The Ozarks Environmental and Water Resources Institute (OEWRI)

Final Report

for the

Water Quality Monitoring and Analysis of the Bennett Spring Watershed and Recharge Area

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SCOPE AND OBJECTIVES

Poorly functioning on-site wastewater systems are perceived as a major contributor of nonpoint source pollution to Ozarks streams. Shallow soils, karst features, and lack of maintenance are often cited as reasons these systems fail in this region leading to ground and surface water contamination. Due to the importance of tourism to the local economy, many communities are concerned with protecting their water resources. Bennett Spring State Park is a major economic generator for Dallas and Laclede counties, and local community leaders are concerned about how on-site wastewater systems impact the water quality of Bennett Spring.

The Southwest Missouri Council of Governments (SMCOG) in cooperation with the Bennett Springs Area Water Protection Committee (BSWPC) has received a Clean Water Act 604(b) subgrant from the U.S. Environmental Protection Agency (EPA) Region 7, through the Missouri Department of Natural Resources (DNR), to address on-site wastewater issues in the watershed.

The objectives of the subgrant are to:

1. Conduct a wastewater system feasibility study of the project area to determine the most cost-effective wastewater system that will meet the area’s needs.

2. Create a plan to implement a wastewater district within, and under the authority of, the existing water district.

3. Provide for water quality education to enhance public awareness of the area’s water quality issues and to build grassroots support for implementing a wastewater system that sustains the quality of the environment.

4. Provide for water quality assessment and monitoring in the project area to establish a baseline for determining water quality and future water quality needs and activities.

The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University is responsible for the water quality assessment and monitoring portion of this project. The specific goals of the water quality monitoring are:

1. Use the watershed approach and most up-to-date estimates of groundwater flow direction and recharge to determine water quality. Available historical water quality and groundwater data will also be used in the assessment.

2. Establish a baseflow sampling network and monitor 14 sites monthly for at least one year.

3. Interpret water quality trends and assess the spatial variability of water quality within the recharge area.

This report summarizes and organizes data collected for this project and interprets water quality of Bennett Spring and contributing recharge area watersheds, analyzes downstream seasonal trends, and make recommendations for further action.

STUDY AREA

The Bennett Spring Branch Watershed (111 km^2) is located in the Niangua River Basin (2,665 km^2) near the eastern Dallas County and western Laclede County with an estimated recharge area of nearly 674 km^2 (Figure 1). The underlying geology is predominately dolomite with layers of shale and sandstone present (Strudevant, et al, 2001). The headwaters begin along the Lebanon plain near Interstate 44 with broad flat uplands with significant loess accumulations to steeper sideslope areas of thin soils derived from cherty residuum (Strudevant, et al, 2001). Land use within the Bennett Spring Branch watershed is mostly forest (>50%) with grass/pasture representing the second highest land use at around 40% of the total area (Table 2). Grass and pasture are the dominant land use in the recharge areas. The Bennett Spring is located only 2.5 km upstream of the confluence with the Niangua River and has an average daily flow of nearly 378 million liters of water per day (MDNR, 2008).

METHODS

This section describes methods used for water quality sample collection and water quality analysis. For more details on these methods the approved Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOPs) for this project are available on our website at http://www.oewri.missouristate.edu .

Sample Sites

There were 14 sampling sites chosen for this project based on the following criteria:

1. Road access
2. Proximity to known dye-trace locations
3. Distribution of monitoring sites throughout the recharge area
4. Having permanent year round flow

Due to the lack of access and absence of water during low-flow periods only 5 sites are sampled within the Bennett Spring Branch Watershed. The remainder of the sites are in the Bennett Spring recharge area (7) and upstream and downstream of the confluence of the Bennett Spring Branch and the Niangua River (2). Figure 2 is a map of the sample sites. Tables 1 and 2 summarizes the sample sites selected for this project including land use (as of 2005) and drainage area details.

Sample Collection

This project sampled water quality at 14 sites in the recharge area of Bennett Spring once a month during the period of March 2007 to February 2008 at baseflow conditions for discharge, nutrients, bacteria and water chemistry. Water chemistry was measured at each site by a Horbia U22 multi-probe meter. Water chemistry parameters measured include temperature, dissolved oxygen, turbidity, conductivity, and pH. Grab samples for nutrients were collected at each site in 500mL containers, preserved and cooled in the field. Bacteria sample were collected in sterilized bacteriology Coli-Test bags that are discarded after use.

Discharge Measurements

Discharge was estimated at sites in one of three ways:

1. Direct measurement of velocity and cross-sectional geometry (sites 1-7, 9 and 13-14).

2. USGS gaging station (site 10).

3. Estimation of discharge for reaches located immediately up or downstream of USGS Gage (sites 8, 11 and 12).

All discharge data are presented in cubic meters per second (m^3/s). Important conversion to flow in other units are given here:

1 m^3/s = 35.31 ft^3/s
1 m^3/s = 22.83 million gallons/day

Due to the karst characteristics of the Ozarks, very low and non-persistent flow during the sampling period made for difficulty in sampling at each location consistently. Sampling data is put into one of four categories:

1. Flow - discharge was measured at this location at this date and sample collected

2. Flow, but too low to measure - flow was observed, but it was too low to measure and sample was collected

3. Water, but no flow (i.e. water in pool) - No flow was observed but water was present and sample was collected

4. Dry, no water - No water present and no sample collected

Nutrient Analysis

Samples were analyzed at Missouri State University Chemistry Laboratory. Total nitrogen (TN) was analyzed by a Hitachi UV-2001 Spectrophotometer and total phosphorus (TP) was analyzed by a Spectronic Genesys 20 Spectrophotometer.

Average detection limits were 0.2 mg/L TN and 3 ug/L TP with accuracy within the range of + or – 20%.

Bacteria Analysis
The IDEXX Quanti-Tray/2000 system is used to analyze water samples for the presence of total Coliform and E. coli. The detection limit of this machine is 1 MPN/100ml with accuracy of + or – 20%.

RESULTS

Data collected for this study is summarized by parameter below.

Sample Collection and Discharge
Each of the 14 sampling sites was visited monthly from February 2007 to February 2008. Over that sampling period a total of 127 discharge measurements, 154 samples were collected and analyzed for nutrients, 126 bacteria samples, 168 water chemistry readings for pH, temperature and specific conductivity, 145 dissolved oxygen, and 149 turbidity readings over the sampling period. Data can be viewed by parameter for each site in Appendix A. During the monthly sampling, flow measurements were either collected at the site or estimated from USGS gages. Over the sampling period, flow occurred 50% of the time at 12 of the 14 sites (Figure 3). Two sites, 1 and 9, had flow less than 50% of the time, but were not ever dry with standing water in pools present throughout the year. Three sites, 5,6, and 7 had periods where they were completely dry over the sampling period. Sites 8, 10, 11, 12, and 14 had 100% flow throughout the sampling period. A lengthy no flow period, with either no water or water standing in pools but no flow, occurred between July and December (Table 3).

Total Phosphorus
Total phosphorus (TP) refers to the combined dissolved and particulate forms of phosphorus found in aquatic ecosystems. This nutrient is known to be the limiting factor for eutropication in streams and rivers in the Ozarks that can impair these sensitive ecosystems even at relatively low concentrations (MEC, 2007). Phosphorus tends to be found in its particulate form and is typically high is storm events where it is washed into streams off of surfaces during overland flow. Average mean TP concentrations for all sites ranged from 0.013 to 0.154 mg/L with an overall average concentration 0.059 mg/L. Using 0.075 mg/L from the James River Basin TMDL as the limit for TP concentration, 12 of the 14 sites have median concentrations less than that limit (MDNR, 2001) (Figure 4). Two sites, sites 2 and 3, are both wastewater treatment plant influenced and have median concentrations of 0.18 and 0.13 respectively. Site 5 has the highest variability between all sites with TP concentrations ranging from 0.027 mg/L to 0.78 mg/L over the sampling period. The median concentration, however, falls below the 0.075 mg/L limit from the James River Basin TMDL. The site at Bennett Spring, site 10, TP concentrations ranged from 0.007 to 0.052 mg/L with a mean concentration of 0.025 mg/L throughout the sampling period. During no flow conditions where water was in pools, TP concentrations ranged from as low as 0.018 mg/L to as high as 0.424 mg/L at site 5 (Table 4).

Total Nitrogen

Total nitrogen (TN) is a combined figure of several forms of nitrogen found in aquatic ecosystems. Nitrogen is a nutrient important to plant growth and tends to be concentrated in its dissolved form during baseflow periods. Average mean TN concentrations for all sites ranged from 0.13 to 1.82 mg/L with an overall average concentration 0.69 mg/L. Using 1.5 mg/L from the James River Basin TMDL as the limit for TN concentration, 12 of the 14 sites have median concentrations less than that limit (Figure 5). Two sites, sites 2 and 5, have median concentrations slightly higher than the 1.5 mg/L limit. Again, site 5 has the highest variability between all sites with TN concentrations over the sampling period. The site at Bennett Spring, site 10, has TN concentrations ranging from 1.32 to 1.56 mg/L with a mean concentration of 1.43 mg/L throughout the sampling period. No flow TN concentrations ranged from 0.25 mg/L to as high as 5.86 mg/L at site 5 (Table 4).

E. Coli

The presence of *E. Coli* in water samples is an indicator of fecal contamination. Average geometric mean *E. Coli* counts for all sites ranged from 3.6 to 169 MPN/100mL with an overall average concentration 46 MPN/100mL. Using 126 MPN/100mL from the MDNR as the limit whole body contact in class A streams, 11 of the 14 sites have median concentrations less than that limit (Figure 6). Three sites, sites 2, 5, and 7, have median concentrations higher than the 126 MPN/100mL limit for class A streams but far below the 548 MPN/100mL designated for class B streams. Site 5 has the highest variability between all sites with E. *Coli* counts over the sampling period. Of the 126 samples collected, 23% of the samples exceeded the whole body contact limit for class A streams. Sites 2 and 5 exceeded this count 5 of the 11 months bacteria samples were collected. The site at Bennett Spring, site 10, has E. *Coli* counts ranging from 1 to 194 MPN/100mL/L with a geometric mean of 25 MPN/100mL over the sampling period. E. *Coli* numbers ranged from 2 to a high of 2,419.6 MPN/100mL at site 5 during no flow conditions (Table 4).

Specific Conductivity

Average mean SC for all sites ranged from 0.460to 0.832 mS/cm with an overall average SC of 0.668 mS/cm. The lowest variability occurred along sites 1,2,8,10, 11, and 12 which are all along either the main stem of the Niangua River or at or below Bennett Spring on the spring branch tributary (Figure 7). The site at Bennett Spring, site 10, has SC ranging from 0.221 to 0.858 mS/cm with a mean of 0.686 throughout the sampling period. Specific conductivity ranged from a high of 0.932 mS/cm to a low of 0.554 mS/cm at site 5 during no flow conditions (Table 4)

Dissolved Oxygen

The level of dissolved oxygen (DO) in water affects aquatic life, chemical activity, and pollutant behavior. Acceptable levels for Missouri streams are > 5 mg D.O. per L. for warm and cool water fisheries and >6 mg/L for cold water fisheries. Average mean DO concentrations for all sites ranged from 6.31 to 10.66 mg/L with an overall average DO concentration of 8.58 mg/L. There are no significant patterns in the variability in DO concentrations between sites (Figure 8). The site at Bennett Spring, site 10, has DO concentrations ranging from 3.79 to 11.58 mg/L with a mean of 8.59 mg/L throughout the sampling period. During no flow conditions DO concentrations were measured as high as 6.2 mg/L to as low as 1.2 mg/L at site 5 (Table 4).

Other Water Chemistry Parameters
No significant trends can be seen in pH, temperature, and turbidity between or at sample sites. The pH ranged from 6.5 to 9 with the highest variability at site 13 (Figure 9). Site 10 at Bennett Spring had the lowest pH variability between sites ranging from 7 to 7.5 throughout the study period. Temperature ranged from 2 to 30 degrees C for the sampling period with site 3 and 8 having the highest variability (Figure 10). Temperature readings at the spring were consistently around 15 degrees C during the study period. Turbidity readings were also highly variable at most sites ranging from very clear around 0 NTUs to as high as 800 NTU (Figure 11).

DOWNSTREAM SEASONAL TRENDS

For the seasonal trend analysis, a subset of 7 sites will be compared. Sites 6,7,9,10, and 11 are in order from upstream to downstream along the Bennett Spring Branch tributary with site 10 being the spring site (Figure 12). Sites 8 and 12 are along the Niangua River with site 8 being upstream of the Bennett Spring Branch and site 12 being downstream of the confluence with the Bennett Spring Branch tributary. For this comparison all samples, including samples from standing pools, were used.

This study focused on baseflow sampling, consequently flow variability upstream of the spring lead to inconstant discharge measurements at sites 6, 7, and 9 compared to downstream of the spring and at Niangua sites with relatively consistent flow during the sampling period. Upstream of the spring discharge was very inconsistent through the sampling period with no fall 2007 flows recorded and only Site 6 had flow during the summer 2007 period (Figure 13). The winter season was the only season of consistent downstream flow record. For the spring sites and big river sites fall 2007 had the lowest flow records and winter 2007/08 had the highest flow records during sampling. Spring and summer had similar flow records.

Wastewater treatment plant influences appear to be major contributors affecting Niangua River TP concentrations more than the trout hatchery, which is the major TP source in the Bennett Spring Branch tributary. Upstream of the spring TP concentrations are lowest in the fall and highest in the summer months with the exception of site 9 with the highest concentration in the winter (Figure 14). The samples during the summer at site 7 illustrate how low water conditions can effect TP concentrations. When DO levels drop, TP is released from sediments and organic matter into its dissolved form and becomes more concentrated during summer baseflow conditions. Downstream of the spring, TP concentrations are high in the spring and summer months and lowest in the winter. Upstream of the tributary branch on the Niangua, TP concentrations are lowest in the spring and highest in the summer. Downstream of the tributary branch on the Niangua TP concentrations were higher in the winter and summer and lower in the fall and spring. These data suggest the

Bennett Spring tributary is diluting the TP concentrations in the Niangua during the summer and fall during low baseflow periods. At higher baseflow conditions during the winter and spring months, the Bennett Spring tributary appears to be a source of TP to the Niangua River system. This appears to have more to do with the Niangua River system and annual hydrologic fluctuations and the trout hatchery located just above the confluence than the water quality of Bennett Spring, which remain relatively consistent throughout the year.

Data from this study show Bennett Spring is a nitrogen source the Niangua River system. Total nitrogen concentrations decreased downstream in the winter and spring at sites located above the spring with the highest concentrations in the summer months for sites 7 and 9 (Figure 15). Below the spring, TN concentrations increase from the low baseflow periods of the summer and fall to the higher baseflow periods in the winter and spring. Concentrations are generally higher in the winter months when uptake by plants is limited due to leaf off conditions and colder weather. Nitrogen remains dissolved in aerobic conditions and tends to be in higher concentrations in groundwater which is apparent in the sharp increase in concentration between Site 9 above and Site 10 at the spring. This is why the Bennett Spring is a TN source to the Niangua River system with TN concentration increase from site 8 to 12 throughout the year.

Bennett Spring also appears to be a source of E. Coli to the Niangua River during a portion of the year. The highest E. *Coli* counts occurred above the spring at sites 6 and 7 with a sharp decrease at site 9 (Figure 16). E. *Coli* jump up almost an order of magnitude at the spring and remaining relatively consistent downstream at site 11 throughout the year. This suggests E. *Coli* contamination from the recharge areas, however the E. *Coli* numbers at the spring remain below 100 MPN/100mL, which is an expectable limit for swimming. E. *Coli* is found in all warm blooded animals so it is not possible to pinpoint one source or industry from this study. It appears the spring is an E. *Coli* source to the Niangua River with increases in numbers from site 8 to 12 in three of the four seasons.

Water chemistry tended to be consistent during the year long sampling period. Above the spring DO concentrations decreased from winter to spring to summer at all sites (Figure 17). Below the spring, DO rose from fall to winter, decreased during the spring, and increased slightly during the summer. Specific conductivity was lowest at all sites during the winter and increased each successive season to the highest SC recorded in the fall (Figure 18)

HISTORICAL DATA COMPARISON

Historical data from USGS at two sites were used for comparison to data from this study. One site is at site 10 just below Bennett Spring where the USGS collected water quality data between 1991 and 1995. The other site used for the comparison is at Site 12 located on the Niangua River below the Bennett Spring Branch Tributary where data was collected between 1994 and 1998. Types of water quality data compared are; discharge, total phosphorus, total nitrogen, specific conductivity, pH, dissolved oxygen, and temperature (Appendix A). In this dataset USGS detection limits ranged from 0.01 to 0.02 mg/L TP while detection limits for this study were 0.003 mg/L for TP.

Data comparison at the Bennett Spring, site 10, show TP and TN concentrations follow similar trends given the limitations of the USGS higher detection limit (Figures 19 and 20). The variability in the TP relationships shows that the spring is less sensitive to discharge variability due to groundwater controls and TN has low variability as discharge changes. This study targeted baseflow conditions as opposed to the USGS sampling design which samples a range of flows. Given this flow disparity these data suggest present nutrient concentrations at these two sites are at similar levels to data collected in the early and middle 1990s. The Niangua River site below the Bennett Spring Branch Tributary (site 12) also shows similar trends to the USGS samples (Figures 21 and 22).

Comparison of both datasets by percentile rank shows similar trends with discharge for the USGS and MSU datasets (Tables 5 and 6). Median discharge was much lower for this study compared to the USGS samples because only baseflow samples were sampled in the present study. This may account for the lower DO levels, higher SC, and higher temperatures collected during this study compared to the USGS, especially at the Bennett Spring site 10. Given the higher detection limits for the USGS it is evident that ambient nutrient concentrations have probably remained at similar levels over the last decade.

RECOMMENDATION

While results of this study suggest current water quality conditions are relatively good at Bennett Spring, “hot spots” within the recharge area deserve future investigation and work. Results of this study have generated three recommendations for future work discussed below.

Of all of the water quality parameters measured for this study, E. *Coli* seems to be of the most concern with 23% of the samples collected exceeding the whole body contact limit for class A streams. This is due to the contrast in E. *Coli* numbers at the spring compared to the rest of the system and the high E. *Coli* counts found in some of the smaller recharge area streams. While the geometric mean values from this study do not exceed whole body contact limits at each site, significant numbers of individual samples (23%) do exceed the limit. Due to the variety of sources of E. *Coli* found in the area it is recommended a bacteria DNA study be performed at the spring to isolate the source of E. *Coli* as to focus management efforts on eliminating that source.

Site 5, at Fourmile Creek, consistently had the poorest water quality of all sites not influenced by point sources. Fourmile Creek has the lowest % forest of all watersheds assessed for this study covering only 10% of the watershed. Research suggests establishing forested area, especially the riparian corridor, are very beneficial in improving water quality by:

1. Filtering runoff,
2. protecting streambanks from erosion, and
3. providing shade to reduce summer water temperatures.

There are a variety programs that work with landowners to improve the riparian corridor on their property through cost share and technical assistance.

Point sources, specifically wastewater treatment plants associated with sites 2 and 3, in the Upper Niangua and Jones Creek watersheds seem to be major contributors of TP to the system. It is recommended to reduce TP concentrations in the effluent of the wastewater treatment plants located above these two sites to reduce the annual mean concentration to 0.075 mg/L TP, the limit for eutrophic conditions (MEC, 2007). This would be the costliest recommendation and probably not necessary until nutrients become a problem at Bennett Spring.

CONCLUSIONS

There are seven main conclusions of this study:

1. High Baseflow Variability - Flow in this karst system is highly variable throughout the year. Out of a total of 182 visits, only 127 flow measurements were collected due to low or no flow conditions in the late summer and early fall.

2. Bennett Spring Water Quality - Data collected for this study suggest water quality at Bennett Spring is relatively good with all parameters usually meeting published limits for streams in the Ozarks.

3. Recharge Area Water Quality - Contributing areas in the recharge area were found to have relatively high E. *Coli* and nutrients at some sites particularly at Fourmile Creek and downstream of some wastewater treatment plants.

4. E. *Coli* Source Tracking - While E. *Coli* counts at Bennett Spring remain low for now, it is advisable to start focusing on sources with a bacteria source tracking study that identifies hosts using DNA identification. These studies can help target specific problems and save resources.

5. Four Mile Creek Drainage Area - Of all the watersheds in the recharge area, the Fourmile Creek drainage has significantly higher nutrients and bacteria when compared to the other sites. With low forest cover in the watershed, it is advisable to focus riparian corridor management programs in this watershed.

6. Point Sources - Reduction in TP concentrations in the Upper Niangua and Jones Creek to 0.075 mg/L through wastewater treatment plant if and when nutrients become a problem at Bennett Spring.

7. Historical Data Comparison - USGS water quality data collected in the early and middle 1990s was compared to data collected during this study at 2 sites. These data show similar nutrient levels and discharge trends have existed over the last 15 years at Bennett Spring.

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Table 1. Sample Site Location and Drainage Area

Site #	Site Location	Stream Name	Northing (UTM)	Easting (UTM)	Ad (km2)
1	Blackhorse Rd.	East Fork Niangua	4,144,309.142760	507,231.319842	66.3
2	State Hwy Y	Niangua River	4,144,834.094600	506,740.017227	144
3	State Hwy Y	Jones Creek	4,153,137.538590	512,673.966756	14.6
4	State Hwy B	Dousinbury Creek	4,158,426.473670	509,441.216000	55.2
5	Pisgah Rd	Fourmile Creek	4,162,462.890700	506,783.801874	10.9
6	State Hwy 32	Bennett Spring Branch	4,164,910.435990	519,122.849915	10.6
7	Memphis Rd	Bennett Spring Branch	4,167,608.358840	516,294.382420	51.7
8	Moon Valley Rd	Niangua River	4,172,764.872650	510,430.751728	988
9	State Hwy OO	Bennett Spring Branch	4,174,241.018770	512,728.346510	110
10	State Hwy OO	Bennett Spring Branch	4,174,501.023220	512,536.764285	110
11	State Hwy 64A	Bennett Spring Branch	4,175,177.488080	512,727.133202	111
12	State Hwy 64A	Niangua River	4,176,760.924800	512,291.919602	1,141
13	State Hwy 32	Dry Auglaize Creek	4,168,168.526400	527,115.224827	20.1
14	State Hwy PP	Brush Creek	4,155,152.838920	528,970.800405	78.5

Table 2. Upstream Land-Use and Point Source Information by Site

Site #	Site Location	Ad (km2)	% High Den Urban	% Low Den Urban	% Crop-land	% Grass/ Pasture	% Forest	% Barren	% Wetland	% Water	# of Point Sources	Point Source Type
1	Blackhorse Rd.	66.3	3.2	1.9	4.5	45	43.3	1.5	0.1	0.6	0	none
2	State Hwy Y	144	2.9	3.4	4.4	50.5	37	1.2	0.1	0.6	6	wwtp
3	State Hwy Y	14.6	5	2.1	7.9	55.6	26.3	2.1	0	1	1	wwtp
4	State Hwy B	55.2	1.1	0.5	7.1	60.5	29.5	0.9	0	0.4	0	none
5	Pisgah Rd	10.9	0.5	0.5	9.8	77.9	10	1.1	0	0.3	0	none
6	State Hwy 32	10.6	0.8	0.9	2.5	37.5	56.6	0.9	0	0.7	0	none
7	Memphis Rd	51.7	0.5	0.5	4.7	48.4	44.6	1	0	0.4	0	none
8	Moon Valley Rd	988	1	1	5.8	52.3	38	0.8	0.2	1	14	wwtp
9	State Hwy OO	110	0.6	0.4	3.2	41	53.6	0.8	0	0.4	1	non-mun
10	State Hwy OO	110	0.6	0.4	3.2	41	53.6	0.8	0	0.4	1	non-mun
11	State Hwy 64A	111	0.6	0.4	3.1	40.8	53.8	0.8	0	0.4	1	non-mun
12	State Hwy 64A	1,141	0.9	0.9	5.6	50.2	40.5	0.8	0.1	1	18	wwtp
13	State Hwy 32	20.1	4.4	2.5	2.6	73	15.2	1.9	0	0.4	0	none
14	State Hwy PP	78.5	1.1	0.4	4.4	62.7	30.1	0.8	0.1	0.4	2	wwtp

wwtp = wastewater treatment plant, non-mun = non-municipal

Table 3. No Flow Sample Days March 2007 to Feb. 2008

Site	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
6						x	x	x	x	x	x		
5						x	x	x	x	x	x		
3									x	x			
13							x		x	x	x		
7						x	x	x	x	x	x		
4										x			
1					x	x	x	x	x	x		x	
14													
9					x	x	x	x	x	x	x	x	
10													
11													
2							x		x	x			
8													
12													

X = no flow days

Table 4. No Flow Water Quality Data

Site	No Flow Days	No Flow Samples	TP (mg/L)	TN (mg/L)	Ecoli (MPN)	Turb (NTU)	Cond (mS/cm)	pH	DO (mg/L)	Temp (C)
1	7	6	0.036	0.32	25.8	152	0.896	7.2	3.2	14.6
2	3	3	0.073	1.24	7.5	232	0.933	7.4	5.3	14.9
3	2	2	0.023	0.48	27.5	244	0.905	7.9	5.9	8.3
4	1	1	0.025	0.22	2.0	218	0.915	7.8	4.5	6.4
5	6	1	0.424	5.86	2419.6	36	0.554	7.1	1.2	24.4
6	6	0	na	na	na	na	na	na	na	na
7	6	4	0.055	0.59	245.4	262	0.781	7.5	6.2	19.4
9	8	8	0.018	0.25	3.9	249	0.762	7.4	6.0	17.3
13	4	4	0.220	0.77	443.4	342	0.654	7.2	2.8	11.9

Table 5. Historical Water Quality Data Statistics Comparison for Bennett Spring Site 10

Parameter	USGS				MSU			
	n	25th Percentile	50th Percentile	75th Percentile	n	25th Percentile	50th Percentile	75th Percentile
Q (cms)	54	4.1	4.7	6.1	12	2.7	3.2	3.6
TP (mg/L)	57	0.02	0.02	0.03	12	0.02	0.022	0.03
TN (mg/L)	8	1.48	1.55	1.73	12	1.19	1.34	1.47
DO (mg/L)	59	13	13.5	14	11	6.6	8.8	10.3
SC (mS/cm)	52	0.315	0.365	0.392	12	0.692	0.757	0.814
pH	52	7.4	7.6	7.6	12	7.1	7.4	7.5
Temp C	59	7.7	8	8.5	12	14.3	14.7	15.5

Table 6. Historical Water Quality Data Statistics Comparison for Niangua River Site 12

Parameter	USGS				MSU			
	n	25th Percentile	50th Percentile	75th Percentile	n	25th Percentile	50th Percentile	75th Percentile
Q (cms)	26	4.8	14.5	23.5	12	4.7	7.3	10.3
TP (mg/L)	20	<0.02	<0.02	0.02	12	0.027	0.032	0.037
TN (mg/L)	20	0.85	0.94	1.03	12	0.82	0.92	0.99
DO (mg/L)	26	9.4	10	11.3	11	8.6	11.2	12.5
SC (mS/cm)	26	0.308	0.352	0.381	12	0.733	0.778	0.815
pH	26	7.6	7.7	7.9	12	7.5	7.7	7.9
Temp C	26	10.5	12.8	16.4	12	11.9	14.3	18.6

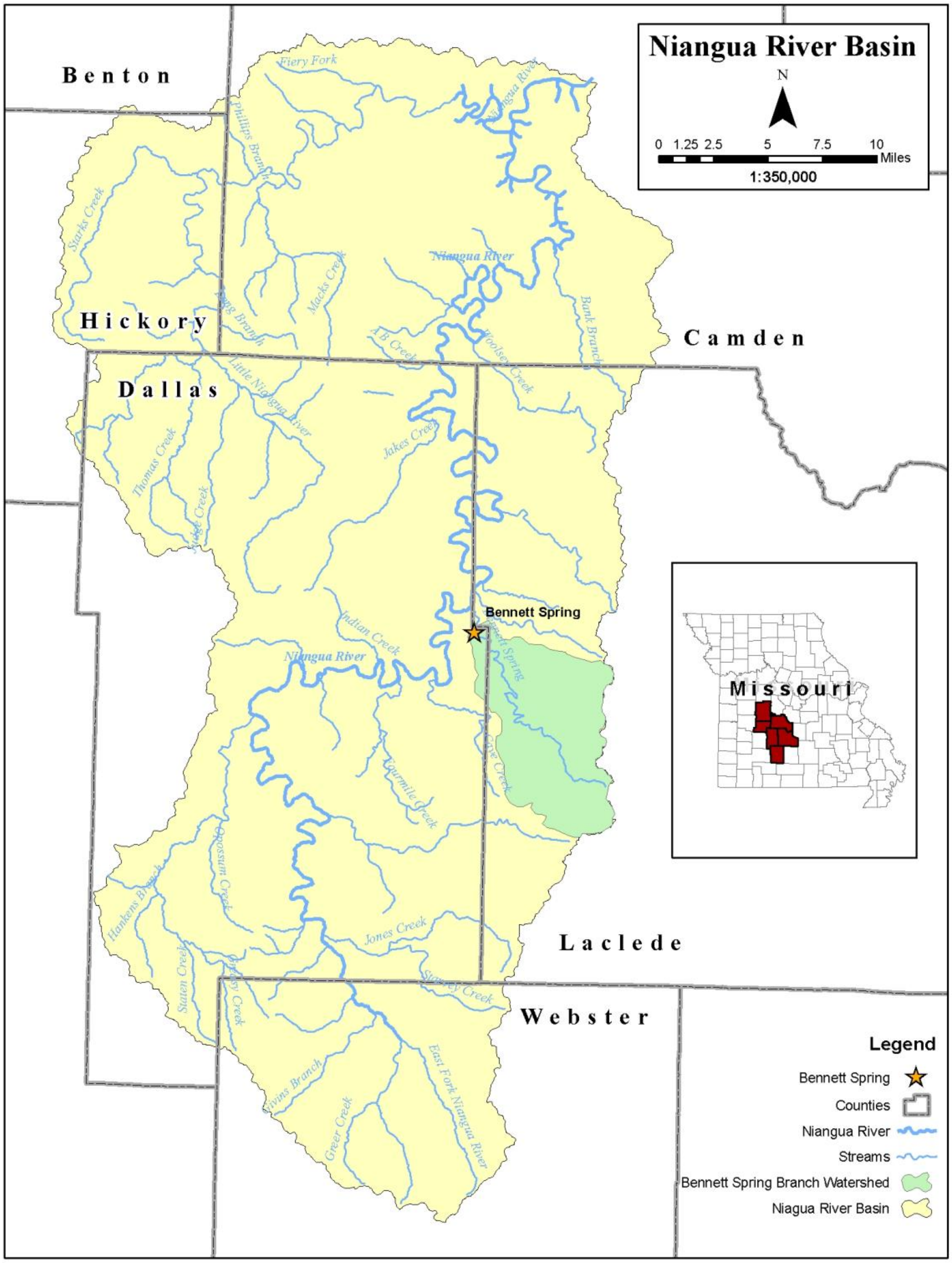

Figure 1. Niangua River Basin

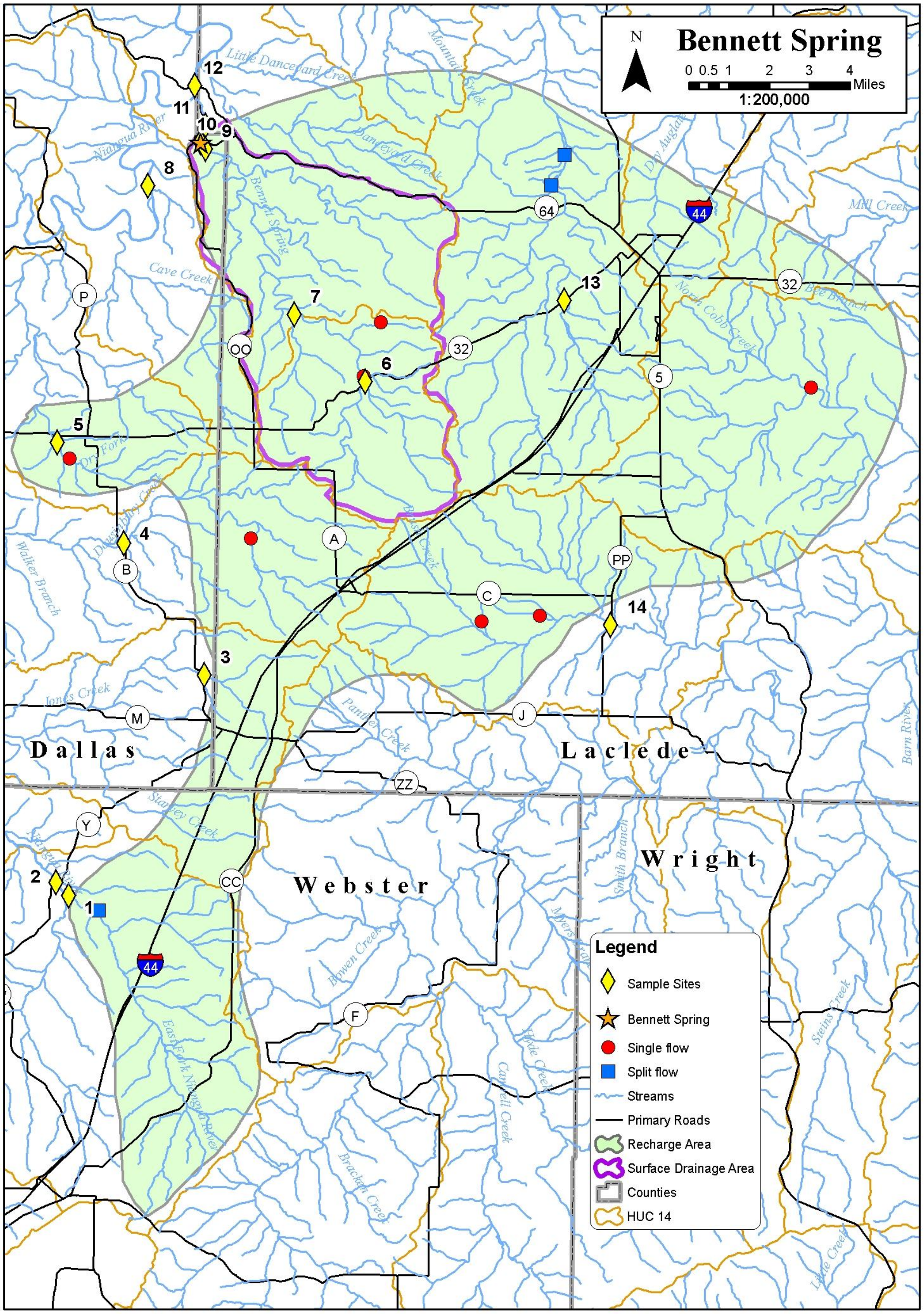

Figure 2. Sample Site Map

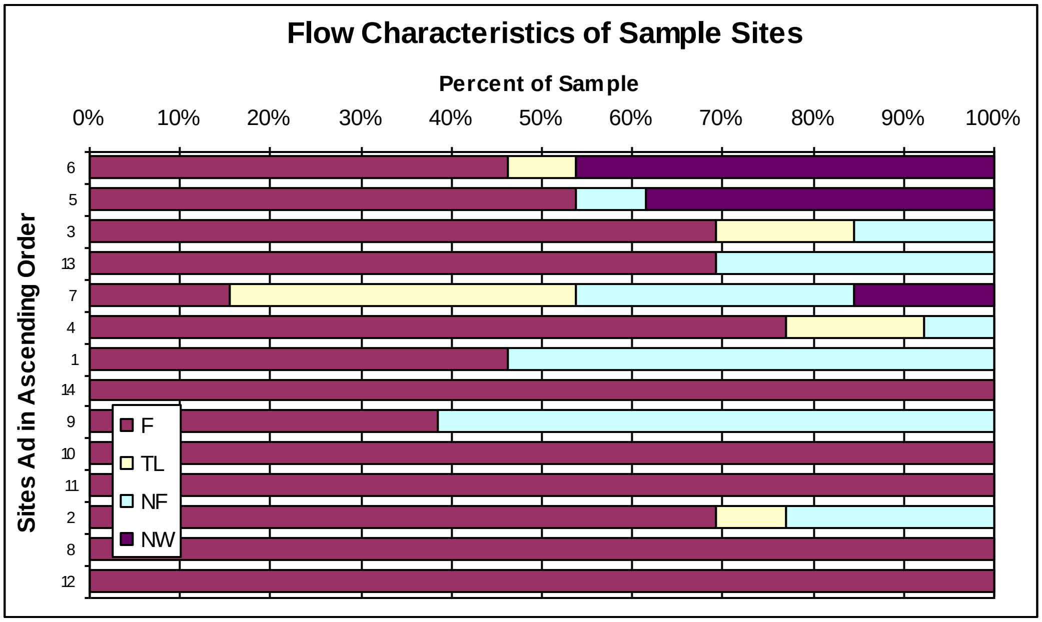

Figure 3. Flow Characteristics of Sample Sites

nw = no water
tl = water, too low to measure
nf = water, no flow
f= flow

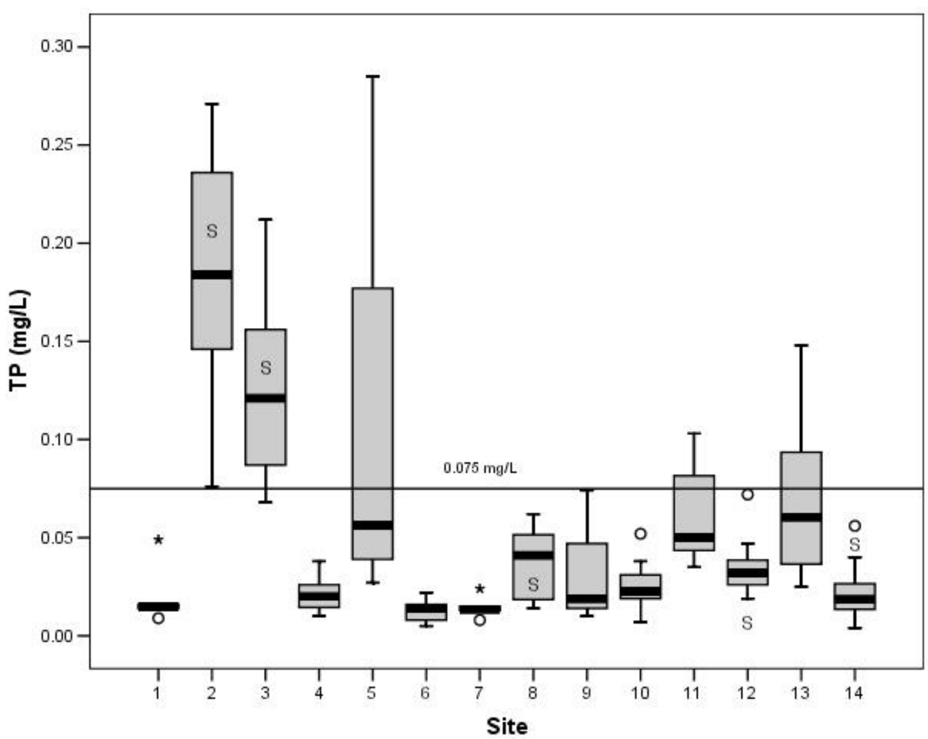

Figure 4. Total Phosphorus (TP) Data by Site

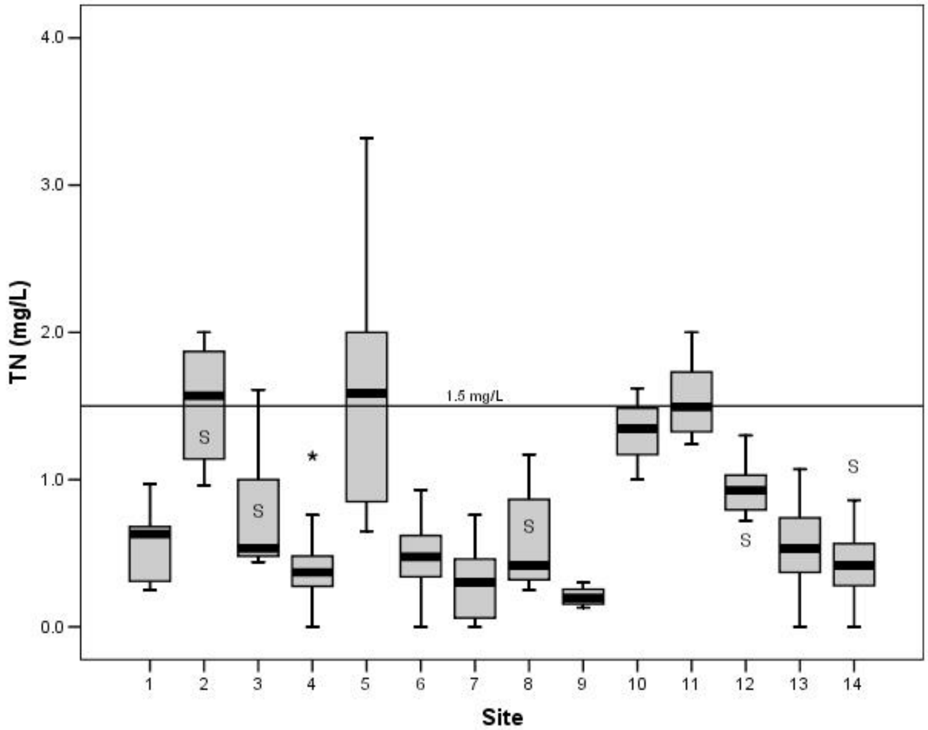

Figure 5. Total Nitrogen (TN) Data by Sample Site

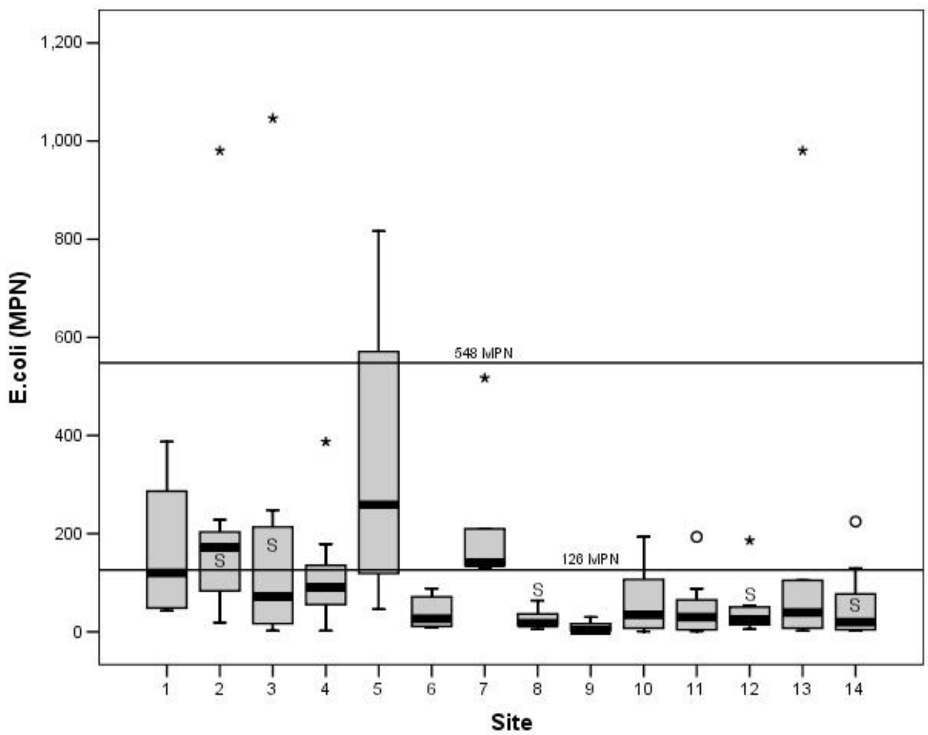

Figure 6. E. Coli Data by Sample Site

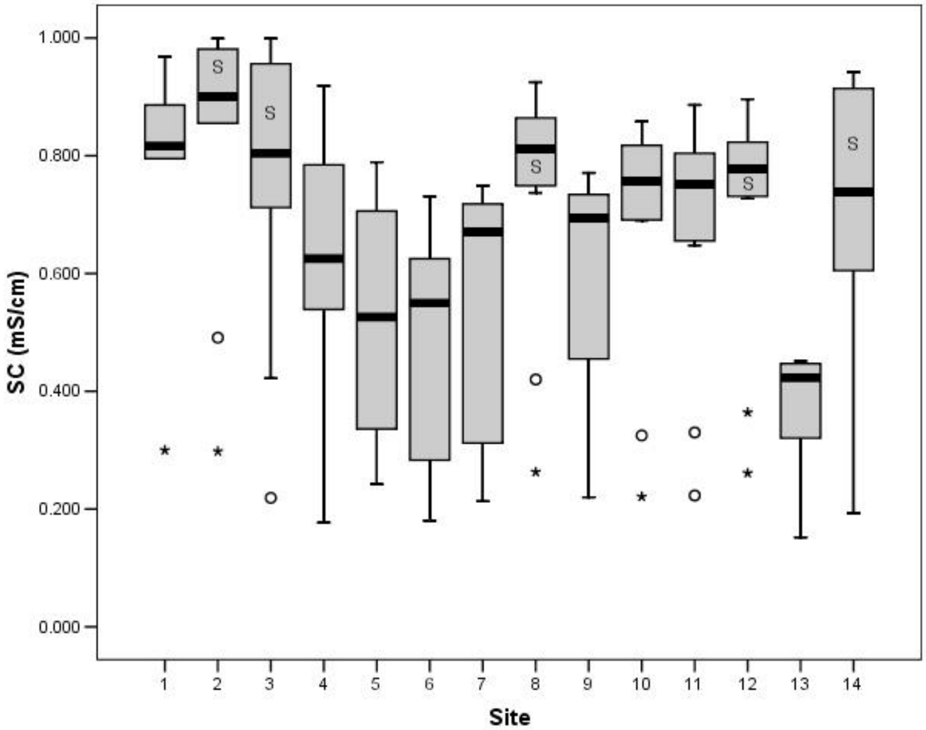

Figure 7. Specific Conductivity data by Sample Site

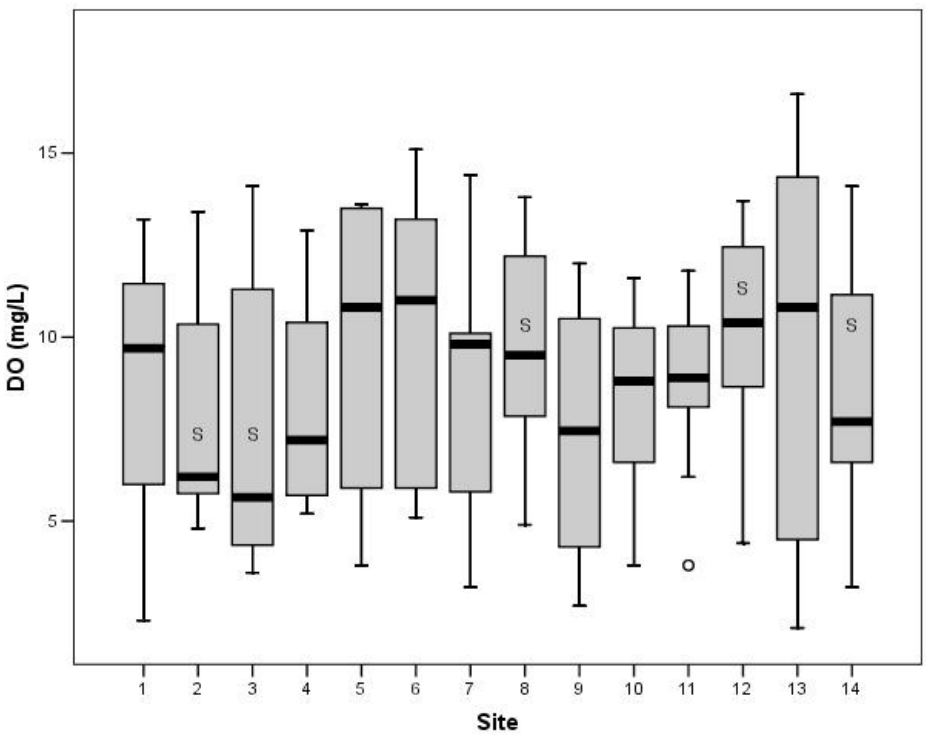

Figure 8. Dissolved Oxygen (DO) Data by Sample Site

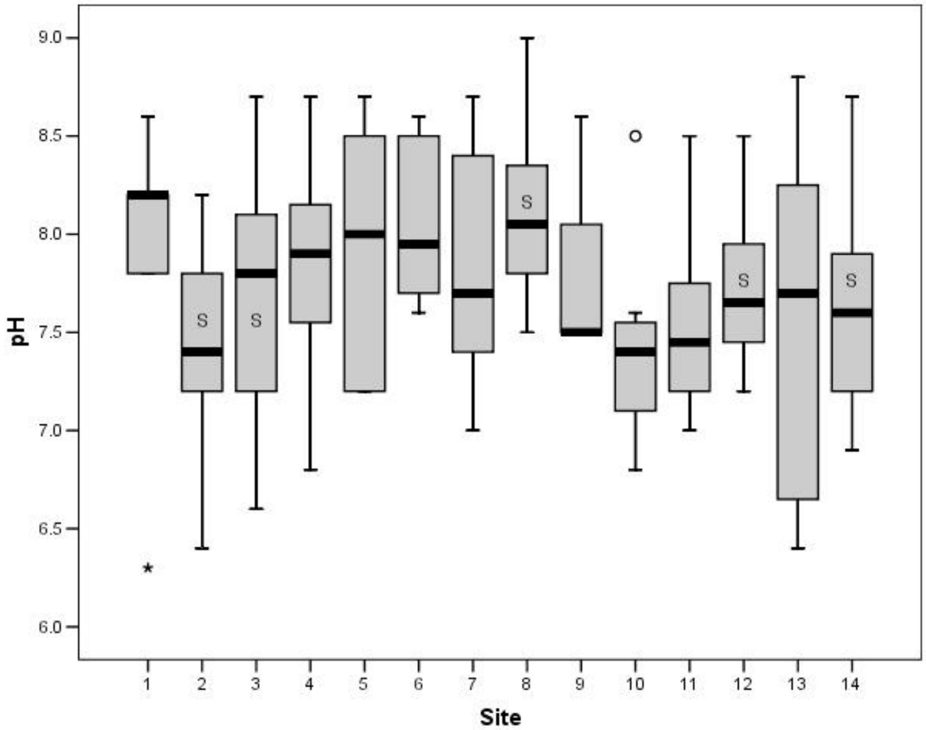

Figure 9. pH Data by Sample Site

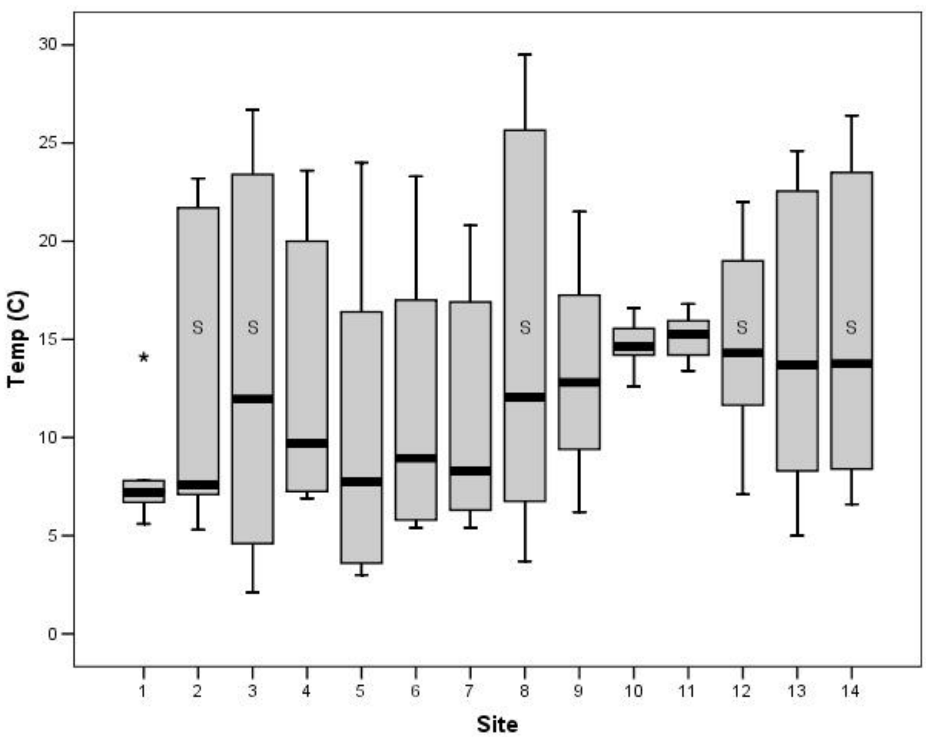

Figure 10. Temperature by Sample Site

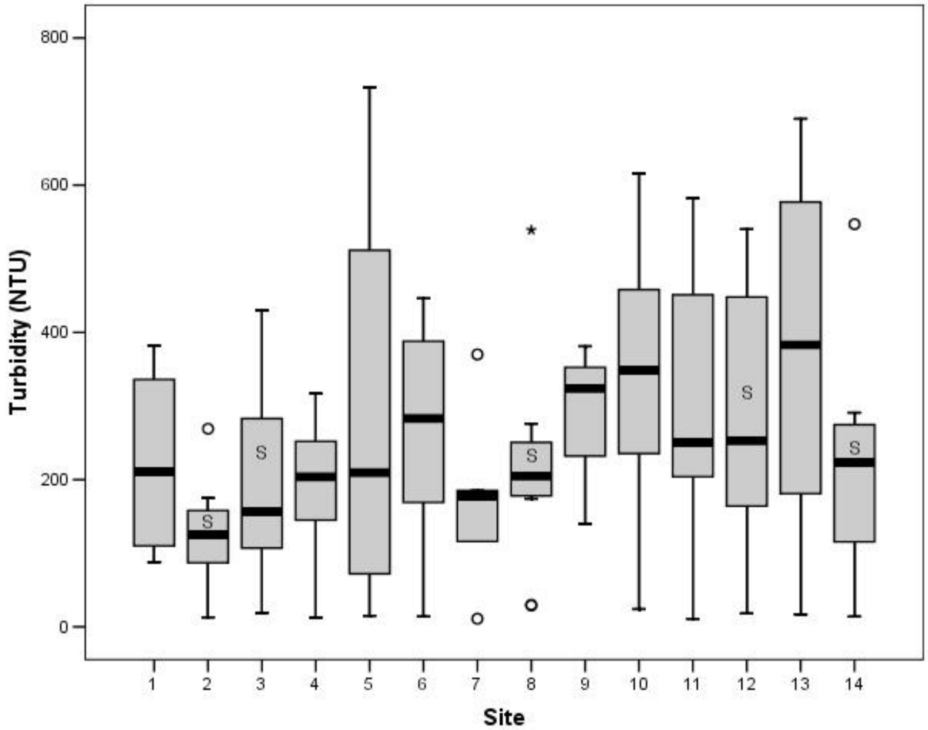

Figure 11. Turbidity by Sample Site

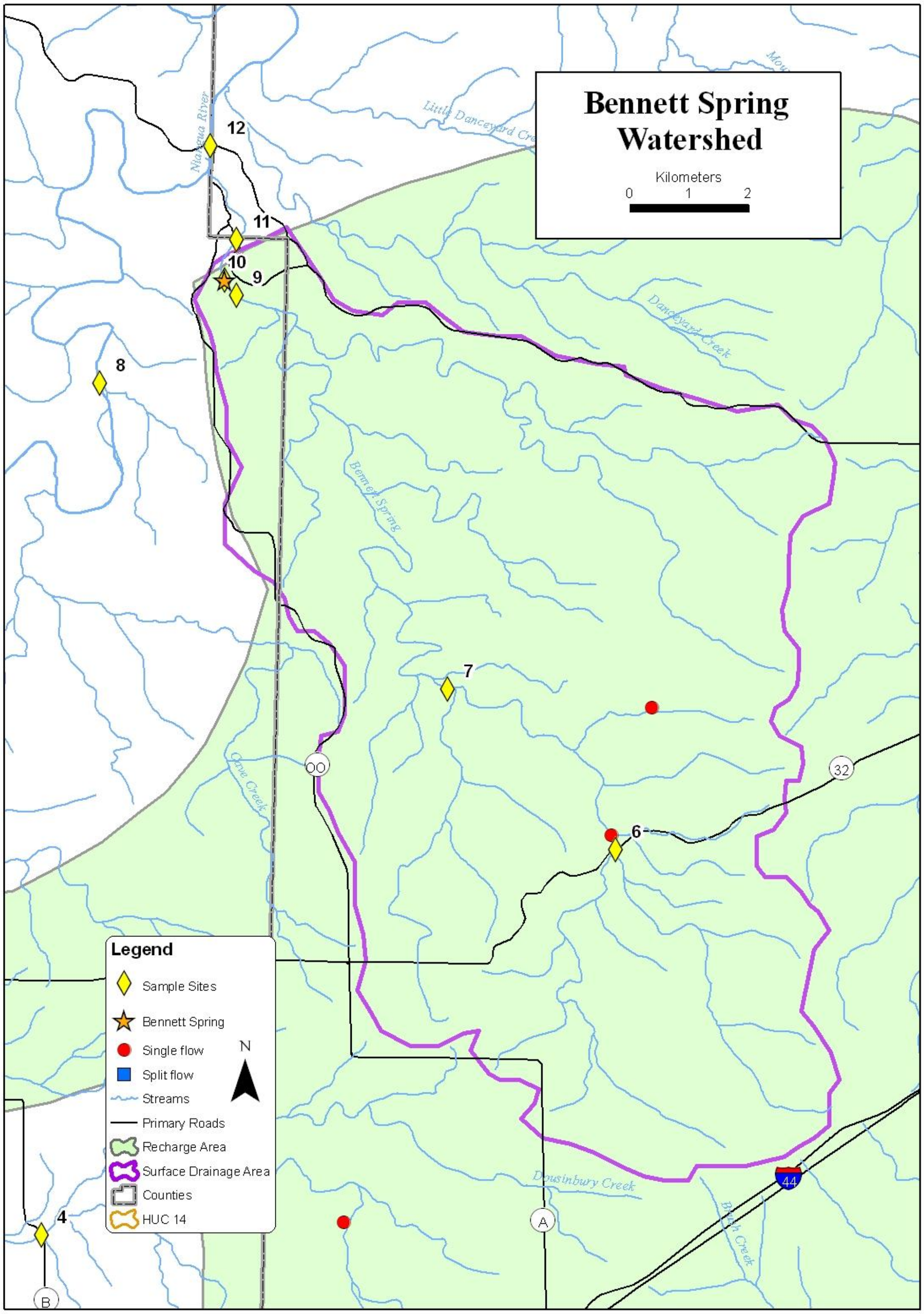

Figure 12. Bennett Spring Branch Tributary Watershed

Note: USB = Upstream of Bennett Spring, DSB = Downstream of Bennett Spring, USN = Upstream on Niangua, DSN = Downstream on Niangua

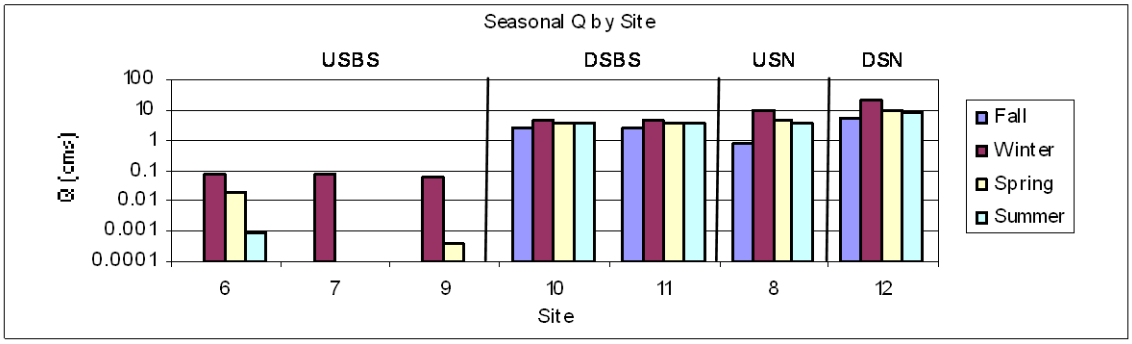

Figure 13. Seasonal Discharge (Q) for Selected Sites

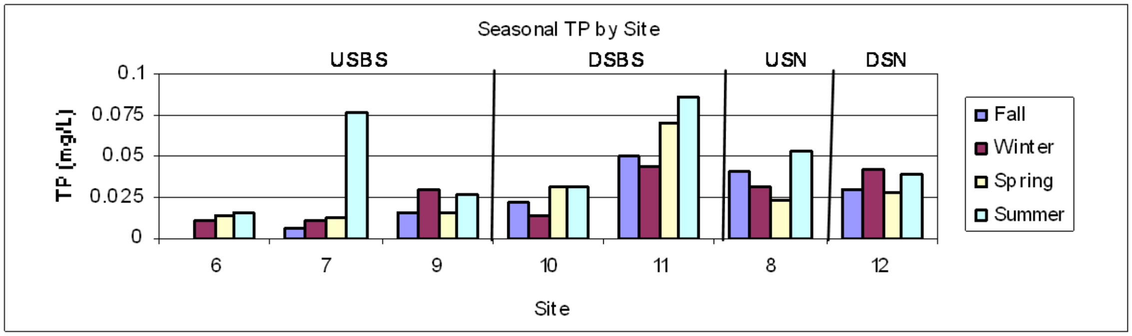

Figure 14. Seasonal Total Phosphorus (TP) for Selected Sites

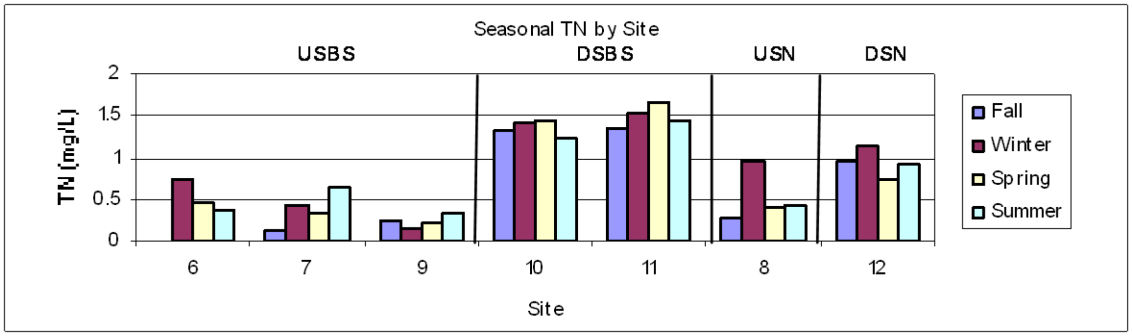

Figure 15. Seasonal Total Nitrogen (TN) for Selected Sites

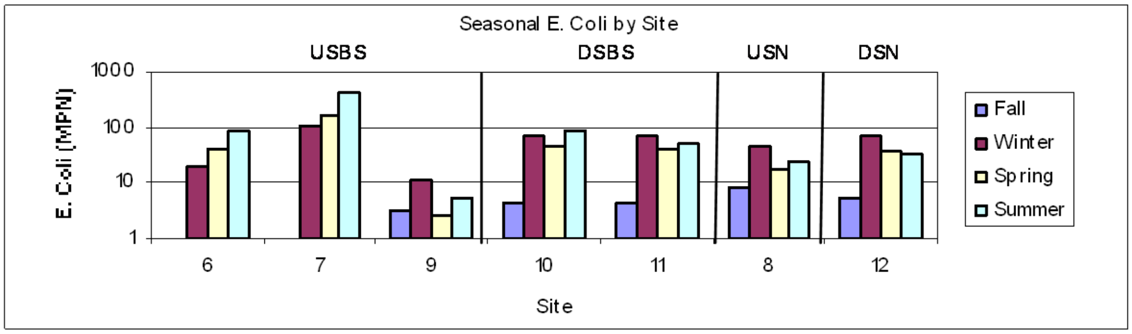

Figure 16. Seasonal E. Coli for Selected Sites

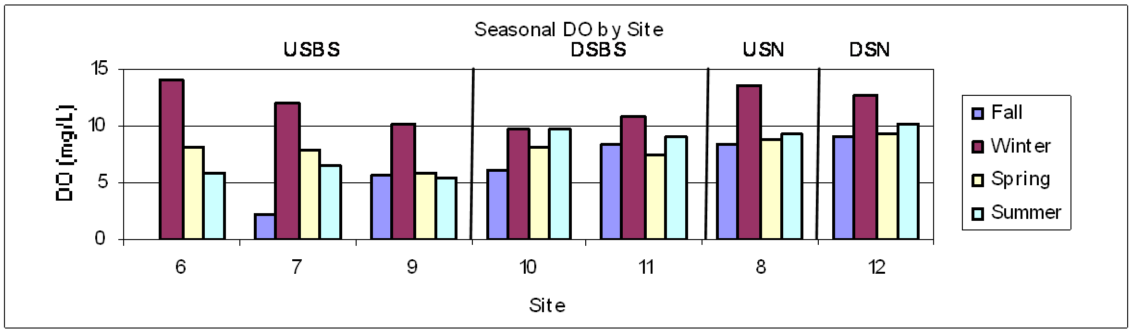

Figure 17. Seasonal Dissolved Oxygen (DO) for Selected Sites

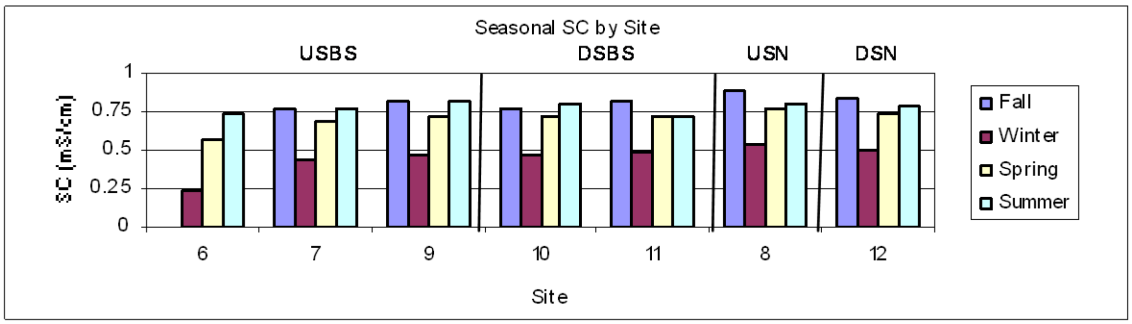

Figure 18. Seasonal Specific Conductivity (SC) for Selected Sites

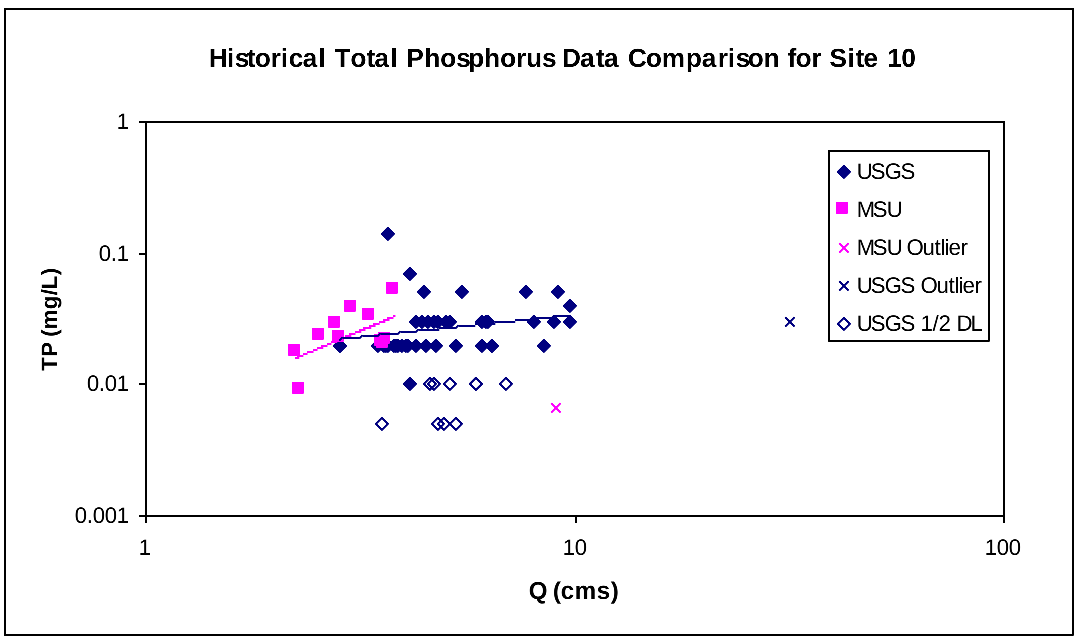

Figure 19. Historical Total Phosphorus Comparison for Site 10 at Bennett Spring

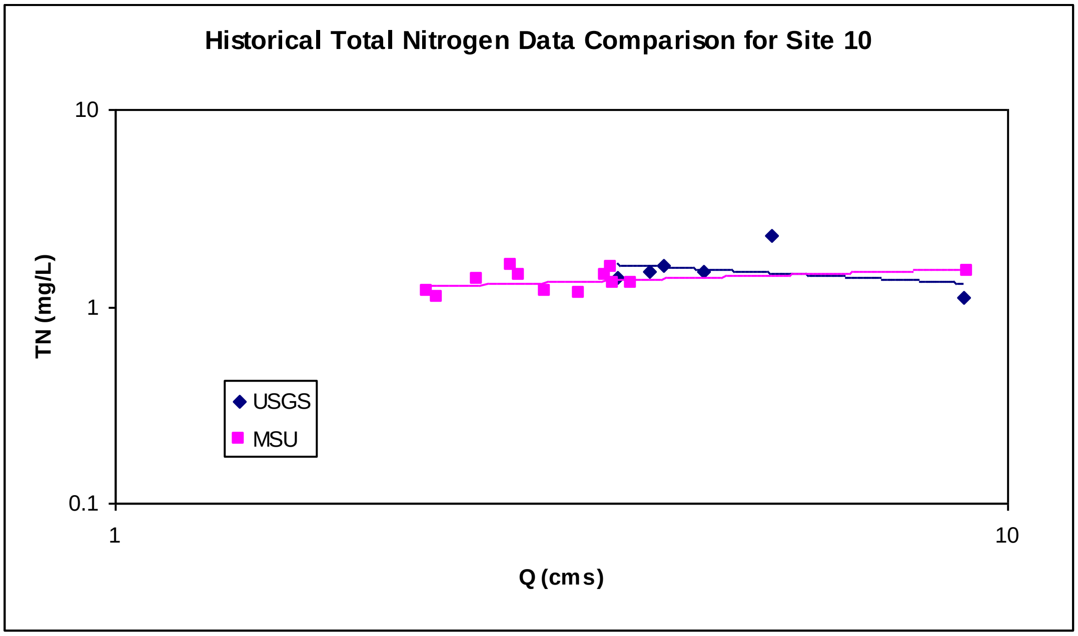

Figure 20. Historical Total Nitrogen Comparison for Site 10 at Bennett Spring

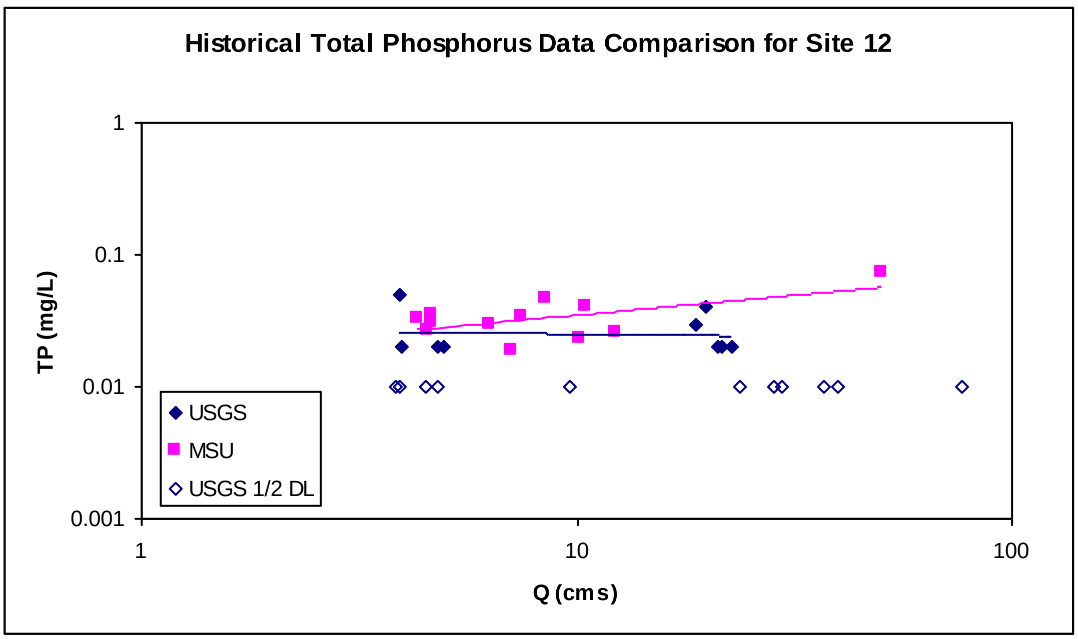

Figure 21. Historical Total Phosphorus Comparison for Site 12 on Niangua River below Bennett Spring

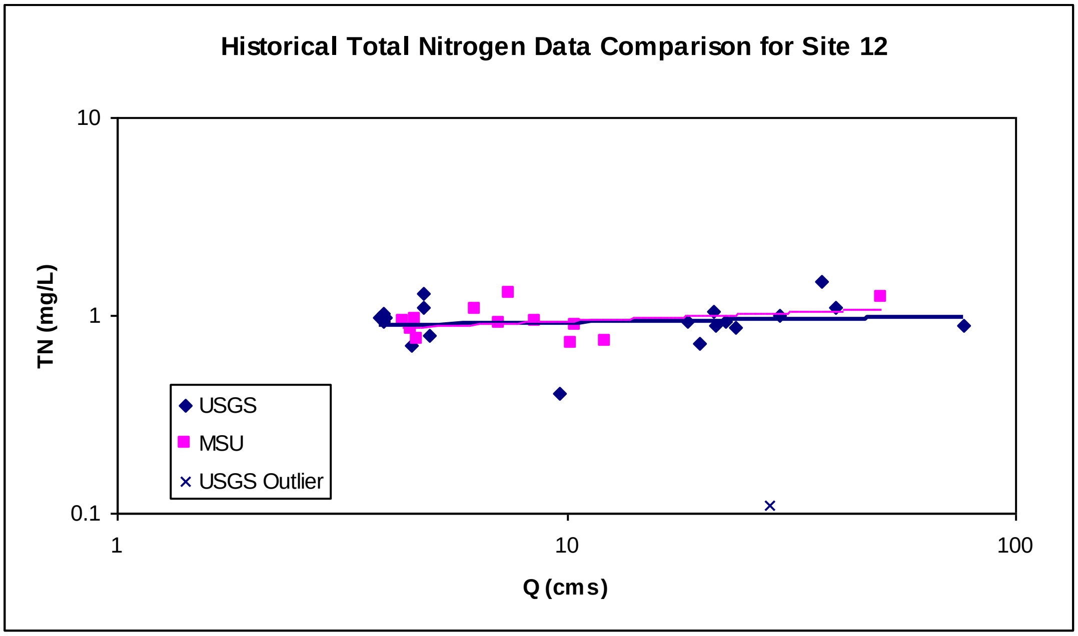

Figure 22. Historical Total Nitrogen Comparison for Site 12 on Niangua River below Bennett Spring

Photo 1. Site 1 at Blackhorse Road on the East Fork of the Niangua River

Photo 2. Site 2 at SH Y on the Niangua River

Photo 3. Site 3 at SH Y on Jones Creek

Photo 4. Site 4 at SH B on Dousinbury Creek

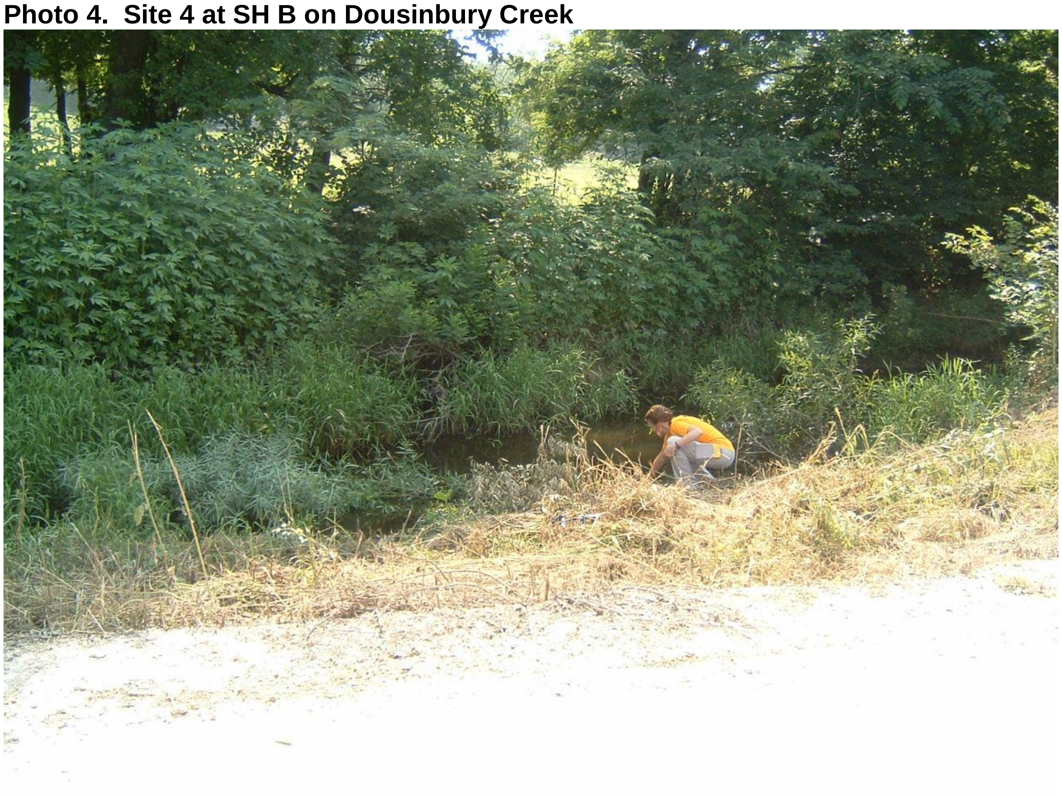

Photo 5. Site 5 at Pisgah Road on Fourmile Creek

Photo 6. Site 6 at SH 32 on Bennett Spring Branch

Photo 7. Site 7 at Memphis Road on Bennett Spring Branch

Photo 8. Site 8 at Moon Valley Road at the Niangua River

Photo 9. Site 9 at the State Park on Bennett Spring Branch above Spring

Photo 10. Site 10 at the State Park at below Bennett Spring at USGS Gaging Station

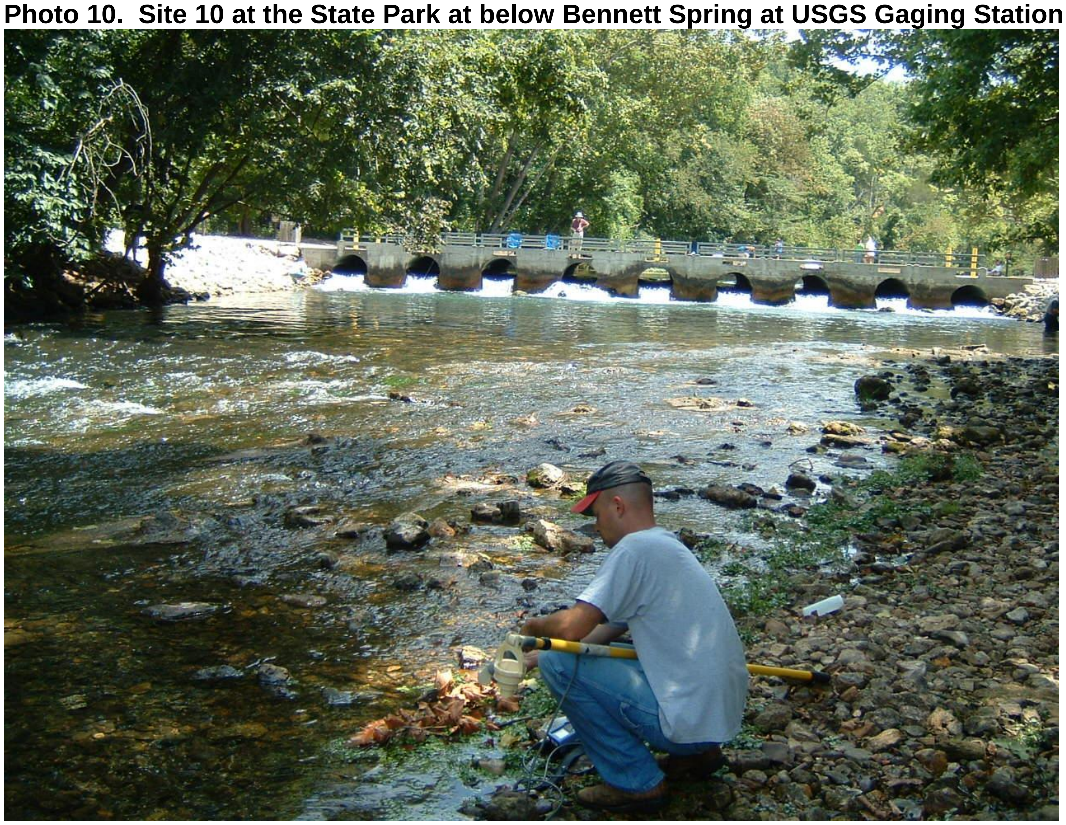

Photo 11. Site 11 at the State Park above the Confluence with the Niangua River

Photo 12. Site 12 at SH 64A on the Niangua River below the Bennett Spring Branch

Photo 13. Site 13 at SH 32 on Dry Auglaize Creek

Photo 14. Site 14 at SH PP on Brush Creek

APPENDIX A - WATER QUALITY DATA BY SITE

Table 7. Monthly Total Phosphorus (mg/L) by Site

Site #	March	April	May	June	July	August	Sept	n	mean	median	min	max	sd	cv%
1	0.015	0.014	0.016	nw	0.022	0.059	0.026	6	0.025	0.019	0.014	0.059	0.017	68.1
2	0.115	0.146	0.247	0.271	0.184	0.091	0.154	7	0.173	0.154	0.091	0.271	0.066	38.3
3	0.099	0.189	0.086	0.139	0.087	0.129	0.068	7	0.114	0.099	0.068	0.189	0.041	36.5
4	0.022	0.010	0.014	0.020	0.028	0.029	0.038	7	0.023	0.022	0.010	0.038	0.010	41.8
5	0.039	0.027	0.060	0.177	0.424	nw	nw	5	0.145	0.060	0.027	0.424	0.167	114.7
6	0.022	0.005	0.014	0.016	nw	nw	nw	4	0.014	0.015	0.005	0.022	0.007	49.2
7	0.015	0.008	0.014	0.024	0.014	0.193	0.006	7	0.039	0.014	0.006	0.193	0.068	173.3
8	0.014	0.018	0.036	0.062	0.051	0.046	0.052	7	0.040	0.046	0.014	0.062	0.018	45.2
9	0.018	0.010	0.020	0.018	0.039	0.022	0.017	7	0.021	0.018	0.010	0.039	0.009	44.1
10	0.020	0.021	0.052	0.022	0.033	0.038	0.023	7	0.030	0.023	0.020	0.052	0.012	39.4
11	0.083	0.046	0.080	0.051	0.102	0.103	0.035	7	0.071	0.080	0.035	0.103	0.028	38.6
12	0.025	0.023	0.036	0.041	0.047	0.031	0.030	7	0.033	0.031	0.023	0.047	0.009	26.0
13	0.037	0.025	0.148	0.069	0.093	0.137	0.094	7	0.086	0.093	0.025	0.148	0.046	53.9
14	0.010	0.012	0.016	0.040	0.024	0.022	0.021	7	0.021	0.021	0.010	0.040	0.010	47.6

Table 8. Monthly Total Nitrogen (mg/L) by Site

Site #	March	April	May	June	July	August	Sept	n	mean	median	min	max	sd	cv%
1	0.63	0.31	0.25	nw	0.29	0.47	0.30	6	0.40	0.31	0.25	0.63	0.209	52.7
2	0.96	1.00	1.27	1.68	1.87	0.58	1.57	7	1.07	1.00	0.96	1.27	0.171	15.9
3	0.53	0.45	0.48	0.78	0.73	0.44	0.48	7	0.49	0.48	0.45	0.53	0.042	8.7
4	0.48	0.23	0.32	0.34	0.46	0.48	0.33	7	0.34	0.32	0.23	0.48	0.125	36.6
5	1.45	0.65	0.85	2.09	5.86	nw	nw	5	0.98	0.85	0.65	1.45	0.419	42.5
6	0.62	0.34	0.41	0.37	nw	nw	nw	4	0.46	0.41	0.34	0.62	0.146	31.8
7	0.46	0.33	0.27	0.18	0.21	1.54	0.12	7	0.35	0.33	0.27	0.46	0.097	27.9
8	0.40	0.39	0.43	0.55	0.47	0.31	0.33	7	0.41	0.40	0.39	0.43	0.021	5.3
9	0.21	0.30	0.13	0.2	0.48	0.37	0.17	7	0.22	0.21	0.13	0.30	0.085	39.0
10	1.56	1.42	1.32	1.32	1.15	1.20	1.45	7	1.43	1.42	1.32	1.56	0.123	8.6
11	1.82	1.69	1.51	1.58	1.42	1.36	1.48	7	1.67	1.69	1.51	1.82	0.155	9.3
12	0.73	0.72	0.75	0.88	0.92	0.96	1.06	7	0.73	0.73	0.72	0.75	0.017	2.3
13	0.71	0.46	0.55	0.23	0.77	1.28	0.28	7	0.57	0.55	0.46	0.71	0.129	22.4
14	0.62	0.50	0.38	0.46	0.33	0.23	0.23	7	0.50	0.50	0.38	0.62	0.119	23.9

Table 9. Monthly Ecoli (MPN/100ml) by Site

Site #	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	n	Geo Mean	median	min	max	sd	cv%
1	186	54.5	nw	9.7	3	ns	23.3	5.2	42.6	88	387.3	9	33.41	42.6	3	387.3	125.88	376.7
2	133.4	228.2	178.5	18.7	19.5	ns	2	1	172.5	33.6	980.4	10	43.18	83.5	1	980.4	294.77	682.7
3	178.9	69.7	2	1046.2	5.5	ns	ns	27.5	73.3	27.9	248.1	9	50.14	69.7	2	1046.2	332.91	664
4	55.7	108.1	387.3	178.9	91	ns	2	2	13.4	135.4	64.4	10	42.16	77.7	2	387.3	115.45	273.8
5	45.7	816.4	325.5	2419.6	nw	ns	4.1	nw	nw	191.8	>2419.6	6	168.77	258.7	4.1	2419.6	922.52	546.6
6	8.5	71.2	88.6	nw	nw	ns	nw	nw	nw	26.6	10.9	5	27.44	26.6	8.5	88.6	36.56	133.3
7	209.8	129.1	517.2	12.2	686.7	ns	nw	nw	37.3	135.4	141.4	8	130.44	138.4	12.2	686.7	239.91	183.9
8	15.8	18.9	17.1	17.3	36.4	ns	5.2	12	63.8	13.4	62.7	10	20.1	17.2	5.2	63.8	21.03	104.6
9	2	3	7.4	7.5	1	ns	5.2	1	2	3.1	29.9	10	3.55	3.1	1	29.9	8.66	243.7
10	33.7	57.1	119.8	106.7	36.4	ns	7.5	1	4.1	18.7	193.5	10	25.11	35.1	1	193.5	63.12	251.4
11	44.1	41	88	65	3.1	ns	7.5	1.2	4.1	18.7	193.5	10	18.33	29.9	1.2	193.5	59.38	324
12	24.6	50.4	52.8	34.1	14.6	ns	5.2	ns	10.8	18.7	186	9	26.46	24.6	5.2	186.0	55.75	210.7
13	2	25.3	105	980.4	1732.9	ns	22.6	1	16.9	7.5	52.9	10	32.63	24	1	1732.9	587.96	1802
14	77.1	129.6	15.5	72.8	12.1	ns	2	3.1	4.1	24.3	224.7	10	21.27	19.9	2	224.7	72.71	341.9

Table 10. Monthly Turbidity (NTU) by Site

Site #	Feb	March	April	May	June	July	Aug	Sept	n	mean	median	min	max	sd	cv%
1	100	88	132	382	nw	124	151	174	7	164	132	88	382	100	61.0
2	286	120	125	141	269	175	157	10	8	160	149	10	286	88	54.6
3	119	102	156	430	283	107	150	206	8	194	153	102	430	113	58.0
4	529	81	252	270	317	180	179	227	8	254	240	81	529	132	51.8
5	620	129	290	10	733	36	nw	nw	6	303	210	10	733	308	101.5
6	408	283	169	446	388	nw	nw	nw	5	339	388	169	446	113	33.2
7	174	116	185	177	370	22.6	596	152	8	224	176	23	596	179	79.7
8	199	174	256	184	539	28.8	182	225	8	223	192	29	539	144	64.4
9	163	140	324	381	491	10	211	256	8	247	234	10	491	151	61.1
10	216	498	432	395	616	78.2	349	234	8	352	372	78	616	172	48.8
11	223	189	392	512	582	68.8	510	250	8	341	321	69	582	184	54.1
12	221	164	448	515	540	87.4	214	263	8	307	242	87	540	171	55.7
13	442	336	181	577	430	10	311	690	8	372	383	10	690	215	57.8
14	216	146	85	164	547	60.8	223	265	8	213	190	61	547	152	71.1

Table 11. Monthly Specific Conductivity (mS/cm) by Site

Site #	Feb	March	April	May	June	July	Aug	Sept	n	mean	median	min	max	sd	cv%
1	0.654	0.795	0.816	0.886	nw	0.99	0.999	0.900	7	0.862	0.886	0.654	0.999	0.120	13.9
2	0.689	0.855	0.911	0.981	0.900	0.9	0.999	0.999	8	0.904	0.906	0.689	0.999	0.102	11.3
3	0.579	0.712	0.795	0.814	0.719	0.91	0.956	0.958	8	0.805	0.805	0.579	0.958	0.133	16.5
4	0.417	0.554	0.635	0.524	0.576	0.63	0.760	0.809	8	0.613	0.601	0.417	0.809	0.126	20.6
5	0.584	0.674	0.706	0.378	0.789	0.55	nw	nw	6	0.614	0.629	0.378	0.789	0.143	23.4
6	0.486	0.625	0.501	0.598	0.731	nw	nw	nw	5	0.588	0.598	0.486	0.731	0.100	17.0
7	0.531	0.652	0.718	0.689	0.749	0.77	0.797	0.766	8	0.709	0.734	0.531	0.797	0.086	12.1
8	0.581	0.737	0.799	0.779	0.761	0.83	0.839	0.853	8	0.772	0.789	0.581	0.853	0.087	11.2
9	0.582	0.690	0.771	0.697	0.860	0.88	0.690	0.844	8	0.752	0.734	0.582	0.878	0.104	13.9
10	0.639	0.718	0.765	0.692	0.811	0.75	0.824	0.784	8	0.748	0.757	0.639	0.824	0.062	8.3
11	0.674	0.713	0.776	0.663	0.778	0.73	0.648	0.769	8	0.719	0.723	0.648	0.778	0.053	7.4
12	0.581	0.727	0.760	0.735	0.788	0.77	0.790	0.806	8	0.744	0.764	0.581	0.806	0.071	9.6
13	0.384	0.422	0.425	0.414	0.446	0.45	0.615	0.451	8	0.451	0.436	0.384	0.615	0.070	15.5
14	0.552	0.625	0.682	0.662	0.585	0.8	0.880	0.921	8	0.713	0.672	0.552	0.921	0.137	19.2

Table 12. Monthly Temperature (C) by Site

Site #	Feb	March	April	May	June	July	Aug	Sept	n	mean	median	min	max	sd	cv%
1	2.1	7.2	6.7	14.1	nw	21.7	24.1	19.2	7	13.6	14.1	2.1	24.1	8.4	62.0
2	1.9	7.6	7.3	15.8	22.1	23.2	24.9	21.7	8	15.6	18.7	1.9	24.9	8.8	56.6
3	1.8	7.0	6.6	16.9	23.4	25	26.7	22.4	8	16.2	19.6	1.8	26.7	9.7	60.0
4	5.7	7.4	7.5	14.1	19.0	21	23.6	21.0	8	14.9	16.5	5.7	23.6	7.2	48.5
5	2.0	7.7	7.8	16.4	24.0	24.4	nw	nw	6	13.7	12.1	2.0	24.4	9.3	68.1
6	2.9	9.0	8.9	17.0	23.3	nw	nw	nw	5	12.2	9.0	2.9	23.3	8.0	65.2
7	7.4	6.3	8.7	16.9	20.8	22.3	28.5	20.0	8	16.4	18.5	6.3	28.5	8.1	49.3
8	3.4	10.7	11.3	20.9	26.7	28.4	29.5	24.6	8	19.4	22.8	3.4	29.5	9.7	50.0
9	4.0	13.0	12.6	21.5	25.5	29.2	27.7	22.3	8	19.5	21.9	4.0	29.2	8.8	45.0
10	13.1	14.7	14.9	15.5	16.6	15.6	15.9	14.6	8	15.1	15.2	13.1	16.6	1.0	6.9
11	13.9	15.1	15.3	15.7	16.2	16.2	16.8	15.6	8	15.6	15.6	13.9	16.8	0.9	5.7
12	4.8	12.2	13.6	18.2	22.0	21.6	19.8	18.2	8	16.3	18.2	4.8	22.0	5.8	35.6
13	5.3	8.6	9.9	17.5	23.5	24.6	24.3	21.6	8	16.9	19.5	5.3	24.6	7.9	46.4
14	5.0	11.7	12.9	18.2	24.7	24.2	26.4	22.8	8	18.2	20.5	5.0	26.4	7.7	42.0

Table 13. Monthly pH by Site

Site #	Feb	March	April	May	June	July	Aug	Sept	n	mean	median	min	max	sd	cv%
1	8.3	8.2	8.6	8.2	nw	6.9	7.2	7.0	7	7.8	8.2	6.9	8.6	0.7	9.1
2	8.3	7.4	8.2	6.7	7.2	7.4	7.4	7.6	8	7.5	7.4	6.7	8.3	0.5	6.9
3	8.4	8.4	8.7	8.1	7.2	7.1	7.6	7.5	8	7.9	7.8	7.1	8.7	0.6	8.0
4	8.4	8.5	8.7	8.2	7.5	7.5	7.6	7.7	8	8.0	7.9	7.5	8.7	0.5	6.1
5	8.5	8.5	8.7	8.0	7.2	7.1	nw	nw	6	8.0	8.2	7.1	8.7	0.7	8.8
6	8.4	8.5	8.6	8.0	7.7	nw	nw	nw	5	8.2	8.4	7.7	8.6	0.4	4.7
7	8.3	8.4	8.7	7.4	7.0	7.0	7.9	7.1	8	7.7	7.6	7.0	8.7	0.7	8.8
8	8.4	8.9	9.0	8.0	7.7	7.9	7.9	8.1	8	8.2	8.1	7.7	9.0	0.5	5.7
9	8.2	8.6	7.5	7.5	6.8	7.3	7.6	7.1	8	7.6	7.5	6.8	8.6	0.6	7.5
10	8.2	8.5	7.6	7.3	6.9	6.8	7.1	7.1	8	7.4	7.2	6.8	8.5	0.6	8.4
11	7.9	8.5	7.8	7.5	7.0	7.0	7.3	7.3	8	7.5	7.4	7.0	8.5	0.5	6.5
12	8.4	8.5	8.0	7.7	7.4	7.4	7.5	7.6	8	7.8	7.7	7.4	8.5	0.4	5.7
13	8.6	8.5	8.8	8.0	6.5	6.4	7.1	6.8	8	7.6	7.6	6.4	8.8	1.0	13.3
14	8.5	8.6	8.7	7.3	6.9	7.0	7.1	7.3	8	7.7	7.3	6.9	8.7	0.8	9.9

Table 14. Monthly Dissolved Oxygen (mg/L) by Site

Site #	Feb	March	April	May	June	July	Aug	Sept	n	mean	median	min	max	sd	cv%
1	12.7	9.7	br	2.3	nw	2.81	1.2	0.2	6	4.8	2.5	0.2	12.7	5.1	106.2
2	12.1	9.3	br	6.2	4.8	5.58	4.4	5.9	7	6.9	5.9	4.4	12.1	2.8	40.6
3	12.0	10.0	br	6.2	3.6	4.86	5.1	3.8	7	6.5	5.1	3.6	12.0	3.3	50.1
4	13.2	10.4	br	7.2	5.5	8.7	6.4	5.7	7	8.2	7.2	5.5	13.2	2.8	34.5
5	13.8	10.8	br	5.9	3.8	1.22	nw	nw	5	7.1	5.9	1.2	13.8	5.1	72.3
6	13.7	11.0	br	5.1	5.9	nw	nw	nw	4	8.9	8.4	5.1	13.7	4.1	46.3
7	13.9	10.1	br	5.8	3.2	4.67	11.6	2.4	7	7.4	5.8	2.4	13.9	4.5	60.7
8	14.1	13.6	4.9	8.2	7.7	10.8	9.5	10.3	8	9.9	9.9	4.9	14.1	3.0	30.8
9	11.3	9.0	2.7	5.9	3.3	8.16	4.6	4.1	8	6.1	5.3	2.7	11.3	3.1	50.0
10	11.2	10.5	3.8	10.0	8.8	11.6	8.8	7.0	8	9.0	9.4	3.8	11.6	2.6	28.5
11	11.1	9.9	3.8	8.6	6.2	11.8	8.9	9.1	8	8.7	9.0	3.8	11.8	2.6	29.7
12	13.8	13.4	4.4	10.4	5.6	12.6	12.3	10.0	8	10.3	11.3	4.4	13.8	3.5	34.4
13	13.4	16.6	15.5	6.7		2.31	3.1	2.1	7	8.5	6.7	2.1	16.6	6.5	75.8
14	13.5	12.7	3.2	8.3	3.4	9.57	7.7	6.8	8	8.1	8.0	3.2	13.5	3.8	46.6

Table 15. USGS Water Quality Data from Bennett Spring (Site 10)

Date	Discharge (cms)	TP (mg/L)	TN (mg/L)	Cond (mS/cm)	pH	DO (mg/L)	Temp (C)
7/1/1991	na	0.02	1.7	na	na	13.5	8.5
7/10/1991	4.45	0.05	na	0.378	7.7	14.0	8.1
7/16/1991	4.25	0.02	na	0.384	7.6	14.5	8.4
7/25/1991	4.11	0.07	1.6	0.388	8.1	14.5	7.6
7/30/1991	3.96	0.02	1.5	0.392	7.7	14.5	7.1
8/8/1991	4.05	0.02	na	0.394	7.7	14.5	8.3
8/15/1991	3.82	0.02	na	0.398	7.7	14.5	9.1
8/22/1991	3.77	0.02	na	na	na	14.5	7.9
8/28/1991	3.6	0.02	na	0.399	7.7	14.0	7.8
9/3/1991	3.62	0.02	na	0.401	7.6	14.0	7.8
9/9/1991	3.65	0.02	1.4	0.401	7.7	14.5	8.0
9/18/1991	6.06	0.02	na	0.396	7.5	14.0	7.5
9/24/1991	4.11	0.01	na	0.392	7.6	14.0	6.2
10/7/1991	3.46	0.02	na	0.384	7.6	14.0	7.4
11/6/1991	4.08	0.02	na	na	na	13.5	7.4
11/12/1991	3.68	0.14	na	0.393	7.4	13.5	7.6
12/4/1991	7.99	0.03	na	0.31	7.4	13.5	7.2
1/7/1992	4.73	0.02	na	0.297	7.3	13.5	8.2
1/16/1992	4.67	0.03	na	0.324	7.6	13.0	9.8
2/3/1992	4.5	0.02	na	0.363	7.5	13.5	7.8
3/2/1992	5.27	0.02	na	0.295	7.5	13.5	7.9
4/7/1992	4.96	0.005	na	0.34	7.6	13.0	7.8
5/7/1992	4.25	0.03	na	na	na	14.5	9.0
5/12/1992	4.81	0.005	na	0.368	7.7	13.0	8.6
6/10/1992	5.27	0.005	na	0.373	7.5	14.0	7.4
7/8/1992	3.88	0.02	na	0.374	7.6	13.5	8.8
7/21/1992	6.06	0.03	na	0.392	7.6	14.0	7.9
8/3/1992	3.54	0.005	na	0.398	7.6	13.5	8.6
9/3/1992	3.51	na	na	0.398	7.6	14.0	8.2
10/13/1992	2.83	0.02	na	0.404	7.7	13.0	7.5
11/5/1992	2.83	0.02	na	0.407	7.8	13.0	7.6
12/3/1992	5.1	0.03	na	0.286	7.2	13.0	8.5
1/27/1993	6.29	0.03	na	0.299	7.8	12.0	8.3
2/10/1993	4.39	0.03	na	0.313	7.5	12.5	8.6
3/11/1993	6.23	0.03	na	0.322	7.4	12.0	8.6
4/14/1993	na	0.09	na	0.342	7.5	12.0	8.6
5/11/1993	6.4	0.02	na	0.331	7.3	12.0	8.0
6/17/1993	na	0.04	1.8	0.3	7.5	13.0	8.1
7/8/1993	6.4	0.02	na	na	na	13.0	7.3
8/11/1993	4.56	0.03	1.5	0.377	7.6	14.4	8.6
9/14/1993	8.92	0.03	1.1	0.299	7.4	14.0	7.0
10/6/1993	9.74	0.03	na	0.237	7.2	14.0	8.2
11/2/1993	4.81	0.03	na	0.346	7.4	13.9	7.4
12/9/1993	7.65	0.05	na	0.315	7.7	13.5	8.0
2/1/1994	na	0.08	na	0.374	7.6	13.5	8.2
3/16/1994	6.91	0.01	na	0.318	7.4	13.0	8.2

4/7/1994	na	0.05	na	0.337	7.4	13.0	8.6
5/10/1994	31.7	0.03	na	0.233	7.3	13.0	8.8
6/1/1994	8.5	0.02	na	0.296	7.5	13.7	7.7
7/12/1994	5.89	0.01	na	0.367	7.5	12.5	7.9
8/24/1994	4.98	0.03	na	0.39	7.6	14.1	10.7
9/15/1994	5.44	0.05	2.3	0.317	7.4	14.6	6.8
10/21/1994	4.76	na	na	na	na	14.3	7.9
10/27/1994	4.67	0.01	na	0.355	7.6	14.1	7.8
11/15/1994	9.74	0.04	na	0.249	7.5	12.7	8.1
12/20/1994	5.13	0.01	na	0.356	7.4	13.7	8.0
1/10/1995	4.61	0.01	na	0.372	7.6	12.2	8.6
2/7/1995	9.12	0.05	na	0.261	7.3	11.0	8.1
3/28/1995	5.89	0.01	na	na	na	13.3	8.4

Note: Red = ½ detection limit

Table 16. USGS Water Quality Data from Niangua River below Bennett Spring Branch (Site 12)

Date	Discharge (cms)	TP (mg/L)	TN (mg/L)	Cond (mS/cm)	pH	DO (mg/L)	Temp (C)
10/27/1994	5.0	0.020	0.8	0.380	7.70	8.80	12.0
11/15/1994	28.3	0.010	0.11	0.292	8.04	9.40	12.5
1/26/1995	21.2	0.020	1.05	0.314	7.60	13.10	3.5
2/7/1995	22.7	0.020	0.94	0.285	7.57	12.10	6.5
3/28/1995	9.6	0.010	0.4	0.353	7.95	11.80	14.0
4/26/1995	29.7	0.010	1.01	0.291	7.75	9.70	12.5
6/30/1995	23.8	0.010	0.87	0.290	7.73	7.30	20.5
8/29/1995	4.8	0.020	1.09	0.381	7.62	9.50	18.0
12/4/1995	3.9	0.050	0.94	0.407	8.00	10.20	13.0
1/31/1996	4.8	0.010	1.3	0.386	7.90	12.60	6.5
3/19/1996	3.8	0.010	0.97	0.389	7.80	9.40	10.5
4/12/1996	4.5	0.010	0.7	0.362	8.10	11.40	16.5
6/11/1996	21.5	0.020	0.9	0.350	6.00	9.10	17.5
8/27/1996	3.9	0.010	1.02	0.382	7.80	7.30	17.0
11/26/1996	36.8	0.010	1.49	0.263	7.36	11.10	10.5
1/22/1997	18.7	0.030	0.94	0.319	7.33	11.30	4.5
3/19/1997	39.6	0.010	1.09	0.278	7.66	11.30	10.5
4/2/1997	19.8	0.040	0.73	0.307	7.83	10.00	13.0
6/26/1997	76.5	0.010	0.9	0.369	7.85	9.40	18.5
8/14/1997	4.0	0.020	0.97	0.397	7.28	7.90	16.0
11/4/1997	5.1	na	na	0.370	6.80	9.80	11.3
1/20/1998	11.0	na	na	0.333	7.96	11.20	5.7
3/13/1998	24.9	na	na	0.890	7.62	12.40	4.6
4/15/1998	18.0	na	na	0.310	7.92	10.70	15.7
6/8/1998	7.1	na	na	0.326	7.46	8.50	16.1
8/11/1998	7.9	na	na	0.377	7.73	9.90	19.0

Note: Red = ½ detection limit