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WATER QUALITY MONITORING AND ANNUAL LOADING OF NUTRIENTS AND SUSPENDED SEDIMENT, WILSONS CREEK AT FARM ROAD 182, GREENE COUNTY, MISSOURI

FINAL REPORT

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SCOPE AND OBJECTIVES

In 1998, segments of the James River were listed on Missouri's 303(d) list as being impaired by nutrients from both point and nonpoint sources (MEC 2007). In 2001, a Total Maximum Daily Load (TMDL) was developed, which set nutrient limits and targets for wastewater treatment facilities and urban nonpoint land use (MDNR 2004). The City of Springfield upgraded phosphorus removal at the Southwest Wastewater Treatment Plant (SWTP) in 2001 that substantially reduced TP concentrations downstream (MDNR 2004; Obrecht et al. 2005; MEC 2007). However, concentrations still remain above the TMDL limits in streams draining urban areas within the Wilsons Creek watershed (Richards and Johnson 2002; Miller 2006; Hutchinson 2010). Recent water quality modeling efforts within the Wilsons Creek watershed also suggest relatively high nonpoint nutrient yields from the urban areas of Springfield (Pavlowsky et al. 2016a; Zeiger et al. 2021). However, there was low confidence in model results from the Lower Wilsons Creek watershed due to the lack of calibration data below Rader Spring, which is the second largest spring in the White River Basin, and the recharge area drains portions of the heavily developed areas of Springfield (Vineyard and Feder 1982).

This project examines water quality in the lower portions of the Wilsons Creek watershed at the United State Geological Survey (USGS) gaging station (#07052160), Wilsons Creek near Battlefield, downstream of Rader Spring. The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University (MSU) and the City of Springfield's Southwest Wastewater Treatment Plant (SWTP) have collaborated to collect and analyze water quality samples over a two-year period. The purpose of this project is to measure water quality and calculate nutrient and sediment loads for the lower Wilsons Creek watershed. OEWRI collected storm flow samples over the two-year monitoring period distributed monthly/seasonally. Personnel from the SWTP collected base flow samples at the same location monthly. Field measurements of specific conductivity (SC), temperature (T), dissolved oxygen (DO), and pH were collected during sampling. All collected samples were submitted to the SWTP Laboratory for analysis. Laboratory analysis completed by the SWTP included total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN), total coliform bacteria, *E. coli* bacteria, and chloride (Cl). Additionally, the SWTP collected base flow water quality samples upstream of the treatment plant using similar methods. However, no storm samples were collected at this site, and nutrient and sediment loads were not calculated. To provide a check on quality controls, the USGS also collected samples at this site that included physical water parameters, nutrients, suspended sediment, chloride, and bacteria analysis over a variety of flows during the monitoring period that are also used to estimate loads.

WATERSHED AND SITE DESCRIPTIONS

The Wilsons Creek watershed (265 km^2) drains the central and western areas of the City of Springfield in Greene County flowing south to the confluence of the James River in Christian County (Figure 1). The underlying geology is the Burlington-Keokuk limestone of Mississippian age within which is formed a karst landscape where sinkholes, losing streams, and springs are common (Vineyard and Feder 1982; Thompson 1986). Typical soils in the area are formed from cherty limestone residuum capped by a relatively thin layer of Pleistocene loess and are generally classified in hydrological soil group C, which have moderately high runoff rates (Hughes 1982; USDA 2009; Pursley 2021). Land use of the watershed ranges from high to low density urban in the upper watershed to lower density residential, livestock grazing, and forage crop production outside the city limits.

The main monitoring site below the USGS gaging station near Battlefield located at Farm Road 182 is downstream of the SWTP and Rader Spring. This monitoring site is located within the Wilson's Creek National Battlefield Park (NBAT) boundary approximately 300 m downstream of the Farm Road 182 bridge and has a drainage area of 148.9 km^2 (Table 1, Figure 2). This monitoring site is located approximately 3.2 km downstream of Rader Spring and 5.1 km downstream of the USGS gaging station (#07052152) Wilsons Creek near Brookline just below the SWTP outfall at Farm Road 168. The portion of Wilsons Creek at the SWTP is a losing stream and effluent from the plant provides sustaining flows to the stream at Farm Road 168 as the two USGS gages immediately upstream of the plant, (#07052100) Wilsons Creek near Springfield at Farm Road 156 and (#07052120) South Creek near Springfield, are generally dry during base flow periods (Figure 3). The monitoring site located upstream of the SWTP has permanent flow and is located near Rutledge-Wilson Park (RWP) at Farm Road 146. The drainage area of RWP is 76.3 km^2 and is about 4.3 km downstream of the USGS gage (#07052000) Wilsons Creek at Springfield located at Scenic Avenue.

Rader Spring is the "master spring" located downstream of a series of reverse sinkholes found along Wilsons Creek (Vineyard and Feder 1982). Reverse sinkholes, or estavelles, are swallow holes in dry weather and during periods of high groundwater flow are "reversed" and become short-term springs. Dye tracing experiments have linked these features downstream to Rader Spring. Therefore, at least some effluent from the SWTP is being discharged at Rader Spring, particularly during periods that flow is entering the karst features described above. The recharge area of Rader Spring is extensive and includes large portions of the urbanized areas of Springfield and Greene County that have also been linked to sinkholes, swallow holes, and caves by several dye tracing investigations (Figure 2; Vineyard and Feder 1982; Thomson 1986). Discharge at the Farm Road 182 gage, which includes Rader Spring discharge, was 2-5 times higher compared to the discharge at Farm Road 168 below the SWTP at base flow conditions

(60-100% exceedance) over the monitoring period (Figure 3). Rader Spring is located within the 5.1 km section between gages and is likely the major source of the increased flow to Wilsons Creek at Farm Road 182.

METHODS

Storm Sample Collection

Storm water quality monitoring was conducted at Farm Road 182 from April 1, 2019 to March 31, 2021. In-situ pH, T, SC, and DO were measured during sample collection using a YSI-multiparameter probe (OEWRI 2015). Storm water samples were collected in 1,000 mL plastic bottles using a depth integrated sampler (OEWRI 2007). Additional surface water grab samples were collected in pre-sterilized 100 mL bottles and analyzed for *E.coli* bacteria. Samples were collected along the deepest portion of the channel. Upon collection, samples were transported on ice and delivered to the SWTP laboratory using standard chain of custody procedures (OEWRI 2006). At the laboratory, the sample was thoroughly mixed and split into two, 100 mL sample analysis cups. One of the sample cups was preserved with sulfuric acid (H_2SO_4) to lower the pH to <2 for total kjeldahl nitrogen (TKN) and TP analysis. The second 100 mL sample cup was analyzed immediately for nitrate-nitrite (N+N) and Cl. For this project, the sum of TKN and N+N is the reported TN value for the sample. The remaining sample (approximately 800 mL) was reserved for TSS analysis. All samples were stored in the laboratory refrigerator. All Standard Operating Procedures (SOP) can be found in the Quality Assurance Project Plan for this project (Owen and Pavlowsky 2018).

Base Flow Sample Collection

Base flow samples were collected by SWTP personnel following procedures outlined in the Wilson's Creek Urban Study Methods Manuel developed by the SWTP for sampling streams (no author or date). Field-based analysis for pH, T, SC and DO were performed in the manner consistent with SOPs developed by OEWRI and SWTP. Samples were collected using a sterilized bucket that was split into 120 mL plastic bottles with lids for transport to the laboratory. Water chemistry parameters were collected in the field using SWTP's SOP: LAB-BIO-007, SOP: LAB-BIO-008, and SOP: LAB-BIO-010. All SOPs can be found in the Quality Assurance Project Plan for this project (Owen and Pavlowsky 2018).

Laboratory Analysis

Samples were analyzed at the City of Springfield's SWTP laboratory for Cl, TP, TN, TSS, Total Coliform, and *E. Coli* in accordance with the appropriate SOPs based on the Environmental

Protection Agency (EPA) methods. All SOPs for can be found in the Quality Assurance Project Plan for this project (Owen and Pavlowsky 2018).

Annual Load Analysis

Water quality trends were analyzed by comparing load duration curves from the two monitoring periods and calculating loads using $FLUX^{32}$ software. Daily sample loads over the monitoring period were calculated using the load duration method outlined by the U.S. Environmental Protection Agency (NDEP 2003, USEPA 2008). Sample loads of TP and TN are calculated from laboratory results and instantaneous sample discharges. These sample loads are plotted against a load duration curve. The load duration curve is created by applying the Total Maximum Daily Load (TMDL) target concentrations of 0.075 mg/L TP and 1.5 mg/L TN to the flow frequency curve (MDNR 2004). This allows for analysis of the percentage of time over the year the site meets or exceeds the water quality standard set forth in the TMDL. A best-fit-line is added to visualize the overall trend.

Annual loads and flow-weighted concentrations were estimated using $FLUX^{32}$, a software package developed by the U.S. Army Corps of Engineers (Walker 1996; USEPA 2008; Brick 2016; UFI 2017). $FLUX^{32}$ estimates nutrient and sediment loadings were calculated from grab sampling data, instantaneous sample discharge, and mean daily flow from a continuous gaging station. Within $FLUX^{32}$ are six different options for estimating loads. For this study, the Times Series load estimate using residual interpolation (Method #8) was chosen since samples were distributed over various flows throughout the year and the method resulted in relatively low error. Error was further decreased by using a stratified discharge separation technique where samples were classified into four categories based on the variability in the mean daily discharge over the sampling period. This stratification method proved to have the lowest error among the available flow separation techniques. Error is expressed as the mean coefficient of variation percentage (cv%) where a value of <10% is considered the most desirable, but <20% is acceptable (Walker 1996). Load estimates using $FLUX^{32}$ had cv% values under 5% for nutrients and less than 12% for TSS. There was a total of three datasets analyzed in $FLUX^{32}$ for this project for TP, TN, and TSS.

RESULTS AND DISCUSSION

Monitoring Period Hydrology

The two-year monitoring period was relatively wet compared to the 30-year average with higher rainfall occurring in the first half of the study. Total rainfall over the two-year monitoring period was 276.3 cm, which is 49.1 cm over the 30-year average (Table 2). This is an annual average of 138.2 cm per year, which is 24.6 cm higher than the 30-year annual average of 113.6 cm per year. However, rainfall was not distributed equally across the monitoring period as the first year of the study was much wetter and the second year was more typical. Between April 1, 2019 and March 31, 2020 the total rainfall was 157.5 cm which is 43.9 cm higher than normal. Then, between April 1, 2020 and March 31, 2021, the total rainfall was 118.8 cm, only 5.2 cm higher than normal. Monthly rainfall totals over the monitoring period shows that the higher-than-normal rainfall occurred between May 2019 and May 2020 and then monthly totals were at or below normal for most of the remainder of the study (Figure 4). This pattern shows that annual average rainfall may be misleading when comparing monitoring periods since instances of high rainfall don't necessarily occur evenly throughout the year.

The distribution of rainfall is reflected in the variability of discharge over the monitoring period as base flow was lower in the second half of the monitoring period compared to the first half. Between April 2019 and April 2020, there were more significant runoff events and the average low discharge was higher than from April 2020 to April 2021 (Figure 5). The frequent runoff events and relatively higher base flow continued in April-June 2020 but decreased significantly from July 2020 onward. As indicated above, the first half of the monitoring period was relatively wetter than normal and represent an abnormally "wet year" while the second half of the monitoring period would be more of a "normal year". However, recent data from weather and discharge gaging stations in the Ozarks show a trend toward wetter conditions and climate change models predict floods will be more frequent in the Midwest in the near future (Vose et al. 2012; Foreman 2014; Mallakpour and Villarini 2015; Pavlowsky et al. 2016b). Average annual discharge and watershed runoff depth for the five USGS gaging stations in the Wilsons Creek watershed for water years 2019-2021 can be seen in Appendix A.

Sample Collection

There was a total of 81 water quality samples collected at NBAT and RWP over the monitoring period. Of the 62 samples collected at NBAT, 22 storm samples were by OEWRI, 19 base flow samples by SWTP, and 21 mixed flow samples by USGS (Table 1). These samples were collected at various discharges that span the flow duration curve with the highest number of samples in the highest 10% of flows that occurred over the monitoring period (Figure 6).
A total of 19 samples were collected at Farm Road 146 during base flow conditions by SWTP personnel. Analytical results for each sample collected by various agencies are provided in Appendix B-E.

Base Flow Water Quality

Samples collected at base flow represent the typical conditions of the stream when not influenced by storm events and forms the basis of the ecological flows to a stream. Base flow samples were collected by SWTP personnel over the monitoring period at both sites. Base flow water quality at each site will be summarized and then compared using descriptive statistics.

<u>Base Flow Physical Water Parameters</u>

Average in-situ SC was higher at NBAT, pH was lower, and T and DO were similar to RWP but had lower variability. Average base flow SC was 697 µS/cm at NBAT compared to 590 µS/cm at RWP over the sampling period with a coefficient of variation (cv% = standard deviation/mean x 100) that varied 50.6% at NBAT compared to 37.7% at RWP (Table 3 and 4, Figure 7). For pH, the mean at NBAT was 7.6 compared to 8.0 at RWP, but both sites had very low variability (cv% = <2%). Mean T was similar at NBAT (18.8^{0}C) and RWP (18.1^{0}C) but was more variable at RWP with a cv% of 35.6% compared to 25.0% at NBAT. Additionally, average DO at NBAT (9.8) and RWP (10.1) were similar, but RWP had higher variability with a cv% of 17.1% compared to 10.2% at NBAT. This suggests flow from Rader Spring is likely responsible for the downstream changes in pH and SC, and the moderation of DO and T at the downstream site since base flow is 3x greater below Radar Spring. The shallow groundwater coming out of the spring in a limestone dominated area will typically be high in dissolved solids, have a buffered pH, and have more consistent DO and T than surface water (Vineyard and Feder 1982; Paukert et al., 2020).

<u>Base Flow Nutrients, Sediment, Chloride, and *E. Coli*</u>

Average base flow TP and TN were higher at NBAT compared to RWP showing the increase in nutrients from the SWTP and the dilution from the discharge from Rader Spring. At NBAT, mean base flow TP was 0.15 mg/L and TN was 7.5 mg/L compared to 0.07 mg/L TP and 2.5 mg/L TN at RWP (Table 3 and 4, Figure 7). The increase in nutrients is a result of SWTP effluent, which has an average discharge of 1.4 m^3/s, with typical nutrient concentrations of 10.5 mg/L TN and 0.31 mg/L TP (MDNR 2020; Zeiger et al. 2021). These concentrations likely are diluted downstream at NBAT from increased flow provided by the Rader Spring system that is about 3x higher than at Farm Road 168 at base flow. Mean base flow TSS was slightly higher at NBAT compared to RWP but was very low at both sites. The geometric mean of base flow *E. Coli* concentration was 56.8 MPN/100mL at NBAT compared to 73.5 MPN/100mL at RWP. This reduction is also likely due to the dilution of the effluent from SWTP which typically has low *E. coli* bacteria concentrations (<20 per 100mL) after treatment (SWTP 2021).

Lower Wilsons Creek Water Quality

<u>Water Quality Sample Variability</u>

Water quality data collected at NBAT shows the consistency of the methods among various agencies as nutrient and sediment concentrations are similar across the various flows within the monitoring period. As discussed above, there was a total of 62 samples collected and analyzed over the monitoring period from various agencies at NBAT. While the targeted flows for sampling varied by agency, data appears to overlap reasonably well suggesting any differences in sampling or analytical protocol do not appear to influence the results (Figure 8). For the physical water parameters measured by the various agencies, pH values ranged from 6.1-7.9, T from 8.2-25.4°C, SC from 182-966 µS/cm, and DO from 5.1-12.1 mg/L (Table 4). The lowest variability in groups of samples was in pH (cv% <6%) and the highest variability was in SC for USGS and OEWRI samples and T for SWTP samples. Similar trends can also be seen in the results for Cl, nutrients, sediment, and bacteria. The Cl values measured among agencies ranged from 5.4-120.0 mg/L, TP from 0.06-0.69 mg/L, TN from 1.2-15.0 mg/L, TSS from 0.5-375 mg/L, and *E. Coli* from 13.0-24,196 MPN/100 mL (Table 5). The highest variability in groups of samples was in *E. coli* and the lowest variability was in TP for USGS and OEWRI samples and TN for SWTP samples. These results are likely due to the USGS and OEWRI having targeted a range of flows while SWTP was targeting base flow. During base flow, SC and TN will be consistent and relatively high compared to storm flows (Owen et al. 2020; Owen et al. 2015; Hutchison 2010). Overall, water quality results from NBAT appear to be consistent across agencies and the variability reflects the differences in the discharge during sampling.

Load Duration Curves

Over the monitoring period most of the daily loads derived from individual samples were higher than the TMDL target load duration curves for TP and TN, showing how the target concentrations are generally not met over the variability of flows at NBAT. Comparing individual daily load values to a TP load duration curve based on the TMDL target of 0.075 mg/L shows that only a few TP loads are at, or just below, the threshold during the monitoring period, but the best fit line is consistently higher than the TMDL target load duration curve (Figure 9). For TN, daily loads exceed the load duration curve based on the TMDL target of 1.5 mg/L over approximately 80% of the monitoring period. However, unlike TP, TN concentrations are near the threshold during the higher flows. This is due to storm flow providing relatively low TN concentrations that dilute the relatively high TN concentration coming from the SWTP. For TP, the load duration curve is about 1.5x higher than the TMDL target load duration curve at the median flow and the TN load duration curve is approximately 4x higher. These data show that while upgrades at the SWTP reduced TP concentrations downstream, nutrients remain above the TMDL target concentrations throughout the year. The best-fit-line used in this analysis was not used to derive loads, but to simply look at trends across the flow duration curve.

Flow-weighted Concentrations, Loads, and Yields

Overall modeled flow-weighted concentrations of nutrients were 2-4x higher than the TMDL target values over the monitoring period. Average flow-weighted concentrations over the two-year monitoring period were 0.196 mg/L TP, 5.64 mg/L TN, and 71.7 mg/L TSS (Table 6). This means TP concentrations are 2.6x higher than the 0.075 mg/L target concentration and TN is 3.8x higher than the 1.5 mg/L target from the TMDL. Annual loads were 30.81 Mg/yr TP, 888.0 Mg/yr TN, and 11,291 Mg/yr TSS. Annual yields were 0.208 Mg/km^2/yr TP, 5.98 Mg/km^2/yr TN, and 76.1 Mg/km^2/yr TSS. Load estimates using $FLUX^{32}$ had cv% values under 5% for nutrients and less than 12% for TSS (Appendix F-H). This suggests the sampling scheme used for this project and the combination of data collection by the various agencies was likely an important factor in the low error in the estimates and should be considered in future studies. Again, efforts to reduce concentrations in effluent from the SWTP have improved conditions downstream in the James River, however, nutrients remain well above the TMDL target concentrations in the lower Wilsons Creek watershed. Estimates of nonpoint source loads were calculated by subtracting the annual SWTP nutrient loads from the from the loads at NBAT (Zeiger et al. 2021). Results show that 55.1% of the TP load and 47.5% of the TN load is from nonpoint sources (Table 7). For TSS, virtually 100% of the load is from nonpoint sources as suspended sediment in SWTP effluent is very low (Zeiger et al. 2021). Further, the suspended sediment yield from this study is lower than the median sediment yield value from recent water quality model simulations for urban land use in the Ozark Highlands Ecoregion (White et al. 2015). Since phosphorus is the limiting nutrient for eutrophication in the James River, the reduction of nonpoint TP in storm flows is probably the most important factor in reducing the overall flow-weighted concentration is the Lower Wilsons Creek watershed (MDNR 2004). Recent water quality modeling efforts have shown the highest nonpoint loads in the James River are from the urban areas of Springfield (Pavlowsky et al. 2016a, Zeiger et. al 2021). Data from this study can be used to better calibrate these models in the lower watershed taking into account flow, nutrients, and sediment from Rader Spring.

CONCLUSIONS

The purpose of this project was to collect and analyze water quality samples that will be used to calculate nutrient and sediment loads for the lower Wilson Creek watershed. A total of 81 samples were collected at two sites by three different agencies over the monitoring period from April 1, 2019 to March 31, 2021. Sample collection included field measurements of basic physical water parameters (pH, T, SC, DO) and laboratory analysis of suspended sediment, nutrients, chloride, and bacteria (TSS, TN, TP, Cl, and *E. coli)*. There are six main conclusions from this study:

1. **Water quality data collected at NBAT reflects both the consistency of the sampling and analytical methods from the various agencies and the variability in concentrations across the entire flow duration curve.** There was a total of 81 water quality samples collected at NBAT and RWP over the monitoring period. Of the 62 samples collected at NBAT, a total of 22 storm samples were collected by OEWRI, 19 base flow samples by SWTP, and 21 mixed flow samples by USGS. A total of 19 samples were collected at RWP during base flow conditions by SWTP personnel. While the targeted flows for sampling varied by agency, data appears to overlap reasonably well suggesting any differences in sampling or analytical protocol do not appear to influence the results.

2. **The two-year monitoring period was relatively wet compared to the 30-year average with most of the higher amounts occurring in the first half of the study.** The distribution of rainfall is reflected in the variability of discharge over the monitoring period where base flow was lower in the second half of the monitoring period compared to the first half. Analyzing monthly rainfall totals over the monitoring period shows that the higher-than-normal rainfall occurred between May 2019 and May 2020 and then monthly totals were at or below normal for most of the remainder of the study. Between April 2019 and April 2020, there were more significant runoff events and the average low discharge was higher than from April 2020 to April 2021. Therefore, the first half of the monitoring period was relatively wetter than normal and represent an abnormally "wet year" while the second half of the monitoring period would be more of a "normal year". However, recent data from weather and discharge gaging stations in the Ozarks show a trend toward wetter conditions and climate changes models predict increased frequency of flooding in the Midwest in the near future.

3. **Average base flow TP and TN were higher at NBAT compared to RWP showing the increase in nutrients from the SWTP and the dilution from the discharge from Rader Spring.** At NBAT, mean base flow TP was 0.15 mg/L and TN was 7.5 mg/L compared to 0.07 mg/L TP and 2.5 mg/L TN at RWP. The increase in nutrients is a result of SWTP effluent, which has an average discharge of 1.4 m^3/s, with typical nutrient concentrations of 10.5 mg/L TN and 0.31 mg/L TP. These concentrations are likely diluted downstream at NBAT from increased flow provided by the Rader Spring system.

4. **Nutrient concentrations exceeded the TMDL for TP and TN over the monitoring period at NBAT and overall load estimates are 2-4x greater than the target load.** Comparing individual daily load values to a TP load duration curve based on the TMDL target of 0.075 mg/L shows that only a few TP loads are at, or just below, the threshold during the

monitoring period. For TN, daily loads exceed the load duration curve based on the TMDL target of 1.5 mg/L during most of the monitoring period. However, unlike TP, concentrations are near the threshold during the higher flows. This is due to storm flow providing relatively low TN concentrations that dilute the relatively high TN concentration coming from the SWTP. Overall flow-weighted concentrations of nutrients were 2-4x higher than the TMDL target values over the monitoring period.

5. **Low error in the load estimates suggest sampling methodology used in this study should be replicated for consistency in the future.**
   Load estimates using FLUX[32] had C.V. values under 5% for nutrients and less than 12% for TSS. Model error is expressed as cv% where a value of <10% is considered the most desirable, but <20% is acceptable. This suggests the sampling scheme used for this project and the combination of data collection by the various agencies was likely an important factor in the low error in the estimates and should be considered in future studies for consistency moving forward.

6. **Efforts to reduce concentrations in effluent from the SWTP have improved conditions downstream in the James River, however, nutrients remain well above the TMDL target concentrations in the lower Wilsons Creek watershed.** Results show that 55.1% of the TP load and 47.5% of the TN load is from nonpoint sources. Since phosphorus is the limiting nutrient for eutrophication in the James River, efforts to reduce nonpoint TP in storm flows is probably the most important factor in reducing the overall flow-weighted concentration in the Lower Wilsons Creek watershed. Recent water quality modeling efforts have shown the highest nonpoint loads in the James River are from the urban areas of Springfield. Data from this study can be used to better calibrate these models in the lower watershed taking into account flow, nutrients, and sediment from Rader Spring.

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TABLES

Table 1. Monitoring site information and sample collection summary.

Site	Northing (m)*	Easting (m)*	Drainage Area (km^2)	USGS Gaging Station?	Total Samples Collected	Collection Agencies
RWP	4,115,860.11338	467,560.68253	76.3	No	19	SWTP
NBAT	4,107,862.42702	463,883.04610	148.9	Yes	62	OEWRI, SWTP, USGS

* UTM, NAD83, Zone 15N, meters
SWTP = Southwest Wastewater Treatment Plant
OEWRI = Ozarks Environmental and Water Resources Institute
USGS = United States Geological Survey

Table 2. Annual rainfall over the monitoring period compared to the 30-year average.

Time Period	Rainfall Total (cm)	Difference Compared to 30-yr Average (cm)
April 1, 2019-March 31, 2020	157.5	+43.9
April 1, 2020-March 31, 2021	118.8	+5.2
Total for both years	276.3	+49.1
Annual average	138.2	+24.6

Note: 30-yr annual average rainfall = 113.6 cm (source: https://www.weather.gov/wrh/climate?wfo=sgf accessed 12/1/2021)

Table 3. Summary of base flow water quality data at RWP.

	Q (m^3/s)*	pH (std)	Temp (°C)	DO (mg/L)	SC (uS/cm)	Cl (mg/L)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	E. coli**
n	19	18	19	19	19	18	19	18	19	19
Min	0.05	7.8	8.1	8.1	410	17.6	0.01	1.7	0.5	6.3
Mean	0.26	8.0	18.1	10.1	590	35.0	0.07	2.5	1.9	73.5***
Median	0.17	8.0	17.5	9.8	583	31.9	0.08	2.3	1.0	71.7
Max	0.61	8.3	27.2	14.8	762	62.2	0.15	4.9	10.0	1,046
Stdev	0.17	0.1	5.8	1.6	75.6	11.9	0.04	0.7	2.2	227
Cv%	72.3	1.6	35.6	17.1	14.2	37.7	65.1	33.2	129.7	189.1

* Discharge data from USGS gaging station (#7052000) at Springfield (@Scenic).
** E. Coli units are MPN/100 mL, MPN = Most Probable Number.
*** "mean" for *E. Coli* is expressed as a geometric mean.

Table 4. Summary of discharge and basic water parameters at NBAT collected by various agencies.

	OEWRI-Storm Flow					SWTP-Base Flow					USGS				
	Q (m^3/s)	pH (std)	Temp (°C)	D.O. (mg/L)	SC (uS/cm)	Q (m^3/s)	pH (std)	Temp (°C)	D.O. (mg/L)	SC (uS/cm)	Q (m^3/s)	pH (std)	Temp (°C)	D.O. (mg/L)	SC (uS/cm)
n	22	22	22	22	22	19	18	19	19	19	21	21	21	21	21
Min	2.6	6.4	8.2	5.1	182	1.0	7.4	11.8	8.0	500	0.8	6.1	12.1	6.1	378
Mean	35.4	7.3	16.2	8.4	436	3.1	7.6	18.8	9.8	697	5.2	7.2	18.3	8.9	667
Median	24.0	7.3	16.2	8.3	395	2.3	7.6	18.8	9.7	729	2.4	7.4	17.8	8.9	677
Max	125	7.9	23.3	11.7	786	7.2	7.8	25.4	12.1	966	38.8	7.7	24.1	11.5	927
Stdev	32.1	0.4	4.1	1.5	177	2.0	0.1	4.2	0.9	130	8.4	0.4	4.0	1.5	162
Cv%	90.6	4.9	25.3	17.8	40.5	72.3	1.4	25.0	10.2	20.7	161.9	5.9	22.0	16.8	24.3

Table 5. Summary of nutrients, suspended sediment, and *E. Coli* data at NBAT collected by various agencies.

	OEWRI-Storm Flow					SWTP-Base Flow					USGS				
	Cl (mg/L)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	E. coli*	Cl (mg/L)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	E. coli*	Cl (mg/L)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	E. coli**
n	21	22	21	22	20	18	19	18	19	19	8	21	21	1	20
Min	5.4	0.13	1.2	1.0	63.6	31.0	0.06	3.4	0.5	21.3	14.6	0.06	2.9	103	13.0
Mean	36.5	0.30	4.39	138	3,410***	54.3	0.15	7.5	3.8	56.8***	61.6	0.13	8.5	103	98.1***
Median	29.0	0.28	3.32	127	3,106	47.7	0.13	8.0	3.0	63.8	58.1	0.11	8.3	103	97
Max	96.9	0.69	13.20	375	24,196	120.0	0.48	12.0	10.0	517	103.0	0.29	15.0	103	4,500
Stdev	26.3	0.14	2.88	117	8,807	24.8	0.10	2.5	2.4	110	30.8	0.06	3.7	*NA*	985
Cv%	72.0	47.2	65.7	84.7	112.0	50.6	69.9	36.6	70.1	148.2	50.0	42.0	43.4	*NA*	295.9

* E. Coli units are MPN/100 mL, MPN = Most Probable Number.
** E. Coli units are CFU/100 mL, CFU = Colony Forming Units.
*** "mean" for *E. Coli* is expressed as a geometric mean.

Table 6. Flow-weighted concentrations, loads, and yields for nutrients and sediment.

Site	Drainage Area km^2	TP Avg. Con. mg/L	TP Annual Load Mg	TP Annual Yield Mg/km^2	TP cv%*	TN Avg. Con. mg/L	TN Annual Load Mg	TN Annual Yield Mg/km^2	TN cv%*	TSS Avg. Con. mg/L	TSS Annual Load Mg	TSS Annual Yield Mg/km^2	TSS cv%*
NBAT	148.4	0.196	30.8	0.208	4.9%	5.64	888.0	5.98	2.9%	71.7	11,291	76.1	11.9%

* cv% = coefficient of variation from FLUX32 for modeled load x 100

Table 7. Nutrient loads at NBAT separated by point and nonpoint source contributions.

Sources	TP Annual Load (kg/year)	TP % of Total Load	TP Avg. Con. (mg/L)	TN Annual Load (kg/year)	TN % of Total Load	TN Avg. Con. (mg/L)
Point*	13,834	44.9	0.313	466,105	52.5	10.54
Nonpoint	16,979	55.1	0.150	421,908	47.5	3.73
Total at NBAT	30,813	100	0.196	888,013	100	5.64

* SWTP outfall loads (Zeiger et al. 2021)

FIGURES

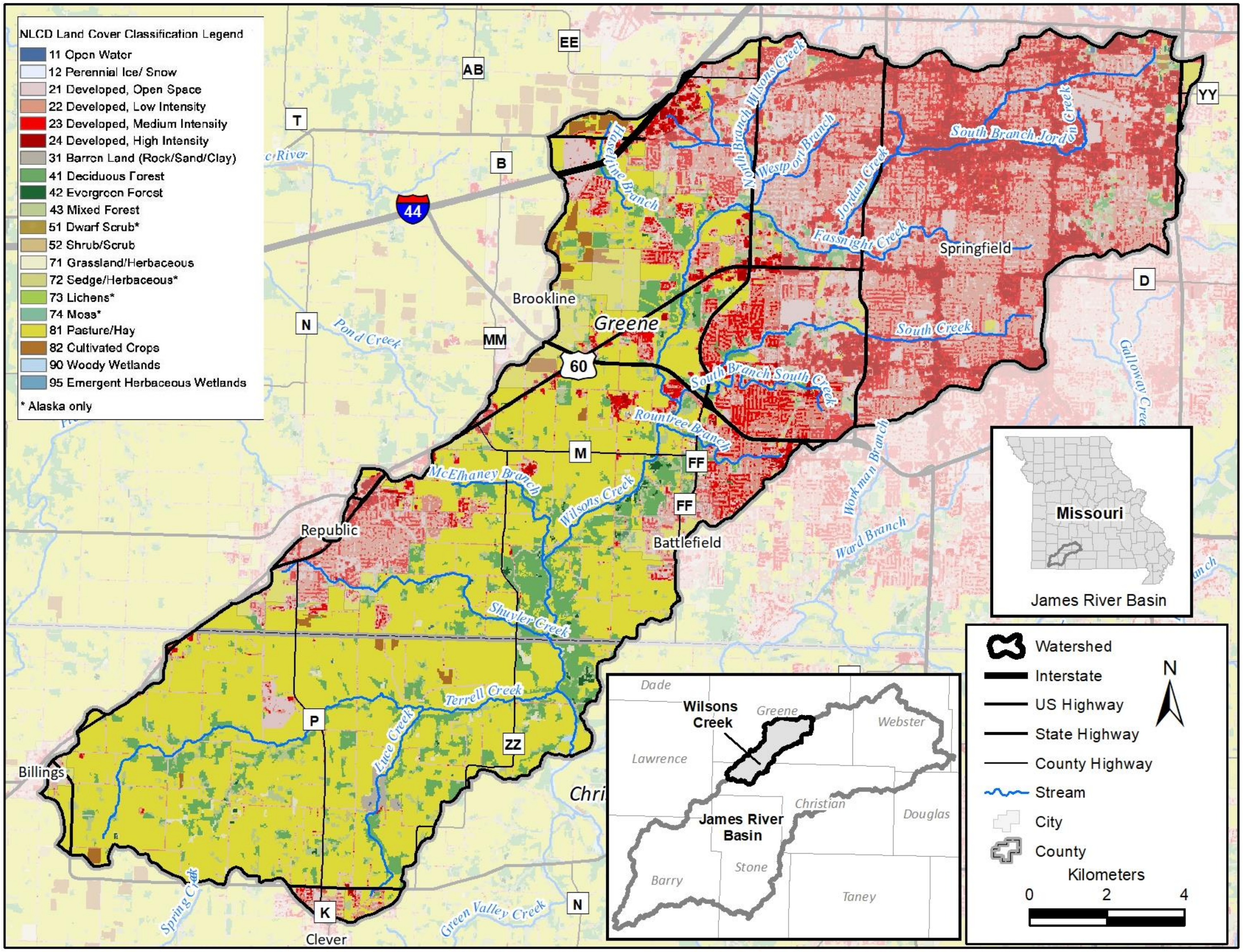


Figure 1. Wilsons Creek Watershed and 2016 Land Use.

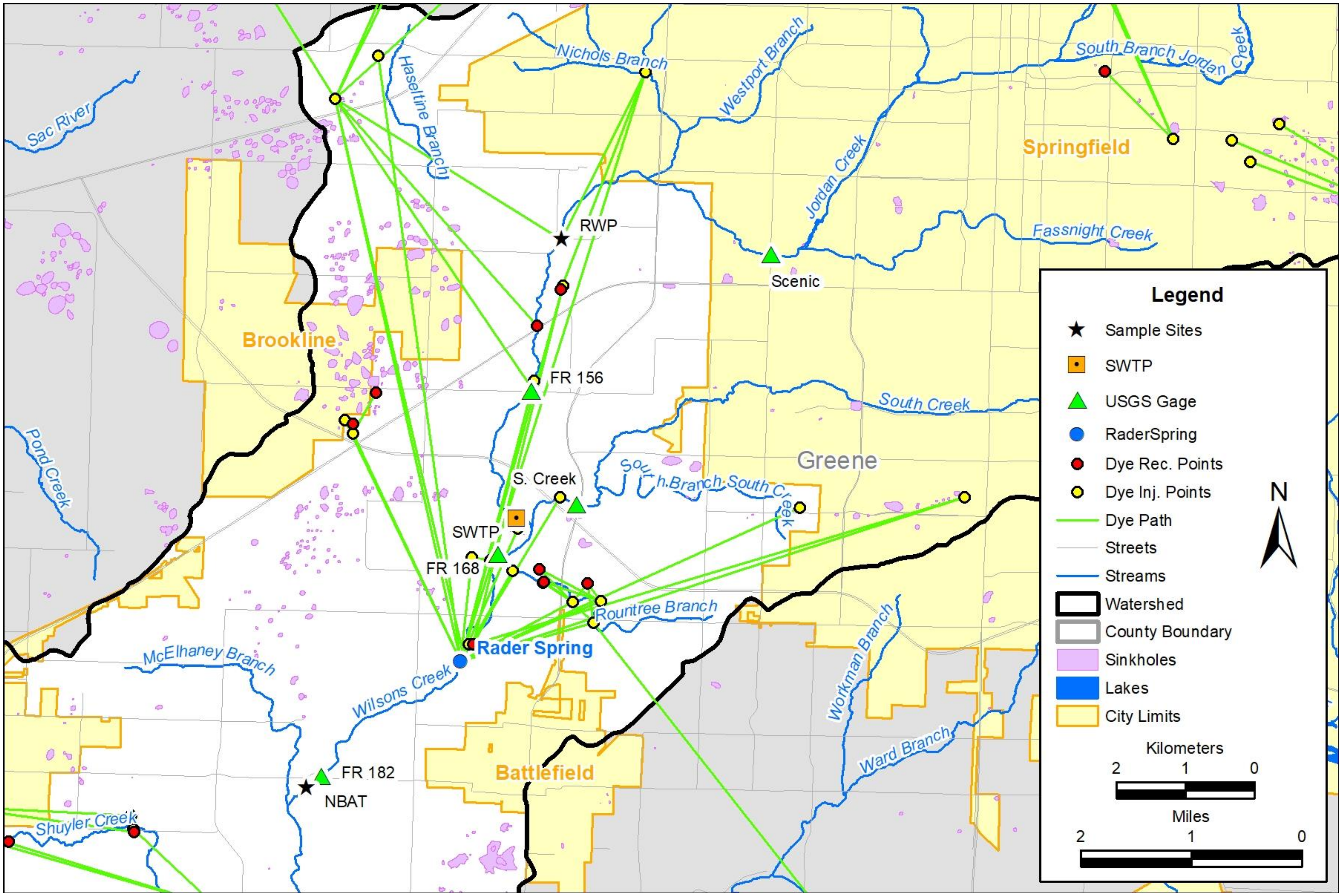


Figure 2. Sample Site Locations, SWTP, USGS Gages, and Rader Spring Dye Trace Paths.

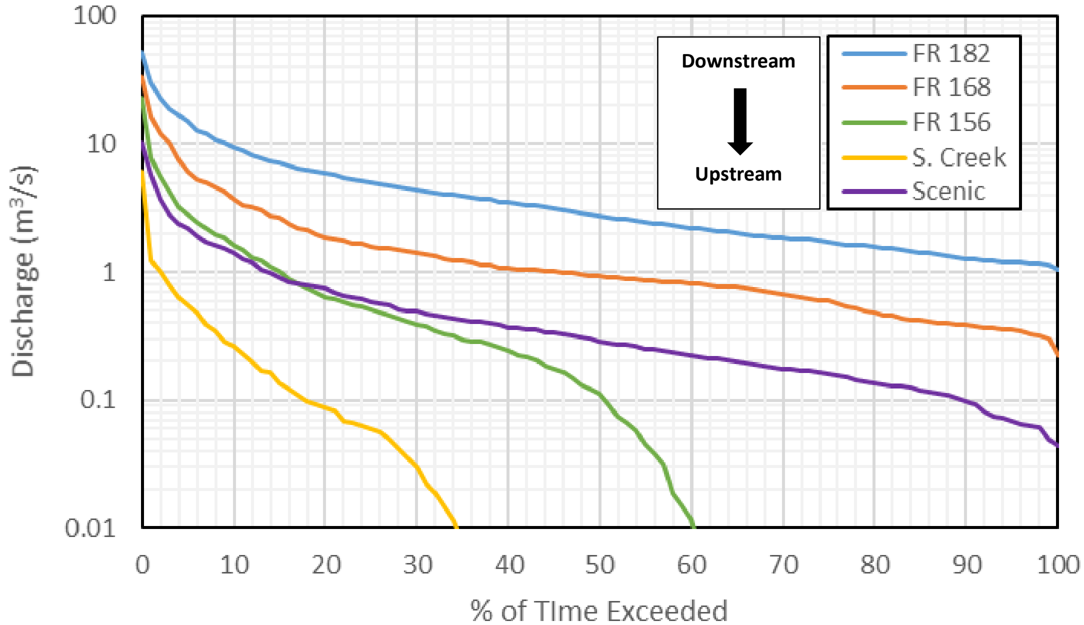


Figure 3. Downstream changes in the flow duration curve in the Wilsons Creek watershed April 1, 2019-March 31, 2021.

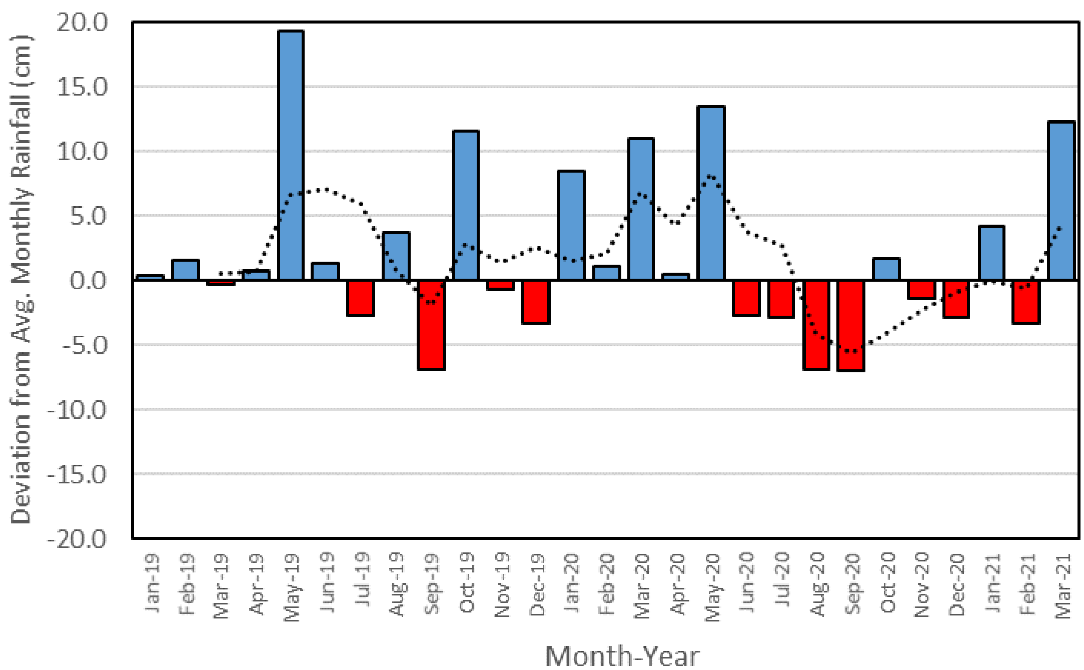
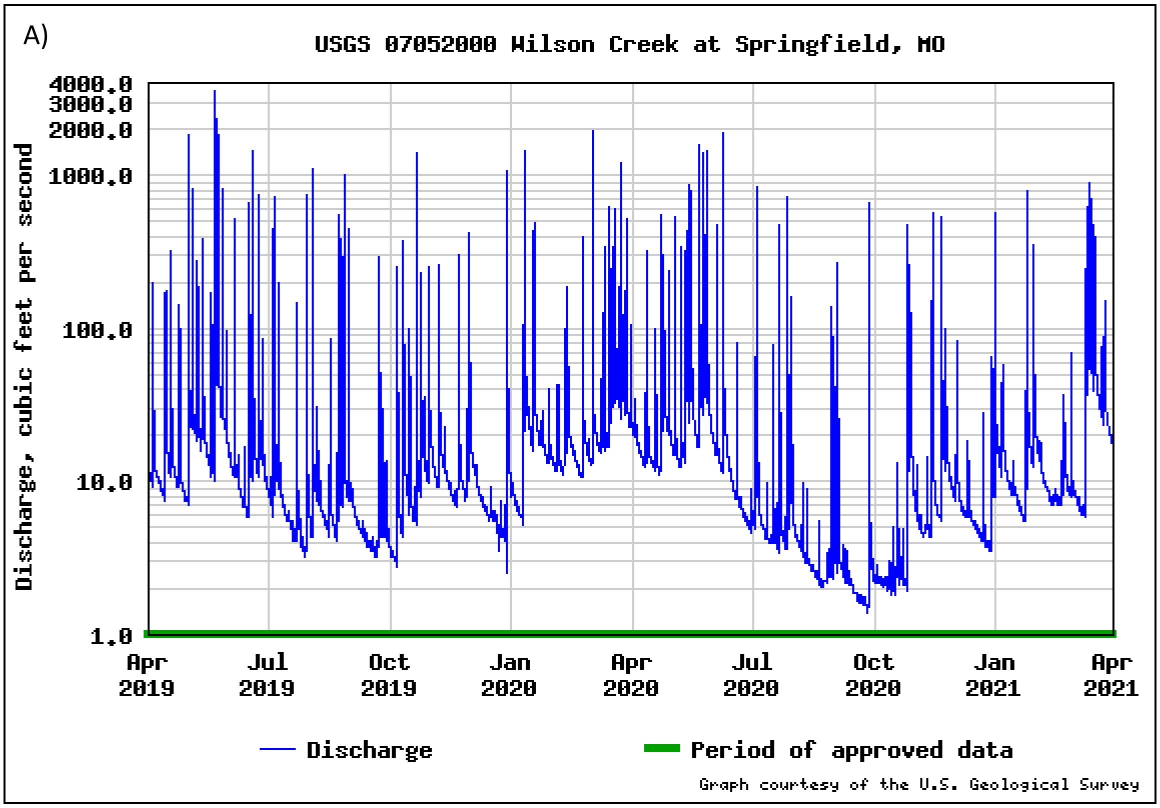


Figure 4. Deviation from the 30-year monthly average rainfall over the monitoring period at the National Weather Service office in Springfield, MO. Note: 30-yr annual average rainfall = 113.6 cm (source: https://www.weather.gov/wrh/climate?wfo=sgf accessed 12/1/2021)



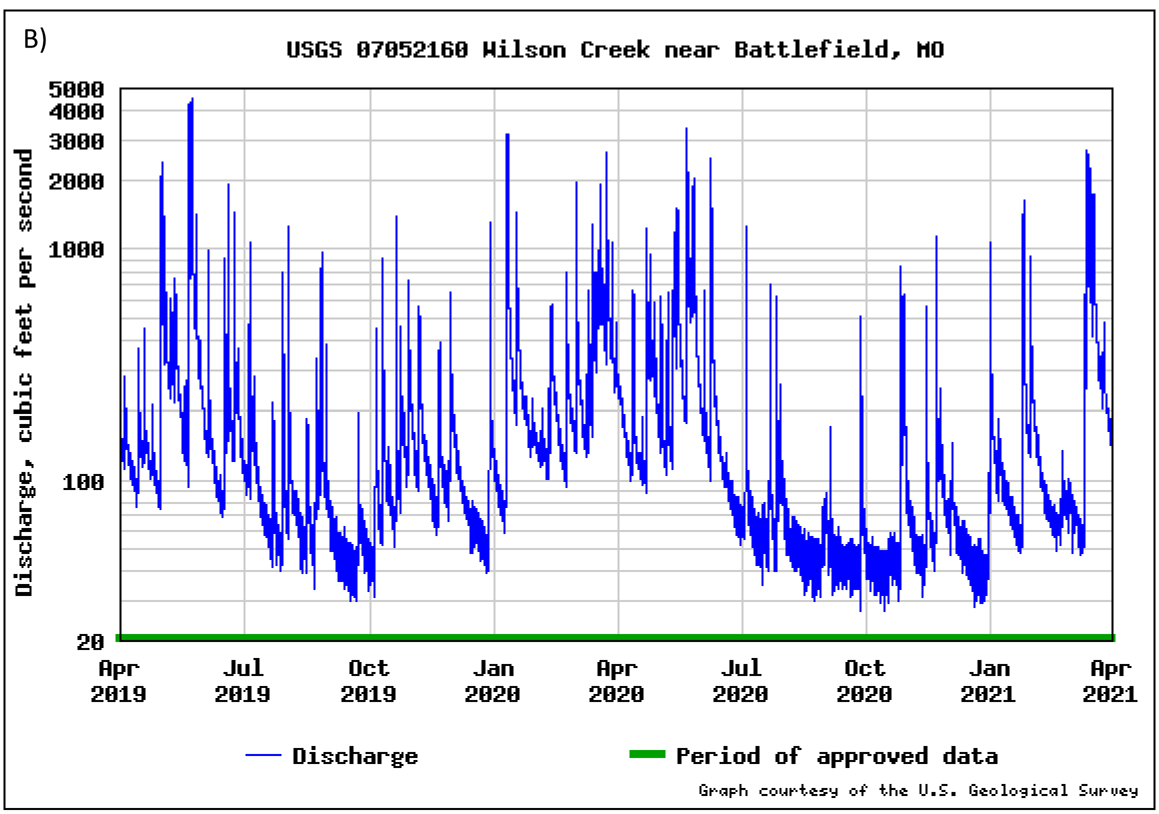


Figure 5. Instantaneous discharge from April 1, 2019 to March 31, 2021 from the USGS gaging stations at A) Scenic and B) Farm Road 182.

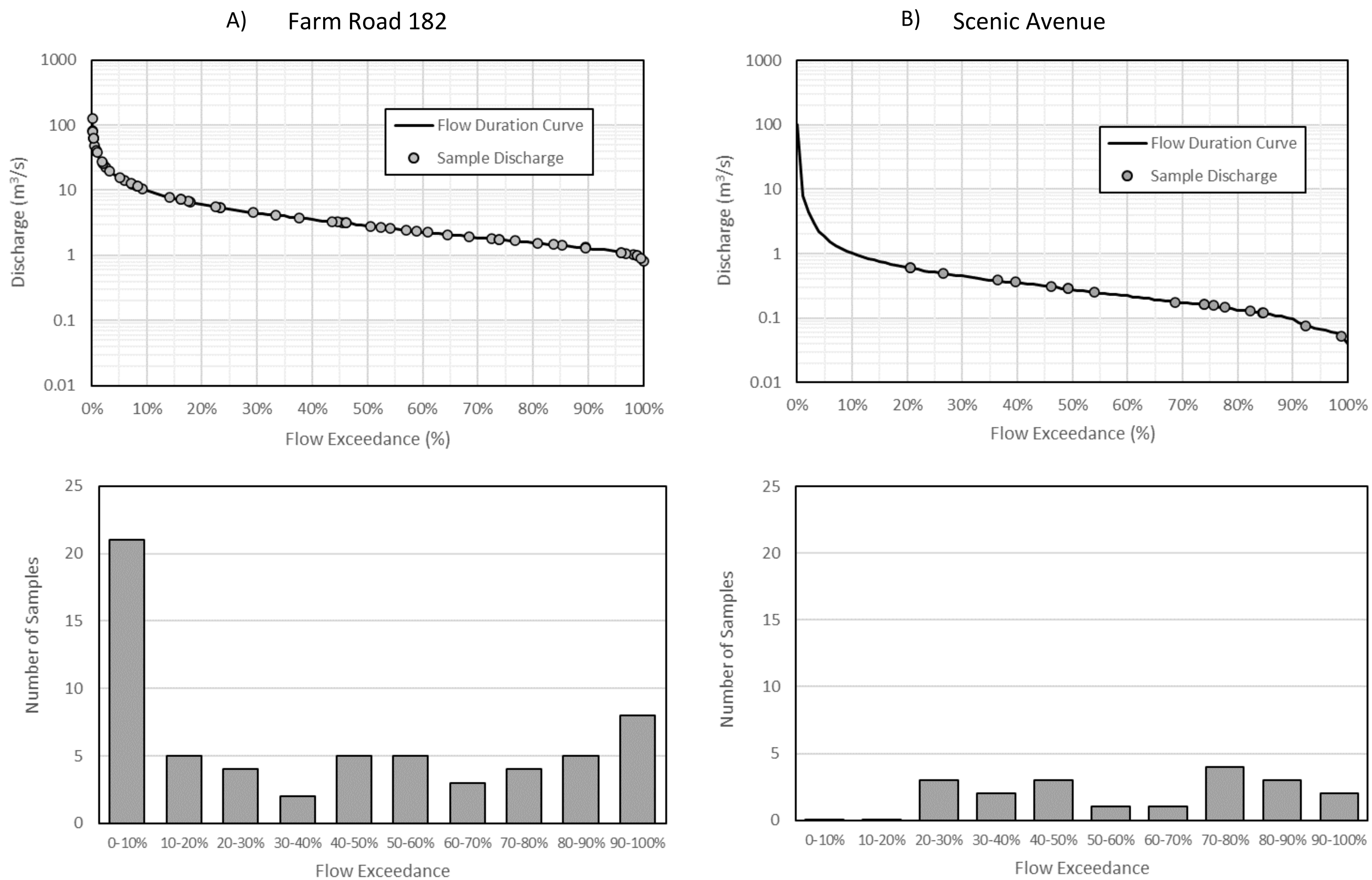


Figure 6. Samples distributed over the two-year monitoring period flow duration curve at the USGS gaging stations at A) Farm Road 182 and B) Scenic Avenue.

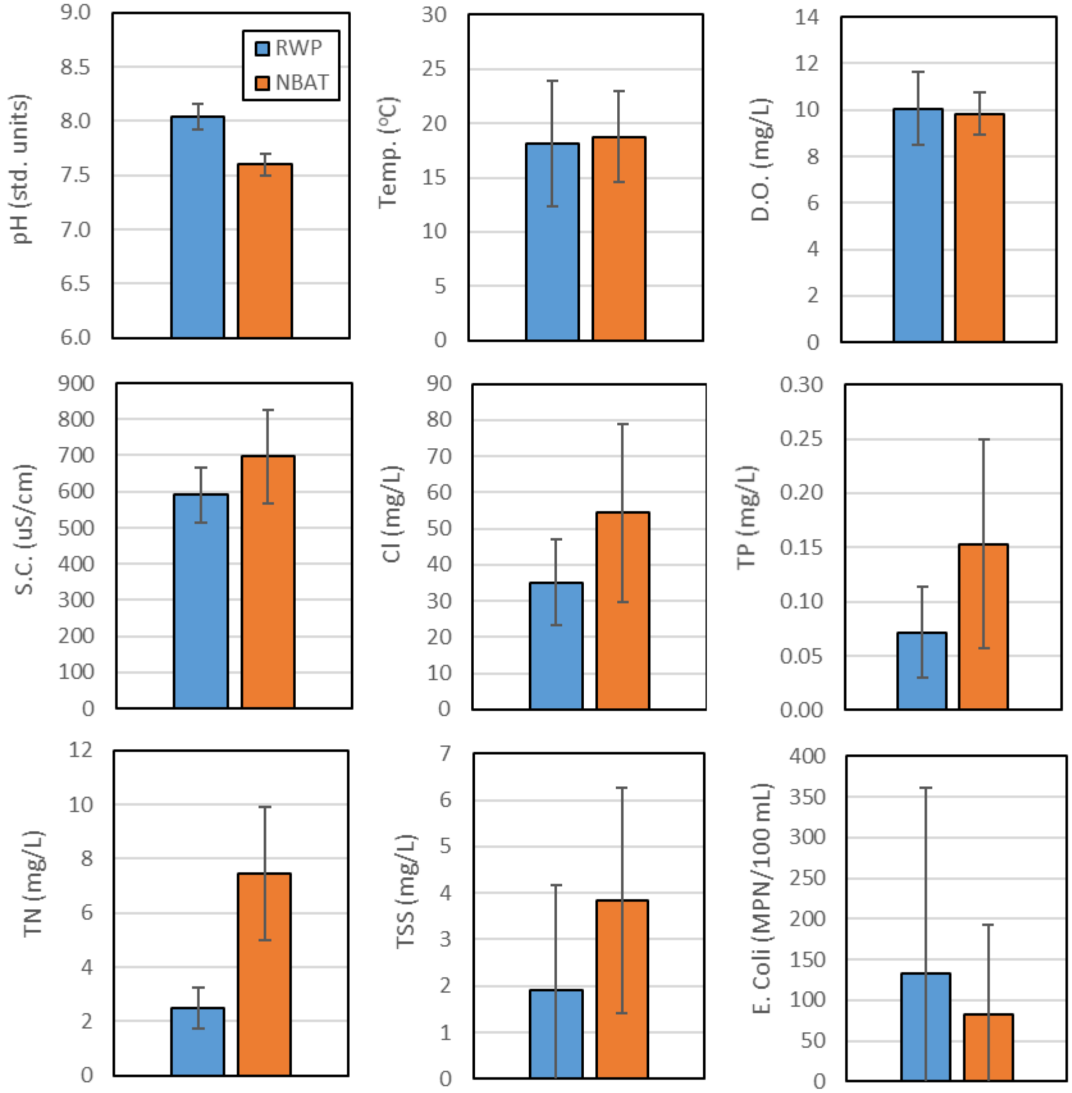


Figure 7. Base flow water quality comparison at RWP and NBAT.

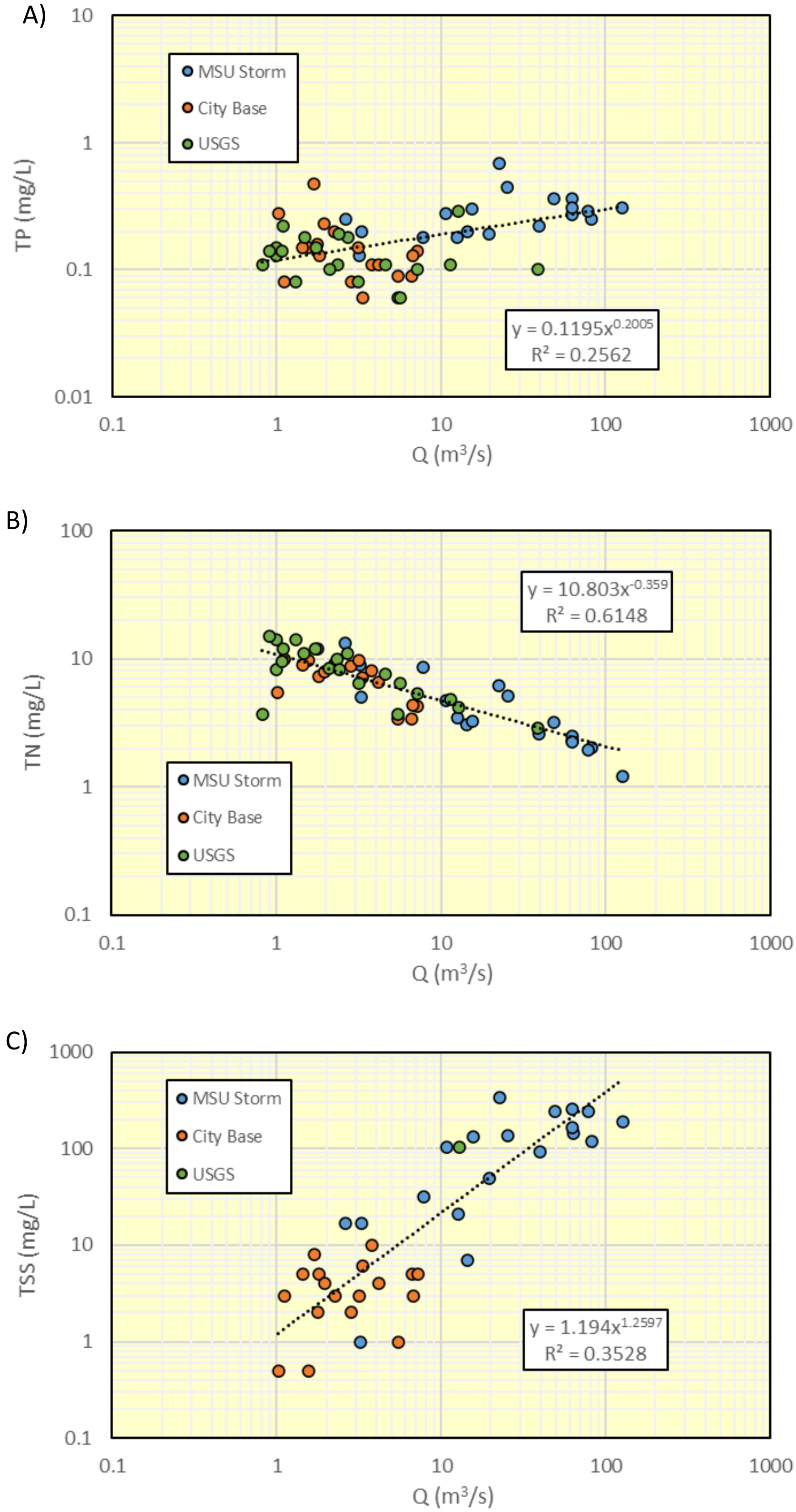


Figure 8. Discharge vs. concentrations of A) TP, B) TN, and C) TSS at NBAT collected over the monitoring period by various agencies.

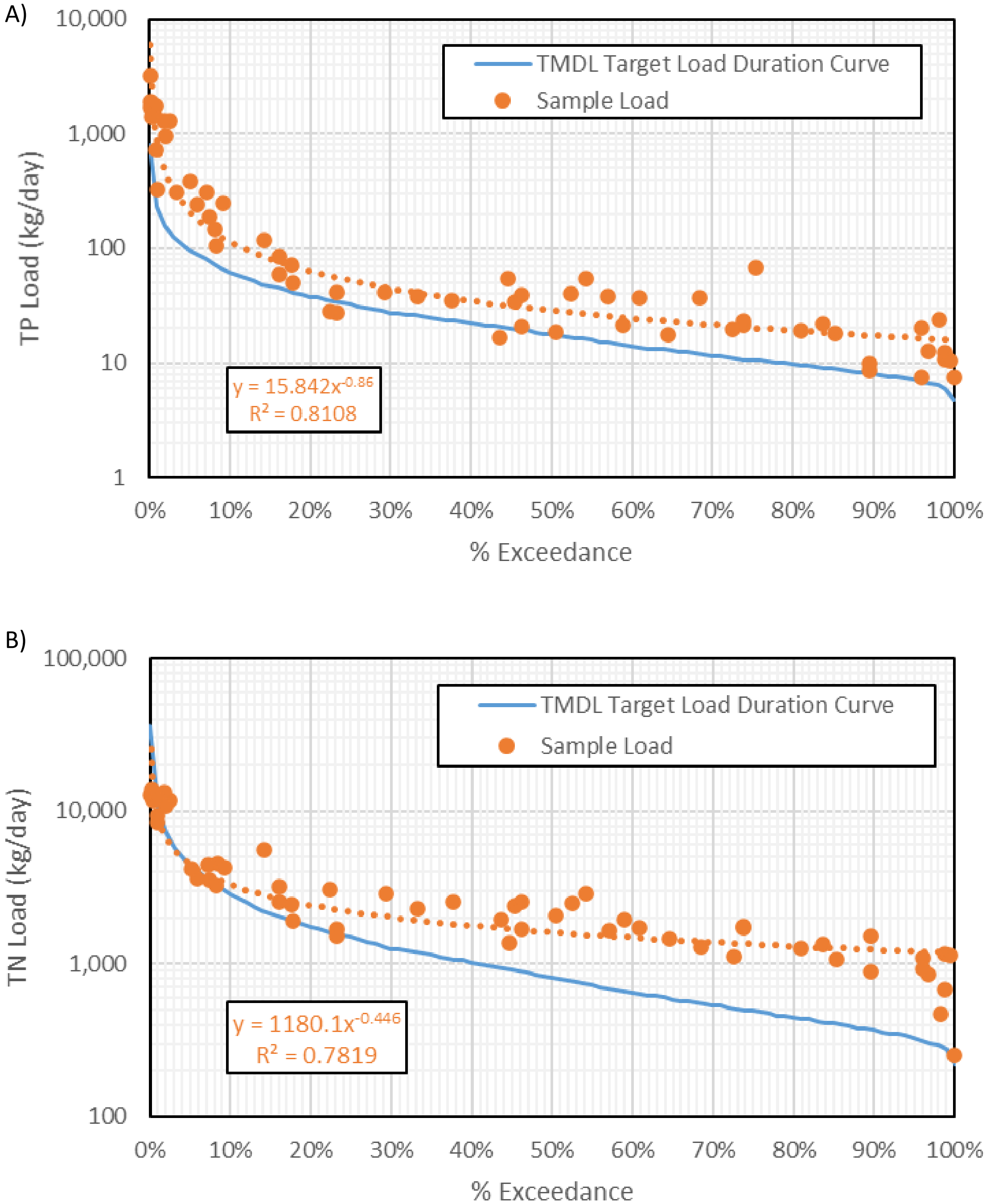


Figure 9. Load Duration Curves for A) TP and B) TN compared to TMDL Target Loads over the monitoring period at NBAT.

APPENDIX

Appendix A. Annual Discharge (Q) and Runoff from USGS Gaging Stations in the Wilsons Creek watershed from Water Years* (WY) 2019-2021.

Site	USGS Gaging Station Number	Drainage Area (km^2)	WY2019 Avg. Q (m^3/s)	WY2020 Avg. Q (m^3/s)	WY2021 Avg. Q (m^3/s)	WY2019 Annual Runoff (cm)	WY2020 Annual Runoff (cm)	WY2021 Annual Runoff (cm)
S. Creek	07052120	27.2	0.12	0.13	0.09	14.0	15.0	10.5
Scenic	07052000	46.1	0.66	0.69	0.59	45.2	47.0	40.1
FR 156	07052100	81.3	0.73	0.80	0.56	28.2	31.2	21.6
FR 168	07052152	132.1	1.80	2.13	1.64	42.9	50.8	39.1
FR 182	07052160	148.5	4.70	5.37	4.03	98.3	112.5	84.1

* Water years go from October 1st-September 30th.

Appendix B. Water Quality Data Collected by OEWRI at National Battlefield (NBAT).

Sample ID	Date	Time	Discharge m^3/s	pH	Temp °C	DO mg/L	SC uS/cm	Cl mg/L	TSS mg/L	TP mg/L	TN mg/L	Total Coliform MPN/100 mL	E. Coli MPN/100 mL	Season
1	4/4/2019	9:10	7.82	6.9	14.1	5.1	650	54.8	32	0.18	8.5	4,836	63.6	Spring
2	5/1/2019	8:10	62.87	6.4	15.9	8.7	238	11.6	145	0.27	2.3	>24,196	9,208	Spring
3	5/1/2019	10:00	39.36	6.7	15.6	9.8	300	15.0	94	0.22	2.6	>24,196	12,033	Spring
4	5/8/2019	13:12	14.36	7.7	16.5	9.0	500	29.0	7.0	0.20	3.1	>24,196	1,373	Spring
5	5/21/2019	8:08	82.41	7.6	16.7	8.0	235	11.2	120	0.25	2.0	>24,196	19,863	Spring
6	5/23/2019	7:25	62.59	7.7	17.4	8.0	345	13.5	258	0.36	2.5	198,630	15,531	Spring
7	5/23/2019	8:58	78.45	7.5	18.0	8.0	237	9.2	241	0.29	1.9	>241,960	24,196	Spring
8	5/23/2019	11:39	125.46	7.7	18.6	7.8	182	5.4	190	0.31	1.2	241,960	24,196	Spring
9	7/29/2019	10:50	22.51	7.9	23.0	7.9	589	72.4	338	0.69	6.2	NA	NA	Summer
10	7/29/2019	11:45	15.49	7.5	23.3	7.2	417	43.4	133	0.30	3.3	NA	NA	Summer
11	8/30/2019	11:00	10.68	7.4	21.2	8.3	755	73.9	105	0.28	4.8	>4,839.2	729.0	Summer
12	10/24/2019	11:30	3.20	7.2	16.5	7.2	685	60.4	1.0	0.13	8.9	>2,419.6	410.6	Fall
13	10/30/2019	12:15	19.57	7.1	12.2	9.8	383	NA	49	0.19	NA	>4,839.2	2,240	Fall
14	3/2/2020	9:15	25.40	7.3	11.0	8.9	351	27.3	135	0.45	5.1	>4,839.2	3,106	Winter
15	3/19/2020	9:30	48.71	7.1	14.4	9.1	337	19.7	246	0.36	3.2	>4,839.2	3,466	Spring
16	6/9/2020	7:45	62.30	7.3	22.0	6.6	427	11.9	166	0.31	2.3	>24,196	24,196	Spring
17	9/28/2020	8:45	3.29	7.0	19.7	6.0	501	51.2	17	0.20	5.0	>2,416.6	5,475	Fall
18	10/26/2020	15:30	2.62	7.3	15.0	8.3	786	96.9	17	0.25	13.2	24,196	2,909	Fall
19	10/29/2020	7:30	12.55	6.8	13.3	8.7	388	29.4	21	0.18	3.4	>24,196	3,106	Fall
20	10/29/2020	12:00	11.75	7.1	13.5	9.3	402	28.4	19	0.15	3.3	>24,196	3,106	Fall
21	1/25/2021	7:30	27.39	7.1	9.8	10.9	611	71.4	322	0.57	5.8	9,804	657.0	Winter
22	1/25/2021	10:00	40.78	7.4	8.2	11.7	277	31.3	375	0.52	3.6	24,196	1,467	Winter

Values <u>underlined</u> and in *italics* are ½ detection limit

NA = not available

Appendix C. Water Quality Data Collected by SWTP at National Battlefield (NBAT).

Sample ID	Date	Time	Discharge m^3/s	pH	Temp °C	DO mg/L	SC uS/cm	Cl mg/L	TSS mg/L	TP mg/L	TN mg/L	Total Coliform MPN/100 mL	E. Coli MPN/100 mL	Season
1	4/10/2019	11:00	2.83	7.5	18.0	10.3	570	57.4	2.0	0.08	8.7	1,733	21.3	Spring
2	5/14/2019	11:39	6.66	7.5	17.5	9.2	580	32.7	5.0	0.09	3.4	>2,419.6	63.8	Spring
3	6/26/2019	11:40	5.49	7.4	19.5	8.0	570	31.0	1.0	0.09	3.4	>2,419.6	131	Summer
4	7/17/2019	15:45	1.82	7.6	25.4	9.0	740	32.4	5.0	0.13	7.4	>2,419.6	74.9	Summer
5	8/12/2019	14:10	1.95	7.7	25.3	9.0	730	46.1	4.0	0.23	7.9	>2,419.6	86.2	Summer
6	9/10/2019	16:01	1.56	7.8	24.4	9.4	760	90.8	<u>*0.5*</u>	0.15	9.8	>2,419.6	68.3	Summer
7	10/22/2019	13:08	3.34	7.4	17.1	9.1	500	43.1	6.0	0.06	7.1	>2,419.6	517	Fall
8	11/13/2019	12:15	3.14	7.5	12.9	10.6	600	57.7	3.0	0.15	9.7	>2,419.6	36.9	Fall
9	12/5/2019	13:25	3.79	7.5	19.0	10.2	610	50.2	10.0	0.11	8.0	2,420	23.3	Fall
10	12/20/2019	14:20	1.77	7.7	12.5	12.1	830	49.3	2.0	0.16	12.0	1,986	34.5	Fall
11	1/28/2020	13:15	4.16	7.5	11.8	10.5	590	65.4	4.0	0.11	6.6	1,046	24.3	Winter
12	3/30/2020	14:30	7.22	NR	14.8	9.7	729	31.8	5.0	0.14	4.2	1,300	32.3	Spring
13	4/28/2020	13:10	6.74	7.6	18.3	9.8	587	32.2	3.0	0.13	4.4	>2,419.6	67.7	Spring
14	6/23/2020	14:20	2.25	7.6	21.8	9.4	605	32.9	3.0	0.20	9.2	>2,419.6	41.4	Summer
15	7/13/2020	15:30	1.68	7.6	24.1	9.7	776	NA	8.0	0.48	NA	>2,419.6	107.6	Summer
16	9/18/2020	12:05	1.12	7.8	21.5	9.3	966	120	3.0	0.08	9.9	>2,419.6	98.5	Summer
17	10/16/2020	13:30	1.02	7.7	18.8	9.8	920	44.1	<u>*0.5*</u>	0.28	5.5	>2,419.6	41.0	Fall
18	11/6/2020	13:50	1.44	7.7	19.0	10.1	777	79.0	5.0	0.15	9.0	>2,419.6	63.8	Fall
19	12/10/2020	12:15	1.33	7.7	15.1	11.2	798	81.4	3.0	0.09	8.1	2,420	28.8	Fall

Values <u>underlined</u> and in *italics* are ½ detection limit

NA = not available

Appendix D. Water Quality Data Collected by USGS at National Battlefield (NBAT).

Sample ID	Date	Time	Discharge m^3/s	pH	Temp °C	DO mg/L	SC uS/cm	Cl mg/L	TP mg/L	TN mg/L	TSS mg/L	E. Coli CFU/100 mL	Season
1	4/9/2019	10:30	3.14	7.5	15.4	10.7	619	NA	0.08	6.4	< 15	**13**	Spring
2	5/22/2019	8:00	38.80	6.7	15.1	8.6	378	14.6	0.10	2.9	< 15	**4,500**	Spring
3	6/12/2019	8:45	2.35	7.3	17.4	7.7	677	NA	0.11	9.9	< 30	120	Spring
4	7/29/2019	12:40	12.80	7.4	23.6	7.2	419	42.6	0.29	4.2	103	210	Summer
5	8/28/2019	9:10	0.82	7.0	19.9	7.1	554	NA	0.11	3.7	< 15	100	Summer
6	9/17/2019	14:45	1.47	7.7	24.1	10	850	NA	0.18	11.0	< 15	**61**	Summer
7	10/17/2019	8:20	2.10	6.2	16.5	6.8	688	70.2	0.10	8.4	< 15	62	Fall
8	11/7/2019	12:00	11.44	7.3	14.3	9.1	450	NA	0.11	4.8	< 15	420	Fall
9	1/15/2020	9:30	7.22	7.2	13.7	8.8	569	39.4	0.10	5.3	< 15	94	Winter
10	2/18/2020	15:10	4.56	7.4	12.7	10.8	633	NA	0.11	7.6	< 15	**171**	Winter
11	6/2/2020	13:15	5.49	7.4	17.8	9.5	551	NA	0.06	3.7	< 15	34	Spring
12	7/6/2020	12:45	2.72	7.4	20.6	8.5	514	NA	0.18	11.0	< 15	**161**	Summer
13	7/27/2020	11:45	0.99	7.7	23.8	8.9	806	94.7	0.13	14.0	< 15	130	Summer
14	8/25/2020	10:45	0.99	7.2	22.6	7.3	927	NA	0.15	8.2	< 15	210	Summer
15	9/1/2020	12:30	2.41	7.4	21.8	6.1	719	82.6	0.19	8.3	< 15	140	Summer
16	9/16/2020	13:10	1.08	7.5	23.1	9.9	855	NA	0.14	9.6	< 15	NA	Summer
17	9/21/2020	10:50	0.91	7.5	20.0	8.2	876	NA	0.14	15.0	< 15	86	Fall
18	10/20/2020	12:45	1.10	7.5	17.7	8.9	789	103	0.22	12.0	< 15	**18**	Fall
19	11/9/2020	14:10	1.73	7.4	19.1	10.1	770	NA	0.15	12.0	< 15	21	Fall
20	12/14/2020	10:00	1.30	6.1	12.1	11.5	825	NA	0.08	14.0	< 15	**37**	Fall
21	2/2/2021	12:50	5.66	7.2	12.3	10.8	533	45.9	0.06	6.5	< 15	**72**	Winter

NA = not available

Bold values are estimated

Appendix E. Water Quality Data Collected by SWTP at Rutledge-Wilson Park (RWP).

Sample ID	Date	Time	Discharge (m^3/s)*	pH	Temp °C	DO mg/L	SC uS/cm	Cl mg/L	TSS mg/L	TP mg/L	TN mg/L	E. Coli MPN/ 100 mL	Season
1	4/10/2019	11:25	0.25	8.2	18.5	10.9	510	38.7	2.0	0.01	2.0	41.4	Spring
2	5/14/2019	11:10	0.50	7.9	16.8	9.6	570	28.6	2.0	*0.01*	2.1	96.0	Spring
3	6/26/2019	11:15	0.36	7.8	20.5	8.1	560	25.6	*0.5*	0.08	1.7	106.7	Summer
4	7/17/2019	14:10	0.15	8.1	25.8	9.2	570	62.2	1.0	0.03	2.2	156.5	Summer
5	8/12/2019	13:40	0.16	8.0	27.2	8.5	570	28.0	*0.5*	*0.01*	2.3	141.4	Summer
6	9/10/2019	15:45	0.12	8.2	26.9	9.8	550	42.3	*0.5*	0.05	2.0	119.8	Summer
7	10/22/2019	12:45	0.29	8.0	15.5	9.0	410	20.3	2.0	0.06	1.9	1,046	Fall
8	11/13/2019	11:46	0.29	8.0	8.7	11.0	590	30.5	1.0	0.10	2.6	71.7	Fall
9	12/5/2019	12:52	0.31	8.1	17.5	11.2	560	33.3	10.0	0.08	2.4	23.1	Fall
10	12/20/2019	13:50	0.16	8.3	8.1	14.8	750	49.2	4.0	0.14	2.2	6.3	Fall
11	1/28/2020	12:52	0.39	8.1	10.3	11.5	580	54.2	1.0	0.08	3.0	48.0	Winter
12	3/30/2020	12:05	0.61	NR	14.4	9.9	762	28.8	2.0	0.10	3.2	62.0	Spring
13	4/28/2020	12:48	0.61	7.9	18.4	9.8	583	29.0	2.0	0.08	3.1	45.7	Spring
14	6/23/2020	13:50	0.16	8.1	23.2	9.6	591	22.5	2.0	0.15	2.9	68.2	Summer
15	7/13/2020	15:10	0.12	8.1	25.7	9.2	597	NA	4.0	0.09	NA	145.5	Summer
16	9/18/2020	11:40	0.05	8.0	19.2	8.9	587	41.1	*0.5*	0.08	4.9	95.9	Summer
17	10/16/2020	13:00	0.08	7.9	13.7	8.4	638	17.6	*0.5*	0.10	2.6	29.2	Fall
18	11/6/2020	13:30	0.13	8.0	17.0	10.3	618	40.0	*0.5*	0.10	1.8	31.8	Fall
19	12/10/2020	12:15	0.17	8.0	16.4	11.7	623	38.8	*0.5*	*0.03*	2.3	196.8	Fall

Values underlined and in *italics* are ½ detection limit

NA = not available

Appendix F. FLUX[32] Total Phosphorus Load Estimate Output.

FLOW AND LOAD SUMMARIES FOR TPmg/L

Method: C/Q Reg3(daily) (6)
DISTRIBUTION OF SAMPLES VS. DAILY FLOWS

Stratum	Flows	Smpls	Evnts	Vol %	Daily Flow (CFS)	Smpl Flow(TPmg/L) (CFS)	(mg/L)	Flux (kg/y)	SLOPE LgC/LgQ	R^2	p > C/Q
1 Flow < 1/2 Me	314	22	22	14.4	58.9137	53.25	0.17	9045.56	0.2088	0.03	0.4748
2 Flow < 2x Mea	342	19	19	45.2	170.025	165.6	0.12	17966.00	-0.2235	0.04	0.4112
3 Flow < 8x Mea	69	9	9	32.6	607.002	719.6	0.27	156282.00	0.2656	0.04	0.6000
4 Flow > 8x Mea	5	5	5	7.8	2015.96	2354	0.30	544602.00	-0.09744	0.03	0.7908
Overall	730	55	55	100.0	176.178	410.3	0.18	30809.80	0.1667	0.16	0.0029

STRATUM BOUNDARIES(CFS)

STRATUM	LOWER LIMIT	UPPER LIMIT
1 Flow < 1/2 Me	0	88.09
2 Flow < 2x Mea	88.09	352.4
3 Flow < 8x Mea	352.4	1409
4 Flow > 8x Mea	1409	4431

DAILY FLOW STATISTICS
Daily Flow Duration 730 Days = 1.999 Years
Daily Mean Flow Rate 176.2 (CFS)
Daily Total Flow Volume 255120 (Acre Feet)
Daily Flow Date Range 04/02/2019 to 03/31/2021
Samples Date Range 04/04/2019 to 02/02/2021

FLOW SEPARATION
Method: Local Minimum
Base Flow Index: 0.701
Base Flow Volume 178732.24 (Acre Feet) Percent of Total 70.06
Storm Flow Volume 76387.765 (Acre Feet) Percent of Total 29.94

LOAD ESTIMATES FOR TPmg/L

Method	Mass(kg)	Flux Rate(kg/y)	Flux Variance	Flw Wgted Conc.(mg/L)	C.V.
1 Average Load	67527.7	33787.00	3.320076E7	0.215	0.1705
2 Flw Wghted Conc.	61887.7	30965.00	1.7798E7	0.197	0.1362
3 Flw Wghted IJC.	61990.6	31016.50	2.078114E7	0.197	0.1470
4 C/Q Reg1	60730.7	30386.10	1.408176E7	0.193	0.1235
5 C/Q Reg2(VarAdj)	60216.4	30128.80	1.179821E7	0.191	0.1140
6 C/Q Reg3(daily)	61577.4	30809.80	1.505975E7	0.196	0.1260
8 Time Series*	61582.7	30812.40	2308903	0.196	0.0493

*Time series estimates use residual interpolation.
Maximum Interpolation Gap is set at 10.03 days

Appendix G. FLUX[32] Total Nitrogen Load Estimate Output.

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                                FLOW AND LOAD SUMMARIES FOR TNmg/L

Method: C/Q Reg3(daily) (6)
DISTRIBUTION OF SAMPLES VS. DAILY FLOWS
                                                  Daily Flow    Smpl Flow(TNmg/L)     Flux     SLOPE
Stratum           Flows  Smpls  Evnts  Vol %         (CFS)         (CFS)    (mg/L)     (kg/y)  LgC/LgQ  R²    p > C/Q
1 Flow < 1/2 Me     314     21     21   14.4       58.9137         52.96     9.76     526621  0.08146 0.01   0.7156
2 Flow < 2x Mea     342     19     19   45.2       170.025         165.6     6.93     944214  -0.7155 0.45   0.0019
3 Flow < 8x Mea      69      8      8   32.6       607.002         723.2     4.16    2273450 -0.06342 0.02   0.7386
4 Flow > 8x Mea       5      5      5    7.8       2015.96          2354     2.36    4558170  -0.6802 0.80   0.0380
Overall             730     53     53  100.0       176.178         411.6     7.20     914985  -0.3455 0.67   0.0000

STRATUM BOUNDARIES(CFS)
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STRATUM            LOWER LIMIT        UPPER LIMIT
1 Flow < 1/2 Me    0                  88.09
2 Flow < 2x Mea    88.09              352.4
3 Flow < 8x Mea    352.4              1409
4 Flow > 8x Mea    1409               4431

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DAILY FLOW STATISTICS
Daily Flow Duration        730 Days = 1.999 Years
Daily Mean Flow Rate       176.2 (CFS)
Daily Total Flow Volume    255120 (Acre Feet)
Daily Flow Date Range      04/02/2019 to 03/31/2021
Samples Date Range         04/04/2019 to 02/02/2021

LOAD ESTIMATES FOR TNmg/L                                                 Flw Wgted
     Method                Mass(kg)  Flux Rate(kg/y)     Flux Variance     Conc.(mg/L)    C.V.
1  Average Load            1835740          918499        3.8688E9          5.833        0.0677
2  Flw Wghted Conc.        1813820          907531       2.28303E9          5.764        0.0526
3  Flw Wghted IJC.         1807320          904279     2.373546E9          5.743        0.0539
4  C/Q Reg1                1811690          906466     2.069262E9          5.757        0.0502
5  C/Q Reg2(VarAdj)        1811340          906290     2.010383E9          5.756        0.0495
6  C/Q Reg3(daily)         1828720          914985     2.013384E9          5.811        0.0490
8  Time Series*            1774810          888013     6.404117E8          5.640        0.0285

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*Time series estimates use residual interpolation.
 Maximum Interpolation Gap is set at 10.03 days
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Appendix H. FLUX32 Total Suspended Sediment Load Estimate Output.

FLOW AND LOAD SUMMARIES FOR TSSmg/L

Method: C/Q Reg3(daily) (6)

DISTRIBUTION OF SAMPLES VS. DAILY FLOWS

Stratum	Flows	Smpls	Evnts	Vol %	Daily Flow (CFS)	Smpl Flow (CFS)	(TSSmg/L) (mg/L)	Flux (kg/y)	SLOPE LgC/LgQ	R^2	p > C/Q
1 Flow < 1/2 Me	314	10	10	14.4	58.9137	56.25	3.40	250071	1.581	0.18	0.2268
2 Flow < 2x Mea	342	13	13	45.2	170.025	163.8	8.15	1445650	0.2403	0.01	0.7700
3 Flow < 8x Mea	69	7	7	32.6	607.002	671.8	122	109636000	1.932	0.34	0.1695
4 Flow > 8x Mea	5	5	5	7.8	2015.96	2354	176	328976000	-0.03321	0.00	0.9658
Overall	730	35	35	100.0	176.178	547.6	53.6	13400900	1.216	0.72	0.0000

STRATUM BOUNDARIES(CFS)

STRATUM	LOWER LIMIT	UPPER LIMIT
1 Flow < 1/2 Me	0	88.09
2 Flow < 2x Mea	88.09	352.4
3 Flow < 8x Mea	352.4	1409
4 Flow > 8x Mea	1409	4431

DAILY FLOW STATISTICS

Daily Flow Duration	730 Days = 1.999 Years
Daily Mean Flow Rate	176.2 (CFS)
Daily Total Flow Volume	255120 (Acre Feet)
Daily Flow Date Range	04/02/2019 to 03/31/2021
Samples Date Range	04/04/2019 to 01/25/2021

LOAD ESTIMATES FOR TSSmg/L

Method	Mass(kg)	Flux Rate(kg/y)	Flux Variance	Flw Wgted Conc.(mg/L)	C.V.
1 Average Load	24311100	12163900	2.210293E13	77.3	0.387
2 Flw Wghted Conc.	21913800	10964400	1.200953E13	69.6	0.316
3 Flw Wghted IJC.	22711300	11363400	1.432501E13	72.2	0.333
4 C/Q Reg1	19089300	9551200	7.233781E12	60.7	0.282
5 C/Q Reg2(VarAdj)	18264500	9138490	3.7457E12	58.0	0.212
6 C/Q Reg3(daily)	26783500	13400900	2.182832E13	85.1	0.349
8 Time Series*	22566400	11290900	1.807814E12	71.7	0.119

*Time series estimates use residual interpolation.
Maximum Interpolation Gap is set at 10.03 days