Small Watershed Rotating Basin Monitoring Program

Basin Group 3: Lower North Canadian, Lower Canadian, and Lower Arkansas Basins Final Report

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND AND DESCRIPTION

The Clean Water Act has charged each state's nonpoint source (NPS) pollution agency with two primary tasks: 1) identify all waters being impacted by NPS pollution, and 2) develop a management program describing implementation plans to correct identified problems. In addition, each state's NPS agency is tasked with the identification of all programs which are actively planning or enforcing NPS controls. Cooperation between local, regional, and interstate entities can magnify the impact of efforts to reduce NPS pollution. The state NPS agency can then report on total program status with regard to efforts to address NPS impacts and improve water quality. The Oklahoma Conservation Commission (OCC) is assigned as the NPS Program technical lead by Oklahoma state statute and therefore must monitor to determine the occurrence, nature and extent of NPS impacts to state waters. Robust and meaningful assessment of the state's water quality is the foundation for meeting the long-term goals of the Oklahoma NPS program and water quality management in general.

In 2000, the Oklahoma Conservation Commission (OCC) initiated a progressive ambient monitoring program to assess NPS issues on a larger spatial and temporal scale than previously done. Known as the *Small Watershed Rotating Basin Monitoring Program* ("Rotating Basin Program"), this effort entails fixed station sampling at or near the outlets of complete eleven digit Hydrologic Unit Code watersheds (HUC-11). Oklahoma contains all or part of 414 U.S. Geological Survey (USGS) 11-digit HUC basins which have been collated into eleven larger planning basins for state water quality management purposes. The sampling units for the Rotating Basin Monitoring Program are based at the outlets of HUC 11 watersheds located entirely in the state. Secondary sites are located upstream in selected watersheds where isolation of a particular tributary influence is necessary. Fixed stations are segregated into five strategic basin groups, which are aggregations of several of the eleven planning basins. Stations are sampled every five weeks for a period of two years. Each year, sampling is initiated in a new basin group, resulting in a statewide coverage of all sites in five years (Figure 1).

To complement the fixed site monitoring, the OCC added a probabilistic component to the Rotating Basin Monitoring Program for Cycle 2 in 2008. This addition to the Rotating Basin Program provided a statistically qualified assessment of water quality conditions throughout the project basin. To accomplish this, sites were randomly selected from all of the waters of interest in a target area (i.e., basin unit), and the monitoring results were used to estimate water quality conditions in the larger area with known confidence (USGAO 2004). Analysis of the probabilistic component indicated that data collected from the fixed sites accurately represents the water quality of the basin. Therefore, probabilistic sites have not been monitored in Cycle 4. The fixed sites monitored in Cycle 4 are shown in Figure 1.

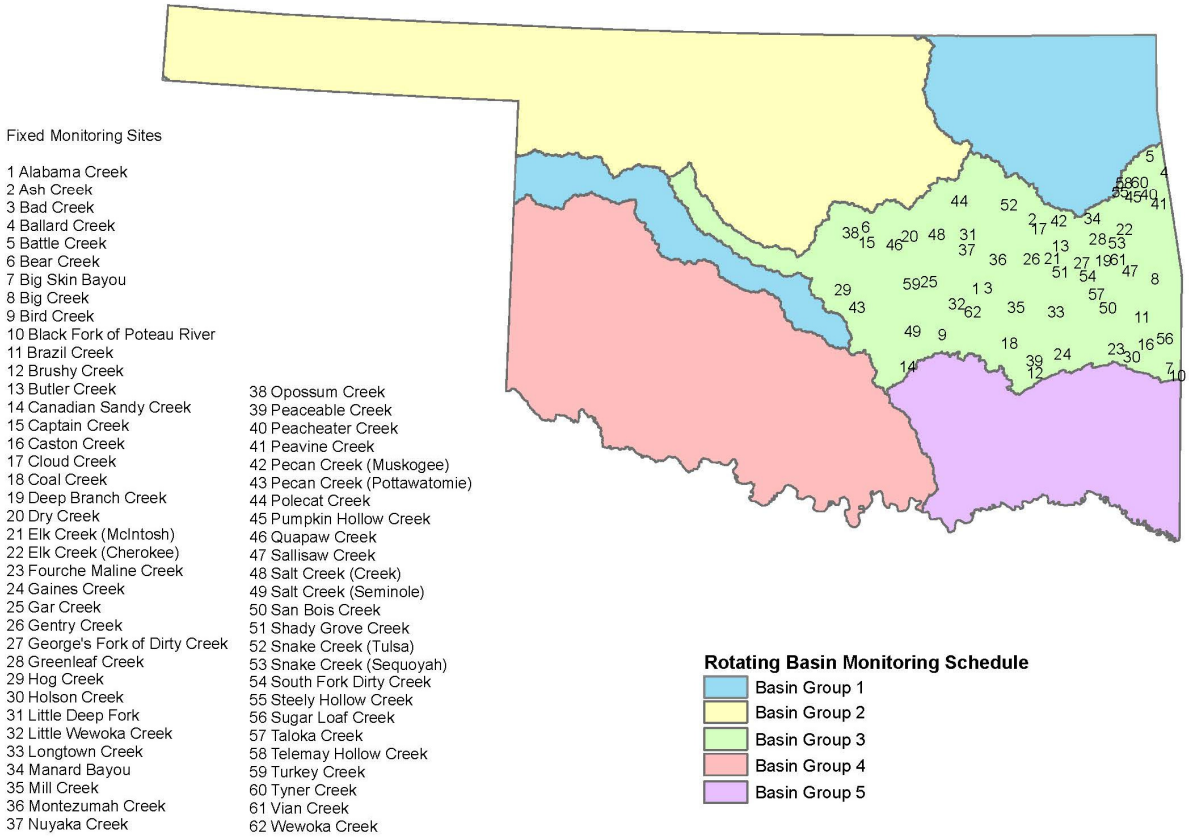


Figure 1. Monitoring sites in "Basin Group 3" for the fourth cycle of the Small Watershed Rotating Basin Monitoring Project.

Effectively coordinated with other state monitoring programs, the OCC's Rotating Basin program is designed to accomplish the state's NPS monitoring needs in four stages. The first stage includes a comprehensive, coordinated investigation and analysis of the causes and sources of NPS pollution throughout the state – *Ambient Monitoring*. The second stage involves more intensive, specialized monitoring designed to identify specific causes and sources of NPS pollution – *Diagnostic Monitoring.* The data from diagnostic monitoring can be used to formulate an implementation plan to specifically address the sources and types of identified NPS pollution. The third stage of monitoring is designed to initiate remedial and/or mitigation efforts to address the NPS problems – *Implementation Monitoring.* Finally, the fourth stage evaluates the effectiveness of the implementation through assessment and post-implementation monitoring – *Success Monitoring.* This assessment program provides a thorough and statistically sound evaluation of Oklahoma's waters every five years, which helps focus NPS program planning, education, and implementation efforts in areas where they can be most effective.

The Small Watershed Rotating Basin Monitoring Program considers the following specific questions in the context of Oklahoma Water Quality Standards and Use Support Assessment Protocols (USAPs) in addressing NPS pollution:

1. Which HUC 11 waterbodies are not supporting assigned beneficial uses due to NPS or NPS plus point source (PS) pollution?
2. Which waterbodies show elevated or increasing levels of NPS or NPS plus PS pollutants, which may threaten water quality?
3. What are the sources and magnitude of pollution loading within threatened or impaired waterbodies?
4. Which land uses or changes in land use are sources or potential sources for pollutants causing beneficial use impairment?

In its entirety, OCC's Rotating Basin Monitoring Program provides an assessment of water quality, watershed condition, and support status for selected streams statewide, which is necessary for planning, implementation, and eventual evaluation of mitigation efforts. The statewide ambient monitoring program has allowed a comprehensive approach for the identification of nonpoint source (NPS) affected waters, as well as the identification of high quality streams. Results from this effort are used to assist the state in producing the 305(b) and 303(d) lists which are required by the EPA to assess beneficial use support for waterbodies biannually.

This report discusses the results of the *ambient* (routine physical, chemical, and biological sampling) and *diagnostic* (special parameter sampling) stages of the fourth cycle of the Rotating Basin program in the Lower North Canadian, Lower Canadian, and Lower Arkansas Basins (Basin 3; see Figure 1). *Implementation* and *success* monitoring are typically accomplished through priority watershed projects and reported on separately in project-specific final reports.

This program will continue to provide a robust baseline dataset to assess the impact of NPS pollution throughout the state, identify the causes and sources of the pollution, and determine the success of measures to improve water conditions.

2.0 MATERIALS AND METHODS

2.1 GENERAL

Sampling stations were selected to effectively represent streams of the Lower North Canadian, Lower Canadian, and Lower Arkansas basins. Candidate streams were selected from sub-watersheds within these basins located entirely within the state of Oklahoma having perennial water. Watersheds that did not have perennial water or were actually a segment of a larger river being sampled by another agency were not chosen. Where a particular watershed was monitored by another entity, the stream was dropped from consideration as a Rotating Basin site, if the external monitoring met the project data quality objectives. For most sub-watersheds, the OCC monitoring site was located near the outflow of

the primary stream but far enough upstream to limit backwater (surface and alluvial) effects of the waterbody to which it drained. For larger sub-watersheds, an additional site was sometimes located upstream to isolate a particularly strong tributary influence. In some cases, sites were specifically chosen to monitor a stream draining an area of land use different from the majority of the other streams being monitored in that region or sub-watershed.

Reconnaissance of all of the potential sites within the Lower North Canadian, Lower Canadian, and Lower Arkansas basins was accomplished prior to the first round of monitoring in 2003, and sites which did not meet the sampling criteria were removed from the project. Thirty-four sites were monitored during the first rotating basin cycle, from 2003-2005. Thirty-three were monitored in the second cycle from June 2008-May 2010. Forty-eight sites were monitored during the third cycle from June 2013-May 2015. The fourth cycle of monitoring in these basins occurred from June 2018-May 2020. There were 62 fixed sites during this cycle of monitoring (Table 1).

The sites monitored in the Lower North Canadian basin occur in two level III ecoregions: Cross Timbers (CT) and Central Irregular Plains (CIP) (Woods et al., 2005). In the Lower Canadian basin, sites are located in the Cross Timbers (CT) and the Arkansas Valley (AV) ecoregions. In the Lower Arkansas basin, sites occur in six ecoregions: Cross Timbers (CT), Arkansas Valley (AV), Central Irregular Plains (CIP), Ozark Highlands (OH), Ouachita Mountains (OM), and Boston Mountains (BM).

Table 1. Site list for Rotating Basin Monitoring Program: Basin Group 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins), Cycle 4. WBID is a unique waterbody identifier for each monitoring site. Ecoregions include Arkansas Valley (AV), Boston Mountains (BM), Cross Timbers (CT), Central Irregular Plains (CIP), Ozark Highlands (OH), and Ouachita Mountains (OM). The modified ecoregion is a representation, not only of the location of the sampling point, but the entirety of the watershed that influences the stream.

Site Name	WBID	Latitude	Longitude	Legal Desc	County	Ecoregion	Modified Ecoregion
Alabama Creek	OK520500-01-0200D	35.3355	-96.1446	NW SW SE SECTION 16-10N-11E	Okfuskee	CT	CT
Ash Creek	OK120410-01-0110E	35.7883	-95.6653	NW¼ SE¼ 12-15N-15E	Muskogee	CIP	CIP
Bad Creek	OK520500-01-0170E	35.3376	-96.0468	NE¼ SW¼ 16-10N-12E	Okfuskee	CT	CT
Ballard Creek	OK121700-03-0370G	36.1063	-94.5646	NW SW SW SECTION 20-19N-26E	Adair	OH	OH
Battle Creek	OK121700-06-0040G	36.2104	-94.6844	SW NE SW Section 18-20N-25E	Delaware	OH	OH
Bear Creek	OK520700-05-0170A	35.7102	-97.1174	SE¼ SW¼ 5-14N-2E	Lincoln	CT	CT
Big Creek	OK220100-02-0080B	34.7692	-94.4981	SW¼ SW¼ 32-4N-27E	LeFlore	OM	OM
Big Skin Bayou	OK220200-01-0030K	35.3981	-94.6576	SW SE NE 28-11N-25E	Sequoyah	AV	AV
Bird Creek	OK520800-01-0050M	35.0336	-96.4235	SE¼ Section 35-7N-8E	Hughes	CT	CT
Black Fork of Poteau River	OK220100-02-0040P	34.76	-94.4901	NW NW SE 5-3N-27E	LeFlore	OM	OM
Brazil Creek	OK220100-03-0010G	35.1388	-94.7690	SE NW NW Section 27-8N-24E	LeFlore	AV	AV

Site Name	WBID	Latitude	Longitude	Legal Desc	County	Ecoregion	Modified Ecoregion
Brushy Creek	OK220600-03-0010L	34.8014	-95.6547	SE NE SE 19-4N-16E	Pittsburg	AV	AV
Butler Creek	OK120400-02-0160P	35.6089	-95.4292	NW NW 17-13N-18E	Muskogee	CIP	CIP
Canadian Sandy Creek	OK520600-03-0010D	34.8119	-96.7036	NE NE NE SECTION 18-4N-6E	Pontotoc	CT	CT
Captain Creek	OK520700-05-0140H	35.6811	-97.0799	SE¼ SW¼ 15-14N-2E	Lincoln	CT	CT
Caston Creek	OK220100-01-0180B	34.9578	-94.7386	SE¼ 26-6N-24E	LeFlore	AV	AV
Cloud Creek	OK120410-01-0100T	35.7402	-95.6132	NW NW NE Section 33-15N-16E	Muskogee	CIP	CIP
Coal Creek	OK220600-02-0010F	34.9695	-95.852	NE¼ NE¼ NW¼ 29-6N-14E	Pittsburg	AV	AV
Deep Branch	OK121700-01-0020A	35.5194	-95.0799	NE¼ NE¼ 16-12N-21E	Sequoyah	AV	BM
Dry Creek	OK520700-04-0020F	35.6848	-96.6949	SW NW SW Section 17-14N-6E	Lincoln	CT	CT
Elk Creek (McIntosh)	OK120400-02-0190F	35.5223	-95.5031	SW¼ SW¼ SW¼ 10-12N-17E	McIntosh	CIP	CIP
Elk Creek (Cherokee)	OK121700-02-0180G	35.7292	-94.904	SE¼ Section 31-15N-23E	Cherokee	BM	BM
Fourche Maline Creek	OK220100-04-0020H	34.9199	-94.9453	NW NW SW SECTION 12-5N-22E	LeFlore	AV	AV
Gaines Creek	OK220600-04-0010F	34.8955	-95.437	NW¼ Section 20-5N-18E	Latimer	AV	AV
Gar Creek	OK520510-00-0080C	35.3768	-96.5355	NW¼ NE¼ 2-10N-7E	Seminole	CT	CT
Gentry Creek	OK520700-01-0080L	35.5368	-95.6764	SE SW SW Section 1-12N-15E	McIntosh	CIP	CIP
George's Fork of Dirty Creek	OK120400-02-0110D	35.4935	-95.2454	NW NE NE Section 25-12N-19E	Muskogee	CIP	CIP
Greenleaf Creek	OK120400-01-0120C	35.6713	-95.1316	SE¼ Section 24-14N-20E	Muskogee	BM	BM
Hog Creek	OK520810-00-0030D	35.3195	-97.2497	SE¼ SE¼ 24-10N-1W	Cleveland	CT	CT
Holson Creek	OK220100-04-0030G	34.8794	-94.8531	SW¼ NW¼ Section 26-5N-23E	LeFlore	OH	AV
Little Deep Fork	OK520700-06-0010D	35.6996	-96.2104	SW SW 12-14N-10E	Creek	CT	CT
Little Wewoka Creek	OK520500-02-0090D	35.2318	-96.2957	NE¼ NW¼ Section 30-9N-10E	Hughes	CT	CT
Longtown Creek	OK220600-01-0070P	35.1804	-95.4728	NE¼ SE¼ 11-8N-17E	Pittsburg	AV	AV
Manard Bayou	OK120400-01-0280E	35.7942	-95.1634	NE NE 10-15N-20E	Muskogee	BM	BM
Mill Creek	OK220600-01-0100J	35.2201	-95.8036	NW SW SW 26 9N 14E	McIntosh	AV	AV
Montezumah Creek	OK520700-01-0220D	35.5359	-95.9521	NE¼ NE¼ 23-13N-10E	Okmulgee	CT	CT
Nuyaka Creek	OK520700-02-0200D	35.5954	-96.2121	NE¼ NE¼ 23-13N-10E	Okfuskee	CT	CT
Opossum Creek	OK520700-05-0200C	35.7100	-97.1639	Sections 2/11 14N-1E	Cleveland	CT	CT
Peaceable Creek	OK220600-03-0050F	34.8519	-95.6542	SW NW NW Section 5-4N-16E	Pittsburg	AV	AV
Peacheater Creek	OK121700-05-0120B	35.9551	-94.6962	SE NW NE Section 13-17N-25E	Adair	OH	OH
Peavine Creek	OK121700-05-0190F	35.9045	-94.6229	SW NE SE 34-17N-25E	Adair	OH	OH
Pecan Creek (Muskogee)	OK120410-01-0030D	35.7842	-95.4497	NE¼ NE¼ 13-15N-17E	Muskogee	CIP	CIP
Pecan Creek (Pottawatomie)	OK520800-02-0080C	35.2032	-97.1182	SE¼ SW¼ 32-9N-2E	Pottawatomie	CT	CT
Polecat Creek	OK120420-02-0050B	35.9197	-96.2815	NE SE 30-17N-10E	Creek	CT	CT
Pumpkin Hollow Creek	OK121700-03-0090G	35.9655	-94.8675	E.B. Section 8-17N-23E	Cherokee	OH	OH

Site Name	WBID	Latitude	Longitude	Legal Desc	County	Ecoregion	Modified Ecoregion
Quapaw Creek	OK520700-04-0260C	35.6221	-96.8196	SE NE NE Section 12-13N-4E	Lincoln	CT	CT
Sallisaw Creek	OK220200-03-0010C	35.4646	-94.8618	SW SE SW Section 34-12N-23E	Sequoyah	AV	BM
Salt Creek (Creek)	OK520700-03-0100B	35.6962	-96.4765	NW NW NW Section 16-14N-8E	Creek	CT	CT
Salt Creek (Seminole)	OK520800-03-0010D	35.049	-96.6676	SE SE SE Section 28-7N-6E	Seminole	CT	CT
San Bois Creek	OK220200-04-0010G	35.2011	-95.0444	NW NE NW Section 1-8N-21E	Haskell	AV	AV
Shady Grove Creek	OK120400-02-0240H	35.4735	-95.4512	NE SE NE Section 36-12N-17E	McIntosh	CIP	CIP
Snake Creek (Tulsa)	OK120410-01-0220G	35.886	-95.8724	SW SW SW Section 6-16N-14E	Tulsa	CIP	CT
Snake Creek (Sequoyah)	OK121700-02-0100G	35.6375	-94.961	NW¼ Section 3-13N-22E	Sequoyah	BM	BM
South Fork Dirty Creek	OK120400-02-0030H	35.4503	-95.2169	SE SW SW 5-11N-20E	Muskogee	CIP	CIP
Steely Hollow Creek	OK121700-03-0120G	35.9769	-94.923	SE¼ Section 2-17N-22E	Cherokee	OH	OH
Sugar Loaf Creek	OK220100-01-0160G	34.9989	-94.5756	SE¼ SE¼ Section 8-6N-26E	LeFlore	AV	AV
Taloka Creek	OK220300-00-0020M	35.2958	-95.1331	SE NE SE SECTION 36-10N-20E	Haskell	AV	AV
Telemay Hollow Creek	OK121700-03-0140G	36.0381	-94.899	SW¼ Section 18-18N-23E	Cherokee	OH	OH
Turkey Creek	OK520510-00-0100F	35.3772	-96.6479	SE SW 35-11N-6E	Seminole	CT	CT
Tyner Creek	OK121700-05-0090J	35.9956	-94.75	SW NE 33-18N-24E	Adair	OH	OH
Vian Creek	OK220200-02-0130E	35.5074	-94.9837	NE NE NW 21-21N-22E	Sequoyah	BM	BM
Wewoka Creek	OK520500-02-0010C	35.2187	-96.2135	NE NW NE Section 35-9N-10E	Hughes	CT	CT

All sampling and analyses performed during this project were conducted under a Quality Assurance Project Plan (QAPP) approved by EPA Region VI and on file at the OCC Water Quality Division (OCC 2018a), the Oklahoma Secretary of Energy & Environment (OSEE), and EPA Region VI in Dallas. All sampling and measurement activities of OCC Water Quality staff followed procedures outlined in the appropriate OCC Standard Operating Procedure (OCC 2018b). Water quality chemical analyses were conducted by the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) laboratory.

2.2 WATER QUALITY MONITORING

Starting in June 2018 and completing in May 2020, 62 sites were monitored for physical and chemical parameters on five week intervals (usually 20 total sampling events per site). This sampling frequency exceeds state data requirements for beneficial use assessment and meets a sample number necessary to provide a 90% level of confidence for principal water quality data (specifically phosphorus, a critical NPS concern) as determined from EPA's DEFT software (USEPA 2001). Samples were collected during both base flow and high flow conditions as they occurred on predetermined sampling dates. All sampling and measurement activities followed procedures outlined in the appropriate OCC SOP (OCC 2018b).

One water sample was collected per site per 35-day interval in two, new, sample-rinsed HDPE bottles; one was preserved to a pH <2 with H_2SO_4, and both were stored and delivered on ice at 4° C or lower. Quality assurance/control samples were collected in accordance with Data Quality Objectives (DQOs) outlined in the project QAPP (OCC 2018a). Samples were submitted to the ODAFF Laboratory for analysis of the following parameters: nitrate (NO_3), orthophosphate (PO_4), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia (NH_3), chloride (Cl), sulfate (SO_4), total suspended solids (TSS), and total dissolved solids (TDS). An estimate of total nitrogen was calculated by summing the values of nitrate and TKN for each sample. Available nitrogen was calculated by summing the values of ammonia and nitrate. Due to high chloride levels in Basin 3 the reporting limits for nitrite (NO_2) were adjusted to levels that were orders of magnitude higher than those typically observed in stream samples, and therefore excluded from total nitrogen and available nitrogen calculations. Samples submitted to the lab mid-March 2020 through May 2020 were analyzed past holding times due to a state-mandated laboratory shut-down; these samples failed QA requirements (OCC 2018a) and were therefore excluded from the statistical analyses presented in this report. In addition, *in-situ* water quality parameters were measured at each sampling location and included the following: water temperature, dissolved oxygen, pH, conductivity, alkalinity, hardness, turbidity, and instantaneous discharge.

Separate samples were collected and submitted concurrently for analysis of *E. coli* bacteria during the recreational season (May 1 – September 30), ensuring that a minimum of 10 samples were assessed per site over the two-year monitoring period. In addition, site observations of odor, excessive bottom deposits, surface scum, oil/grease, foam and other observations were recorded each time a site was visited.

Select parameters (pH, TSS, DO, turbidity, PO_4, TP, total nitrogen, and available nitrogen) sampled at each monitoring location were compared to the mean of regionally located high quality sites. Sampling sites where a portion of the interquartile range of a measured parameter fell outside two standard deviations of the mean for high quality sites are targeted for further evaluation. High quality sites were determined in a previously completed project, by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005).

In order to track trends in water quality at fixed sampling locations, water quality data collected during cycle 4 (2018-2020) were compared to previous data collection efforts in the same streams. Cycle 4 data were compared to cycle 3 data (2013-2015), as well as data from all previous cycles using one-way ANOVAs. Comparisons between cycles exclude high flow data. Additionally, to maintain consistency in methods between cycles, nitrite was excluded from total nitrogen and available nitrogen calculations for all monitoring cycles.

For each site a water quality index was computed by comparing rotating basin site values relative to regionally located high quality site values. The parameters assessed using this scoring system included phosphorus, nitrogen (excluding nitrite), DO, turbidity, and salts (TDS, chloride, and sulfate). For each of these parameters, a score of 5 (best), 3, or 1 was assigned based on the comparison with high quality sites in that ecoregion. All parameter scores were added together for a total score for each monitoring

location. This score was then compared to the average high quality sites' total score in that ecoregion, to calculate the percentage of reference for each monitoring location.

All data were compiled and entered into an Access database for later analysis. Upon retrieval, data were proofed and quality assured, and the descriptive statistics were generated for each parameter using the statistical software package *Minitab V. 17*.

2.3 BIOLOGICAL MONITORING

2.3.1 Habitat Assessment

In the summer of 2018, OCC staff began conducting instream and riparian habitat assessments at sites concurrent with fish collections (described in Section 2.3.2); any sites not sampled in 2018 were sampled in the summer of 2019. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP (OCC 2018b). The OCC's habitat assessment adheres to a modified version of the EPA Rapid Bioassessment Protocols (RBP) (Plafkin et al., 1989) and is designed to assess habitat quality in relation to its ability to support biological communities in the stream. The assessment is based on particular parameters grouped into three categories for a total of eleven components (Plafkin et al., 1989). The eleven components are discussed in more detail below. The three primary categories assessed include micro scale habitat, macro scale habitat, and riparian/bank structure. Micro scale habitat includes substrate composition, stable cover, canopy, depth, and velocity. Macro scale assesses the channel morphology, sediment deposits, and other parameters. The third category looks at the riparian zone quality, width, and structure (trees, shrubs, vines, and grasses) as well as bank features. Bank erosion and streamside vegetative cover are incorporated into this section.

Each stream segment was surveyed for 400 meters upstream or downstream of the starting point (usually a road crossing). Investigators recorded data for the described parameters for 20 stations at 20 meter intervals. Habitat data were entered, metrics were computed, and a "total habitat score" was rendered via calculations completed in Microsoft® *Access ®*. The total habitat score, which can reach a maximum of 180 points, was calculated based on quantitative weighting given to each of the habitat parameters in relation to their biological significance. Scores were computed for each of the eleven categories, summed, and assigned as an evaluation of that stream section and riparian zone.

Habitat scores that fell outside two standard deviations of the mean habitat score at high quality reference sites in the same ecoregion are targeted for further investigation. Additionally, habitat scores for all monitoring locations were divided by the average habitat score for high quality sites in the same ecoregion to calculate 'percent of reference'.

OCC's habitat assessment components include:

(1) **Instream cover** is the component of habitat that organisms hide behind, within, or under. High quality cover consists of submerged logs, cobble and boulders, root wads, and beds of aquatic plants. Cover required by smaller members of the stream community will consist of gravel, cobbles, small woody debris, and dense beds of fine aquatic plants. At least 50% of the stream's area should be occupied by a mixture of stable cover types for this category to be considered optimal.

(2) **Pool bottom substrate** describes the type of stream bed found in pools. Pools are depositional areas of the stream, and as such, are easily damaged by materials that settle. A loose shifting pool bottom will not provide substrate for burrowing organisms and will not allow bottom-spawning fish to successfully spawn. It will not provide habitat to the smaller vertebrates and invertebrates that are necessary to support many of the pool dwelling fish. At least 80% of all pool bottoms must have stable substrate for a reach to be considered optimal for the habitat component.

(3) **Pool variability** describes the depth of pools. A healthy, diverse community of aquatic organisms requires both deep and shallow pools. A fairly even mix of pool depths from a few centimeters to 0.5 meters or greater is optimal.

(4) **Canopy cover** assesses the shading of the stream section. Plants lie at the base of almost all food chains. Since plants require light for growth and survival, a stream that is functioning well needs some amount of light. Moderation is optimal, however, because light is associated with heat, and most aquatic organisms are stressed by the higher water temperature, lower oxygen solubility and higher metabolic rates that accompany the warming of water.

(5) The **percent of rocky runs and riffles** is calculated for the fifth component. Rocky runs and riffles offer a unique combination of highly oxygenated, turbulent water, flowing over high quality cover and substrate. Turbulence prevents the formation of nutrient concentration gradients from cell membranes outward so that algae and other plants grow at a much higher rate than they would at the same concentration in pools. More food means more growth. Larger crops of algae are translated into larger invertebrate crops. It is these invertebrates, reared in riffle areas that feed many of the fish in the stream. Because turbulent water is well oxygenated, there has been no selection pressure for riffle dwelling organisms to develop tolerance to poorly oxygenated waters. These are often the first animals to disappear from the stream if oxygen becomes scarce. The presence of rocky runs and riffles offers habitat for many highly adapted animals that will increase diversity of samples collected from the streams they occupy.

(6) **Discharge** at representative low flow reflects stream size. Water is the most basic requirement of aquatic organisms. Larger streams tend to have more water, and thus, more varied high quality habitat. Overall habitat quality should rise as streams increase in size and discharge, other factors being equal.

(7) **Channel alteration** is the seventh category. The presence of newly formed point bars and islands is very significant. Unstable streambeds support fewer types of animals than those that are stable. This is because unstable streambeds tend to have unstable pool bottom substrate, riffle areas whose cobbles are embedded in finer material, and little cover because it is continually being buried. Few or no signs of channel alteration are considered optimal.

(8) **Channel sinuosity** measures how far a channel deviates from a straight line. More sinuous channels tend to have more undercut banks, root wads, submerged logs, etc. Index of Biotic Integrity

(IBI) scores should be higher as channels become more sinuous. Sinuosity is calculated by dividing the length of the assessment (400 meters) by the distance between the GPS location of the start point and end point of the assessment.

(9) The **bank erosion** index assesses the stability of the stream bank. Stable stream banks tend to increase IBI scores for many reasons. Most importantly, they do not contribute sediment to the stream channel. As a rule, channels with stable banks tend to be deeper and narrower than channels with unstable banks. Because of the increased depth and decreased width, they tend to be cooler and they also tend to grow less algae for a given amount of nutrients than do shallow, wide channels. Overall habitat quality should increase as bank stability increases.

(10) The **vegetative stability** of the stream bank is an important component. Stream banks can be stabilized with a number of materials including rock, concrete, and fabric. Banks that are stabilized with vegetation benefit the aquatic community more than those stabilized with other materials. This is because the vegetation offers several extra advantages beyond that of bank stability. The riparian plants of the stream bank offer a high quality source of food and shade to the aquatic community. Riparian vegetation stabilizes point bars and contributes greatly to structure in the form of root wads and woody debris. Overall habitat quality should improve as bank vegetative stability increases.

(11) The last category is **streamside cover**. A large part of the energy and food input to the stream comes from the terrestrial vegetation along the banks. A mixture of grasses, forbs, shrubs, vines, saplings, and large trees transfer these necessities to the stream more effectively than does any single type of vegetation. Habitat quality should increase as the form of bank vegetation increases in diversity.

2.3.2 Fish

Fish collections were completed in the summer of 2018 or 2019 for each site. Fish were collected from a 400-meter reach at all sites using a combination of seining and electroshocking according to procedures outlined in OCC SOP (2018). The collection of fish follows a modified version of the EPA Rapid Bioassessment Protocol V (Plafkin et al., 1989) supplemented by other documents. Specific techniques and relative advantages of seining and electrofishing vary considerably according to stream type and conductivity. Depending upon workable habitat, seining was performed first at all sites and was accomplished by use of either 6’ X 10’ or 6’ X 20’ seines of ¼ inch mesh equipped with 8’ brailes. Electroshocking was undertaken at all sites with suitable conductivities (usually < 1000 µS/cm) and involved the use of a Smith Root LR 24 backpack shocker. For sites possessing long pools too deep to seine or backpack shock, OCC field personnel employed a boat electrofishing unit consisting of a Smith-Root GPP 2.5 shocking unit powered by a Honda 5kw generator.

Except for those individuals readily identifiable, fish were placed in 10% formalin upon capture and identified to species by a professional taxonomist. Fish species identified and released in the field were photographed for reference. All fixed fish samples were transferred to ethanol and retained for future reference.

Fish data were compiled and analyzed by site using state biocriteria and methods outlined in the state's *Use Support Assessment Protocols* (OWRB 2016). In addition, each site was assessed using OCC's modified RBP method, which is a modified version of Karr's Index of Biotic Integrity (IBI) (adapted from Plafkin et al., 1989). Descriptive statistics were determined for each metric using the *Minitab V 17* software. The condition of the fish community was based on indices of species richness, community quality, trophic structure, and by comparison to the average scores of high-quality streams in that ecoregion. High quality sites were determined by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005). The modified IBI score was calculated using the following metrics:

(1) The **total number of fish species** decreases with decreasing water or habitat quality.

(2) The **number of sensitive benthic species (darters, madtoms, sculpins)** decreases with increasing siltation and increasing benthic oxygen demand. Many of these fish actually live within the cobble and gravel interstices and are very good indicators of conditions that make this environment inhospitable. These species are weak swimmers that do not readily travel up and down a stream, so their presence or absence at a site relates well to both past and present habitat and water quality conditions at that site.

(3) The **number of sunfish species** decreases with decreasing pool quality and with decreasing cover. Sunfish also require a fairly stable substrate on which to spawn, so their long-term success is also tied to conditions that affect the amount of sediment that enters and leaves the stream.

(4) The **number of intolerant species** is a characteristic of the fish community that separates high quality from moderate quality sites. A high quality stream will have several members of the fish community that are intolerant to environmental stress. A stream of only moderate quality will have fish that are moderately and highly tolerant of environmental stress. The intolerant species will not be present in the moderate quality stream.

(5) The **proportion of tolerant individuals** is a characteristic that allows moderate quality streams to be separated from low quality streams. These are opportunistic, tolerant fish that dominate communities that have lost their competitors through loss of habitat or water quality.

(6) The **proportion of individuals as insectivorous cyprinids** increases as the quality and quantity of the invertebrate food base increases. These are the dominant minnows in North American streams but are replaced by either omnivorous or herbivorous minnows as the quality of the food base deteriorates. Often, as the density of aquatic invertebrates decreases, the standing crop of algae increases. This is because the aquatic invertebrates are the largest group of primary consumers. Fish that can switch their diet to algae or fish that eat only algae will replace fish that cannot adapt to the new conditions.

(7) The **proportion of individuals as lithophilic spawners** decreases as the quality of the stream decreases. Lithophilic spawners require cobble or gravel in order to spawn; hence, these fish are sensitive to siltation. This metric allows separation of excellent streams from moderate quality streams.

For each of these seven metrics, a score of 5, 3, or 1 was assigned (Table 2), and these scores were summed to get a total IBI score (35 point maximum) for each site. For all "proportion" metrics, the score was based on the actual metric. For all non–proportion metrics, the score was determined by dividing the monitoring site's metric by the average high quality site metric of the same ecoregion. Each monitoring site's total score was then compared to the high quality site total score in that ecoregion and given an integrity rating (as established and suggested by the EPA RBP; see Table 3, below. This score indicates the quality of the fish community (high scores indicate higher quality) but says nothing about whether any deficiencies are due to degraded water quality or to degraded habitat.

Table 2. Index of Biotic Integrity (IBI) scoring criteria for fish.

Metrics	***5***	***3***	***1***
Number of species	>67%	33-67%	<33%
Number of sensitive benthic species	>67%	33-67%	<33%
Number of sunfish species	>67%	33-67%	<33%
Number of intolerant species	>67%	33-67%	<33%
Proportion tolerant individuals	<10%	10-25%	>25%
Proportion insectivorous cyprinid individuals	>45%	20-45%	<20%
Proportion individuals as lithophilic spawners	>36%	18-36%	<18%

Table 3. Index of Biotic Integrity (IBI) score interpretations for fish.

% Comparison to the Reference Score	Integrity Class	Characteristics
90 – 100 %	Excellent	Comparable to pristine conditions, exceptional species assemblage
78 – 89%	Good	Decreased species richness, especially intolerant species
62 – 77%	Fair	Intolerant and sensitive species rare or absent
42 – 61%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
0 – 41%	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

2.3.3 Macroinvertebrates

Collection of macroinvertebrates was attempted at all sites during both winter and summer index periods from June 2018 through March 2020 according to procedures outlined in the OCC SOP (2018). Index periods represent seasons of relative community stability that afford opportunity for meaningful site comparisons. For Oklahoma, the summer index occurs from June 1 to September 15; the winter index occurs from January 1 to March 15. In order for macroinvertebrate collections to be obtained, flowing water must be present. Sampling efforts included attempts to procure animals from all available habitats at a site; thus, total effort at a site may entail up to three total samples with one from each of the following habitats: rocky riffles, streamside vegetation, and woody debris.

Collection methods involved sampling each of the habitats similar to methods outlined in the EPA Rapid Bioassessment Protocols (Plafkin et at., 1989). Riffle sampling effort consisted of three, one meter squared kicknet samples in the areas of rocky substrate reflecting the breadth of the velocity regime at a site. Riffles with substrates of bedrock or tight clay were not sampled. Any streamside vegetation in the current that appeared to offer fine structure was sampled by agitation within a #30 mesh dip net for three minutes total agitation time. Any dead wood with or without bark which was in current fast enough to offer suitable habitat for organisms was sampled by agitation or by scraping/brushing upstream of a #30 mesh dip net for five minutes. Woody debris sampled generally ranged in size from ¼" to about 8" in diameter. Each sample type was preserved independently in quart mason jars with ethanol, labeled, and sent to a professional taxonomist for picking and identification.

Data were compiled, collated by year, season, and sample type and entered into a spreadsheet for metric calculations. The six metrics used to assess the macroinvertebrate community include the following:

(1) The **number of taxa** refers to the total number of taxonomically different types of animals in the sample. As is the case with the fish, this number rises with increasing water and/or habitat quality (Plafkin et al., 1989).

(2) The **Modified Hilsenhoff Biotic Index (HBI)** is a measure of the invertebrate community's tolerance to organic pollution. It ranges between 0 and 10 with 0 being the most pollution sensitive. The index used in the RBP Manual is based on the pollution tolerance of invertebrates from the upper Midwest. The Index used here is calculated the same way, but used tolerance values of North Carolina invertebrates (Plafkin et al., 1989).

(3) The **EPT Index** is the number of different taxa from the orders Ephemeroptera, Plecoptera, and Trichoptera, the mayflies, stoneflies, and caddis flies respectively. With few exceptions, these insects are more sensitive to pollution than any other groups. As a stream deteriorates in quality, members of this group will be the first to disappear. This robust metric allows discrimination between all but the worst of streams (Plafkin et al., 1989).

(4) The **percent EPT** is a measure of how many individuals in the sample are members of the EPT group. This metric helps to separate high quality streams from those of moderately high quality. The highest quality streams will have many individuals of many different taxa of EPT. As conditions deteriorate, animals will begin to die or to drift downstream. At this point, the community will still have many taxa of EPT, but there will be fewer individuals (Plafkin et al., 1989).

(5) **Percent dominant two taxa** is the percentage of the collection composed of the most common two taxa. As more and more species are excluded by increasing pollution, the remaining species can increase in numbers due to the unused resources left by the excluded animals. This metric helps to separate the high quality streams from those of moderate quality (Plafkin et al., 1989).

(6) The **Shannon-Weaver Species Diversity Index** measures the evenness of the species distribution. It increases as more taxa are found in the collection and as individual taxa become less dominant. The metric increases with increasing biotic quality (Plafkin et al., 1989).

Descriptive statistics of each season-specific sample type (e.g., summer riffle, winter vegetation, summer woody) for each site were determined via *Minitab V. 17* and were compared to the average respective metric of high-quality streams in the ecoregion. High quality sites were determined by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005). A Bioassessment score was calculated similarly to the IBI score for fish. For each site, scores of 6, 4, 2, or 0 were assigned for each metric (according to the criteria in Table 4, below) and then summed to get a total Bioassessment score for each site, with a maximum of 36 points. For taxa richness and EPT taxa richness, the percentages used to assign scores were obtained by dividing each monitoring site metric by the average high quality site metric in a particular ecoregion. For the HBI metric, the high quality site value was divided by the monitoring site value (high quality site metric / monitoring site metric). For the remaining metrics, the score was based on the actual values obtained instead of being relative to the high quality site metric. Each monitoring site's total score was then compared to the average high quality sites' total score (in that ecoregion) and classified according to the condition gradient outlined in Table 5 (adapted from Plafkin et al., 1989).

Table 4. Bioassessment scoring criteria for macroinvertebrates

Metrics	***6***	***4***	***2***	***0***
Taxa Richness**	>80%	60-80%	40-60%	<40%
Modified HBI* (**)	>85%	70-85%	50-70%	<50%
EPT/Total***	>30%	20-30%	10-20%	<10%
EPT Taxa**	>90%	80-90%	70-80%	<70%
% Dominant 2 Taxa**	<20%	20-30%	30-40%	>40%
Shannon-Weaver***	>3.5	2.5-3.5	1.5-2.5	<1.5

*Modified HBI Using North Carolina Tolerance Values
**RBP for Use in Streams and Rivers 1989
***Modified by OCC

Table 5. Bioassessment score interpretation for macroinvertebrates

% Comparison to the Reference Score	Biological Condition	Characteristics
>80%	Non-Impaired	Comparable to the best situation expected within the ecoregion. Balanced trophic and community structure for stream size.
52-79%	Slightly Impaired	Community structure less than expected. Species richness is less than expected due to loss of some intolerant forms. Percent contribution of tolerant forms is increased.
20-51%	Moderately Impaired	Fewer species due to the loss of most intolerant forms. Reduction in EPT index.
<19%	Severely Impaired	Few species present. If high densities of organisms occur, they are dominated by 1 or 2 taxa.

2.4 WATERSHED ASSESSMENT

To investigate potential sources of NPS pollution for streams showing beneficial use impairment, relevant data layers were explored using ArcMap 10.1 Geographic Information System (GIS) software. Data explored included the 2016 USGS National Land Cover Dataset (NLCD), oil and gas wells, confined animal feeding operations, national pollution discharge elimination system permit holders, total retention sites, biosolid land application sites and other data layers. To examine the effects of point source versus non-point source pollution on the parameters at the monitoring sites, one-way ANOVAs were performed comparing sites with the permitted discharge to sites with no permitted discharge. The NLCD was explored to determine percent occurrence of particular land-use types such as bare rock/sand/clay, vegetation (separated into several categories, both natural and agricultural), open water, and residential/commercial/industrial uses (divided into several categories).

2.5 BENEFICIAL USE SUPPORT ASSESSMENT

Each fixed site's assigned beneficial uses were evaluated following the protocols outlined in the state's *Continuing Planning Process, Integrated Water Quality Report Listing Methodology* (Oklahoma Department of Environmental Quality, 2012) and per *Oklahoma Administrative Code 785, Chapter 46: Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (OWRB 2016). Streams were considered non-supporting when Oklahoma Water Quality Standards were violated as determined by criteria and rules listed in these documents. Parameters not addressed in OAC 785:46-15 were assessed using applicable state and federal rules and regulations to determine support status. Assessment results were submitted to the ODEQ for final assimilation in the state's 2020 Integrated Report submitted to EPA Region VI.

3.0 RESULTS AND DISCUSSION

3.1 WATER QUALITY MONITORING

All chemical and physical water quality data collected for the project are included in Appendix A.1; Appendix A.2 contains the bacteria data. Table 6 gives the mean values of all water quality parameters collected in-situ for each site, regardless of elevated or base flow. Table 7 provides the means for all chemical analytes assessed, regardless of flow. Descriptive statistics for water quality parameters are presented by site in Appendix A.3.

Table 6. Mean in situ water quality values for Basin Group 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) monitoring sites, 2018-2020. WBID is a unique waterbody identifier for each monitoring site.

Site Name	WBID	Alkalinity (CaCO3)	Conductivity (µs/cm)	DO (mg/l)	DO % Saturation	Hardness (mg/l)	pH (SU)	Water Temp (°C)	Turbidity (NTU)	Flow (cfs)
Alabama Creek	OK520500-01-0200D	70.8	449.26	8.30	83.37	116.7	7.45	17.45	26.04	5.77
Ash Creek	OK120410-01-0110E	82.8	356.10	8.49	83.05	142.9	7.53	17.11	50.96	10.46
Bad Creek	OK520500-01-0170E	118.7	497.69	7.52	73.84	151.9	7.20	17.47	27.75	0.72
Ballard Creek	OK121700-03-0370G	104.3	245.35	8.93	86.86	136.2	7.66	15.95	7.15	46.15
Battle Creek	OK121700-06-0040G	83.2	274.70	8.67	86.13	99.2	7.38	15.37	1.52	15.73
Bear Creek	OK520700-05-0170A	286.6	664.83	8.81	84.31	304.7	7.94	16.03	73.76	65.60
Big Creek	OK220100-02-0080B	16.1	28.95	8.58	87.48	34.6	6.79	17.15	27.26	3.79
Big Skin Bayou	OK220200-01-0030K	35.3	79.26	9.00	92.32	80.8	7.29	17.30	17.44	5.30
Bird Creek	OK520800-01-0050M	155.0	1727.50	7.95	79.37	361.1	7.42	17.35	13.32	4.52
Black Fork of Poteau River	OK220100-02-0040P	16.4	35.45	8.18	80.89	37.9	6.99	16.78	14.17	1.15
Brazil Creek	OK220100-03-0010G	62.1	149.97	7.74	77.79	96.8	7.07	17.44	49.54	14.17
Brushy Creek	OK220600-03-0010L	52.0	128.66	7.80	77.38	99.8	7.21	17.11	72.52	0.74
Butler Creek	OK120400-02-0160P	82.0	342.81	5.54	49.79	132.1	7.28	16.08	29.38	12.37
Canadian Sandy Creek	OK520600-03-0010D	256.9	519.89	9.46	97.19	277.6	8.00	18.49	24.69	155.10
Captain Creek	OK520700-05-0140H	313.0	682.60	9.32	89.69	335.9	8.22	15.90	34.84	20.93
Caston Creek	OK220100-01-0180B	61.6	204.66	8.99	92.95	103.0	7.34	18.49	28.61	5.52
Cloud Creek	OK120410-01-0100T	70.9	284.21	7.29	71.45	117.1	7.42	17.29	33.94	30.36
Coal Creek	OK220600-02-0010F	77.0	288.19	7.12	69.70	125.4	7.35	17.51	79.06	7.82
Deep Branch	OK121700-01-0020A	43.2	118.80	7.10	69.20	86.0	7.20	17.50	11.30	0.48
Dry Creek	OK520700-04-0020F	261.1	725.70	9.10	92.39	326.7	7.91	17.93	45.84	63.88
Elk Creek (McIntosh)	OK120400-02-0190F	62.4	400.61	7.58	73.51	169.6	7.34	17.03	24.60	44.06
Elk Creek (Cherokee)	OK121700-02-0180G	141.4	269.17	8.26	85.82	186.5	7.69	17.11	3.76	4.76
Fourche Maline Creek	OK220100-04-0020H	47.0	108.60	7.52	75.22	89.9	6.98	17.87	42.30	4.15

Site Name	WBID	Alkalinity (CaCO3)	Conductivity (µs/cm)	DO (mg/l)	DO % Saturation	Hardness (mg/l)	pH (SU)	Water Temp (°C)	Turbidity (NTU)	Flow (cfs)
Gaines Creek	OK220600-04-0010F	41.4	102.51	7.00	68.89	88.9	6.92	17.33	53.23	3.25
Gar Creek	OK520510-00-0080C	101.1	307.97	8.87	84.93	150.2	7.26	16.49	18.32	25.19
Gentry Creek	OK520700-01-0080L	81.6	284.63	7.22	71.08	145.6	7.50	16.89	21.68	0.84
George's Fork of Dirty Creek	OK120400-02-0110D	68.9	209.72	6.60	61.19	105.6	7.26	17.15	27.96	56.53
Greenleaf Creek	OK120400-01-0120C	72.2	175.19	8.72	89.72	116.4	7.52	17.75	9.20	2.01
Hog Creek	OK520810-00-0030D	249.4	584.10	8.96	87.32	313.7	7.85	16.70	36.33	17.76
Holson Creek	OK220100-04-0030G	25.1	44.76	8.29	86.09	59.3	6.81	18.69	22.96	8.95
Little Deep Fork	OK520700-06-0010D	92.5	398.07	8.73	86.65	155.2	7.64	17.15	70.71	212.67
Little Wewoka Creek	OK520500-02-0090D	92.7	494.98	8.73	87.95	162.0	7.62	17.75	44.87	42.84
Longtown Creek	OK220600-01-0070P	47.6	133.97	8.29	83.61	66.1	7.30	18.03	15.18	25.67
Manard Bayou	OK120400-01-0280E	116.8	246.12	9.22	94.90	145.5	7.80	18.19	17.51	23.95
Mill Creek	OK220600-01-0100J	62.9	143.46	7.55	74.36	83.4	7.20	17.90	40.46	38.70
Montezumah Creek	OK520700-01-0220D	77.0	323.12	6.36	60.47	117.8	7.30	17.17	32.90	41.84
Nuyaka Creek	OK520700-02-0200D	112.8	355.99	6.98	68.68	143.1	7.48	17.35	43.96	36.14
Opossum Creek	OK520700-05-0200C	316.4	756.40	8.25	79.77	362.8	8.10	15.42	95.09	14.73
Peaceable Creek	OK220600-03-0050F	60.0	304.45	7.17	71.35	132.7	7.37	17.22	51.44	7.00
Peacheater Creek	OK121700-05-0120B	74.7	161.04	8.94	94.13	92.5	7.43	17.23	3.18	28.33
Peavine Creek	OK121700-05-0190F	116.0	243.23	9.31	96.00	134.4	7.80	17.12	1.40	13.37
Pecan Creek (Muskogee)	OK120410-01-0030D	79.3	267.70	7.70	76.24	117.3	7.35	16.52	59.65	13.07
Pecan Creek (Pottawatomie)	OK520800-02-0080C	250.2	496.71	9.95	100.99	275.5	8.20	17.00	28.05	12.82
Polecat Creek	OK120420-02-0050B	69.5	214.50	8.97	88.62	104.5	7.26	17.47	126.87	149.73
Pumpkin Hollow Creek	OK121700-03-0090G	70.2	136.10	8.17	82.56	80.1	7.30	16.75	4.60	14.76
Quapaw Creek	OK520700-04-0260C	252.5	570.60	9.42	95.47	263.6	8.25	17.42	75.10	73.29
Sallisaw Creek	OK220200-03-0010C	74.6	220.69	9.61	99.28	106.4	7.54	18.53	14.47	31.78
Salt Creek (Creek)	OK520700-03-0100B	162.9	552.01	8.42	85.64	213.8	7.50	17.91	33.56	53.36
Salt Creek (Seminole)	OK520800-03-0010D	269.0	2196.52	9.16	95.07	539.2	8.09	18.36	48.27	57.80
San Bois Creek	OK220200-04-0010G	86.5	290.29	7.85	78.62	131.5	7.56	17.55	57.11	13.52
Shady Grove Creek	OK120400-02-0240H	54.3	800.80	7.73	74.88	535.8	6.73	16.87	17.58	11.10
Snake Creek (Tulsa)	OK120410-01-0220G	91.9	289.90	8.76	86.97	126.6	7.60	17.78	52.26	91.86
Snake Creek (Sequoyah)	OK121700-02-0100G	137.5	278.93	8.48	84.02	177.8	7.73	16.00	4.08	3.10
South Fork Dirty Creek	OK120400-02-0030H	114.1	434.81	8.00	78.83	212.2	7.59	17.83	12.36	13.00
Steely Hollow Creek	OK121700-03-0120G	91.1	178.59	9.66	98.32	104.6	7.92	16.53	1.38	3.64
Sugar Loaf Creek	OK220100-01-0160G	42.8	74.35	7.63	74.74	79.4	6.90	17.05	40.31	1.79

Site Name	WBID	Alkalinity (CaCO3)	Conductivity (µs/cm)	DO (mg/l)	DO % Saturation	Hardness (mg/l)	pH (SU)	Water Temp (°C)	Turbidity (NTU)	Flow (cfs)
Taloka Creek	OK220300-00-0020M	247.4	875.74	8.49	84.42	314.1	7.87	16.73	33.20	4.26
Telemay Hollow Creek	OK121700-03-0140G	113.3	226.86	9.45	93.94	138.6	7.87	15.91	2.77	2.93
Turkey Creek	OK520510-00-0100F	218.1	2037.30	8.58	81.94	428.5	7.75	15.90	31.53	32.60
Tyner Creek	OK121700-05-0090J	78.7	176.55	8.21	82.23	92.9	7.34	16.80	1.74	32.97
Vian Creek	OK220200-02-0130E	102.5	287.93	9.22	94.70	128.6	7.64	17.90	3.68	4.12
Wewoka Creek	OK520500-02-0010C	116.2	828.03	8.85	92.46	202.1	7.85	18.94	63.57	146.87

Table 7. Mean water quality values for Basin Group 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) monitoring sites, 2018-2020. WBID is a unique waterbody identifier for each monitoring site.

Site Name	WBID	Ammonia (mg/l)	Chloride (mg/l)	TDS (mg/l)	TKN (mg/l)	Nitrate (mg/l)	Ortho P (mg/l)	Total P (mg/l)	Sulfate (mg/l)	TSS (mg/l)
Alabama Creek	OK520500-01-0200D	0.0245	84.3	278.8	0.502	0.068	0.0159	0.0461	16.09	19.3
Ash Creek	OK120410-01-0110E	0.0463	32.2	229.4	0.709	0.086	0.0316	0.0813	40.88	19.5
Bad Creek	OK520500-01-0170E	0.0150	79.5	340.6	0.523	0.048	0.0245	0.0654	15.16	17.4
Ballard Creek	OK121700-03-0370G	0.0150	8.6	154.4	0.311	2.134	0.0944	0.1068	11.36	12.5
Battle Creek	OK121700-06-0040G	0.0150	6.8	124.4	0.286	2.769	0.0718	0.0764	4.36	10.0
Bear Creek	OK520700-05-0170A	0.0461	24.4	361.7	0.748	0.164	0.0562	0.1096	14.51	50.9
Big Creek	OK220100-02-0080B	0.0166	2.0	50.6	0.205	0.094	0.0052	0.0147	2.38	10.1
Big Skin Bayou	OK220200-01-0030K	0.0151	3.9	75.2	0.274	0.111	0.0105	0.0292	8.96	20.6
Bird Creek	OK520800-01-0050M	0.0195	416.3	951.7	0.421	0.026	0.0131	0.0312	32.84	10.1
Black Fork of Poteau River	OK220100-02-0040P	0.0191	2.2	53.4	0.226	0.068	0.0053	0.0196	3.66	10.0
Brazil Creek	OK220100-03-0010G	0.0317	4.6	115.9	0.547	0.106	0.0317	0.0756	23.85	23.1
Brushy Creek	OK220600-03-0010L	0.0363	4.4	113.2	0.686	0.064	0.0282	0.0956	13.11	73.8
Butler Creek	OK120400-02-0160P	0.1583	28.7	230.0	0.912	0.098	0.0487	0.0973	48.92	14.7
Canadian Sandy Creek	OK520600-03-0010D	0.0220	15.5	312.2	0.417	0.096	0.0583	0.0818	14.23	21.5
Captain Creek	OK520700-05-0140H	0.0627	30.7	373.2	0.385	0.198	0.0260	0.0441	17.89	19.8
Caston Creek	OK220100-01-0180B	0.0316	4.9	136.4	0.488	0.257	0.0406	0.0721	41.42	14.9
Cloud Creek	OK120410-01-0100T	0.0317	26.9	194.4	0.642	0.111	0.0417	0.0882	33.40	28.5
Coal Creek	OK220600-02-0010F	0.1864	13.1	190.0	0.946	0.235	0.1233	0.1977	41.73	77.0
Deep Branch	OK121700-01-0020A	0.0187	2.9	72.4	0.348	0.027	0.0070	0.0235	8.76	10.1
Dry Creek	OK520700-04-0020F	0.0367	71.4	426.1	0.621	0.108	0.0619	0.0992	19.92	24.2

Site Name	WBID	Ammonia (mg/l)	Chloride (mg/l)	TDS (mg/l)	TKN (mg/l)	Nitrate (mg/l)	Ortho P (mg/l)	Total P (mg/l)	Sulfate (mg/l)	TSS (mg/l)
Elk Creek (McIntosh)	OK120400-02-0190F	0.0486	14.8	278.9	0.787	0.319	0.0899	0.1251	113.82	11.8
Elk Creek (Cherokee)	OK121700-02-0180G	0.0360	3.1	173.9	0.219	0.090	0.0184	0.0383	11.63	11.6
Fourche Maline Creek	OK220100-04-0020H	0.0353	6.2	101.6	0.512	0.102	0.0278	0.0669	13.80	20.1
Gaines Creek	OK220600-04-0010F	0.0411	3.6	100.7	0.481	0.076	0.0257	0.0692	14.94	44.3
Gar Creek	OK520510-00-0080C	0.0152	35.4	199.4	0.287	0.033	0.0109	0.0248	8.84	10.6
Gentry Creek	OK520700-01-0080L	0.0179	7.3	196.7	0.579	0.072	0.0322	0.0693	55.26	12.6
George's Fork of Dirty Creek	OK120400-02-0110D	0.0427	11.1	152.2	0.793	0.111	0.0429	0.0882	27.86	13.5
Greenleaf Creek	OK120400-01-0120C	0.0166	3.4	117.3	0.219	0.057	0.0136	0.0305	19.19	10.5
Hog Creek	OK520810-00-0030D	0.0718	28.4	338.9	0.463	0.078	0.0209	0.0393	8.62	20.1
Holson Creek	OK220100-04-0030G	0.0153	2.7	63.4	0.242	0.035	0.0062	0.0278	5.49	18.5
Little Deep Fork	OK520700-06-0010D	0.0351	72.2	272.2	0.779	0.148	0.0388	0.0922	11.89	64.5
Little Wewoka Creek	OK520500-02-0090D	0.0267	89.6	321.1	0.749	0.086	0.0375	0.0796	13.27	21.0
Longtown Creek	OK220600-01-0070P	0.0269	6.9	98.7	0.347	0.087	0.0102	0.0326	20.54	10.0
Manard Bayou	OK120400-01-0280E	0.0162	4.9	162.8	0.241	0.197	0.0274	0.0450	19.39	10.0
Mill Creek	OK220600-01-0100J	0.0363	7.5	135.0	0.632	0.068	0.0200	0.0606	11.52	15.3
Montezumah Creek	OK520700-01-0220D	0.0290	45.3	219.4	0.697	0.052	0.0237	0.0672	16.97	18.4
Nuyaka Creek	OK520700-02-0200D	0.0464	35.6	237.8	0.835	0.092	0.0349	0.0855	15.38	23.6
Opossum Creek	OK520700-05-0200C	0.0599	61.6	470.0	0.553	0.072	0.0539	0.0891	13.61	25.0
Peaceable Creek	OK220600-03-0050F	0.0564	25.4	211.7	0.766	0.116	0.0888	0.1397	43.19	14.8
Peacheater Creek	OK121700-05-0120B	0.0150	6.5	104.3	0.203	2.553	0.0423	0.0508	4.21	11.8
Peavine Creek	OK121700-05-0190F	0.0150	9.1	153.9	0.152	1.547	0.0352	0.0364	8.42	10.0
Pecan Creek (Muskogee)	OK120410-01-0030D	0.0626	11.1	215.3	0.910	0.189	0.0739	0.1379	50.55	25.4
Pecan Creek (Pottawatomie)	OK520800-02-0080C	0.0150	20.3	307.4	0.263	0.028	0.0092	0.0180	9.16	11.1
Polecat Creek	OK120420-02-0050B	0.0330	20.8	193.3	0.757	0.133	0.0278	0.0846	10.92	57.3
Pumpkin Hollow Creek	OK121700-03-0090G	0.5763	4.2	90.5	0.278	0.398	0.0120	0.0243	5.76	10.7
Quapaw Creek	OK520700-04-0260C	0.0237	24.2	343.9	0.606	0.138	0.0533	0.0943	23.77	46.6
Sallisaw Creek	OK220200-03-0010C	0.0166	3.3	104.8	0.259	0.172	0.0130	0.0315	7.27	10.9
Salt Creek (Creek)	OK520700-03-0100B	0.0489	70.1	358.8	0.585	0.093	0.0347	0.0678	18.38	23.9
Salt Creek (Seminole)	OK520800-03-0010D	0.0275	598.6	1253.2	0.374	0.031	0.0226	0.0389	64.41	23.7
San Bois Creek	OK220200-04-0010G	0.0303	5.1	241.7	0.638	0.108	0.0383	0.0846	59.50	31.6
Shady Grove Creek	OK120400-02-0240H	0.0729	7.0	662.2	0.463	0.250	0.0132	0.0283	652.61	11.3
Snake Creek (Tulsa)	OK120410-01-0220G	0.0394	22.4	206.5	0.701	0.105	0.0612	0.1119	22.21	24.8
Snake Creek (Sequoyah)	OK121700-02-0100G	0.0229	2.1	171.1	0.147	0.046	0.0084	0.0121	10.98	10.0
South Fork Dirty Creek	OK120400-02-0030H	0.0230	5.3	289.4	0.491	0.070	0.0208	0.0452	112.23	10.1
Steely Hollow Creek	OK121700-03-0120G	0.0150	5.9	115.7	0.127	0.433	0.0092	0.0174	4.54	10.0
Sugar Loaf Creek	OK220100-01-0160G	0.0377	4.3	73.1	0.396	0.127	0.0207	0.0592	8.81	15.5

Site Name	WBID	Ammonia (mg/l)	Chloride (mg/l)	TDS (mg/l)	TKN (mg/l)	Nitrate (mg/l)	Ortho P (mg/l)	Total P (mg/l)	Sulfate (mg/l)	TSS (mg/l)
Taloka Creek	OK220300-00-0020M	0.0270	7.0	637.2	0.500	0.071	0.0267	0.0598	204.98	36.6
Telemay Hollow Creek	OK121700-03-0140G	0.0150	2.9	143.2	0.133	0.037	0.0070	0.0149	12.16	20.6
Turkey Creek	OK520510-00-0100F	0.0163	528.5	1185.0	0.499	0.043	0.0298	0.0572	24.99	17.2
Tyner Creek	OK121700-05-0090J	0.0150	5.1	115.5	0.131	2.409	0.0202	0.0274	4.14	11.1
Vian Creek	OK220200-02-0130E	0.0150	3.1	126.9	0.166	0.038	0.0086	0.0162	10.42	10.2
Wewoka Creek	OK520500-02-0010C	0.0152	172.3	486.1	0.667	0.143	0.0540	0.1029	19.09	41.6

Dissolved Oxygen criteria depend on the use designation of the waterbody. Fifty-three of the fixed sites are designated as Warm Water Aquatic Communities (WWAC) and have a critical DO level of 5.0 mg/L most of the year (6.0 mg/L from April 1 – June 15). Bird Creek is designated as Habitat Limited Aquatic Community (HLAC) with a critical DO level of 4.0 mg/L from April 1 – June 15 and 3.0 mg/L from June 16 – March 31. Eight sites have Cool Water Aquatic Community (CWAC) designations, with a critical DO level of 6.0 mg/L most of the year (7.0 mg/L March 1 – May 31). Nineteen sites exhibited dissolved oxygen levels which were always above criteria values: Alabama Creek, Big Skin Bayou, Canadian Sandy Creek, Captain Creek, Caston Creek, Dry Creek, Hog Creek, Holson Creek, Little Deep Creek, Little Wewoka Creek, Opossum Creek, Peacheater Creek, Sallisaw Creek, Salt Creek (Creek), Salt Creek (Seminole), Snake Creek (Tulsa), Snake Creek (Sequoyah), Taloka Creek, and Vian Creek. Table 8 (below) reflects the DO values at the 33 sites with low dissolved oxygen values occurring in 10% or more of samples and the total percentage of low DO samples.

Table 9 shows the geometric mean of *E. coli* bacteria samples for each site over the two-year monitoring period. Bird Creek is highlighted in yellow and is designated Secondary Body Contact Recreation (SBRC), which allows for a higher bacteria concentration. All other sites are designated Primary Body Contract Recreation (PBCR). Pecan Creek (Muskogee) does not meet the *E. coli* standard. To be listed on the state's 303(d) list, the geometric mean must exceed the set criteria for at least one of the bacteria types (OWRB 2016).

Table 8. Low dissolved oxygen values (based on OAC 785:46-15; OWRB 2014) at rotating basin sites in the Lower North Canadian, Lower Canadian, and Lower Arkansas Basins 2018-2020. WBID is a unique waterbody identifier for each monitoring site. Each site is designated as a warm water (WWAC), habitat limited (HLAC), or a cool water aquatic community (CWAC) for the fish and wildlife propagation (FWP) beneficial use.

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
15%	Ash Creek	OK120410-01-0110E	WWAC	7/23/2018	3.69
				8/27/2018	4.15
				6/21/2018	3.7
24%	Bad Creek	OK520500-01-0170E	WWAC	10/1/2018	4.41
				11/6/2018	4.8
				6/3/2019	5.8
				8/20/2019	4.82
				9/23/2019	3.27
15%	Ballard Creek	OK121700-03-0370G	CWAC	7/17/2018	5.01
				6/25/2018	5.88
				9/25/2019	5.36
10%	Bear Creek	OK520700-05-0170A	WWAC	5/21/2018	5.92
				6/11/2018	5.48
24%	Big Creek	OK220100-02-0080B	CWAC	6/5/2018	5.88
				7/17/2018	5.58
				8/21/2018	5.57
				8/20/2019	5.15
				9/23/2019	5.88
19%	Black Fork of Poteau River	OK220100-02-0040P	WWAC	6/5/2018	5.57
				7/17/2018	4.64
				8/20/2019	4.79
				9/23/2019	4.29
19%	Brazil Creek	OK220100-03-0010G	WWAC	6/5/2018	5.04
				7/17/2018	3.38
				8/20/2019	4.33
				5/5/2020	5.47
10%	Brushy Creek	OK220600-03-0010L	WWAC	6/4/2018	3.45
				8/19/2019	3.07
53%	Butler Creek	OK120400-02-0160P	WWAC	7/16/2019	0.25
				6/4/2019	3.49
				9/9/2019	0.85
				6/18/2018	1.1
				7/23/2018	1.15
				7/10/2018	0.9
				10/1/2018	0.6
				10/29/2018	3.47
				4/30/2019	3.41
35%	Cloud Creek	OK120410-01-0100T	WWAC	6/18/2018	3.93
				7/23/2018	1.8
				8/27/2018	1.5
				7/10/2018	3.55
				10/1/2018	2.45
				7/16/2019	3.98
				6/4/2019	5.97

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
24%	Coal Creek	OK220600-02-0010F	WWAC	6/4/2018	3.34
				8/20/2018	2.93
				9/6/2018	2.57
				6/3/2019	5.78
				7/8/2019	3.89
				9/23/2019	2.12
				5/4/2020	5.56
33%	Deep Branch	OK121700-01-0020A	WWAC	8/1/2018	3.51
				6/11/2018	3.05
				7/23/2018	4.51
				8/27/2018	4.99
				5/28/2019	2.45
				9/17/2019	3.08
				7/15/2019	2.96
35%	Elk Creek (McIntosh)	OK120400-02-0190F	WWAC	7/23/2018	4.7
				8/27/2018	4.05
				10/1/2018	4.24
				4/30/2019	5.55
				7/16/2019	3.78
				6/4/2019	5.49
				8/19/2019	3.43
14%	Elk Creek (Cherokee)	OK121700-02-0180G	WWAC	6/11/2018	4.35
				8/28/2018	3.01
				7/15/2019	3.56

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
29%	Fourche Maline Creek	OK220100-04-0020H	WWAC	6/4/2018	5.4
				9/17/2018	4.46
				6/3/2019	5.9
				7/8/2019	1.63
				8/19/2019	3.26
				9/28/2019	4.24
38%	Gaines Creek	OK220600-04-0010F	WWAC	6/4/2018	2.36
				7/16/2018	3.08
				8/20/2018	4.44
				9/13/2018	3.34
				10/1/2018	4.91
				7/8/2019	4.11
				8/19/2019	2.11
				9/23/2019	3.14
45%	Gentry Creek	OK520700-01-0080L	WWAC	7/23/2018	4.6
				8/27/2018	4.35
				7/9/2018	4.2
				10/1/2018	1.65
				4/30/2019	4.12
				7/16/2019	4.33
				6/4/2019	5.97
				8/19/2019	4.61
				9/9/2019	1.23

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
50%	George's Fork of Dirty Creek	OK120400-02-0110D	WWAC	6/19/2018	2
				7/24/2018	1.8
				8/28/2018	2.12
				8/13/2018	0.89
				10/2/2018	2.85
				4/29/2019	5.68
				7/15/2019	3.01
				6/3/2019	4.59
				8/20/2019	1.21
				9/10/2019	2.97
12%	Greenleaf Creek	OK120400-01-0120C	WWAC	6/19/2018	4.66
				8/28/2018	3.98
15%	Longtown Creek	OK220600-01-0070P	WWAC	7/19/2018	3.6
				6/19/2018	4.5
				8/20/2019	2.25
26%	Mill Creek	OK220600-01-0100J	WWAC	7/24/2018	4.7
				8/28/2018	3.3
				7/15/2019	4.6
				8/20/2019	1.97
				9/10/2019	3.4

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
52%	Montezumah Creek	OK520700-01-0220D	WWAC	6/12/2018	3.55
				7/17/2018	2.27
				8/21/2018	1.51
				6/14/2018	2.14
				9/25/2018	1.32
				12/4/2018	1.95
				5/29/2019	5.15
				7/9/2019	3.23
				8/13/2019	2.33
				10/22/2019	4.35
				9/17/2019	4.3
35%	Nuyaka Creek	OK520700-02-0200D	WWAC	6/12/2018	5.51
				8/21/2018	3.49
				7/19/2018	3.59
				9/25/2018	3.63
				5/29/2019	5.4
				8/13/2019	4.64
				9/17/2019	3.82

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
33%	Peaceable Creek	OK220600-03-0050F	WWAC	6/4/2018	4.01
				8/20/2018	3.31
				6/3/2019	5.89
				7/8/2019	4.61
				8/19/2019	4.1
				9/23/2019	3.95
				5/4/2020	5.31
11%	Pecan Creek (Muskogee)	OK120410-01-0030D	WWAC	8/20/2018	4.72
				9/24/2018	4.3
10%	Polecat Creek	OK120420-02-0050B	WWAC	6/12/2018	5.55
				8/1/2018	4.11
13%	Pumpkin Hollow Creek	OK121700-03-0090G	WWAC	7/16/2018	1.46
				8/20/2019	4.24
24%	San Bois Creek	OK220200-04-0010G	WWAC	6/12/2018	4.98
				8/27/2018	4.68
				5/28/2019	5.21
				7/16/2019	4.56
				8/12/2019	3.51
30%	Shady Grove Creek	OK120400-02-0240H	WWAC	7/24/2018	4.68
				8/28/2018	4.26
				7/11/2018	0.36
				10/2/2018	3.8
				7/15/2019	4.81
				8/20/2019	3.71
35%	South Fork Dirty Creek	OK120400-02-0030H	WWAC	6/19/2018	4.05
				8/28/2018	4.8
				7/12/2018	4.3
				10/2/2018	3.75
				7/15/2019	4.97
				6/3/2019	5.75
				8/20/2019	4.37
29%	Sugar Loaf Creek	OK220100-01-0160G	WWAC	6/5/2018	3.41
				7/17/2018	3.26
				9/20/2018	4.1
				8/20/2019	1.44
				9/23/2019	3.5
				5/5/2020	5.99
14%	Turkey Creek	OK520510-00-0100F	WWAC	10/2/2018	4.93
				8/19/2019	3.91
				9/24/2019	3.1
16%	Tyner Creek	OK121700-05-0090J	CWAC	7/16/2018	4.5
				9/25/2018	3.38
				10/30/2018	4.96

Table 9. Geometric mean of bacteria values for Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) monitoring sites, 2018-2020. An asterisk (*) indicates that the stream does not meet state standards for E. coli. Those highlighted in yellow have secondary body contact recreation (SBCR) designation, allowing for higher bacteria concentrations.

Site Name	WBID	E. coli
Alabama Creek	OK520500-01-0200D	13.2
Ash Creek	OK120410-01-0110E	16.6
Bad Creek	OK520500-01-0170E	4.5
Ballard Creek	OK121700-03-0370G	10.6
Battle Creek	OK121700-06-0040G	4.3
Bear Creek	OK520700-05-0170A	55.4
Big Creek	OK220100-02-0080B	10.5
Big Skin Bayou	OK220200-01-0030K	14.9
Bird Creek	OK520800-01-0050M	7.6
Black Fork of Poteau River	OK220100-02-0040P	17.9
Brazil Creek	OK220100-03-0010G	51.8
Brushy Creek	OK220600-03-0010L	50.7
Butler Creek	OK120400-02-0160P	13.1
Canadian Sandy Creek	OK520600-03-0010D	28.9
Captain Creek	OK520700-05-0140H	30.1
Caston Creek	OK220100-01-0180B	22.9
Cloud Creek	OK120410-01-0100T	19.8
Coal Creek	OK220600-02-0010F	24.0
Deep Branch	OK121700-01-0020A	3.3
Dry Creek	OK520700-04-0020F	28.0
Elk Creek (McIntosh)	OK120400-02-0190F	25.4
Elk Creek (Cherokee)	OK121700-02-0180G	6.5
Fourche Maline Creek	OK220100-04-0020H	18.0
Gaines Creek	OK220600-04-0010F	43.1
Gar Creek	OK520510-00-0080C	24.8
Gentry Creek	OK520700-01-0080L	13.7
George's Fork of Dirty Creek	OK120400-02-0110D	13.1
Greenleaf Creek	OK120400-01-0120C	4.7
Hog Creek	OK520810-00-0030D	16.0
Holson Creek	OK220100-04-0030G	4.2
Little Deep Fork	OK520700-06-0010D	47.1

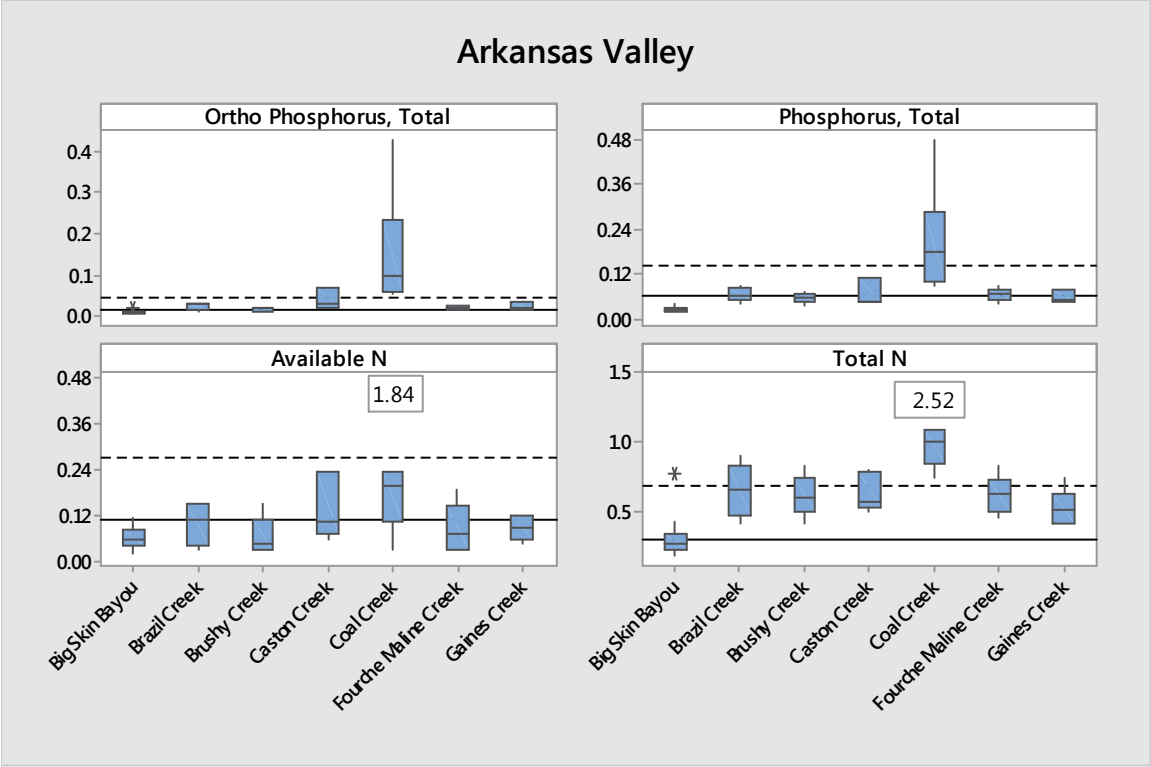
Site Name	WBID	E. coli
Little Wewoka Creek	OK520500-02-0090D	25.2
Longtown Creek	OK220600-01-0070P	8.3
Manard Bayou	OK120400-01-0280E	58.3
Mill Creek	OK220600-01-0100J	8.2
Montezumah Creek	OK520700-01-0220D	17.7
Nuyaka Creek	OK520700-02-0200D	56.4
Opossum Creek	OK520700-05-0200C	28.4
Peaceable Creek	OK220600-03-0050F	19.1
Peacheater Creek	OK121700-05-0120B	35.4
Peavine Creek	OK121700-05-0190F	7.0
Pecan Creek (Muskogee)	OK120410-01-0030D	153.3 *
Pecan Creek (Pottawatomie)	OK520800-02-0080C	24.9
Polecat Creek	OK120420-02-0050B	42.6
Pumpkin Hollow Creek	OK121700-03-0090G	15.9
Quapaw Creek	OK520700-04-0260C	38.5
Sallisaw Creek	OK220200-03-0010C	1.7
Salt Creek (Creek)	OK520700-03-0100B	22.1
Salt Creek (Seminole)	OK520800-03-0010D	19.2
San Bois Creek	OK220200-04-0010G	6.4
Shady Grove Creek	OK120400-02-0240H	15.5
Snake Creek (Tulsa)	OK120410-01-0220G	28.1
Snake Creek (Sequoyah)	OK121700-02-0100G	8.8
South Fork Dirty Creek	OK120400-02-0030H	13.1
Steely Hollow Creek	OK121700-03-0120G	27.8
Sugar Loaf Creek	OK220100-01-0160G	47.7
Taloka Creek	OK220300-00-0020M	36.9
Telemay Hollow Creek	OK121700-03-0140G	12.6
Turkey Creek	OK520510-00-0100F	13.7
Tyner Creek	OK121700-05-0090J	3.5
Vian Creek	OK220200-02-0130E	3.0
Wewoka Creek	OK520500-02-0010C	9.8

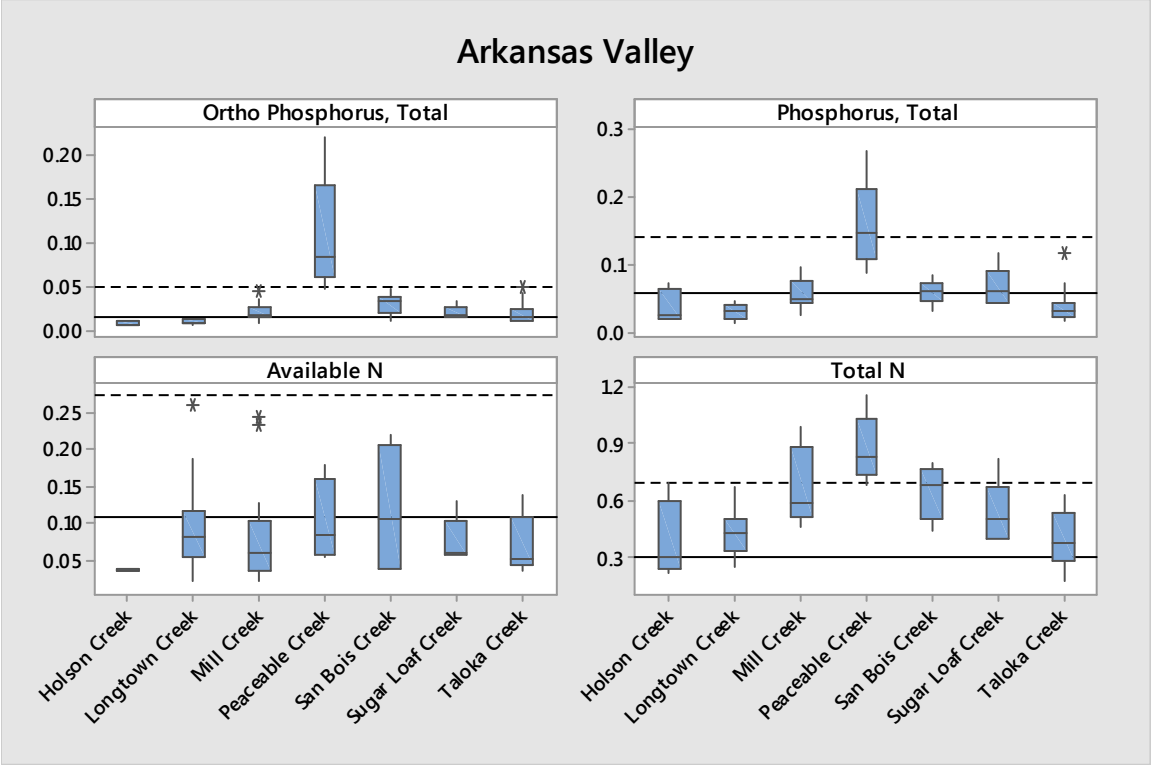
Select water quality parameters for each site during the sample period are summarized by box plots in Figure 2 and Figure 3, below. Figure 2 shows interquartile range plots by site for four important indicators of pollution: orthophosphorus, total phosphorus, estimated total nitrogen (TKN plus nitrate), and available nitrogen (ammonia and nitrate). All elevated flow data were omitted in these analyses in order to standardize the results. To account for natural differences, sites were collated and analyzed by level III ecoregions (Woods et al. 2005). Additionally, sites were compared to streams determined to be high quality sites in each ecoregion to determine general stream condition.

In the Arkansas Valley, Coal Creek and Peaceable Creek had higher orthophosphorus, total phosphorus, and total nitrogen values than the high quality sites. Manard Bayou in the Boston Mountains had higher orthophosphorus values than the high quality sites.

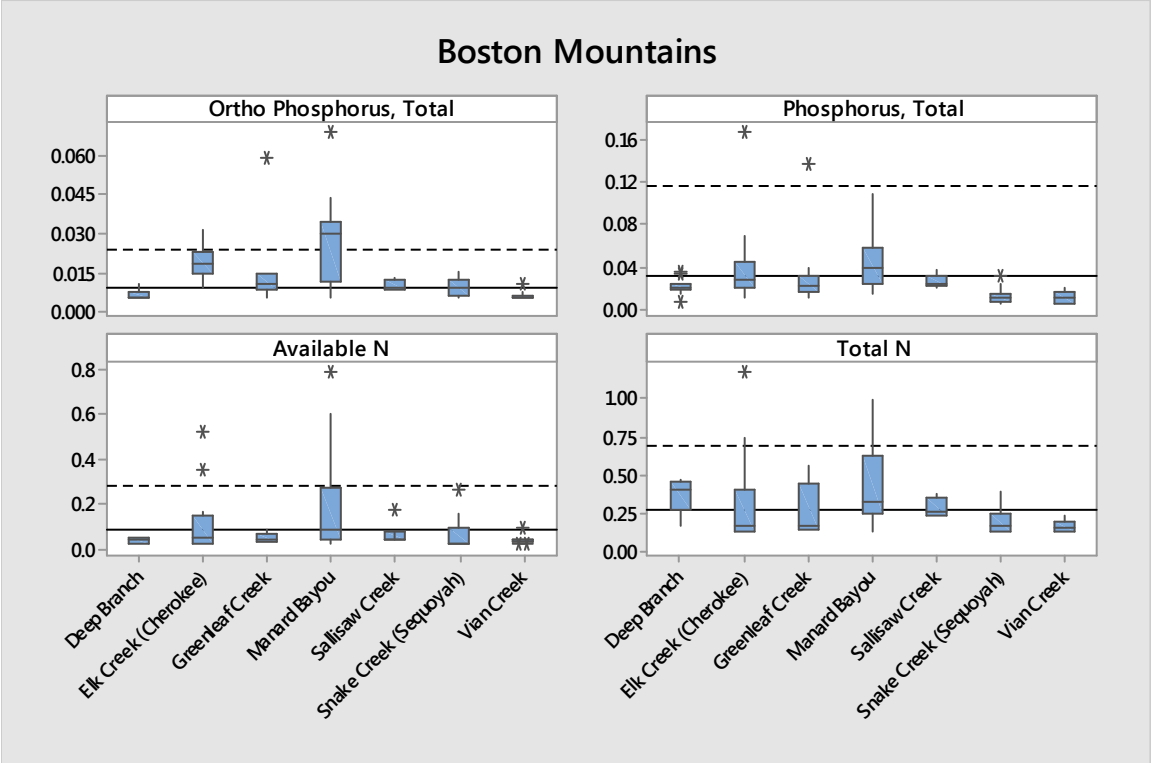
Figure 3 shows interquartile range plots for four physical parameters (all high flow data excluded): dissolved oxygen (percent saturation), pH, turbidity, and total suspended solids. Most streams in the Boston Mountains, Central Irregular Plains, Cross Timbers, Ozark Highlands, and Ouachita Mountains fell within two standard deviations for the physical parameters. In the Arkansas Valley, Bushy Creek, Coal Creek, Fourche Maline, Gaines Creek, and Sugar Loaf Creek had lower dissolved oxygen saturation levels. Holson Creek had higher total suspended solid values than the high quality sites. In the Central Irregular Plains, Butler Creek and George's Fork of Dirty Creek had lower dissolved oxygen saturation levels. Shady Creek had lower pH values than the high quality sites. In the Cross Timbers, Montezumah Creek had lower dissolved oxygen levels.

(a)

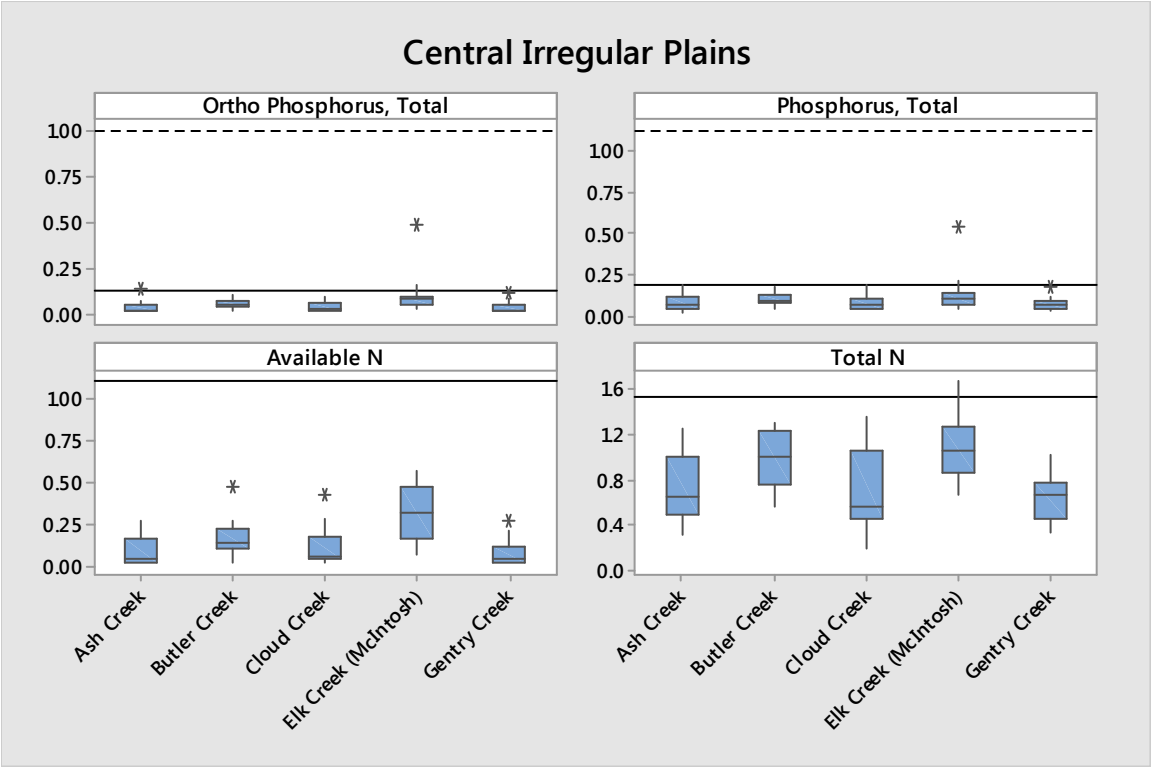


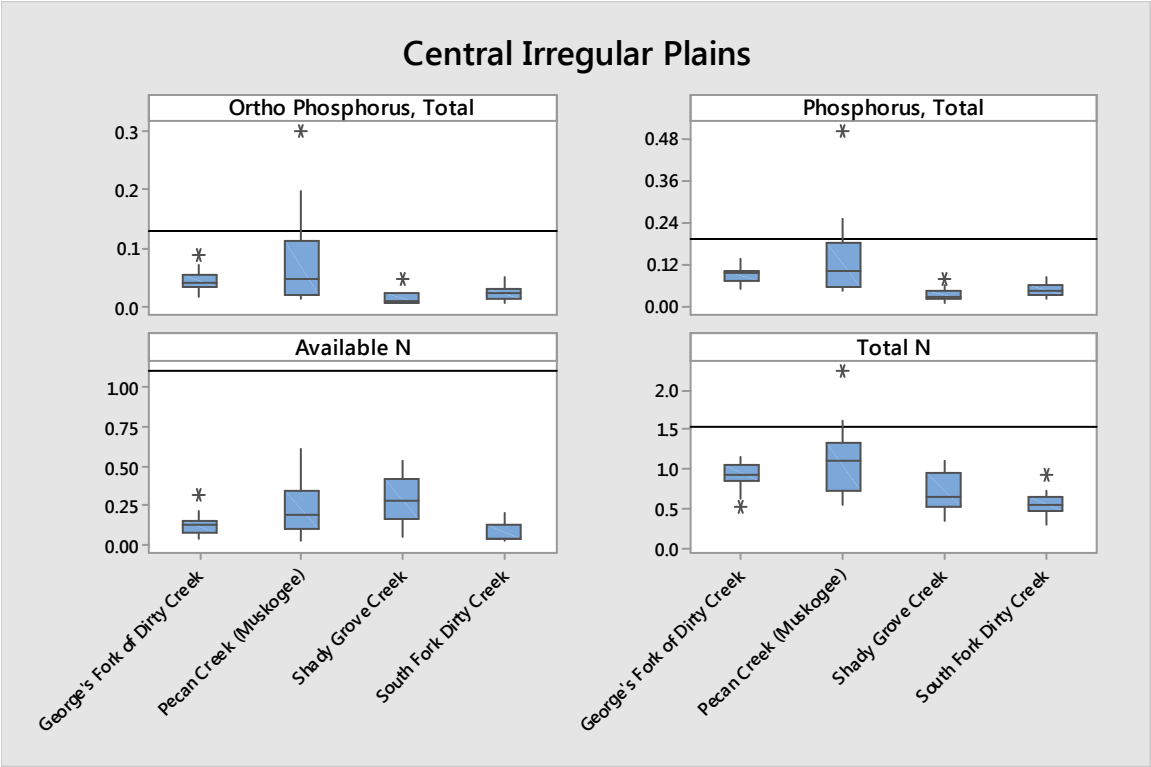

Arkansas Valley
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Holson Creek
Longtown Creek
Mill Creek
Peaceable Creek
San Bois Creek
Sugar Loaf Creek
Taloka Creek

(b)

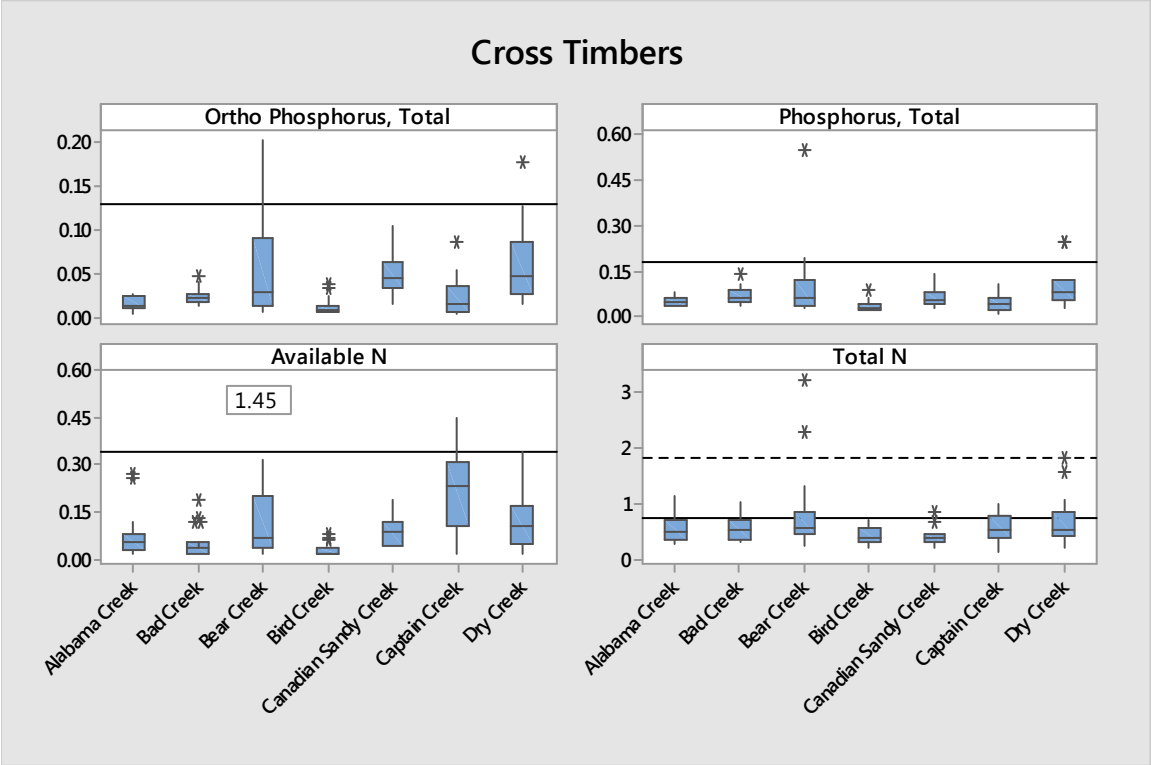

Boston Mountains
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Deep Branch
Elk Creek (Cherokee)
Greenleaf Creek
Manard Bayou
Sallisaw Creek
Snake Creek (Sequoyah)
Vian Creek

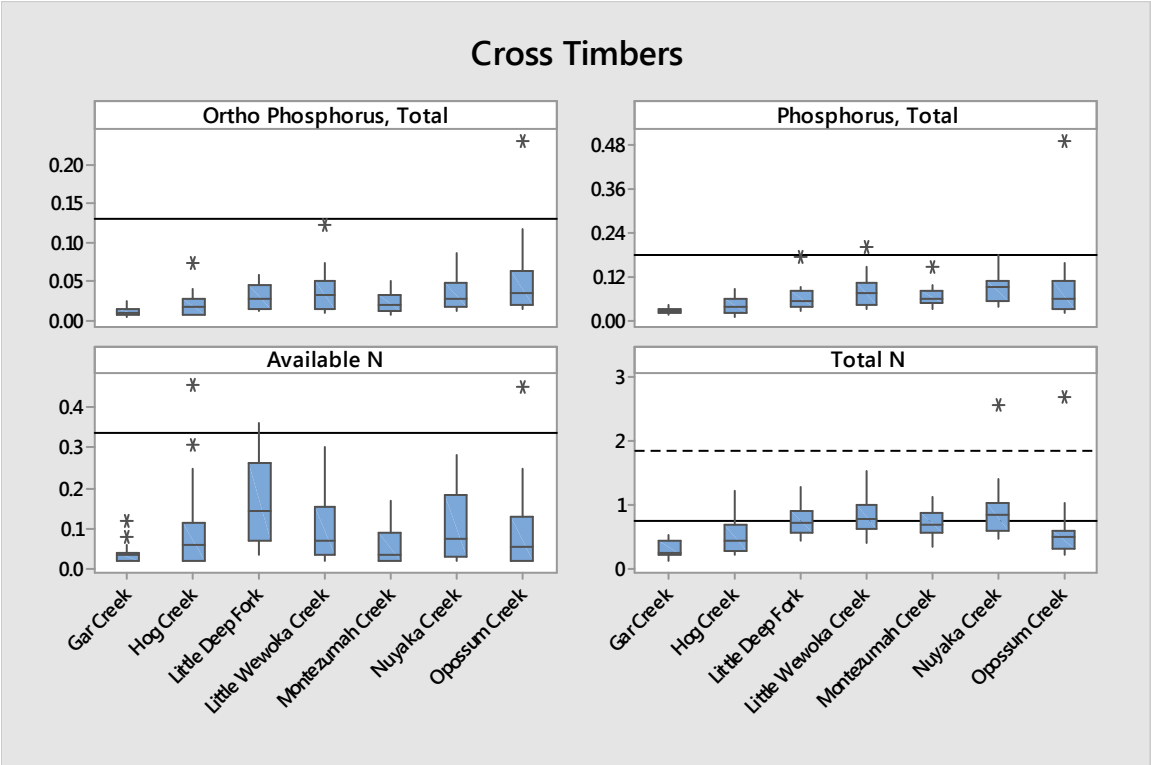
(c)

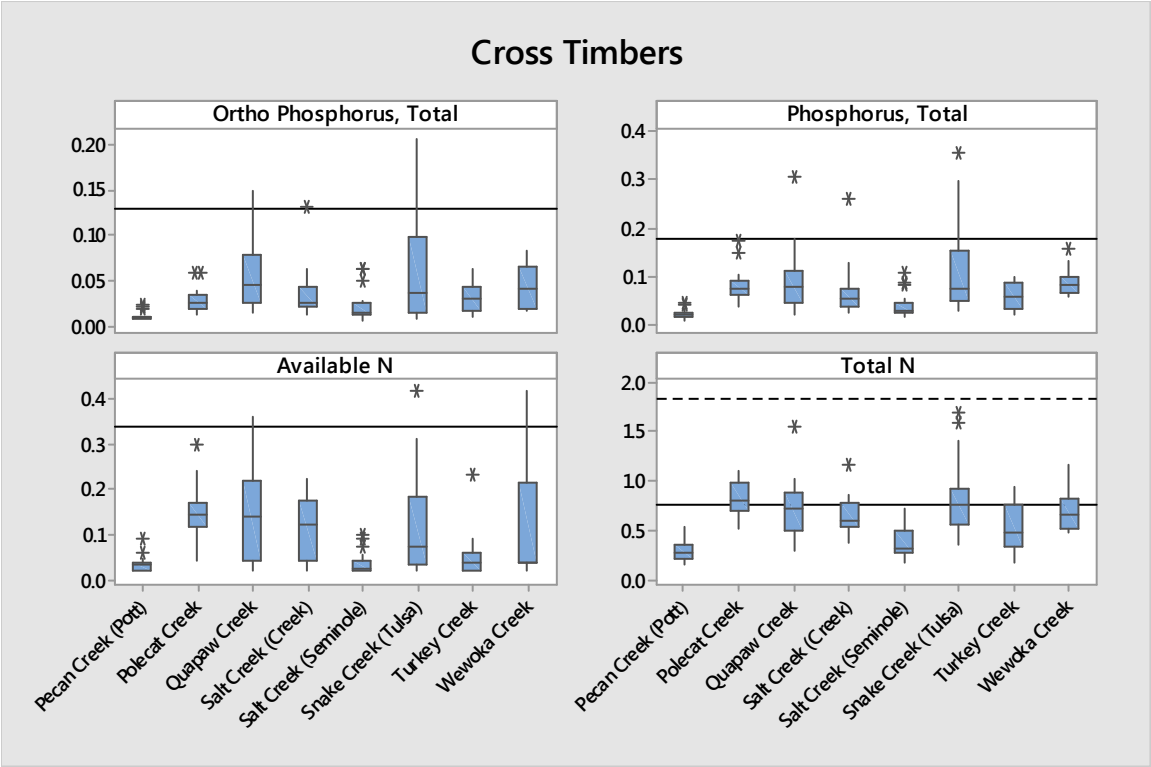

Central Irregular Plains
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Ash Creek
Butler Creek
Cloud Creek
Elk Creek (McIntosh)
Gentry Creek


Central Irregular Plains
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
George's Fork of Dirty Creek
Pecan Creek (Muskogee)
Shady Grove Creek
South Fork Dirty Creek

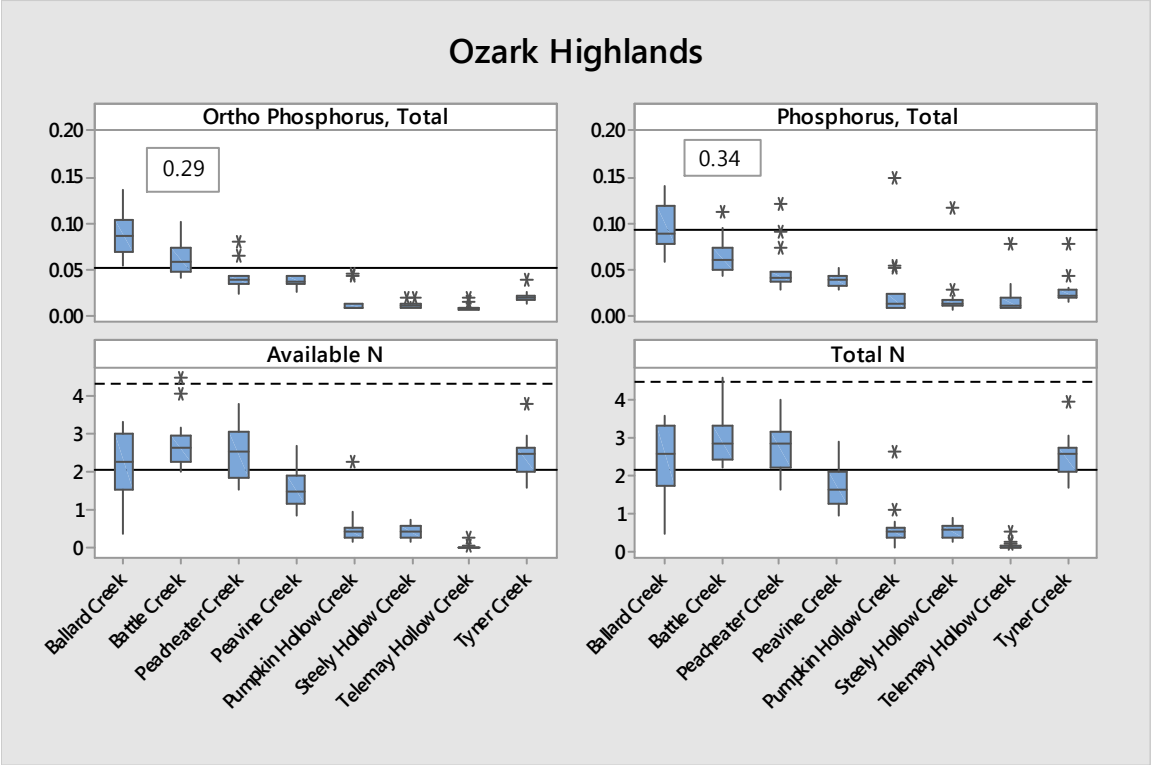
(d)


Cross Timbers
Ortho Phosphorus, Total
Phosphorus, Total
Available N
1.45
Total N
Alabama Creek
Bad Creek
Bear Creek
Bird Creek
Canadian Sandy Creek
Captain Creek
Dry Creek


Cross Timbers
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Gar Creek
Hog Creek
Little Deep Fork
Little Wewoka Creek
Montezumah Creek
Nuyaka Creek
Opossum Creek


Cross Timbers
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Pecan Creek (Pott)
Polecat Creek
Quapaw Creek
Salt Creek (Creek)
Salt Creek (Seminole)
Snake Creek (Tulsa)
Turkey Creek
Wewoka Creek

(e)


Ozark Highlands
Ortho Phosphorus, Total
0.29
Phosphorus, Total
0.34
Available N
Total N
Ballard Creek
Battle Creek
Peacheater Creek
Peavine Creek
Pumpkin Hollow Creek
Steely Hollow Creek
Telemay Hollow Creek
Tyner Creek

(f)

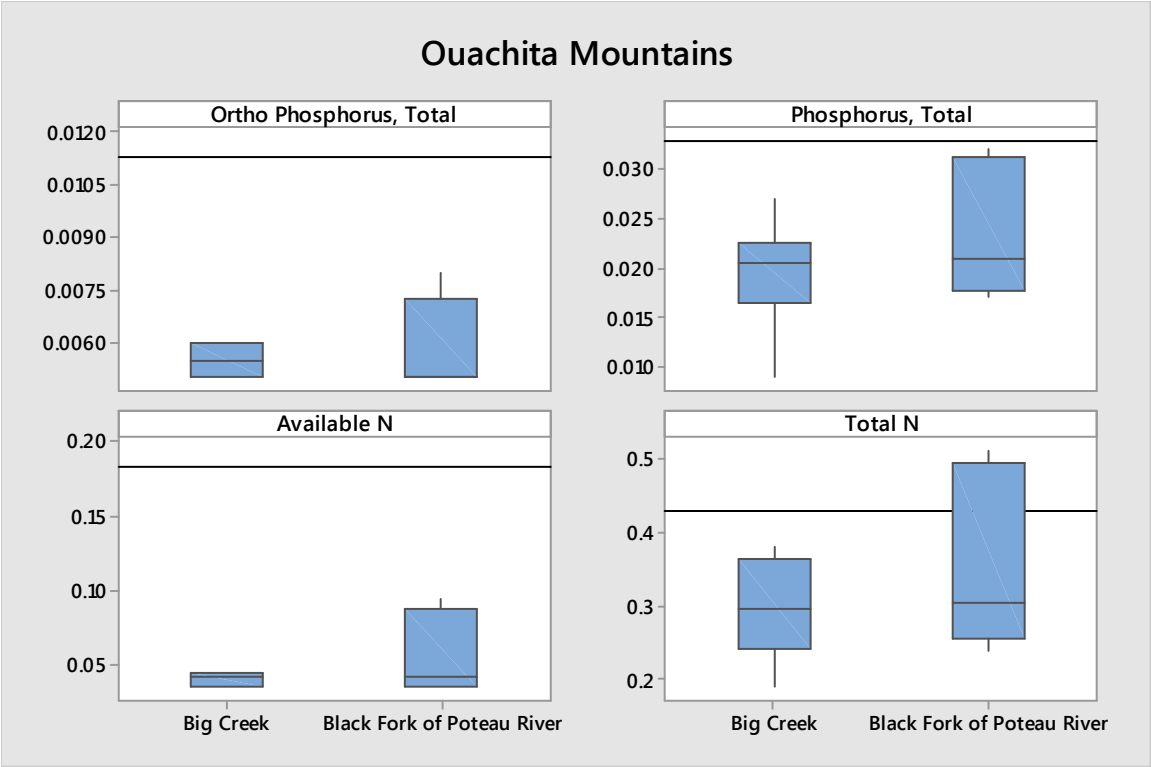
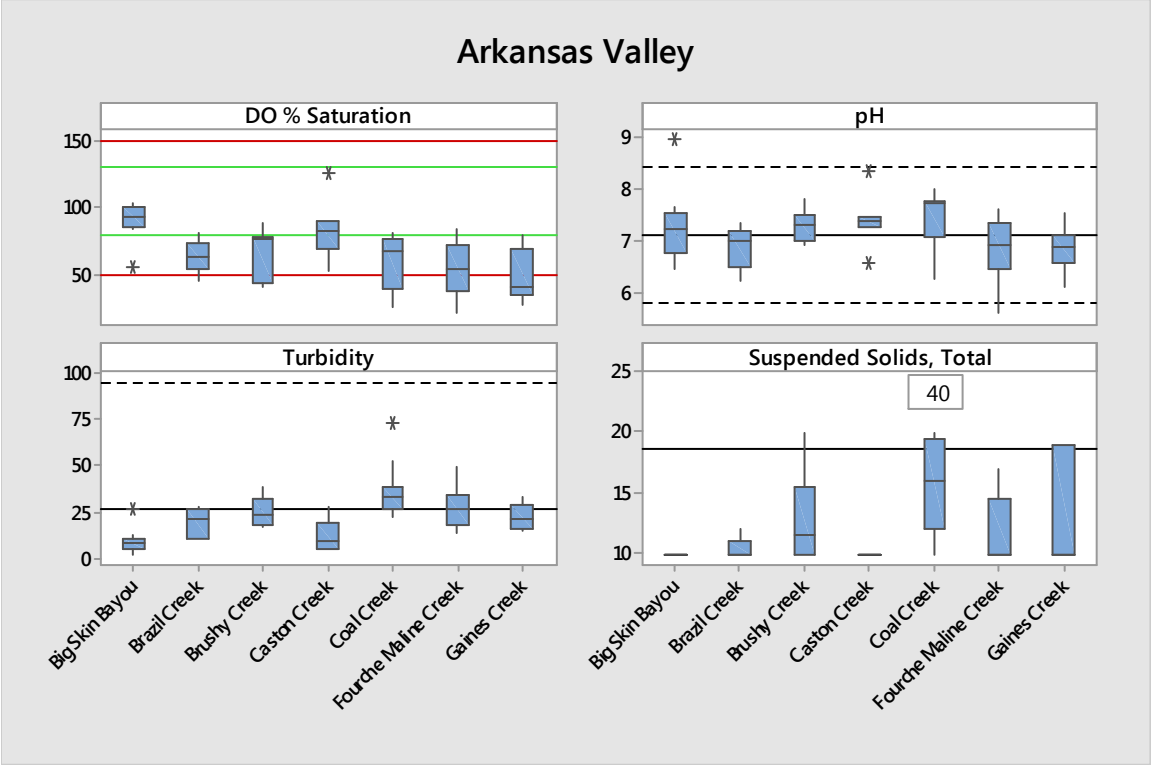
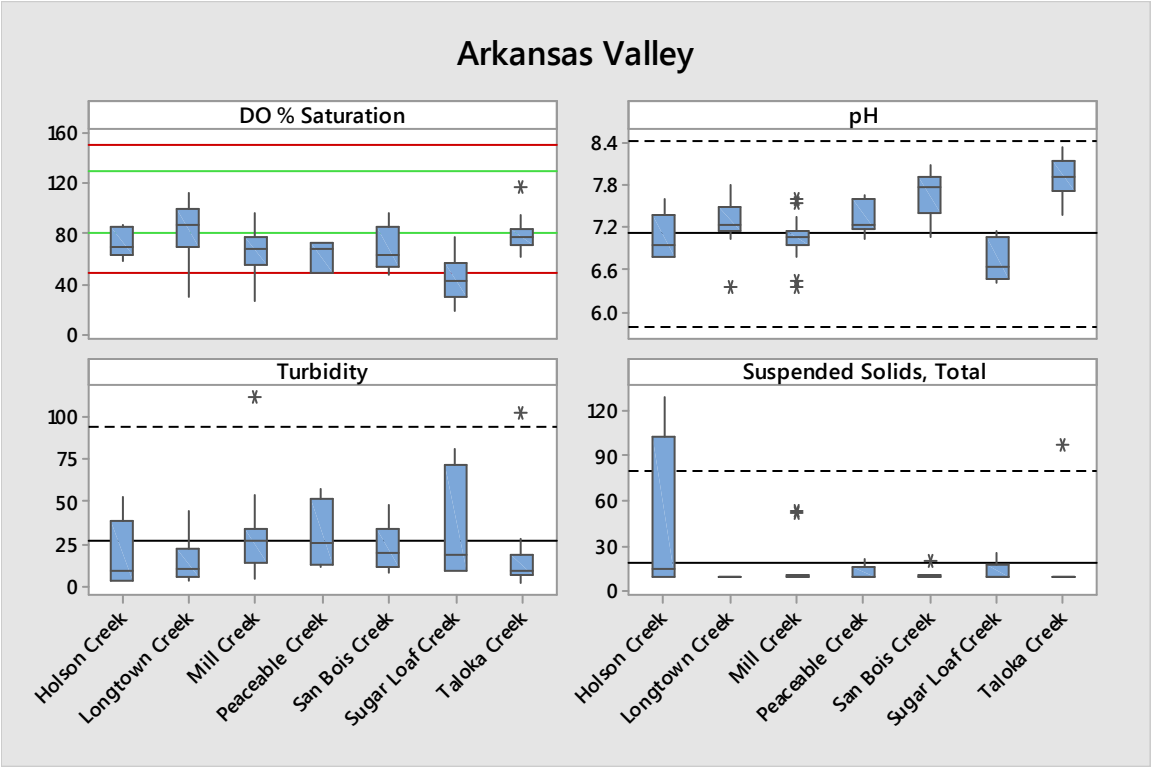


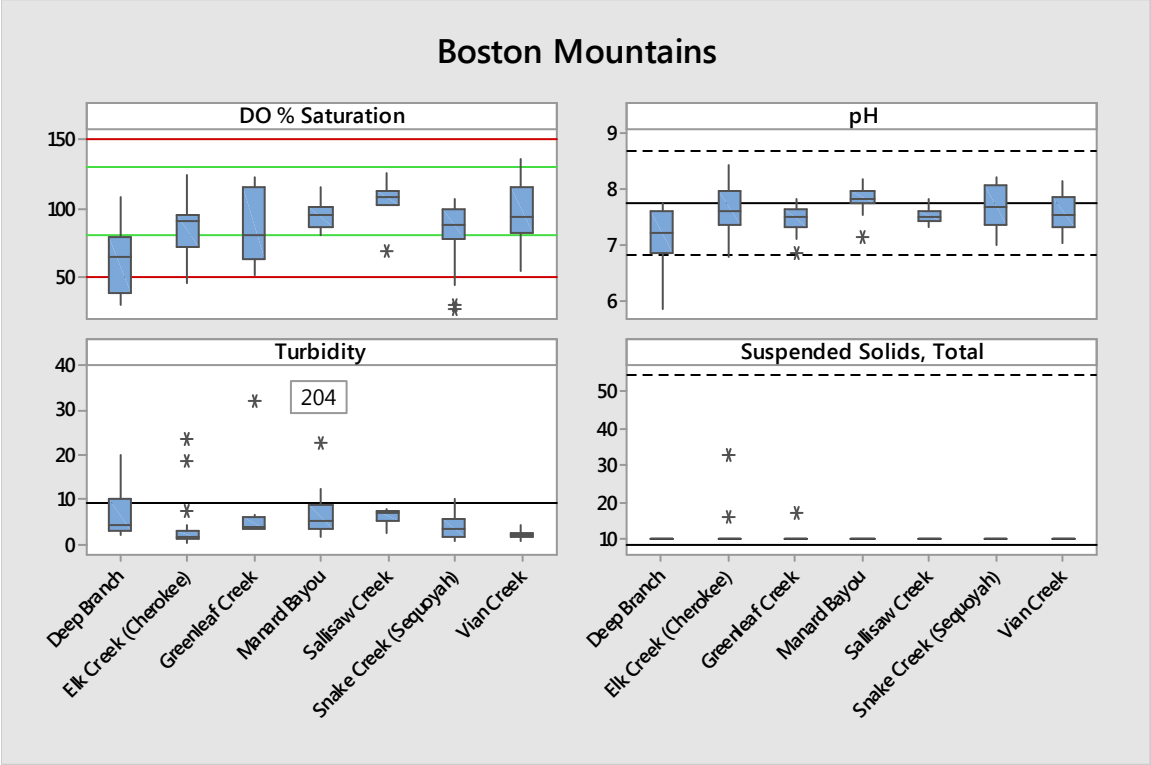
Figure 2. Select nutrients (orthophosphorus, total phosphorous, available nitrogen, and total nitrogen) for each site in the (a) Arkansas Valley, (b) Boston Mountains, (c) Central Irregular Plains, (d) Cross Timbers, (e) Ozark Highlands, and (f) Ouachita Mountains. The median of each site is shown by a line within the box with most outliers denoted by asterisks. The extreme outliers are denoted by values within a box on the graph. The solid line indicates the mean value of that parameter at high quality sites in each ecoregion, while the dashed line represents two standards deviations from the mean for high quality sites.

(a)

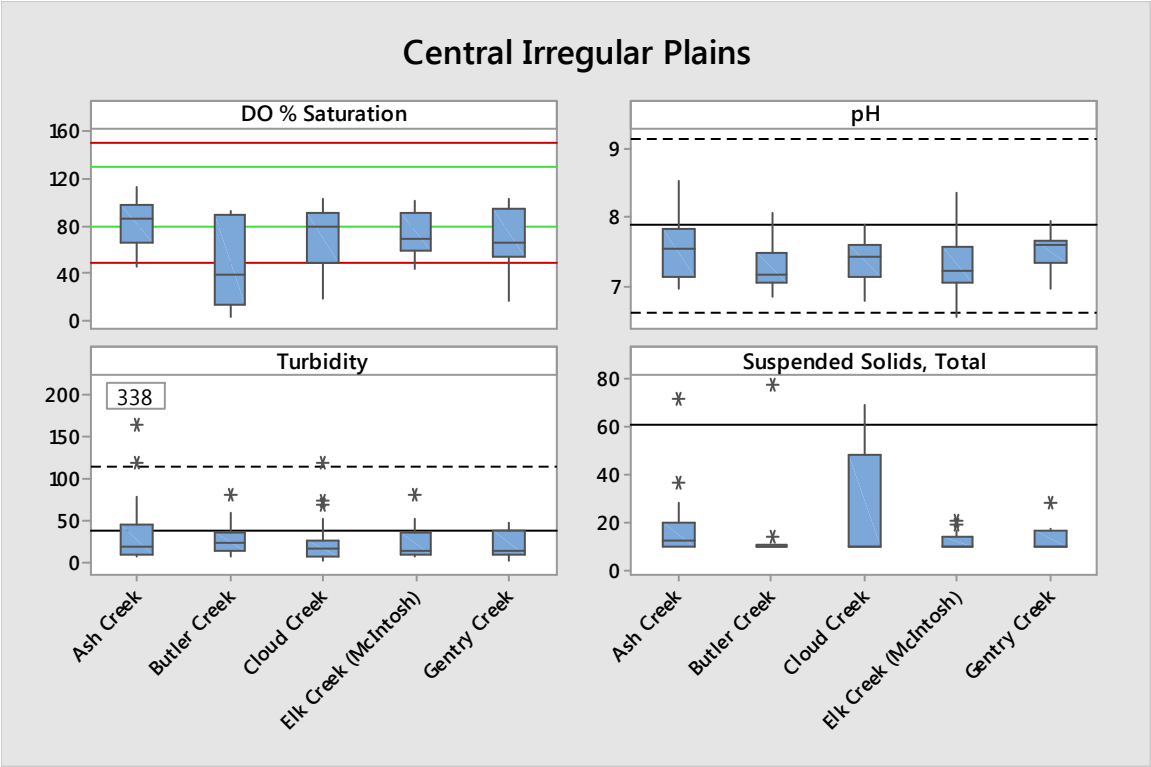

Arkansas Valley
DO % Saturation
pH
Turbidity
Suspended Solids, Total
40
Big Skin Bayou
Brazil Creek
Brushy Creek
Caston Creek
Coal Creek
Fourche Maline Creek
Gaines Creek

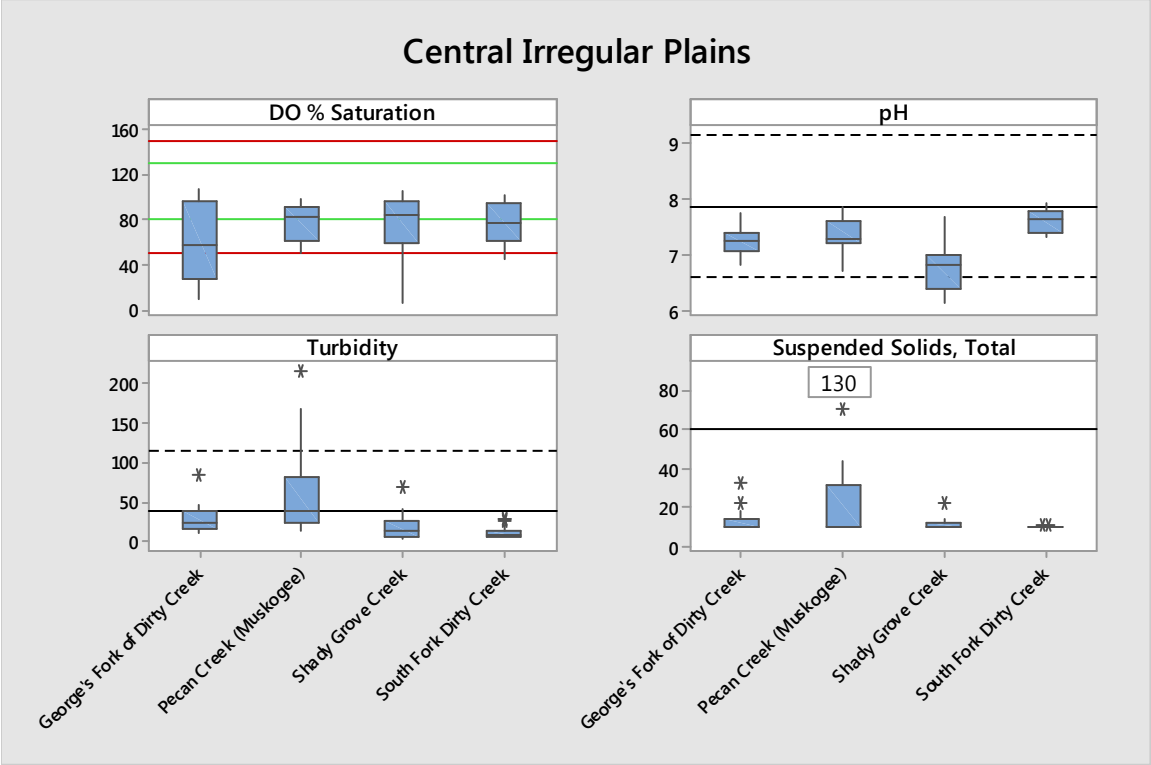

Arkansas Valley
DO % Saturation
pH
Turbidity
Suspended Solids, Total
Holson Creek
Longtown Creek
Mill Creek
Peaceable Creek
San Bois Creek
Sugar Loaf Creek
Taloka Creek

(b)

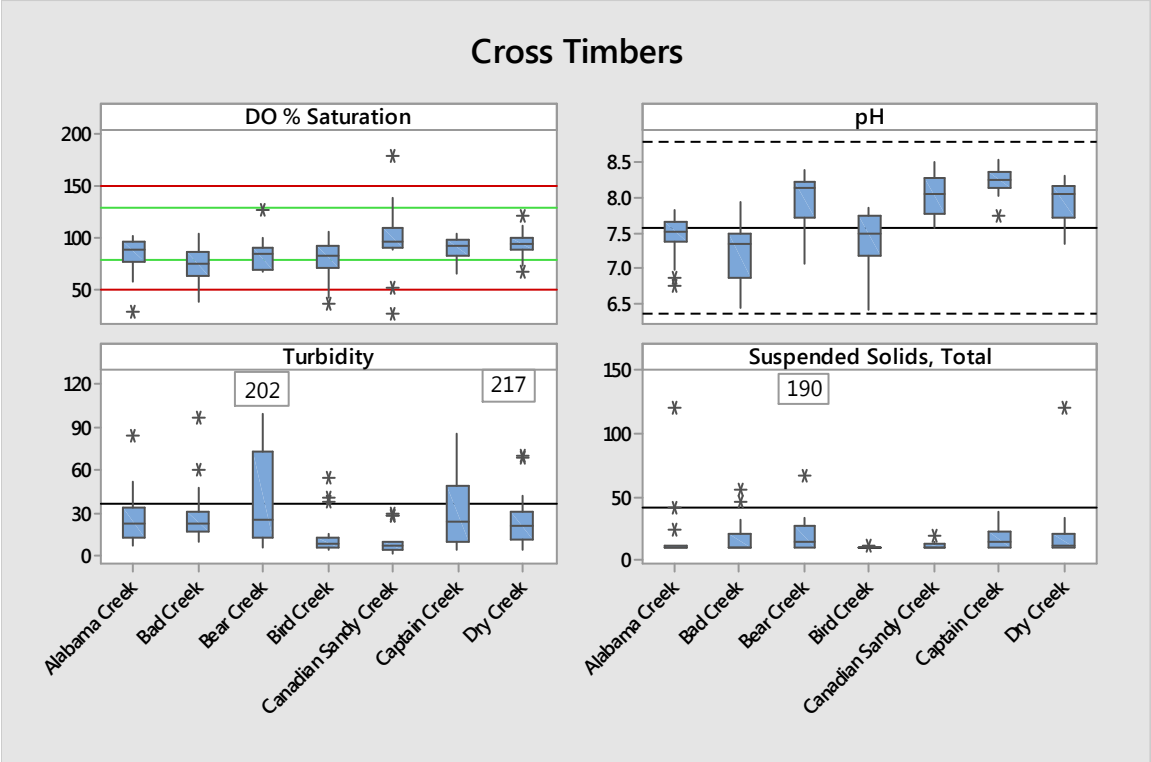

Boston Mountains
DO % Saturation
pH
Turbidity
204
Suspended Solids, Total
Deep Branch
Elk Creek (Cherokee)
Greenleaf Creek
Manard Bayou
Sallisaw Creek
Snake Creek (Sequoyah)
Vian Creek

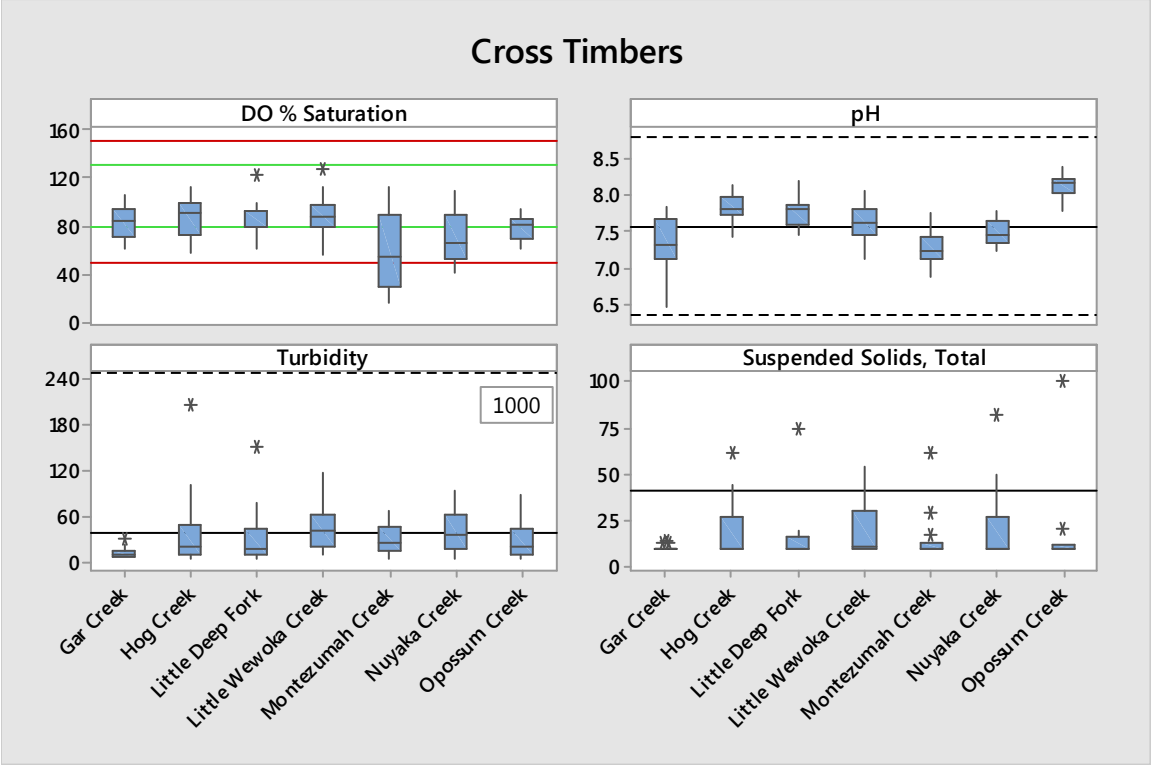
(c)

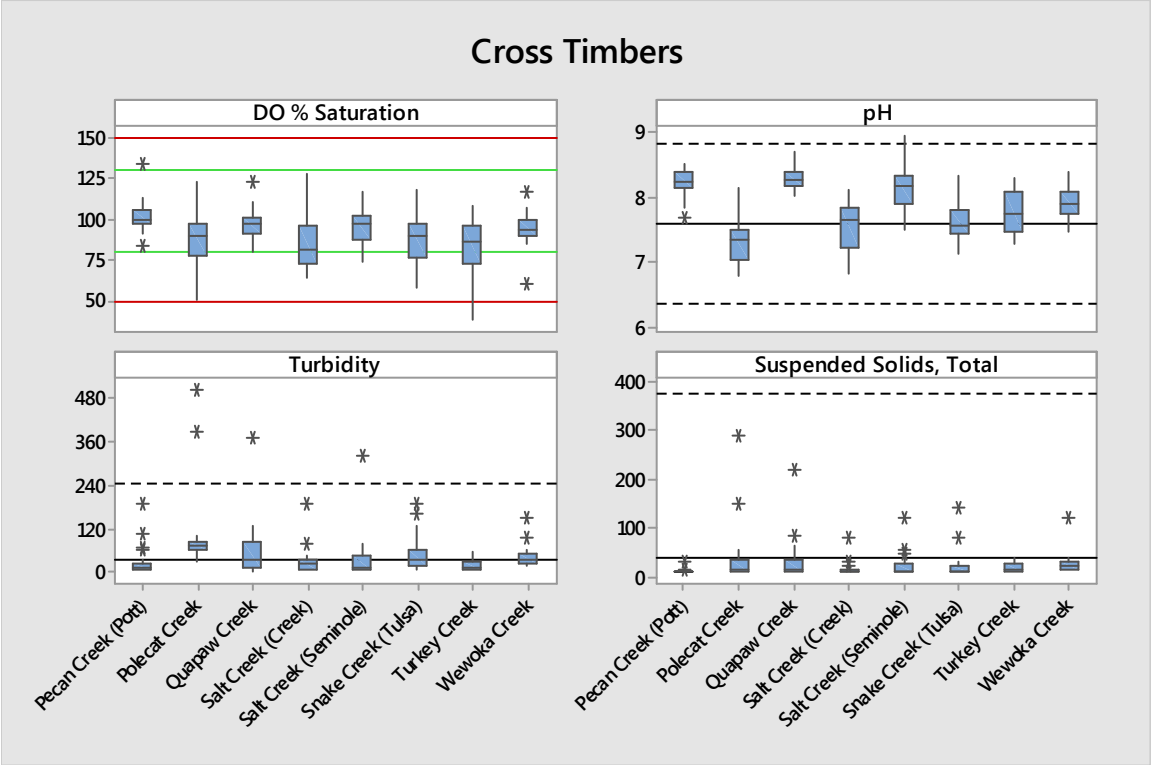

Central Irregular Plains
DO % Saturation
pH
Turbidity
338
Suspended Solids, Total
Ash Creek
Butler Creek
Cloud Creek
Elk Creek (McIntosh)
Gentry Creek


Central Irregular Plains
DO % Saturation
pH
Turbidity
Suspended Solids, Total
130
George's Fork of Dirty Creek
Pecan Creek (Muskogee)
Shady Grove Creek
South Fork Dirty Creek

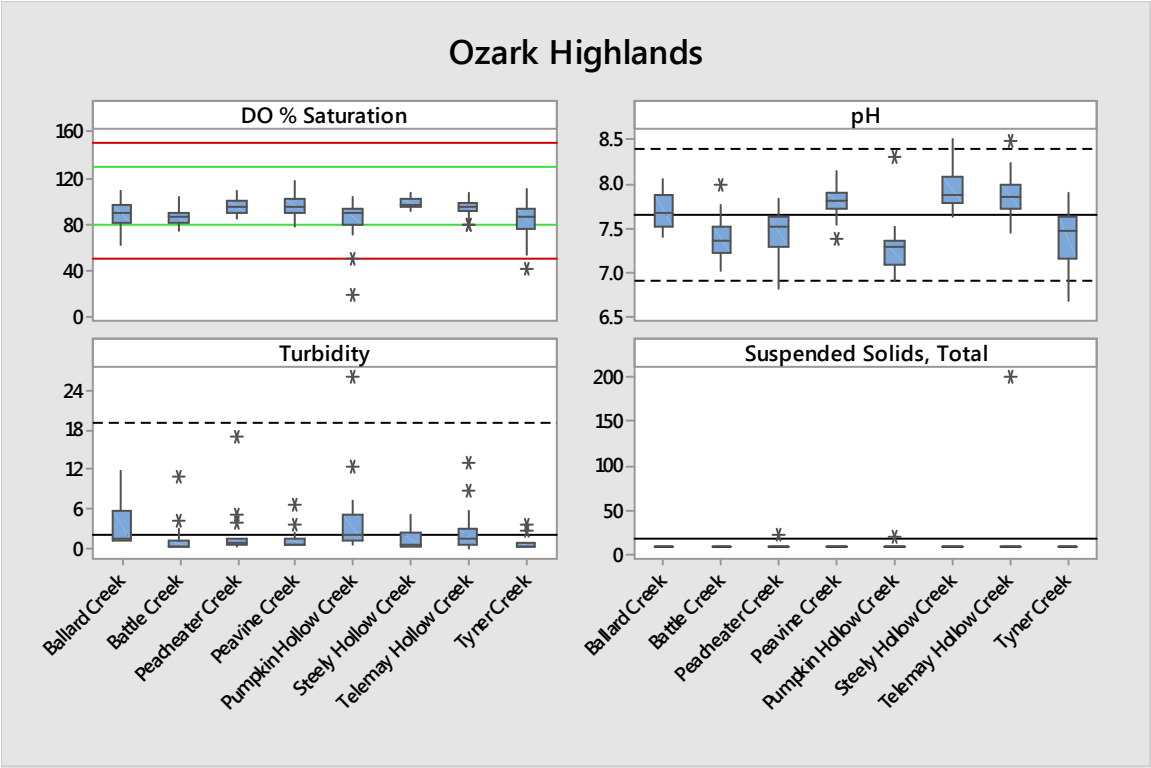
(d)


Cross Timbers
DO % Saturation
pH
Turbidity
202
217
Suspended Solids, Total
190
Alabama Creek
Bad Creek
Bear Creek
Bird Creek
Canadian Sandy Creek
Captain Creek
Dry Creek


Cross Timbers
DO % Saturation
160
120
80
40
0
pH
8.5
8.0
7.5
7.0
6.5
Turbidity
240
180
120
60
0
1000
Suspended Solids, Total
100
75
50
25
0
Gar Creek
Hog Creek
Little Deep Fork
Little Wewoka Creek
Montezumah Creek
Nuyaka Creek
Opossum Creek


Cross Timbers
DO % Saturation
150
125
100
75
50
pH
9
8
7
6
Turbidity
480
360
240
120
0
Suspended Solids, Total
400
300
200
100
0
Pecan Creek (Poti)
Polecat Creek
Quapaw Creek
Salt Creek (Creek)
Salt Creek (Seminole)
Snake Creek (Tulsa)
Turkey Creek
Wewoka Creek

(e)


Ozark Highlands
DO % Saturation
160
120
80
40
0
pH
8.5
8.0
7.5
7.0
6.5
Turbidity
24
18
12
6
0
Suspended Solids, Total
200
150
100
50
0
Ballard Creek
Battle Creek
Peacheater Creek
Peavine Creek
Pumpkin Hollow Creek
Steely Hollow Creek
Telemay Hollow Creek
Tyner Creek

(f)

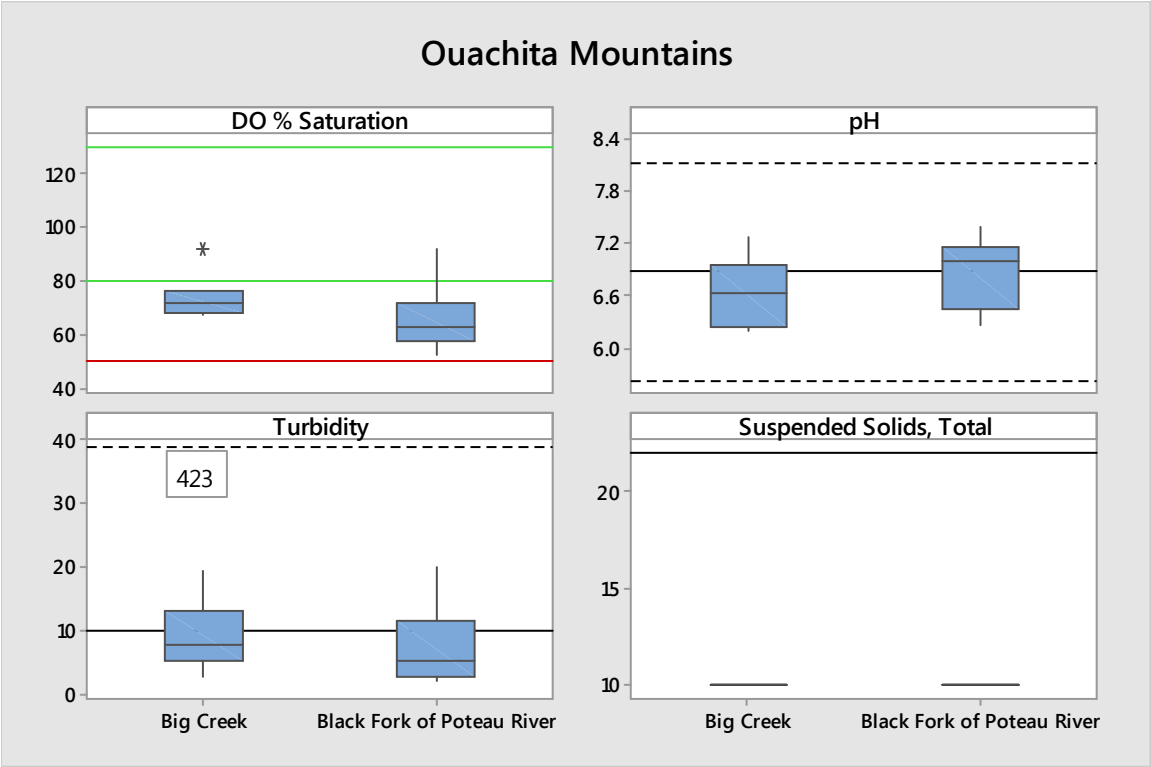


Figure 3. Select physical parameters by ecoregion (DO % Saturation, pH, turbidity, total suspended solids) for each site in the (a) Arkansas Valley, (b) Boston Mountains, (c) Central Irregular Plains, (d) Cross Timbers, (e) Ozark Highlands, and (f) Ouachita Mountains. The median of each site is shown by a line within the box with most outliers denoted by asterisks. The extreme outliers are denoted by values within a box on the graph. The solid line indicates the mean value of that parameter at high quality sites in each ecoregion, while the dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero). Oxygen charts use a green line to indicate 80% and 130% and a red line to indicate 50% and 150% DO saturation.

Table 10 shows a comparison between base flow water quality data (high flow data omitted) collected for the same site in the previous rotating basin cycle(s) and the fourth cycle in order to examine whether water conditions have improved, worsened, or remained the same at a particular site. One-way ANOVAs were performed for each set of data. Only statistically significant differences between the means of each parameter in all four cycles or between cycle 3 and 4 are shown in the table. Level of significance is indicated by p-values, with any $p < 0.050$ considered significant and $0.050 < p < 0.100$ considered marginally significant.

Cloud Creek was not sampled in Cycle 1. Ash Creek, Bear Creek, Big Creek, Captain Creek, Caston Creek, Coal Creek, Deep Branch, Gar Creek, Greenleaf Creek, Hog Creek, Little Deep Fork, Longtown Creek, Manard Bayou, Montezumah Creek, Nuyaka Creek, Pecan Creek (Muskogee), Pecan Creek (Pottawatomie), Sugar Loaf Creek, Turkey Creek, and Vian Creek were first sampled in cycle 3. Six streams had significantly higher levels of dissolved oxygen percent saturation, but seven streams had reduced DO % saturation. Total N decreased in eight streams and increased in 13. Available Nitrogen decreased in seven streams and increased in five. Phosphorus increased in 13 streams. Turbidity and/or total suspended solids (TSS) was significantly lower in five streams; alkalinity and/or hardness was

significantly lower in 16 streams and increased in four stream; six streams exhibited increased salt concentrations (sulfate, chloride, or total dissolved solids) while 27 showed lower salt concentrations.

Table 10. Statistical comparisons of cycles one, two, three, and four Rotating Basin Project (RB Cycle) water quality data. "N" is the number of base flow samples included in the analyses. Mean value is presented for each parameter with a significant result using a one-way ANOVA. The p-value between Cycle 3 and Cycle 4 parameter values was calculated using a one-way ANOVA. The p-value all cycles were calculated using one-way ANOVAs comparing the current monitoring cycle parameter with all previous data collections. The "Results" column is a qualitative graphical interpretation of the change in the parameter over time through all monitoring cycles.

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Alabama Creek	OK520500-01-0200D	Alkalinity	1	17	58	25.31	0.001	<0.001	
			2	17	98.06	37.43			
			3	20	104.4	31.42			
			4	20	70.8	28.17			
		Conductivity	1	16	597.6	321.1		0.002	
			2	17	945	571			
			3	20	530.4	286.7			
			4	21	449.3	342			
		DO	1	17	7.472	2.653	0.049		
			2	16	7.39	2.999			
			3	20	6.357	3.334			
			4	20	8.295	2.669			
		DO % Saturation	1	17	75.44	17.26	<0.001	0.001	
			2	16	71.17	18.4			
			3	20	58.61	20.37			
			4	20	83.36	17.03			
		Hardness	1	17	114.6	48.8	<0.001	<0.001	
			2	16	193.1	98.2			
			3	20	185.3	45.9			
			4	20	116.7	56.2			
		pH	1	17	7.196	0.545	0.037		
			2	13	7.1923	0.1553			
			3	18	7.123	0.577			
			4	19	7.4495	0.3044			
		Chloride	1	17	123.2	72		<0.001	
			2	16	251.5	167.9			
			3	19	94.9	59.6			
			4	17	84.3	89.6			
		TDS	1	17	337.8	135.7		<0.001	
			2	16	543.9	302.7			
			3	19	286	127.4			
			4	17	278.8	175.8			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Alabama Creek (Cont.)		Nitrate	1	17	0.0553	0.0499	0.039		
			2	16	0.1244	0.2299			
			3	19	0.0274	0.0242			
			4	18	0.0678	0.0783			
		Ortho P	1	17	0.0226	0.0188	0.079	0.027	
			2	16	0.0126	0.0086			
			3	19	0.0116	0.0076			
			4	18	0.0159	0.007			
		Total P	1	17	0.0808	0.0304		<0.001	
			2	16	0.0417	0.0251			
			3	19	0.0438	0.0157			
			4	18	0.0461	0.017			
		Sulfate	1	17	18.69	5.59		<0.001	
			2	16	25.11	7.41			
			3	19	18.74	5.57			
			4	17	16.09	4.55			
		Available N	1	17	0.096	0.0926	0.091	0.072	
			2	16	0.1552	0.2294			
			3	19	0.0416	0.0433			
			4	18	0.0759	0.0739			
		Flow	1	12	2.94	5.46	0.036	0.06	
			2	14	1.952	1.914			
			3	18	2.344	3.199			
			4	18	5.77	5.87			
Ash Creek	OK120410-01-0110E	Alkalinity	3	21	99.52	25.62	0.07		
			4	19	84.32	26.01			
		Conductivity	3	21	449.4	148	0.053		
			4	20	363.7	125.7			
		Hardness	3	20	200	66.8	0.006		
			4	19	146.84	43.38			
		pH	3	20	7.826	0.2621	0.013		
			4	19	7.5379	0.4107			
		Chloride	3	20	58	49.4	0.058		
			4	17	33.11	18.04			
		TDS	3	20	279.9	77.1	0.07		
			4	17	233.5	73.1			
		Flow	3	19	1.061	1.927	0.019		
			4	18	8.7	13.35			
Bad Creek	OK520500-01-0170E	Alkalinity	1	18	44.49	14.87	0.016	<0.001	
			2	18	65.67	16.03			
			3	21	74.81	19.86			
			4	21	118.7	77.1			
		Conductivity	1	17	662.5	250.3		<0.001	
			2	18	913	324.1			
			3	21	478.9	236.3			
			4	22	497.7	247.3			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Bad Creek (Cont.)		DO % Saturation	1	18	89.77	19.87		0.007	
			2	17	85.13	16.73			
			3	21	71.73	19.81			
			4	21	73.84	16.7			
		Hardness	1	18	106.69	35.85		0.007	
			2	17	158.8	43.8			
			3	21	158.72	44.18			
			4	20	151.8	71.4			
		pH	1	18	7.473	0.454	0.089		
			2	14	7.4143	0.1956			
			3	21	7.507	0.719			
			4	21	7.1952	0.39			
		Chloride	1	18	152.5	69	0.092	<0.001	
			2	17	238.4	98.3			
			3	20	109.4	55.3			
			4	18	79.5	51.1			
		TKN	1	18	0.5278	0.42	0.037		
			2	17	0.5041	0.3468			
			3	20	0.6855	0.253			
			4	18	0.5233	0.202			
		Ortho P	1	18	0.0156	0.0139	<0.001	<0.001	
			2	17	0.0105	0.0086			
			3	20	0.0095	0.006			
			4	18	0.0245	0.009			
		Total P	1	18	0.0748	0.0373	0.033	0.003	
			2	17	0.0427	0.0244			
			3	20	0.0477	0.0215			
			4	18	0.0654	0.0278			
		Sulfate	1	18	20.3	4.76	0.052	<0.001	
			2	17	24.49	5.37			
			3	20	18.47	5.83			
			4	19	15.163	4.283			
		TSS	1	18	14.94	7.46	0.024	0.014	
			2	17	10.412	1.46			
			3	20	10.2	0.894			
			4	18	17.39	13.62			
		TN	1	18	0.583	0.459	0.082		
			2	17	0.761	0.937			
			3	20	0.715	0.2623			
			4	18	0.5711	0.2302			
Ballard Creek	OK121700-03-0370G	Conductivity	1	19	278.1	23.4	0.002	0.005	
			2	15	274.49	34.27			
			3	21	276.04	26.4			
			4	18	248.47	26.19			
		Hardness	1	19	124.75	10.19		0.017	
			2	14	125.75	23.77			
			3	21	156.14	34.78			
			4	17	140.1	51.5			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Ballard Creek (Cont.)		Chloride	1	19	10.721	1.029	<0.001	0.009	
			2	14	10.271	3.367			
			3	20	11.22	1.196			
			4	16	8.987	1.83			
		TDS	1	19	166.32	27.4	0.012	0.082	
			2	13	153.23	23.59			
			3	20	168.25	14.23			
			4	16	153.75	18.57			
		Ortho P	1	19	0.0666	0.04	0.098		
			2	14	0.1073	0.1859			
			3	20	0.0658	0.0446			
			4	16	0.0867	0.0231			
		Sulfate	1	19	9.463	3.1		0.001	
			2	13	8.777	2.393			
			3	20	12.815	3.573			
			4	16	11.494	2.532			
		Flow	1	19	26.04	25.06	0.008	0.007	
			2	15	19.17	12.85			
			3	18	16.47	14.83			
			4	17	46.1	42			
Battle Creek	OK121700-06-0040G	Alkalinity	1	20	78.75	19.95		0.011	
			2	18	69.49	12.82			
			3	21	95	29.21			
			4	19	83.16	27.24			
		DO % Saturation	1	20	89.94	11.7	0.079		
			2	18	92.23	11.99			
			3	21	91.62	11.35			
			4	20	83.13	7.66			
		Hardness	1	20	100.01	23.47	0.004	0.001	
			2	17	100.94	31.22			
			3	21	133.79	40.89			
			4	19	99.16	28.41			
		Chloride	1	20	8.93	5.68	0.024	0.036	
			2	17	12.44	10.24			
			3	20	8.125	1.004			
			4	18	6.806	2.275			
		TKN	1	20	0.1154	0.0138	0.087	0.033	
			2	17	0.1206	0.0388			
			3	20	0.1245	0.0214			
			4	18	0.2856	0.4092			
		Nitrate	1	20	3.059	0.872	0.058	0.062	
			2	17	2.6859	0.3811			
			3	20	3.324	1.029			
			4	18	2.769	0.656			
		Ortho P	1	20	0.0327	0.0149	0.015	0.001	
			2	17	0.0371	0.0137			
			3	20	0.0387	0.006			
			4	18	0.0718	0.058			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Battle Creek (Cont.)		Total P	1	20	0.0853	0.0356	0.032	0.019	
			2	17	0.0694	0.0447			
			3	20	0.0427	0.0083			
			4	18	0.0764	0.0671			
		Sulfate	1	20	4.93	0.906	0.071		
			2	17	7.37	8.5			
			3	20	4.765	0.679			
			4	18	4.361	0.656			
		TSS	1	20	12.85	6.15		0.012	
			2	17	10	0			
			3	20	10	0			
			4	18	10	0			
		Available N	1	20	3.077	0.871	0.057	0.068	
			2	17	2.7115	0.3728			
			3	20	3.329	1.028			
			4	18	2.773	0.655			
		Flow	1	20	13.61	19.34	0.02		
			2	18	10.84	10.11			
			3	19	5.109	3.883			
			4	19	15.73	18.65			
Bear Creek	OK520700-05-0170A	Alkalinity	3	20	355.1	94.6	0.094		
			4	19	304.1	90.1			
		DO % Saturation	3	20	73.09	16.47	0.04		
			4	18	84	14.96			
		TDS	3	19	416.1	86.9	0.084		
			4	17	368.2	72.5			
Big Creek	OK220100-02-0080B	DO	3	12	8.107	2.64	0.051		
			4	7	5.956	0.653			
		DO % Saturation	3	12	82.75	10.8	0.089		
			4	7	74.13	8.52			
		Water Temp	3	12	19.33	9.36	0.067		
			4	7	26.443	2.332			
		TDS	3	11	30.45	10.27	0.031		
			4	6	43.67	12.24			
		TKN	3	11	0.1364	0.0545	0.001		
			4	6	0.27	0.0785			
		Nitrate	3	11	0.0591	0.0383	0.062		
			4	6	0.0267	0.0082			
		Ortho P	3	11	0.005	0	0.007		
			4	6	0.0055	0.0005			
		Total P	3	11	0.0113	0.0045	0.006		
			4	6	0.0195	0.0059			
		Sulfate	3	11	3.064	1.095	0.034		
			4	6	1.95	0.521			
		TN	3	11	0.1955	0.0885	0.03		
			4	6	0.2967	0.0706			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Bird Creek	OK520800-01-0050M	Alkalinity	1	19	140.32	33.32	0.036	0.007	
			2	20	170.9	44.8			
			3	20	126.75	28.12			
			4	21	155	51.4			
		Conductivity	1	19	697.7	383.7	0.028	<0.001	
			2	20	1999	1383			
			3	20	1134	765			
			4	22	1728	902			
		DO	1	20	11.553	3.64		0.001	
			2	19	9.272	2.4			
			3	20	8.473	2.765			
			4	21	7.951	2.782			
		DO % Saturation	1	19	117.33	28.12		<0.001	
			2	19	97.69	24.1			
			3	20	88.43	29.72			
			4	21	79.37	17.14			
		Hardness	1	20	191.5	78.3	0.006	<0.001	
			2	19	373.8	157.9			
			3	20	239.6	124.2			
			4	21	361.1	140.9			
		pH	1	20	7.785	0.663	<0.001	0.002	
			2	16	7.7937	0.1769			
			3	20	7.9365	0.2956			
			4	21	7.4167	0.3706			
		Turbidity	1	19	20.14	32.16	0.002	0.025	
			2	20	14.53	16.59			
			3	21	32.42	22.92			
			4	22	13.32	13.2			
		Chloride	1	20	102.2	100.4		<0.001	
			2	18	640	610			
			3	19	294.5	282.8			
			4	18	416.3	260.2			
		TDS	1	20	392.9	212.2	0.042	<0.001	
			2	18	1136	773			
			3	19	643.5	399.6			
			4	18	952	486			
		TKN	1	20	0.6196	0.3255	<0.001	0.04	
			2	18	2.36	4.49			
			3	19	0.8353	0.2931			
			4	18	0.4211	0.1465			
		Nitrate	1	20	2.587	2.538	0.082	0.001	
			2	18	0.253	0.591			
			3	19	1.31	3.044			
			4	18	0.0261	0.0179			
		Ortho P	1	20	1.146	0.722	0.074	<0.001	
			2	18	0.475	0.811			
			3	19	0.212	0.458			
			4	18	0.0131	0.0101			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Bird Creek (Cont.)		TP	1	20	1.313	0.757	0.038	<0.001	
			2	18	0.57	0.964			
			3	19	0.26	0.451			
			4	18	0.0312	0.0189			
		TSS	1	20	59.1	204.4	0.067		
			2	18	12.06	6.44			
			3	19	15.84	12.85			
			4	18	10.111	0.471			
		Available N	1	20	2.663	2.552	0.083	0.028	
			2	18	1.848	3.521			
			3	19	1.322	3.063			
			4	18	0.0326	0.019			
		TN	1	20	3.207	2.698	0.024	0.042	
			2	18	2.62	4.46			
			3	19	2.145	3.055			
			4	18	0.4472	0.1511			
		Flow	1	18	3.66	5.05	0.012	0.018	
			2	17	1.251	1.916			
			3	19	0.911	3.518			
			4	20	4.52	4.83			
Brazil Creek	OK220100-03-0010G	Alkalinity	1	12	40.61	11.61		0.001	
			2	8	107	46.6			
			3	9	92.4	47.2			
			4	6	63.6	28			
		Conductivity	1	14	168.57	27.74		<0.001	
			2	8	245.8	41.6			
			3	9	222.46	21.97			
			4	6	206.5	48.8			
		DO	1	14	6.361	2.368		0.058	
			2	8	6.938	2.075			
			3	9	4.698	0.734			
			4	6	5.075	1.199			
		DO % Saturation	1	14	70.96	21.63	0.088	0.035	
			2	8	73.92	13.71			
			3	9	52.22	9.87			
			4	6	62.67	12.05			
		Hardness	1	14	46.69	9.29	0.042	<0.001	
			2	8	82.63	20.31			
			3	9	111.2	34.9			
			4	6	69.5	35.2			
		pH	1	14	7.2686	0.2914		0.089	
			2	8	7.1875	0.1959			
			3	9	7.088	0.368			
			4	6	6.87	0.413			
		Chloride	1	14	5.943	1.427		0.074	
			2	7	7.129	1.539			
			3	8	5.45	1.249			
			4	5	5.14	1.341			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Brazil Creek (Cont.)		TDS	1	14	97.79	31.3		0.018	
			2	7	142.9	31.3			
			3	8	132	16.66			
			4	5	122.4	47.9			
		TKN	1	14	0.3326	0.3476		0.07	
			2	7	0.2129	0.1427			
			3	8	0.5275	0.2725			
			4	5	0.582	0.1575			
		Sulfate	1	14	24.16	7.09		0.079	
			2	7	30.2	7.88			
			3	8	34.14	5.56			
			4	5	31.98	16.87			
		Flow	1	8	28.3	17.86		0.04	
			2	8	11.07	8.72			
			3	8	9.97	8.34			
			4	4	14.17	18.08			
Brushy Creek	OK220600-03-0010L	Alkalinity	1	16	41.11	18.51		<0.001	
			2	14	60.36	16.72			
			3	12	73.75	17.39			
			4	7	64.29	20.93			
		Hardness	1	17	57.27	17.06	0.09	<0.001	
			2	14	82.43	24.03			
			3	12	119.5	44.3			
			4	7	87.14	21.26			
		pH	1	17	7.308	0.747	0.09		
			2	14	6.9214	0.3683			
			3	12	6.937	0.465			
			4	7	7.293	0.311			
		Water Temp	1	17	19.48	7.83	0.074		
			2	14	18.23	9.33			
			3	12	17.68	9.89			
			4	7	25.14	3.8			
		TKN	1	17	0.3172	0.3479	0.085	0.022	
			2	13	0.2408	0.1719			
			3	11	0.4664	0.0836			
			4	6	0.575	0.1622			
		TN	1	17	0.3631	0.3877	0.065	0.056	
			2	13	0.3008	0.1819			
			3	11	0.51	0.0823			
			4	6	0.62	0.1479			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Canadian Sandy Creek	OK520600-03-0010D	Alkalinity	1	18	234.6	51.7	0.044	0.007	
			2	17	275	32.7			
			3	21	251	42.69			
			4	16	279	37.07			
		DO % Saturation	1	19	94.53	18.36	0.051	0.038	
			2	17	80.37	16.28			
			3	21	74.77	38.99			
			4	16	99.3	33.24			
		Hardness	1	19	234	52.8		0.018	
			2	16	277.25	38.54			
			3	21	276.5	78.5			
			4	16	293.2	40.4			
		Turbidity	1	19	63.7	118.5		0.026	
			2	16	11.71	24.19			
			3	22	12.65	18.96			
			4	16	9.7	9.44			
		Chloride	1	19	36.4	44.6	0.015		
			2	16	40.25	26.13			
			3	20	29.38	17.37			
			4	14	17.09	4.21			
		TKN	1	19	0.1962	0.1274	0.016	<0.001	
			2	16	0.2487	0.1612			
			3	20	0.4785	0.1642			
			4	14	0.3364	0.1537			
		Nitrate	1	19	0.0974	0.0696	0.024		
			2	16	0.315	0.948			
			3	20	0.0385	0.048			
			4	14	0.0821	0.0591			
		Ortho P	1	19	0.0631	0.0469	0.032	0.009	
			2	16	0.0353	0.022			
			3	20	0.0787	0.0477			
			4	14	0.0478	0.0223			
		Total P	1	19	0.1397	0.0775	0.011	<0.001	
			2	16	0.072	0.0392			
			3	20	0.1018	0.0501			
			4	14	0.0616	0.0281			
		Sulfate	1	19	20.94	9.09	0.069		
			2	16	21.09	4.1			
			3	20	21.8	12.99			
			4	14	15.05	3.705			
		TSS	1	19	56.8	79.3		0.004	
			2	16	11.75	3.512			
			3	20	14.5	12.16			
			4	14	11.429	2.738			
		Flow	1	19	16.2	20.92	0.005	<0.001	
			2	17	19.84	26.6			
			3	18	5.73	8.57			
			4	14	95.5	124.2			

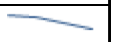
Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Captain Creek	OK520700-05-0140H	Conductivity	3	21	617.7	106.7	0.027		
			4	21	685.8	84.9			
		Chloride	3	20	35.19	5.34	0.007		
			4	17	30.871	3.434			
		Nitrate	3	20	0.0995	0.0711	0.002		
			4	17	0.1982	0.1084			
		Available N	3	20	0.1141	0.0939	0.004		
			4	17	0.2241	0.1249			
Caston Creek	OK220100-01-0180B	Alkalinity	3	13	126.9	64.8	0.055		
			4	7	74.29	24.53			
		Conductivity	3	13	488.6	199.4	0.007		
			4	7	245.5	88.9			
		Hardness	3	13	163.9	73.8	0.013		
			4	7	84	24.75			
		Water Temp	3	13	21.28	7.75	0.048		
			4	7	27.79	2.82			
		Chloride	3	12	8.142	2.438	0.013		
			4	5	4.9	1.179			
		TDS	3	12	307.5	114.7	0.009		
			4	5	141	66.4			
		Sulfate	3	12	130.9	58.3	0.008		
			4	5	46	28.7			
Cloud Creek	OK120410-01-0100T	Alkalinity	2	15	109.1	60.3		0.013	
			3	20	77.2	24.01			
			4	18	72.28	18.17			
		Conductivity	2	14	507.5	288.8		0.001	
			3	20	315.7	92			
			4	19	298.8	87.2			
		Hardness	2	14	262.2	172.1	0.026	0.001	
			3	20	157.8	61.2			
			4	18	119.33	36.2			
		pH	2	14	7.143	0.392	0.004	<0.001	
			3	20	7.7025	0.3532			
			4	18	7.3783	0.2884			
		Chloride	2	14	46.11	19.72		0.014	
			3	19	35.55	14.63			
			4	16	28.7	12.56			
		TDS	2	14	445.4	296.2		<0.001	
			3	19	209.5	49.2			
			4	16	200	44			
		Sulfate	2	14	192.3	167.2		<0.001	
			3	19	39.48	20.1			
			4	16	35.08	14.33			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Coal Creek	OK220600-02-0010F	Hardness	3	15	156.3	44.1	0.031		
			4	10	115.6	42.3			
		Water Temp	3	15	16.81	9.47	0.059		
			4	10	23.21	4.41			
		Chloride	3	14	26.03	14.58	0.045		
			4	8	14.57	4.83			
		TSS	3	14	11.5	3.82	0.034		
			4	8	18	9.56			
Deep Branch	OK121700-01-0020A	Chloride	3	17	4.341	1.667	0.008		
			4	13	2.869	0.91			
		TDS	3	17	58.53	15.42	0.011		
			4	13	73.69	14.65			
		TKN	3	17	0.2629	0.1025	0.053		
			4	13	0.34	0.1044			
		Ortho P	3	17	0.0051	0.0002	0.023		
			4	13	0.0062	0.002			
		Total P	3	17	0.0147	0.0056	0.016		
			4	13	0.0206	0.0072			
		Sulfate	3	17	12.547	2.661	<0.001		
			4	13	8.192	2.558			
		Flow	3	18	3.8	5.01	0.025		
			4	14	0.479	1.791			
Dry Creek	OK520700-04-0020F	pH	1	15	8.0493	0.2706		0.066	
			2	15	8.24	0.2558			
			3	16	8.002	0.418			
			4	19	7.9558	0.282			
		TKN	1	17	0.3552	0.2954		0.016	
			2	15	0.374	0.3482			
			3	15	0.737	0.442			
			4	17	0.6006	0.4103			
		Nitrate	1	17	0.0894	0.0773	0.001	<0.001	
			2	15	0.0287	0.0217			
			3	15	0.0253	0.0181			
			4	17	0.1071	0.0839			
		Ortho P	1	17	0.0304	0.0286	0.021	0.006	
			2	15	0.0213	0.0255			
			3	15	0.0279	0.0277			
			4	17	0.0595	0.043			
		TP	1	17	0.1017	0.0461		0.017	
			2	15	0.0457	0.0368			
			3	15	0.0789	0.0535			
			4	17	0.0943	0.0643			
		Sulfate	1	17	14.66	4.86	0.021	0.011	
			2	15	16.1	4.64			
			3	15	15.667	3.1111			
			4	17	20.31	6.75			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Dry Creek (Cont.)		Available N	1	17	0.146	0.1257	<0.001	<0.001	
			2	15	0.0524	0.0313			
			3	15	0.0334	0.0257			
			4	17	0.1222	0.0842			
		TN	1	17	0.4446	0.3006		0.024	
			2	15	0.4027	0.3635			
			3	15	0.762	0.454			
			4	17	0.708	0.433			
		Flow	1	14	9.07	7.72	0.002	<0.001	
			2	14	14.07	18.44			
			3	15	4.04	6.51			
			4	19	51.5	54.5			
Elk Creek (McIntosh)	OK120400-02-0190F	Alkalinity	1	16	77.38	28.57	<0.001	<0.001	
			2	17	75.41	32.51			
			3	17	127.59	39.61			
			4	19	60.74	23.25			
		Conductivity	1	18	477.3	199.3	0.094		
			2	16	514.9	190.7			
			3	17	496.7	194			
			4	20	406.1	122.9			
		Hardness	1	18	179.8	78.5	0.035	0.056	
			2	16	218.4	43.2			
			3	17	218.9	80.1			
			4	19	171.4	47			
		pH	1	17	7.642	0.467		0.006	
			2	17	7.1765	0.3052			
			3	17	7.068	0.61			
			4	19	7.338	0.506			
		Turbidity	1	17	41	49.3		0.02	
			2	16	10.69	4.8			
			3	19	19.95	18.26			
			4	21	23.71	20.16			
		Chloride	1	18	22.02	17.77	0.031		
			2	16	29.45	25.69			
			3	16	25.69	15.08			
			4	17	15.34	11.09			
		TKN	1	18	0.52	0.428		0.014	
			2	16	0.4469	0.2329			
			3	16	0.6694	0.2913			
			4	17	0.7882	0.2692			
		Sulfate	1	18	123.9	99.1		0.015	
			2	16	203.5	53.2			
			3	16	157.5	117.3			
			4	17	115.41	39.86			
		TSS	1	18	26.78	22.04		0.003	
			2	16	11.44	4.59			
			3	16	14.56	11.84			
			4	17	11.941	3.526			

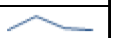
Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Elk Creek (McIntosh) cont.		TN	1	18	0.757	0.458		0.078	
			2	16	0.743	0.558			
			3	16	0.894	0.42			
			4	17	1.1	0.3015			
		Flow	1	16	13.34	18.77	0.054	0.038	
			2	17	7.98	9.46			
			3	16	0.293	1.147			
			4	16	44.1	87.1			
Fourche Maline Creek	OK220100-04-0020H	Alkalinity	1	13	38.76	15.45		0.007	
			2	7	69.14	24.94			
			3	10	58.62	17.38			
			4	6	56.67	16.08			
		Hardness	1	14	38.07	8.85		<0.001	
			2	7	100.3	33.7			
			3	10	94	41.2			
			4	6	65.33	7.71			
		pH	1	14	7.18	0.49		0.092	
			2	7	7.0429	0.1813			
			3	10	6.64	0.599			
			4	6	6.81	0.681			
		TDS	1	14	77.43	28.62	0.091	0.028	
			2	6	103.33	19.54			
			3	9	90.11	27.62			
			4	5	125.2	44.6			
		TKN	1	14	0.2196	0.1701		<0.001	
			2	6	0.225	0.1597			
			3	9	0.4589	0.1542			
			4	5	0.572	0.0963			
		Sulfate	1	14	13.28	3.91		0.026	
			2	6	20.15	7.66			
			3	9	12.27	3.42			
			4	5	15.46	6.11			
		TN	1	14	0.2974	0.1607		<0.001	
			2	6	0.265	0.1797			
			3	9	0.5544	0.1936			
			4	5	0.626	0.1379			
		Flow	1	8	20.59	18.39	0.074		
			2	7	8.34	7.22			
			3	10	16.38	14.96			
			4	6	4.15	4.26			
Gar Creek	OK520510-00-0080C	Ortho P	3	15	0.0066	0.0022	0.004		
			4	18	0.0109	0.005			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
George's Fork of Dirty	OK120400-02-0110D	Alkalinity	1	17	75.12	30.8	0.001	0.017	
			2	18	103.4	60.5			
			3	18	103.28	29.25			
			4	18	70.61	24.55			
		Hardness	1	18	79.02	22.04	0.007	0.001	
			2	18	141.7	86			
			3	18	153	51.9			
			4	18	108.78	39.47			
		pH	1	17	7.6518	0.3495		0.039	
			2	18	7.317	0.88			
			3	18	7.077	0.633			
			4	18	7.2361	0.2774			
		TKN	1	18	0.5102	0.3182		0.018	
			2	17	0.5176	0.2788			
			3	17	1.041	1.006			
			4	16	0.7988	0.1778			
		TSS	1	18	26.17	22.14		0.002	
			2	17	11.059	2.633			
			3	16	12	8			
			4	16	13.13	6.12			
		TN	1	18	0.6569	0.3425		0.029	
			2	17	0.6147	0.3016			
			3	17	1.151	1.035			
			4	16	0.9044	0.1777			
Greenleaf Creek	OK120400-01-0120C	DO	3	20	10.093	3.111	0.076		
			4	10	7.909	2.955			
		DO % Saturation	3	20	108.53	25.36	0.028		
			4	10	85.7	25.32			
		pH	3	19	7.975	0.622	0.017		
			4	10	7.446	0.2871			
		Flow	3	18	22.11	28.33	0.077		
			4	7	2.008	1.897			
Hog Creek	OK520810-00-0030D	Chloride	3	19	33.72	8.18	0.015		
			4	18	28.411	3.255			
		Nitrate	3	19	0.03	0.0216	0.015		
			4	18	0.0783	0.0794			
		Sulfate	3	19	10.816	2.001	0.002		
			4	18	8.617	1.97			
		Available N	3	19	0.0406	0.039	0.038		
			4	18	0.1023	0.1184			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Little Deep Fork	OK520700-06-0010D	Alkalinity	3	21	132.57	22.3	0.019		
			4	15	111.53	28.92			
		Conductivity	3	20	772.4	259.7	0.001		
			4	16	491.7	172.1			
		Hardness	3	21	216	63.4	0.092		
			4	15	184.27	37.23			
		Turbidity	3	23	14.56	13.35	0.053		
			4	17	31.07	36.56			
		Chloride	3	20	179.8	67.9	0.001		
			4	12	95.7	41.9			
		TDS	3	20	434.4	116.7	0.004		
			4	12	316.7	78.3			
		TKN	3	20	0.962	0.626	0.095		
			4	12	0.6375	0.2174			
		Flow	3	20	2	4.52	0.002		
			4	15	88.6	116			
Little Wewoka Creek	OK520500-02-0090D	Alkalinity	1	17	82	41.5	0.007	0.002	
			2	17	108.34	40.47			
			3	18	141.7	52.8			
			4	21	92.7	53.3			
		Conductivity	1	16	770.6	270.2	0.055	0.004	
			2	17	750.2	267			
			3	18	643.7	207.2			
			4	22	495	257			
		pH	1	17	7.4182	0.3955		0.02	
			2	15	7.5333	0.1915			
			3	18	7.7294	0.291			
			4	21	7.6224	0.2622			
		Turbidity	1	17	22.25	18.6	0.007	0.006	
			2	17	22.09	25.8			
			3	19	21.57	22.12			
			4	22	44.87	28.9			
		Chloride	1	17	172.2	84.8	0.071	0.001	
			2	16	179.2	68.2			
			3	17	127.6	55.4			
			4	18	89.6	64.4			
		TDS	1	17	428.2	162.8		0.082	
			2	16	413	121.6			
			3	17	365.6	100.8			
			4	18	321.1	135.8			
		TKN	1	17	0.5098	0.3237		0.003	
			2	16	0.4225	0.2519			
			3	17	0.66	0.2305			
			4	18	0.7489	0.241			
		Nitrate	1	17	0.0724	0.0822	0.025	0.082	
			2	16	0.045	0.0392			
			3	17	0.0335	0.0437			
			4	18	0.0856	0.0809			

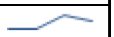
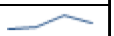
Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Little Wewoka Creek (Cont.)		Ortho P	1	17	0.021	0.0192	0.005	0.001	
			2	16	0.0124	0.0093			
			3	17	0.0139	0.0138			
			4	18	0.0375	0.0293			
		TP	1	17	0.0799	0.0427	0.013	0.003	
			2	16	0.0435	0.0217			
			3	17	0.0459	0.0306			
			4	18	0.0796	0.0439			
		Sulfate	1	17	13.5	5.78		0.046	
			2	16	17.413	3.398			
			3	17	15.39	5.47			
			4	18	13.272	3.629			
		TSS	1	17	20	15.12	0.015	0.029	
			2	16	12.75	5.93			
			3	17	11.588	3.083			
			4	18	21	14.8			
		Available N	1	17	0.1093	0.1037	0.018	0.042	
			2	16	0.0724	0.0409			
			3	17	0.0415	0.0455			
			4	18	0.0944	0.0758			
		TN	1	17	0.5821	0.3546		0.005	
			2	16	0.4675	0.27			
			3	17	0.6935	0.2595			
			4	18	0.8344	0.2941			
		Flow	1	14	9.04	16.39	0.048	0.018	
			2	17	4.71	5.94			
			3	16	3.54	6.57			
			4	19	42.8	76.2			
Longtown Creek	OK220600-01-0070P	Alkalinity	3	17	81.53	19.74	<0.001		
			4	19	47.58	18.43			
		Conductivity	3	16	191.76	34.78	<0.001		
			4	20	136.14	31.74			
		Hardness	3	17	130.06	36.34	<0.001		
			4	19	66.32	14.07			
		pH	3	17	7.0106	0.4007	0.034		
			4	19	7.2732	0.3111			
		Chloride	3	16	11.044	1.823	<0.001		
			4	17	7.129	2.541			
		Sulfate	3	16	30.19	9.69	0.001		
			4	17	20.682	3.529			
		TN	3	16	0.5506	0.2159	0.056		
			4	17	0.4306	0.1218			

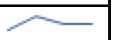
Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Manard Bayou	OK120400-01-0280E	Alkalinity	3	21	130.67	18.54	0.077		
			4	18	117.94	24.99			
		Conductivity	3	21	285.51	30.05	0.001		
			4	18	246.91	38.29			
		Hardness	3	21	169.67	41.3	0.058		
			4	18	146.94	28.87			
		Chloride	3	19	6.953	1.753	0.002		
			4	17	5.024	1.776			
		Flow	3	10	4.52	8.11	0.045		
			4	14	23.95	27.87			
Mill Creek	OK220600-01-0100J	Conductivity	1	20	148.3	56.8		0.036	
			2	17	206.9	71.9			
			3	19	184	73.8			
			4	15	161.1	42.2			
		Hardness	1	20	50.29	17.43	0.004	<0.001	
			2	16	108.69	33.04			
			3	19	146.2	62.8			
			4	14	87.29	35.22			
		pH	1	19	8.0105	0.411		<0.001	
			2	17	7.1941	0.3929			
			3	19	6.991	0.725			
			4	14	7.0286	0.3525			
		Water Temp	1	20	16.93	8.09	0.095		
			2	17	14.94	8.94			
			3	19	16.82	9.07			
			4	14	22.06	8			
		Chloride	1	20	7.775	2.95		0.014	
			2	17	10.941	3.433			
			3	18	9.75	3.222			
			4	13	8.262	2.608			
		TDS	1	20	116.66	44.15		0.084	
			2	17	141.53	23.25			
			3	18	131.22	22.95			
			4	13	135.38	15.06			
		TKN	1	20	0.4279	0.2688		0.002	
			2	17	0.4559	0.2357			
			3	18	0.6772	0.1794			
			4	13	0.61	0.1525			
		Total P	1	20	0.1076	0.0637		0.001	
			2	17	0.0586	0.0301			
			3	18	0.0644	0.0264			
			4	13	0.0582	0.021			
		Sulfate	1	20	10.5	6.39		0.005	
			2	17	18.42	7.34			
			3	18	14.21	7.41			
			4	13	11.73	5.37			
		TN	1	20	0.5475	0.3765		0.055	
			2	17	0.5229	0.2422			
			3	18	0.7511	0.2193			
			4	13	0.6738	0.1944			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Montezumah Creek	OK520700-01-0220D	Turbidity	3	22	52.1	42.89	0.028		
			4	21	28.83	19.25			
		TKN	3	19	0.8737	0.3265	0.05		
			4	17	0.6853	0.2108			
		Total P	3	19	0.0995	0.0656	0.052		
			4	17	0.0648	0.029			
		TN	3	19	0.9111	0.3365	0.076		
			4	17	0.7353	0.2212			
		Flow	3	12	0.208	0.722	0.067		
			4	18	28.4	51.1			
Nuyaka Creek	OK520700-02-0200D	Hardness	3	21	190.4	63.2	0.026		
			4	18	146.7	52.7			
		Ammonia	3	6	0.1255	0.0962	0.063		
			4	7	0.0464	0.0313			
		TDS	3	20	441	473	0.093		
			4	17	240	80.2			
		Nitrate	3	20	0.036	0.0319	0.008		
			4	18	0.0911	0.0812			
		Flow	3	18	1.367	3.013	0.055		
			4	17	20.39	40.46			
Peaceable Creek	OK220600-03-0050F	Alkalinity	1	15	53.69	9.88		0.05	
			2	13	96.7	72.3			
			3	15	73.48	20.45			
			4	7	74.57	10.39			
		Hardness	1	16	101.9	55		0.02	
			2	13	173.3	83.9			
			3	15	143.5	42.6			
			4	7	142.3	35.9			
		pH	1	16	7.17	0.784	0.072		
			2	13	7.1538	0.2634			
			3	15	7.0387	0.3837			
			4	7	7.34	0.2373			
		Water Temp	1	16	19.58	7.35	0.07		
			2	13	17.95	9.82			
			3	15	17.48	9.22			
			4	7	24.46	3.57			
		TKN	1	16	0.5068	0.3552		0.01	
			2	12	0.5025	0.2885			
			3	14	0.8107	0.23			
			4	5	0.818	0.176			
		Nitrate	1	16	0.0738	0.0691		0.038	
			2	12	0.472	0.722			
			3	14	0.1371	0.1456			
			4	5	0.056	0.0513			
		Ortho P	1	16	0.0514	0.0394		<0.001	
			2	12	0.1916	0.1037			
			3	14	0.0976	0.0828			
			4	5	0.107	0.0668			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Peaceable Creek (Cont.)		Sulfate	1	16	95.5	101.8		0.079	
			2	12	211.4	223.9			
			3	14	84.9	67.9			
			4	5	87.3	67.4			
		Available N	1	16	0.1147	0.109		0.045	
			2	12	0.503	0.719			
			3	14	0.1535	0.163			
			4	5	0.1034	0.0549			
		TN	1	16	0.5806	0.3739		0.099	
			2	12	0.975	0.73			
			3	14	0.9479	0.3081			
			4	5	0.874	0.1801			
Pecan Creek (Muskogee)	OK120410-01-0030D	Hardness	3	21	162.5	57.3	0.014		
			4	18	117.3	50.8			
		Flow	3	18	4.07	6.13	0.029		
			4	16	15.53	20.34			
Pecan Creek (Pottawatomie)	OK520800-02-0080C	Chloride	3	18	24.75	5.05	0.002		
			4	18	20.344	2.679			
		Nitrate	3	18	0.02	0	0.081		
			4	18	0.0278	0.0183			
		Sulfate	3	18	11.128	2.005	0.002		
			4	18	9.161	1.459			
		Available N	3	18	0.025	0.0073	0.098		
			4	18	0.0328	0.018			
Polecat Creek	OK120420-02-0050B	Alkalinity	1	19	92.26	40.74	<0.001	<0.001	
			2	13	124.54	25			
			3	21	121.19	25.46			
			4	16	74.19	13.76			
		Conductivity	1	19	487	173.5	<0.001	<0.001	
			2	12	632.3	149.1			
			3	21	645.1	186			
			4	17	230.27	39.47			
		Hardness	1	19	136.79	37.45	<0.001	<0.001	
			2	12	221.6	70.5			
			3	21	217.7	63			
			4	16	108.63	29.51			
		pH	1	19	7.939	0.52	0.005	0.002	
			2	13	7.669	0.375			
			3	20	7.818	0.611			
			4	16	7.3006	0.3448			
		Turbidity	1	17	48.59	35.09	0.003	0.001	
			2	13	27.38	11.98			
			3	22	25.54	18.25			
			4	18	111	125.6			
		Chloride	1	19	73.24	33.69	<0.001	<0.001	
			2	12	123.27	31.21			
			3	20	120.9	52.9			
			4	14	22.093	3.404			

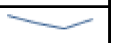
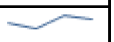
Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Polecat Creek (Cont.)		TDS	1	19	292.2	79.8	<0.001	<0.001	
			2	12	367.2	59			
			3	20	367.1	102.5			
			4	14	195	51			
		TKN	1	19	0.455	0.3132	0.002	<0.001	
			2	12	0.738	0.393			
			3	19	1.0974	0.4205			
			4	14	0.6929	0.1506			
		Nitrate	1	19	0.1537	0.0986	0.002	<0.001	
			2	12	0.526	0.873			
			3	20	1.356	1.332			
			4	14	0.1379	0.0635			
		Ortho P	1	19	0.0747	0.132	0.001	<0.001	
			2	12	0.0595	0.0483			
			3	20	0.2518	0.2391			
			4	14	0.0272	0.0146			
		Total P	1	19	0.1739	0.1459	0.001	<0.001	
			2	12	0.1187	0.0605			
			3	20	0.3308	0.2452			
			4	14	0.081	0.0361			
		Sulfate	1	19	22.27	7.02	<0.001	<0.001	
			2	12	27.97	6.59			
			3	20	29.9	9.98			
			4	14	11.9	8.77			
		Available N	1	19	0.2586	0.3121	0.002	<0.001	
			2	12	0.76	1.073			
			3	20	1.366	1.328			
			4	14	0.1505	0.0634			
		TN	1	19	0.6087	0.3302	<0.001	<0.001	
			2	12	1.264	1.034			
			3	20	2.398	1.36			
			4	14	0.8307	0.1692			
		Flow	1	17	28.73	19.12	0.033	0.01	
			2	11	28.61	16.76			
			3	10	14.75	16.68			
			4	15	71.3	77			
Quapaw Creek	OK520700-04-0260C	Conductivity	1	19	541.3	161		0.097	
			2	18	675.3	130.7			
			3	19	578.5	162.8			
			4	20	596.5	191			
		Hardness	1	19	222	61.9		0.05	
			2	17	288.8	86.3			
			3	19	279.9	80.6			
			4	19	274.7	84.6			
		Turbidity	1	19	47.5	65.4	0.048	0.026	
			2	18	10.8	6.6			
			3	21	19.32	28.38			
			4	21	58	82			

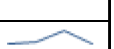
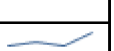
Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Quapaw Creek (Cont.)		Chloride	1	19	31.55	13.93	0.005	0.001	
			2	17	42.26	10.55			
			3	18	37.3	13.99			
			4	17	24.84	10.3			
		TKN	1	19	0.42	0.608		0.037	
			2	17	0.2441	0.1387			
			3	18	0.6089	0.395			
			4	17	0.5776	0.2786			
		Ortho P	1	19	0.0357	0.029	0.002	<0.001	
			2	17	0.0135	0.008			
			3	18	0.0184	0.0176			
			4	17	0.0511	0.0361			
		TP	1	19	0.1143	0.0654	0.056	<0.001	
			2	17	0.0307	0.0131			
			3	18	0.0518	0.0368			
			4	17	0.0892	0.0706			
		Sulfate	1	19	20.9	8.43		0.017	
			2	17	30.55	7.89			
			3	18	28.72	11.1			
			4	17	24.55	10.8			
		TSS	1	19	37.11	40.29		0.038	
			2	17	10.118	0.485			
			3	18	14.61	12.3			
			4	17	34.6	52.2			
		TN	1	19	0.55	0.617		0.073	
			2	17	0.3824	0.212			
			3	18	0.7094	0.4018			
			4	17	0.7153	0.3085			
		Flow	1	16	11.29	11.49	0.005	0.001	
			2	17	9.48	8.05			
			3	18	5.05	8.79			
			4	19	40.2	48.7			
Sallisaw Creek	OK220200-03-0010C	Alkalinity	1	13	72.46	17.26		0.001	
			2	16	71.5	14.54			
			3	12	98.33	18.99			
			4	7	86.14	18.18			
		DO % Saturation	1	13	101.49	12.36	0.02	0.006	
			2	15	98.97	10.8			
			3	12	84.27	15.46			
			4	7	103.84	17.12			
		Hardness	1	13	81.71	15.66	0.007	<0.001	
			2	16	89.19	25.68			
			3	12	146.17	28.75			
			4	7	106.57	24.1			
		Water Temp	1	13	23.64	7.01	0.026	0.025	
			2	16	17.66	9.63			
			3	12	19.32	10.18			
			4	7	28.971	2.577			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Sallisaw Creek (Cont.)		Chloride	1	13	3.431	0.877	0.019	0.002	
			2	15	3.847	1.112			
			3	11	5.155	1.193			
			4	6	3.7	0.844			
		TKN	1	13	0.1771	0.1546		0.015	
			2	15	0.1147	0.0125			
			3	11	0.2327	0.0962			
			4	6	0.235	0.0432			
		Ortho P	1	13	0.0137	0.0112	<0.001	0.047	
			2	15	0.0083	0.0049			
			3	11	0.0058	0.001			
			4	6	0.0093	0.0023			
		TP	1	13	0.0787	0.0388		<0.001	
			2	15	0.0309	0.0259			
			3	11	0.0209	0.0063			
			4	6	0.0262	0.0057			
		Sulfate	1	13	5.892	1.29		0.045	
			2	15	7.08	2.167			
			3	11	8.127	2.162			
			4	6	6.617	1.488			
Salt Creek (Creek)	OK520700-03-0100B	Alkalinity	1	20	150.1	43.61		0.013	
			2	19	196.26	42.82			
			3	20	170.45	26.35			
			4	19	169.6	54.1			
		Conductivity	1	19	640.5	297.2	0.014	0.049	
			2	19	708.4	150			
			3	20	798.3	304.8			
			4	20	580.6	221.8			
		DO % Saturation	1	20	78.65	23.39		0.044	
			2	18	95.44	14.9			
			3	20	77.42	25.21			
			4	18	85.58	19.23			
		Hardness	1	20	187.2	67.7	0.009	<0.001	
			2	17	235.7	44.7			
			3	20	282.3	66.7			
			4	19	222.5	68.7			
		Turbidity	1	20	29.98	26.29		0.072	
			2	20	9.073	4.052			
			3	22	18.34	23.53			
			4	21	27.39	41.39			
		Ammonia	1	20	0.0539	0.0513	0.075		
			2	18	0.0384	0.0292			
			3	5	0.025	0.0213			
			4	7	0.0489	0.02			
		Chloride	1	20	101.7	58.5	0.001	0.001	
			2	18	129.6	62.4			
			3	19	169	97.1			
			4	16	73.6	44.4			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Salt Creek (Creek) Cont.		TDS	1	20	350.7	155.5	0.073	0.049	
			2	18	425.7	97.3			
			3	19	483.4	165			
			4	16	370	196.9			
		TKN	1	20	0.5142	0.4251	0.068	0.027	
			2	18	0.4322	0.2403			
			3	19	0.7405	0.3311			
			4	16	0.5694	0.1617			
		Nitrate	1	20	0.11	0.0845	<0.001	<0.001	
			2	18	0.0422	0.0508			
			3	19	0.0232	0.01			
			4	16	0.0912	0.0605			
		Ortho P	1	20	0.032	0.0237	0.099	0.018	
			2	18	0.0153	0.0086			
			3	19	0.0224	0.0125			
			4	16	0.0349	0.0291			
		Total P	1	20	0.0986	0.0412		<0.001	
			2	18	0.0386	0.0197			
			3	19	0.0647	0.0384			
			4	16	0.0666	0.0577			
		Available N	1	20	0.1639	0.1124	<0.001	<0.001	
			2	18	0.0807	0.0687			
			3	19	0.0297	0.0238			
			4	16	0.1126	0.0687			
		TN	1	20	0.6242	0.442		0.067	
			2	18	0.4744	0.2454			
			3	19	0.7637	0.3331			
			4	16	0.6606	0.1915			
		Flow	1	19	10.48	15.56	0.061	0.039	
			2	19	4.46	4.6			
			3	17	1.331	1.482			
			4	19	27.7	55.9			
Salt Creek (Seminole)	OK520800-03-0010D	Alkalinity	1	16	226.2	63.3	0.03	0.014	
			2	16	284.6	65.8			
			3	21	231.5	65.9			
			4	20	280.4	72.8			
		TKN	1	18	1.006	2.799	0.005		
			2	15	0.338	0.2119			
			3	20	0.535	0.2151			
			4	18	0.3561	0.1434			
		Ortho P	1	18	0.0441	0.07		0.07	
			2	15	0.0135	0.0089			
			3	20	0.0161	0.0142			
			4	18	0.0213	0.0177			
		Total P	1	18	0.1307	0.1501		0.002	
			2	15	0.0427	0.0517			
			3	20	0.0391	0.0302			
			4	19	0.0366	0.0261			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Salt Creek (Seminole) Cont.		TSS	1	18	149	371.5		0.094	
			2	15	10.667	2.093			
			3	20	17.15	12.44			
			4	18	22.61	27.99			
		TN	1	18	1.094	2.912	0.009		
			2	15	0.416	0.3245			
			3	20	0.566	0.2414			
			4	18	0.3839	0.1506			
Snake Creek (Tulsa)	OK120410-01-0220G	Conductivity	1	19	429.6	178.4	0.012	0.024	
			2	17	385.6	103.6			
			3	22	470.9	289.1			
			4	20	293.3	85.7			
		Hardness	1	19	123.54	39.29	0.039	0.016	
			2	17	162.5	47			
			3	22	174.8	89.4			
			4	19	128.21	35.19			
		pH	1	18	7.814	0.689		0.066	
			2	18	7.4556	0.2406			
			3	21	7.719	0.2937			
			4	19	7.6179	0.2881			
		Chloride	1	19	56.19	38.64	0.01	0.008	
			2	17	49.83	21.22			
			3	20	89.3	101.1			
			4	17	22.44	7.58			
		TDS	1	19	258.4	90.5	0.008	0.062	
			2	17	264.5	128.9			
			3	20	305.9	143.7			
			4	17	206.47	30.81			
		TKN	1	19	0.3084	0.2118		<0.001	
			2	17	0.3247	0.1489			
			3	20	0.7455	0.4137			
			4	17	0.7012	0.3251			
		Ortho P	1	19	0.0316	0.0206	0.062	0.011	
			2	17	0.0189	0.0095			
			3	20	0.0294	0.0292			
			4	17	0.0612	0.0671			
		Total P	1	19	0.124	0.0644		0.015	
			2	17	0.0532	0.0315			
			3	20	0.0838	0.0625			
			4	17	0.1119	0.1			
		Sulfate	1	19	30.95	25.47	0.027		
			2	17	33.84	13.18			
			3	20	36.35	24.48			
			4	17	22.21	6.27			
		TN	1	19	0.3842	0.2408		<0.001	
			2	17	0.3912	0.1306			
			3	20	0.834	0.551			
			4	17	0.8065	0.4003			
		Flow	1	18	13.11	17.22	0.005	0.001	
			2	17	14.78	13.83			
			3	21	4.44	8.92			
			4	18	59	83.2			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
South Fork Dirty Creek	OK120400-02-0030H	Alkalinity	1	19	88.32	35.34		0.01	
			2	17	142.9	53.8			
			3	19	131.37	38.21			
			4	17	121.1	67.9			
		DO % Saturation	1	19	53.28	19.58		0.013	
			2	17	65.05	18.33			
			3	19	65.52	22.01			
			4	17	75.48	18.43			
		Hardness	1	19	140.8	63		0.005	
			2	17	247.1	110.7			
			3	19	218.2	70			
			4	17	225.4	120			
		pH	1	18	7.7739	0.3423	0.005	<0.001	
			2	17	7.4412	0.3842			
			3	19	7.213	0.49			
			4	17	7.5965	0.2092			
		Chloride	1	19	6.311	1.099	0.001	<0.001	
			2	16	8.819	2.466			
			3	18	8.672	3.29			
			4	16	5.425	1.766			
		TDS	1	19	240.6	99.9		0.065	
			2	16	396.3	260.6			
			3	18	263.4	114			
			4	16	306.9	205.5			
		TKN	1	19	0.4053	0.306		<0.001	
			2	16	0.265	0.1521			
			3	18	0.58	0.1881			
			4	16	0.4931	0.1392			
		Total P	1	19	0.0784	0.0387		0.006	
			2	16	0.0465	0.0342			
			3	18	0.0514	0.0292			
			4	16	0.0441	0.0191			
		Sulfate	1	19	84.7	47.2		0.022	
			2	16	182.4	141.1			
			3	18	100.8	76.4			
			4	16	120.1	98.7			
		TSS	1	19	16.11	11.04		0.014	
			2	16	10.313	1.25			
			3	18	11.222	3.813			
			4	16	10.125	0.3416			
		Available N	1	19	0.1694	0.1265		0.093	
			2	16	0.0981	0.0974			
			3	18	0.1176	0.1484			
			4	16	0.0738	0.0561			
		TN	1	19	0.5363	0.3714	0.081	0.001	
			2	16	0.3213	0.1393			
			3	18	0.6861	0.248			
			4	16	0.5569	0.152			
		Flow	1	7	15.98	20.81	0.063	0.062	
			2	15	3.84	6.25			
			3	17	3.08	4.058			
			4	16	13	20.83			

Site Name	WBID	Variable	RB Cycle	N	Mean	Standard Deviations	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Sugar Loaf Creek	OK220100-01-0160G	Water Temp	3	13	18.78	9.13	0.09		
			4	6	25.65	2.061			
		Sulfate	3	12	10.092	2.601	0.054		
			4	5	7.32	2.153			
Turkey Creek	OK520510-00-0100F	Conductivity	3	18	2827	1189	0.036		
			4	21	2128	804			
		Chloride	3	17	880	501	0.013		
			4	18	528.5	252			
		TDS	3	17	1569	647	0.051		
			4	18	1185	465			
		TKN	3	17	0.7935	0.3087	0.003		
			4	18	0.4989	0.2248			
		Ortho P	3	17	0.0175	0.0125	0.018		
			4	18	0.0298	0.0166			
		Sulfate	3	17	32.06	12.22	0.034		
			4	18	24.99	5.82			
		TN	3	17	0.8182	0.3163	0.007		
			4	18	0.5417	0.2459			
Vian Creek	OK220200-02-0130E	DO % Saturation	3	19	68.86	17.09	<0.001		
			4	14	96.34	21.25			
		Hardness	3	19	160.58	34.26	0.077		
			4	14	136.9	39.7			
		Turbidity	3	21	4.24	4.94	0.087		
			4	17	2.097	0.955			
		Chloride	3	18	5.306	1.584	0.002		
			4	12	3.442	1.367			
		Sulfate	3	18	12.467	1.526	0.01		
			4	12	10.758	1.838			
Wewoka Creek	OK520500-02-0010C	Alkalinity	1	16	107	26.45		0.012	
			2	17	130.53	31.63			
			3	15	144.33	36.51			
			4	16	128.06	27.52			
		TKN	1	16	0.5768	0.2864	<0.001	0.001	
			2	16	0.78	0.401			
			3	14	1.0021	0.2739			
			4	14	0.5843	0.1344			
		Nitrate	1	16	0.1425	0.1563		0.076	
			2	16	0.1106	0.1489			
			3	14	0.6	1.174			
			4	14	0.1164	0.1411			
		Sulfate	1	16	22.88	6.52	0.061		
			2	16	22.76	7.7			
			3	14	28.33	12.46			
			4	14	21.18	5.59			
		TN	1	16	0.719	0.404		0.005	
			2	16	0.891	0.476			
			3	14	1.602	1.351			
			4	14	0.7007	0.207			
		Flow	1	16	20.32	18.85		0.038	
			2	16	39.1	47.8			
			3	11	17.39	10.07			
			4	12	83.6	118.2			

3.2 BIOLOGICAL MONITORING

3.2.1 Habitat Assessment

Total habitat scores for each site and computed metric scores are listed below (Table 11). Big Skin Bayou had the highest habitat score, while Snake Creek (Tulsa) had the lowest habitat score.

Table 11. Habitat assessment values for monitoring sites in the Rotating Basin Group 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas), Cycle 4. Each site is assigned a unique waterbody identifier (WBID). The total habitat score (Total Points) is calculated by aggregating the eleven metrics listed below for a maximum of 180 points.

Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Alabama Creek	OK520500-01-0200D	11.1	8.6	19.4	19.3	10.3	0	7.7	0.5	9.9	6	10	102.8
Ash Creek	OK120410-01-0110E	7.5	5.1	19.9	5.7	4.1	15.2	1.4	3.4	8.5	6	9.5	86.3
Bad Creek	OK520500-01-0170E	3.5	1.8	19.8	20	0	2.9	1	0.5	8.2	5.5	10	73.2
Ballard Creek	OK121700-03-0370G	17.1	15.4	20.1	18.5	15.9	18.2	0.4	-0.1	8.6	4.3	9.7	128.1
Battle Creek	OK121700-06-0040G	17.8	17	0	20	13.3	10.1	0.4	0.5	9.8	5.6	10	104.5
Bear Creek	OK520700-05-0170A	3.4	1.7	7.1	3.7	0	0	0.4	0.2	9.6	7.6	9.3	43
Big Creek	OK220100-02-0080B	19.5	18.7	19.4	13.1	10.3	0	16.5	0.5	10	7.2	9.9	125.1
Big Skin Bayou	OK220200-01-0030K	18.6	10.7	19.6	18.5	16.1	11.4	11.1	2.3	8.3	5	9.9	131.5
Bird Creek	OK520800-01-0050M	1.2	1.2	7.7	12.9	0	7.3	8.7	0.5	9.6	7.2	10	66.3
Black Fork of Poteau River	OK220100-02-0040P	19.4	15.7	16.1	19.1	5.9	0	7.7	1.9	10	8.1	9.9	113.8
Brazil Creek	OK220100-03-0010G	18.4	12.1	13.2	12.2	11.4	7.2	13.7	1.2	9.8	3.9	10	113.1
Brushy Creek	OK220600-03-0010L	5.1	6.8	13.5	10.8	4.1	8.8	5	7.5	5.8	3.1	7	77.5
Butler Creek	OK120400-02-0160P	4.5	5.2	1.3	20	0	0	8.7	2.9	3.9	4.8	9.2	60.5
Canadian Sandy Creek	OK520600-03-0010D	5.6	1.7	0	19	5.9	15.9	0.4	3.4	8.2	2.5	9.9	72.5
Captain Creek	OK520700-05-0140H	3	1.3	17.2	8.8	2.2	15	15.1	0.1	7.1	5.9	8.9	84.6
Caston Creek	OK220100-01-0180B	18.9	16.9	16.3	18.5	15.2	4.3	5.8	2	9.6	7.6	10	125.1
Cloud Creek	OK120410-01-0100T	3.8	5.1	17.6	19.4	2.2	1	0.4	0.5	8.9	7.1	9.6	75.6
Coal Creek	OK220600-02-0010F	15.2	13.3	17.8	15.9	12.4	11.7	6.7	1	7.1	3.4	8.8	113.3
Deep Branch	OK121700-01-0020A	17.2	12.6	8.3	12.9	0	0	16.5	3.8	10	8.4	10	99.7
Dry Creek	OK520700-04-0020F	2.3	2.8	0	19.4	0	16.2	3.5	0.6	6.4	3	6.6	60.8
Elk Creek (McIntosh)	OK120400-02-0190F	6.4	4.9	13.8	18.1	2.2	1.5	1.8	0.7	7.9	5.9	10	73.2
Elk Creek (Cherokee)	OK121700-02-0180G	18.4	15.2	9.9	19.3	11.4	1.7	0.4	4.5	10	7.2	9.9	107.9
Fourche Maline Creek	OK220100-04-0020H	9.6	8.4	18.5	15.2	9	6.2	2.8	1.8	7.2	3.5	9.3	91.5
Gaines Creek	OK220600-04-0010F	7.2	7	15.7	17.6	4.1	4.3	9.9	4.9	8.2	5.2	6.4	90.5

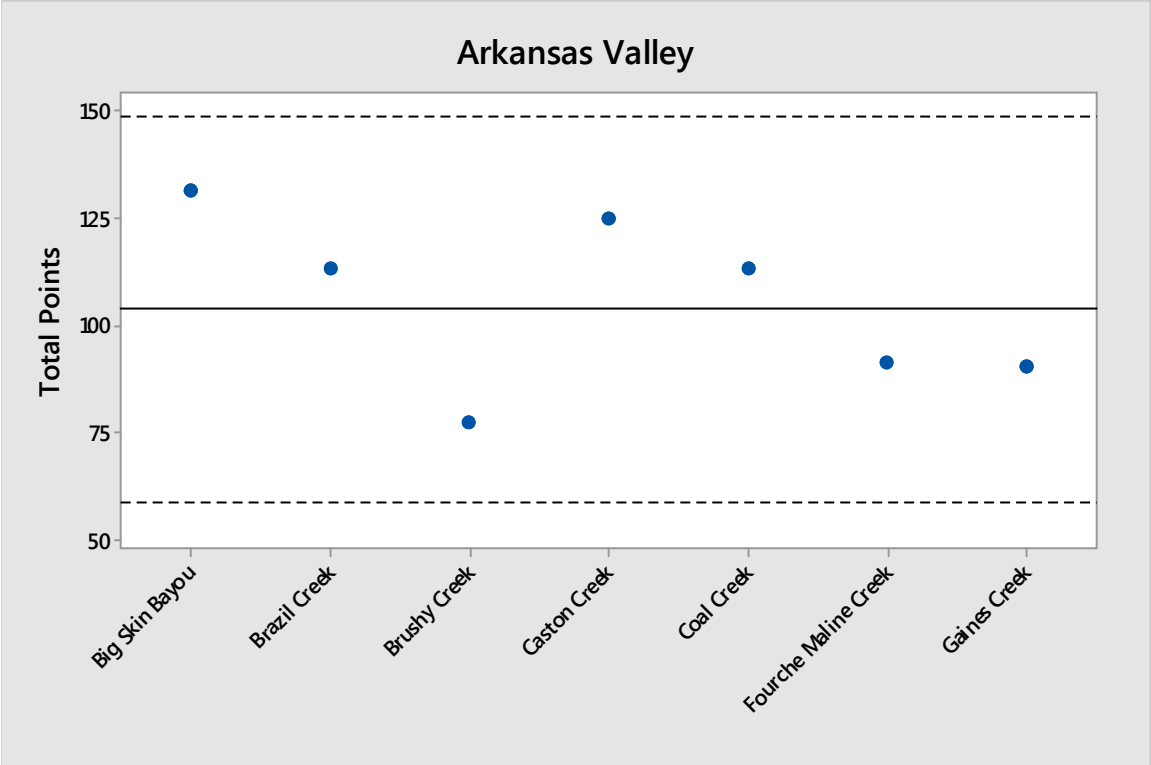
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Gar Creek	OK520510-00-0080C	6	3.2	6.8	17.9	7.5	3.2	2.3	2.4	9.5	4.8	10	73.6
Gentry Creek	OK520700-01-0080L	2.7	7.4	9.9	20	0	0	0.5	0.5	5.7	5	10	61.7
George's Fork of Dirty Creek	OK120400-02-0110D	5.6	4.6	13.6	18.3	0	0	5.8	0.3	7	4.7	10	69.9
Greenleaf Creek	OK120400-01-0120C	14.6	9.5	18.2	7.7	7.5	11.3	7.7	0.3	7.5	4.4	9.9	98.6
Hog Creek	OK520810-00-0030D	4	1	15.7	20	0	6.8	15.1	0.3	10	8.9	10	91.8
Holson Creek	OK220100-04-0030G	17.3	17.8	13.2	15.5	7.5	0	11.1	1.9	9.8	7.1	9.7	110.9
Little Deep Fork	OK520700-06-0010D	2.8	1.9	20.2	12.5	0	18.6	0.4	1.6	9.5	6.7	9.9	84.1
Little Wewoka Creek	OK520500-02-0090D	6	2.7	5.5	12.1	4.1	3.7	5.8	0.8	8.3	5.4	9.1	63.5
Longtown Creek	OK220600-01-0070P	10.5	12.8	10.5	13.1	5.9	0.5	0.4	3.4	8.7	6.7	10	82.5
Manard Bayou	OK120400-01-0280E	9.7	5.7	16.1	11.9	5.9	10.7	4.2	1.1	7.6	4.2	9.9	87
Mill Creek	OK220600-01-0100J	6.9	6	20.2	14.9	2.2	0.5	0.4	2.9	8.7	5.9	10	78.6
Montezumah Creek	OK520700-01-0220D	6.9	4.1	13.2	19.9	5.9	3.1	13.7	5.7	6.8	2.9	6.4	88.6
Nuyaka Creek	OK520700-02-0200D	3	1.9	13.4	19.8	0	0.5	15.1	0.1	6.6	5.5	6.4	72.3
Opossum Creek	OK520700-05-0200C	2.5	2.7	18.8	19.3	0	6.2	11.1	0.4	5.1	4.5	9.7	80.3
Peaceable Creek	OK220600-03-0050F	9.6	6.2	13.2	16.2	9	17.1	5.8	2	7.1	4.2	8.8	99.2
Peacheater Creek	OK121700-05-0120B	16.5	17.8	6.1	12	16.2	12.4	0.4	1.8	6.9	2.6	2.6	95.3
Peavine Creek	OK121700-05-0190F	18.3	14.8	7.7	9.5	15.9	15.2	0.4	0.7	7.5	4.4	8.7	103.1
Pecan Creek (Muskogee)	OK120410-01-0030D	8.1	4.3	16.3	13.1	0	7.5	5.8	2.7	6.7	3.9	9.7	78.1
Pecan Creek (Pottawatomie)	OK520800-02-0080C	1.9	0.9	0	8.1	7.5	10.9	0.4	0.4	8	5.6	10	53.7
Polecat Creek	OK120420-02-0050B	7.1	2	1.3	10.9	2.2	5	0.7	0	7.5	5.4	9.7	51.8
Pumpkin Hollow Creek	OK121700-03-0090G	2.8	11.7	13	2.7	0	0	0.4	2	2.6	3	5	43.2
Quapaw Creek	OK520700-04-0260C	3.6	4.3	17.2	11.4	0	16.6	0.4	0.3	10	7.9	10	81.7
Sallisaw Creek	OK220200-03-0010C	17.8	12.3	18.2	9.9	9	11.3	2.8	1.2	9.3	4.8	3.4	100
Salt Creek (Creek)	OK520700-03-0100B	3	1	9.9	18.4	0	12.7	0.4	0.1	8.4	5.5	9.9	69.3
Salt Creek (Seminole)	OK520800-03-0010D	4.8	4.3	0	5.7	4.1	15.4	0.4	1.1	7.8	2.4	9.9	55.9
San Bois Creek	OK220200-04-0010G	13.5	9	13.3	16	12.4	10.2	15.1	0.6	8.7	4.6	10	113.4
Shady Grove Creek	OK120400-02-0240H	4.7	3.1	14	17.4	0	0.5	1.4	4.4	7.2	4.6	8.9	66.2
Snake Creek (Tulsa)	OK120410-01-0220G	5.2	3.5	0	6.4	0	1	0.4	2.1	7.2	5.5	10	41.3
Snake Creek (Sequoyah)	OK121700-02-0100G	14.8	12.9	5	20	12.4	3.2	11.1	2.4	10	8.2	9.7	109.7
South Fork Dirty Creek	OK120400-02-0030H	4.9	7.9	15.7	19.6	4.1	0.5	5	3	6.5	5.1	6.4	78.7
Steely Hollow Creek	OK121700-03-0120G	15.4	16.3	6.1	19.9	15.2	6.7	0.4	1.5	10	8	10	109.5

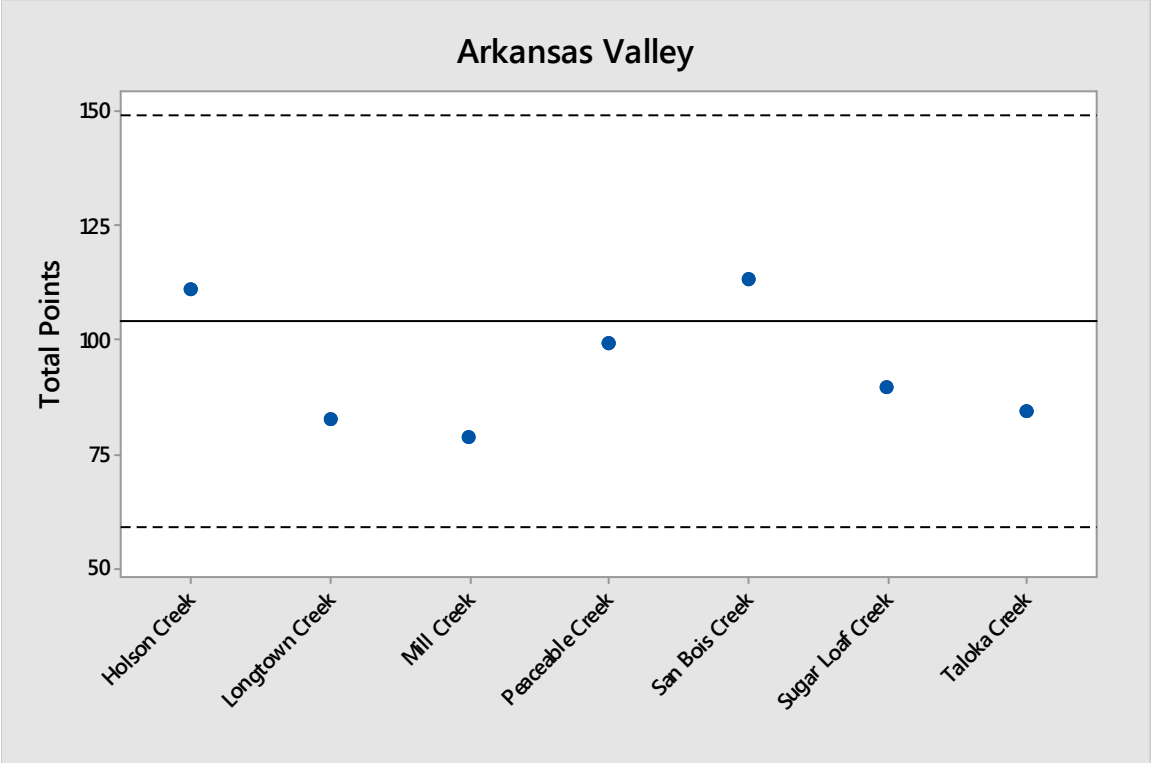
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Sugar Loaf Creek	OK220100-01-0160G	9.7	8.7	19.6	17.3	5.9	0	0.7	2.1	8.6	6.9	10	89.5
Taloka Creek	OK220300-00-0020M	1.9	3.7	13.4	14.8	0	12	13.7	2.9	8.2	3.9	10	84.5
Telemay Hollow Creek	OK121700-03-0140G	15	11.2	0	19.8	12.4	0	1.4	0.8	8.8	6.7	9.7	85.8
Turkey Creek	OK520510-00-0100F	1.4	4.3	19.3	17.2	4.1	8.8	0.4	1.3	8.8	4.3	9.5	79.4
Tyner Creek	OK121700-05-0090J	18.5	18.2	20.2	10.9	16.3	15	0.4	1.4	8.7	5.2	9.2	124
Vian Creek	OK220200-02-0130E	19	16.4	19.1	17.4	12.4	2	1.8	2	9.9	5.1	10	115.1
Wewoka Creek	OK520500-02-0010C	3.9	1.2	19.9	2.1	4.1	15.7	4.2	4.2	7.3	3.4	10	76

Sites were compared relative to the mean total habitat score of high quality sites in the respective ecoregion and a range determined by +/- two standard deviations (Figure 4). Sites with scores that are within +/- two standard deviations of the mean of the high quality sites do not necessarily have "reference" conditions; rather, sites outside of these values have either extremely good or extremely poor conditions which merit further investigation. Low habitat scores could be the result of anthropogenic activities, could be naturally occurring, or could indicate an unrepresentative reach.

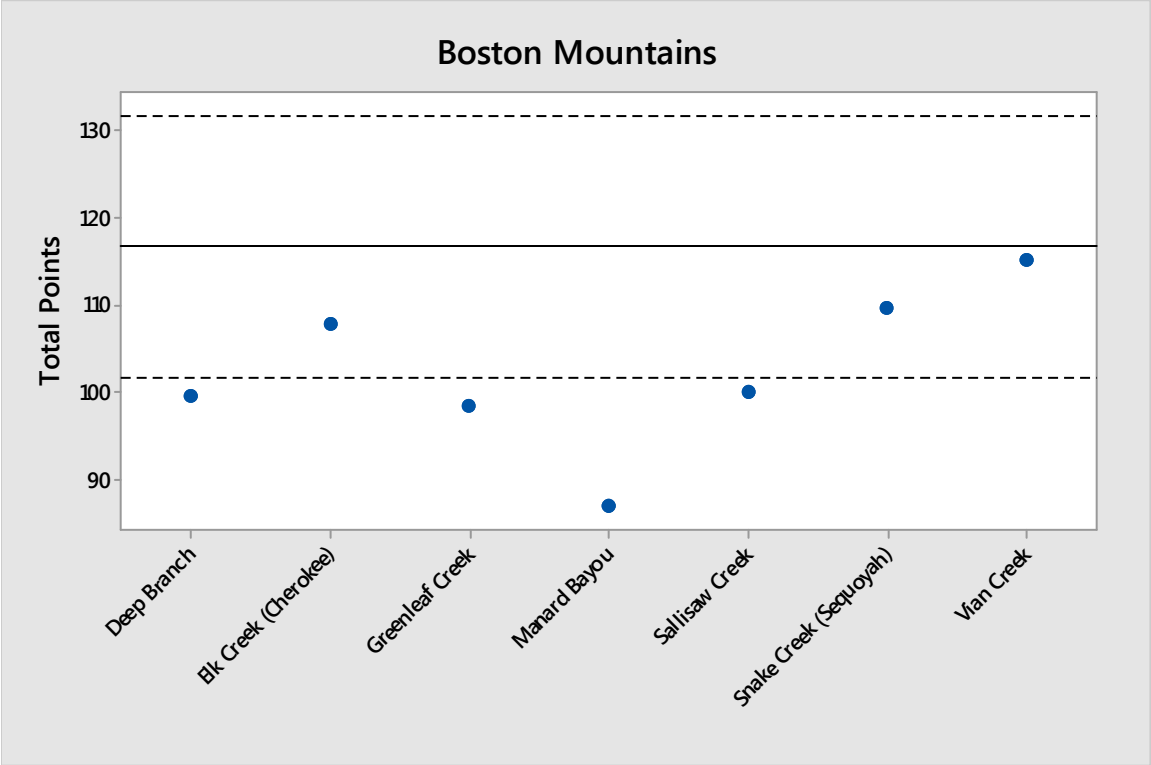
In the Boston Mountains: Deep Branch, Greenleaf Creek, Manard Bayou, and Sallisaw creek habitat scores fell below two standard deviations for high quality sites. In the Cross Timbers: Bear Creek, Polecat Creek, and Snake Creek (Tulsa) had lower habitat scores than the high quality sites. Pumpkin Hollow Creek and Telemay Hollow in the Ozark Highlands had a lower habitat score than the high quality sites in that ecoregion.

(a)

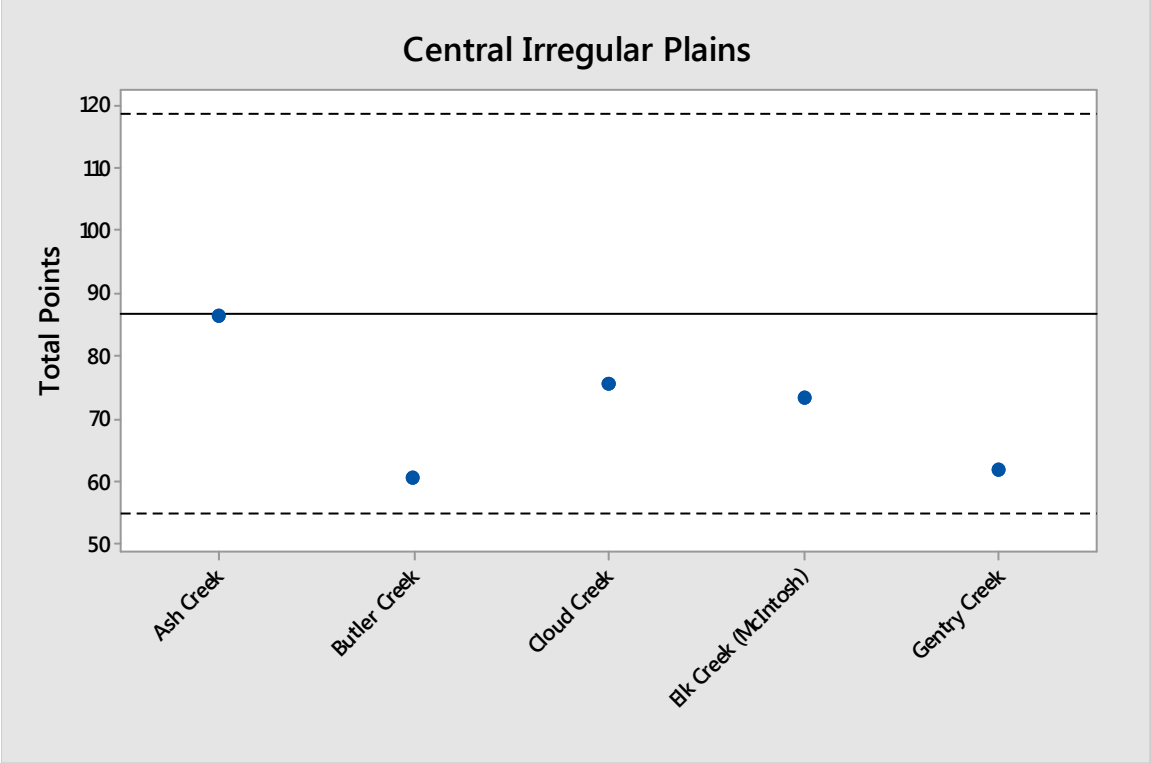

Arkansas Valley
Total Points
150
125
100
75
50
Big Skin Bayou
Brazil Creek
Brushy Creek
Caston Creek
Coal Creek
Fourche Maline Creek
Gaines Creek

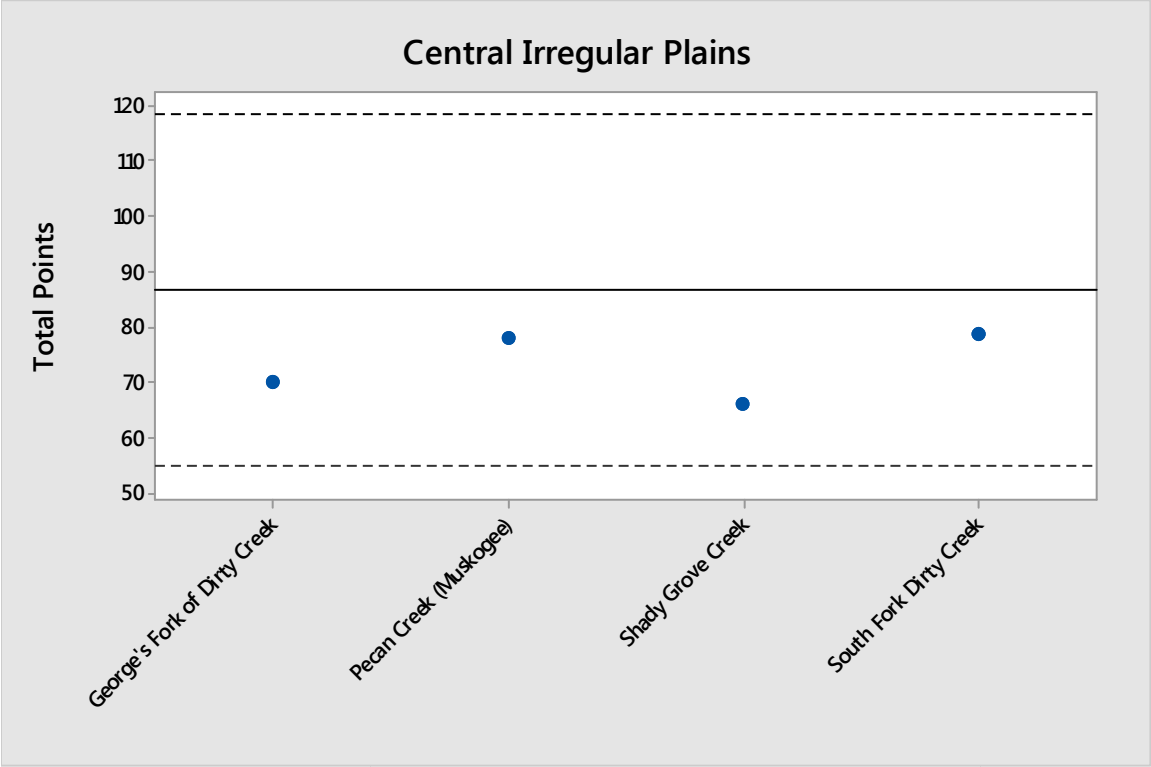

Arkansas Valley
Total Points
150
125
100
75
50
Holson Creek
Longtown Creek
Mill Creek
Peaceable Creek
San Bois Creek
Sugar Loaf Creek
Taloka Creek

(b)

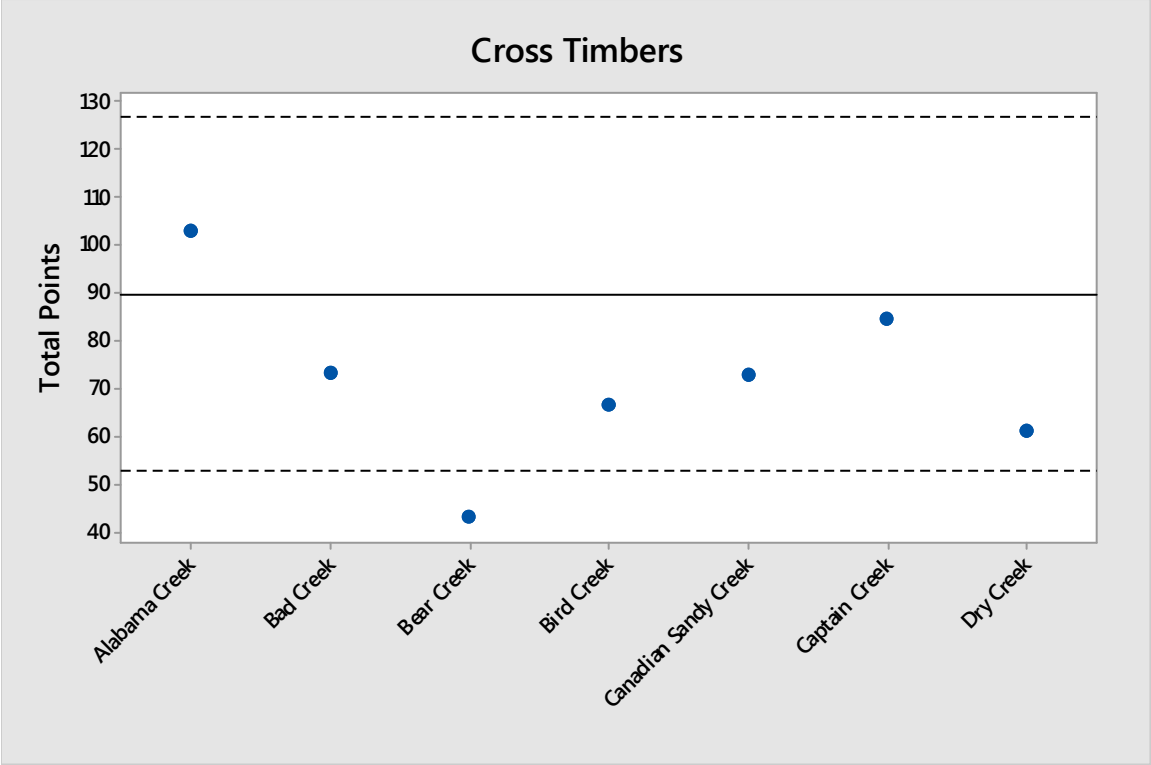

Boston Mountains
Total Points
130
120
110
100
90
Deep Branch
Elk Creek (Cherokee)
Greenleaf Creek
Manard Bayou
Sallisaw Creek
Snake Creek (Sequoyah)
Vian Creek

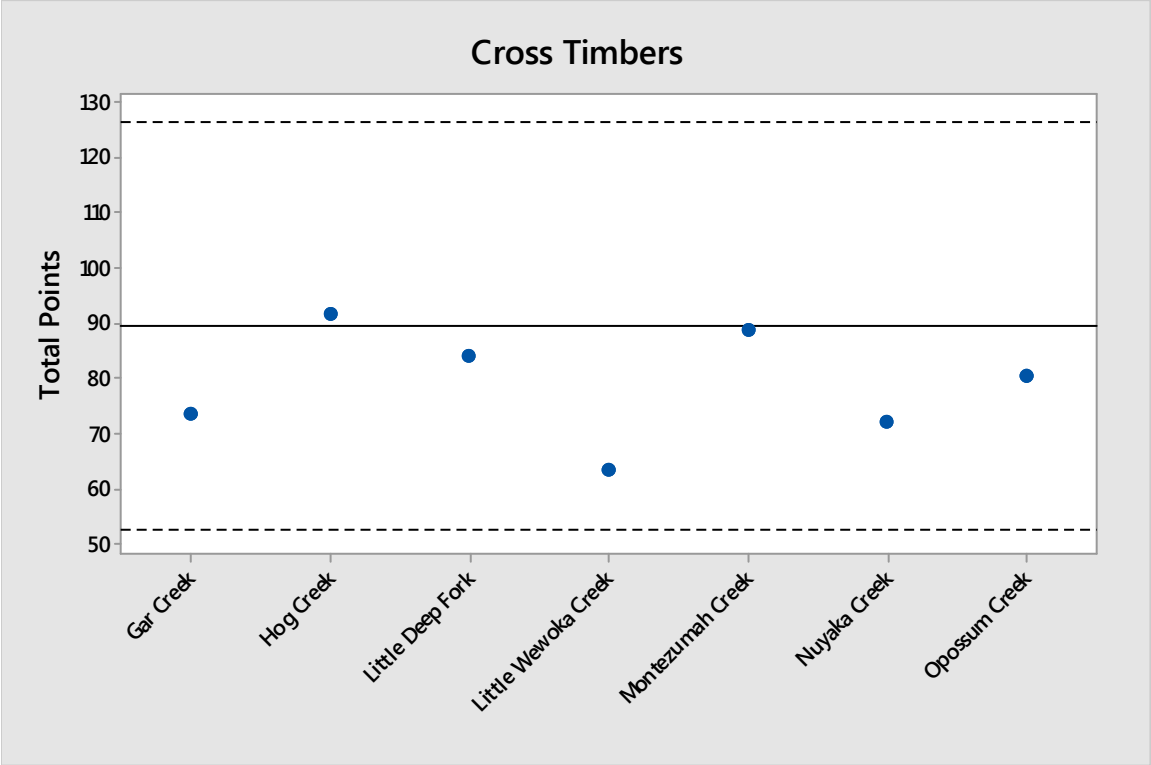
(c)

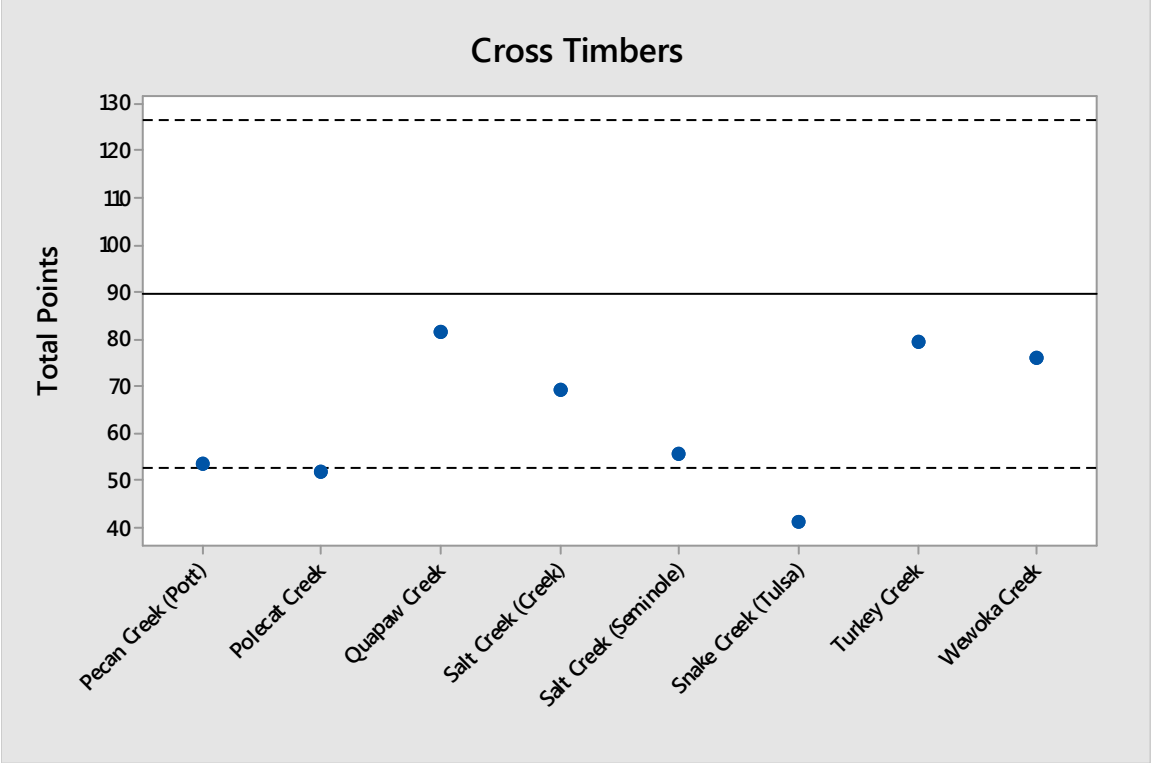

Central Irregular Plains
Total Points
120
110
100
90
80
70
60
50
Ash Creek
Butler Creek
Cloud Creek
Elk Creek (McIntosh)
Gentry Creek


Central Irregular Plains
Total Points
120
110
100
90
80
70
60
50
George's Fork of Dirty Creek
Pecan Creek (Muskogee)
Shady Grove Creek
South Fork Dirty Creek

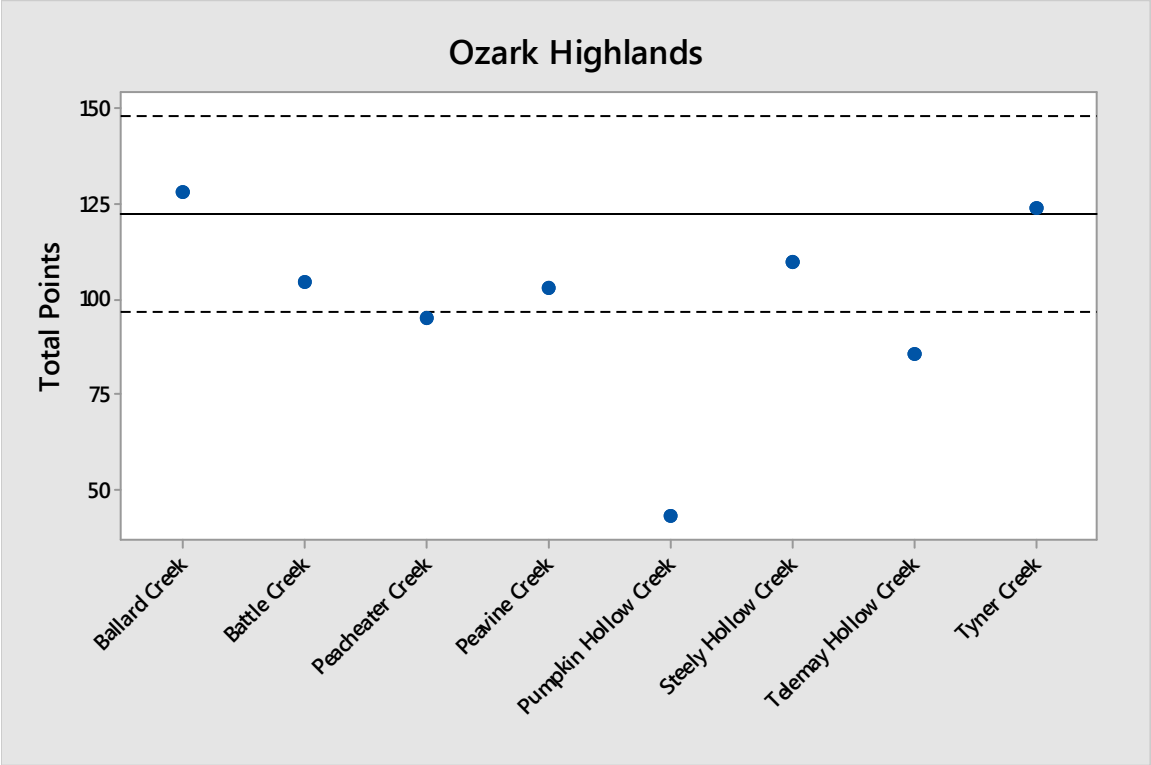
(d)


Cross Timbers
Total Points
130
120
110
100
90
80
70
60
50
40
Alabama Creek
Bad Creek
Bear Creek
Bird Creek
Canadian Sandy Creek
Captain Creek
Dry Creek


Cross Timbers
Total Points
130
120
110
100
90
80
70
60
50
Gar Creek
Hog Creek
Little Deep Fork
Little Wewoka Creek
Montezumah Creek
Nuyaka Creek
Opossum Creek


Cross Timbers
Total Points
130
120
110
100
90
80
70
60
50
40
Pecan Creek (Pott)
Polecat Creek
Quapaw Creek
Salt Creek (Creek)
Salt Creek (Seminole)
Snake Creek (Tulsa)
Turkey Creek
Wewoka Creek

(e)


Ozark Highlands
Total Points
150
125
100
75
50
Ballard Creek
Battle Creek
Peacheater Creek
Peavine Creek
Pumpkin Hollow Creek
Steely Hollow Creek
Tedmay Hollow Creek
Tyner Creek

(f)

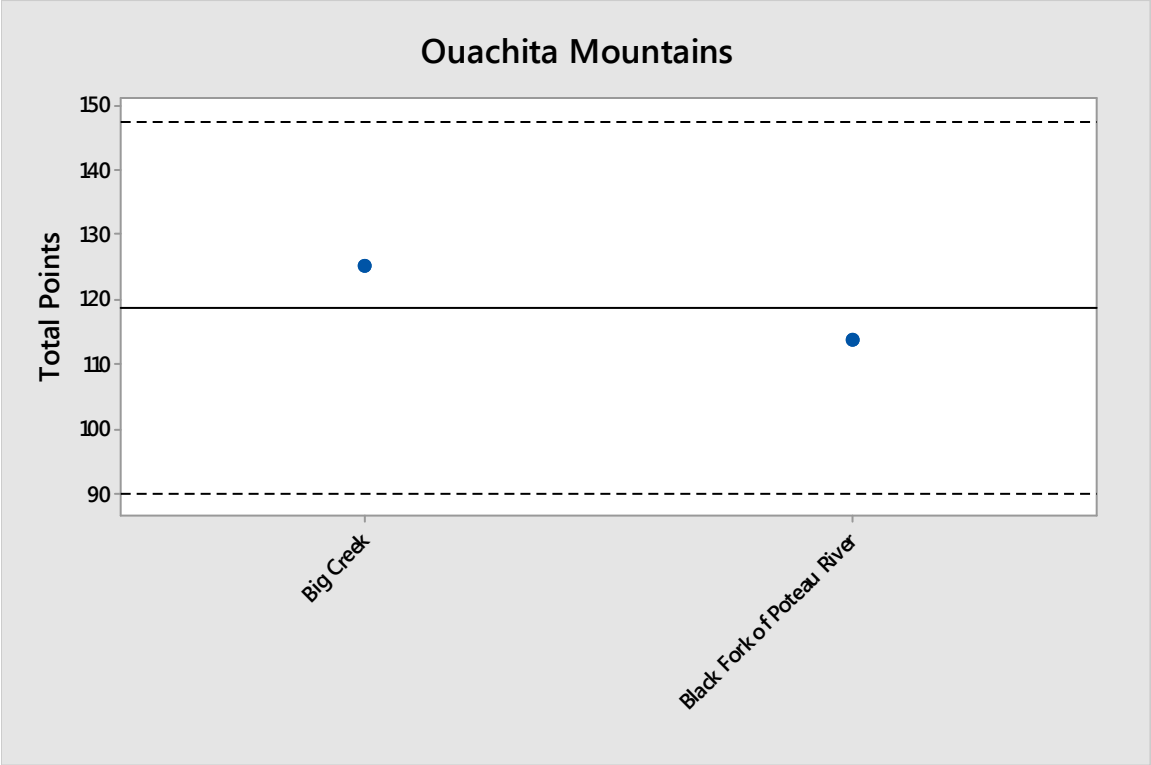


Figure 4. Total habitat score for sites monitored in Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) during 2018-2020 for (a) Arkansas Valley, (b) Boston Mountains, (c) Central Irregular Plains, (d) Cross Timbers, (e) Ozark Highlands, and (f) Ouachita Mountains Ecoregions. Habitat scores aggregate 11 different measures of habitat conditions with a maximum score of 180. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

3.2.2 Fish Collections

Fish metrics used to compute IBI scores for the Rotating Basin sites using the OCC method are listed in Table 12. Use of this IBI method allows assessment of streams which lack definite support assignment using the state biocriteria method. For a complete listing of fish collection data, including species and numbers caught, consult Appendix B. All data were compared to the mean of the high quality sites for the respective ecoregion in order to obtain the IBI score (OCC method).

Table 12. Metric values for calculations of fish IBI scores (OCC method) for Rotating Basin Group 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins), cycle 4 monitoring sites collected between 2018 and 2019. Each site is assigned a unique waterbody identifier (WBID).

Site Name	WBID	Total Number	Total Spp	Sensitive Benthic Species	Sunfish Spp	Intolerant Spp	Percent tolerant	percent insectivorous Cyprinid	Percent lithophyiic spawners
Alabama Creek	OK520500-01-0200D	242	22	5	8	3	0.77	0.04	0.11
Ash Creek	OK120410-01-0110E	1158	24	5	10	3	0.66	0.00	0.25
Bad Creek	OK520500-01-0170E	930	29	5	9	4	0.64	0.02	0.15
Ballard Creek	OK121700-03-0370G	723	20	7	6	11	0.16	0.19	0.84
Battle Creek	OK121700-06-0040G	353	18	6	4	11	0.02	0.24	0.98
Bear Creek	OK520700-05-0170A	1827	13	0	5	0	1.00	0.00	0.00
Big Creek	OK220100-02-0080B	1032	24	10	6	10	0.29	0.05	0.66
Big Skin Bayou	OK220200-01-0030K	473	20	7	6	5	0.22	0.17	0.42
Bird Creek	OK520800-01-0050M	312	12	1	7	0	0.86	0.00	0.02
Black Fork of Poteau River	OK220100-02-0040P	549	32	13	8	12	0.47	0.08	0.28
Brazil Creek	OK220100-03-0010G	337	28	8	7	10	0.33	0.11	0.40
Brushy Creek	OK220600-03-0010L	265	21	6	6	2	0.41	0.02	0.32
Butler Creek	OK120400-02-0160P	312	18	1	8	0	0.86	0.00	0.08
Canadian Sandy Creek	OK520600-03-0010D	493	21	3	8	1	0.79	0.14	0.06
Captain Creek	OK520700-05-0140H	2222	17	2	6	2	0.93	0.03	0.04
Caston Creek	OK220100-01-0180B	565	31	8	9	6	0.49	0.06	0.38
Cloud Creek	OK120410-01-0100T	726	31	7	6	6	0.65	0.10	0.13
Coal Creek	OK220600-02-0010F	677	34	6	8	3	0.40	0.02	0.38
Deep Branch	OK121700-01-0020A	192	14	3	7	1	0.56	0.00	0.32
Dry Creek	OK520700-04-0020F	760	18	3	7	3	0.95	0.03	0.01
Elk Creek (Cherokee Co)	OK121700-02-0180G	682	19	6	5	7	0.26	0.10	0.58
Elk Creek (McIntosh Co)	OK120400-02-0190F	618	23	5	9	3	0.74	0.02	0.05
Fourche Maline Creek	OK220100-04-0020H	1072	48	17	7	16	0.34	0.27	0.50
Gaines Creek	OK220600-04-0010F	286	21	5	6	4	0.33	0.02	0.38
Gar Creek	OK520510-00-0080C	778	21	4	8	2	0.69	0.06	0.16
Gentry Creek	OK520700-01-0080L	750	16	3	9	2	0.76	0.00	0.15
George's Fork of Dirty Creek	OK120400-02-0110D	531	29	4	9	3	0.74	0.00	0.05
Greenleaf Creek	OK120400-01-0120C	1485	25	8	7	9	0.25	0.26	0.63
Hog Creek	OK520810-00-0030D	526	14	1	6	1	1.00	0.00	0.00

Site Name	WBID	Total Number	Total Spp	Sensitive Benthic Species	Sunfish Spp	Intolerant Spp	Percent tolerant	percent insectivorous Cyprinid	Percent lithophyiic spawners
Holson Creek	OK220100-04-0030G	369	35	10	9	9	0.27	0.12	0.48
Little Deep Fork	OK520700-06-0010D	911	16	3	6	2	0.99	0.01	0.00
Little Wewoka Creek	OK520500-02-0090D	542	17	3	6	2	0.86	0.00	0.12
Longtown Creek	OK220600-01-0070P	1308	21	4	7	2	0.37	0.05	0.45
Manard Bayou	OK120400-01-0280E	2561	25	7	7	7	0.21	0.25	0.75
Mill Creek	OK220600-01-0100J	477	27	4	10	3	0.61	0.01	0.26
Montezumah Creek	OK520700-01-0220D	369	22	5	10	3	0.60	0.01	0.33
Nuyaka Creek	OK520700-02-0200D	303	23	2	8	1	0.87	0.03	0.04
Opossum Creek	OK520700-05-0200C	906	15	1	6	1	0.89	0.11	0.00
Peaceable Creek	OK220600-03-0050F	345	23	5	7	3	0.47	0.03	0.27
Peacheater Creek	OK121700-05-0120B	933	20	8	5	12	0.06	0.23	0.93
Peavine Creek	OK121700-05-0190F	899	21	7	7	10	0.13	0.23	0.87
Pecan Creek (Muskogee)	OK120410-01-0030D	558	21	5	5	3	0.77	0.09	0.12
Pecan Creek (Pottawatomie)	OK520800-02-0080C	364	13	1	4	1	0.77	0.23	0.00
Polecat Creek	OK120420-02-0050B	769	26	5	9	4	0.87	0.08	0.03
Pumpkin Hollow Creek	OK121700-03-0090G	917	20	7	3	12	0.04	0.10	0.95
Quapaw Creek	OK520700-04-0260C	1040	23	1	7	1	0.90	0.10	0.00
Sallisaw Creek	OK220200-03-0010C	1339	33	13	10	16	0.45	0.10	0.47
Salt Creek (Creek)	OK520700-03-0100B	968	18	3	9	2	0.84	0.10	0.04
Salt Creek (Seminole)	OK520800-03-0010D	530	15	2	5	1	0.91	0.09	0.00
San Bois Creek	OK220200-04-0010G	550	29	7	8	8	0.57	0.03	0.27
Shady Grove Creek	OK120400-02-0240H	88	12	1	6	1	0.94	0.01	0.01
Snake Creek (Sequoyah)	OK121700-02-0100G	221	11	4	4	4	0.16	0.32	0.68
Snake Creek (Tulsa)	OK120410-01-0220G	749	27	5	9	3	0.72	0.02	0.17
South Fork Dirty Creek	OK120400-02-0030H	1257	24	6	9	4	0.44	0.00	0.31
Steely Hollow Creek	OK121700-03-0120G	868	20	6	4	13	0.03	0.07	0.97
Sugar Loaf Creek	OK220100-01-0160G	595	38	10	8	9	0.42	0.07	0.40
Taloka Creek	OK220300-00-0020M	520	26	4	8	3	0.64	0.00	0.19
Telemay Hollow Creek	OK121700-03-0140G	366	8	3	1	3	0.01	0.00	0.99
Turkey Creek	OK520510-00-0100F	414	13	1	7	1	0.93	0.00	0.00
Tyner Creek	OK121700-05-0090J	1415	18	8	4	12	0.02	0.19	0.98
Vian Creek	OK220200-02-0130E	688	17	7	4	8	0.26	0.23	0.73
Wewoka Creek	OK520500-02-0010C	563	26	3	8	2	0.85	0.12	0.02

Table 13 presents the results of the fish assessment based on the OCC's modified RBP method compared with the fish assessment based on Oklahoma state biocriteria (as described in Oklahoma Water Resource Board, *Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (USAP), OAC 785:46-15). The state biocriteria are based on older delineations of the level III ecoregions, so there were some differences in scoring based on the differences in grouping of sites. The OCC method allowed greater discrimination of the biological condition among sites. Of the 62 sites, 33 were "excellent" when compared with high quality sites with the same FWP use in the ecoregion, 11 were "good", 11 were "fair", and seven were "poor".

Table 13. IBI scores for fish communities at sites in Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) during 2018-2020. Each site is given a unique waterbody Identifier (WBID). The designation of the streams for the Fish and Wildlife Propagation beneficial use include: WWAC = warm water aquatic community, HLAC = habitat limited aquatic community, and CWAC = cool water aquatic community. Results are based on Use Support Assessment Protocol (USAP) biocriteria (OWRB 2016) and OCC's modified RBP method (OCC). The use determinations based on fish community (USAP Fish) are as follows: S = supporting, N = not supporting, U = undetermined. For OCC's modified method the value of the IBI score relative to reference is provided (% of reference) as well as a condition category of the community (Score Interpretation).

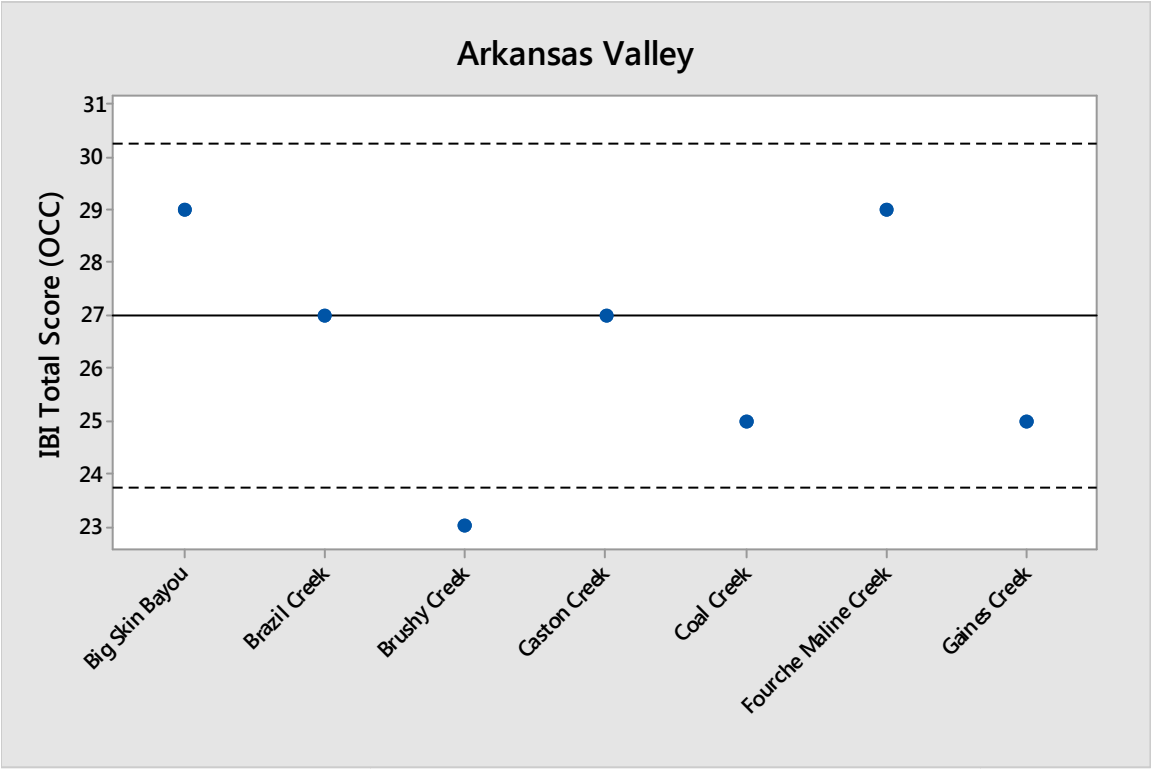
Modified Ecoregion	Site Name	WBID	FWProp	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
AV	Big Skin Bayou	OK220200-01-0030K	WWAC	37	S	29	1.1	Excellent
AV	Brazil Creek	OK220100-03-0010G	WWAC	43	S	27	1	Excellent
AV	Brushy Creek	OK220600-03-0010L	WWAC	33	U	23	0.9	Good
AV	Caston Creek	OK220100-01-0180B	WWAC	41	S	27	1	Excellent
AV	Coal Creek	OK220600-02-0010F	WWAC	39	S	25	0.9	Excellent
AV	Fourche Maline Creek	OK220100-04-0020H	WWAC	43	S	29	1.1	Excellent
AV	Gaines Creek	OK220600-04-0010F	WWAC	39	S	25	0.9	Excellent
AV	Holson Creek	OK220100-04-0030G	WWAC	43	S	27	1	Excellent
AV	Longtown Creek	OK220600-01-0070P	WWAC	35	S	23	0.9	Good
AV	Mill Creek	OK220600-01-0100J	WWAC	33	U	21	0.8	Fair
AV	Peaceable Creek	OK220600-03-0050F	WWAC	35	S	21	0.8	Fair
AV	San Bois Creek	OK220200-04-0010G	WWAC	39	S	25	0.9	Excellent
AV	Sugar Loaf Creek	OK220100-01-0160G	WWAC	43	S	27	1	Excellent
AV	Taloka Creek	OK220300-00-0020M	WWAC	33	U	21	0.8	Fair
BM	Sallisaw Creek	OK220200-03-0010C	CWAC	39	S	27	0.8	Good
BM	Vian Creek	OK220200-02-0130E	CWAC	39	S	27	0.8	Good
BM	Deep Branch	OK121700-01-0020A	WWAC	29	U	17	0.5	Poor

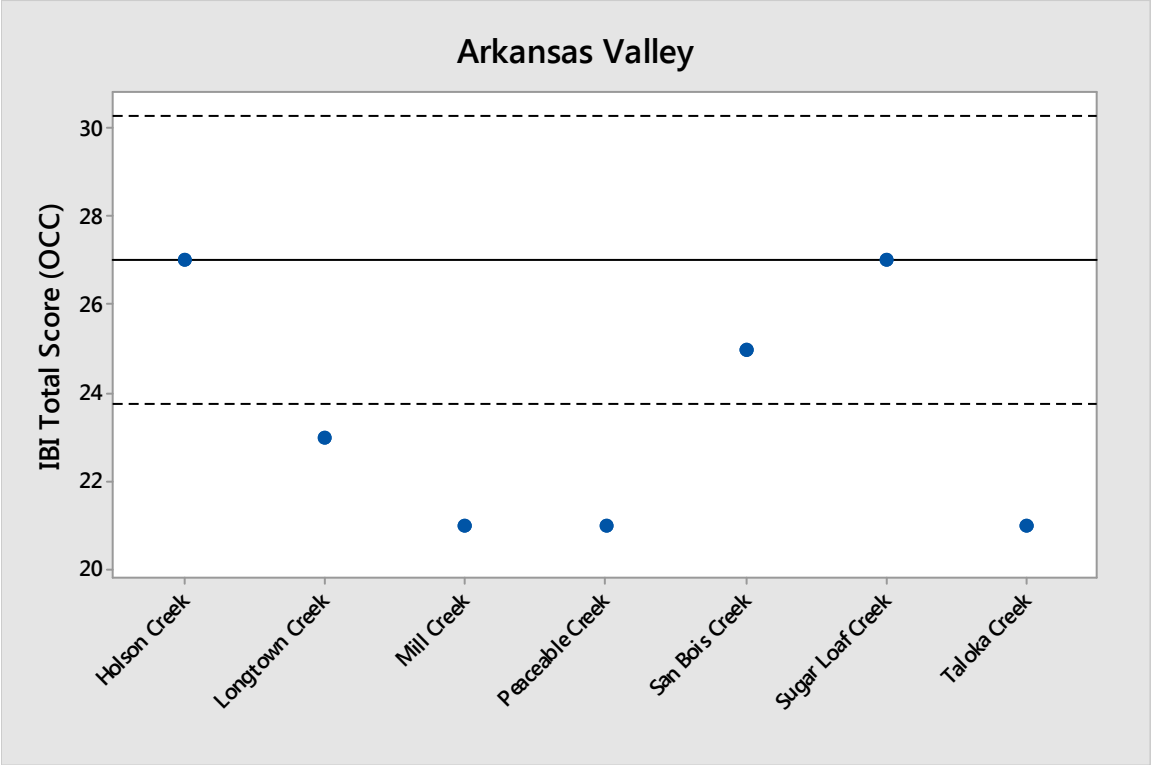
Modified Ecoregion	Site Name	WBID	FWProp	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
BM	Elk Creek (Cherokee)	OK121700-02-0180G	WWAC	41	S	27	0.9	Good
BM	Greenleaf Creek	OK120400-01-0120C	WWAC	45	S	29	0.9	Excellent
BM	Manard Bayou	OK120400-01-0280E	WWAC	43	S	31	1	Excellent
BM	Snake Creek (Sequoyah)	OK121700-02-0100G	WWAC	39	S	23	0.7	Fair
CIP	Ash Creek	OK120410-01-0110E	WWAC	35	S	25	1	Excellent
CIP	Butler Creek	OK120400-02-0160P	WWAC	27	U	15	0.6	Poor
CIP	Cloud Creek	OK120410-01-0100T	WWAC	37	S	23	0.9	Excellent
CIP	Elk Creek (McIntosh)	OK120400-02-0190F	WWAC	31	S	23	0.9	Excellent
CIP	Gentry Creek	OK520700-01-0080L	WWAC	29	U	19	0.8	Fair
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	WWAC	31	S	21	0.8	Good
CIP	Pecan Creek (Muskogee)	OK120410-01-0030D	WWAC	31	S	23	0.9	Excellent
CIP	Shady Grove Creek	OK120400-02-0240H	WWAC	25	U	15	0.6	Poor
CIP	South Fork Dirty Creek	OK120400-02-0030H	WWAC	35	S	25	1	Excellent
CT	Alabama Creek	OK520500-01-0200D	WWAC	33	S	23	1	Excellent
CT	Bad Creek	OK520500-01-0170E	WWAC	35	S	23	0.9	Excellent
CT	Bear Creek	OK520700-05-0170A	WWAC	23	U	13	0.5	Poor
CT	Bird Creek	OK520800-01-0050M	HLAC	27	S	13	0.5	Poor
CT	Canadian Sandy Creek	OK520600-03-0010D	WWAC	29	S	21	0.8	Good
CT	Captain Creek	OK520700-05-0140H	WWAC	25	U	21	0.8	Good
CT	Dry Creek	OK520700-04-0020F	WWAC	25	U	23	0.9	Excellent
CT	Gar Creek	OK520510-00-0080C	WWAC	31	S	23	0.9	Excellent
CT	Hog Creek	OK520810-00-0030D	WWAC	25	U	17	0.7	Fair
CT	Little Deep Fork	OK520700-06-0010D	WWAC	23	U	23	0.9	Excellent
CT	Little Wewoka Creek	OK520500-02-0090D	WWAC	27	S	23	0.9	Excellent
CT	Montezumah Creek	OK520700-01-0220D	WWAC	33	S	25	1	Excellent
CT	Nuyaka Creek	OK520700-02-0200D	WWAC	29	S	19	0.8	Fair
CT	Opossum Creek	OK520700-05-0200C	WWAC	25	U	17	0.7	Fair
CT	Pecan Creek (Pottawatomie)	OK520800-02-0080C	WWAC	27	S	15	0.6	Poor
CT	Polecat Creek	OK120420-02-0050B	WWAC	29	S	23	0.9	Excellent
CT	Quapaw Creek	OK520700-04-0260C	WWAC	27	S	17	0.7	Fair
CT	Salt Creek (Creek)	OK520700-03-0100B	WWAC	27	S	23	0.9	Excellent
CT	Salt Creek (Seminole)	OK520800-03-0010D	WWAC	23	U	19	0.8	Fair
CT	Snake Creek (Tulsa)	OK120410-01-0220G	WWAC	35	S	23	0.9	Excellent

Modified Ecoregion	Site Name	WBID	FWProp	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CT	Turkey Creek	OK520510-00-0100F	WWAC	27	S	15	0.6	Poor
CT	Wewoka Creek	OK520500-02-0010C	WWAC	29	S	23	0.9	Excellent
OH	Ballard Creek	OK121700-03-0370G	CWAC	41	S	29	0.8	Good
OH	Battle Creek	OK121700-06-0040G	CWAC	41	S	33	0.9	Excellent
OH	Peacheater Creek	OK121700-05-0120B	CWAC	41	S	33	0.9	Excellent
OH	Peavine Creek	OK121700-05-0190F	CWAC	43	S	31	0.9	Good
OH	Tyner Creek	OK121700-05-0090J	CWAC	39	S	31	0.9	Good
OH	Pumpkin Hollow Creek	OK121700-03-0090G	WWAC	39	S	31	0.9	Excellent
OH	Steely Hollow Creek	OK121700-03-0120G	WWAC	41	S	31	0.9	Excellent
OH	Telemay Hollow Creek	OK121700-03-0140G	WWAC	29	U	21	0.6	Fair
OM	Big Creek	OK220100-02-0080B	CWAC	37	No criteria	27	1	Excellent
OM	Black Fork of Poteau River	OK220100-02-0040P	WWAC	39	S	25	1	Excellent

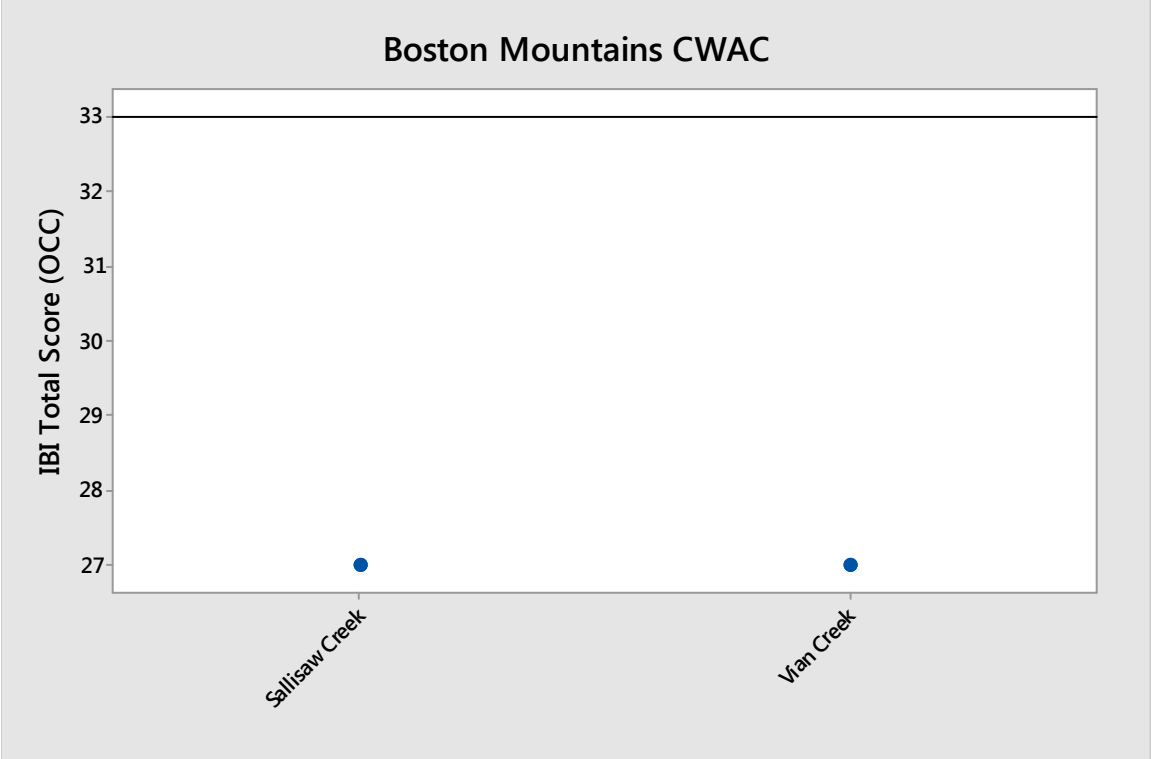
Figure 5 shows the IBI score (OCC Method) for each monitoring site (indicated by a blue dot) relative to the mean value for the high quality sites in that ecoregion (indicated by a solid line).

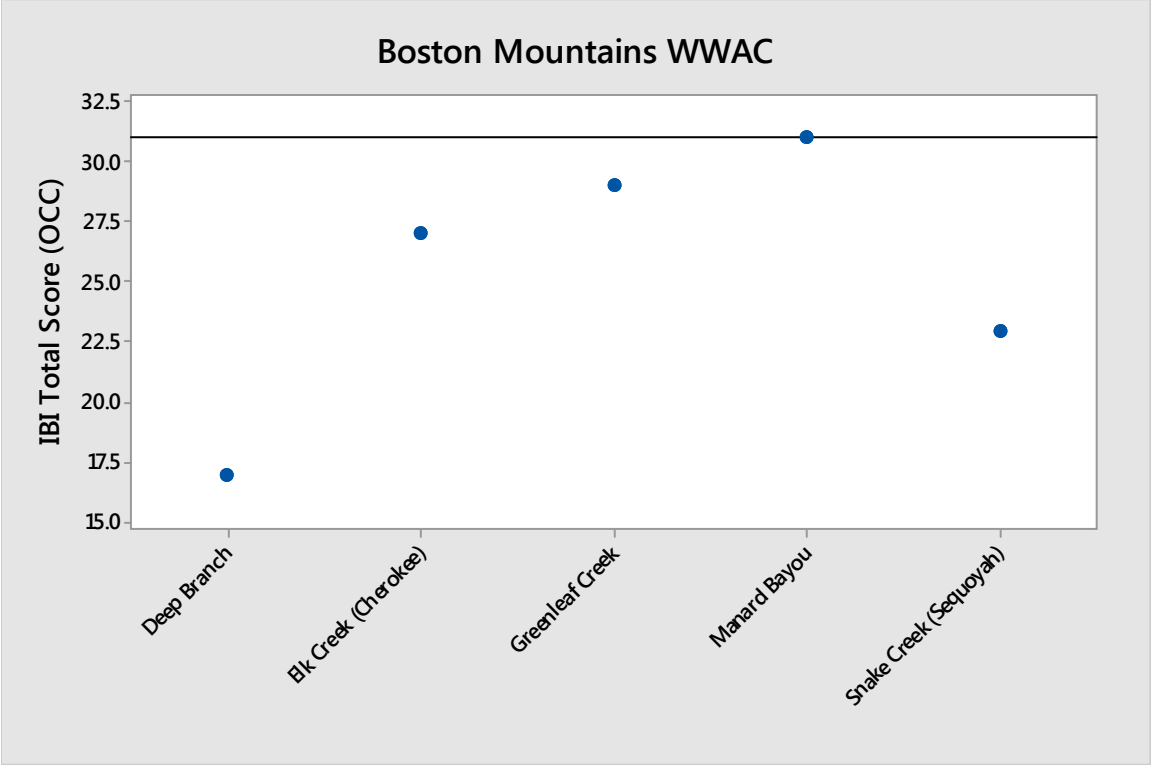
(a)



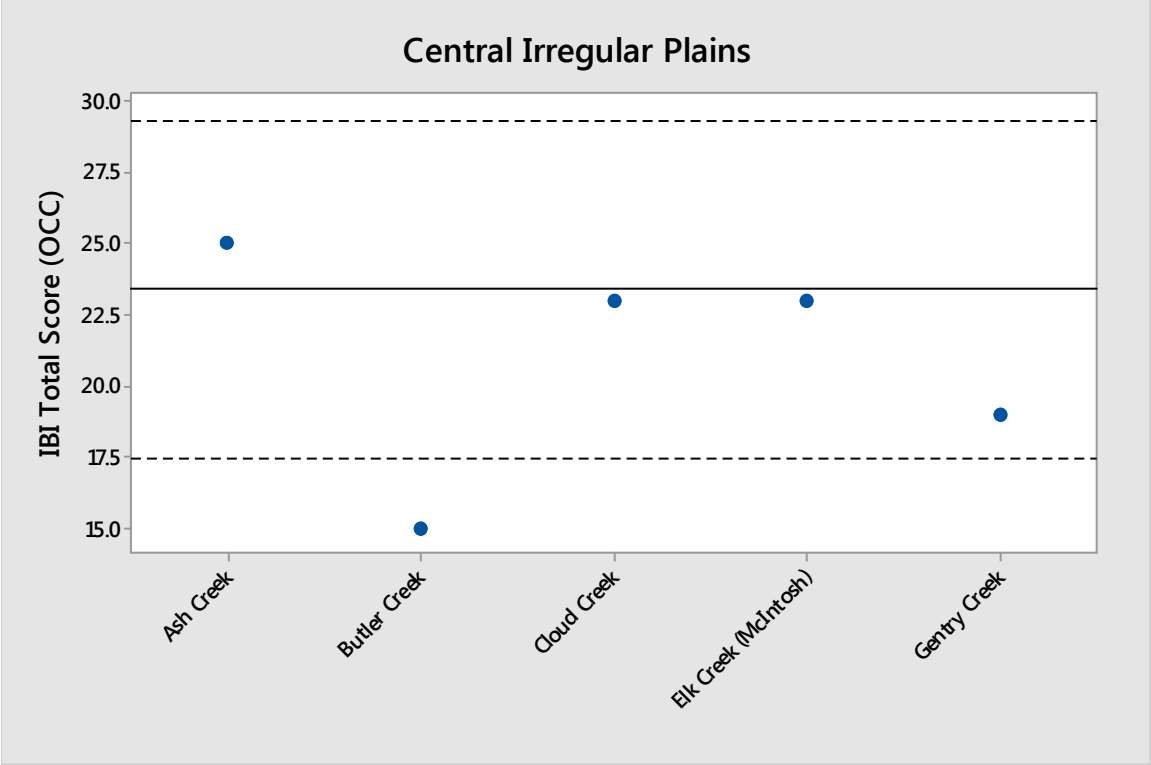

Arkansas Valley
IBI Total Score (OCC)
30
28
26
24
22
20
Holson Creek
Longtown Creek
Mill Creek
Peaceable Creek
San Bois Creek
Sugar Loaf Creek
Taloka Creek

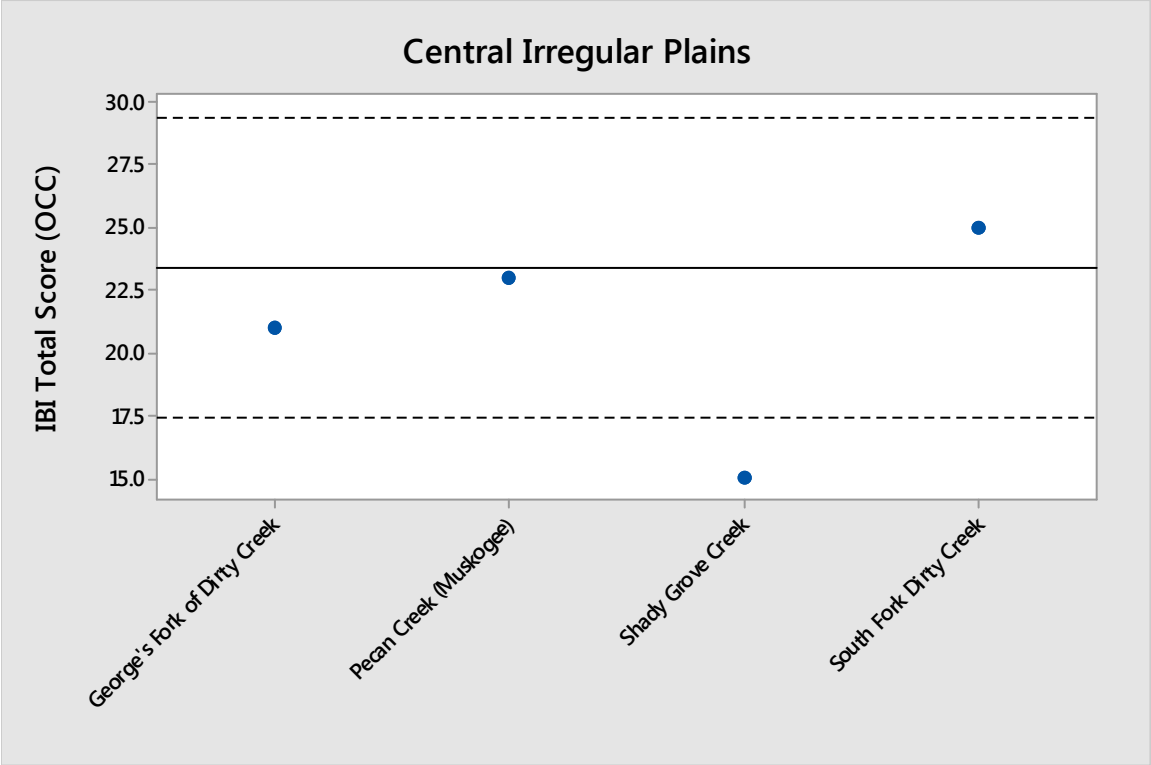
(b)


Boston Mountains CWAC
IBI Total Score (OCC)
33
32
31
30
29
28
27
Sallisaw Creek
Vian Creek

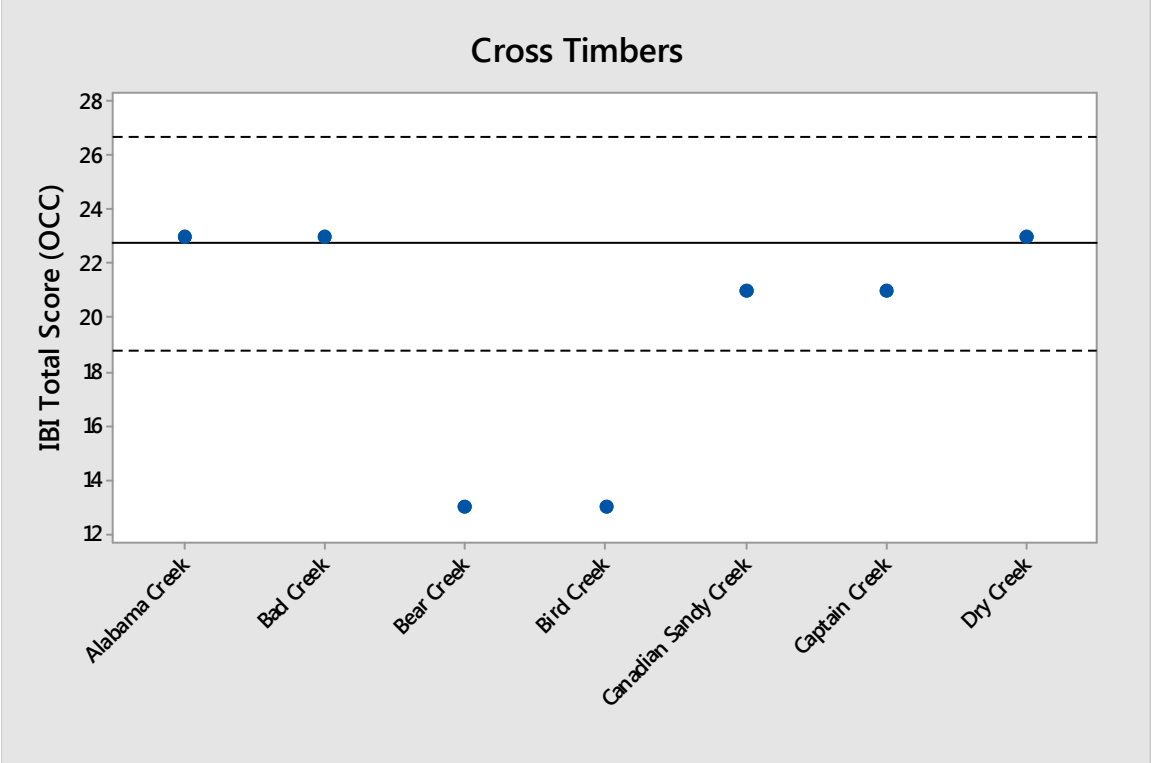

Boston Mountains WWAC
IBI Total Score (OCC)
32.5
30.0
27.5
25.0
22.5
20.0
17.5
15.0
Deep Branch
Elk Creek (Cherokee)
Greenleaf Creek
Manard Bayou
Snake Creek (Sequoyah)

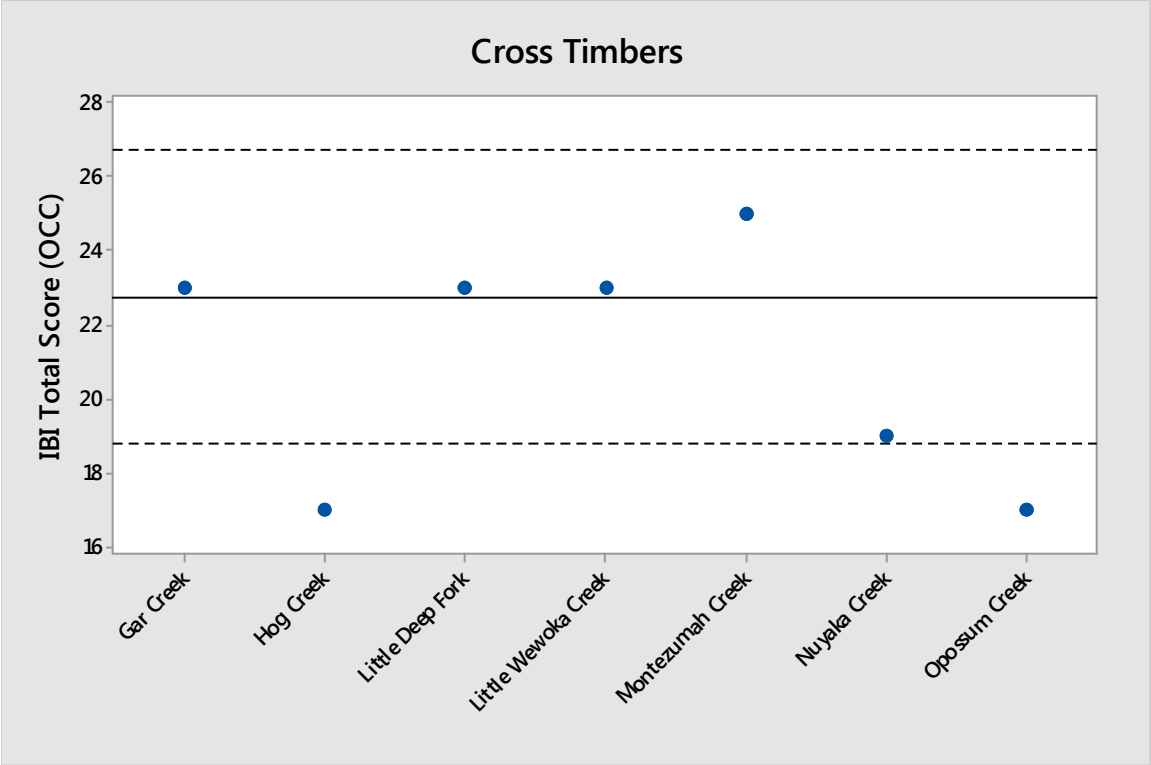
(c)

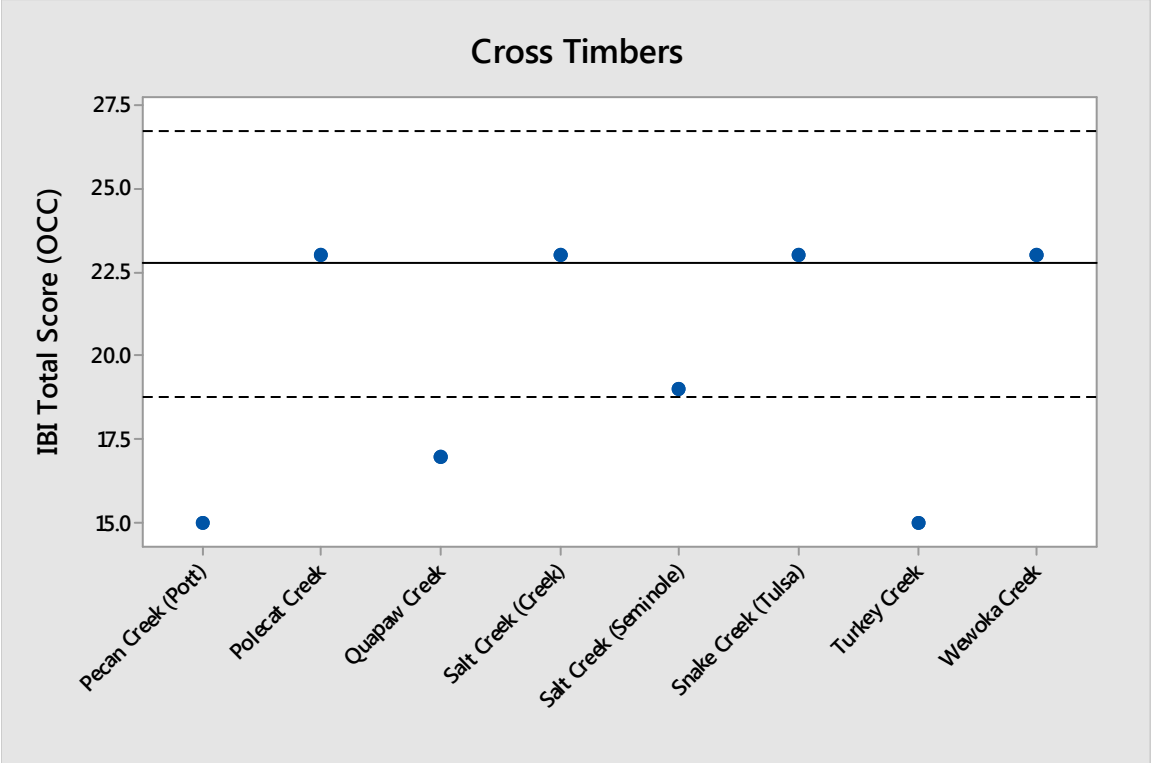

Central Irregular Plains
IBI Total Score (OCC)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
Ash Creek
Butler Creek
Cloud Creek
Elk Creek (McIntosh)
Gentry Creek


Central Irregular Plains
IBI Total Score (OCC)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
George's Fork of Dirty Creek
Pecan Creek (Muskogee)
Shady Grove Creek
South Fork Dirty Creek

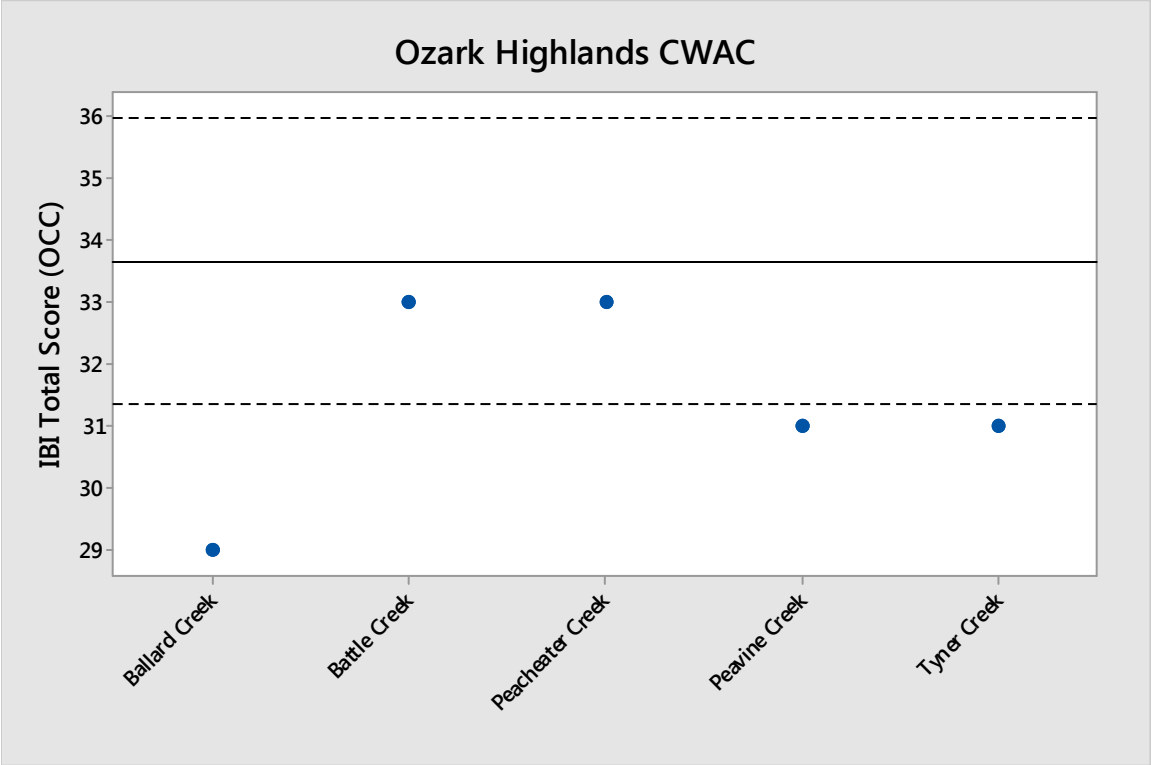
(d)

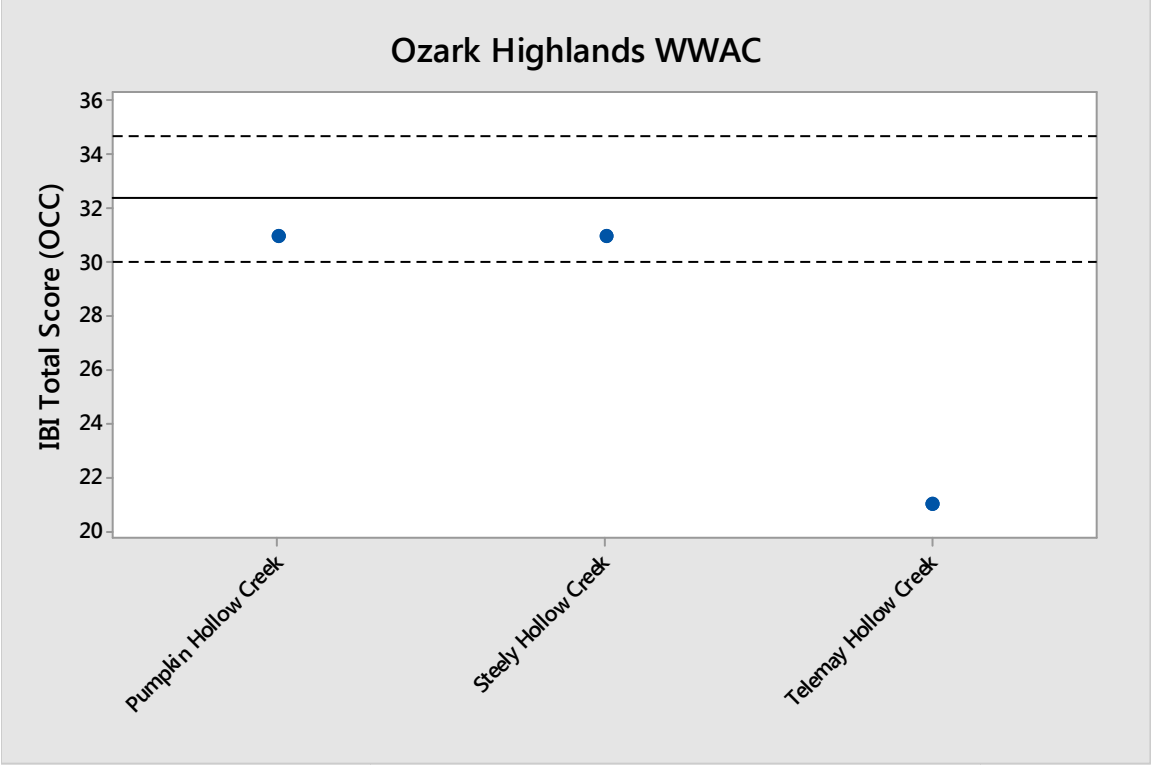

Cross Timbers
IBI Total Score (OCC)
28
26
24
22
20
18
16
14
12
Alabama Creek
Bad Creek
Bear Creek
Bird Creek
Canadian Sandy Creek
Captain Creek
Dry Creek


Cross Timbers
IBI Total Score (OCC)
28
26
24
22
20
18
16
Car Creek
Hog Creek
Little Deep Fork
Little Wewoka Creek
Montezumah Creek
Nuyaka Creek
Opossum Creek

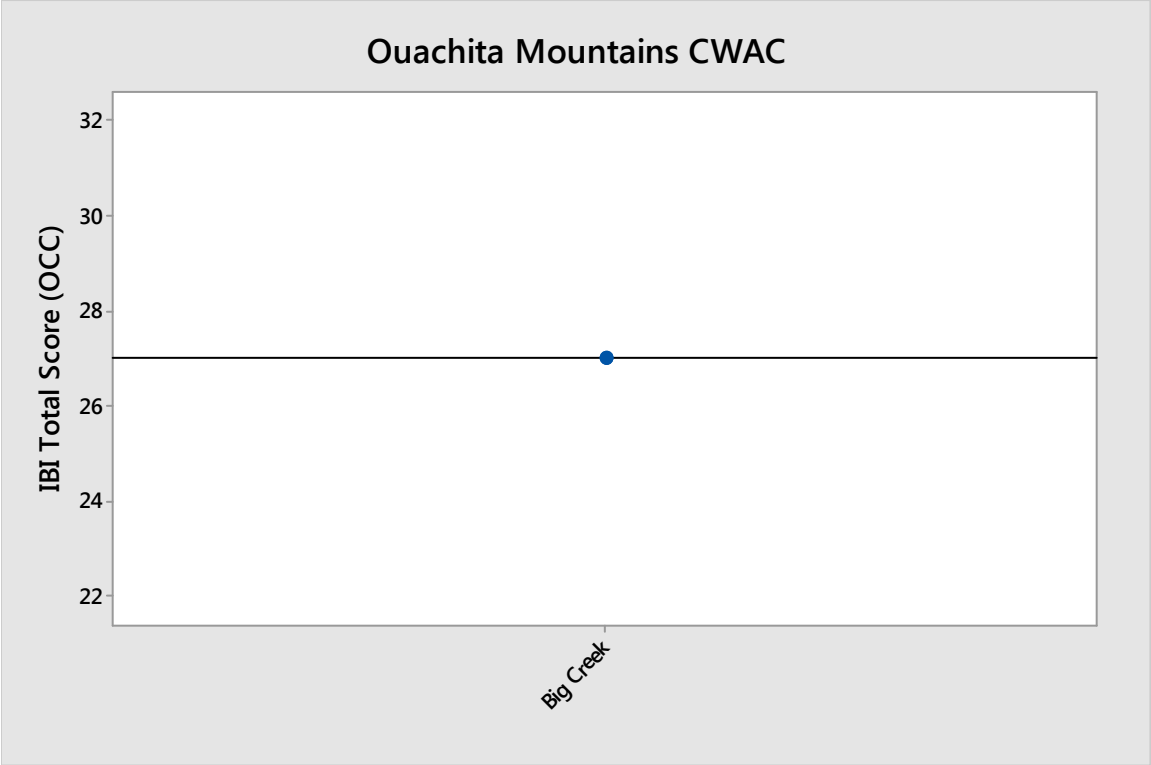

Cross Timbers
IBI Total Score (OCC)
27.5
25.0
22.5
20.0
17.5
15.0
Pecan Creek (Pott)
Polecat Creek
Quapaw Creek
Salt Creek (Creek)
Salt Creek (Seminole)
Snake Creek (Tulsa)
Turkey Creek
Wewoka Creek

(e)


Ozark Highlands CWAC
IBI Total Score (OCC)
36
35
34
33
32
31
30
29
Ballard Creek
Battle Creek
Peacheater Creek
Peavine Creek
Tyner Creek


Ozark Highlands WWAC
IBI Total Score (OCC)
36
34
32
30
28
26
24
22
20
Pumpkin Hollow Creek
Steely Hollow Creek
Telemay Hollow Creek

(f)


Ouachita Mountains CWAC
IBI Total Score (OCC)
32
30
28
26
24
22
Big Creek

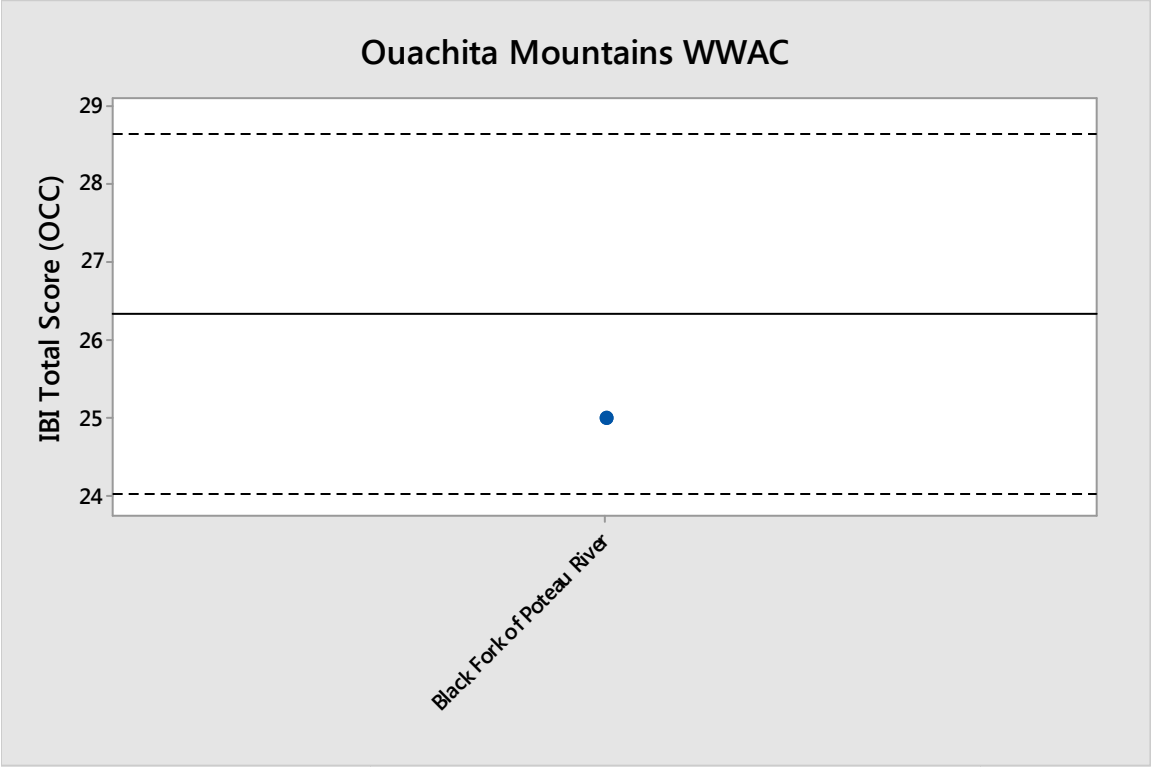


Figure 5. IBI scores for fish communities for monitoring sites in Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) assessed between 2018 and 2020 in (a) Arkansas Valley, (b) Boston Mountains, (c) Central Irregular Plains, (d) Cross Timbers, (e) Ozark Highlands, and (f) Ouachita Mountains Ecoregions. IBI scores were calculated used the modified OCC rotating Basin Method. Solid Lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

Table 14 shows a comparison between fish data collected in cycle 1 (2003 or 2004), cycle 2 (2008 or 2009), cycle 3 (2013 or 2014), and cycle 4 (2018 or 2019) of the rotating basin project in order to examine whether biological conditions have improved, worsened, or remained the same at a particular site. IBI scores were calculated relative to the same high quality sites data for all cycles, so any change in condition is due only to a change at a monitoring location, not to a change in the high quality sites. When comparing the last two cycles, the fish community remained in the same condition for 19 of the 44 sites. Nine streams had worse fish community conditions, while 16 streams had improved fish communities.

Table 14. Comparison of fish IBIs from cycle 1 (2003-2005), cycle 2 (2008-2010), cycle 3 (2013-2015), and cycle 4 (2018-2020) at sites in Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins). Each site is given a unique waterbody identifier (WBID). Results are based on OCC's modified RBP method (OCC). IBI scores relative to reference are provided (% of reference) as well as condition category of the community (Score Interpretation).

Modified Ecoregion	Site Name	WBID	Year	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent insectivorous Cyprinid	Percent lithophilic spawners	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CT	Alabama Creek	OK520500-01-0200D	1	113	13	0		5	0	0.96	0.00	0.02	26	0.65	Fair
CT	Alabama Creek	OK520500-01-0200D	2	318	25	1	2	8	2	0.83	0.02	0.11	21	0.84	Good
CT	Alabama Creek	OK520500-01-0200D	3	238	17	2	3	7	1	0.90	0.00	0.08	21	0.84	Good
CT	Alabama Creek	OK520500-01-0200D	4	242	22	2	5	8	3	0.769	0.0413	0.112	23	1	Excellent
CIP	Ash Creek	OK120410-01-0110E	3	255	16	1	2	7	2	0.706	0.0039	0.145	19	0.70	Fair
CIP	Ash Creek	OK120410-01-0110E	4	1158	24	2	5	10	3	0.655	0.0026	0.248	25	1	Excellent
CT	Bad Creek	OK520500-01-0170L	1	434	20	1		8	1	0.42	0.02	0.18	32	0.80	Good
CT	Bad Creek	OK520500-01-0170L	2	295	25	1	2	7	2	0.64	0.05	0.28	23	0.92	Excellent
CT	Bad Creek	OK520500-01-0170E	3	321	24	3	3	7	2	0.69	0.00	0.20	25	1.00	Excellent
CT	Bad Creek	OK520500-01-0170E	4	930	29	3	5	9	4	0.64	0.0215	0.146	23	0.92	Excellent
OH	Ballard Creek	OK121700-03-0370G	1	910	23	3		6	12	0.03	0.42	0.97	44	0.96	Excellent
OH	Ballard Creek	OK121700-03-0370G	2	682	21	3	6	7	10	0.09	0.54	0.91	35	1.40	Excellent
OH	Ballard Creek	OK121700-03-0370G	3	997	21	4	8	6	10	0.17	0.34	0.83	31	1.15	Excellent
OH	Ballard Creek	OK121700-03-0370G	4	723	20	3	7	6	11	0.158	0.1936	0.835	29	0.829	Good
OH	Battle Creek	OK121700-06-0040G	1	566	15	3		1	12	0.00	0.35	1.00	40	0.91	Good
OH	Battle Creek	OK121700-06-0040G	2	409	14	3	5	4	8	0.02	0.11	0.98	31	1.24	Excellent
OH	Battle Creek	OK121700-06-0040G	3	620	17	4	7	4	12	0.01	0.16	0.73	31	1.15	Excellent
OH	Battle Creek	OK121700-06-0040G	4	353	18	2	6	4	11	0.023	0.2436	0.977	33	0.94	Excellent
CT	Bear Creek	OK520700-05-0170A	3	361	16	0	1	6	1	0.994	0.0028	0.003	17	0.68	Fair
CT	Bear Creek	OK520700-05-0170A	4	1827	13	0	0	5	0	0.999	0.0005	0	13	0.52	Poor
OM	Big Creek	OK220100-02-0080B	3	571	18	5	8	5	8	0.256	0.0473	0.704	27	0.93	Excellent
OM	Big Creek	OK220100-02-0080B	4	1032	24	6	10	6	10	0.293	0.0494	0.659	27	1	Excellent
CT	Bird Creek	OK520800-01-0050M	2	168	11	0	0	5	0	0.74	0.01	0.03	13	0.52	Poor
CT	Bird Creek	OK520800-01-0050M	3	535	23	1	2	9	1	0.77	0.02	0.13	19	0.76	Fair
CT	Bird Creek	OK520800-01-0050M	4	312	12	0	1	7	0	0.862	0	0.022	13	0.52	Poor

Modified Ecoregion	Site Name	WBID	Year	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent insectivorous Cyprinid	Percent lithophilic spawners	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
AV	Brazil Creek	OK220100-03-0010G	1	515	26	5		7	5	0.31	0.18	0.53	40	1.00	Excellent
AV	Brazil Creek	OK220100-03-0010G	2	333	26	3	6	5	6	0.32	0.13	0.24	23	0.85	Good
AV	Brazil Creek	OK220100-03-0010G	3	377	24	4	6	7	6	0.41	0.03	0.58	27	1.00	Excellent
AV	Brazil Creek	OK220100-03-0010G	4	337	28	7	8	7	10	0.332	0.1098	0.398	27	1	Excellent
AV	Brushy Creek	OK220600-03-0010J	1	329	28	4		9	3	0.41	0.11	0.26	42	1.05	Excellent
AV	Brushy Creek	OK220600-03-0010J	2	358	31	2	5	9	4	0.81	0.01	0.13	21	0.78	Good
AV	Brushy Creek	OK220600-03-0010L	3	750	35	7	9	9	6	0.32	0.05	0.45	27	1.00	Excellent
AV	Brushy Creek	OK220600-03-0010L	4	265	21	4	6	6	2	0.411	0.0226	0.317	23	0.852	Good
CT	Canadian Sandy Creek	OK520600-03-0010D	1	453	14	0		5	0	0.93	0.06	0.01	24	0.60	Poor
CT	Canadian Sandy Creek	OK520600-03-0010D	2	464	14	0	1	4	1	0.85	0.10	0.05	15	0.60	Poor
CT	Canadian Sandy Creek	OK520600-03-0010D	3	316	20	1	3	6	1	0.91	0.06	0.03	21	0.84	Good
CT	Canadian Sandy Creek	OK520600-03-0010D	4	493	21	1	3	8	1	0.793	0.142	0.061	21	0.84	Good
CT	Captain Creek	OK520700-05-0140H	3	208	16	0	1	4	1	0.981	0.0192	0	15	0.60	Poor
CT	Captain Creek	OK520700-05-0140H	4	2222	17	1	2	6	2	0.932	0.0329	0.036	21	0.84	Good
AV	Caston Creek	OK220100-01-0180B	3	417	28	5	8	8	4	0.362	0.0863	0.197	25	0.93	Excellent
AV	Caston Creek	OK220100-01-0180B	4	565	31	5	8	9	6	0.49	0.0637	0.384	27	1	Excellent
CIP	Cloud Creek	OK120410-01-0100T	2	429	26	1	4	9	3	0.66	0.13	0.02	21	0.84	Good
CIP	Cloud Creek	OK120410-01-0100T	3	554	27	2	4	8	3	0.69	0.05	0.06	21	0.78	Fair
CIP	Cloud Creek	OK120410-01-0100T	4	726	31	4	7	6	6	0.654	0.0978	0.129	23	0.92	Excellent
AV	Coal Creek	OK220600-02-0010F	3	664	32	2	6	9	4	0.515	0	0.304	25	0.93	Excellent
AV	Coal Creek	OK220600-02-0010F	4	677	34	3	6	8	3	0.405	0.0192	0.377	25	0.926	Excellent
BM	Deep Branch	OK121700-01-0020A	3	167	9	0	1	5	1	0.527	0.0359	0.407	17	0.63	Fair
BM	Deep Branch	OK121700-01-0020A	4	192	14	2	3	7	1	0.557	0	0.318	17	0.548	Poor
CT	Dry Creek	OK520700-04-0020F	1	289	15	1		4	0	0.99	0.00	0.01	24	0.60	Poor
CT	Dry Creek	OK520700-04-0020F	2	332	15	1	2	4	2	0.99	0.00	0.00	19	0.76	Fair
CT	Dry Creek	OK520700-04-0020F	3	672	19	0	2	7	2	0.92	0.03	0.00	21	0.84	Good
CT	Dry Creek	OK520700-04-0020F	4	760	18	1	3	7	3	0.954	0.0316	0.013	23	0.92	Excellent
CIP	Elk Creek (McIntosh)	OK120400-02-0190D	1	231	18	1		8	1	0.66	0.01	0.22	32	0.80	Good
CIP	Elk Creek (McIntosh)	OK120400-02-0190D	2	397	20	0	2	8	2	0.80	0.01	0.09	17	0.68	Fair
CIP	Elk Creek (McIntosh)	OK120400-02-0190F	3	475	19	3	4	7	3	0.43	0.05	0.21	23	0.85	Good
CIP	Elk Creek (McIntosh)	OK120400-02-0190F	4	618	23	4	5	9	3	0.738	0.0243	0.049	23	0.92	Excellent
AV	Fourche Maline Creek	OK220100-04-0020H	2	371	36	3	7	10	7	0.76	0.08	0.16	21	0.78	Good

Modified Ecoregion	Site Name	WBID	Year	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent insectivorous Cyprinid	Percent lithophilic spawners	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
AV	Fourche Maline Creek	OK220100-04-0020H	3	557	44	11	15	8	15	0.47	0.11	0.38	27	1.00	Excellent
AV	Fourche Maline Creek	OK220100-04-0020H	4	1072	48	12	17	7	16	0.336	0.2743	0.499	29	1.074	Excellent
CT	Gar Creek	OK520510-00-0080C	3	516	20	1	3	7	2	0.789	0.0174	0.078	23	0.92	Excellent
CT	Gar Creek	OK520510-00-0080C	4	778	21	2	4	8	2	0.685	0.0553	0.161	23	0.92	Excellent
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	1	242	19	1		7	0	0.85	0.00	0.03	30	0.75	Fair
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	2	59	9	1	2	6	2	0.97	0.00	0.02	17	0.68	Fair
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	3	540	21	3	4	7	2	0.69	0.01	0.22	21	0.78	Fair
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	4	531	29	3	4	9	3	0.744	0.0019	0.047	21	0.84	Good
BM	Greenleaf Creek	OK120400-01-0120C	3	984	25	5	7	7	6	0.207	0.0478	0.453	29	1.07	Excellent
BM	Greenleaf Creek	OK120400-01-0120C	4	1485	25	5	8	7	9	0.253	0.2559	0.627	29	0.935	Excellent
CT	Hog Creek	OK520810-00-0030D	3	353	15	0	0	7	0	0.98	0.00	0.00	15	0.60	Poor
CT	Hog Creek	OK520810-00-0030D	4	526	14	0	1	6	1	0.996	0.0019	0	17	0.68	Fair
CT	Little Deep Fork	OK520700-06-0010D	3	521	14	0	1	7	1	0.988	0.0038	0.01	17	0.68	Fair
CT	Little Deep Fork	OK520700-06-0010D	4	911	16	0	3	6	2	0.989	0.0055	0.003	23	0.92	Excellent
CT	Little Wewoka Creek	OK520500-02-0090D	1	268	8	0		5	0	0.94	0.00	0.06	26	0.65	Fair
CT	Little Wewoka Creek	OK520500-02-0090D	2	587	14	1	2	5	2	0.78	0.16	0.06	21	0.84	Good
CT	Little Wewoka Creek	OK520500-02-0090D	3	488	14	1	2	6	2	0.87	0.01	0.11	21	0.84	Good
CT	Little Wewoka Creek	OK520500-02-0090D	4	542	17	1	3	6	2	0.862	0.0018	0.122	23	0.92	Excellent
AV	Longtown Creek	OK220600-01-0070P	3	480	21	3	4	8	2	0.346	0.0896	0.11	19	0.70	Fair
AV	Longtown Creek	OK220600-01-0070P	4	1308	21	3	4	7	2	0.371	0.0505	0.452	23	0.852	Good
BM	Manard Bayou	OK120400-01-0280E	3	1170	29	3	8	7	8	0.455	0.2316	0.51	29	1.07	Excellent
BM	Manard Bayou	OK120400-01-0280E	4	2561	25	3	7	7	7	0.213	0.2487	0.746	31	1	Excellent
AV	Mill Creek	OK220600-01-0100P	1	242	16	1		6	2	0.45	0.00	0.53	36	0.90	Good
AV	Mill Creek	OK220600-01-0100P	2	346	21	1	1	10	1	0.71	0.00	0.22	17	0.63	Fair
AV	Mill Creek	OK220600-01-0100P	3	291	17	1	3	6	1	0.62	0.00	0.34	19	0.70	Fair
AV	Mill Creek	OK220600-01-0100J	4	477	27	3	4	10	3	0.608	0.0063	0.262	21	0.778	Fair
CT	Montezumah Creek	OK520700-01-0220D	3	166	22	2	4	9	2	0.837	0.0361	0.11	23	0.92	Excellent
CT	Montezumah Creek	OK520700-01-0220D	4	369	22	2	5	10	3	0.602	0.0136	0.333	25	1	Excellent
CT	Nuyaka Creek	OK520700-02-0200D	3	171	19	0	2	8	1	0.93	0.0234	0.04	19	0.76	Fair
CT	Nuyaka Creek	OK520700-02-0200D	4	303	23	0	2	8	1	0.875	0.033	0.036	19	0.76	Fair

Modified Ecoregion	Site Name	WBID	Year	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent insectivorous Cyprinid	Percent lithophilic spawners	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
AV	Peaceable Creek	OK220600-03-0050F	1	229	19	4		6	2	0.41	0.08	0.27	38	0.95	Excellent
AV	Peaceable Creek	OK220600-03-0050F	2	163	17	2	3	7	2	0.74	0.09	0.14	19	0.70	Fair
AV	Peaceable Creek	OK220600-03-0050F	3	394	19	3	4	7	3	0.74	0.01	0.20	21	0.78	Fair
AV	Peaceable Creek	OK220600-03-0050F	4	345	23	4	5	7	3	0.467	0.0319	0.272	21	0.778	Fair
CIP	Pecan Creek (Muskogee)	OK120410-01-0030D	3	411	18	1	3	8	3	0.781	0.1436	0.06	21	0.78	Fair
CIP	Pecan Creek (Muskogee)	OK120410-01-0030D	4	558	21	3	5	5	3	0.772	0.0896	0.118	23	0.92	Excellent
CT	Pecan Creek (Pottawatomie)	OK520800-02-0080C	3	330	13	0	1	6	2	0.9	0.097	0.00	17	0.68	Fair
CT	Pecan Creek (Pottawatomie)	OK520800-02-0080C	4	364	13	0	1	4	1	0.775	0.2253	0	15	0.6	Poor
CT	Polecat Creek	OK120420-02-0050D	1	446	23	4		5	3	0.92	0.31	0.04	36	0.90	Good
CT	Polecat Creek	OK120420-02-0050D	2	326	20	1	2	6	2	0.94	0.03	0.02	21	0.84	Good
CT	Polecat Creek	OK120420-02-0050G	3	1612	30	3	6	8	4	0.80	0.06	0.06	23	0.92	Excellent
CT	Polecat Creek	OK120420-02-0050B	4	769	26	3	5	9	4	0.874	0.0754	0.033	23	0.92	Excellent
CT	Quapaw Creek	OK520700-04-0260C	1	440	18	1		6	0	0.92	0.06	0.02	26	0.65	Fair
CT	Quapaw Creek	OK520700-04-0260C	2	910	16	0	0	6	0	1.00	0.00	0.00	15	0.60	Poor
CT	Quapaw Creek	OK520700-04-0260C	3	94	9	0	0	3	0	1.00	0.00	0.00	11	0.44	Poor
CT	Quapaw Creek	OK520700-04-0260C	4	1040	23	0	1	7	1	0.898	0.099	0	17	0.68	Fair
BM	Sallisaw Creek	OK220200-03-0010C	1	430	31	5		7	11	0.21	0.30	0.60	42	0.91	Good
BM	Sallisaw Creek	OK220200-03-0010C	2	479	32	3	8	9	13	0.25	0.19	0.51	27	0.82	Good
BM	Sallisaw Creek	OK220200-03-0010C	3	815	35	4	10	12	13	0.33	0.38	0.63	29	1.07	Excellent
BM	Sallisaw Creek	OK220200-03-0010C	4	1339	33	8	13	10	16	0.451	0.1031	0.471	27	0.818	Good
CT	Salt Creek (Creek)	OK520700-03-0100B	1	294	15	1		3	2	0.98	0.01	0.00	26	0.65	Fair
CT	Salt Creek (Creek)	OK520700-03-0100B	2	200	12	1	3	4	3	0.96	0.01	0.01	17	0.68	Fair
CT	Salt Creek (Creek)	OK520700-03-0100B	3	211	15	0	1	7	1	0.98	0.01	0.00	17	0.68	Fair
CT	Salt Creek (Creek)	OK520700-03-0100B	4	968	18	0	3	9	2	0.838	0.095	0.036	23	0.92	Excellent
CT	Salt Creek (Seminole)	OK520800-03-0010D	1	203	8	0		1	1	0.94	0.16	0.00	16	0.40	Very poor
CT	Salt Creek (Seminole)	OK520800-03-0010D	2	349	12	0	1	5	1	0.98	0.01	0.00	15	0.60	Poor
CT	Salt Creek (Seminole)	OK520800-03-0010D	3	251	12	1	2	5	2	0.96	0.02	0.01	19	0.76	Fair
CT	Salt Creek (Seminole)	OK520800-03-0010D	4	530	15	0	2	5	1	0.911	0.0868	0.002	19	0.76	Fair
CT	Snake Creek (Tulsa)	OK120410-01-0220G	1	453	25	1		7	2	0.62	0.03	0.14	38	0.95	Excellent
CT	Snake Creek (Tulsa)	OK120410-01-0220G	2	130	16	1	2	5	2	0.92	0.04	0.04	21	0.84	Good

Modified Ecoregion	Site Name	WBID	Year	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent insectivorous Cyprinid	Percent lithophilic spawners	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CT	Snake Creek (Tulsa)	OK120410-01-0220G	3	667	23	3	4	8	4	0.76	0.09	0.12	23	0.92	Excellent
CT	Snake Creek (Tulsa)	OK120410-01-0220G	4	749	27	3	5	9	3	0.721	0.0227	0.166	23	0.92	Excellent
CIP	South Fork Dirty Creek	OK120400-02-0030F	1	354	32	2		9	3	0.55	0.00	0.07	40	1.00	Excellent
CIP	South Fork Dirty Creek	OK120400-02-0030F	2	262	19	1	2	7	3	0.73	0.00	0.08	21	0.84	Good
CIP	South Fork Dirty Creek	OK120400-02-0030H	3	635	21	3	4	8	3	0.49	0.02	0.13	21	0.78	Fair
CIP	South Fork Dirty Creek	OK120400-02-0030H	4	1257	24	3	6	9	4	0.435	0	0.305	25	1	Excellent
AV	Sugar Loaf Creek	OK220100-01-0160G	3	269	27	3	7	8	3	0.565	0.0223	0.34	23	0.85	Good
AV	Sugar Loaf Creek	OK220100-01-0160G	4	595	38	8	10	8	9	0.415	0.0655	0.397	27	1	Excellent
CT	Turkey Creek	OK520510-00-0100F	3	709	18	1	2	7	1	0.989	0.0014	0.00	19	0.76	Fair
CT	Turkey Creek	OK520510-00-0100F	4	414	13	0	1	7	1	0.928	0.0048	0	15	0.6	Poor
BM	Vian Creek	OK220200-02-0130E	3	294	19	4	8	5	7	0.354	0.3435	0.62	29	1.07	Excellent
BM	Vian Creek	OK220200-02-0130E	4	688	17	3	7	4	8	0.263	0.2267	0.73	27	0.818	Good
CT	Wewoka Creek	OK520500-02-0010C	1	622	16	1		4	1	0.99	0.12	0.00	26	0.65	Fair
CT	Wewoka Creek	OK520500-02-0010C	2	438	15	0	1	5	1	0.89	0.11	0.00	17	0.68	Fair
CT	Wewoka Creek	OK520500-02-0010C	3	261	19	1	2	5	2	0.78	0.21	0.01	23	0.92	Excellent
CT	Wewoka Creek	OK520500-02-0010C	4	563	26	1	3	8	2	0.845	0.1226	0.02	23	0.92	Excellent

3.2.3 Macroinvertebrate Collections

The complete macroinvertebrate dataset, including species and numbers captured per site, can be found in Appendix C. Macroinvertebrates were collected for most sites at least once during the project period. Lack of flow during the collection periods prevented acquisition of all planned samples over the cycle. Macroinvertebrates were not collected at Bad Creek, Salt Creek (Seminole), and Sugar Loaf Creek.

Table 15 presents the mean values, by season and sample type, for each metric at each site for the two year cycle 4 monitoring period. Riffle samples were collected at most sites and, generally, best reflect the macroinvertebrate community as a single habitat (Plafkin et al., 1989).

Table 15. Macroinvertebrate metric values determined for each monitoring site in Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) collected from 2018-2020, averaged per season (S=Spring and W=Winter) and habitat (Riffle, Sveg=Submerged Aquatic Vegetation, and Woody=Woody Debris). Each site is given a unique waterbody identifier (WBID). Each of the six metric (Total Species, Number of EPT Species, Percent EPT species, Shannon Diversity, Modified HBI, and Percent Dominant 2 Taxa) are scaled form 0-6 and summed to calculate Total Points, which ranges from 0 to 36. Total Points are then compared to scores at reference sites (% of Reference) to determine the average condition (NI = non-impaired, SI = slightly impaired, MI = moderately impaired).

Site Name	WBID	Habitat	Season	Number of Samples	Total species	EPT Taxa	Total Id'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
Alabama Creek	OK520500-01-0200D	Riffle	S	1	16	4	115	0.09	2.43	6.14	0.34	16	0.51	MI	MI
		Riffle	W	1	17	3	129	0.09	2.11	7.06	0.43	12	0.39	MI	
		Woody	S	1	11	2	112	0.04	1.72	5.76	0.63	12	0.41	MI	
Ash Creek	OK120410-01-0110E	Riffle	S	2	9	3	122	0.48	1.49	5.69	0.7	14	0.45	MI	MI
		Riffle	W	1	12	1	90	0.03	1.55	6.1	0.72	10	0.38	MI	
Ballard Creek	OK121700-03-0370G	Riffle	S	2	25	11	183	0.6	2.17	4.6	0.56	26	0.81	NI	SI
		Riffle	W	1	19	8	111	0.67	2.22	4.26	0.46	20	0.6	SI	
Battle Creek	OK121700-06-0040G	Riffle	S	2	17	9	114	0.35	2.11	4.02	0.49	26	0.81	NI	NI
		Riffle	W	1	22	13	105	0.46	2.47	4.2	0.38	28	0.84	NI	
Bear Creek	OK520700-05-0170A	Riffle	W	1	16	4	130	0.19	1.95	6.34	0.63	14	0.45	MI	MI
		Sveg	W	1	11	2	86	0.03	1.53	6.19	0.69	12	0.44	MI	
Big Creek	OK220100-02-0080B	Riffle	S	2	17	7.5	92	0.49	2.24	4.42	0.49	20	0.61	SI	SI
		Riffle	W	1	18	11	127	0.4	2.11	5.31	0.54	26	0.8	SI	
Big Skin Bayou	OK220200-01-0030K	Riffle	S	2	17	5.5	76.5	0.34	2.31	4.76	0.46	24	0.75	SI	SI
		Riffle	W	1	21	10	132	0.2	2.31	5.64	0.52	22	0.69	SI	
Bird Creek	OK520800-01-0050M	Riffle	S	1	22	11	124	0.42	2.56	5.15	0.4	28	0.89	NI	NI
		Sveg	W	1	11	4	112	0.3	1.65	6.04	0.66	20	0.73	SI	
Black Fork of Poteau River	OK220100-02-0040P	Riffle	S	1	26	14	118	0.63	2.53	4.33	0.45	28	0.86	NI	SI
		Riffle	W	1	16	9	96	0.46	2.24	5.15	0.47	22	0.67	SI	
Brazil Creek	OK220100-03-0010G	Riffle	S	2	18	8.5	137	0.19	1.97	4.68	0.54	22	0.69	SI	SI
Brushy Creek	OK220600-03-0010L	Riffle	S	1	18	8	121	0.4	2.34	4.7	0.38	28	0.88	NI	NI
Butler Creek	OK120400-02-0160P	Woody	W	2	12	4	99	0.15	1.39	5.81	0.78	18	0.73	SI	SI
Canadian Sandy Creek	OK520600-03-0010D	Riffle	S	1	16	8	112	0.49	2.08	4.26	0.54	26	0.83	NI	NI
Captain Creek	OK520700-05-0140H	Riffle	S	1	20	7	124	0.1	2.37	5.19	0.43	22	0.7	SI	MI

Site Name	WBID	Habitat	Season	Number of Samples	Total species	EPT Taxa	Total Id'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
		Riffle	W	1	15	3	130	0.15	2.13	5.97	0.5	16	0.52	MI	
		Sveg	W	1	6	1	98	0.03	0.45	5.97	0.94	8	0.29	MI	
Caston Creek	OK220100-01-0180B	Riffle	S	2	18	9.5	111	0.5	2.34	4.47	0.41	26	0.81	NI	NI
Cloud Creek	OK120410-01-0100T	Riffle	S	1	19	7	117	0.7	2.23	5.13	0.55	26	0.84	NI	SI
		Riffle	W	1	13	2	85	0.14	1.88	6.48	0.56	12	0.45	MI	
Coal Creek	OK220600-02-0010F	Riffle	S	2	10	2	121	0.03	1.22	5.07	0.82	8	0.25	MI	MI
		Riffle	W	1	15	5	94	0.12	1.95	6.18	0.64	14	0.44	MI	
Deep Branch	OK121700-01-0020A	Riffle	W	1	19	8	112	0.26	1.69	5.36	0.67	18	0.58	SI	SI
Dry Creek	OK520700-04-0020F	Woody	S	1	12	3	100	0.14	1.57	6.81	0.73	14	0.47	MI	MI
		Woody	W	2	9	3	96.5	0.1	0.93	5.87	0.84	10	0.39	MI	
Elk Creek (McIntosh)	OK120400-02-0190F	Riffle	S	2	12	3	99	0.17	1.91	4.64	0.54	14	0.45	MI	SI
		Riffle	W	2	14	5	116	0.16	1.9	5.52	0.59	22	0.83	NI	
Elk Creek (Cherokee)	OK121700-02-0180G	Riffle	S	1	15	8	111	0.44	1.94	5.57	0.61	24	0.73	SI	SI
		Riffle	W	1	10	7	114	0.62	1.51	4.16	0.68	16	0.52	MI	
Fourche Maline Creek	OK220100-04-0020H	Riffle	S	2	21	9.5	104	0.32	2.56	5.59	0.37	28	0.88	NI	NI
Gaines Creek	OK220600-04-0010F	Riffle	S	2	17	7	128	0.3	2	4.65	0.56	26	0.81	NI	NI
		Riffle	W	1	17	8	96	0.41	2.38	5.21	0.39	28	0.88	NI	
Gar Creek	OK520510-00-0080C	Sveg	S	1	15	6	114	0.11	1.87	6.28	0.64	20	0.65	SI	SI
		Woody	W	1	15	3	82	0.32	2.05	5.59	0.59	20	0.79	SI	
Gentry Creek	OK520700-01-0080L	Woody	W	1	9	1	123	0.34	1.14	6.52	0.88	16	0.65	SI	SI
George's Fork of Dirty Creek	OK120400-02-0110D	Riffle	S	2	12	4	110	0.14	1.71	5.1	0.59	14	0.45	MI	SI
		Riffle	W	1	15	3	113	0.44	2.26	5.09	0.38	22	0.83	NI	
		Woody	W	1	15	6	96	0.39	2.12	5.01	0.52	26	1.05	NI	
Greenleaf Creek	OK120400-01-0120C	Riffle	S	2	13	4.5	114	0.52	1.9	4.62	0.52	18	0.55	SI	SI
		Riffle	W	1	17	9	101	0.3	1.97	5.28	0.59	20	0.65	SI	
Hog Creek	OK520810-00-0030D	Woody	S	1	14	4	116	0.11	1.94	5.75	0.63	16	0.54	SI	SI
		Woody	W	1	16	4	119	0.08	1.41	6.12	0.8	16	0.63	SI	
Holson Creek	OK220100-04-0030G	Riffle	S	2	13	5	122	0.35	1.83	4.6	0.58	20	0.63	SI	SI
		Riffle	W	1	16	11	135	0.26	1.9	6.12	0.66	22	0.69	SI	
Little Deep Fork	OK520700-06-0010D	Sveg	S	1	18	5	94	0.47	2.11	6.21	0.55	22	0.71	SI	SI
		Sveg	W	1	12	4	86	0.08	1.63	6.01	0.71	16	0.59	SI	
		Woody	S	1	18	5	124	0.3	1.88	6.72	0.63	20	0.68	SI	

Site Name	WBID	Habitat	Season	Number of Samples	Total species	EPT Taxa	Total Id'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
		Woody	W	2	9	2	89.5	0.04	1.39	6.2	0.74	10	0.39	MI	
Little Wewoka Creek	OK520500-02-0090D	Riffle	S	1	15	8	110	0.18	1.9	4.79	0.59	22	0.7	SI	SI
		Riffle	W	1	18	7	121	0.4	2.34	4.83	0.36	28	0.9	NI	
		Woody	S	1	10	3	117	0.16	1.71	5.23	0.6	14	0.47	MI	
Longtown Creek	OK220600-01-0070P	Riffle	S	1	11	3	120	0.28	2.07	5.35	0.44	14	0.44	MI	SI
		Riffle	W	2	20	7	116	0.35	2.41	5.02	0.42	26	0.81	NI	
Manard Bayou	OK120400-01-0280E	Riffle	S	2	16	7	105	0.42	2.14	4.53	0.51	26	0.79	SI	SI
		Riffle	W	1	13	5	113	0.27	1.78	5.96	0.58	12	0.39	MI	
Mill Creek	OK220600-01-0100J	Riffle	S	2	20	6.5	174	0.15	2.2	4.9	0.49	22	0.69	SI	MI
		Riffle	W	1	13	3	96	0.09	1.82	6.55	0.61	10	0.31	MI	
Montezumah Creek	OK520700-01-0220D	Riffle	S	1	20	6	105	0.3	2.46	6.02	0.4	24	0.76	SI	NI
		Riffle	W	2	30	9	219	0.26	2.72	5.75	0.32	28	0.9	NI	
Nuyaka Creek	OK520700-02-0200D	Riffle	S	1	18	5	104	0.3	2.21	5.72	0.44	20	0.63	SI	SI
		Riffle	W	1	18	5	109	0.16	2.1	6.64	0.54	14	0.45	MI	
Opossum Creek	OK520700-05-0200C	Riffle	S	1	18	7	104	0.14	2.17	5.87	0.55	22	0.7	SI	SI
		Woody	W	1	15	5	91	0.11	1.62	5.9	0.67	22	0.87	NI	
Peaceable Creek	OK220600-03-0050F	Riffle	S	1	15	6	137	0.51	2.13	5.32	0.45	24	0.75	SI	SI
Peacheater Creek	OK121700-05-0120B	Riffle	S	2	15	8	114	0.64	1.79	3.97	0.62	24	0.75	SI	SI
		Riffle	W	1	15	7	115	0.23	1.56	5.47	0.7	14	0.42	MI	
Peavine Creek	OK121700-05-0190F	Riffle	S	2	18	8	117	0.63	2.22	4.36	0.47	26	0.81	NI	SI
		Riffle	W	1	19	7	106	0.26	1.75	5.53	0.65	14	0.42	MI	
Pecan Creek (Muskogee)	OK120410-01-0030D	Riffle	W	1	14	5	109	0.22	1.82	5.48	0.61	24	0.91	NI	NI
Pecan Creek (Pottawatomie)	OK520800-02-0080C	Riffle	S	1	16	5	112	0.36	2.31	5.35	0.4	22	0.7	SI	SI
		Riffle	W	1	16	3	99	0.1	1.56	5.99	0.71	16	0.52	MI	
Polecat Creek	OK120420-02-0050B	Riffle	S	2	15	5.5	102	0.18	2.11	4.61	0.51	20	0.63	SI	MI
		Riffle	W	2	12	2	102	0.04	1.74	5.99	0.63	12	0.39	MI	
Pumpkin Hollow Creek	OK121700-03-0090G	Riffle	S	1	16	6	119	0.35	2.38	5.43	0.34	22	0.69	SI	SI
		Riffle	W	1	8	3	116	0.33	1.55	5.29	0.63	12	0.36	MI	
Quapaw Creek	OK520700-04-0260C	Sveg	W	2	12	2	104	0.16	1.36	5.97	0.76	14	0.51	MI	SI
		Woody	W	1	16	4	106	0.24	2.1	6.54	0.54	18	0.61	SI	
Sallisaw Creek	OK220200-03-0010C	Riffle	S	2	15	7.5	92.5	0.24	1.9	5.28	0.63	20	0.61	SI	SI
		Riffle	W	1	16	9	92	0.45	2.03	5.36	0.52	22	0.71	SI	

Site Name	WBID	Habitat	Season	Number of Samples	Total species	EPT Taxa	Total Id'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
Salt Creek (Creek)	OK520700-03-0100B	Woody	S	1	11	3	70	0.17	1.9	5.3	0.54	14	0.47	MI	SI
		Woody	W	2	13	5	108	0.08	1.22	5.92	0.79	18	0.71	SI	
San Bois Creek	OK220200-04-0010G	Riffle	S	2	16	7	108	0.31	2.23	4.55	0.45	26	0.81	NI	NI
Shady Grove Creek	OK120400-02-0240H	Riffle	W	1	8	0	66	0	1.61	6.61	0.58	8	0.3	MI	MI
		Woody	S	1	9	3	91	0.07	1.35	6.45	0.76	10	0.36	MI	
		Woody	W	1	12	4	67	0.09	1.65	5.69	0.66	18	0.73	SI	
Snake Creek (Tulsa)	OK120410-01-0220G	Riffle	S	1	14	3	92	0.09	1.92	6.18	0.55	14	0.44	MI	SI
		Riffle	W	1	16	3	113	0.11	2.14	7.07	0.5	14	0.45	MI	
		Sveg	W	1	18	4	95	0.35	2.5	4.73	0.29	28	1.02	NI	
Snake Creek (Sequoyah)	OK121700-02-0100G	Riffle	S	1	21	10	91	0.24	2.12	6.53	0.58	20	0.61	SI	SI
		Riffle	W	1	13	7	94	0.51	2.12	4.7	0.4	16	0.52	MI	
South Fork Dirty Creek	OK120400-02-0030H	Riffle	S	2	16	6	101	0.3	2.11	4.58	0.54	22	0.71	SI	SI
		Riffle	W	1	21	4	92	0.14	2.31	5.93	0.43	18	0.68	SI	
Steely Hollow Creek	OK121700-03-0120G	Riffle	S	2	24	9.5	111	0.39	2.53	4.47	0.41	28	0.88	NI	SI
		Riffle	W	1	19	10	107	0.48	2.17	4.49	0.56	22	0.66	SI	
Taloka Creek	OK220300-00-0020M	Sveg	W	1	17	6	99	0.18	2.37	6.19	0.43	14	0.44	MI	SI
		Woody	S	1	18	8	87	0.4	2.37	5.02	0.43	26	0.81	NI	
Telemay Hollow Creek	OK121700-03-0140G	Riffle	S	1	20	5	116	0.11	2.36	5.82	0.41	14	0.44	MI	MI
		Riffle	W	1	11	6	113	0.63	1.68	4.19	0.63	16	0.48	MI	
Turkey Creek	OK520510-00-0100F	Riffle	W	1	17	4	107	0.18	1.86	5.91	0.62	16	0.52	MI	SI
Tyner Creek	OK121700-05-0090J	Riffle	S	2	19	8.5	109	0.5	2.32	4.03	0.45	26	0.81	NI	MI
		Riffle	W	1	11	4	115	0.12	1.22	6.02	0.8	6	0.18	Svl	
Vian Creek	OK220200-02-0130E	Riffle	S	2	18	8	110	0.54	2.3	4.88	0.46	26	0.79	SI	SI
		Riffle	W	1	17	6	122	0.29	1.8	5.31	0.66	16	0.52	MI	
Wewoka Creek	OK520500-02-0010C	Riffle	S	1	21	12	105	0.57	2.77	5.11	0.26	32	1.02	NI	SI
		Woody	W	1	10	3	104	0.07	1.83	5.87	0.5	12	0.47	MI	

3.2.4 Overall Biological Assessment

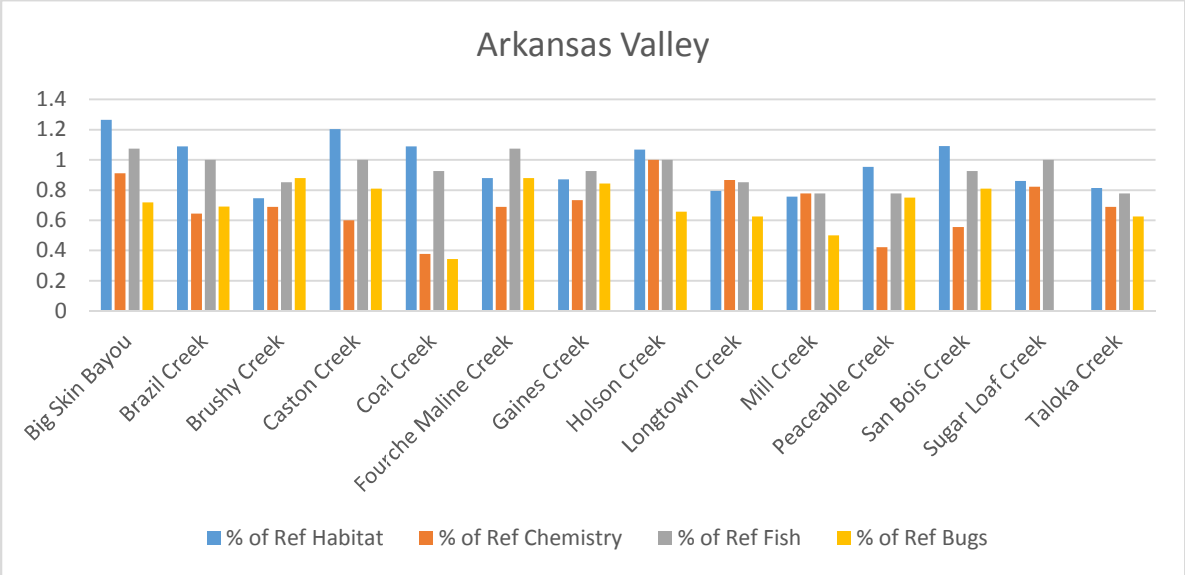
In order to synthesize the biological findings into a meaningful representation of the overall quality of each site, the biological assessments were compared with the habitat and water chemistry results. A water quality score was computed similarly to the other index scores by comparing rotating basin site

water chemistry data relative to high quality site values. The parameters included in the water quality score were phosphorus, nitrogen, DO, turbidity, and salts (TDS, chloride, and sulfate). Then, the habitat, fish, macroinvertebrate, and water quality scores (relative to the mean of high quality sites in the respective ecoregions) were examined in concert with one another (Figure 6).

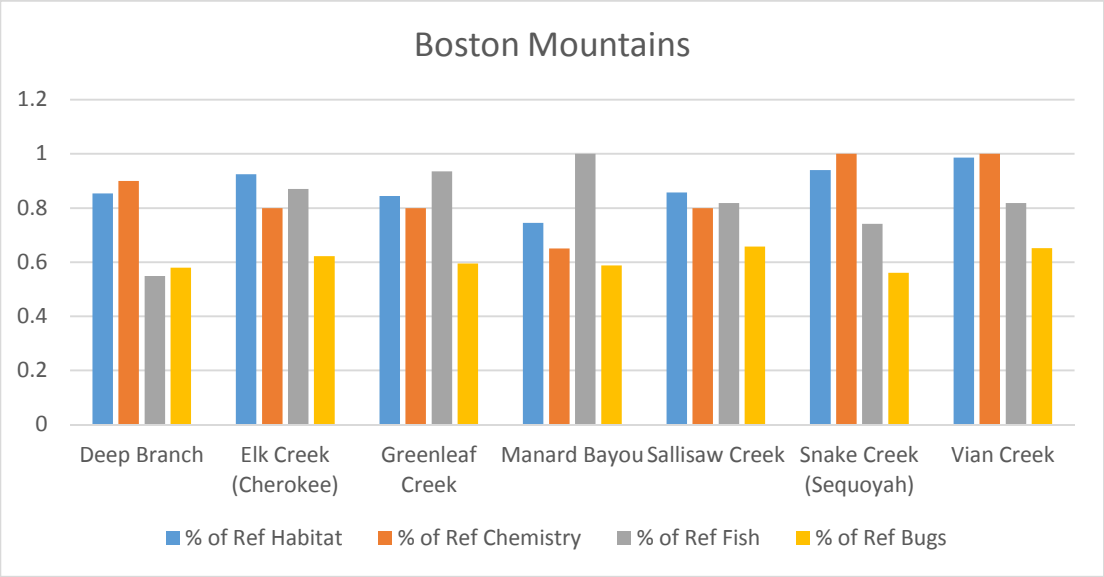
A determination of "good" or "excellent" stream health is indicated by a relatively high score for all categories. Most streams had relatively good agreement among the categories, but there are instances where one score is quite different than the others. It is generally recognized that fish communities are especially sensitive to habitat degradation and that macroinvertebrates more quickly integrate effects of water quality decline. Thus, sites with a high habitat and fish score yet a low macroinvertebrate and water chemistry score could indicate potential water quality impairment. Low habitat scores correlated with low fish scores yet high bug scores could indicate habitat impairments despite good water quality.

Many of the sites sampled during this rotation have macroinvertebrate collections or fish collections that indicate poorer conditions than the rest of the parameters. Instances where biological communities indicate impairment but habitat and water quality scores are not impaired, could be due to extreme weather conditions such as drought and abundant rainfall.

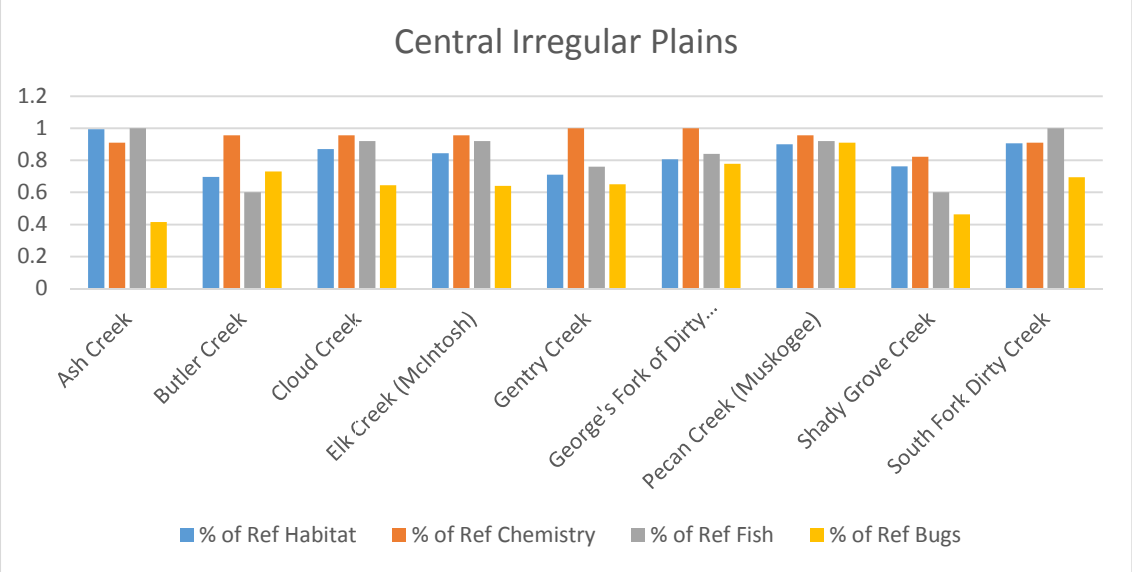
(a)



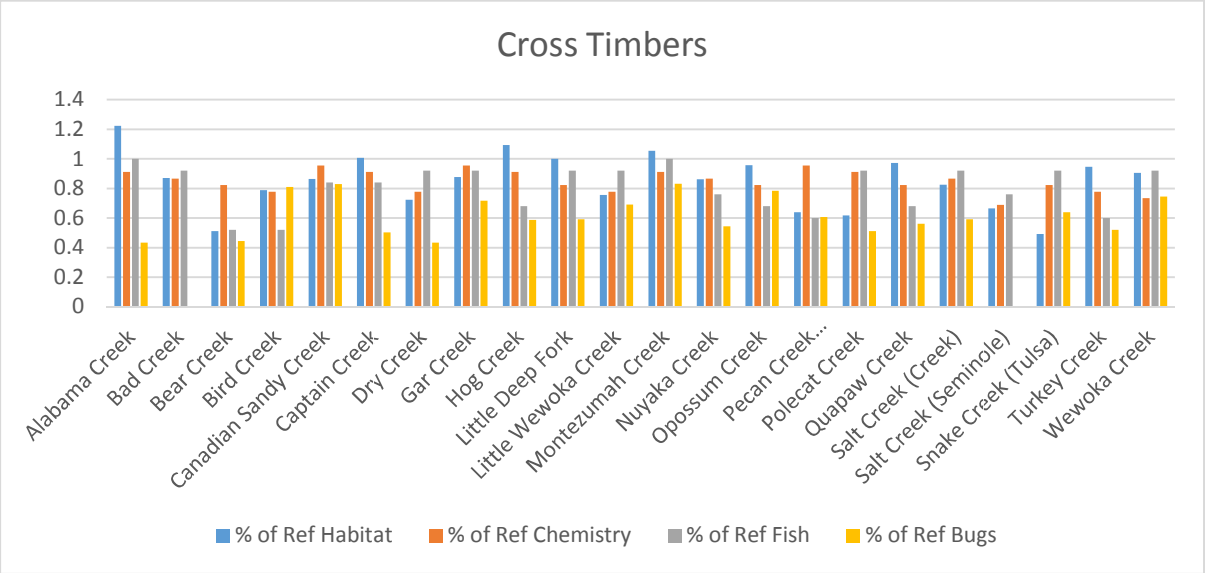
(b)


Boston Mountains
1.2
1
0.8
0.6
0.4
0.2
0
Deep Branch
Elk Creek (Cherokee)
Greenleaf Creek
Manard Bayou
Sallisaw Creek
Snake Creek (Sequoyah)
Vian Creek
% of Ref Habitat
% of Ref Chemistry
% of Ref Fish
% of Ref Bugs

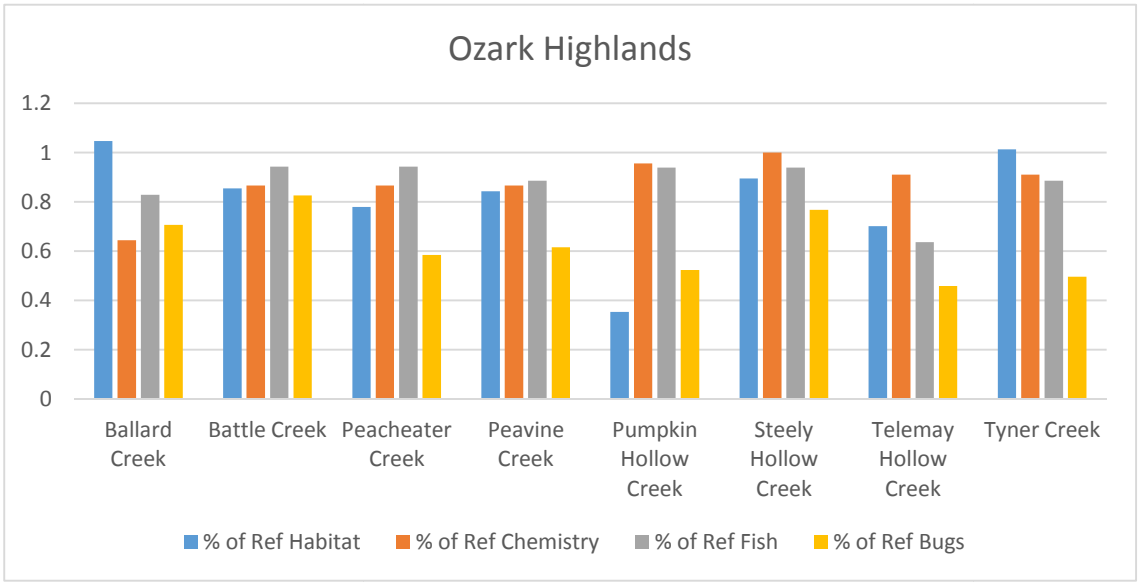
(c)


Central Irregular Plains
1.2
1
0.8
0.6
0.4
0.2
0
Ash Creek
Butler Creek
Cloud Creek
Elk Creek (McIntosh)
Gentry Creek
George's Fork of Dirty...
Pecan Creek (Muskogee)
Shady Grove Creek
South Fork Dirty Creek
% of Ref Habitat
% of Ref Chemistry
% of Ref Fish
% of Ref Bugs

(d)


Cross Timbers
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Alabama Creek
Bad Creek
Bear Creek
Bird Creek
Canadian Sandy Creek
Captain Creek
Dry Creek
Gar Creek
Hog Creek
Little Deep Fork
Little Wewoka Creek
Montezumah Creek
Nuyaka Creek
Opossum Creek
Pecan Creek...
Polecat Creek
Quapaw Creek
Salt Creek (Creek)
Salt Creek (Seminole)
Snake Creek (Tulsa)
Turkey Creek
Wewoka Creek
% of Ref Habitat
% of Ref Chemistry
% of Ref Fish
% of Ref Bugs

(e)


Ozark Highlands
1.2
1
0.8
0.6
0.4
0.2
0
Ballard Creek
Battle Creek
Peacheater Creek
Peavine Creek
Pumpkin Hollow Creek
Steely Hollow Creek
Telemay Hollow Creek
Tyner Creek
% of Ref Habitat
% of Ref Chemistry
% of Ref Fish
% of Ref Bugs

(f)

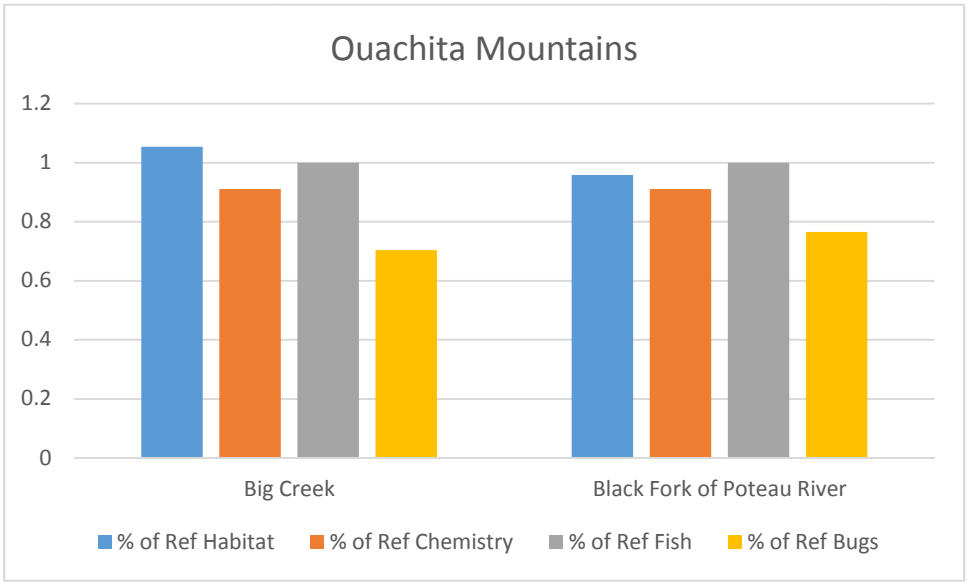


Figure 6. Comparison of habitat, fish, macroinvertebrate, and chemistry scores relative to the average high quality sites for rotating basin monitoring sites in Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) collected in 2018-2020 for (a) Arkansas Valley, (b) Boston Mountains, (c) Central Irregular Plains, (d) Cross Timbers, (e) Ozark Highlands, and (f) Ouachita Mountains

3.3 WATERSHED ASSESSMENT

Table 16 shows the land-use upstream of each monitoring site calculated from the 2016 NRCS National Land Cover Dataset in Geographic Information Systems (GIS). The watershed sizes and land uses vary widely, with Telemay Hollow Creek having the smallest watershed area, less than 500 hectares, while the Wewoka Creek watershed includes more than 100,000 hectares. Deciduous Forest makes up the largest percentage of land use, on average, in this basin, followed by pasture/hay. Watersheds range from having 0.3% pasture/hay to having 74% in pasture/hay, and from having 11% deciduous forest in the watershed to having 88% of the watershed in deciduous forest. Table 17 presents the types and number of permitted activities (e.g. Concentrated Animal Feeding Operations [CAFOs], landfills, National Pollution Discharge Elimination System[NPDES] permits) that occur upstream of each site. Ballard Creek, Big Creek, Black Fork of Poteau River, Deep Branch, Elk Creek (Cherokee), Peavine Creek, Snake Creek (Sequoyah), Steely Hollow Creek, and Telemay Hollow Creek did not have any permitted activities in the watershed.

Eleven sites had national pollution discharge elimination systems (NPDES) in the watershed. To examine the effects of point source versus non-point source pollution on the parameters at the monitoring sites, one-way ANOVAs were performed comparing sites with the permitted discharge to sites with no permitted discharge. Table 18 shows the results: most of the parameters except for nitrogen are significantly lower in the sites with no permitted discharge.

Table 16. Watershed land use (% of total watershed area) for each Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) monitoring sites based on the most recent Land Cover Dataset (NLCD; USGS 2016). Each site is given a unique waterbody identifier (WBID).

Site Name	WBID	Watershed Area (Hectares)	Open Water	Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Barren Land	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Woody Wetlands	Emergent Wetlands
Alabama Creek	OK520500-01-0200D	5789.62	0.53%	4.26%	0.43%	0.13%	0.01%	0.00%	54.23%	0.04%	0.08%	1.55%	21.36%	17.22%	0.05%	0.03%	0.08%
Ash Creek	OK120410-01-0110E	9232.52	0.26%	3.28%	0.12%	0.01%	0.00%	0.00%	18.65%	0.02%	0.02%	1.96%	5.13%	69.91%	0.59%	0.01%	0.05%
Bad Creek	OK520500-01-0170E	9215.76	0.41%	3.25%	0.37%	0.07%	0.00%	0.00%	50.67%	0.02%	0.05%	2.45%	19.55%	22.67%	0.34%	0.12%	0.04%
Ballard Creek	OK121700-03-0370G	11724.84	0.08%	4.58%	1.16%	0.52%	0.29%	0.01%	25.94%	0.18%	2.12%	0.65%	1.10%	62.94%	0.00%	0.37%	0.07%
Battle Creek	OK121700-06-0040G	2150.06	0.02%	3.34%	0.18%	0.24%	0.15%	0.02%	36.63%	0.44%	2.96%	0.47%	0.20%	55.34%	0.00%	0.00%	0.00%
Bear Creek	OK520700-05-0170A	29804.82	0.84%	3.23%	0.09%	0.03%	0.03%	0.01%	40.18%	0.19%	0.20%	1.75%	46.91%	2.90%	3.55%	0.01%	0.10%
Big Creek	OK220100-02-0080B	11142.54	0.00%	2.31%	0.12%	0.01%	0.00%	0.00%	49.24%	33.90%	11.64%	0.58%	0.50%	1.62%	0.00%	0.07%	0.00%
Big Skin Bayou	OK220200-01-0030K	12651.96	0.21%	2.85%	0.81%	0.10%	0.01%	0.08%	39.77%	0.76%	9.92%	1.10%	1.91%	41.56%	0.00%	0.89%	0.03%
Bird Creek	OK520800-01-0050M	6682.31	0.36%	2.94%	0.45%	0.15%	0.05%	0.00%	48.77%	0.00%	0.11%	1.68%	30.25%	15.23%	0.00%	0.00%	0.01%
Black Fork of Poteau River	OK220100-02-0040P	12149.18	0.05%	1.68%	0.05%	0.00%	0.00%	0.00%	19.84%	58.95%	13.58%	0.51%	0.87%	4.44%	0.00%	0.02%	0.00%
Brazil Creek	OK220100-03-0010G	47407.59	0.42%	2.22%	0.23%	0.23%	0.10%	0.21%	21.20%	11.35%	27.19%	2.27%	5.93%	27.81%	0.00%	0.83%	0.02%
Brushy Creek	OK220600-03-0010L	35941.75	0.41%	1.60%	0.20%	0.12%	0.00%	0.01%	47.53%	5.69%	9.19%	3.05%	9.01%	22.44%	0.00%	0.68%	0.07%
Butler Creek	OK120400-02-0160P	7814.49	0.47%	4.68%	1.05%	0.19%	0.04%	0.01%	16.67%	0.06%	0.03%	0.98%	4.31%	71.26%	0.19%	0.02%	0.05%
Canadian Sandy Creek	OK520600-03-0010D	52548.02	0.59%	3.02%	1.19%	0.35%	0.09%	0.02%	29.49%	0.01%	0.04%	0.90%	45.73%	16.87%	1.67%	0.00%	0.01%
Captain Creek	OK520700-05-0140H	15282.85	0.15%	4.70%	0.29%	0.12%	0.01%	0.00%	46.85%	0.10%	0.11%	2.35%	38.39%	5.58%	1.34%	0.00%	0.01%
Caston Creek	OK220100-01-0180B	18777.24	0.72%	2.44%	0.35%	0.15%	0.04%	0.22%	20.59%	8.31%	24.45%	2.22%	14.85%	25.52%	0.00%	0.12%	0.01%
Cloud Creek	OK120410-01-0100T	39573.23	0.90%	3.15%	0.17%	0.02%	0.01%	0.00%	14.04%	0.02%	0.01%	1.28%	3.57%	74.29%	2.45%	0.05%	0.04%
Coal Creek	OK220600-02-0010F	59219.26	0.51%	4.02%	1.37%	0.64%	0.39%	0.03%	50.01%	1.06%	0.57%	3.39%	17.42%	20.15%	0.01%	0.32%	0.09%
Deep Branch	OK121700-01-0020A	2845.80	0.09%	2.09%	0.25%	0.03%	0.03%	0.00%	38.87%	0.08%	15.87%	1.19%	1.31%	40.19%	0.00%	0.00%	0.00%
Dry Creek	OK520700-04-0020F	45299.27	0.54%	3.93%	0.36%	0.20%	0.06%	0.01%	29.95%	0.59%	0.15%	1.55%	51.88%	8.91%	1.62%	0.14%	0.11%
Elk Creek (McIntosh)	OK120400-02-0190F	23078.91	0.53%	4.24%	1.39%	0.48%	0.18%	0.04%	12.56%	0.07%	0.08%	1.49%	5.00%	71.89%	1.95%	0.05%	0.06%

Site Name	WBID	Watershed Area (Hectares)	Open Water	Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Barren Land	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Woody Wetlands	Emergent Wetlands
Elk Creek (Cherokee)	OK121700-02-0180G	3701.61	0.05%	1.33%	0.05%	0.00%	0.00%	0.00%	81.92%	0.04%	2.67%	0.48%	0.72%	12.74%	0.00%	0.00%	0.00%
Fourche Maline Creek	OK220100-04-0020H	68961.56	0.46%	2.57%	0.60%	0.22%	0.11%	0.04%	24.07%	16.87%	29.46%	1.83%	2.92%	19.14%	0.00%	1.65%	0.06%
Gaines Creek	OK220600-04-0010F	46584.52	0.13%	1.88%	0.26%	0.08%	0.07%	0.13%	29.59%	13.36%	21.35%	2.82%	8.19%	20.15%	0.00%	1.92%	0.06%
Gar Creek	OK520510-00-0080C	9480.86	0.27%	3.05%	0.17%	0.10%	0.01%	0.00%	48.00%	0.00%	0.01%	1.72%	31.09%	15.59%	0.00%	0.00%	0.00%
Gentry Creek	OK520700-01-0080L	3232.77	0.40%	2.72%	0.03%	0.01%	0.00%	0.00%	18.02%	0.03%	0.00%	2.83%	4.94%	65.76%	5.25%	0.00%	0.01%
George's Fork of Dirty Creek	OK120400-02-0110D	13444.00	0.57%	3.92%	1.16%	0.32%	0.10%	0.02%	26.41%	0.03%	0.02%	0.20%	5.37%	61.44%	0.19%	0.22%	0.03%
Greenleaf Creek	OK120400-01-0120C	17629.15	0.08%	2.90%	0.12%	0.04%	0.02%	0.31%	73.57%	0.04%	1.64%	0.52%	1.49%	19.03%	0.00%	0.23%	0.01%
Hog Creek	OK520810-00-0030D	10691.35	0.19%	10.40%	4.40%	0.94%	0.14%	0.03%	44.05%	0.04%	0.08%	3.59%	32.15%	3.98%	0.00%	0.01%	0.01%
Holson Creek	OK220100-04-0030G	18146.62	0.07%	1.83%	0.10%	0.01%	0.00%	0.00%	14.54%	63.38%	15.42%	0.71%	1.23%	2.70%	0.00%	0.01%	0.00%
Little Deep Fork	OK520700-06-0010D	65141.05	0.68%	3.29%	0.64%	0.26%	0.09%	0.00%	49.57%	0.01%	0.04%	2.39%	29.24%	13.27%	0.44%	0.01%	0.06%
Little Wewoka Creek	OK520500-02-0090D	15291.49	1.25%	2.65%	0.15%	0.02%	0.00%	0.00%	40.29%	0.03%	0.05%	2.33%	27.38%	25.65%	0.05%	0.14%	0.02%
Longtown Creek	OK220600-01-0070P	8274.25	0.16%	2.44%	0.19%	0.11%	0.01%	0.03%	32.67%	1.16%	6.63%	1.97%	8.22%	46.39%	0.00%	0.01%	0.00%
Manard Bayou	OK120400-01-0280E	13620.01	0.18%	3.22%	0.56%	0.44%	0.05%	0.15%	44.09%	0.19%	4.81%	1.58%	1.52%	43.20%	0.00%	0.02%	0.00%
Mill Creek	OK220600-01-0100J	18082.75	0.34%	2.15%	0.31%	0.10%	0.01%	0.01%	53.44%	0.36%	0.32%	6.37%	20.50%	16.01%	0.03%	0.04%	0.02%
Montezumah Creek	OK520700-01-0220D	12538.85	0.30%	2.93%	0.31%	0.05%	0.02%	0.01%	38.26%	0.01%	0.02%	2.27%	24.16%	31.51%	0.06%	0.06%	0.03%
Nuyaka Creek	OK520700-02-0200D	16399.76	0.40%	3.06%	0.21%	0.07%	0.01%	0.01%	36.57%	0.00%	0.06%	2.41%	17.73%	38.11%	1.22%	0.12%	0.02%
Opossum Creek	OK520700-05-0200C	7490.59	0.58%	2.94%	0.14%	0.00%	0.00%	0.02%	48.28%	0.01%	0.08%	1.50%	42.62%	2.31%	1.42%	0.02%	0.07%
Peaceable Creek	OK220600-03-0050F	34804.06	1.00%	3.99%	1.02%	0.73%	0.40%	0.11%	42.17%	0.10%	0.16%	4.11%	22.47%	23.31%	0.00%	0.35%	0.08%
Peacheater Creek	OK121700-05-0120B	6382.01	0.01%	3.59%	0.32%	0.12%	0.05%	0.03%	43.05%	0.31%	1.68%	0.86%	1.48%	48.48%	0.00%	0.03%	0.00%
Peavine Creek	OK121700-05-0190F	3367.62	0.04%	5.38%	0.63%	0.11%	0.03%	0.02%	40.65%	0.16%	0.78%	2.80%	1.26%	48.11%	0.00%	0.01%	0.00%
Pecan Creek (Muskogee)	OK120410-01-0030D	13108.19	0.64%	3.43%	0.28%	0.05%	0.06%	0.00%	21.31%	0.14%	0.07%	1.82%	4.00%	67.85%	0.23%	0.07%	0.06%
Pecan Creek (Pottawatomie)	OK520800-02-0080C	8341.44	0.13%	5.91%	0.51%	0.06%	0.01%	0.00%	64.53%	0.01%	0.01%	1.75%	23.95%	3.08%	0.00%	0.02%	0.02%
Polecat Creek	OK120420-02-0050B	32923.31	0.98%	2.88%	0.42%	0.10%	0.02%	0.01%	59.63%	0.00%	0.02%	1.77%	27.98%	6.12%	0.07%	0.00%	0.03%

Site Name	WBID	Watershed Area (Hectares)	Open Water	Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Barren Land	Deciduous Forest	Evergreen Forest	Mixed Forest	Shrub/Scrub	Grassland/Herbaceous	Pasture/Hay	Cultivated Crops	Woody Wetlands	Emergent Wetlands
Pumpkin Hollow Creek	OK121700-03-0090G	4088.45	0.00%	2.03%	0.02%	0.00%	0.00%	0.00%	63.53%	5.17%	17.42%	0.28%	0.55%	10.95%	0.00%	0.02%	0.02%
Quapaw Creek	OK520700-04-0260C	38595.69	0.93%	3.49%	0.55%	0.07%	0.03%	0.01%	34.69%	0.05%	0.13%	1.15%	48.78%	8.90%	1.17%	0.01%	0.03%
Sallisaw Creek	OK220200-03-0010C	46944.31	0.70%	2.47%	0.39%	0.06%	0.01%	0.13%	63.58%	0.36%	3.36%	1.28%	1.28%	26.16%	0.01%	0.20%	0.00%
Salt Creek (Creek)	OK520700-03-0100B	23996.00	1.49%	3.36%	0.70%	0.33%	0.16%	0.00%	39.41%	0.12%	0.03%	2.18%	39.92%	11.34%	0.87%	0.03%	0.05%
Salt Creek (Seminole)	OK520800-03-0010D	54600.73	0.61%	3.28%	0.37%	0.04%	0.01%	0.03%	45.53%	0.02%	0.12%	1.42%	40.85%	6.45%	0.11%	0.47%	0.68%
San Bois Creek	OK220200-04-0010G	75831.79	0.47%	1.98%	0.32%	0.13%	0.05%	0.25%	22.75%	10.12%	20.70%	1.46%	6.68%	33.89%	0.04%	1.08%	0.07%
Shady Grove Creek	OK120400-02-0240H	3870.43	1.03%	2.80%	0.46%	0.13%	0.00%	0.03%	24.87%	0.07%	0.00%	0.60%	10.41%	59.32%	0.00%	0.03%	0.24%
Snake Creek (Tulsa)	OK120410-01-0220G	42347.87	0.37%	3.65%	0.64%	0.19%	0.05%	0.00%	36.76%	0.00%	0.02%	1.78%	9.46%	46.12%	0.84%	0.07%	0.04%
Snake Creek (Sequoyah)	OK121700-02-0100G	845.94	0.28%	3.22%	0.33%	0.09%	0.02%	0.01%	85.90%	0.15%	5.89%	0.39%	0.47%	3.26%	0.00%	0.00%	0.00%
South Fork Dirty Creek	OK120400-02-0030H	11937.25	0.54%	3.72%	0.55%	0.13%	0.02%	0.03%	20.92%	0.07%	0.03%	0.09%	9.11%	62.84%	1.70%	0.19%	0.06%
Steely Hollow Creek	OK121700-03-0120G	1023.07	0.01%	5.40%	0.39%	0.02%	0.00%	0.00%	60.92%	2.15%	7.21%	0.02%	1.04%	22.85%	0.00%	0.00%	0.00%
Sugar Loaf Creek	OK220100-01-0160G	16130.35	0.07%	2.19%	0.18%	0.10%	0.01%	0.01%	22.48%	27.10%	22.36%	1.16%	2.46%	21.76%	0.00%	0.11%	0.01%
Taloka Creek	OK220300-00-0020M	5233.44	0.98%	4.30%	2.07%	0.78%	0.35%	0.12%	11.24%	0.01%	1.14%	0.67%	5.91%	72.30%	0.00%	0.13%	0.01%
Telemay Hollow Creek	OK121700-03-0140G	536.09	0.03%	0.40%	0.00%	0.00%	0.00%	0.00%	88.79%	0.39%	8.60%	0.35%	1.13%	0.30%	0.00%	0.00%	0.00%
Turkey Creek	OK520510-00-0100F	13573.95	0.66%	3.36%	0.93%	0.22%	0.04%	0.00%	18.06%	0.01%	0.06%	1.43%	48.21%	25.97%	1.02%	0.00%	0.03%
Tyner Creek	OK121700-05-0090J	9223.39	0.02%	3.18%	0.11%	0.14%	0.14%	0.01%	55.74%	0.06%	0.48%	3.30%	1.85%	34.94%	0.00%	0.03%	0.00%
Vian Creek	OK220200-02-0130E	6288.70	0.05%	3.67%	0.40%	0.03%	0.00%	0.04%	76.87%	0.07%	1.51%	1.31%	1.29%	14.72%	0.00%	0.03%	0.00%
Wewoka Creek	OK520500-02-0010C	108806.03	1.54%	4.07%	1.12%	0.36%	0.12%	0.06%	34.31%	0.09%	0.12%	1.83%	29.50%	26.17%	0.14%	0.45%	0.13%

Table 17. Permitted land use for each Group 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) monitoring sites. Each site given a unique identifier (WBID)

Site Name	WBID	# CAFO	# Landfill	# Permitted Discharge	# O & G Wells	# Total Retention Lagoon	# Land Application	# Public Water Intakes
Alabama Creek	OK520500-01-0200D				590			
Ash Creek	OK120410-01-0110E				1537			
Bad Creek	OK520500-01-0170E				1416			1
Ballard Creek	OK121700-03-0370G							
Battle Creek	OK121700-06-0040G				2			
Bear Creek	OK520700-05-0170A			4	1105	1	5	12
Big Creek	OK220100-02-0080B							
Big Skin Bayou	OK220200-01-0030K		1		29			
Bird Creek	OK520800-01-0050M	1			774		1	
Black Fork of Poteau River	OK220100-02-0040P							
Brazil Creek	OK220100-03-0010G			78	1255			
Brushy Creek	OK220600-03-0010L				223			
Butler Creek	OK120400-02-0160P				134		2	
Canadian Sandy Creek	OK520600-03-0010D		2	16	1342		1	9
Captain Creek	OK520700-05-0140H				479		1	2
Caston Creek	OK220100-01-0180B			20	136		1	
Cloud Creek	OK120410-01-0100T			37	7620		1	
Coal Creek	OK220600-02-0010F		2	22	1243	1	1	5
Deep Branch	OK121700-01-0020A							
Dry Creek	OK520700-04-0020F			8	3009	10	1	7
Elk Creek (McIntosh)	OK120400-02-0190F			19	229	1		
Elk Creek (Cherokee)	OK121700-02-0180G							
Fourche Maline Creek	OK220100-04-0020H			39	767			2
Gaines Creek	OK220600-04-0010F			20	321			
Gar Creek	OK520510-00-0080C				766			4
Gentry Creek	OK520700-01-0080L				105			
George's Fork of Dirty Creek	OK120400-02-0110D			6	159			
Greenleaf Creek	OK120400-01-0120C		1	5	2			4
Hog Creek	OK520810-00-0030D				144	3		41
Holson Creek	OK220100-04-0030G				10			
Little Deep Fork	OK520700-06-0010D		2	23	8093	1	4	33

Site Name	WBID	# CAFO	# Landfill	# Permitted Discharge	# O & G Wells	# Total Retention Lagoon	# Land Application	# Public Water Intakes
Little Wewoka Creek	OK520500-02-0090D	5			1878			
Longtown Creek	OK220600-01-0070P				199			
Manard Bayou	OK120400-01-0280E			4	7			2
Mill Creek	OK220600-01-0100J				249			7
Montezumah Creek	OK520700-01-0220D	1			1942			1
Nuyaka Creek	OK520700-02-0200D				1357			
Opossum Creek	OK520700-05-0200C				279			1
Peaceable Creek	OK220600-03-0050F			20	330			
Peacheater Creek	OK121700-05-0120B					2		
Peavine Creek	OK121700-05-0190F							
Pecan Creek (Muskogee)	OK120410-01-0030D				711		12	
Pecan Creek (Pottawatomie)	OK520800-02-0080C				154			6
Polecat Creek	OK120420-02-0050B				3944	1	7	10
Pumpkin Hollow Creek	OK121700-03-0090G				2			
Quapaw Creek	OK520700-04-0260C			8	752	2		8
Sallisaw Creek	OK220200-03-0010C			10	8	6		
Salt Creek (Creek)	OK520700-03-0100B		1	8	1691	1	2	21
Salt Creek (Seminole)	OK520800-03-0010D			22	5648			12
San Bois Creek	OK220200-04-0010G			14	2290			
Shady Grove Creek	OK120400-02-0240H				5			
Snake Creek (Tulsa)	OK120410-01-0220G			17	4490	3	22	1
Snake Creek (Sequoyah)	OK121700-02-0100G							
South Fork Dirty Creek	OK120400-02-0030H			8	41			
Steely Hollow Creek	OK121700-03-0120G							
Sugar Loaf Creek	OK220100-01-0160G				249			
Taloka Creek	OK220300-00-0020M			10	17	1		
Telemay Hollow Creek	OK121700-03-0140G							
Turkey Creek	OK520510-00-0100F				1340			
Tyner Creek	OK121700-05-0090J				1			
Vian Creek	OK220200-02-0130E			4	2			
Wewoka Creek	OK520500-02-0010C	9	1	55	11029	2	1	89

Table 18. Comparisons of site chemistry at rotating Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins) monitoring sites with and without National Pollution Discharge Elimination System (NPDES) permits based on one-way ANOVAs. Comparisons where p-values were less than 0.05 were considered significantly different.

Parameter	NPDES Permit	Sample Size (N)	Mean	Standard Deviation	p Value	Result
Alkalinity	NO	627	118.11	85.88	<0.001	Lower
	YES	351	155.06	106.68		
Conductivity	NO	654	439.4	516.6	<0.001	Lower
	YES	366	591.3	622.1		
DO	NO	628	8.039	2.963	0.381	No significant difference
	YES	349	7.865	2.975		
DO % Saturation	NO	626	80.855	21.588	0.372	No significant difference
	YES	347	82.19	23.45		
Flow	NO	593	14.47	32.29	<0.001	Lower
	YES	306	35.6	68.12		
Hardness	NO	626	178.90	140.25	<0.001	Lower
	YES	351	215.58	155.75		
pH	NO	624	7.4967	0.4751	<0.001	Lower
	YES	350	7.6571	0.4783		
Water Temp	NO	634	17.626	8.161	<0.001	Lower
	YES	353	19.832	8.932		
Turbidity	NO	687	23.80	54.99	0.214	No significant difference
	YES	390	27.74	39.72		
Ammonia	NO	219	0.0431	0.1549	0.668	No significant difference
	YES	150	0.0371	0.0822		
Chloride	NO	559	52.24	132.46	0.123	No significant difference
	YES	306	68.37	170.28		
TDS	NO	560	272.3	290.7	<0.001	Lower
	YES	306	353.9	347.8		
TKN	NO	561	0.4312	0.3266	<0.001	Lower
	YES	306	0.5377	0.3121		
Nitrate	NO	560	0.4345	0.8545	<0.001	Higher
	YES	306	0.1124	0.147		
Ortho P	NO	560	0.02679	0.03094	<0.001	Lower
	YES	306	0.0424	0.05077		
Total P	NO	561	0.05113	0.04834	<0.001	Lower
	YES	307	0.07464	0.07076		
Sulfate	NO	562	37.2	248.8	0.461	No significant difference

Parameter	NPDES Permit	Sample Size (N)	Mean	Standard Deviation	p Value	Result
	YES	306	47.93	76.49		
TSS	NO	559	15.131	20.105	0.071	No significant difference
	YES	306	17.89	23.59		
Available N	NO	560	0.4513	0.8546	<0.001	Higher
	YES	306	0.1306	0.1717		
Total N	NO	561	0.8649	0.8319	<0.001	Higher
	YES	306	0.6501	0.3839		

3.4 DESIGNATED USE SUPPORT ASSESSMENT

The designated uses assessed for the monitoring sites are presented in Table 19 below, along with the current attainment status of each use based on the 2020 Integrated Report (ODEQ). The causes and potential source(s) (if known) of any impairments can be found in the Integrated Report. No stream monitored in Basin 3 is in full attainment of its designated uses. A list of parameters for which a stream is listed can be found in Appendix D, along with information regarding TMDL development status.

Table 19. Designated use support assessment for rotating basin monitoring sites in Basin 3 (Lower North Canadian, Lower Canadian, and Lower Arkansas Basins). Each site was assigned a unique waterbody identifier (WBID). Beneficial uses are listed along with the support status (F = fully supporting, N = not supporting, I = insufficient information, X = use not assessed, * = antidegredation designation). The category describes the different levels of beneficial use attainment (2 = attaining some uses and insufficient or no data to determine others, 3 = insufficient or no data to determine if any use is attaining, 4a = not attaining one or more use, but a TMDL has been completed, 5a = one or more use is not attaining due to pollutants, but a TMDL is underway or scheduled, and 5b = one or more use is not attaining due to pollutants, a TMDL is required.) Blanks indicate that a particular beneficial use was not designated for a waterbody.

SiteName	WBID	Size (Miles)	Category	Aesthetic	Agriculture	Cool Water Aquatic	Habitat Limited Aquatic	Warm Water Aquatic	Fish Consumption	Primary Body Contact Rec	Secondary Body Contact Rec	Public and Private Water Supply	Emergency Water Supply	Sensitive Water Supply	High Quality Water
Alabama Creek	OK520500-01-0200D	14.20	5a	N	F			N	X	F		N			
Ash Creek	OK120410-01-0110E	17.71	5a	F	F			N	X	F		I			
Bad Creek	OK520500-01-0170E	19.11	5a	N	F			N	X	F		N			
Ballard Creek	OK121700-03-0370G	12.60	2	F	F	I			X	F		I			
Battle Creek	OK121700-06-0040G	5.43	2	F	F	F			X	F					
Bear Creek	OK520700-05-0170A	26.06	5a	F	F			N	X	F		I			
Big Creek	OK220100-02-0080B	12.57	5a	F	F	N			X	F		I			
Big Skin Bayou	OK220200-01-0030K	18.51	2	F	F			I	X	F		I			
Bird Creek	OK520800-01-0050M	13.81	5a	F	F		N		X		F				
Black Fork of Poteau River	OK220100-02-0040P	28.60	5a	F	F			N	X	I		I			

SiteName	WBID	Size (Miles)	Category	Aesthetic	Agriculture	Cool Water Aquatic	Habitat Limited Aquatic	Warm Water Aquatic	Fish Consumption	Primary Body Contact Rec	Secondary Body Contact Rec	Public and Private Water Supply	Emergency Water Supply	Sensitive Water Supply	High Quality Water
Brazil Creek	OK220100-03-0010G	17.83	2	F	F			I	X	F		I			
Brushy Creek	OK220600-03-0010L	25.03	5a	F	F			N	I	F		I			
Butler Creek	OK120400-02-0160P	10.34	5a	F	F			N	X	N					
Canadian Sandy Creek	OK520600-03-0010D	37.70	5a	F	F			N	X	F		I			
Captain Creek	OK520700-05-0140H	4.40	5a	F	F			N	X	N		I			
Caston Creek	OK220100-01-0180B	14.43	5b	F	N			F	X	F		I			
Cloud Creek	OK120410-01-0100T	4.77	5a	F	F			N	X	F		I			
Coal Creek	OK220600-02-0010F	9.77	5a	F	F			N	X	F		I			
Deep Branch	OK121700-01-0020A	8.71	5a	F	F			N	X	F					
Dry Creek	OK520700-04-0020F	28.27	5c	F	F			N	X	N		I			
Elk Creek (McIntosh)	OK120400-02-0190F	13.96	5b	F	N			I	X	F					
Elk Creek (Cherokee)	OK121700-02-0180G	8.46	5a	F	F			N	X	I					
Fourche Maline Creek	OK220100-04-0020H	36.94	5a	F	F			N	F	N		F			
Gaines Creek	OK220600-04-0010F	38.22	5a	F	F			N	X	F		I			
Gar Creek	OK520510-00-0080C	12.60	2	F	F			F	X	F					
Gentry Creek	OK520700-01-0080L	9.64	5a	F	F			N	X	N					
George's Fork of Dirty Creek	OK120400-02-0110D	10.05	5a	F	F			N	X	F		I	F		
Greenleaf Creek	OK120400-01-0120C	15.31	5c	F	F			N	X	F		I		*	
Hog Creek	OK520810-00-0030D	11.89	2	F	F			I	X	F		I		*	
Holson Creek	OK220100-04-0030G	17.38	5a	F	F			N	X	I		X			
Little Deep Fork	OK520700-06-0010D	20.30	2	F	F			I	I	F					
Little Wewoka Creek	OK520500-02-0090D	20.44	5a	F	F			N	X	F		I			
Longtown Creek	OK220600-01-0070P	12.14	5a	F	F			N	X	F		I			
Manard Bayou	OK120400-01-0280E	14.02	5c	F	F			N	X	F		I			
Mill Creek	OK220600-01-0100J	24.16	5a	F	F			N	X	F		I			
Montezumah Creek	OK520700-01-0220D	22.39	5a	F	F			N	X	F					
Nuyaka Creek	OK520700-02-0200D	21.72	5a	F	F			N	X	N		I			
Opossum Creek	OK520700-05-0200C	7.37	4a	F	F			N	X	I					
Peaceable Creek	OK220600-03-0050F	17.14	5a	F	F			N	I	F		I			
Peacheater Creek	OK121700-05-0120B	10.95	2	F	F	F			X	F		I			
Peavine Creek	OK121700-05-0190F	7.19	2	F	F	F			X	I					
Pecan Creek (Muskogee)	OK120410-01-0030D	17.01	5a	F	F			N	X	N		I			
Pecan Creek (Pottawatomie)	OK520800-02-0080C	10.80	5a	F	F			N	X	F					
Polecat Creek	OK120420-02-0050B	29.83	2	F	F			I	X	I					
Pumpkin Hollow Creek	OK121700-03-0090G	9.27	5a	X	X			N	X	X					
Quapaw Creek	OK520700-04-0260C	26.81	5c	F	F			N	X	F		I			
Sallisaw Creek	OK220200-03-0010C	9.00	2	F	F	I			X	F		I			*
Salt Creek (Creek)	OK520700-03-0100B	22.35	2	F	F			I	X	F		I			
Salt Creek (Seminole)	OK520800-03-0010D	39.02	5b	F	N			F	X	F		I			
San Bois Creek	OK220200-04-0010G	10.76	5b	F	N			I	X	F		I			
Shady Grove Creek	OK120400-02-0240H	10.80	5a	F	N			N	X	F					

SiteName	WBID	Size (Miles)	Category	Aesthetic	Agriculture	Cool Water Aquatic	Habitat Limited Aquatic	Warm Water Aquatic	Fish Consumption	Primary Body Contact Rec	Secondary Body Contact Rec	Public and Private Water Supply	Emergency Water Supply	Sensitive Water Supply	High Quality Water
Snake Creek (Tulsa)	OK120410-01-0220G	31.43	5a	F	F			N	X	N		I			
Snake Creek (Sequoyah)	OK121700-02-0100G	2.66	5a	F	F			N	X	I					
South Fork Dirty Creek	OK120400-02-0030H	15.55	5a	F	N			N	X	F					
Steely Hollow Creek	OK121700-03-0120G	3.12	2	F	F			I	X	X					
Sugar Loaf Creek	OK220100-01-0160G	15.00	5a	F	F			N	X	F		I			
Taloka Creek	OK220300-00-0020M	16.00	5b	F	N			F	X	X		X			
Telemay Hollow Creek	OK121700-03-0140G	2.54	2	F	F			F	X	X					
Turkey Creek	OK520510-00-0100F	16.42	5b	F	N			I	X	F		I			
Tyner Creek	OK121700-05-0090J	15.92	5a	F	I	N			X	F		X			
Vian Creek	OK220200-02-0130E	21.42	5a	F	F	N			X	F		I			
Wewoka Creek	OK520500-02-0010C	42.99	5c	F	F			N	X	F			F		

4.0 SUMMARY

In general, water chemistry for the Rotating Basin Group 3 monitoring sites showed some changes when compared with the previous cycles. Salt concentrations (chloride, sulfate, and total dissolved solids) decreased as well as alkalinity and/or hardness.

Habitat at Deep Branch, Greenleaf Creek, Manard Bayou, Sallisaw Creek, Bear Creek, Polecat Creek, Snake Creek (Tulsa), Peacheater Creek, Pumpkin Hollow Creek, and Telemay Hollow Creek fell below two standard deviations of the mean habitat score of high quality sites in the same ecoregion. Comparisons of fish collections with the last two cycles indicate 16 of the sites showed improved conditions, nine of the sites showed worse conditions, and 19 indicated the same conditions. Overall, approximately 53% of the sites scored excellent, 18% were good, 18% were fair, and 11% were poor.

Most sites had either non-impaired (17%) or slightly impaired (64%) macroinvertebrate communities overall; 19% of the sites had collections that indicate moderately impaired communities. Three sites did not have macroinvertebrate collections due to lack of flow.

The next cycle of monitoring in Basin 3 is scheduled to begin in June, 2023.

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