.97	1.123	0.27	0.141	44.94	0.062	15.543	12.778	58.48	154.61
Spring	1.04	0.256	0.22	0.102	42.14	0.072	5.724	8.066	53.20	79.96
Summer	3.38	2.489	0.42	0.264	87.58	0.091	18.640	10.290	78.33	185.37

Measured concentrations were multiplied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020. The R^2 and NSE values for each constituent's GAM were greater than 0.80, and all constituents but NN were greater than 0.90 (Table 19). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 19). Constituent loads were greater in 2020 compared to 2018 and 2019. NN loads generally made up about 28% of TN loads, while SRP loads made up closer to 43% of TP loads. However, NN and SRP made up about 57% of TN and TP concentrations each year.

Poteau River Headwaters (Site 10)

The Poteau River Headwaters monitoring site (Figure 18) lies just upstream of Waldron,

Table 19: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the Lower Poteau River (Site 9). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	162	206	310
TN	0.963	0.967	640 (462-889)	177,880	206,216	317,869
NN	0.891	0.907	180 (105-309)	52,066	58,410	86,904
TP	0.975	0.981	146 (91-236)	40,059	40,520	80,444
SRP	0.947	0.954	64 (37-111)	16,782	18,575	35,179
TSS	0.980	0.989	29,710 (12,180-74,315)	7,723,583	7,559,837	17,279,592
Fl	0.967	0.969	37 (27-51)	9,832	12,459	18,957
Cl	0.954	0.966	2,409 (1,560-3,743)	669,780	877,048	1,093,483
SO_4^{2-}	0.983	0.985	4,057 (3,173-5,199)	1,118,073	1,411,727	1,917,708

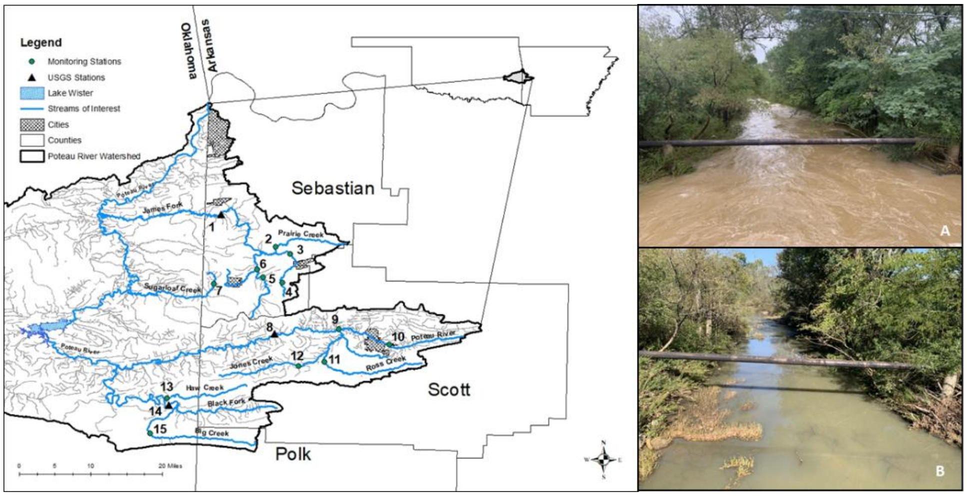


Figure 18: Upper Poteau River Watershed site map (left) and images of the Poteau River Headwaters (Site 10) during storm flow (A) and baseflow conditions (B).

Arkansas, and its watershed covers an area of 39 km^2 that is 52.7% forest, 5.5% urban and 33.1% agriculture. A pressure transducer was installed at site 10 on December 20, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 0.3 and 12.1 ft. Due to equipment malfunction, stage measurements were not collected for 18 days in January 2019 (i.e., January 8 – 25 2019). Baseflow discharge measurements were collected on 16 occasions throughout the project period, with baseflows ranging from 0.0 to 26.2 cfs. A SonTek-IQ was deployed between December 2018, and March 2019, and again from October, 2019, to January, 2020. Flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 60 and 4,000 cfs. Between SonTek-IQ and manual discharge measurements, 99.5% of all stage measurements were captured by flow measurements,

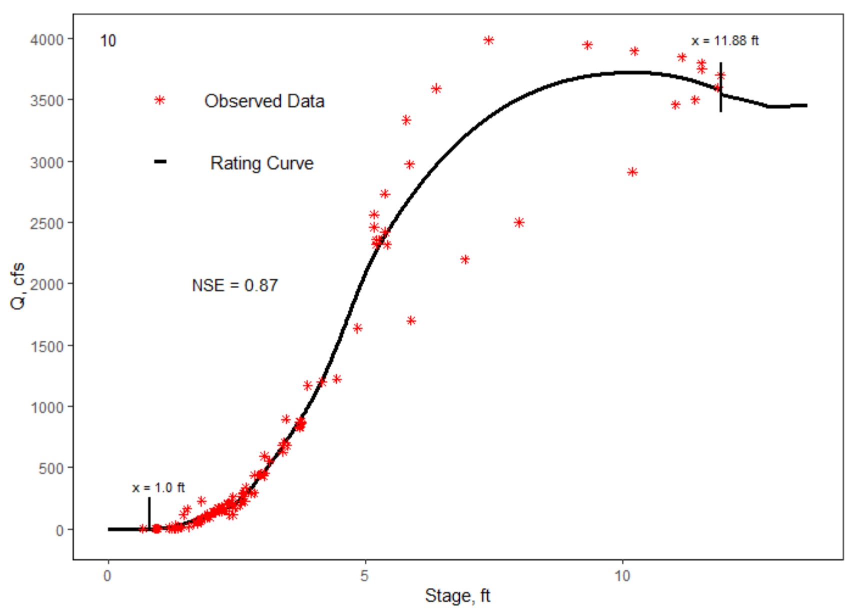


Figure 19: Rating curve for the Poteau River Headwaters (Site 10). Two-point regression was used for stages below 1 ft, LOESS regression for stages between 1 and 11.88 ft, and Manning's equations for stages above 11.88 ft.

Table 20: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the Poteau River Headwaters (Site 10).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	----------	----------	----------	----------	mg L^{-1}	----------	----------	----------	NTU	µS cm^{-1}
2017	0.96	0.134	0.24	0.143	25.62	0.104	6.651	9.802	40.12	119.49
2018	0.75	0.110	0.16	0.080	23.71	0.089	3.595	8.340	41.92	68.49
2019	0.79	0.170	0.15	0.082	20.07	0.105	4.046	8.447	29.56	81.45
Fall	0.85	0.203	0.18	0.111	11.85	0.083	5.314	9.124	29.39	98.32
Winter	0.81	0.208	0.17	0.084	21.49	0.078	5.795	10.317	40.00	89.65
Spring	0.61	0.058	0.12	0.051	19.20	0.083	3.116	7.767	32.20	61.77
Summer	0.97	0.113	0.24	0.133	36.31	0.136	4.313	8.244	44.08	95.81

(i.e., less than 1% of all stage measurements fell outside the range of measured flow).

A total of 96 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. The largest storm event captured by the SonTek-IQ occurred in January 2020, reaching a stage of 11.9 ft. Prior to this event, the maximum stage captured by the SonTek-IQ was 5 ft. Therefore, more data points were included from this event in January 2020, compared to other events in order to fill in the upper end of the rating curve. For the final rating curve (Figure 19), a two-point regression with a slope of 0.08 ft^2/s was used for stage values less than 1.0 ft. LOESS regression was used between 1 and 11.9 ft, where measured flow data exists, and Manning's equation was used to predict flows above 11.9 ft, with a Manning's n of 0.002. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020 (except for the missing days of stage in January 2019).

A total of 71 water samples were collected from site 10, with 39 during baseflow conditions and 32 during storm flow between October 2017 and September 2020. Water samples were collected across 96.8% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 3.1% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 20). Additionally, constituent concentrations were generally greatest in the summer months (i.e., June, July, and August), and least in spring months (i.e., March, April, and May). However, NN, Cl and $SO_4^{2`}$ concentrations were greatest in the winter months (i.e., December, January, and February) and least in spring months.

Measured concentrations were multi-plied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020 (except for the missing days of stage in January 2019). The R^2 and NSE values for each constituent's GAM were greater than 0.90 (Table 21). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 21). Constituent loads in January 2019 may be

Table 21: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the Poteau River Headwaters (Site 10). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	42.2	44.2	56.8
TN	0.987	0.988	91 (67-127)	29,266	26,558	43,007
NN	0.924	0.934	15 (6-39)	5,753	3,934	6,011
TP	0.980	0.983	23 (14-37)	6,645	6,069	12,001
SRP	0.963	0.966	11 (5-23)	3,323	2,715	5,788
TSS	0.970	0.975	4,778 (2,558-9,151)	995,412	1,267,920	2,892,855
Fl	0.978	0.982	8 (6-11)	2,494	2,715	3,848
Cl	0.990	0.992	357 (276-464)	129,773	114,779	141,559
SO_4^{2-}	0.989	0.992	834 (684-1,021)	285,499	271,569	343,677

underestimated due to 18 days of missing stage data. However, the USGS monitoring station in this watershed (Black Fork- USGS 07294000) expressed mostly baseflow conditions during this time period, with one small storm event raising the stage by about 2 ft. Therefore, constituent loads during this time were likely small. Constituent loads were greatest in 2020 compared to 2018 and 2019. NN loads generally made up about 15% of TN loads, while SRP loads made up closer to 50% of TP loads, and similar trends occurred for mean concentrations each year.

Ross Creek (Site 11)

The Ross Creek monitoring site (Figure 20) lies just south of Waldron, Arkansas, and its watershed covers an area of 77 km^2 that is 71.8% forest, 4.6% urban and 13.9% agriculture. A pressure transducer was installed at site 11 on December 20, 2017, and stage measurements throughout the study (January 2018 – December

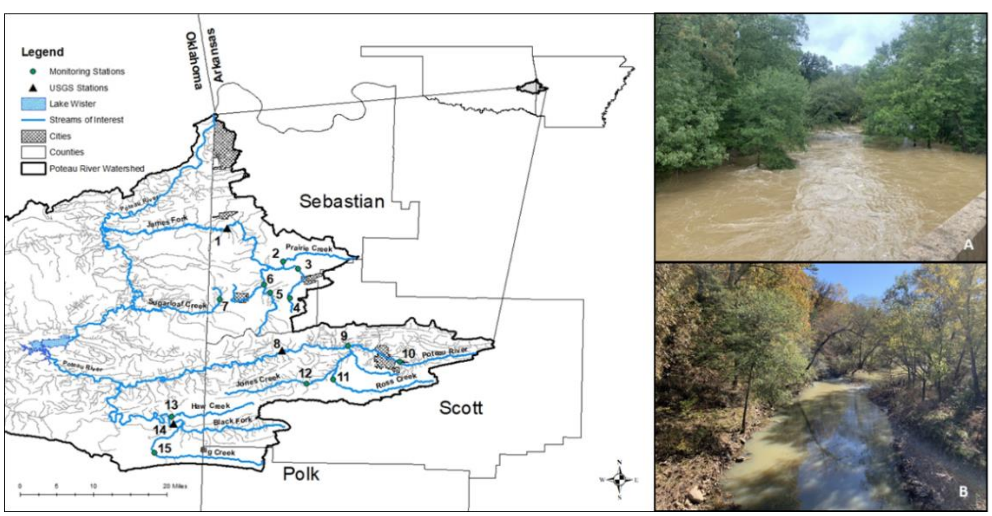


Figure 20: Upper Poteau River Watershed site map (left) and images of Ross Creek (Site 11) during storm flow (A) and baseflow conditions (B).

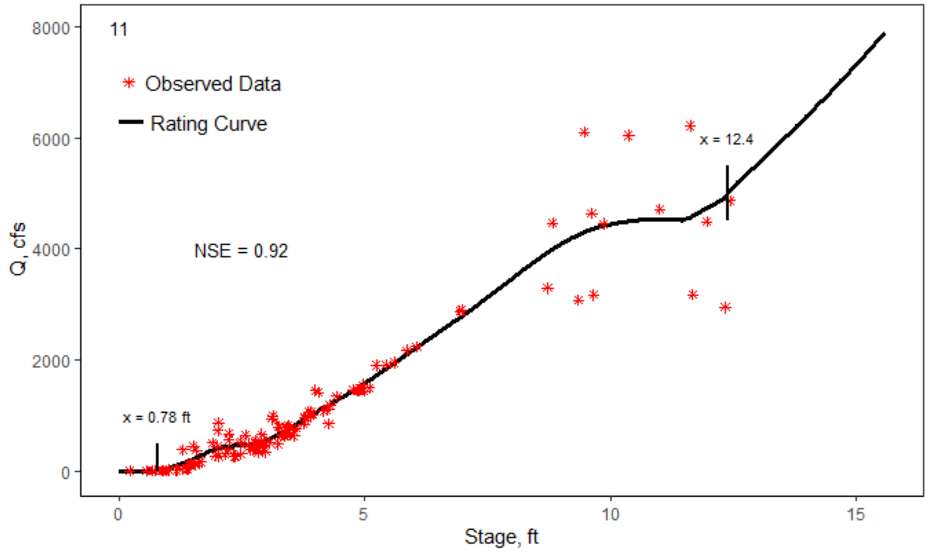


Figure 21: Rating curve for Ross Creek (Site 11). Two-point regression was used for stages below 0.78 ft, LOESS regression for stages between 0.78 and 12.4 ft, and Manning's equations for stages above 12.4 ft.

2020) ranged between 0.1 and 14.9 ft. Due to equipment malfunction, stage measurements were not collected for 13 days in 2020 (i.e., May 23 – June 4, 2020). Baseflow discharge measurements were collected on 18 occasions throughout the project period, with baseflows ranging from 0.0 to 39.9 cfs. A SonTek-IQ was deployed between March and December 2020, and flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 100 and 6,400 cfs. Between SonTek-IQ and manual discharge measurements, 96.5% of all stage measurements were captured by flow measurements, (i.e., less than 4% of all stage measurements fell outside the range of measured flow).

A total of 108 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. For the final rating curve (Figure 21), a two-point regression with a slope of 2.37 ft^2/s was used for stage values less than 0.78 ft. LOESS regression was used between 0.78 and 12.4 ft, where measured flow data exists, and

Table 22: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at Ross Creek (Site 11).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	mg L^{-1}								NTU	µS cm^{-1}
2017	0.52	0.118	0.05	0.016	9.77	0.061	4.101	6.061	15.62	72.15
2018	0.62	0.154	0.12	0.032	38.54	0.074	2.579	7.015	55.82	47.37
2019	0.62	0.168	0.10	0.027	37.26	0.079	2.602	8.478	40.82	55.64
Fall	0.57	0.178	0.07	0.024	13.29	0.069	3.647	9.519	19.43	72.09
Winter	0.61	0.194	0.12	0.031	41.64	0.054	3.694	8.428	57.61	56.55
Spring	0.53	0.110	0.10	0.025	28.14	0.066	2.178	6.293	42.33	42.02
Summer	0.66	0.133	0.11	0.025	38.97	0.097	2.668	5.635	40.46	59.63

Manning's equation was used to predict flows above 12.4 ft, with a Manning's n of 0.022. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020 (except for the missing days of stage in May and June 2020).

A total of 64 water samples were collected from site 11, with 36 during baseflow conditions and 28 during storm flow between October 2017 and September 2020. Water samples were collected across 96.2% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 3.7% of stage measurements falling below. Cl and EC concentrations were greatest in the 2017 project year (i.e., October 2017 – September 2018), while TN, TP, SRP, TSS, and turbidity were greatest in the 2018 project year, and NN, Fl and $SO_4^{2`}$ were greatest in the 2019 project year (Table 22). Additionally, constituent concentrations were generally greatest in the winter months (i.e., December, January, and February), except $SO_4^{2`}$ and EC were greatest in the fall (i.e., September, October, and November), and TN and Fl were greatest in the summer (i.e., June, July, and August).

Measured concentrations were multiplied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020 (except for the missing days of stage in May and June 2020. The R^2 and NSE values for each constituent's GAM were greater than 0.90 (Table 23). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 23). Constituent loads in May and June 2020 may be underestimated due to 13 days of missing stage data. The USGS monitoring station in this watershed (Poteau River- USGS 07247000) expressed two storm events in the May portion of this timespan, where stage raised about 10 ft each. Therefore, constituent loads during this time may be underestimated. Constituent loads were greatest in 2020, except for NN and Fl which was greatest in 2019. NN and SRP loads generally made up about 26% of TN and TP loads, respectively, and similar trends occurred for mean concentrations each year.

Upper Jones Creek (Site 12)

Table 23: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at Ross Creek (Site 11). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	105	168	203
TN	0.990	0.991	223 (182-275)	55,161	85,545	102,088
NN	0.962	0.967	59 (37-96)	15,496	24,759	24,014
TP	0.977	0.979	38 (26-54)	8,789	13,489	18,679
SRP	0.971	0.975	10 (6-16)	2,331	3,565	4,648
TSS	0.987	0.992	10,967 (5,846-20,933)	3,145,849	3,299,191	5,454,193
Fl	0.960	0.977	28 (12-68)	7,495	11,704	11,209
Cl	0.989	0.990	931 (788-1,102)	235,382	377,461	398,109
SO_4^{2-}	0.982	0.983	2,629 (2,110-3,284)	664,550	1,060,151	1,128,423

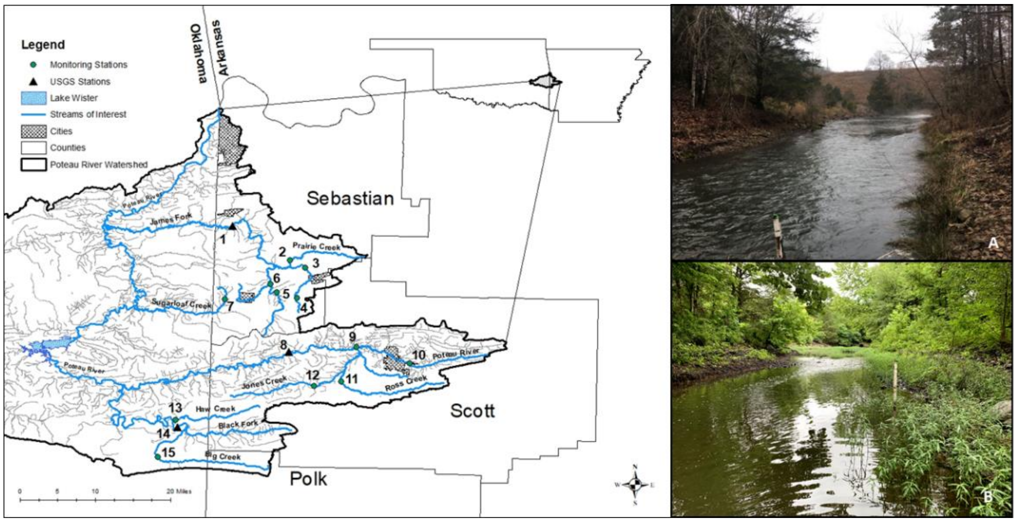


Figure 22: Upper Poteau River Watershed site map (left) and images of Upper Jones Creek (Site 12) during storm flow (A) and baseflow conditions (B).

The Upper Jones Creek monitoring site (Figure 22) is south of Waldron, Arkansas, just downstream of the Lake Hinkle Dam, and its watershed covers an area of 73 km^2 that is 84.8% forest, 2.7% urban and 2.2% agriculture. A pressure transducer was installed at site 12 on December 20, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 0.0 and 4.69 ft. Baseflow discharge measurements were collected on 13 occasions throughout the project period, with baseflows ranging from 0.0 to 40.9 cfs. A SonTek-IQ was deployed between January and November 2018, and flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 20 and 575 cfs. Between SonTek-IQ and manual discharge measurements, 96.0% of all stage measurements were captured by flow

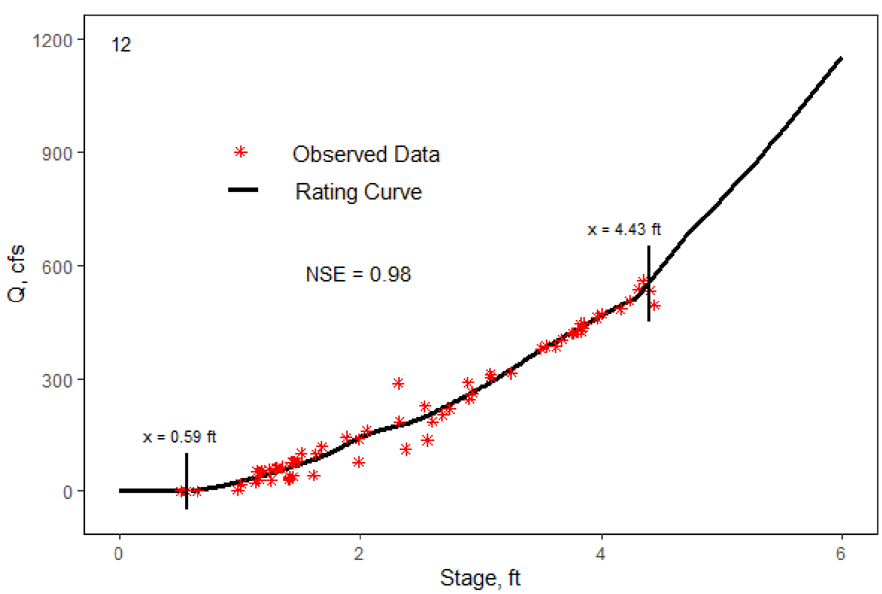


Figure 23: Rating curve for Upper Jones Creek (Site 12). Two-point regression was used for stages below 0.59 ft, LOESS regression for stages between 0.59 and 4.43 ft, and Manning's equations for stages above 4.43 ft.

Table 24: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at Upper Jones Creek (Site 12).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	------------------				mg L^{-1}			------------------	NTU	µS cm^{-1}
2017	0.59	0.104	0.03	0.003	6.50	0.039	2.049	3.235	6.09	45.53
2018	0.51	0.072	0.02	0.002	4.31	0.066	1.926	4.113	5.82	40.63
2019	0.51	0.089	0.02	0.003	3.82	0.063	1.625	3.425	5.23	34.11
Fall	0.54	0.057	0.02	0.004	3.93	0.053	1.871	3.153	5.00	43.28
Winter	0.59	0.169	0.02	0.002	5.20	0.052	2.048	3.478	6.83	41.16
Spring	0.44	0.090	0.02	0.002	4.00	0.051	1.878	3.911	5.38	37.32
Summer	0.58	0.043	0.03	0.004	6.10	0.069	1.677	3.763	5.68	38.75

measurements, (i.e., only 4% of all stage measurements fell outside the range of measured flow).

A total of 56 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. For the final rating curve (Figure 23), a two-point regression with a slope of 0.12 ft^2/s was used for stage values less than 0.59 ft. LOESS regression was used between 0.59 and 4.43 ft, where measured flow data exists, and Manning's equation was used to predict flows above 4.43 ft, with a Manning's n of 0.036. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020.

A total of 92 water samples were collected from site 12, with 67 during baseflow conditions and 25 during storm flow between October 2017 and September 2020. Water samples were

Table 25: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at Upper Jones Creek (Site 12). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	46	74	78
TN	0.998	0.999	77 (68-88)	20,444	31,927	31,141
NN	0.970	0.976	15 (8-27)	5,611	5,219	5,306
TP	0.982	0.983	3 (2-4)	737	1,280	1,427
SRP	0.967	0.970	0.3 (0-1)	73	113	135
TSS	0.979	0.982	686 (477-992)	159,774	287,066	295,520
Fl	0.916	0.918	8 (6-12)	2,007	3,252	3,515
Cl	0.998	0.998	288 (259-321)	73,814	116,750	121,647
SO_4^{2-}	0.992	0.992	553 (496-616)	131,639	227,877	238,496

collected across 97.1% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 2.9% of stage measurements falling below. Constituent concentrations were generally greater in the 2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 20). TN, NN, Cl and turbidity were greatest in the winter months (i.e., December, January, and February), TP, SRP, TSS, and Fl were greatest in the summer months (i.e., June, July, and August), SO_4^{2-} was greatest in the spring months (i.e., March, April, and May), and EC was greatest in the fall months (i.e., September, August, November).

Measured concentrations were multiplied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020. The R^2 and NSE values for each constituent's GAM were greater than 0.90 (Table 23). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 25). Constituent loads were greatest in 2020, except for TN was greatest in 2019 and NN was greatest in 2018. NN loads generally made up about 22% of TN loads, while SRP loads made up about 10% of TP loads. However, NN concentrations made up about 16% of TN concentrations each year, and SRP concentrations made up about 11% of TP concentrations.

Haw Creek (Site 13)

The Haw Creek monitoring site (Figure 24) is south of Waldron, Arkansas, and its watershed covers an area of 62 km² that is 90.3% forest, 1.8% urban and 1.1% agriculture. A pressure transducer was installed at site 13 on December 20, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 0.99 and 12.4 ft. This site was too deep for manual discharge measurements and SonTek-IQ installation, therefore no flow measurements were collected at this site.

A total of 60 water samples were collected from site 13, with 35 during baseflow conditions and 25 during storm flow between October 2017 and September 2020. Water samples were collected across 95.8% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 4.1% of stage measurements falling below. Constituent concentrations were generally greater in the

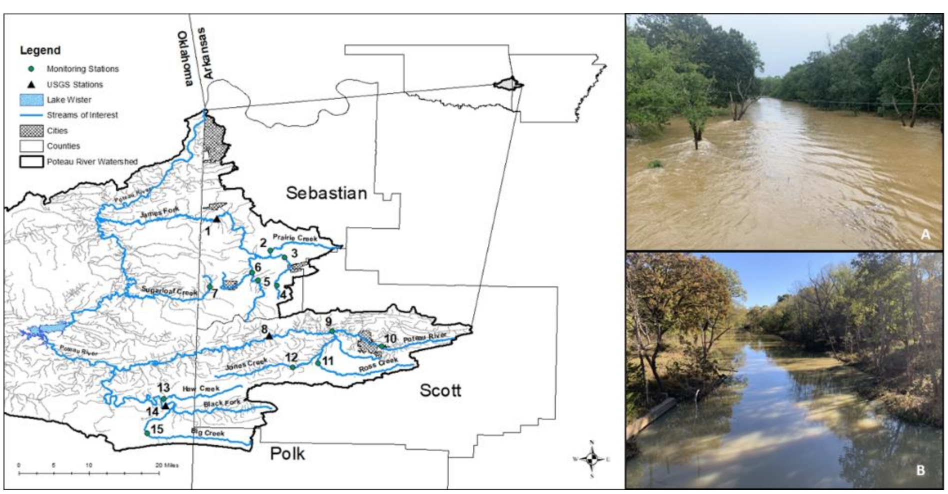


Figure 24: Upper Poteau River Watershed site map (left) and images of Haw Creek (Site 13) during storm flow (A) and baseflow conditions (B).

Table 26: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at Haw Creek (Site 13).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	mg L^{-1}								NTU	µS cm^{-1}
2017	0.44	0.070	0.04	0.002	14.30	0.041	2.540	3.182	24.54	45.78
2018	0.30	0.040	0.04	0.003	12.62	0.063	1.947	4.858	32.01	30.64
2019	0.26	0.061	0.03	0.003	7.60	0.084	2.080	4.497	21.02	32.66
Fall	0.34	0.066	0.04	0.003	9.35	0.070	2.484	4.347	22.63	38.62
Winter	0.32	0.057	0.05	0.003	21.10	0.047	2.198	4.135	40.04	30.39
Spring	0.28	0.066	0.03	0.003	7.89	0.053	1.763	4.438	24.85	29.29
Summer	0.37	0.034	0.04	0.002	6.71	0.090	2.220	4.053	15.67	47.03

2017 project year (i.e., October 2017 – September 2018) compared to 2018 and 2019 (Table 26). Cl was greatest in the fall months (i.e., September, October, and November), TP, SRP, TSS, and turbidity were greatest in the winter months (i.e., December, January, and February), NN and SO_4^{2-} were greatest in the spring months (i.e., March, April, and May), and TN, Cl, and EC were greatest in the summer months (i.e., June, July, and August).

USGS 07294000- Black Fork (Site 14)

Constituent Loads

The USGS gaging station on the Black Fork (Figure 25) is near Page, Oklahoma, and its watershed covers an area of 245 km^2 that is 88.3% forest, 3.5% urban and 9.8% agriculture. Flow measurements for the project period of October, 2017 and September, 2020 ranged from 0.02 and 23,100 cfs. A total of 107 water samples were collected during the project period, with 75 during baseflow conditions and 32 during storm flow. Water samples were collected across 98.8% of all flow measurements, with no flow measurements falling above where water samples were collected, and 1.2% of flow measurements falling below.

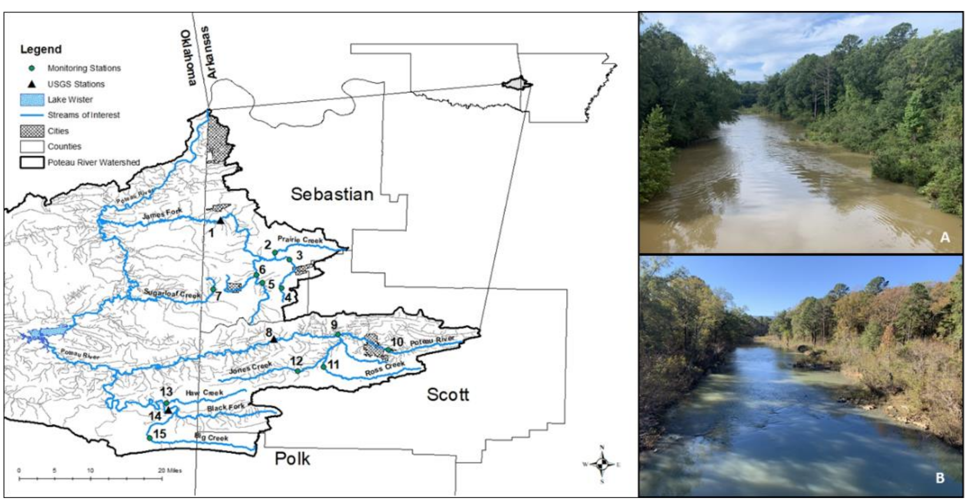


Figure 25: Upper Poteau River Watershed site map (left) and images of the Black Fork (Site 14) during storm flow (A) and baseflow conditions (B).

Table 27: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at the Black Fork (USGS 07294000, Site 14).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	---------- mg L^{-1} ----------								NTU	µS cm^{-1}
2017	0.34	0.081	0.04	0.007	12.83	0.031	2.272	3.161	20.55	32.24
2018	0.38	0.100	0.06	0.014	29.35	0.064	2.119	5.964	37.26	38.63
2019	0.31	0.124	0.03	0.005	11.73	0.069	1.659	3.523	18.45	25.36
Fall	0.33	0.095	0.04	0.005	9.82	0.052	2.197	3.730	15.74	32.08
Winter	0.37	0.146	0.04	0.006	21.14	0.040	2.060	3.583	33.58	26.45
Spring	0.38	0.106	0.06	0.014	32.17	0.070	2.012	5.941	39.07	36.71
Summer	0.30	0.055	0.04	0.008	6.17	0.059	1.773	3.517	11.54	33.11

Constituent concentrations were generally greater in the 2018 project year (i.e., October, 2018 – September, 2019) compared to 2017 and 2019 (Table 27), except for NN and Fl which were greatest in 2019 and Cl which was greatest in 2017. Additionally, constituent concentrations were generally greatest in the spring months (i.e., March, April, and May), and least in summer months (i.e., June, July, and August).

Measured concentrations were multi-plied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The R^2 and NSE values for each constituent's GAM were greater than 0.80 (Table 28). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 27). Constituent loads were greatest in the 2019 project year. NN loads generally made up about 28% of TN loads, while SRP loads made about 13% of TP loads, and similar trends occurred for mean concentrations each year.

Table 28: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at the Black Fork (USGS 07294000, Site 14). Additionally, the mean daily flow (Q_d) for each project year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2017	2018	2019
Q_d	--	--	--	118	256	338
TN	0.986	0.987	128 (101-163)	21,819	47,759	70,762
NN	0.946	0.951	35 (20-64)	6,303	14,104	18,658
TP	0.961	0.964	18 (12-19)	2,629	6,121	11,901
SRP	0.939	0.949	2 (1-5)	304	973	1,464
TSS	0.970	0.973	10,855 (6,166-19,824)	1,446,673	3,502,257	6,938,003
Fl	0.877	0.892	15 (6-40)	1,678	6,320	8,799
Cl	0.992	0.993	482 (412-565)	86,260	198,208	243,376
SO_4^{2-}	0.981	0.983	1,208 (880-1,668)	186,614	499,292	616,174

Table 29: Optimal LOESS Sampling Proportion, LOESS RMSE, Linear Model Slope, Linear Model p-Value, Seasonal Kendall's Test (SKT) Sen's Slope, and Seasonal Kendall's Test p-Value for Trends in Flow Adjusted Concentrations (FACS) for each Parameter the Black Fork (USGS 07294000, Site 14).

Parameter	LOESS Sampling Proportion	LOESS RMSE	Linear Model Slope (%/yr)	Linear Model p-Value	SKT Sen's Slope (%/yr)	SKT p-Value
TN	0.4	0.16	-0.60	<0.01	-0.66	<0.01
NN	0.4	0.26	-0.01	0.97	-0.01	0.94
TP	0.6	0.25	-1.04	<0.01	-1.07	<0.01
SRP	0.4	0.22	-0.90	<0.01	-0.40	<0.01
SS	0.4	0.32	-0.19	0.52	-0.25	0.28

Trend Analysis

Trend analysis was conducted using the 27 years of available flow and water quality data from the USGS. All constituents at the Black Fork generally increased in concentration with increasing discharge. LOESS was fit to each concentration and discharge relationship with sampling proportions of 0.4 – 0.7 (Table 29). All LOESS fits for the constituents had low RMSEs (< 0.35).

The flow-adjusted concentrations were either extremely likely decreasing or likely not changing over time (i.e., 1991 – 2018). The specific changes include:

- TN decreased ($p < 0.05$) at -0.60 % yr^{-1}, showing a change point in March 2002 (Figure 26, A); FACs to the right or left of the change were likely not changing over time ($p > 0.20$).
- NN was likely not changing over time ($p = 0.97$, Figure 26, B), and no change point in NN FACs occurred over time.
- TP decreased ($p < 0.05$) with the greatest magnitude of change compared to other constituents (-1.04 % yr^{-1}); two change points occurred in TP FACs, one in November 1998 and one in January 2003 (Figure 26, C).
- No monotonic changes occurred after the change point in 2003, but there was an extremely likely increase in TP FACs between 1991 and 2003 ($p = 0.03$); average TP FACs between 1998 and 2003 were 23% greater than between 1991 and 2003 and 19% greater than after 2003.
- SRP decreased ($p < 0.05$) by a magnitude of -0.90 % yr^{-1}, but nearly 40% of the data are censored; one change point in SRP FACs occurred in May 2000 (Figure 26, D), but no monotonic changes occurred before or after ($p > 0.20$).
- SS was likely not changing between 1991 and 2018 ($p = 0.52$), and no significant change point occurred in the FACs (Figure 26, E).

Big Creek (Site 15)

The Big Creek monitoring site (Figure 27) is near Page, Oklahoma, and its watershed covers an area of 60 km^2 that is 92.3% forest, 6.2% urban and 0.0% agriculture. A pressure transducer was installed at site 15 on December 20, 2017, and stage measurements throughout the study (January 2018 – December 2020) ranged between 0.0 and 9.40 ft. Baseflow discharge measurements were collected on 17 occasions throughout the project period, with baseflows ranging from 0.0 to 77.5 cfs. A SonTek-IQ was deployed between October 2019 and January 2020, and again between March and May 2020. Flows captured by the SonTek-IQ, above 1.5 ft stage, ranged between 15 and 2,700 cfs. Between SonTek-IQ and manual discharge measurements, 89.0% of all stage measurements were captured by flow

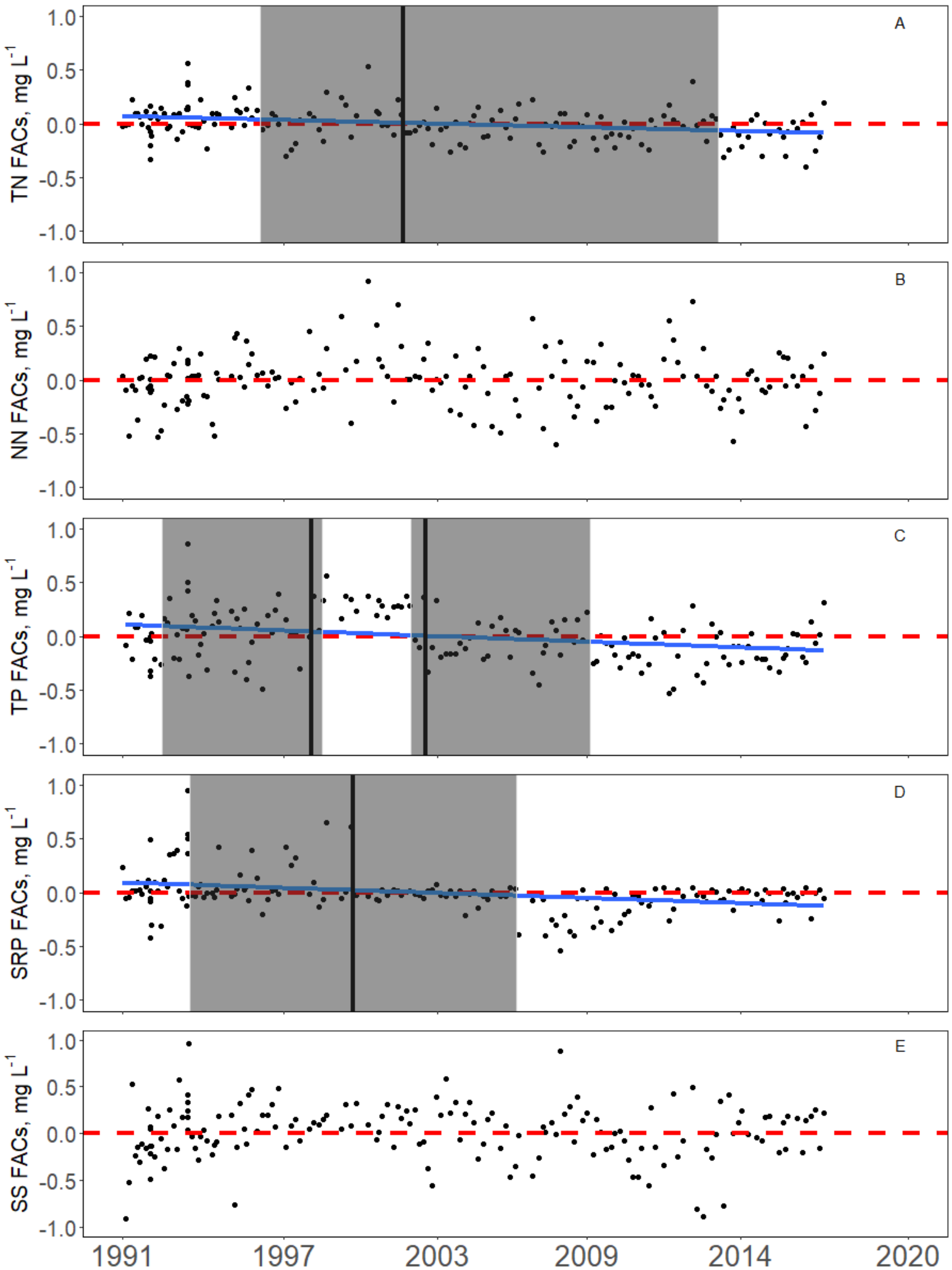


Figure 26: Trends in Flow Adjusted Concentrations (FACs) of Total Nitrogen (TN), Total Phosphorus (TP), Suspended Sediments (SS), Nitrate+Nitrite (NN), and Soluble Reactive Phosphorus (SRP) at the Black Fork. The FACs were truncated from -1 to 1 for consistency. This may cause a few data points to be missing from the figure, but all data were included in trend analysis. Significant change points are identified by solid vertical lines, the grey areas are the 95% confidence intervals around the change points, and significant linear model slopes are identified by solid blue lines.

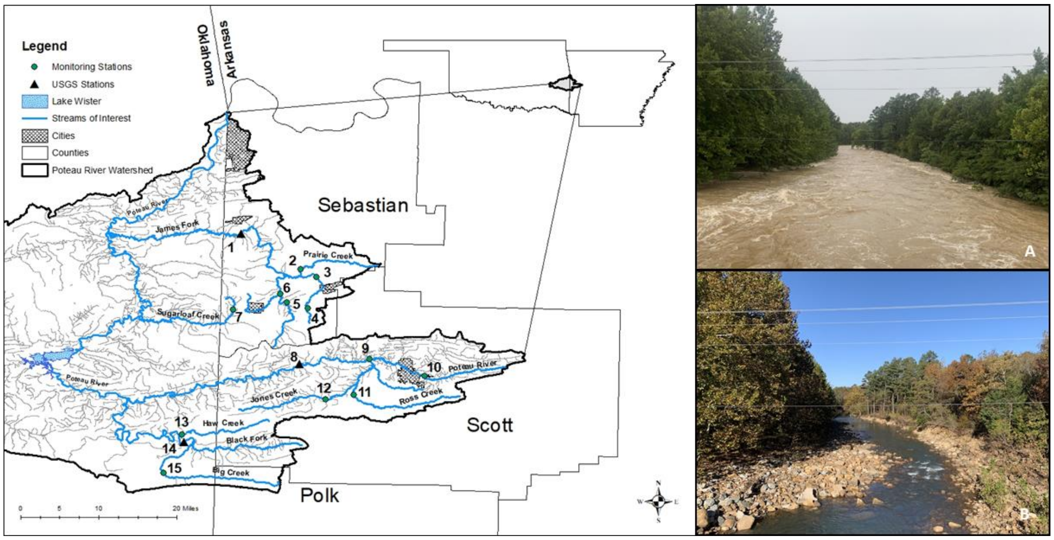


Figure 27: Upper Poteau River Watershed site map (left) and images of Big Creek (Site 15) during storm flow (A) and baseflow conditions (B).

measurements, (i.e., less than 1% of all stage measurements fell above the range of measured flow, and 11% fell below the range of measured flow).

A total of 68 points were used from the SonTek-IQ data and combined with the baseflow discharge measurements to develop a rating curve. For the final rating curve (Figure 28), a two-point regression with a slope of 6.21 ft^2/s was used for stage values less than 0.21 ft. LOESS regression was used between 0.21 and 4.43 ft, where measured flow data exists, and Manning's equation was used to predict flows above 4.43 ft, with a Manning's n of 0.025. The rating curve was used to develop a continuous record of flow from January 2018 through December 2020.

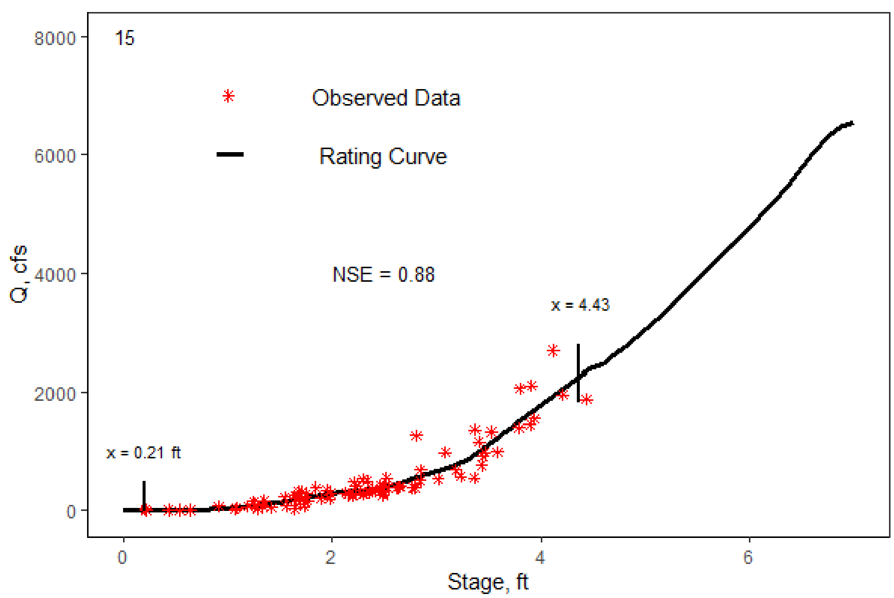


Figure 28: Rating curve for Big Creek (Site 15). Two-point regression was used for stages below 0.21 ft, LOESS regression for stages between 0.59 and 4.43 ft, and Manning's equations for stages above 4.43 ft.

Table 30: Project year (e.g., 2017 project year is October 1, 2017 through September 30, 2018) and seasonal mean concentrations for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), sulfate (SO_4^{2-}), turbidity and electrical conductivity (EC) at Big Creek (Site 15).

Project Year/ Season	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}	Turbidity	EC
	--------	--------	--------	--------	mg L^{-1}	--------	--------	--------	NTU	µS cm^{-1}
2017	0.30	0.151	0.02	0.003	7.52	0.035	1.868	3.054	13.91	25.23
2018	0.28	0.137	0.02	0.002	8.13	0.054	1.638	3.536	15.14	20.05
2019	0.38	0.241	0.02	0.002	13.39	0.068	1.398	2.783	16.14	19.60
Fall	0.36	0.194	0.03	0.002	17.27	0.057	1.692	3.502	19.77	23.27
Winter	0.34	0.195	0.02	0.002	9.13	0.039	1.740	2.711	16.06	20.28
Spring	0.31	0.170	0.01	0.002	8.47	0.049	1.394	3.156	14.67	18.06
Summer	0.28	0.146	0.01	0.003	3.94	0.073	1.663	3.233	9.68	24.23

A total of 61 water samples were collected from site 15, with 36 during baseflow conditions and 25 during storm flow between October 2017 and September 2020. Water samples were collected across 96.2% of all stage measurements, with less than 1% of stage measurements falling above where water samples were collected, and 3.7% of stage measurements falling below. Constituent concentrations were generally greater in the 2019 project year (i.e., October 2019 – September 2020) compared to 2017 and 2018 (Table 30). NN and Cl were greatest in the winter months (i.e., December, January, and February), SRP, Fl, and EC were greatest in the summer months (i.e., June, July, and August), and TN, TP, TSS, SO_4^{2-}, and turbidity were greatest in the fall months (i.e., September, August, November).

Measured concentrations were multi-plied by instantaneous flow (Q_i) to estimate constituent loads (L_i). The GAM for log

Table 31: Generalized additive model (GAM) R^2 and Nash-Sutcliffe Efficiency (NSE), mean daily loads (kg day^{-1}) with 95% confidence intervals, and calendar year annual loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) at Big Creek (Site 15). Additionally, the mean daily flow (Q_d) for each calendar year (cfs).

Constituent	R^2	NSE	Mean Daily Load	2018	2019	2020
Q_d	--	--	--	157	135	72
TN	0.986	0.988	103 (78-137)	50,530	37,649	24,811
NN	0.961	0.967	53 (34-85)	26,150	20,609	10,942
TP	0.938	0.948	5 (2-16)	2,145	1,436	2,292
SRP	0.955	0.970	1 (0-2)	259	231	129
TSS	0.849	0.860	3,990 (1,062-20,101)	1,555,542	643,735	2,174,644
Fl	0.886	0.900	13 (6-28)	6,126	5,253	2,686
Cl	0.995	0.996	421 (372-477)	198,068	177,215	86,158
SO_4^{2-}	0.988	0.989	899 (784-1,033)	428,868	360,873	196,302

transformed L_i, Q_i, and day of year (DOY) was used to develop a continuous record of constituent loads from January 2018 through December 2020. The R^2 and NSE values for each constituent's GAM were greater than 0.80 (Table 31). Daily constituent loads were then estimated by integrating L_i over time, and then daily loads were summed into monthly (Appendix A) and annual loads (Table 31). Constituent loads were generally greatest in 2018, except TP and TSS were greatest in 2020. NN loads generally made up about 50% of TN loads, while SRP loads made up about 12% of TP loads, and similar trends occurred in mean concentrations each year.

Constituent Concentrations and Land Use

The human development index (HDI, % urban plus % agriculture land use) ranges from 2.9 to 66.5% across sites in the UPRW. The majority of human development is represented by agricultural land use, since urban areas make up less than 8% of land use across all subwatersheds (Table 1). When comparing constituent concentrations and HDI, site 3 was removed since only 1.5 years of concentration data was available compared to 3 years of data for the remaining sites. Across the 3 year monitoring period, arithmetic mean concentrations under baseflow conditions gen-

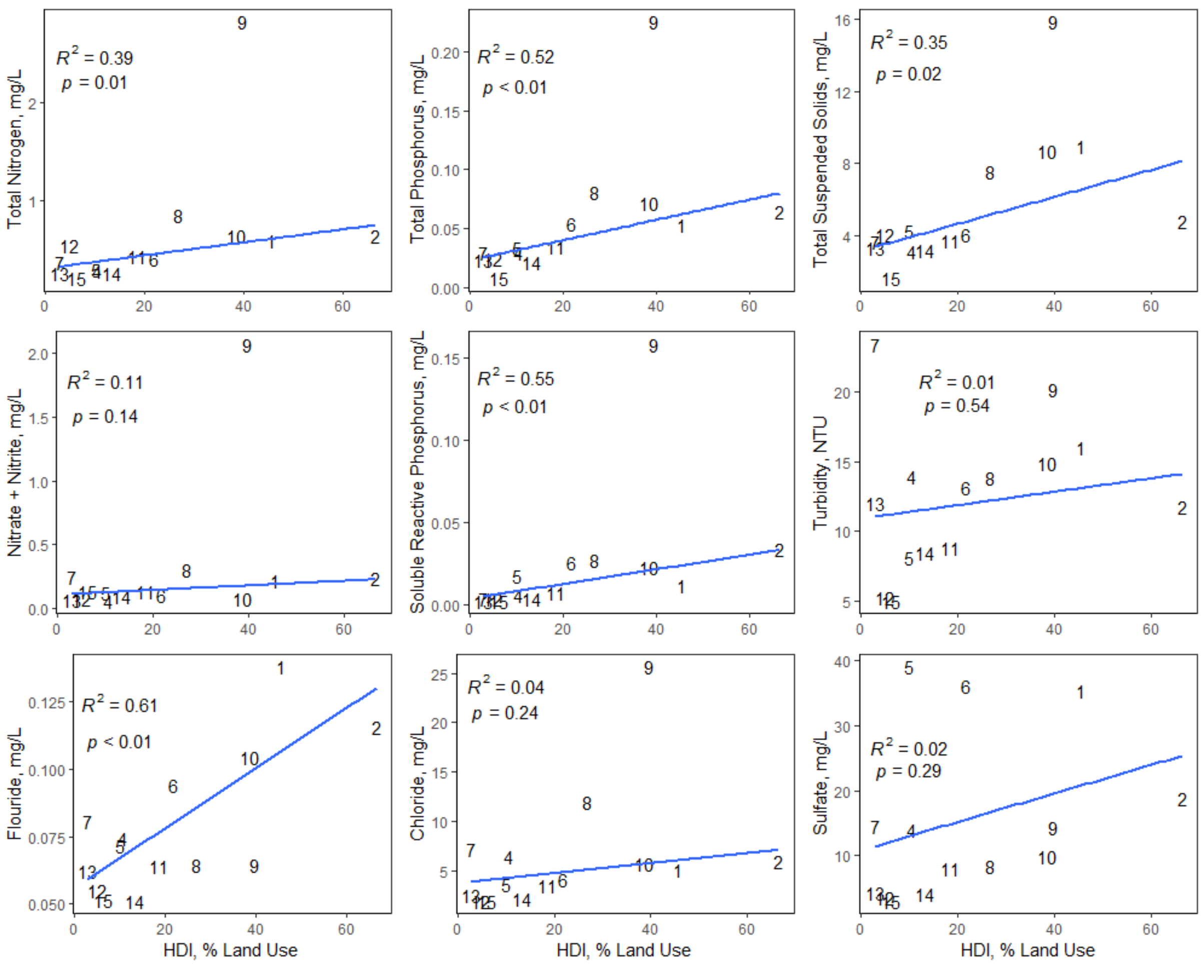


Figure 29: Arithmetic mean concentrations under baseflow conditions from October 1, 2017 through September 30, 2020 versus human development index (HDI, % urban area plus % agriculture land use). Data points are represented by site numbers, which correspond to Table 1, and blue lines indicate slopes of simple linear regression. Site 9 was removed from regression analyses due to its location directly downstream from the waste water treatment plant in Waldron, Arkansas.

erally increased with increasing HDI (Figure 29). For regression analyses, site 9 was also removed since it lies just downstream of the waste water treatment plant in Waldron, Arkansas. Significant increases in TN, TP, SRP, TSS, and Fl occurred with increasing HDI ($p < 0.05$), while no significant change occurred in NN, turbidity, Cl and SO_4^{2-} ($p > 0.05$). Similar trends occurred with baseflow geometric means, arithmetic and geometric means of all flow conditions, and flow-weighted mean concentrations (FWMC) and HDI across sites (Appendix B).

Summary and Conclusions

The UPRW has been listed as a priority watershed in Arkansas since 1998 due to nutrient and sediment enrichment. According to the NPS pollution plan, the goals for the UPRW are to reduce pollutant levels that will restore designated uses and target subwatersheds where implementation of management practices can have the greatest impact. This study successfully monitored 15 sites within the UPRW, three of these existing at USGS monitoring sites, and the remaining 12 on the HUC-12 subwatershed scale, for three years. Specifically, this project:

- Collected water quality samples across a range of flows at all 15 sites,
- Collected stage and discharge measurements at 8 of the 12 subwatershed sites,
- Developed rating curves for subwatersheds with stage and discharge measurements,
- Estimated monthly and annual constituent loads for the 3 USGS sites and the 8 subwatershed sites with discharge measurements,
- Conducted water quality trend analyses at the 3 USGS sites, and
- Analyzed nutrient concentrations in relationship to land use and human development.

The major findings from the three USGS sites in the UPRW include:

- Constituent concentrations were generally greatest in the winter and lowest in the spring at the James Fork (Site 1) and Poteau River (Site 8), but at the Black Fork (Site 14) constituent concentrations were generally greatest in the spring and least in the summer.
- Constituent loads were generally greatest in the 2019 project year at all three sites, as well as mean daily flow.
- At the Black Fork, the relatively undisturbed watershed within the UPRW, slight decreases or no changes occurred in flow-adjusted constituents over the 27 years of available data.
- At the Poteau River, which is impacted by both point and nonpoint sources, flow-adjusted N is increasing while flow-adjusted P and sediments are decreasing.
- At the James Fork, which has the largest percentage of agriculture land use in the watershed, flow-adjusted N and SRP are increasing, while sediments are decreasing.
- Decreasing sediments and P and on the James Fork and Poteau river are likely due to restrictions and improvements in point source outputs, as well as other 319(h) efforts implemented in the watershed.
- The magnitude of decreasing flow-adjusted concentrations were generally greater than increasing flow-adjusted concentrations, suggesting water quality is improving at a faster rate than it may be worsening.
- Continued monitoring will be important to insure increasing trends do not lead to more excessive nutrient concentrations.

The major findings from the HUC-12 subwatersheds in the UPRW include:

- The magnitude of constituent concentrations were variable across sites and seasons, but were most commonly greatest in the summer months and least in the spring.

- In general, constituent loads were greatest in 2020 compared to 2018 and 2019.
- The largest magnitude of constituent loads occurred at the Lower Poteau River (Site 9), which lies just downstream of the waste water treatment plant in Waldron, Arkansas, and has a watershed that is 33% agricultural land use.
- The smallest magnitude of constituent loads occurred at the Cherokee Creek Headwaters (Site 4), which has a watershed area of 14 km^2 that is predominately forested.

Lastly, average and flow-weighted concentrations increased with increasing human development index across sites (while excluding sites 3 and 9). The majority of human development in the UPRW is represented by agricultural land use, since urban areas make up less than 8% of land use. Ultimately, the data collected in this project is important for understanding small-watershed pollutant sources and long-term trends in water quality at the UPRW.

Appendix A: Summary of monthly loads (kg) for total nitrogen (TN), nitrate plus nitrite (NN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), fluoride (Fl), chloride (Cl), and sulfate (SO_4^{2-}) for monitoring sites with flow records.

James Fork (USGS 07249400, Site 1)

Project Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2017	Oct	160	20	10	1	2,200	20	1,600	8,500
	Nov	40	2	3	0.2	400	3	360	1,500
	Dec	190	40	10	1	1,800	30	2,200	12,300
	Jan	1,900	710	290	40	100,000	240	12,900	87,300
	Feb	43,800	8,800	11,600	1,900	5,805,200	2,400	122,900	615,100
	Mar	10,800	3,400	1,700	320	500,900	1,100	53,400	299,500
	Apr	13,600	4,200	2,400	520	813,200	1,700	58,200	324,600
	May	1,500	580	140	30	29,100	330	10,500	70,700
	Jun	2,200	730	470	130	169,300	440	7,900	57,700
	Jul	120	10	10	1	2,500	30	1,100	8,600
	Aug	29,700	7,100	10,500	3,100	7,892,000	3,800	63,600	475,900
	Sep	21,900	5,500	7,100	2,000	3,446,900	1,900	54,800	313,000
2018	Oct	16,700	5,100	3,600	970	1,137,100	1,500	63,700	313,400
	Nov	28,000	6,200	7,600	1,900	2,540,300	1,800	85,300	383,200
	Dec	44,500	7,600	9,800	2,100	3,475,900	4,000	150,100	722,800
	Jan	30,000	9,900	5,600	720	2,014,300	3,800	150,800	975,000
	Feb	27,800	8,000	5,600	880	2,554,200	2,200	117,600	652,000
	Mar	7,500	2,800	910	160	201,100	930	45,400	266,600
	Apr	35,000	8,400	8,300	1,900	3,749,700	3,400	105,400	550,400
	May	51,700	11,600	13,400	3,300	6,385,000	5,600	131,600	728,900
	Jun	42,300	8,900	13,700	3,800	6,146,000	5,800	87,800	597,300
	Jul	1,500	740	130	30	26,300	540	11,300	103,800
	Aug	4,900	1,700	1,200	350	699,300	860	18,100	146,700
	Sep	370	100	30	4	7,500	80	3,400	27,000
2019	Oct	6,700	2,200	1,200	300	236,700	640	29,600	145,400
	Nov	26,900	6,400	6,000	1,400	1,677,100	2,000	97,300	434,200
	Dec	10,400	2,600	1,600	340	385,800	1,300	56,100	294,500
	Jan	31,900	9,000	7,000	890	2,908,700	3,300	138,300	876,000
	Feb	27,500	8,300	5,400	820	2,384,700	2,300	121,800	688,400
	Mar	27,700	7,200	5,700	1,100	1,952,700	2,400	100,600	522,700
	Apr	36,600	9,400	7,900	1,800	3,098,600	3,700	118,700	618,500
	May	72,100	14,500	21,700	5,600	11,665,400	7,700	152,900	871,700
	Jun	1,200	520	110	20	18,900	340	7,800	60,500
	Jul	470	170	40	7	8,800	160	3,800	34,000
	Aug	10,500	3,000	3,200	940	2,170,900	1,500	28,800	218,800
	Sep	44,600	9,500	16,200	4,600	9,120,600	4,600	92,600	635,200

Cherokee Creek Headwaters (Site 4)

Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2018	Jan	10	3	1	0.3	120	1	150	410
	Feb	630	60	100	30	13,700	70	2,900	10,700
	Mar	210	20	30	6	2,800	30	1,900	6,200
	Apr	130	10	20	3	1,700	30	1,400	4,800
	May	8	1	1	0.1	90	2	110	380
	Jun	1	0.1	0.1	0.01	10	0.4	20	70
	Jul	1	0.1	0.05	0.01	6	0.2	20	40
	Aug	220	20	80	50	11,100	30	800	3,200
	Sep	600	50	150	80	23,100	80	1,400	6,100
	Oct	560	60	100	20	11,600	100	2,500	9,100
	Nov	600	50	90	30	12,600	100	2,500	9,200
	Dec	900	70	150	20	28,600	160	4,700	16,400
2019	Jan	380	90	30	4	4,600	40	3,200	9,900
	Feb	490	60	90	30	6,500	60	3,900	12,600
	Mar	140	20	20	3	1,600	20	1,600	5,000
	Apr	840	60	130	20	18,300	160	5,400	21,100
	May	740	50	100	20	16,700	170	4,800	19,800
	Jun	1,700	110	180	40	72,800	310	4,700	23,600
	Jul	2	0.2	0.1	0.02	10	1	30	80
	Aug	4	1	1	1	100	1	40	120
	Sep	1	0.1	0.1	0.01	7	0.1	10	30
	Oct	1	0.1	0.1	0.01	9	0.2	20	40
	Nov	110	10	20	6	1,400	20	770	2,600
	Dec	30	3	5	1	470	7	300	890
2020	Jan	470	90	40	9	9,100	40	2,900	9,600
	Feb	310	40	50	20	4,200	40	2,500	8,000
	Mar	360	30	50	10	6,200	60	2,600	9,400
	Apr	250	20	40	7	3,800	50	2,300	8,100
	May	2,200	120	310	80	123,800	420	6,400	33,300
	Jun	5	1	1	0.1	60	2	90	290
	Jul	1	0.1	0.06	0.01	8	0.2	20	40
	Aug	400	30	60	20	19,100	50	560	2,900
	Sep	1,800	140	230	70	98,500	200	2,000	11,300
	Oct	80	7	10	3	1,200	10	360	1,300
	Nov	10	2	2	1	120	3	150	440
	Dec	110	10	20	2	1,500	30	1,100	3,300

James Fork Headwaters (Site 5)

Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2018	Jan	30	10	3	1	410	4	520	3,400
	Feb	2,400	370	530	100	201,400	190	10,300	36,100
	Mar	1,800	340	320	20	84,500	180	7,600	41,000
	Apr	660	140	90	10	12,200	130	5,300	31,600
	May	290	60	30	4	5,400	70	2,300	17,600
	Jun	10	4	0.4	0.1	130	4	180	2,700
	Jul	10	4	0.5	0.1	180	4	140	2,800
	Aug	660	110	130	30	43,100	80	2,500	16,900
	Sep	720	110	190	190	19,400	70	2,500	14,600
	Oct	1,600	300	340	30	74,500	170	6,700	32,500
	Nov	3,800	560	1,100	140	267,600	430	15,400	59,100
	Dec	3,900	1,000	790	40	431,800	600	15,700	79,300
2019	Jan	1,400	420	290	7	55,400	170	6,600	47,800
	Feb	3,100	540	610	90	181,400	240	17,200	59,000
	Mar	840	180	120	8	17,400	110	5,100	29,400
	Apr	2,500	310	540	50	149,900	480	15,800	69,800
	May	3,300	460	600	50	171,500	690	18,000	103,500
	Jun	4,400	320	1,500	60	1,815,700	870	14,800	88,800
	Jul	10	3	0.4	0.1	160	4	130	2,700
	Aug	30	6	3	1	820	6	280	3,200
	Sep	20	4	1	1	70	3	160	2,400
	Oct	20	6	1	0.2	160	4	250	2,500
	Nov	170	50	20	9	3,700	20	1,300	6,200
	Dec	50	30	4	0.4	1,000	10	490	4,000
2020	Jan	960	170	250	20	67,800	110	6,800	27,900
	Feb	1,200	250	200	20	48,300	90	6,400	25,800
	Mar	1,200	240	210	10	31,800	160	6,500	32,700
	Apr	1,000	200	150	20	25,000	190	6,900	38,300
	May	5,200	320	1,500	120	945,600	1,100	23,000	110,700
	Jun	10	3	1	0.1	170	5	190	2,700
	Jul	9	1	0.3	0.1	110	3	110	2,100
	Aug	1,400	60	700	20	208,500	150	2,400	16,200
	Sep	7,400	410	5,100	110	1,979,100	840	9,600	66,200
	Oct	250	50	40	4	6,800	30	1,100	7,500
	Nov	20	6	1	1	90	4	340	2,300
	Dec	240	110	30	2	7,000	40	1,600	11,600

Lower James Fork (Site 6)

Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2018	Jan	830	250	260	60	41,500	60	4,100	31,000
	Feb	10,600	1,700	4,300	1,100	1,047,400	720	31,300	243,800
	Mar	3,600	520	450	200	141,800	430	16,700	107,700
	Apr	2,200	260	380	90	75,400	380	11,800	82,200
	May	330	40	50	10	8,200	70	2,200	16,400
	Jun	30	6	3	0.4	390	8	210	2,000
	Jul	2	0.3	0.1	0.01	10	1	20	260
	Aug	3,900	790	1,600	380	438,300	450	9,500	93,700
	Sep	4,600	740	1,600	790	371,300	480	10,400	89,100
	Oct	4,000	600	1,600	650	173,400	550	15,500	87,700
	Nov	6,500	920	2,600	1,400	524,600	710	22,600	129,000
	Dec	10,600	1,600	2,100	530	773,100	1,400	41,300	241,300
2019	Jan	6,600	2,400	290	510	467,400	350	20,200	98,000
	Feb	7,400	1,500	3,100	610	400,600	610	32,000	211,100
	Mar	1,700	260	150	70	43,900	270	10,000	79,900
	Apr	7,800	800	1,800	450	650,500	980	28,100	181,800
	May	7,900	880	1,900	480	802,000	1,100	26,000	176,900
	Jun	16,600	3,100	6,600	2,000	3,507,500	1,700	24,700	212,700
	Jul	90	20	6	1	1,200	20	750	8,200
	Aug	200	50	40	8	3,800	40	1,100	10,200
	Sep	10	2	1	0.3	80	4	120	1,300
	Oct	240	40	70	20	2,700	50	1,700	11,000
	Nov	3,000	430	680	330	144,000	420	15,000	90,700
	Dec	800	140	130	20	20,400	160	5,900	38,600
2020	Jan	8,400	2,800	1,500	1,000	966,200	410	24,000	180,600
	Feb	5,300	1,200	2,000	450	293,600	430	23,600	141,800
	Mar	5,300	630	630	290	269,100	650	21,800	154,500
	Apr	4,100	460	750	180	182,000	660	19,500	130,000
	May	21,600	2,800	6,000	1,800	3,427,900	2,400	46,800	331,300
	Jun	140	30	20	3	2,100	40	960	9,000
	Jul	6	1	0.3	0.04	40	2	50	650
	Aug	5,000	990	1,600	980	808,600	420	7,700	57,600
	Sep	17,500	3,700	6,100	5,000	3,016,300	1,400	21,900	142,100
	Oct	1,600	210	740	320	113,100	160	4,900	26,000
	Nov	400	80	60	20	3,700	100	4,500	33,900
	Dec	1,800	290	220	70	45,900	340	11,700	72,900

Poteau River (USGS 07247000, Site 8)

Project Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2017	Oct	210	10	20	3	1,500	10	3,400	1,900
	Nov	150	4	10	1	810	6	3,000	2,000
	Dec	1,000	180	80	20	8,400	60	11,000	16,200
	Jan	960	320	80	20	6,200	20	8,900	10,200
	Feb	82,600	19,100	22,100	7,300	6,422,100	3,300	180,500	454,700
	Mar	33,600	9,800	5,800	1,500	1,487,100	1,900	124,200	282,300
	Apr	21,500	4,500	3,500	860	1,081,400	1,600	84,600	192,500
	May	2,800	470	240	60	29,100	190	20,900	27,100
	Jun	370	10	30	4	2,800	20	4,500	3,500
	Jul	430	30	40	3	4,000	20	4,700	3,800
	Aug	14,700	4,000	2,900	720	918,000	1,400	56,700	100,100
	Sep	2,900	1,200	370	130	56,600	270	18,300	19,500
2018	Oct	11,600	5,200	1,600	690	294,300	1,000	61,300	81,600
	Nov	35,800	11,700	7,000	3,000	1,493,300	2,800	138,300	235,900
	Dec	34,700	6,900	6,100	2,000	1,834,300	2,500	152,100	412,100
	Jan	35,600	24,800	5,800	2,600	1,031,600	1,400	149,900	334,500
	Feb	47,700	17,600	9,100	3,300	2,245,600	2,100	158,500	375,900
	Mar	8,500	2,900	880	180	123,500	600	50,000	89,400
	Apr	59,700	10,200	12,300	3,400	4,212,500	4,400	175,100	470,400
	May	45,100	7,700	8,500	2,700	2,855,300	3,800	149,300	342,200
	Jun	65,600	9,200	16,800	4,000	5,063,500	5,800	156,900	351,800
	Jul	7,600	1,900	880	110	126,800	950	41,900	59,800
	Aug	660	120	70	10	8,000	50	6,400	5,500
	Sep	370	20	30	6	3,200	20	5,100	3,000
2019	Oct	1,200	440	110	30	10,200	90	11,200	10,400
	Nov	21,800	6,300	3,500	1,400	667,400	1,600	99,000	190,000
	Dec	17,000	4,700	2,200	770	361,400	1,400	99,400	199,800
	Jan	63,600	34,000	13,700	6,700	2,867,800	2,300	200,400	497,500
	Feb	39,800	17,200	6,500	2,300	1,457,600	2,000	158,800	348,900
	Mar	44,700	10,700	7,500	1,700	2,187,700	2,900	160,200	387,200
	Apr	64,300	12,600	11,000	2,700	3,499,100	5,000	219,400	571,600
	May	131,900	17,000	33,700	13,300	11,726,900	10,300	297,100	745,900
	Jun	9,400	2,100	1,000	260	173,300	1,100	50,700	76,700
	Jul	660	40	60	4	5,700	40	7,100	5,900
	Aug	30,600	7,400	8,600	2,800	3,019,700	2,500	90,000	152,500
	Sep	107,500	27,600	30,600	11,900	10,383,400	9,100	262,500	532,600

Lower Poteau River (Site 9)

Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
	Jan	1,100	880	70	40	2,200	20	11,600	8,400
	Feb	42,200	8,100	14,400	4,800	3,873,900	2,200	107,600	252,600
	Mar	20,300	5,300	4,300	1,500	494,300	1,200	81,100	159,800
	Apr	18,400	4,100	2,700	1,200	536,400	1,200	66,900	138,100
	May	5,900	2,400	410	230	22,000	180	39,100	36,200
2018	Jun	230	130	10	10	240	5	2,500	1,300
	Jul	1,000	670	100	70	2,800	30	12,400	4,900
	Aug	10,900	4,300	3,900	1,500	803,000	730	34,200	55,600
	Sep	5,200	3,200	740	420	64,300	260	29,800	26,600
	Oct	13,100	5,700	2,000	1,200	281,900	810	61,000	74,000
	Nov	29,200	9,300	5,200	3,100	568,700	1,600	103,900	153,200
	Dec	30,500	8,200	6,200	2,700	1,074,000	1,600	119,700	207,400
	Jan	18,200	8,300	2,700	1,300	383,700	1,100	112,700	190,900
	Feb	27,300	7,900	7,200	2,400	1,891,100	1,600	114,900	225,100
	Mar	9,200	3,700	920	390	68,600	520	59,100	85,900
	Apr	31,800	5,400	5,800	2,500	1,280,700	2,000	85,900	206,000
	May	28,100	5,400	5,400	2,200	1,407,900	1,900	88,500	189,300
2019	Jun	45,500	9,600	11,500	6,100	2,120,200	3,000	149,400	224,300
	Jul	6,800	3,600	740	460	54,300	410	79,700	44,300
	Aug	880	560	150	70	5,300	40	4,500	4,100
	Sep	260	210	20	20	340	5	2,200	1,100
	Oct	2,900	1,900	240	170	9,600	110	20,500	15,700
	Nov	18,200	5,400	3,500	1,800	213,500	950	66,200	102,200
	Dec	17,100	6,500	2,300	1,100	124,500	860	93,600	122,800
	Jan	29,500	11,100	5,700	2,600	1,044,500	1,600	139,900	257,700
	Feb	22,400	7,100	5,500	1,800	1,319,600	1,400	104,500	199,600
	Mar	27,400	6,100	4,700	2,000	815,100	1,600	91,800	200,800
	Apr	38,900	6,300	6,800	2,900	1,526,100	2,600	103,800	276,500
	May	73,600	10,900	20,800	8,300	3,974,100	4,700	162,900	382,700
2020	Jun	10,600	4,300	1,300	630	170,300	660	71,200	72,700
	Jul	3,400	2,200	230	200	7,200	70	47,600	15,600
	Aug	22,000	7,100	9,200	4,100	2,343,200	1,300	49,800	85,000
	Sep	55,200	15,500	22,300	10,200	5,735,700	3,500	117,800	218,800
	Oct	9,700	4,400	1,400	950	132,600	420	47,500	44,500
	Nov	9,900	5,900	660	480	21,100	270	65,600	51,000
	Dec	15,200	6,200	1,900	880	190,200	700	91,100	112,900

Poteau River Headwaters (Site 10)

Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2018	Jan	710	30	80	30	4,300	130	11,700	20,000
	Feb	9,200	770	2,200	1,000	474,600	680	36,100	76,000
	Mar	2,400	270	470	220	58,100	250	13,700	31,000
	Apr	2,400	310	480	210	106,800	300	10,300	29,300
	May	270	30	40	10	3,100	60	2,000	6,000
	Jun	8	0.2	0.8	0.2	90	2	70	150
	Jul	60	5	10	4	800	10	390	830
	Aug	2,200	370	740	430	76,800	190	4,900	12,400
	Sep	290	50	50	20	2,700	40	1,500	3,600
	Oct	1,900	480	420	250	32,500	160	7,800	16,900
	Nov	4,500	1,200	1,000	600	123,300	300	17,500	36,200
	Dec	5,400	2,200	1,100	540	112,500	360	23,800	53,300
2019	Jan	2,500	220	500	270	41,400	220	16,800	29,900
	Feb	4,000	390	790	380	85,700	360	23,400	48,100
	Mar	930	90	120	50	9,600	160	9,000	20,200
	Apr	5,300	720	1,200	520	326,900	560	17,400	51,000
	May	4,400	640	1,000	450	245,800	500	12,100	39,500
	Jun	5,300	660	1,700	680	511,000	520	10,200	29,600
	Jul	70	5	10	3	870	20	470	1,100
	Aug	5	0.1	1	0.1	50	1	40	70
	Sep	4	0.03	0.3	0.04	30	1	30	40
	Oct	760	140	110	50	5,400	90	5,400	11,100
	Nov	2,400	770	470	260	34,300	190	12,400	25,300
	Dec	930	290	130	60	6,800	100	7,600	15,700
2020	Jan	4,900	320	1,100	510	225,200	430	29,700	52,900
	Feb	3,600	320	740	350	91,100	340	22,000	44,500
	Mar	3,000	410	570	270	71,300	330	15,500	37,900
	Apr	5,400	840	1,200	540	186,700	580	19,000	56,200
	May	9,600	1,300	2,600	1,100	917,900	980	19,800	64,900
	Jun	260	30	40	10	3,500	60	1,600	4,500
	Jul	50	6	9	3	760	7	200	480
	Aug	4,700	640	1,900	980	496,400	310	6,400	17,000
	Sep	8,600	1,300	3,300	1,800	828,000	590	12,700	34,500
	Oct	1,300	310	360	200	59,300	80	3,700	7,800
	Nov	160	20	20	6	910	30	1,900	3,500
	Dec	1,300	500	200	100	11,800	120	9,100	19,500

Ross Creek (Site 11)

Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2018	Jan	90	40	4	1	800	5	1,400	2,500
	Feb	17,100	3,500	3,600	950	1,821,400	1,400	54,800	166,700
	Mar	6,500	1,600	920	250	201,700	940	30,800	88,100
	Apr	7,000	1,500	1,100	290	319,400	1,400	31,200	93,500
	May	920	250	90	20	8,500	130	5,300	15,000
	Jun	20	3	1	0.2	150	3	170	270
	Jul	20	3	1	0.1	250	3	140	200
	Aug	1,900	400	220	50	46,900	460	7,000	19,100
	Sep	860	190	80	20	4,900	140	4,200	10,500
	Oct	3,100	1,000	320	80	25,900	1,000	15,100	39,100
	Nov	7,800	2,800	1,200	320	271,500	620	30,600	83,100
	Dec	9,700	4,200	1,300	360	444,300	1,500	54,600	146,500
2019	Jan	9,000	3,500	880	210	123,600	530	64,500	160,200
	Feb	9,600	2,900	1,200	310	470,200	1,000	54,000	145,000
	Mar	4,100	1,200	400	90	45,900	640	27,100	73,700
	Apr	13,800	2,600	2,600	680	852,200	2,200	49,600	155,400
	May	10,900	2,200	1,900	530	434,500	1,300	37,300	117,900
	Jun	18,200	3,600	4,400	1,200	1,078,200	2,700	40,700	133,300
	Jul	1,700	500	170	40	16,600	410	7,500	20,500
	Aug	20	3	1	0.2	490	3	170	240
	Sep	30	3	2	0.3	150	2	240	340
	Oct	2,300	820	230	50	21,100	400	10,700	28,000
	Nov	12,000	5,200	1,400	380	210,700	1,800	56,700	152,800
	Dec	4,000	2,100	370	90	45,800	700	28,900	72,700
2020	Jan	12,800	4,000	2,000	440	591,600	400	68,100	177,300
	Feb	9,800	3,000	1,200	310	511,700	1,000	56,100	149,800
	Mar	9,800	2,300	1,400	380	275,200	1,300	46,200	134,900
	Apr	15,900	3,100	2,600	750	661,300	2,500	59,600	186,600
	May	11,000	2,000	2,700	670	1,188,600	1,300	29,000	95,000
	Jun	1,700	530	170	40	12,900	370	8,100	22,800
	Jul	210	60	20	3	2,000	40	1,300	3,000
	Aug	9,300	1,300	2,300	510	700,800	1,300	20,200	60,400
	Sep	19,700	2,400	5,000	1,200	1,278,400	1,400	39,300	119,400
	Oct	4,400	1,300	670	190	147,100	410	16,500	44,200
	Nov	2,000	1,100	150	30	13,700	280	15,400	37,000
	Dec	5,500	2,800	520	130	70,900	930	38,200	98,100

Upper Jones Creek (Site 12)

Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2018	Jan	380	110	10	1	2,200	20	1,200	2,200
	Feb	5,000	1,800	170	20	39,500	380	17,000	29,900
	Mar	5,900	2,300	240	20	50,000	520	22,500	41,000
	Apr	1,600	320	80	6	13,400	160	7,000	13,300
	May	490	10	20	2	4,800	50	2,100	4,000
	Jun	150	6	5	1	1,300	8	430	800
	Jul	9	1	0.3	0.04	80	0.4	20	50
	Aug	120	5	6	1	1,200	9	350	720
	Sep	180	7	9	1	1,300	20	620	1,200
	Oct	530	20	20	2	2,900	60	1,800	3,400
	Nov	3,300	290	100	10	21,400	430	11,200	19,700
	Dec	2,700	730	70	7	21,700	370	9,700	15,400
2019	Jan	4,900	1,400	130	10	34,300	360	18,200	34,600
	Feb	5,100	1,600	170	20	32,200	360	17,300	32,000
	Mar	2,000	570	90	7	13,800	160	7,700	14,700
	Apr	3,300	670	170	20	35,200	390	15,400	28,800
	May	3,700	170	210	20	44,100	500	18,100	35,300
	Jun	5,500	100	240	20	63,500	620	16,900	37,400
	Jul	3,000	60	140	10	32,400	330	8,700	20,700
	Aug	290	10	20	1	3,100	20	870	1,800
	Sep	20	2	1	0.2	130	1	60	110
	Oct	30	4	1	0.1	150	2	80	130
	Nov	1,600	180	40	4	9,700	180	5,100	8,700
	Dec	2,400	520	60	7	18,500	310	8,400	13,700
2020	Jan	4,200	1,200	120	10	30,100	310	15,700	29,600
	Feb	3,800	1,100	130	10	21,900	260	12,700	23,800
	Mar	3,400	1,200	160	10	29,400	320	14,000	26,300
	Apr	4,700	1,200	240	20	47,400	540	21,300	39,900
	May	5,900	130	300	30	79,700	790	25,700	50,300
	Jun	2,000	30	90	7	19,900	220	6,700	14,300
	Jul	2	0.1	0.1	0.01	10	0.1	4	9
	Aug	570	10	40	3	5,600	70	1,900	4,500
	Sep	4,500	80	300	30	48,500	780	16,900	38,300
	Oct	530	30	20	2	3,100	70	1,800	3,400
	Nov	750	90	20	2	4,300	80	2,400	4,100
	Dec	780	190	20	2	5,600	80	2,500	4,000

Black Fork (USGS 07247250, Site 14)

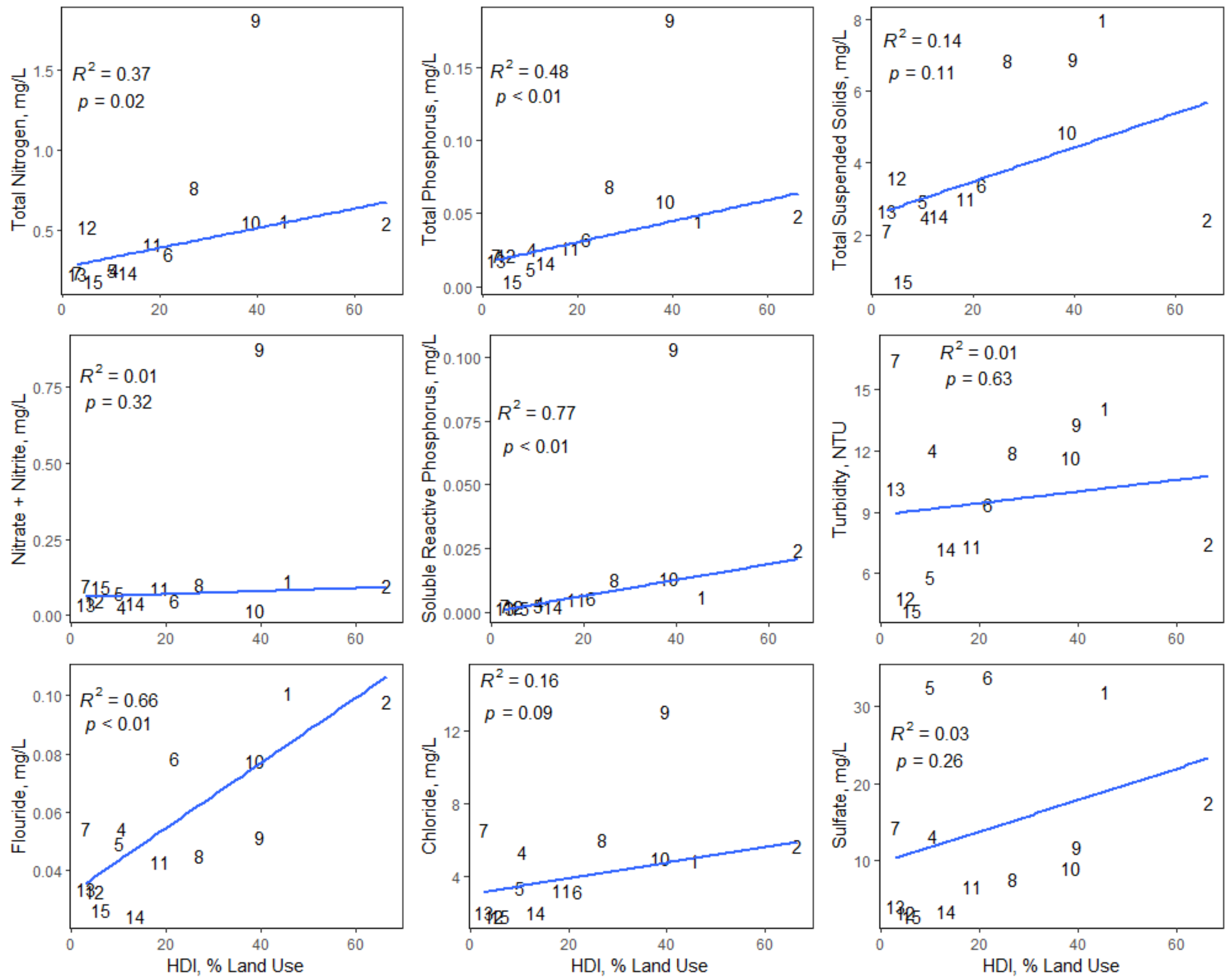
Project Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2017	Oct	10	1	1	0.1	130	1	150	180
	Nov	5	0.2	0.3	0.02	50	0.1	70	70
	Dec	120	50	6	1	1,400	20	1,200	2,400
	Jan	510	400	30	7	5,900	30	4,000	6,400
	Feb	14,600	3,800	2,000	200	1,244,700	770	40,200	89,500
	Mar	3,100	1,000	280	40	102,500	240	17,700	34,900
	Apr	2,100	630	190	20	70,200	300	13,600	33,100
	May	540	160	40	10	9,900	80	4,400	10,600
	Jun	60	4	4	1	880	5	460	750
	Jul	40	4	4	0.5	560	5	280	420
	Aug	390	90	50	9	6,400	150	2,000	4,200
	Sep	320	80	30	5	4,100	80	2,200	4,100
2018	Oct	2,100	580	230	30	64,300	350	10,300	22,900
	Nov	4,100	1,100	500	40	214,000	500	16,400	39,900
	Dec	5,900	1,900	500	100	364,200	860	26,500	68,900
	Jan	4,500	3,500	320	60	113,000	180	21,100	42,700
	Feb	3,800	1,800	290	60	90,100	230	24,600	40,700
	Mar	1,400	640	100	10	16,700	200	12,300	22,900
	Apr	6,500	1,400	820	80	502,200	820	26,800	76,400
	May	8,200	1,500	1,100	260	710,500	1,100	30,900	96,400
	Jun	10,500	1,500	2,100	320	1,408,100	1,800	24,800	78,800
	Jul	820	190	100	10	18,300	250	4,000	9,000
	Aug	50	2	5	1	650	8	380	530
	Sep	20	1	2	0.1	200	2	170	210
2019	Oct	1,100	330	100	10	21,000	140	6,300	13,700
	Nov	4,000	1,300	360	40	144,700	510	20,100	47,500
	Dec	2,500	960	170	30	74,800	360	15,900	36,500
	Jan	9,100	5,000	1,100	110	749,300	260	25,000	57,300
	Feb	5,400	2,400	450	90	161,300	310	31,300	53,400
	Mar	7,200	2,000	740	90	330,900	630	33,600	75,400
	Apr	6,800	1,600	720	90	333,200	790	33,300	89,300
	May	14,000	2,100	2,600	670	2,329,300	1,600	35,500	123,800
	Jun	360	90	30	10	5,400	80	2,600	5,900
	Jul	210	40	20	3	3,000	60	1,300	2,400
	Aug	5,000	780	1,000	120	359,400	1,500	12,400	33,100
	Sep	15,100	2,000	4,500	200	2,425,100	2,500	25,600	76,900

Big Creek (Site 15)

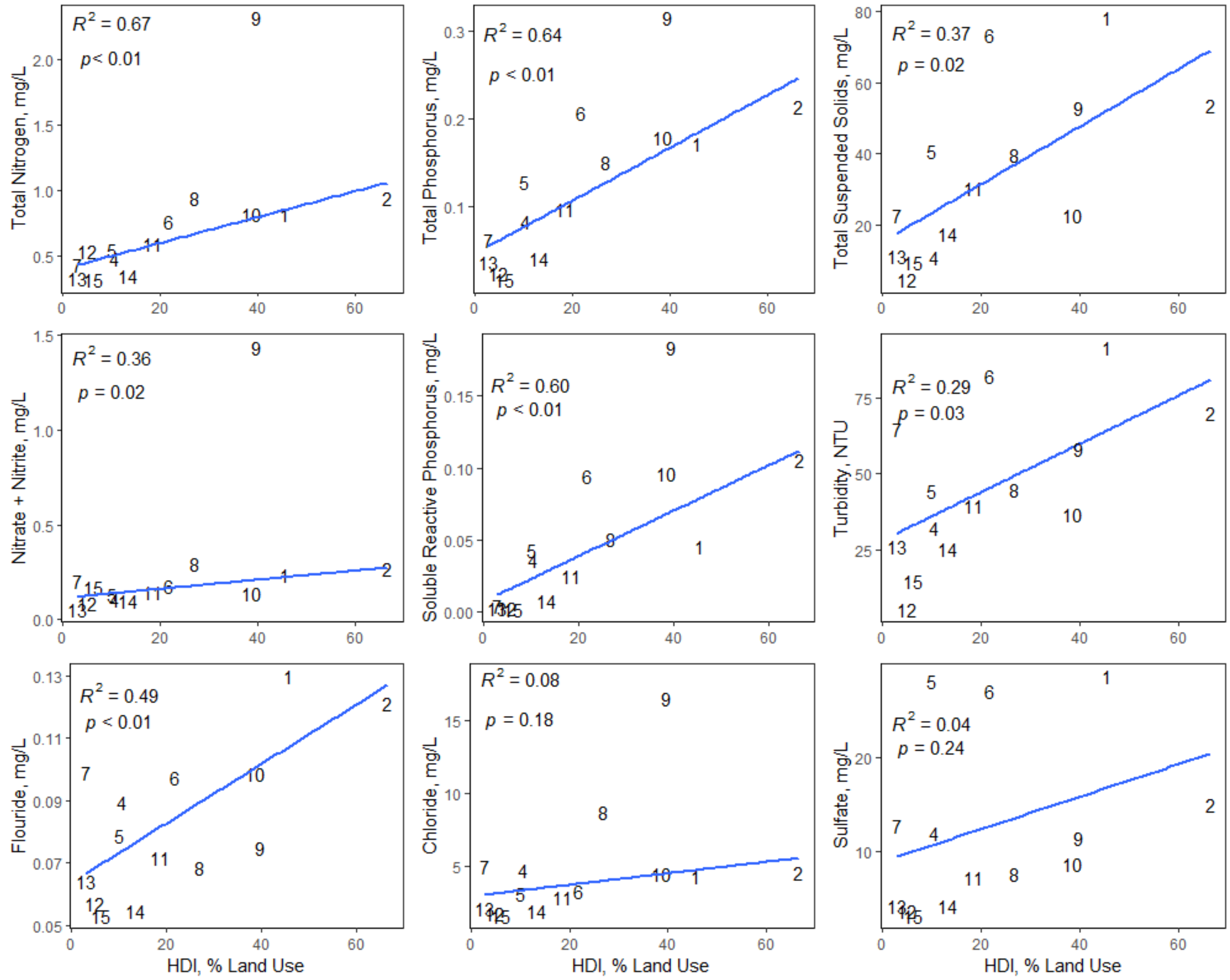
Calendar Year	Month	TN	NN	TP	SRP	TSS	Fl	Cl	SO_4^{2-}
2018	Jan	2,300	1,500	60	30	16,500	210	19,000	26,300
	Feb	15,100	7,100	830	50	746,500	790	44,000	101,400
	Mar	6,100	3,200	230	30	112,700	490	25,500	51,400
	Apr	5,400	3,100	180	40	80,700	610	23,400	50,000
	May	1,200	640	20	7	7,300	180	9,200	17,400
	Jun	110	70	2	1	300	30	1,000	1,600
	Jul	110	70	2	1	240	30	1,000	1,600
	Aug	430	240	20	8	3,500	90	2,700	5,100
	Sep	520	300	20	4	4,900	120	3,200	6,100
	Oct	4,400	2,300	190	30	91,600	840	18,500	41,300
	Nov	6,000	3,000	270	20	194,000	1,100	22,000	52,500
	Dec	8,900	4,600	310	30	297,500	1,700	28,600	74,100
2019	Jan	3,700	2,200	130	30	37,200	290	24,700	35,900
	Feb	2,500	1,500	70	10	19,000	240	17,800	27,500
	Mar	1,600	940	40	20	10,600	190	13,200	21,900
	Apr	6,700	3,600	260	50	157,000	670	25,100	57,000
	May	6,400	3,400	250	20	107,500	770	24,000	56,100
	Jun	6,100	3,100	300	40	140,600	780	21,700	53,000
	Jul	810	440	30	5	6,500	150	5,600	10,800
	Aug	80	50	2	1	150	20	650	990
	Sep	120	70	3	1	280	40	1,100	1,700
	Oct	2,400	1,300	100	20	35,900	510	11,300	24,100
	Nov	5,300	2,800	200	20	99,700	1,100	21,600	49,200
	Dec	2,100	1,100	60	10	29,300	490	10,500	22,800
2020	Jan	3,200	1,400	260	20	253,700	150	10,800	21,200
	Feb	800	500	20	6	4,900	80	7,100	9,900
	Mar	3,300	1,900	110	30	40,200	340	16,600	31,300
	Apr	2,800	1,600	80	20	26,800	350	14,800	29,500
	May	4,400	1,500	550	10	622,800	340	8,000	26,700
	Jun	30	20	1	0.3	60	7	270	430
	Jul	5	3	0.1	0.03	10	1	40	60
	Aug	1,800	810	130	10	88,100	210	4,600	12,800
	Sep	6,400	2,000	1,100	20	1,112,700	630	9,400	36,000
	Oct	460	250	20	3	7,400	100	2,300	4,500
	Nov	390	210	7	3	2,000	110	3,700	6,300
	Dec	1,400	780	30	8	16,000	370	8,600	17,600

Appendix B: Concentrations from October 1, 2017 through September 30, 2020 versus human development index (HDI, % urban area plus % agriculture land use). Data points are represented by site numbers, which correspond to Table 1, and blue lines indicate slopes of simple linear regression. Site 9 was removed from regression analyses due to its location directly downstream from the waste water treatment plant in Waldron, Arkansas.

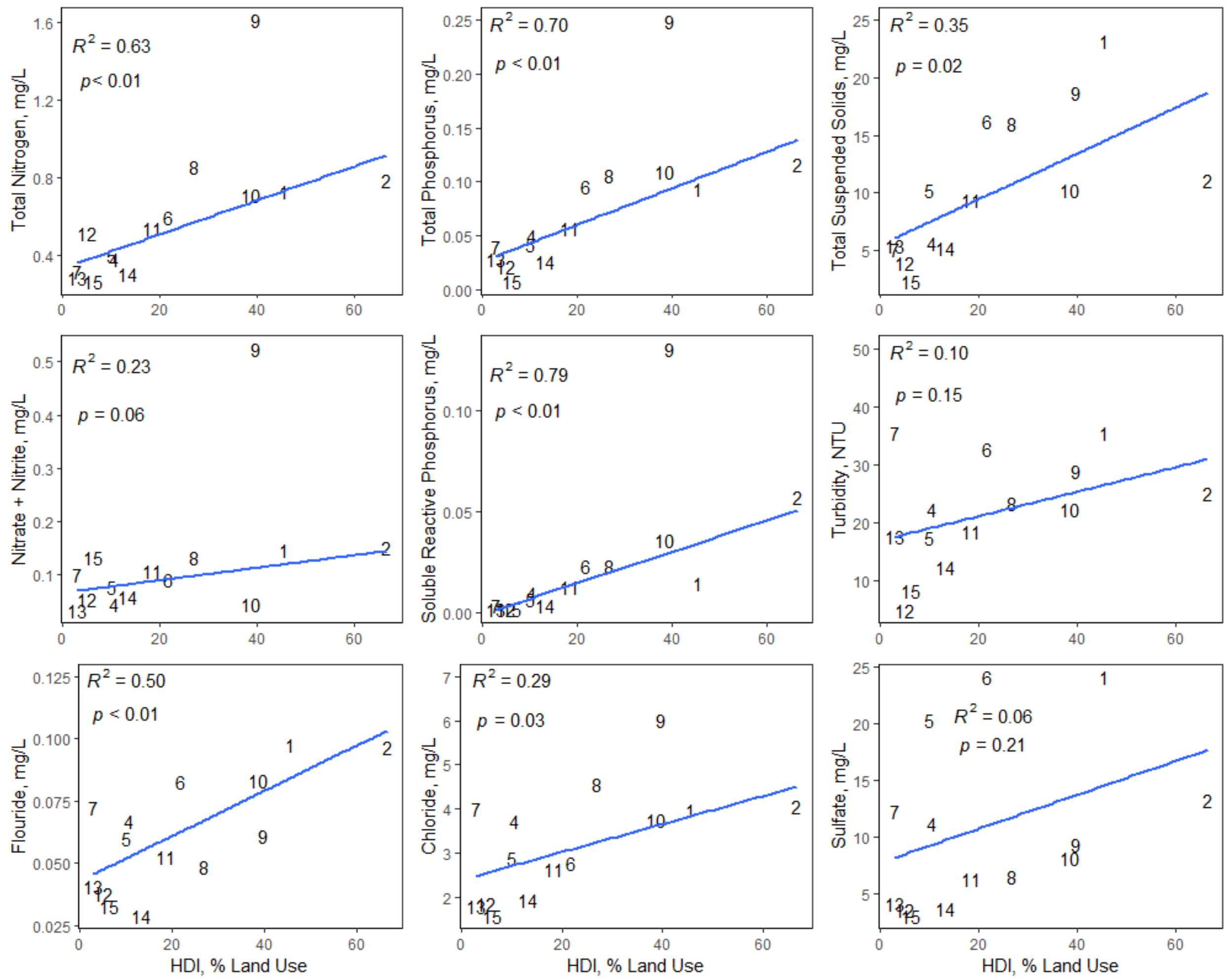
Geometric mean concentrations under baseflow conditions



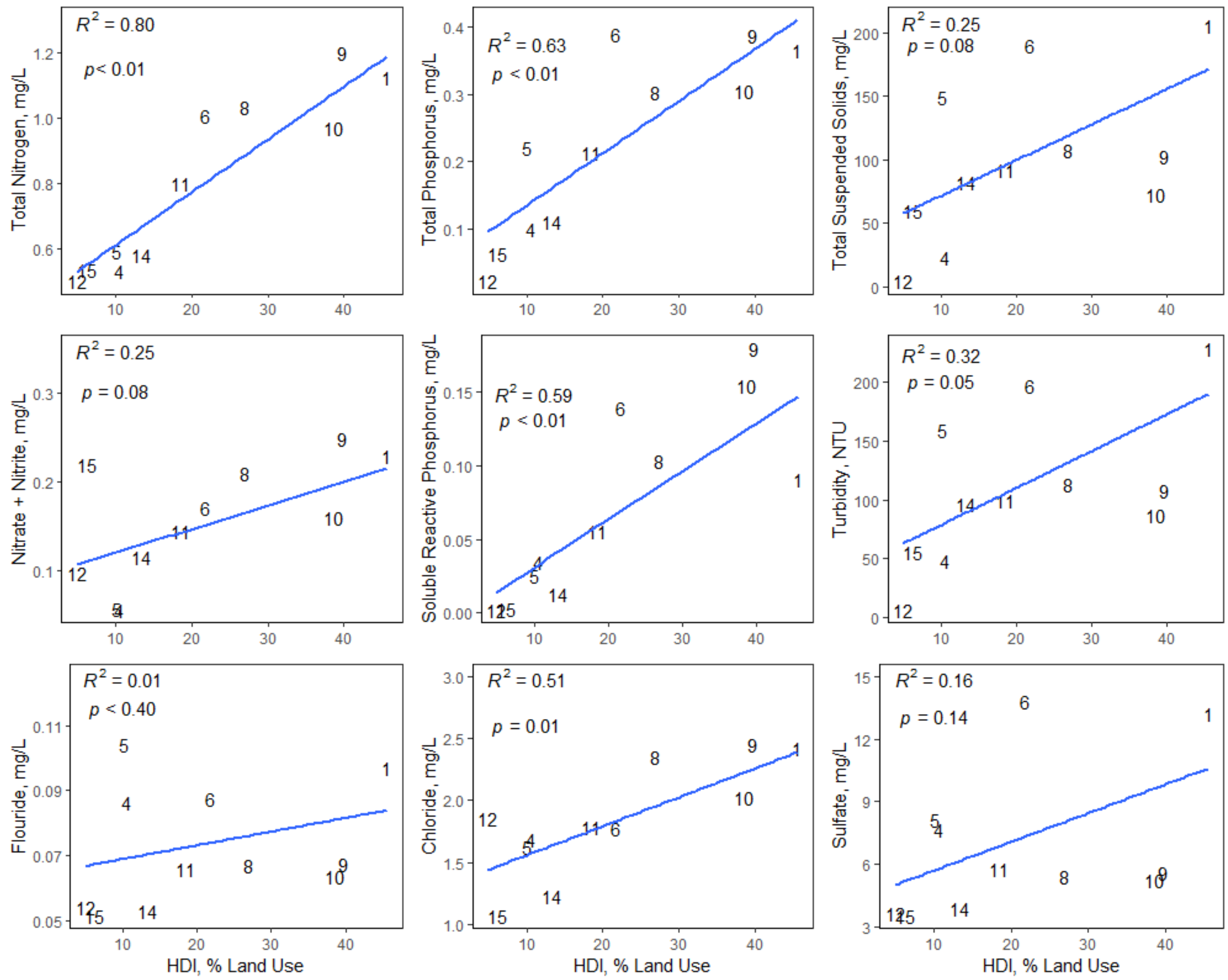
Arithmetic mean concentrations under all flow conditions



Geometric mean concentrations under all flow conditions



Flow-weighted mean concentrations



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