Small Watershed Rotating Basin Monitoring Program

Basin Group 5: Lower Red River Basin

Final Report

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1.0 INTRODUCTION

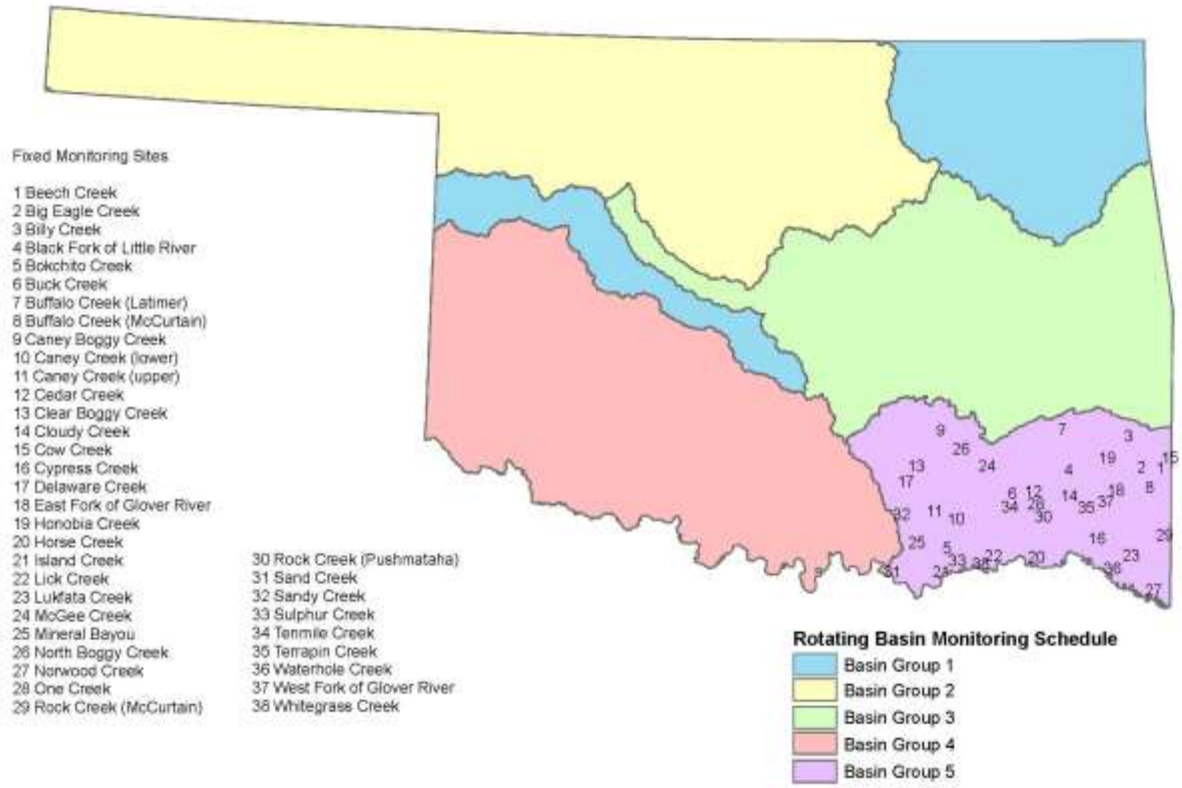
1.1 PROJECT BACKGROUND AND DESCRIPTION

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 programs to be implemented to correct any identified problems. In addition, each state's NPS agency is charged with identification of all programs which are actively planning or enforcing NPS controls in order to reduce NPS pollution in cooperation with local, regional, and interstate entities. 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 charged by Oklahoma state statute as the NPS Program technical lead 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-111). 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, with secondary sites located upstream in selected watersheds where isolation of a particular tributary influence is necessary. Fixed stations are segregated into strategic basin groups and 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. Probabilistic sites have not been monitored in Cycle 3. The fixed sites monitored in Cycle 3 are shown in Figure 1.

Figure 1. Monitoring sites in "Basin group 5" for third 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? Which waterbodies show elevated or increasing levels of NPS or NPS plus PS pollutants, which may threaten water quality?
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 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 third cycle of the Rotating Basin program in the Lower Red Basin (see Figure 1). Data will be discussed. *Implementation* and *success* monitoring are typically accomplished through priority watershed projects and reported on 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 Red Basin. 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 for a Rotating Basin site if the monitoring being conducted met the project data quality objectives. For most sub-watersheds, the monitoring site was located near the outflow of the primary stream 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 landuse 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 Red basin was accomplished prior to the first round of monitoring in 2005, and sites which did not meet the sampling criteria were removed from the project. Forty-two sites were monitored during the first rotating basin cycle, from 2005-2007. The second cycle of the monitoring of 41 sites in this basin occurred from June 2010-May 2012. The third cycle of monitoring in this basin occurred from June 2015-May 2017. Each cycle, several sites changed slightly due to landowner permission issues and several more were removed or added. There were 38 sites during this cycle of monitoring.

The sites monitored in the Lower Red Basin occur in five level-three ecoregions: the Arkansas Valley (AV), Cross Timbers (CT), East Central Texas Plains (ECTP), Ouachita Mountains (OM), and South Central Plains (SCP) (Woods et al., 2005). The fixed sites in the CT are in the “Arbuckle Uplift” level 4 ecoregion, which is a unique area in the CT region. These changes are indicated by the “modified ecoregion” column in Table 1.

Table 1. Site list for Rotating Basin Monitoring Program: Basin Group 5, Cycle 3.

Site Name	WBID	Latitude	Longitude	Legal Desc	County	Ecoregion	Modified Ecoregion
Beech Creek	OK410210-06-0320G	34.48682	-94.53915	SW¼ NW¼ NW¼ Section 12-1S-26E	McCurtain	OM	OM
Big Eagle Creek	OK410210-06-0160I	34.4899	-94.6842	NE NE 9-1S-25E	McCurtain	OM	OM
Billy Creek	OK410310-02-0070C	34.6822	-94.7759	SW¼ SE¼ SW¼ Section 34-3N-24E	LeFlore	OM	OM
Black Fork of Little River	OK410210-03-0020C	34.4729	-95.2171	NW¼ NE¼ NW¼ Section 16-1S-20E	Pushmataha	OM	OM
Bokchito Creek	OK410600-01-0090G	34.013	-96.12138	NE¼ SE¼ SW¼ Section 23-6S-11E	Bryan	SCP	SCP
Buck Creek	OK410300-03-0420C	34.3394	-95.6417	SE¼ SE¼ NE¼ Section 32-2S-16E	Pushmataha	OM	OM
Buffalo Creek (Latimer)	OK410310-03-0030N	34.7229	-95.2695	NW NW 24-3N-19E	Latimer	OM	OM
Buffalo Creek (McCurtain)	OK410210-06-0020G	34.36953	-94.62245	NW¼ SW¼ NW¼ Section 19-2S-26E	McCurtain	OM	OM
Caney Boggy Creek	OK410400-06-0120G	34.7195	-96.1731	NE¼ SW¼ NW¼ Section 20-3N-11E	Pontotoc	AV	AV
Caney Creek (lower)	OK410400-02-0200G	34.186	-96.0581	SE¼ SE¼ SE¼ Section 20-4S-12E	Atoka	SCP	SCP
Caney Creek (upper)	OK410400-03-0020C	34.241	-96.21708	NW¼ NE¼ NE¼ Section 2-4S-10E	Atoka	SCP	SCP
Cedar Creek	OK410300-03-0020M	34.33125	-95.4777	NW¼ NW¼ NW¼ Section 1-3S-17E	Pushmataha	OM	OM
Clear Boggy Creek	OK410400-03-0230K	34.5055	-96.3542	SE SE SE 33-1N-9E	Coal/Pontotoc	AV	AV
Cloudy Creek	OK410210-02-0300C	34.3247	-95.2234	SE¼ SE¼ NE¼ Section 5-3S-20E	Pushmataha	OM	OM
Cow Creek	OK410210-06-0350G	34.5068	-94.4939	NE¼ NW¼ NE¼ Section 5-1S-27E	McCurtain	OM	OM
Cypress Creek	OK410210-01-0070D	34.0695	-95.0193	NE NE 5-6S-22E	McCurtain	SCP	OM
Delaware Creek	OK410400-03-0240M	34.407	-96.4244	NW¼ SW¼ SW¼ SECTION 1-2S-8E	Johnston	CT	Arbuckle
East Fork of Glover River	OK410210-09-0010G	34.3557	-94.8721	NE¼ SW¼ NW¼ Section 26-2S-23E	McCurtain	OM	OM

Site Name	WBID	Latitude	Longitude	Legal Desc	County	Ecoregion	Modified Ecoregion
Honobia Creek	OK410210-03-0150H	34.548	-94.9329	SE NW 19-1N-23E	LeFlore	OM	OM
Horse Creek	OK410400-01-0040G	33.91003	-95.47578	NW¼ NW¼ NE¼ Section 36-7S-17E	Choctaw	SCP	SCP
Island Bayou	OK410700-00-0040G	33.85362	-96.16523	SW¼ SW¼ SW¼ Section 16-8S-11E	Bryan	ECTP	ECTP
Lick Creek	OK410400-01-0130G	33.95413	-95.78193	NE¼ NE¼ NE¼ Section 18-7S-15E	Choctaw	SCP	SCP
Lukfata Creek	OK410210-07-0010G	33.96817	-94.76617	NW¼ NW¼ NE¼ Section 11-7S-24E	McCurtain	SCP	SCP
McGee Creek	OK410400-07-0010L	34.5066	-95.8305	NW NW NW 3-1S-14E	Atoka	OM	OM
Mineral Bayou	OK410600-01-0300G	34.04478	-96.34497	SE¼ SE¼ SW¼ Section 10-6S-9E	Bryan	SCP	SCP
North Boggy Creek	OK410400-08-0010E	34.6078	-96.0172	SW SE SW 26-2N-12E	Atoka	AV	AV
Norwood Creek	OK410100-01-0050H	33.7133	-94.6075	NW¼ NW¼ SW¼ Section 4-10S-26E	McCurtain	SCP	SCP
One Creek	OK410300-03-0060F	34.3168	-95.4699	SE¼ SE¼ SE¼ Section 2-3S-17E	Pushmataha	OM	OM
Rock Creek (McCurtain)	OK410200-03-0010G	34.08407	-94.49043	NW¼ NE¼ NW¼ Section 33-5S-27E	McCurtain	OM	OM
Rock Creek (Pushmataha)	OK410300-02-0190G	34.2005	-95.418	SE¼ SW¼ SE¼ Section 16-4S-18E	Pushmataha	OM	OM
Sand Creek	OK410700-00-0260G	33.853	-96.5499	NE¼ NW¼ NW¼ Section 23-8S-7E	Bryan	ECTP	ECTP
Sandy Creek	OK410600-02-0020G	34.21688	-96.45925	NE¼ NE¼ NE¼ SECTION 16-4S-8E	Johnston	SCP	SCP
Sulphur Creek	OK410600-01-0030G	33.94658	-96.04985	SW¼ SW¼ NE¼ Section 16-7S-12E	Bryan	SCP	SCP
Tenmile Creek	OK410300-03-0270C	34.29913	-95.66118	SE¼ NW¼ NE¼ Section 18-3S-16E	Pushmataha	OM	OM
Terrapin Creek	OK410210-02-0150G	34.2551	-95.0981	SW¼ NW¼ NW¼ Section 34-3S-21E	Pushmataha	OM	OM
Waterhole Creek	OK410100-01-0340D	33.853	-94.91352	SE¼ SE¼ SE¼ Section 17-8S-23E	McCurtain	SCP	SCP
West Fork of Glover River	OK410210-08-0010M	34.30885	-94.9359	SW¼ NE¼ NW¼ Section 7-3S-23E	McCurtain	OM	OM
Whitegrass Creek	OK410400-01-0210G	33.88108	-95.85132	SW¼ SW¼ SW¼ Section 4-8S-14E	Choctaw	SCP	SCP

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, the Oklahoma Secretary of the Environment (OSE), and EPA Region VI in Dallas. The reader is encouraged to obtain and consult the QAPP for specific questions concerning laboratory analytical methods, detection limits, and accuracy and precision limits. All sampling and measurement activities of OCC Water Quality staff followed procedures outlined in the appropriate OCC Standard Operating Procedure (OCC 2015). 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 2015, 38 sites were monitored for physical and chemical parameters on a fixed interval schedule of ten sampling events per year (five-week intervals) through May 2017 (usually 20 total events per sites). 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. 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 2015).

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. Samples were submitted to the ODAFF Laboratory for analysis of the following parameters: Nitrate (NO_3), nitrite (NO_2), 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, nitrite, and TKN for each sample. Available nitrogen was calculated by summing the values of ammonia, nitrate, and nitrite. In addition, *in-situ* water quality parameters were measured at each sampling location and include 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.

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 2015, OCC staff began conducting instream and riparian habitat assessments at sites concurrent with fish collections; any sites not sampled in 2015 were sampled in the summer of 2016. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP (OCC 2015). 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 makeup, 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 general makeup (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 *Access* programming. 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.

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 things like 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 more stressed by the warmer waters and the 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 an 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, which 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 obtained in the summer of 2015 or 2016 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 (2015). 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 2013). In addition, each site was assessed using 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. 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). IBI scores that fell between the assessment ranges were classified in the closest scoring group. 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 interpretation for fish.

% Comparison to the Reference Score	Integrity Class	Characteristics
97 – 100 %	Excellent	Comparable to pristine conditions, exceptional species assemblage
80 – 87%	Good	Decreased species richness, especially intolerant species
67 – 73%	Fair	Intolerant and sensitive species rare or absent
47 – 57%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
20 – 37%	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 for both winter and summer index periods of July 2015 through March 2017 according to procedures outlined in the OCC SOP (2015). Index periods represent seasons of relative community stability that afford opportunity for meaningful site comparisons. For Oklahoma, the summer index occurs from July 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 5 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 was 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 and 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. 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
>83%	Non-Impaired	Comparable to the best situation expected within the ecoregion. Balanced trophic and community structure for stream size.
54-79%	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.
21-50%	Moderately Impaired	Fewer species due to the loss of most intolerant forms. Reduction in EPT index.
<17%	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 2011 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. The NLCD was explored to determine percent occurrence of particular landuse types such as bare rock/sand/clay, vegetation (broken 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 2013). 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 2016 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 5 monitoring sites, 2015-2017

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)	Base Flow (cfs)
Beech Creek	OK410210-06-0320G	21.0	28.2	9.17	91	25.9	6.70	17.3	4.21	13.15	13.15
Big Eagle Creek	OK410210-06-0160I	18.9	28.3	8.43	84	32.8	6.86	17.5	4.75	17.07	17.07
Billy Creek	OK410310-02-0070C	26.1	56.0	8.48	86	20.0	6.23	17.3	11.92	2.64	2.34
Black Fork of Little River	OK410210-03-0020C	14.4	46.5	7.70	79	17.1	5.97	18.4	10.54	19.19	19.19
Bokchito Creek	OK410600-01-0090G	188.0	427.3	7.94	86	245.6	7.65	19.6	12.19	3.68	3.68
Buck Creek	OK410300-03-0420C	32.7	98.7	7.97	83	40.6	7.43	18.4	18.21	3.06	3.06
Buffalo Creek (Latimer)	OK410310-03-0030N	21.3	67.8	8.02	84	22.4	6.29	19.4	16.35	6.59	6.59
Buffalo Creek (McCurtain)	OK410210-06-0020G	28.4	43.6	8.04	80	49.1	6.87	17.7	5.35	16.61	16.61
Caney Boggy Creek	OK410400-06-0120G	90.2	280.8	6.71	70	129.3	7.65	18.4	40.97	10.48	10.48
Caney Creek (lower)	OK410400-02-0200G	103.2	378.3	5.33	53	189.8	7.68	17.4	42.60	0.01	0.01
Caney Creek (upper)	OK410400-03-0020C	185.4	487.0	8.05	85	245.8	7.79	18.8	24.10	2.84	2.84
Cedar Creek	OK410300-03-0020M	29.2	88.0	6.87	43	7.2	18.62	20.7	71.13	11.08	11.08
Clear Boggy Creek	OK410400-03-0230K	225.9	790.1	8.59	90	302.8	8.04	18.1	59.13	29.97	29.97
Cloudy Creek	OK410210-02-0300C	19.9	65.2	7.19	76	22.9	6.48	19.9	13.15	14.42	14.42
Cow Creek	OK410210-06-0350G	26.8	34.0	8.25	82	30.9	6.59	17.3	8.37	13.26	13.26
Cypress Creek	OK410210-01-0070D	53.7	94.9	6.76	65	111.5	6.73	17.1	6.96	2.60	2.60

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)	Base Flow (cfs)
Delaware Creek	OK410400-03-0240M	203.4	690.5	7.44	77	283.4	8.04	17.9	19.79	13.60	13.60
East Fork of Glover River	OK410210-09-0010G	12.7	36.3	8.21	84	11.6	6.11	18.6	7.00	10.33	10.07
Honobia Creek	OK410210-03-0150H	11.8	27.7	9.15	93	20.4	6.09	17.9	7.55	13.47	13.47
Horse Creek	OK410400-01-0040G	128.0	355.3	7.36	75	188.7	7.47	18.1	19.57	7.12	7.12
Island Bayou	OK410700-00-0040G	191.6	665.0	7.76	82	268.5	7.66	19.3	45.64	2.42	2.42
Lick Creek	OK410400-01-0130G	135.3	291.2	5.57	57	194.5	7.41	18.1	56.13	0.30	0.30
Lukfata Creek	OK410210-07-0010G	121.9	169.4	7.86	81	153.5	6.90	18.7	11.92	7.99	7.99
McGee Creek	OK410400-07-0010L	46.3	133.8	7.48	78	64.7	7.27	19.6	24.20	10.41	10.41
Mineral Bayou	OK410600-01-0300G	163.1	394.8	8.78	94	198.8	7.77	19.3	35.40	4.80	4.80
North Boggy Creek	OK410400-08-0010E	53.1	301.5	6.92	75	106.8	7.35	19.2	68.88	3.82	3.82
Norwood Creek	OK410100-01-0050H	113.0	199.1	6.31	63	163.0	7.03	18.0	35.30	1.13	1.13
One Creek	OK410300-03-0060F	32.2	80.7	7.18	43	7.2	18.73	16.4	75.18	10.94	10.94
Rock Creek (McCurtain)	OK410200-03-0010G	46.3	52.1	8.01	79	78.8	6.87	18.0	6.91	5.31	5.31
Rock Creek (Pushmataha)	OK410300-02-0190G	23.5	77.7	7.11	74	23.3	6.38	19.4	14.96	9.96	9.96
Sand Creek	OK410700-00-0260G	131.1	356.8	9.05	101	190.2	7.96	21.6	29.04	6.62	6.62
Sandy Creek	OK410600-02-0020G	131.1	311.7	7.66	82	177.3	7.80	18.0	14.33	8.76	8.76
Sulphur Creek	OK410600-01-0030G	186.8	465.0	7.50	77	259.6	7.59	18.0	17.27	2.85	2.85
Tenmile Creek	OK410300-03-0270C	37.7	121.3	5.71	57	54.5	7.21	17.6	32.09	15.25	15.25
Terrapin Creek	OK410210-02-0150G	13.3	43.4	8.53	84	13.9	6.51	17.5	10.38	15.79	15.79
Waterhole Creek	OK410100-01-0340D	198.4	428.1	7.61	78	248.8	7.30	18.8	34.61	0.65	0.65
West Fork of Glover River	OK410210-08-0010M	14.5	43.8	8.13	84	13.4	6.40	19.1	8.10	24.46	24.46
Whitegrass Creek	OK410400-01-0210G	131.8	284.6	5.77	58	191.5	7.37	18.0	36.78	4.17	4.17

Table 7. Mean water quality values for Basin Group 5 monitoring sites, 2015-2017

Site Name	WBID	Ammonia (mg/L)	Chloride (mg/L)	TDS (mg/L)	TKN (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	OrthoP (mg/L)	Total P (mg/L)	Sulfate (mg/L)	TSS (mg/L)
Beech Creek	OK410210-06-0320G	0.0169	1.58	20.2	0.142	0.035	0.022	0.0050	0.0086	2.10	10.0
Big Eagle Creek	OK410210-06-0160I	0.0176	1.87	19.7	0.158	0.047	0.037	0.0051	0.0109	2.19	10.0
Billy Creek	OK410310-02-0070C	0.0266	3.17	32.7	0.322	0.060	0.022	0.0067	0.0236	3.70	11.2
Black Fork of Little River	OK410210-03-0020C	0.0165	3.64	31.6	0.252	0.081	0.021	0.0055	0.0203	3.37	10.2
Bokchito Creek	OK410600-01-0090G	0.0189	12.20	260.5	0.375	0.204	0.061	0.0153	0.0334	36.53	12.1

Site Name	WBID	Ammonia (mg/L)	Chloride (mg/L)	TDS (mg/L)	TKN (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	OrthoP (mg/L)	Total P (mg/L)	Sulfate (mg/L)	TSS (mg/L)
Buck Creek	OK410300-03-0420C	0.0290	9.50	70.3	0.384	0.049	0.030	0.0085	0.0355	6.56	15.0
Buffalo Creek (Latimer)	OK410310-03-0030N	0.0150	3.45	45.4	0.266	0.081	0.026	0.0088	0.0328	6.57	11.8
Buffalo Creek (McCurtain)	OK410210-06-0020G	0.0219	2.86	28.5	0.273	0.181	0.035	0.0091	0.0244	2.67	10.1
Caney Boggy Creek	OK410400-06-0120G	0.0367	17.43	191.5	0.625	0.105	0.058	0.0323	0.0751	31.13	25.3
Caney Creek (lower)	OK410400-02-0200G	0.1856	38.81	242.6	1.028	0.081	0.075	0.0438	0.1076	31.67	25.8
Caney Creek (upper)	OK410400-03-0020C	0.0536	39.32	296.0	0.587	0.067	0.118	0.0287	0.0654	26.51	32.1
Cedar Creek	OK410300-03-0020M	0.0193	8.17	57.5	0.357	0.074	0.030	0.0091	0.0361	4.65	12.0
Clear Boggy Creek	OK410400-03-0230K	0.0399	149.54	492.5	0.530	0.129	0.264	0.0709	0.1201	20.94	73.3
Cloudy Creek	OK410210-02-0300C	0.0270	5.73	49.0	0.337	0.089	0.021	0.0065	0.0270	3.73	10.0
Cow Creek	OK410210-06-0350G	0.0159	1.89	26.0	0.161	0.033	0.046	0.0057	0.0151	1.93	10.0
Cypress Creek	OK410210-01-0070D	0.0370	5.15	56.2	0.281	0.089	0.040	0.0097	0.0234	4.75	10.0
Delaware Creek	OK410400-03-0240M	0.0296	77.96	368.5	0.456	0.086	0.111	0.0557	0.0858	17.41	23.7
East Fork of Glover River	OK410210-09-0010G	0.0423	2.17	23.1	0.233	0.071	0.020	0.0053	0.0183	2.32	10.0
Honobia Creek	OK410210-03-0150H	0.0150	1.94	19.6	0.168	0.035	0.026	0.0050	0.0117	2.14	10.0
Horse Creek	OK410400-01-0040G	0.0581	32.77	226.5	0.758	1.443	0.074	0.1028	0.1507	30.90	19.5
Island Bayou	OK410700-00-0040G	0.0569	64.25	391.0	0.739	0.463	0.120	0.3049	0.3555	77.55	30.2
Lick Creek	OK410400-01-0130G	0.4330	21.28	187.6	1.242	0.106	0.114	0.0601	0.1580	16.32	26.0
Lukfata Creek	OK410210-07-0010G	0.0303	5.61	96.5	0.319	0.149	0.029	0.0279	0.0500	6.78	15.0
McGee Creek	OK410400-07-0010L	0.0161	8.11	99.4	0.440	0.060	0.049	0.0116	0.0446	16.20	11.1
Mineral Bayou	OK410600-01-0300G	0.0436	20.73	242.5	0.570	0.255	0.078	0.0784	0.1212	34.82	36.0
North Boggy Creek	OK410400-08-0010E	0.0309	10.45	148.9	0.707	0.076	0.055	0.0241	0.0853	16.12	203.9
Norwood Creek	OK410100-01-0050H	0.0570	19.66	136.8	0.885	0.228	0.094	0.0785	0.1347	12.27	15.5
One Creek	OK410300-03-0060F	0.0224	6.12	60.5	0.326	0.048	0.030	0.0119	0.0366	5.51	10.5
Rock Creek (McCurtain)	OK410200-03-0010G	0.0284	4.23	31.5	0.276	0.252	0.079	0.0052	0.0172	2.73	10.2
Rock Creek (Pushmataha)	OK410300-02-0190G	0.0175	5.30	56.9	0.472	0.087	0.022	0.0099	0.0421	5.87	10.1
Sand Creek	OK410700-00-0260G	0.0630	36.35	233.5	0.424	0.761	0.086	0.0302	0.0540	21.08	18.7
Sandy Creek	OK410600-02-0020G	0.0184	15.31	202.5	0.407	0.078	0.055	0.0260	0.0475	29.32	19.7
Sulphur Creek	OK410600-01-0030G	0.0390	38.71	294.0	0.427	0.048	0.083	0.0186	0.0416	22.31	13.2
Tenmile Creek	OK410300-03-0270C	0.0581	8.90	89.3	0.778	0.081	0.031	0.0379	0.1048	7.68	21.5
Terrapin Creek	OK410210-02-0150G	0.0668	4.06	35.8	0.384	0.088	0.022	0.0050	0.0205	2.82	10.0
Waterhole Creek	OK410100-01-0340D	0.0596	22.74	266.0	0.886	0.525	0.093	0.0900	0.1609	25.19	22.3
West Fork of Glover River	OK410210-08-0010M	0.0254	2.59	29.5	0.263	0.210	0.022	0.0065	0.0226	2.73	10.0
Whitegrass Creek	OK410400-01-0210G	0.0474	21.99	180.4	0.644	0.109	0.054	0.1056	0.1529	16.19	14.0

24 of the sites are designated as Warm Water Aquatic Communities (WWAC) and have a critical dissolved oxygen (DO) level of 5.0 mg/L most of the year (6.0 mg/L from April 1 – June 15). 14 of the sites have a Cool Water Aquatic Community (CWAC) designation, with a critical DO level of 6.0 mg/L most of the year (7.0 mg/L March 1 – May 31). Table 8 shows all instances of criteria exceedance. Only six sites (Bokchito Creek, Buffalo Creek in Latimer County, Clear Boggy Creek, Honobia Creek, Mineral Bayou, and Sand Creek) exhibited dissolved oxygen levels which were always above criteria values. Three sites (Beech, Buck, and Island Bayou Creeks) had one or two low DO samples but met the standards because 10% or fewer samples fell below critical levels.

It is commonly known that systems in the southeastern portion of the state, particularly those in McCurtain, LeFlore, and Pushmataha Counties, naturally tend toward sluggish, organically enriched conditions with promote high biological oxygen demand. These conditions result because few of these systems have a ground water influence, and most are high gradient riffle-pool habitat streams that cease flowing in early summer. Biological communities have developed under these naturally occurring conditions and are well adapted to the significantly lower DO trends. Fish and macroinvertebrate collections for many of these sites, which are discussed later, reflect good to excellent community assessment scores. In addition, this region of the state has some of the least developed landscapes, so there are few sources that would be causing the low DO. Because of this and other observations supporting these findings, OCC recommends for stat consideration the development of sites specific, if not regional, DO criteria that better reflect the naturally occurring low DO conditions that typify systems in this area.

Table 8. Low dissolved oxygen values (based on OAC 785:46-15; OWRB 2013)

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
10%	Beech Creek	OK410210-06-0320G	CWAC	8/25/2015	5.19
				9/29/2015	5.39
24%	Big Eagle Creek	OK410210-06-0160I	CWAC	7/21/2015	5.93
				8/25/2015	5.51
				9/29/2015	5.12
				8/9/2016	4.54
				7/6/2016	5.74
14%	Billy Creek	OK410310-02-0070C	WWAC	8/17/2015	4.2
				9/21/2015	2.43
				11/2/2015	3.95
43%	Black Fork of Little River	OK410210-03-0020C	CWAC	7/28/2015	4.93
				8/17/2015	5.25
				9/21/2015	5.28
				11/2/2015	4.79
				5/24/2016	6.7
				6/27/2016	5.54
				8/2/2016	5.52
				10/10/2016	4.9
				11/14/2016	5.43
5%	Buck Creek	OK410300-03-0420C	WWAC	10/18/2016	3.4
24%	Buffalo Creek (McCurtain)	OK410210-06-0020G	CWAC	6/16/2015	4.49
				7/21/2015	4.46
				8/25/2015	4.46
				9/29/2015	4.92
				8/9/2016	5.61
30%	Caney Boggy Creek	OK410400-06-0120G	WWAC	8/25/2015	4.53
				8/2/2016	3.51
				9/12/2016	2.81
				10/17/2016	3.02
				1/3/2017	4.54
				4/11/2017	5.2
53%	Caney Creek (lower)	OK410400-02-0200G	WWAC	6/8/2015	4.96
				8/20/2015	1.82
				8/17/2015	2.32
				9/21/2015	2.02
				10/26/2015	3.37
				6/27/2016	1.1
				8/9/2016	1.43
				8/29/2016	1.39
				11/15/2016	4.43
				4/4/2017	5.84
20%	Caney Creek (upper)	OK410400-03-0020C	WWAC	6/8/2015	5.99
				8/17/2015	4.1
				8/9/2016	3.35
				8/29/2016	3.87
45%	Cedar Creek	OK410300-03-0020M	CWAC	7/20/2015	4.87
				8/12/2015	4
				10/5/2015	5.58
				11/3/2015	3.24
				7/6/2016	4.14
				8/1/2016	3.7
				9/13/2016	4.27
				10/18/2016	3.77
				11/22/2016	5.83

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
38%	Cloudy Creek	OK410210-02-0300C	CWAC	6/9/2015	5.97
				7/14/2015	5.58
				7/21/2015	5.68
				8/18/2015	4.6
				9/22/2015	5.05
				11/3/2015	3.4
				6/28/2016	4.73
				10/10/2016	5.92
29%	Cow Creek	OK410210-06-0350G	CWAC	7/21/2015	5.48
				8/25/2015	4.02
				9/29/2015	4.11
				11/2/2015	4.56
				10/18/2016	4.31
				7/6/2016	5.39
48%	Cypress Creek	OK410210-01-0070D	CWAC	7/2/2015	4.4
				7/20/2015	2.99
				8/24/2015	3.64
				9/28/2015	2.08
				11/2/2015	1.82
				5/31/2016	5.88
				8/8/2016	2.06
				10/17/2016	2.24
				11/21/2016	4.99
				7/5/2016	3.29
19%	Delaware Creek	OK410400-03-0240M	WWAC	8/6/2015	4.9
				8/2/2016	4.74
				9/12/2016	3.06
				10/17/2016	1.13
25%	East Fork of Glover River	OK410210-09-0010G	CWAC	7/14/2015	5.97
				7/28/2015	3.86
				8/18/2015	4.15
				6/28/2016	4.1
				8/1/2016	4.95

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
24%	Horse Creek	OK410400-01-0040G	WWAC	6/9/2015	3.85
				7/30/2015	3.23
				8/18/2015	4.51
				8/8/2016	4.97
				7/14/2015	4.57
5%	Island Bayou	OK410700-00-0040G	WWAC	8/10/2016	4.98
43%	Lick Creek	OK410400-01-0130G	WWAC	6/9/2015	3.59
				8/18/2015	1.27
				9/22/2015	1.41
				10/27/2015	2.34
				6/28/2016	3.35
				8/30/2016	2.75
				11/14/2016	3.28
				7/14/2015	2.18
				10/10/2016	4.07
50%	Lukfata Creek	OK410210-07-0010G	CWAC	7/1/2015	5.11
				7/20/2015	5.6
				8/24/2015	4.86
				9/28/2015	4.85
				11/2/2015	5.85
				5/31/2016	6.95
				8/8/2016	1.89
				10/17/2016	3.61
				7/5/2016	5.75
				4/11/2017	6.34
20%	McGee Creek	OK410400-07-0010L	WWAC	8/1/2016	4.09
				9/13/2016	3.2
				10/18/2016	3.73
				4/10/2017	5.65
20%	North Boggy Creek	OK410400-08-0010E	WWAC	4/25/2016	5.48
				8/2/2016	4.46
				10/18/2016	3.52
				4/10/2017	4.13

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
45%	Norwood Creek	OK410100-01-0050H	WWAC	9/2/2015	3.12
				8/24/2015	4.27
				9/28/2015	1.78
				5/17/2016	4.83
				8/8/2016	3.32
				10/17/2016	1.71
				11/21/2016	4.18
				7/5/2016	4.19
				4/11/2017	5.36
30%	One Creek	OK410300-03-0060F	WWAC	6/15/2015	5.43
				7/20/2015	4.56
				11/3/2015	4.23
				7/6/2016	4.7
				8/1/2016	3.73
				10/18/2016	4
43%	Rock Creek (McCurtain)	OK410200-03-0010G	CWAC	6/15/2015	5.76
				7/20/2015	4.32
				7/16/2015	3.76
				8/24/2015	3.58
				9/28/2015	4.55
				5/31/2016	6.85
				8/8/2016	4.35
				10/17/2016	4.38
				7/5/2016	4.05

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
48%	Rock Creek (Pushmataha)	OK410300-02-0190G	CWAC	7/29/2015	2.14
				8/17/2015	5.88
				9/21/2015	4.95
				11/2/2015	2.63
				5/23/2016	6.46
				6/28/2016	5.15
				8/1/2016	4.87
				9/6/2016	5.67
				10/10/2016	4.79
				11/14/2016	5.25
15%	Sandy Creek	OK410600-02-0020G	WWAC	8/2/2016	4.76
				9/12/2016	4.53
				10/17/2016	2.96
15%	Sulphur Creek	OK410600-01-0030G	WWAC	8/18/2015	3.92
				9/22/2015	4.51
				10/10/2016	4.7
55%	Tenmile Creek	OK410300-03-0270C	WWAC	7/20/2015	2.27
				7/21/2015	2.62
				8/24/2015	3.32
				10/5/2015	2.54
				11/3/2015	2.95
				5/23/2016	5.49
				7/6/2016	2.29
				8/1/2016	2.26
				9/13/2016	4.24
				10/18/2016	4.07
				4/10/2017	5.52

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
19%	Terrapin Creek	OK410210-02-0150G	CWAC	8/18/2015	2.8
				11/3/2015	5.3
				6/28/2016	5.24
				8/1/2016	5.67
24%	Waterhole Creek	OK410100-01-0340D	WWAC	9/1/2015	4.52
				11/2/2015	4.5
				8/8/2016	3.31
				11/21/2016	3.59
				7/5/2016	4.35
29%	West Fork of Glover River	OK410210-08-0010M	CWAC	7/14/2015	5.9
				7/28/2015	5.27
				8/18/2015	4.63
				9/22/2015	5.72
				11/3/2015	5.75
				6/28/2016	5.1
43%	Whitegrass Creek	OK410400-01-0210G	WWAC	6/9/2015	5.23
				8/6/2015	3.28
				8/18/2015	4.02
				9/22/2015	3.36
				10/27/2015	2.29
				6/28/2016	3.79
				8/8/2016	2.89
				8/30/2016	2.28
				10/10/2016	2.38

Table 9 shows the geometric mean of *E. coli* bacteria samples for each site over the two-year monitoring period. Creeks highlighted in yellow are designated Secondary Body Contact Recreation (SBRC), which allows for a higher bacteria concentration: Caney Creek (upper) and Island Bayou. All other sites are designated Primary Body Contract Recreation (PBCR). Sixty-one percent of the streams meet the *E. coli* standard, as denoted by the asterisk in Table 9. 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 2013).

Table 9. Geometric mean of bacteria values for Basin 5 monitoring sites, 2015-2017 OCC data. An asterisk (*) indicates that the stream meets state standards for *E. coli.* Those highlighted in yellow have a SBCR designation, allowing higher bacteria concentrations.

Site Name	WBID	E. coli		Comments
Beech Creek	OK410210-06-0320G	21.68	*	Geometric Mean
Big Eagle Creek	OK410210-06-0160I	27.67	*	Geometric Mean
Billy Creek	OK410310-02-0070C	64.28	*	Geometric Mean
Black Fork of Little River	OK410210-03-0020C	50.05	*	Geometric Mean
Bokchito Creek	OK410600-01-0090G	68.68	*	Geometric Mean
Buck Creek	OK410300-03-0420C	62.89	*	Geometric Mean
Buffalo Creek (Latimer)	OK410310-03-0030N	141.32		Geometric Mean
Buffalo Creek (McCurtain)	OK410210-06-0020G	29.05	*	Geometric Mean
Caney Boggy Creek	OK410400-06-0120G	164.14		Geometric Mean
Caney Creek (lower)	OK410400-02-0200G	142.95		Geometric Mean
Caney Creek (upper)	OK410400-03-0020C	229.17		Geometric Mean
Cedar Creek	OK410300-03-0020M	257.73		Geometric Mean
Clear Boggy Creek	OK410400-03-0230K	207.20		Geometric Mean
Cloudy Creek	OK410210-02-0300C	54.57	*	Geometric Mean
Cow Creek	OK410210-06-0350G	36.71	*	Geometric Mean
Cypress Creek	OK410210-01-0070D	85.09	*	Geometric Mean
Horse Creek	OK410400-01-0040G	283.32		Geometric Mean
Island Bayou	OK410700-00-0040G	203.24		Geometric Mean
Lick Creek	OK410400-01-0130G	140.00		Geometric Mean
Lukfata Creek	OK410210-07-0010G	80.78	*	Geometric Mean
McGee Creek	OK410400-07-0010L	28.86	*	Geometric Mean
Mineral Bayou	OK410600-01-0300G	394.85		Geometric Mean
North Boggy Creek	OK410400-08-0010E	103.84	*	Geometric Mean
Norwood Creek	OK410100-01-0050H	138.24		Geometric Mean
One Creek	OK410300-03-0060F	91.45	*	Geometric Mean
Rock Creek (McCurtain)	OK410200-03-0010G	54.24	*	Geometric Mean
Rock Creek (Pushmataha)	OK410300-02-0190G	37.10	*	Geometric Mean
Sand Creek	OK410700-00-0260G	132.53		Geometric Mean
Sandy Creek	OK410600-02-0020G	400.04		Geometric Mean
Sulphur Creek	OK410600-01-0030G	102.00	*	Geometric Mean
Tenmile Creek	OK410300-03-0270C	64.05	*	Geometric Mean
Terrapin Creek	OK410210-02-0150G	19.13	*	Geometric Mean

Site Name	WBID	E. coli		Comments
Delaware Creek	OK410400-03-0240M	89.02	*	Geometric Mean
East Fork of Glover River	OK410210-09-0010G	28.77	*	Geometric Mean
Honobia Creek	OK410210-03-0150H	15.94	*	Geometric Mean

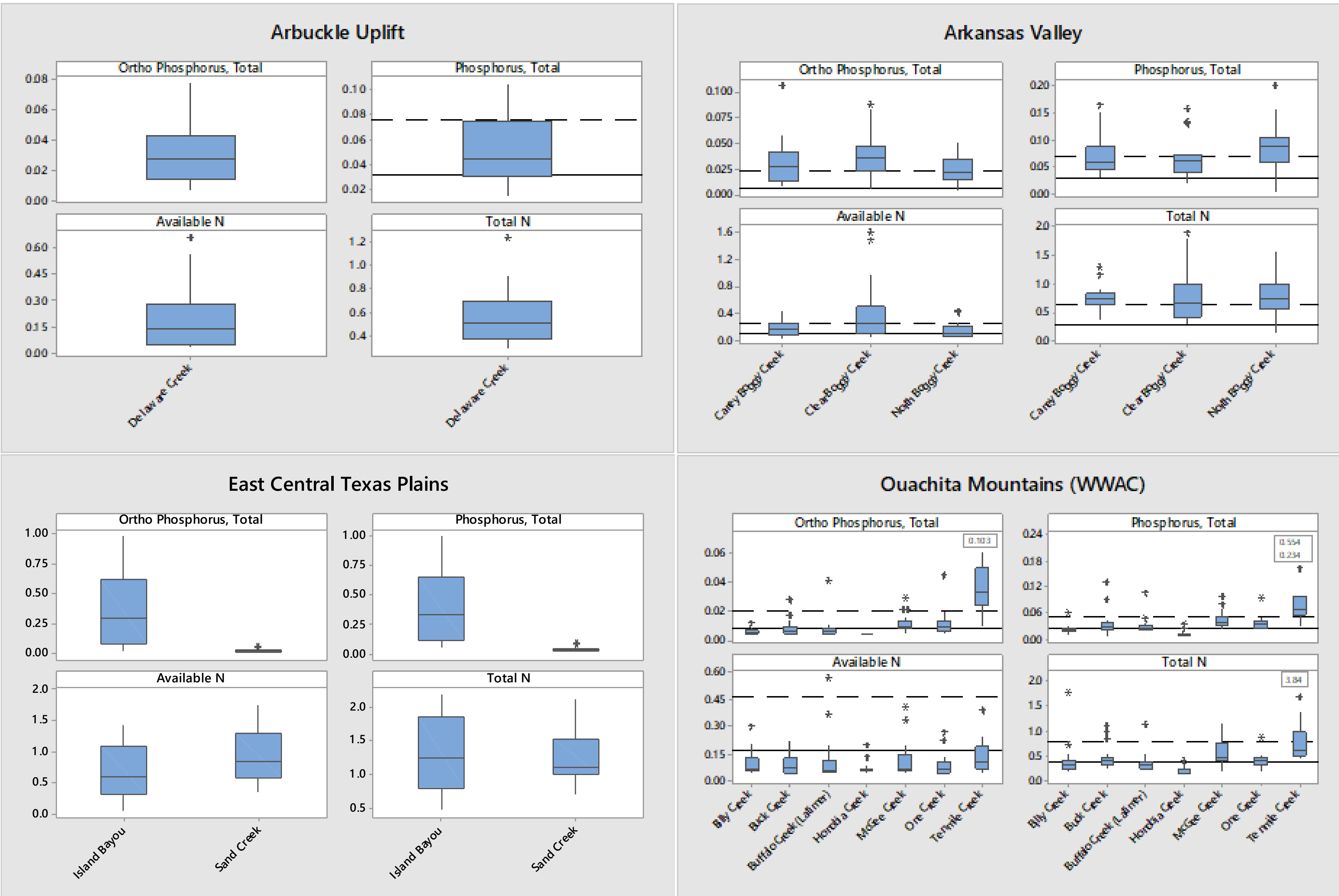
Site Name	WBID	E. coli		Comments
Waterhole Creek	OK410100-01-0340D	141.16		Geometric Mean
West Fork of Glover River	OK410210-08-0010M	15.85	*	Geometric Mean
Whitegrass Creek	OK410400-01-0210G	270.29		Geometric Mean

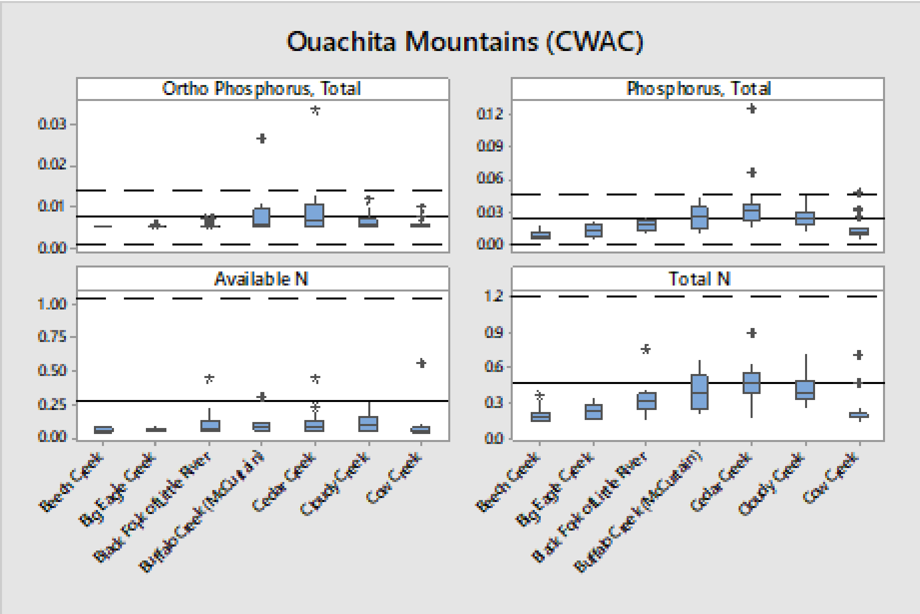
Select water quality parameters are summarized by box plots in Figure 2, below. To account for natural differences, sites were collated and analyzed by Level III ecoregions (Woods et al. 2005). Additionally, sites were compared to streams determined to be "high quality" sites in each ecoregion to determine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

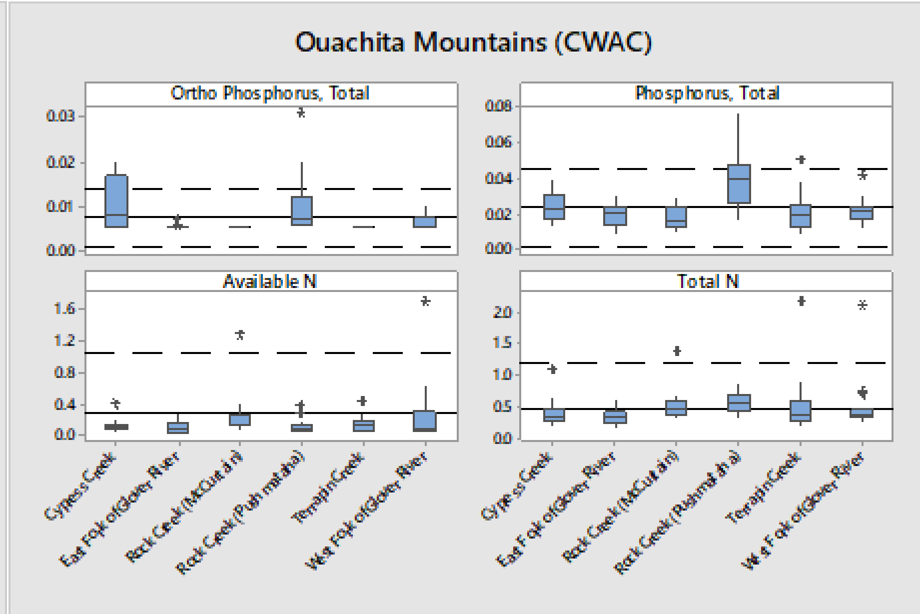
Regarding boxplot composition, the median of each site is shown by a line within the box with most outliers denoted by asterisks. The extreme outliers are denoted by values within a box on the graph. The mean of the high quality stream sites in a particular ecoregion is represented by a solid horizontal line, while dashed lines indicate +/- two standard deviations (representing 95% of the high quality data) for high quality site parameters. In instances where only one dashed line is present, the lower value was below zero.

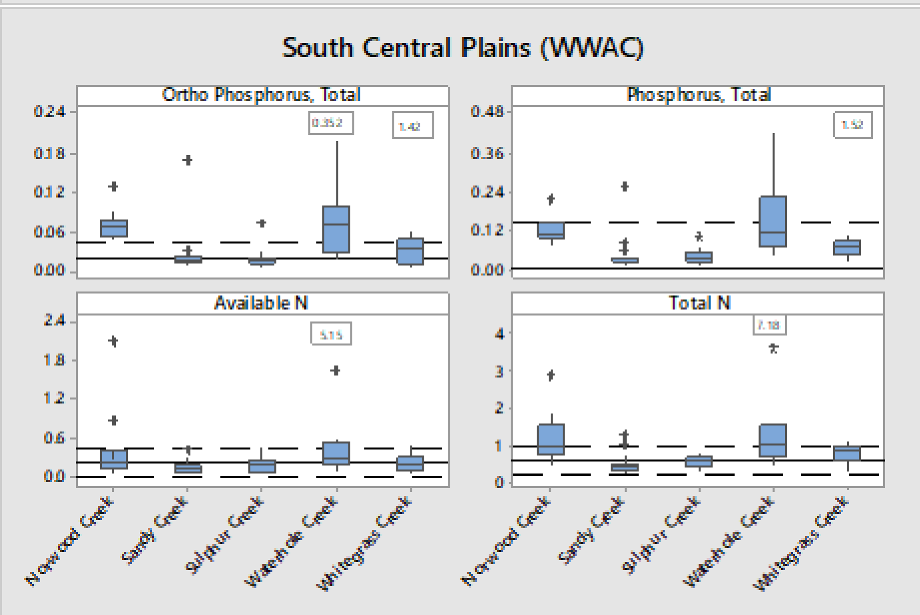
Streams in the Arkansas Valley ecoregion tended to exhibit significantly higher nutrient concentrations than the high quality sites (Figure 2). Island Bayou in the East Central Texas Plains ecoregion had high nutrient concentrations relative to most other streams in that region. It also has multiple NPDES permits and is designated secondary body contact recreation. Without reference data for this ecoregion and the Arbuckle Mountains, it is not clear whether these values are significantly high for those areas. Cypress Creek, Rock Creek (Pushmataha Co.), and Tenmile Creek, in the Ouachita Mountains ecoregion, had high phosphorus and orthophosphorus values relative to high quality mean. Tenmile Creek also had high total nitrogen values. Horse Creek, in the South Central Plains ecoregion, had significantly high values for all four nutrient parameters; Lick Creek had high orthophosphorus and total nitrogen values.

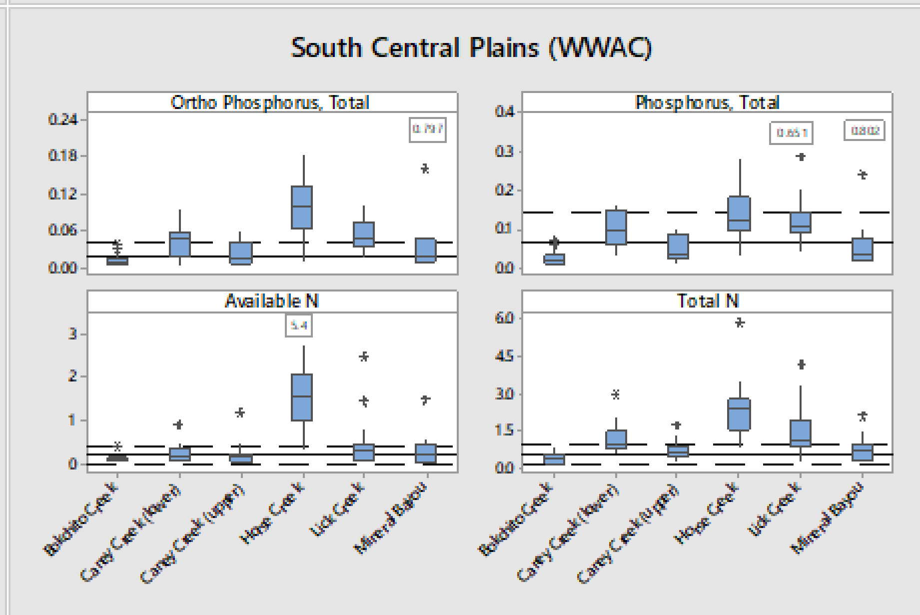
Figure 2. Select nutrients for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).




Ouachita Mountains (CWAC)
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Beech Creek
Big Eagle Creek
Black Fork of Little River
Buffalo Creek (McCurtain)
Cedar Creek
Cloudy Creek
Cow Creek


Ouachita Mountains (CWAC)
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Cypress Creek
East Fork of Glover River
Rock Creek (McCurtain)
Rock Creek (Pushmataha)
Terrapin Creek
West Fork of Glover River


South Central Plains (WWAC)
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Norwood Creek
Sandy Creek
Sulphur Creek
Waterhole Creek
Whitegrass Creek


South Central Plains (WWAC)
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Bokchito Creek
Caney Creek (lower)
Caney Creek (upper)
Hope Creek
Lick Creek
Mineral Bayou

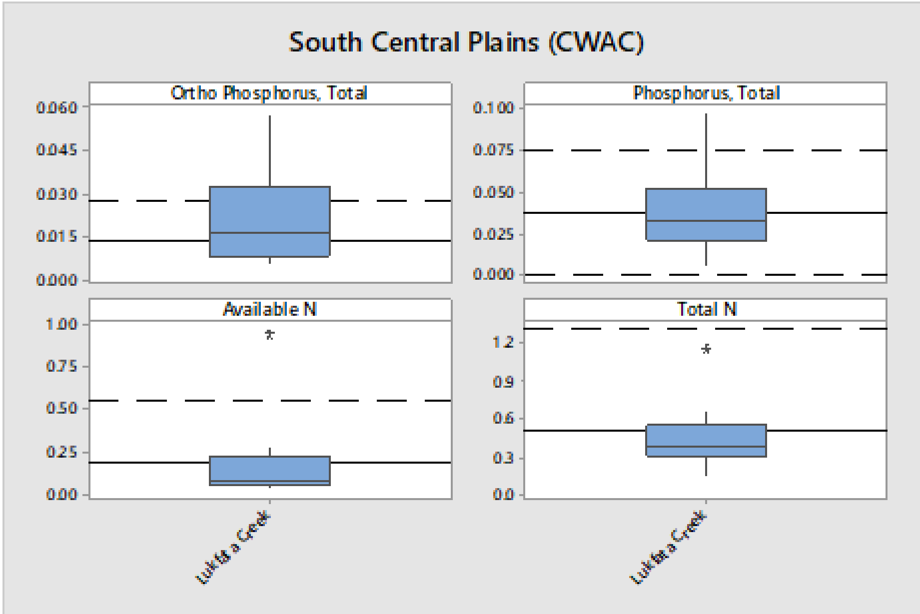
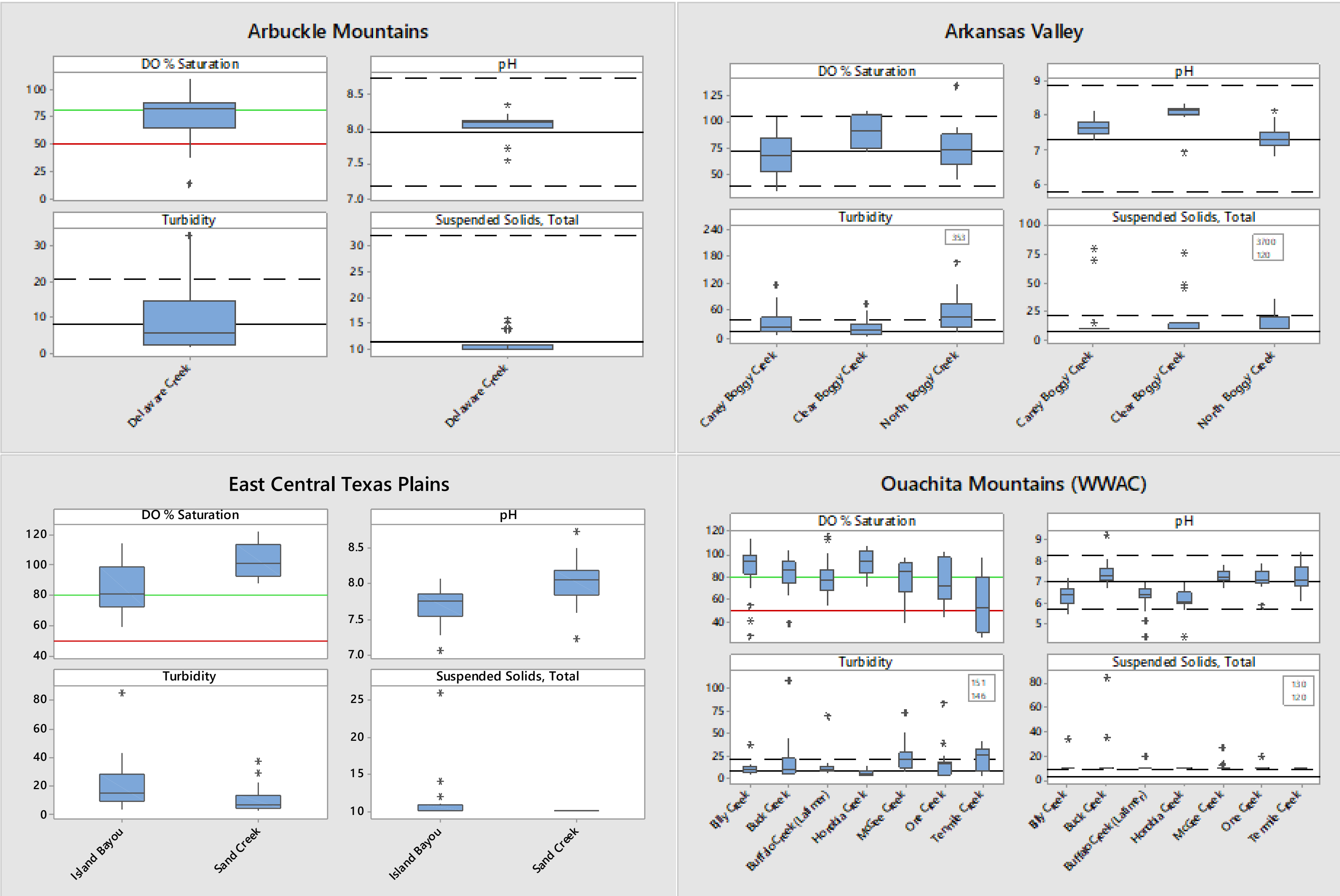
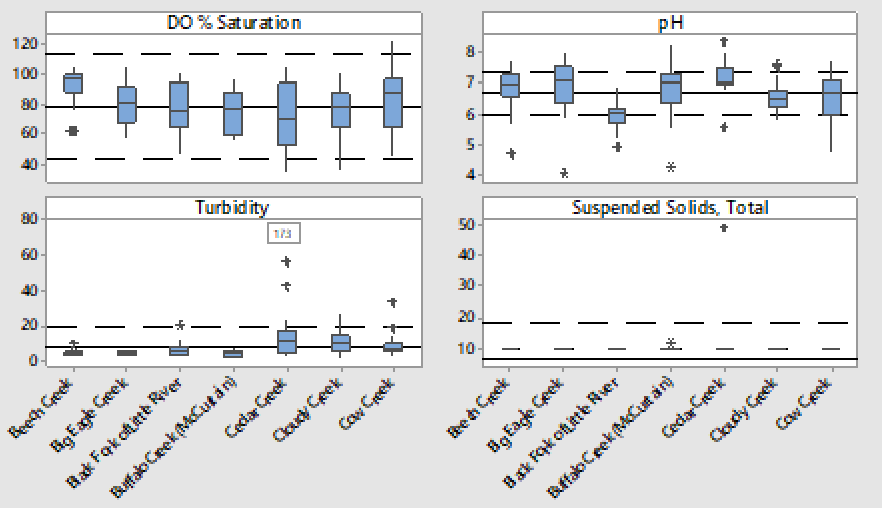


Figure 3 shows interquartile range plots for four physical parameters (all high flow data excluded): dissolved oxygen (percent saturation), pH, turbidity, and total suspended solids. For ecoregions where there is no “high quality” data, a green line indicates 80% saturation, and a red line indicates 50% saturation on the dissolved oxygen % saturation charts. North Boggy Creek had significantly higher turbidity than the high quality sites in the Arkansas Valley ecoregion, and the median turbidity value of Lick Creek was higher than the high quality range in the South Central Plains ecoregion. McGee Creek and Tenmile Creek in the Ouachita Mountains ecoregion had significantly higher turbidity than the high quality sites. Other streams fell within the high quality range for the other parameters. These findings will be discussed further at the end of this report.

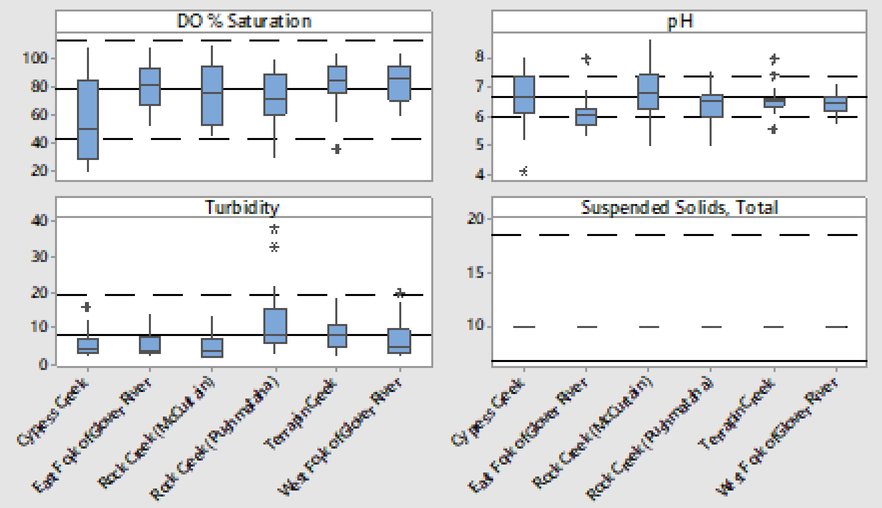
Figure 3. Select physical parameters by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dash line, the lower standard deviation was below zero). In ecoregions with no high quality data, a green line indicates 80% and a red line indicates 50% DO saturation.



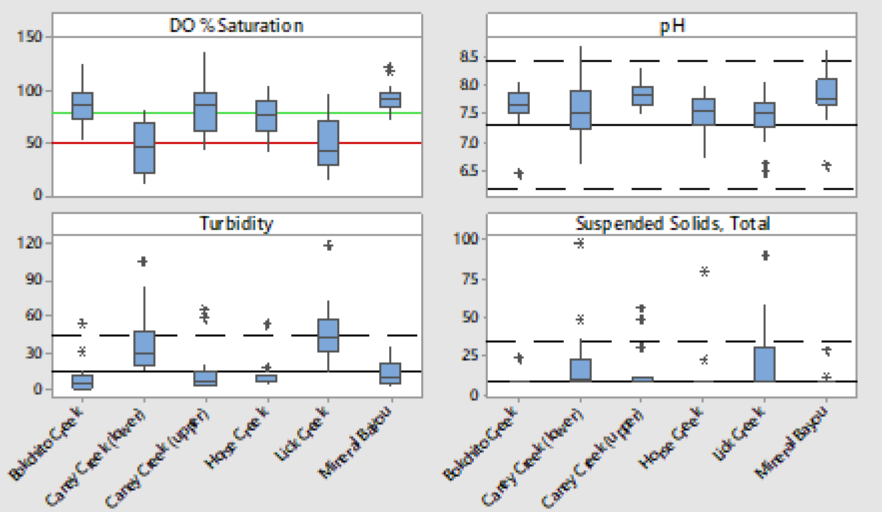
Ouachita Mountains (CWAC)



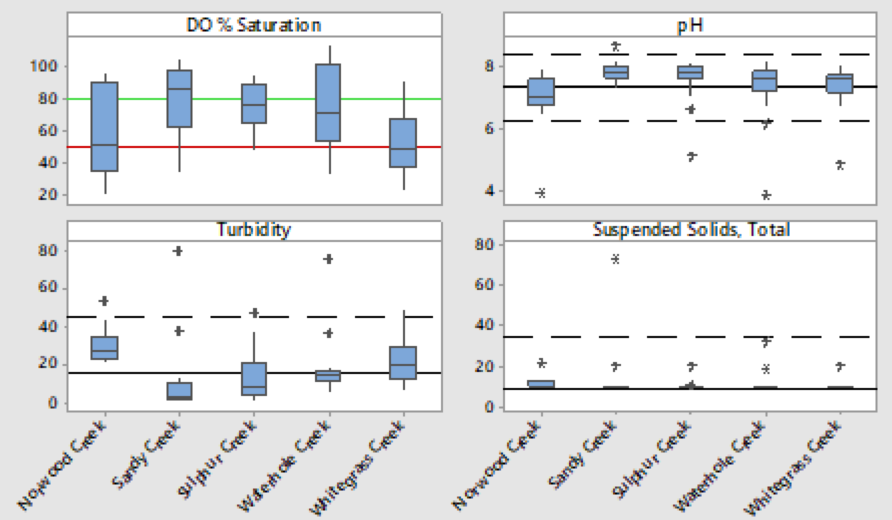
Ouachita Mountains (CWAC)



South Central Plains (WWAC)



South Central Plains (WWAC)



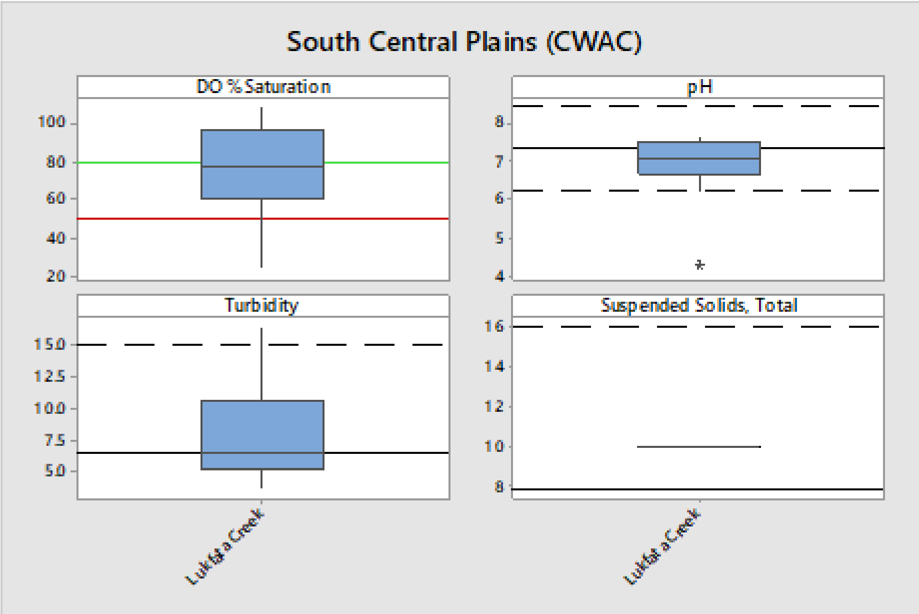


Table 10 shows a comparison between base flow water quality data (high flow data omitted) collected for the same site in the previous rotating basin cycle(s) and the third cycle in order to examine whether water conditions have improved, worsened, or remained the same at a particular site. One-way ANOVAs were performed for each set of data. Only statistically significant differences between the means of each parameter 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.

All of the parameters had some streams that increased significantly and some that decreased significantly. Ammonia was increased in seven streams and other forms of nitrogen were significantly increased in 12 streams. TKN and Total Nitrogen significantly increased from cycle 1 to cycle 2 and significantly decrease from cycle 2 to cycle 3 in 15 streams. Alkalinity and/or hardness was significantly higher in 13. Eleven streams exhibited decreased salt concentrations (sulfate, chloride, or total dissolved solids) while four showed higher salt concentrations.

Table 10. Statistical comparisons of cycles one, two, and three Rotating Basin Project water quality data. "N" is the number of base flow samples included in the analyses.

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Beech Creek	OK410210-06-0320G	Hardness	2005-2007	17	11.49		0.047 *	
			2010-2012	18	16.58			
			2015-2017	19	26.73			
		Turbidity	2005-2007	18	17.39	0.033 *	0.039 *	
			2010-2012	18	6.91			
			2015-2017	21	4.08			
		Ammonia	2005-2007	17	0.015		0.064	
			2010-2012	14	0.021			
			2015-2017	9	0.015			
		Chloride	2005-2007	17	2.694	0.080		
			2010-2012	17	1.941			
			2015-2017	18	1.622			
		TDS	2005-2007	17	39.76	0.02 *	0.007 *	
			2010-2012	17	31.88			
			2015-2017	18	20.83			
		TKN	2005-2007	17	0.307	0.005 *	0.023 *	
			2010-2012	17	0.272			
			2015-2017	18	0.145			
		Ortho P	2005-2007	17	0.008		0.002 *	
			2010-2012	17	0.005			
			2015-2017	18	0.005			
		Total P	2005-2007	17	0.026	0.038 *	0.000 *	
			2010-2012	17	0.015			
			2015-2017	18	0.009			
		Sulfate	2005-2007	17	2.976	0.075	0.059	
			2010-2012	17	2.471			
			2015-2017	18	2.072			
		TSS	2005-2007	17	12.71		0.073	
			2010-2012	17	10.24			
			2015-2017	18	10			
		Total N	2005-2007	17	0.412	0.005 *	0.021 *	
			2010-2012	17	0.339			
			2015-2017	18	0.199			
Big Eagle Creek	OK410210-06-0160I	pH	2005-2007	16	6.773	0.028 *	0.045 *	
			2010-2012	17	6.232			
			2015-2017	14	6.822			
		TDS	2005-2007	16	29.13	0.006 *	0.046 *	
			2010-2012	16	34.25			
			2015-2017	13	21.08			
		Ortho P	2005-2007	16	0.008		0.016 *	
			2010-2012	16	0.005			
			2015-2017	13	0.005			
		Total P	2005-2007	16	0.024	0.082	0.000 *	
			2010-2012	16	0.009			
			2015-2017	13	0.013			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Big Eagle Creek (cont)		Sulfate	2005-2007	16	2.719	0.001 *	0.004 *	
			2010-2012	16	2.544			
			2015-2017	13	1.977			
Billy Creek	OK410310-02-0070C	DO	2005-2007	19	5.161	0.007 *	0.003 *	
			2010-2012	16	5.546			
			2015-2017	19	8.316			
		DO % Sat	2005-2007	19	51.28	0.000 *	0.000 *	
			2010-2012	16	55.07			
			2015-2017	19	86.12			
		Hardness	2005-2007	17	25.91	0.011 *	0.011 *	
			2010-2012	16	41.13			
			2015-2017	19	21.09			
		pH	2005-2007	18	7.396		0.000 *	
			2010-2012	16	6.387			
			2015-2017	18	6.339			
		Turbidity	2005-2007	18	9.9	0.038 *	0.087	
			2010-2012	16	6.603			
			2015-2017	20	10.78			
		Chloride	2005-2007	17	12.72	0.044 *		
			2010-2012	15	4.367			
			2015-2017	18	3.317			
		TDS	2005-2007	17	58.9	0.001 *	0.091	
			2010-2012	15	52.33			
			2015-2017	18	32.39			
		Ortho P	2005-2007	17	0.011		0.008 *	
			2010-2012	15	0.006			
			2015-2017	18	0.006			
		Total P	2005-2007	17	0.042		0.015 *	
			2010-2012	15	0.03			
			2015-2017	18	0.023			
Black Fork of Little River	OK410210-03-0020C	Alkalinity	2005-2007	19	16.58	0.090		
			2010-2012	21	21.23			
			2015-2017	18	15.44			
		Conductivity	2005-2007	19	64.99	0.011 *	0.008 *	
			2010-2012	21	64.29			
			2015-2017	18	47.42			
		pH	2005-2007	19	6.64	0.004 *	0.000 *	
			2010-2012	21	6.35			
			2015-2017	17	5.956			
		Turbidity	2005-2007	18	5.077	0.038 *	0.065	
			2010-2012	21	4.3			
			2015-2017	19	6.599			
		Chloride	2005-2007	18	5.122	0.007 *	0.007 *	
			2010-2012	20	5.082			
			2015-2017	17	3.604			
		TDS	2005-2007	18	40.83	0.006 *	0.031 *	
			2010-2012	20	41.45			
			2015-2017	17	29.12			
		TKN	2005-2007	18	0.209	0.013 *	0.003 *	
			2010-2012	20	0.415			
			2015-2017	17	0.234			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Black Fork of Little River (cont)		Ortho P	2005-2007	18	0.007		0.028 *	
			2010-2012	20	0.006			
			2015-2017	17	0.005			
		Sulfate	2005-2007	18	3.822	0.094		
			2010-2012	20	4.095			
			2015-2017	17	3.235			
		Total N	2005-2007	18	0.27	0.021 *	0.002 *	
			2010-2012	20	0.556			
			2015-2017	17	0.335			
Bokchito Creek	OK410600-01-0090G	Alkalinity	2005-2007	18	145.1	0.092	0.007 *	
			2010-2012	20	166.2			
			2015-2017	20	189.6			
		DO % Sat	2005-2007	18	66.73		0.018 *	
			2010-2012	18	78.11			
			2015-2017	19	85.18			
		pH	2005-2007	19	7.319		0.005 *	
			2010-2012	20	7.568			
			2015-2017	19	7.657			
		Chloride	2005-2007	18	15.41	0.096	0.085	
			2010-2012	19	14.46			
			2015-2017	19	12.62			
		TKN	2005-2007	18	0.206	0.093	0.011 *	
			2010-2012	19	0.419			
			2015-2017	19	0.306			
		Nitrite	2005-2007	18	0.022	0.002 *	0.000 *	
			2010-2012	19	0.021			
			2015-2017	19	0.062			
		Sulfate	2005-2007	18	54.2	0.010 *	0.004 *	
			2010-2012	19	52.78			
			2015-2017	19	37.92			
		Flow	2005-2007	16	0.822	0.090	0.084	
			2010-2012	20	0.855			
			2015-2017	19	3.68			
Buck Creek	OK410300-03-0420C	Alkalinity	2005-2007	17	33.86	0.040 *	0.040 *	
			2010-2012	15	49.73			
			2015-2017	21	32.71			
		DO	2005-2007	17	6.714	0.092		
			2010-2012	14	6.583			
			2015-2017	20	7.969			
		DO % Sat	2005-2007	17	69.42	0.008 *	0.011 *	
			2010-2012	14	69.54			
			2015-2017	20	83.15			
		pH	2005-2007	17	6.999	0.017 *	0.005 *	
			2010-2012	15	6.978			
			2015-2017	21	7.428			
		Turbidity	2005-2007	17	5.521		0.052	
			2010-2012	15	12.19			
			2015-2017	21	18.21			
		Ammonia	2005-2007	16	0.015		0.079	
			2010-2012	13	0.022			
			2015-2017	7	0.029			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Buck Creek (cont)		TDS	2005-2007	16	95.9		0.066	
			2010-2012	14	83.43			
			2015-2017	20	70.25			
		TKN	2005-2007	16	0.182	0.005 *	0.000 *	
			2010-2012	14	0.616			
			2015-2017	20	0.384			
		Total N	2005-2007	16	0.245	0.008 *	0.000 *	
			2010-2012	14	0.749			
			2015-2017	20	0.463			
Buffalo Creek (McCurtain)	OK410210-06-0020G	DO	2005-2007	14	7.451	0.095		
			2010-2012	17	8.554			
			2015-2017	14	6.998			
		DO % Sat	2005-2007	14	82.65	0.001 *	0.029 *	
			2010-2012	17	94.13			
			2015-2017	14	74.81			
		Ammonia	2005-2007	13	0.015		0.039 *	
			2010-2012	13	0.027			
			2015-2017	8	0.019			
		TDS	2005-2007	13	30	0.082		
			2010-2012	16	37.25			
			2015-2017	13	27.54			
		TKN	2005-2007	13	0.305	0.034 *	0.051	
			2010-2012	16	0.475			
			2015-2017	13	0.307			
		Total N	2005-2007	13	0.38	0.013 *	0.017 *	
			2010-2012	16	0.581			
			2015-2017	13	0.389			
Caney Boggy Creek	OK410400-06-0120G	Alkalinity	2005-2007	16	70.9		0.095	
			2010-2012	19	98.95			
			2015-2017	20	90.4			
		Hardness	2005-2007	16	87.68		0.002 *	
			2010-2012	18	169			
			2015-2017	19	129.4			
		pH	2005-2007	16	7.368	0.000 *	0.001 *	
			2010-2012	19	7.306			
			2015-2017	20	7.66			
		Chloride	2005-2007	16	12.05		0.008 *	
			2010-2012	17	16.04			
			2015-2017	19	17.62			
		TDS	2005-2007	16	157.8		0.034 *	
			2010-2012	17	194.6			
			2015-2017	19	191.1			
		TKN	2005-2007	16	0.424		0.039 *	
			2010-2012	17	0.724			
			2015-2017	19	0.595			
		Nitrite	2005-2007	16	0.02		0.083	
			2010-2012	17	0.02			
			2015-2017	19	0.06			
		Ortho P	2005-2007	16	0.026	0.069		
			2010-2012	18	0.019			
			2015-2017	19	0.032			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Caney Creek (lower)	OK410400-02-0200G	DO	2005-2007	15	4.466	0.040 *	0.031 *	
			2010-2012	17	6.794			
			2015-2017	16	4.534			
		pH	2005-2007	14	7.09	0.000 *	0.002 *	
			2010-2012	19	6.935			
			2015-2017	16	7.603			
		Turbidity	2005-2007	14	18.48		0.063	
			2010-2012	18	28.56			
			2015-2017	17	38.45			
		Ammonia	2005-2007	13	0.073	0.089	0.082	
			2010-2012	16	0.098			
			2015-2017	8	0.186			
		TKN	2005-2007	13	0.589		0.034 *	
			2010-2012	18	0.857			
			2015-2017	16	1.041			
		Nitrite	2005-2007	13	0.024	0.004 *	0.001 *	
			2010-2012	18	0.026			
			2015-2017	16	0.086			
		Total P	2005-2007	13	0.074	0.002 *	0.013 *	
			2010-2012	18	0.062			
			2015-2017	16	0.105			
		Total N	2005-2007	13	0.731		0.037 *	
			2010-2012	18	1.067			
			2015-2017	16	1.206			
		Flow	2005-2007	14	8.43	0.040 *		
			2010-2012	20	1.331			
			2015-2017	16	0.006			
Caney Creek (upper)	OK410400-03-0020C	Hardness	2005-2007	17	234.2	0.046 *		
			2010-2012	16	218.5			
			2015-2017	17	259.7			
		Ammonia	2005-2007	17	0.015	0.002 *	0.000 *	
			2010-2012	14	0.024			
			2015-2017	8	0.046			
		TKN	2005-2007	17	0.347		0.024 *	
			2010-2012	17	0.579			
			2015-2017	16	0.536			
		Nitrite	2005-2007	17	0.02	0.096	0.061	
			2010-2012	17	0.021			
			2015-2017	16	0.142			
		TSS	2005-2007	17	14.65	0.088		
			2010-2012	17	10.35			
			2015-2017	16	16.88			
		Available N	2005-2007	17	0.109	0.039 *	0.045 *	
			2010-2012	17	0.078			
			2015-2017	16	0.231			
		Total N	2005-2007	17	0.44		0.022 *	
			2010-2012	17	0.637			
			2015-2017	16	0.743			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Cedar Creek	OK410300-03-0020M	pH	2005-2007	19	6.865	0.000 *	0.000 *	
			2010-2012	20	6.611			
			2015-2017	21	7.176			
		Ammonia	2005-2007	18	0.015		0.034 *	
			2010-2012	15	0.026			
			2015-2017	7	0.019			
		TKN	2005-2007	18	0.279	0.008 *	0.001 *	
			2010-2012	19	0.588			
			2015-2017	20	0.357			
		Nitrite	2005-2007	18	0.024	0.092		
			2010-2012	19	0.02			
			2015-2017	20	0.027			
		Sulfate	2005-2007	18	5.717	0.008 *	0.063	
			2010-2012	19	6.637			
			2015-2017	20	4.645			
		Total N	2005-2007	18	0.412	0.008 *	0.003 *	
			2010-2012	19	0.804			
			2015-2017	20	0.46			
Cloudy Creek	OK410210-02-0300C	Conductivity	2005-2007	18	96.43		0.054	
			2010-2012	20	82.37			
			2015-2017	19	68.46			
		Turbidity	2005-2007	18	50.9	0.020 *		
			2010-2012	20	6.428			
			2015-2017	20	10.66			
		Chloride	2005-2007	17	9.388	0.005 *	0.004 *	
			2010-2012	19	8.984			
			2015-2017	18	5.933			
		TDS	2005-2007	17	83.2	0.009 *		
			2010-2012	19	67.26			
			2015-2017	18	47.5			
		TKN	2005-2007	17	0.281	0.007 *	0.002 *	
			2010-2012	19	0.568			
			2015-2017	18	0.325			
		Sulfate	2005-2007	17	11.74	0.012 *		
			2010-2012	19	5.742			
			2015-2017	18	3.739			
		Total N	2005-2007	17	0.384	0.007 *	0.003 *	
			2010-2012	19	0.675			
			2015-2017	18	0.43			
Cow Creek	OK410210-06-0350G	Turbidity	2005-2007	18	24.5		0.088	
			2010-2012	19	9.28			
			2015-2017	22	8.38			
		Ammonia	2005-2007	17	0.015		0.068	
			2010-2012	14	0.022			
			2015-2017	9	0.015			
		TDS	2005-2007	17	46.35	0.005 *	0.001 *	
			2010-2012	18	41.61			
			2015-2017	19	26.32			
		TKN	2005-2007	17	0.182	0.015 *	0.014 *	
			2010-2012	18	0.33			
			2015-2017	19	0.163			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Cow Creek (cont)		Ortho P	2005-2007	17	0.009		0.011 *	
			2010-2012	18	0.006			
			2015-2017	19	0.006			
		Total P	2005-2007	17	0.034		0.002 *	
			2010-2012	18	0.016			
			2015-2017	19	0.015			
		Sulfate	2005-2007	17	2.935	0.035 *	0.011 *	
			2010-2012	18	2.472			
			2015-2017	19	1.926			
		TSS	2005-2007	17	16.41		0.057	
			2010-2012	18	10			
			2015-2017	19	10			
		Total N	2005-2007	17	0.275	0.040 *	0.080	
			2010-2012	18	0.396			
			2015-2017	19	0.244			
Cypress Creek	OK410210-01-0070D	Alkalinity	2005-2007	18	18.76	0.000 *	0.000 *	
			2010-2012	19	15.05			
			2015-2017	17	57.91			
		Conductivity	2005-2007	18	71.35	0.009 *	0.005 *	
			2010-2012	19	68.52			
			2015-2017	17	103.2			
		DO % Sat	2005-2007	18	69.67	0.075		
			2010-2012	18	73.51			
			2015-2017	16	57.01			
		Hardness	2005-2007	17	21.18	0.000 *	0.000 *	
			2010-2012	19	19.19			
			2015-2017	17	116.5			
		Ammonia	2005-2007	17	0.015	0.036 *	0.006 *	
			2010-2012	14	0.016			
			2015-2017	9	0.039			
		TKN	2005-2007	17	0.227		0.017 *	
			2010-2012	18	0.453			
			2015-2017	16	0.295			
		Ortho P	2005-2007	17	0.006	0.001 *	0.000 *	
			2010-2012	18	0.005			
			2015-2017	16	0.01			
Delaware Creek	OK410400-03-0240M	Conductivity	2005-2007	18	540		0.039 *	
			2010-2012	16	584.1			
			2015-2017	19	735.4			
		Hardness	2005-2007	19	241.8		0.093	
			2010-2012	16	281.3			
			2015-2017	18	299			
		Chloride	2005-2007	17	36.98		0.064	
			2010-2012	16	65			
			2015-2017	18	85.5			
		TKN	2005-2007	17	0.262	0.036 *	0.001 *	
			2010-2012	16	0.618			
			2015-2017	18	0.392			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Delaware Creek (cont)		Nitrite	2005-2007	17	0.023		0.040 *	
			2010-2012	16	0.046			
			2010-2012	18	0.12			
		TSS	2005-2007	17	13	0.050 *		
			2010-2012	16	10			
			2015-2017	18	11.06			
		Total N	2005-2007	17	0.693	0.070		
			2010-2012	16	0.995			
			2015-2017	18	0.587			
East Fork of Glover River	OK410210-09-0010G	Conductivity	2005-2007	15	52.06	0.045 *	0.013 *	
			2010-2012	18	46.32			
			2015-2017	16	37.74			
		pH	2005-2007	15	6.728	0.007 *	0.000 *	
			2010-2012	18	6.582			
			2015-2017	15	6.109			
		Chloride	2005-2007	14	3.15	0.000 *	0.000 *	
			2010-2012	17	3.594			
			2015-2017	16	2.251			
		TDS	2005-2007	14	34.93	0.000 *	0.004 *	
			2010-2012	17	44.41			
			2015-2017	16	23.06			
		TKN	2005-2007	14	0.259	0.053	0.076	
			2010-2012	17	0.41			
			2015-2017	16	0.241			
		Ortho P	2005-2007	14	0.008		0.004 *	
			2010-2012	17	0.006			
			2015-2017	16	0.005			
		Total P	2005-2007	14	0.031		0.009 *	
			2010-2012	17	0.024			
			2015-2017	16	0.018			
		Sulfate	2005-2007	14	2.386	0.035 *	0.063	
			2010-2012	17	3.176			
			2015-2017	16	2.269			
		TSS	2005-2007	14	10.64		0.091	
			2010-2012	17	10			
			2015-2017	16	10			
		Total N	2005-2007	14	0.341	0.041 *	0.055	
			2010-2012	17	0.523			
			2015-2017	16	0.331			
Horse Creek	OK410400-01-0040G	Alkalinity	2005-2007	20	100.7		0.015 *	
			2010-2012	20	125.2			
			2015-2017	18	133.4			
		Hardness	2005-2007	19	132.7		0.001 *	
			2010-2012	19	168.8			
			2015-2017	17	191.9			
		Chloride	2005-2007	19	45.59	0.003 *	0.015 *	
			2010-2012	18	51.84			
			2015-2017	17	36.66			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Horse Creek (cont)		TDS	2005-2007	19	281.8	0.007 *	0.004 *	
			2010-2012	18	283.6			
			2015-2017	17	235.9			
		TKN	2005-2007	19	0.509	0.056	0.001 *	
			2010-2012	18	1.037			
			2015-2017	17	0.72			
		Nitrite	2005-2007	19	0.037	0.003 *	0.002 *	
			2010-2012	18	0.021			
			2015-2017	17	0.079			
		Ortho P	2005-2007	19	0.43		0.000 *	
			2010-2012	18	0.125			
			2015-2017	17	0.099			
		Total P	2005-2007	19	0.496		0.002 *	
			2010-2012	18	0.292			
			2015-2017	17	0.141			
		Flow	2005-2007	19	2.084	0.034	0.007 *	
			2010-2012	20	2.784			
			2015-2017	19	7.12			
Island Bayou	OK410700-00-0040G	Ammonia	2005-2007	16	0.026		0.028 *	
			2010-2012	14	0.052			
			2015-2017	7	0.058			
		TKN	2005-2007	16	0.492	0.023 *	0.000 *	
			2010-2012	16	0.886			
			2015-2017	16	0.67			
		Nitrite	2005-2007	16	0.023	0.002 *	0.000 *	
			2010-2012	16	0.02			
			2015-2017	16	0.144			
		TSS	2005-2007	16	19.38		0.041 *	
			2010-2012	16	12.25			
			2015-2017	16	11.44			
		Total N	2005-2007	16	0.758		0.012 *	
			2010-2012	16	1.743			
			2015-2017	16	1.301			
Lick Creek	OK410400-01-0130G	Hardness	2005-2007	12	106.2		0.001 *	
			2010-2012	11	193.1			
			2015-2017	15	208.2			
		pH	2005-2007	13	7.344	0.017 *	0.068	
			2010-2012	11	7.028			
			2015-2017	16	7.434			
		TKN	2005-2007	12	0.633		0.069	
			2010-2012	10	1.201			
			2015-2017	15	1.306			
		Nitrate	2005-2007	12	0.099	0.064	0.047 *	
			2010-2012	10	0.385			
			2015-2017	15	0.11			
		Total N	2005-2007	14	0.672		0.002 *	
			2010-2012	10	1.62			
			2015-2017	15	1.557			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Lukfata Creek	OK410210-07-0010G	Alkalinity	2005-2007	16	90.63	0.090	0.005 *	
			2010-2012	16	106.5			
			2015-2017	16	130.5			
		DO % Sat	2005-2007	16	56.82	0.086	0.082	
			2010-2012	16	60.72			
			2015-2017	16	75.29			
		Hardness	2005-2007	16	95.33		0.001 *	
			2010-2012	14	147			
			2015-2017	16	153.6			
		Ammonia	2005-2007	16	0.019		0.061	
			2010-2012	12	0.062			
			2015-2017	10	0.03			
		Chloride	2005-2007	16	5.469	0.000 *	0.000 *	
			2010-2012	15	8.68			
			2015-2017	16	6.2			
		TDS	2005-2007	16	123.1	0.018 *	0.015 *	
			2010-2012	15	128.8			
			2015-2017	16	100.1			
		TKN	2005-2007	16	0.387	0.001 *	0.025 *	
			2010-2012	15	0.617			
			2015-2017	16	0.285			
		Nitrite	2005-2007	16	0.022	0.044 *	0.042 *	
			2010-2012	15	0.02			
			2015-2017	16	0.031			
		Total N	2005-2007	16	0.464	0.002 *	0.004 *	
			2010-2012	15	0.899			
			2015-2017	16	0.446			
		Flow	2005-2007	16	2.585		0.041 *	
			2010-2012	15	4.09			
			2015-2017	16	7.84			
McGee Creek	OK410400-07-0010L	Alkalinity	2005-2007	14	31.98	0.009 *	0.016 *	
			2010-2012	16	23.61			
			2015-2017	21	46.34			
		Conductivity	2005-2007	17	75	0.000 *	0.000 *	
			2010-2012	16	74.88			
			2015-2017	21	133.8			
		DO	2005-2007	14	8.465	0.050 *	0.094	
			2010-2012	14	9.089			
			2015-2017	20	7.475			
		DO % Sat	2005-2007	14	87.44	0.006 *	0.008 *	
			2010-2012	14	93.26			
			2015-2017	20	78.04			
		Hardness	2005-2007	13	24.31	0.001 *	0.000 *	
			2010-2012	16	31.26			
			2015-2017	19	64.73			
		Turbidity	2005-2007	14	8.36	0.000 *	0.000 *	
			2010-2012	16	5.442			
			2015-2017	21	24.2			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
McGee Creek (cont)		Chloride	2005-2007	13	6.231	0.001 *	0.001 *	
			2010-2012	16	4.475			
			2015-2017	20	8.11			
		TDS	2005-2007	13	50.15	0.000 *	0.000 *	
			2010-2012	16	48.56			
			2015-2017	20	99.35			
		TKN	2005-2007	13	0.212	0.091	0.001 *	
			2010-2012	16	0.346			
			2015-2017	20	0.44			
		Ortho P	2005-2007	13	0.012	0.000 *	0.041 *	
			2010-2012	16	0.005			
			2015-2017	20	0.012			
		Total P	2005-2007	13	0.023	0.000 *	0.000 *	
			2010-2012	16	0.01			
			2015-2017	20	0.045			
		Sulfate	2005-2007	13	9.99	0.000 *	0.000 *	
			2010-2012	16	8.906			
			2015-2017	20	16.2			
		Total N	2005-2007	13	0.329		0.034 *	
			2010-2012	16	0.458			
			2015-2017	20	0.548			
Mineral Bayou	OK410600-01-0300G	Alkalinity	2005-2007	17	122.3		0.005 *	
			2010-2012	20	165.6			
			2015-2017	17	170.8			
		Conductivity	2005-2007	18	329.5		0.080	
			2010-2012	19	385.8			
			2015-2017	16	423.3			
		DO	2005-2007	18	8.555	0.061		
			2010-2012	18	7.079			
			2015-2017	16	8.598			
		Hardness	2005-2007	17	142.5		0.001 *	
			2010-2012	19	213.8			
			2015-2017	17	215.4			
		Ammonia	2005-2007	17	0.026	0.063		
			2010-2012	15	0.023			
			2015-2017	8	0.041			
		TDS	2005-2007	17	204.6		0.096	
			2010-2012	19	249.7			
			2015-2017	16	250			
		TKN	2005-2007	17	0.246		0.005 *	
			2010-2012	19	0.452			
			2015-2017	16	0.489			
		Nitrite	2005-2007	17	0.032	0.001 *	0.000 *	
			2010-2012	19	0.023			
			2015-2017	16	0.091			
		TSS	2005-2007	17	19.29		0.031 *	
			2010-2012	19	10.21			
			2015-2017	16	11.31			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Mineral Bayou (cont)		Available N	2005-2007	17	0.234	0.052	0.100	
			2010-2012	19	0.153			
			2015-2017	16	0.336			
		Total N	2005-2007	17	0.455		0.042 *	
			2010-2012	19	0.587			
			2015-2017	16	0.804			
North Boggy Creek	OK410400-08-0010E	Alkalinity	2005-2007	19	101	0.000 *	0.000 *	
			2010-2012	20	141.9			
			2015-2017	21	53.1			
		Conductivity	2005-2007	20	1259	0.007 *	0.003 *	
			2010-2012	19	1431			
			2015-2017	21	301.5			
		Hardness	2005-2007	19	729.6	0.000 *	0.000 *	
			2010-2012	19	724.3			
			2015-2017	20	106.8			
		Turbidity	2005-2007	20	10.93	0.001 *	0.000 *	
			2010-2012	19	7.2			
			2015-2017	21	68.9			
		Chloride	2005-2007	19	17.96	0.001 *	0.000 *	
			2010-2012	19	17.4			
			2015-2017	20	10.45			
		TDS	2005-2007	19	1103	0.000 *	0.000 *	
			2010-2012	19	931			
			2015-2017	20	148.8			
		TKN	2005-2007	19	0.253	0.091	0.000 *	
			2010-2012	19	0.547			
			2015-2017	20	0.707			
		Nitrite	2005-2007	19	0.023		0.095	
			2010-2012	19	0.02			
			2015-2017	20	0.055			
		Ortho P	2005-2007	19	0.033	0.017 *		
			2010-2012	18	0.039			
			2015-2017	20	0.024			
		Total P	2005-2007	19	0.06	0.072		
			2010-2012	19	0.062			
			2015-2017	20	0.085			
		Sulfate	2005-2007	19	527.4	0.000 *	0.000 *	
			2010-2012	19	555.4			
			2015-2017	20	16.12			
		Total N	2005-2007	20	0.437	0.035 *	0.005 *	
			2010-2012	19	0.615			
			2015-2017	20	0.838			
Norwood Creek	OK410100-01-005H	Alkalinity	2005-2007	19	92.63	0.031 *	0.006 *	
			2010-2012	17	105.2			
			2015-2017	11	145.9			
		Conductivity	2005-2007	19	501.7		0.093	
			2010-2012	17	355.5			
			2015-2017	11	280.9			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Norwood Creek (cont)		Chloride	2005-2007	18	77.6	0.018 *		
			2010-2012	16	61.8			
			2015-2017	10	28.64			
		TDS	2005-2007	18	313.4	0.032 *	0.081	
			2010-2012	16	248.1			
			2015-2017	10	171			
		TKN	2005-2007	18	0.631		0.062	
			2010-2012	16	0.923			
			2015-2017	10	0.831			
		Nitrite	2005-2007	18	0.029	0.089	0.057	
			2010-2012	16	0.02			
			2015-2017	10	0.13			
		Total P	2005-2007	18	0.125	0.083	0.092	
			2010-2012	16	0.09			
			2015-2017	10	0.123			
		Flow	2005-2007	19	0.73		0.019 *	
			2010-2012	18	3.262			
			2015-2017	10	1.35			
One Creek	OK410300-03-0060F	Alkalinity	2005-2007	19	47.49		0.054	
			2010-2012	20	25.21			
			2015-2017	21	32.2			
		Conductivity	2005-2007	19	224.8		0.066	
			2010-2012	20	91.9			
			2015-2017	21	80.72			
		DO % Sat	2005-2007	19	71.39	0.087		
			2010-2012	20	63.31			
			2015-2017	20	75.18			
		Hardness	2005-2007	18	45.01	0.048 *	0.092	
			2010-2012	19	27.47			
			2015-2017	20	43.21			
		pH	2005-2007	19	7.082	0.001 *	0.002 *	
			2010-2012	20	6.714			
			2015-2017	21	7.16			
		Ammonia	2005-2007	18	0.017		0.010 *	
			2010-2012	15	0.035			
			2015-2017	7	0.022			
		Chloride	2005-2007	18	9.82		0.018 *	
			2010-2012	19	7.4			
			2015-2017	20	6.115			
		TDS	2005-2007	18	99.1	0.027 *	0.081	
			2010-2012	19	89.5			
			2015-2017	20	60.45			
		TKN	2005-2007	18	0.297	0.004 *	0.001 *	
			2010-2012	19	0.701			
			2015-2017	20	0.326			
		Total N	2005-2007	18	0.35	0.007 *	0.001 *	
			2010-2012	19	0.819			
			2015-2017	20	0.404			
		Flow	2005-2007	16	4.33	0.056	0.093	
			2010-2012	19	2.535			
			2015-2017	21	10.94			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Rock Creek (McCurtain)	OK410200-03-0010G	Alkalinity	2005-2007	17	19.83	0.060	0.003 *	
			2010-2012	16	30.81			
			2015-2017	16	50.88			
		Hardness	2005-2007	16	18.48	0.000 *	0.000 *	
			2010-2012	16	25.32			
			2015-2017	16	68.43			
		Ammonia	2005-2007	16	0.017		0.006 *	
			2010-2012	14	0.037			
			2015-2017	8	0.032			
		TDS	2005-2007	16	44.88	0.013 *	0.030 *	
			2010-2012	15	55.53			
			2015-2017	15	31.6			
		TKN	2005-2007	16	0.291	0.032 *	0.023 *	
			2010-2012	15	0.538			
			2015-2017	15	0.288			
		Ortho P	2005-2007	16	0.007	0.048 *	0.021 *	
			2010-2012	15	0.006			
			2015-2017	15	0.005			
		Total P	2005-2007	16	0.025	0.054	0.072	
			2010-2012	15	0.028			
			2015-2017	15	0.017			
Rock Creek (Pushmataha)	OK410300-02-0190G	Alkalinity	2005-2007	19	37.79		0.014 *	
			2010-2012	20	25.64			
			2015-2017	18	24.9			
		Conductivity	2005-2007	19	118.7		0.021 *	
			2010-2012	20	92.91			
			2015-2017	19	80.71			
		Hardness	2005-2007	18	33.81		0.020 *	
			2010-2012	20	25.29			
			2015-2017	18	24.36			
		pH	2005-2007	19	6.903		0.008 *	
			2010-2012	20	6.655			
			2015-2017	17	6.363			
		Turbidity	2005-2007	19	6.15	0.036 *	0.009 *	
			2010-2012	20	6.97			
			2015-2017	20	12.22			
		Chloride	2005-2007	18	8.678	0.007 *	0.007 *	
			2010-2012	19	8.342			
			2015-2017	18	5.529			
		TDS	2005-2007	18	75.78	0.064	0.060	
			2010-2012	19	69.53			
			2015-2017	18	55.67			
		TKN	2005-2007	18	0.254	0.028 *	0.000 *	
			2010-2012	19	0.677			
			2015-2017	18	0.456			
		Total N	2005-2007	18	0.372	0.043 *	0.001 *	
			2010-2012	19	0.864			
			2015-2017	18	0.565			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Sand Creek	OK410700-00-0260G	Alkalinity	2005-2007	18	96.1	0.017 *	0.000 *	
			2010-2012	19	114			
			2015-2017	18	131.1			
		Conductivity	2005-2007	19	299.7		0.000 *	
			2010-2012	19	390			
			2015-2017	17	382			
		DO % Sat	2005-2007	18	92.61	0.036 *		
			2010-2012	18	87.78			
			2015-2017	17	102.5			
		Hardness	2005-2007	18	103.4		0.001 *	
			2010-2012	20	176.3			
			2015-2017	17	189.4			
		Chloride	2005-2007	18	25.11		0.000 *	
			2010-2012	19	41.61			
			2015-2017	17	39.07			
		TDS	2005-2007	18	201.5		0.029 *	
			2010-2012	19	236.8			
			2015-2017	17	230.6			
		Nitrite	2005-2007	18	0.035	0.008 *	0.007 *	
			2010-2012	19	0.02			
			2015-2017	17	0.096			
		Ortho P	2005-2007	18	0.029	0.067	0.069	
			2010-2012	19	0.011			
			2015-2017	17	0.02			
		Total N	2005-2007	18	0.859		0.035 *	
			2010-2012	19	1.212			
			2015-2017	17	1.258			
		Flow	2005-2007	19	2.02	0.094	0.014 *	
			2010-2012	18	3.34			
			2015-2017	14	6.62			
Sandy Creek	OK410600-02-0020G	TKN	2005-2007	17	0.175		0.036 *	
			2010-2012	19	0.829			
			2015-2017	19	0.345			
		Nitrite	2005-2007	17	0.022	0.023 *	0.011 *	
			2010-2012	19	0.02			
			2015-2017	19	0.056			
		Total N	2005-2007	17	0.336	0.061	0.020 *	
			2010-2012	19	1.15			
			2015-2017	19	0.47			
		Flow	2005-2007	16	1.251	0.031 *	0.014 *	
			2010-2012	19	1.406			
			2015-2017	18	9.16			
Sulphur Creek	OK410600-01-0030G	Alkalinity	2005-2007	15	125.3	0.029 *	0.000 *	
			2010-2012	14	154.2			
			2015-2017	18	193.6			
		DO % Sat	2005-2007	15	55.21	0.025 *	0.031 *	
			2010-2012	12	57.25			
			2015-2017	18	75.29			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Sulphur Creek (cont)		Hardness	2005-2007	14	173.9		0.002 *	
			2010-2012	13	233.5			
			2015-2017	18	268.6			
		Turbidity	2005-2007	15	41.1		0.079	
			2010-2012	14	20.41			
			2015-2017	18	13.77			
		TKN	2005-2007	14	0.483	0.021 *	0.013 *	
			2010-2012	13	1.385			
			2015-2017	18	0.406			
		Nitrite	2005-2007	14	0.026	0.009 *	0.002 *	
			2010-2012	13	0.02			
			2015-2017	18	0.089			
		Total N	2005-2007	14	0.583	0.016 *	0.008 *	
			2010-2012	13	1.581			
			2015-2017	18	0.542			
Tenmile Creek	OK410300-03-0270C	Turbidity	2005-2007	18	9.91		0.034 *	
			2010-2012	17	17.24			
			2015-2017	21	32.09			
		Ammonia	2005-2007	17	0.016		0.009 *	
			2010-2012	15	0.038			
			2015-2017	7	0.058			
		Chloride	2005-2007	17	10.52	0.060		
			2010-2012	16	11.51			
			2015-2017	20	8.9			
		TDS	2005-2007	17	93	0.089		
			2010-2012	16	99.56			
			2015-2017	20	89.3			
		TKN	2005-2007	17	0.28		0.007 *	
			2010-2012	16	0.728			
			2015-2017	20	0.778			
		Ortho P	2005-2007	17	0.02		0.022 *	
			2010-2012	16	0.03			
			2015-2017	20	0.038			
		Total P	2005-2007	17	0.042		0.031 *	
			2010-2012	16	0.057			
			2015-2017	20	0.105			
		Total N	2005-2007	17	0.511		0.086	
			2010-2012	16	1.209			
			2015-2017	20	0.89			
Terrapin Creek	OK410210-02-0150G	DO % Sat	2005-2007	16	89.52	0.006 *	0.068	
			2010-2012	19	95.97			
			2015-2017	18	81.79			
		pH	2005-2007	16	6.906	0.005 *	0.080	
			2010-2012	20	6.952			
			2015-2017	17	6.541			
		Turbidity	2005-2007	16	26.5	0.014 *		
			2010-2012	20	5.45			
			2015-2017	19	8.7			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
Terrapin Creek (cont)		TDS	2005-2007	15	64.2	0.017 *		
			2010-2012	19	53.63			
			2015-2017	17	34.88			
		Ortho P	2005-2007	15	0.013	0.054		
			2010-2012	19	0.006			
			2015-2017	17	0.005			
		Flow	2005-2007	16	2.38		0.078	
			2010-2012	19	7.27			
			2015-2017	17	16.17			
Waterhole Creek	OK410100-01-0340D	Alkalinity	2005-2007	20	148.1		0.001 *	
			2010-2012	17	213.6			
			2015-2017	14	242.4			
		DO	2005-2007	21	4.557	0.047 *	0.022 *	
			2010-2012	17	4.942			
			2015-2017	14	7.164			
		DO % Sat	2005-2007	21	47.51		0.004 *	
			2010-2012	17	61.22			
			2015-2017	14	75.4			
		Hardness	2005-2007	19	180.6		0.000 *	
			2010-2012	17	264.1			
			2015-2017	14	299.5			
		TDS	2005-2007	19	246.5		0.008 *	
			2010-2012	16	315.8			
			2015-2017	13	347.7			
		TKN	2005-2007	19	0.488		0.003 *	
			2010-2012	16	0.914			
			2015-2017	13	0.909			
		Nitrate	2005-2007	19	0.055		0.097	
			2010-2012	16	0.088			
			2015-2017	13	0.603			
		Nitrite	2005-2007	19	0.022	0.003 *	0.000 *	
			2010-2012	16	0.02			
			2015-2017	13	0.114			
		Available N	2005-2007	19	0.096		0.036 *	
			2010-2012	16	0.157			
			2015-2017	13	0.749			
		Total N	2005-2007	19	0.565		0.019 *	
			2010-2012	16	1.022			
			2015-2017	13	1.626			
West Fork of Glover River	OK410210-08-0010M	Conductivity	2005-2007	16	69.55	0.053	0.064	
			2010-2012	19	66.6			
			2015-2017	18	44.94			
		pH	2005-2007	16	7.019	0.000 *	0.000 *	
			2010-2012	19	6.879			
			2015-2017	16	6.408			
		Chloride	2005-2007	15	3.633	0.000 *	0.000 *	
			2010-2012	18	4.333			
			2015-2017	17	2.624			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 2 vs Cycle 3	p value (all cycles)	Result
West Fork of Glover River (cont)		TDS	2005-2007	15	32.2	0.000 *	0.001 *	
			2010-2012	18	56.44			
			2015-2017	17	28.65			
		TKN	2005-2007	15	0.289	0.002 *	0.002 *	
			2010-2012	18	0.523			
			2015-2017	17	0.267			
		Ortho P	2005-2007	15	0.01	0.052	0.030 *	
			2010-2012	18	0.009			
			2015-2017	17	0.006			
		Total P	2005-2007	15	0.03	0.074	0.075	
			2010-2012	18	0.031			
			2015-2017	17	0.021			
		Total N	2005-2007	16	0.374		0.026 *	
			2010-2012	18	0.704			
			2015-2017	17	0.508			
Whitegrass Creek	OK410400-01-0210G	Alkalinity	2005-2007	14	98.26		0.045 *	
			2010-2012	12	125			
			2015-2017	15	138.7			
		Hardness	2005-2007	13	118.3		0.002 *	
			2010-2012	12	177.2			
			2015-2017	14	205.9			
		Turbidity	2005-2007	13	47.32	0.078	0.033 *	
			2010-2012	12	35.9			
			2015-2017	15	22			
		TKN	2005-2007	13	0.375	0.000 *	0.000 *	
			2010-2012	11	1.055			
			2015-2017	14	0.583			
		TSS	2005-2007	13	23.62		0.005 *	
			2010-2012	11	15.55			
			2015-2017	14	10.71			
		Total N	2005-2007	13	0.445	0.002 *	0.000 *	
			2010-2012	11	1.304			
			2015-2017	14	0.772			

3.2 BIOLOGICAL MONITORING

3.2.1 Habitat Assessment

Total habitat scores for each site computed metric scores are listed below (Table 11). Buck Creek and Terrapin Creek had the highest habitat score, while Sandy Creek had the lowest habitat score.

Table 11. Habitat assessment metric values for monitoring sites in the Rotating Basin Group 5, Cycle 3.

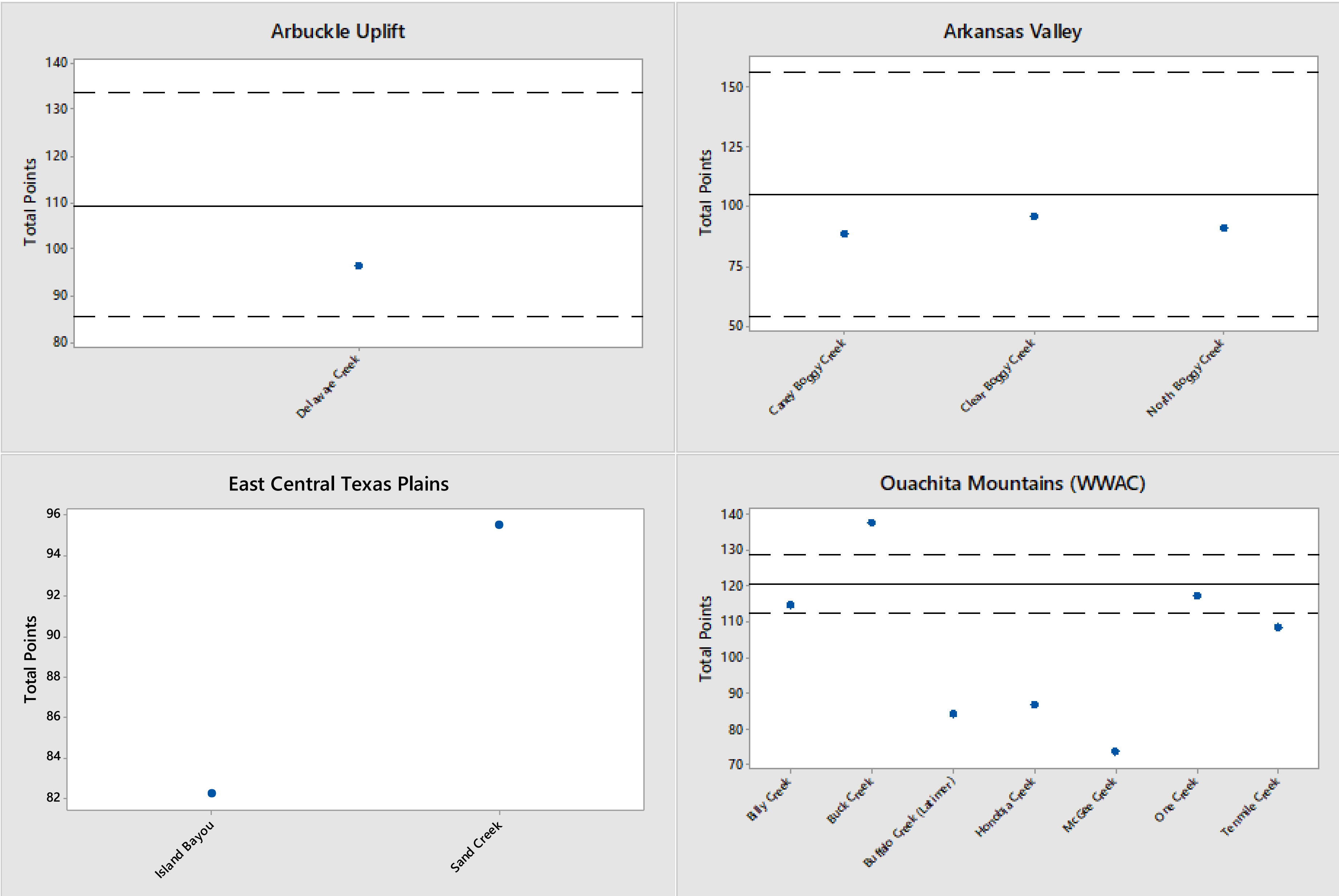
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Beech Creek	OK410210-06-0320G	19.1	12.3	20	5.8	10.3	4.9	13.7	1.8	10	7.1	10	115
Big Eagle Creek	OK410210-06-0160I	17.6	18.5	14.6	8.8	10.3	18.9	16.5	0.8	9.1	5.9	9.5	131
Billy Creek	OK410310-02-0070C	16.8	12.2	17.2	19.4	10.3	5.9	6.7	2.7	7.5	6	10	115
Black Fork of Little River	OK410210-03-0020C	18.8	16.5	13.6	16.2	0	4.9	13.7	0.8	10	5.1	9.9	110
Bokchito Creek	OK410600-01-0090G	10.8	4.1	19.8	10.8	12.4	10.5	0.5	2.4	7	6.5	10	94.8
Buck Creek	OK410300-03-0420C	19.6	15.7	13.2	18.8	13.3	15.2	16.5	0.7	10	4.9	9.9	138
Buffalo Creek (Latimer)	OK410310-03-0030N	8.6	13.9	14.6	2.8	4.1	1.2	15.1	0.4	7.7	6.7	8.9	84
Buffalo Creek (McCurtain)	OK410210-06-0020G	19.6	16	16.6	13.3	7.5	3.1	4.2	0.4	9.3	7.4	9.2	107
Caney Boggy Creek	OK410400-06-0120G	10.4	5.4	13.3	13.1	9	11.3	0.4	1.8	8	5.9	10	88.6
Caney Creek (lower)	OK410400-02-0200G	11.7	5.2	3.8	19.5	0	0.5	1	6.1	6.2	3.6	6	63.6
Caney Creek (upper)	OK410400-03-0020C	4	0.4	0	19	2.2	10.2	0.4	1.9	7.3	6.4	8.7	60.5
Cedar Creek	OK410300-03-0020M	19.6	17	13.8	14.7	4.1	0.5	16.5	2.2	10	5.4	10	114
Clear Boggy Creek	OK410400-03-0230K	2.3	5.5	14.6	16.3	4.1	20	15.1	1.3	6.1	1.3	9.6	96.2
Cloudy Creek	OK410210-02-0300C	12.5	19.6	20.2	4.6	16.3	6.8	16.5	1	10	9.9	10	127
Cow Creek	OK410210-06-0350G	16.8	15.9	19.8	16.3	14.1	3.5	16.5	0.6	7.6	5.1	6.4	123
Cypress Creek	OK410210-01-0070D	16.1	15.3	16.7	15.9	9	9.9	11.1	5.6	6.4	4.1	9.6	120
Delaware Creek	OK410400-03-0240M	9	6.1	13.5	20	5.9	15.5	2.3	1	7	6.8	9.5	96.6
East Fork of Glover River	OK410210-09-0010G	19.6	10.5	20.2	20	7.5	1.9	13.7	0.6	8.3	7	9.5	119
Honobia Creek	OK410210-03-0150H	18.3	19.2	0	9.5	14.1	1.6	0.4	0.1	8	5.7	10	86.9
Horse Creek	OK410400-01-0040G	4	0.9	14.6	20	0	10.6	9.9	2.4	2	1.7	8	74.1
Island Bayou	OK410700-00-0040G	13	2.5	13.2	18.3	0	6.6	4.2	1.6	6.5	6.3	10	82.2
Lick Creek	OK410400-01-0130G	4.1	1.9	9.9	19.6	0	0.5	16.5	6.7	6	3.7	9.9	78.8
Lukfata Creek	OK410210-07-0010G	10.1	13.8	13.2	18.6	10.3	17	4.2	0.6	6.5	5.8	6.6	107
McGee Creek	OK410400-07-0010L	10.4	11.1	14	11.2	0	0	2.8	1	7.2	6.1	9.9	73.7
Mineral Bayou	OK410600-01-0300G	8.5	4.4	17.2	14.1	4.1	13.9	0.4	3.4	6.5	4.8	9.1	86.4
North Boggy Creek	OK410400-08-0010E	11.1	12.1	19.6	15.2	5.9	1.2	5.8	0.5	5.4	5.2	9.1	91.1

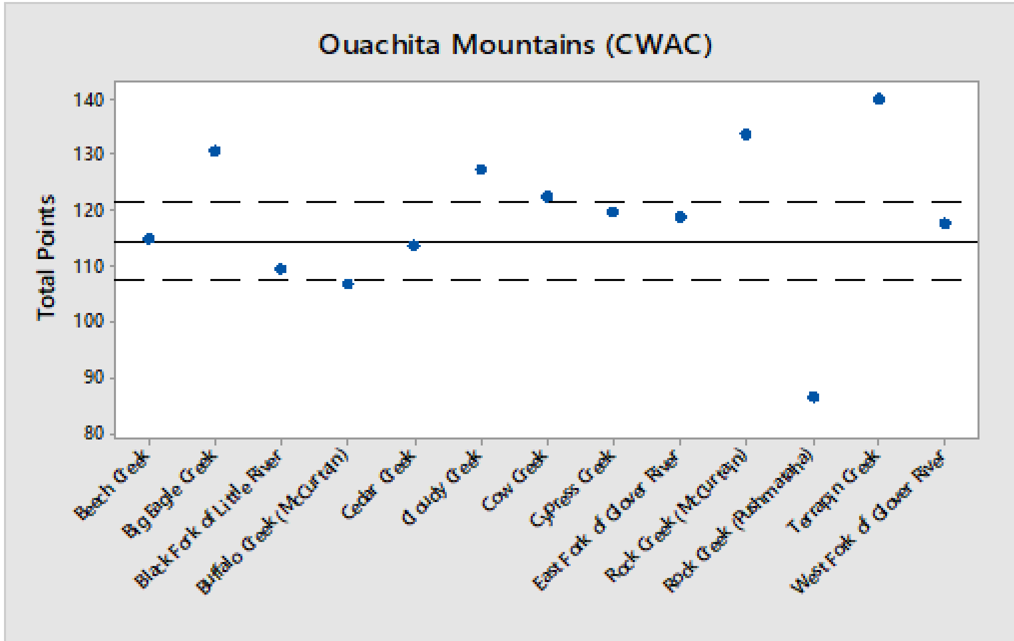
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Norwood Creek	OK410100-01-0050H	4.4	3.6	10.5	18.1	2.2	0.5	13.7	0.8	3.4	4	6.2	67.4
One Creek	OK410300-03-0060F	13.6	9.2	20	20	12.4	10.4	4.2	3.5	8.3	5.8	10	117
Rock Creek (McCurtain)	OK410200-03-0010G	19.3	13.4	16.3	14.6	14.1	15.2	16.5	1.1	8.7	4.8	9.7	134
Rock Creek (Pushmataha)	OK410300-02-0190G	6.4	3.4	14.6	17.4	0	0.5	16.5	0.3	10	7.5	10	86.6
Sand Creek	OK410700-00-0260G	13.8	6.7	19.4	5.3	11.4	15.2	0.4	0	7.1	6.6	9.6	95.5
Sandy Creek	OK410600-02-0020G	5.5	2.6	0	8.9	0	11.1	0.4	1.2	8.4	6.6	9.9	54.6
Sulphur Creek	OK410600-01-0030G	9.6	3.5	17.2	15.8	2.2	10.1	0.4	7.3	5.8	4.3	9.7	85.9
Tenmile Creek	OK410300-03-0270C	13.4	6.1	13.8	19.6	11.4	10.3	11.1	0.2	9.3	3.3	9.9	108
Terrapin Creek	OK410210-02-0150G	19.1	17.5	14.6	6	16.1	20	16.5	0.3	10	10	10	140
Waterhole Creek	OK410100-01-0340D	3	4.6	18.5	19.8	5.9	0.5	9.9	1.5	5.5	1.9	9.9	81
West Fork of Glover River	OK410210-08-0010M	16.8	14.9	9.9	19.9	9	1.5	16.5	0.8	9.8	8.8	9.6	118
Whitegrass Creek	OK410400-01-0210G	9.3	4.2	19.8	19.6	2.2	0.5	5	2.6	1.8	2.8	6.2	74

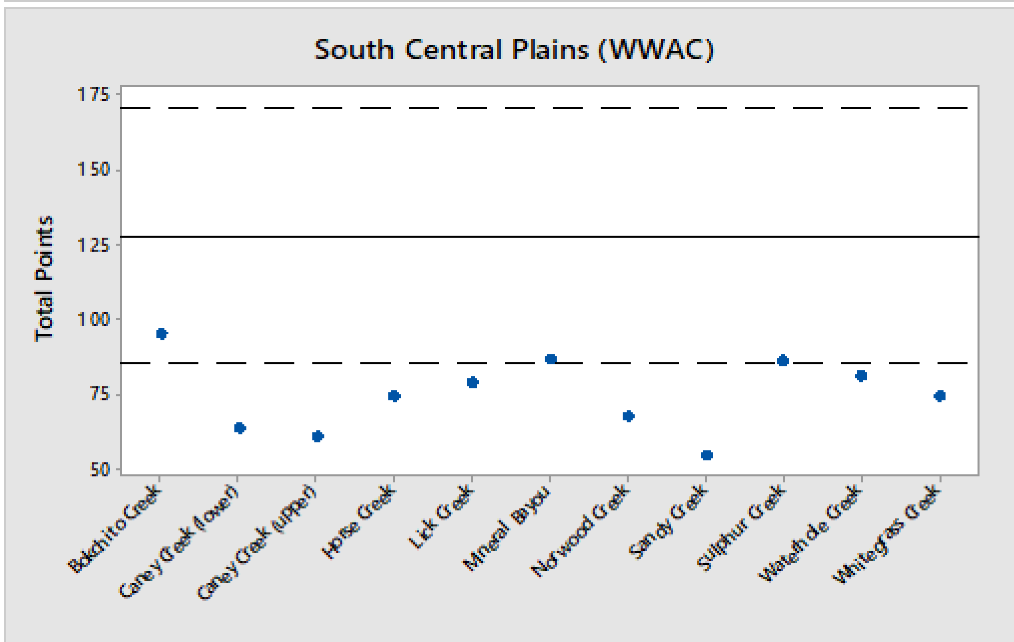
Sites were compared relative to the mean total habitat score of high quality sites in the respective ecoregion and a range determined by +/- two standard deviations (Figure 4). Sites with scores that are within +/- two standard deviations of the mean of the high quality sites do not necessarily have "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.

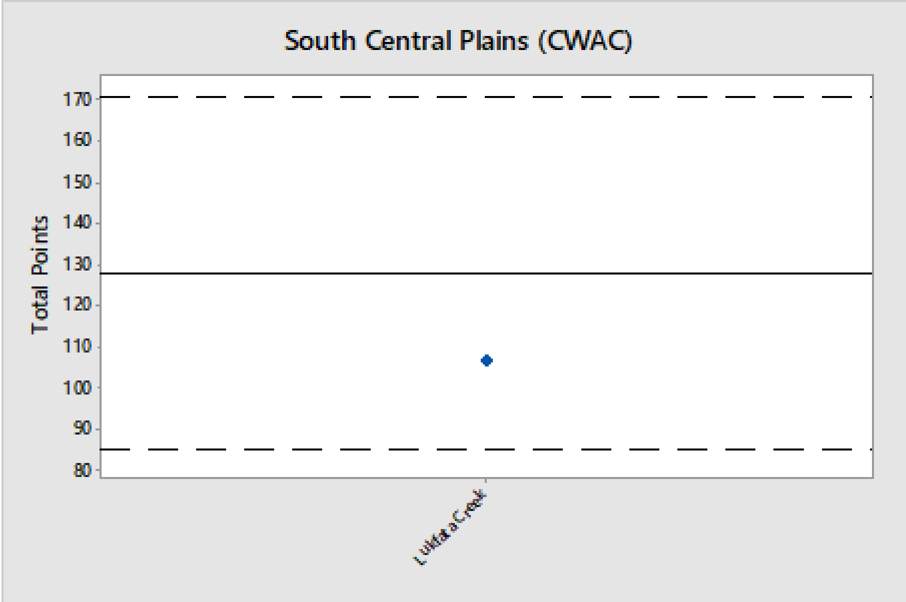
All of the sites in the Arkansas Valley and Arbuckle Uplift ecoregions were within two standard deviations of the high quality sites. Most of the warm water sites in the Ouachita Mountain ecoregion were below the high quality value; only Billy Creek and One Creek were within two standard deviations of the high quality mean, but Buck Creek had a significantly higher habitat score than the average high quality sites. The cool water sites in the OM ecoregion had only 2 of 13 sites which fell significantly below the average high quality sites; 5 of 13 sites were significantly better than the high quality average. Similarly, in the South Central Plains ecoregion, only 4 of 12 sites were within the high quality range, with the others being below. The sites in the East Central Texas Plains were plotted for information, but without high quality reference conditions, there is nothing to compare against.

Figure 4. Total habitat score for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.




Ouachita Mountains (CWAC)
Total Points
140
130
120
110
100
90
80
Beech Creek
Big Eagle Creek
Black Fork of Little River
Buffalo Creek (McCurtain)
Cedar Creek
Cloudy Creek
Cow Creek
Cypress Creek
East Fork of Glover River
Rock Creek (McCurtain)
Rock Creek (Pushmataha)
Terrapin Creek
West Fork of Glover River


South Central Plains (WWAC)
Total Points
175
150
125
100
75
50
Bokchito Creek
Caney Creek (lower)
Caney Creek (upper)
Horse Creek
Lick Creek
Mineral Bayou
Norwood Creek
Sandy Creek
Sulphur Creek
Waterhole Creek
Whitegrass Creek



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 was compared relative to the same mean of the high quality sites for the respective ecoregion in order to obtain the IBI score (OCC method). Although, ideally, one would use collections from the same years for comparison, multiyear collections at sites deemed "high quality" were not available.

Table 12. Metric values for calculation of fish IBI scores (OCC method) for Rotating Basin Group 4, cycle 3 monitoring sites.

Site Name	WBID	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent insectivorous Cyprinid	Percent lithophylic spawners
Beech Creek	OK410210-06-0320G	914	17	5	5	8	0.25	0.11	0.71
Big Eagle Creek	OK410210-06-0160I	420	18	7	5	7	0.55	0.21	0.29
Billy Creek	OK410310-02-0070C	400	16	5	4	4	0.56	0.19	0.38
Black Fork of Little River	OK410210-03-0020C	357	22	4	7	5	0.61	0.18	0.24
Bokchito Creek	OK410600-01-0090G	789	23	4	8	3	0.39	0.28	0.48
Buck Creek	OK410300-03-0420C	743	24	6	7	5	0.46	0.21	0.50

Site Name	WBID	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent insectivorous Cyprinid	Percent lithophylic spawners
Buffalo Creek (Latimer)	OK410310-03-0030N	323	31	5	8	6	0.49	0.12	0.45
Buffalo Creek (McCurtain)	OK410210-06-0020G	987	18	3	7	5	0.47	0.26	0.38
Caney Boggy Creek	OK410400-06-0120G	871	27	7	9	6	0.42	0.13	0.46
Caney Creek (lower)	OK410400-02-0200G	453	18	1	9	2	0.87	0.00	0.02
Caney Creek (upper)	OK410400-03-0020C	1087	30	5	9	5	0.56	0.26	0.08
Cedar Creek	OK410300-03-0020M	781	27	5	7	7	0.55	0.16	0.26
Clear Boggy Creek	OK410400-03-0230K	411	32	6	7	5	0.58	0.24	0.13
Cloudy Creek	OK410210-02-0300C	52	15	2	7	4	0.21	0.12	0.52
Cow Creek	OK410210-06-0350G	905	13	5	2	6	0.17	0.14	0.74
Cypress Creek	OK410210-01-0070D	312	27	5	11	9	0.51	0.19	0.31
Delaware Creek	OK410400-03-0240M	841	31	11	8	8	0.63	0.18	0.14
East Fork of Glover River	OK410210-09-0010G	1276	22	6	6	9	0.56	0.12	0.41
Honobia Creek	OK410210-03-0150H	1265	15	6	3	7	0.48	0.05	0.52
Horse Creek	OK410400-01-0040G	1503	33	6	9	6	0.75	0.12	0.05
Island Bayou	OK410700-00-0040G	757	27	6	7	5	0.62	0.21	0.10
Lick Creek	OK410400-01-0130G	375	30	6	8	8	0.71	0.05	0.07
Lukfata Creek	OK410210-07-0010G	405	32	8	11	11	0.51	0.22	0.33
McGee Creek	OK410400-07-0010L	465	23	6	9	4	0.69	0.11	0.13
Mineral Bayou	OK410600-01-0300G	1016	31	7	10	4	0.53	0.43	0.11
North Boggy Creek	OK410400-08-0010E	1365	31	3	9	6	0.29	0.02	0.65
Norwood Creek	OK410100-01-0050H	1111	30	2	11	7	0.93	0.00	0.00
One Creek	OK410300-03-0060F	1305	31	8	8	9	0.56	0.40	0.31
Rock Creek (McCurtain)	OK410200-03-0010G	1872	28	7	7	13	0.18	0.30	0.76
Rock Creek (Pushmataha)	OK410300-02-0190G	309	24	5	10	4	0.84	0.01	0.12
Sand Creek	OK410700-00-0260G	3176	34	5	11	4	0.76	0.16	0.05
Sandy Creek	OK410600-02-0020G	746	22	6	6	4	0.28	0.53	0.18
Sulphur Creek	OK410600-01-0030G	637	23	3	5	2	0.79	0.15	0.06
Tenmile Creek	OK410300-03-0270C	455	20	5	5	5	0.42	0.17	0.55
Terrapin Creek	OK410210-02-0150G	388	18	3	5	5	0.32	0.26	0.63
Waterhole Creek	OK410100-01-0340D	347	28	4	11	7	0.78	0.00	0.01
West Fork of Glover River	OK410210-08-0010M	1254	16	3	5	6	0.61	0.18	0.38
Whitegrass Creek	OK410400-01-0210G	319	22	6	6	5	0.79	0.05	0.07

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 3 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. There are no reference conditions for the East Central Texas Plains ecoregion. Of the 38 sites, 32 were "excellent" when compared with high quality sites with the same FWP use in the ecoregion, 2 were "good", and 2 were "fair".

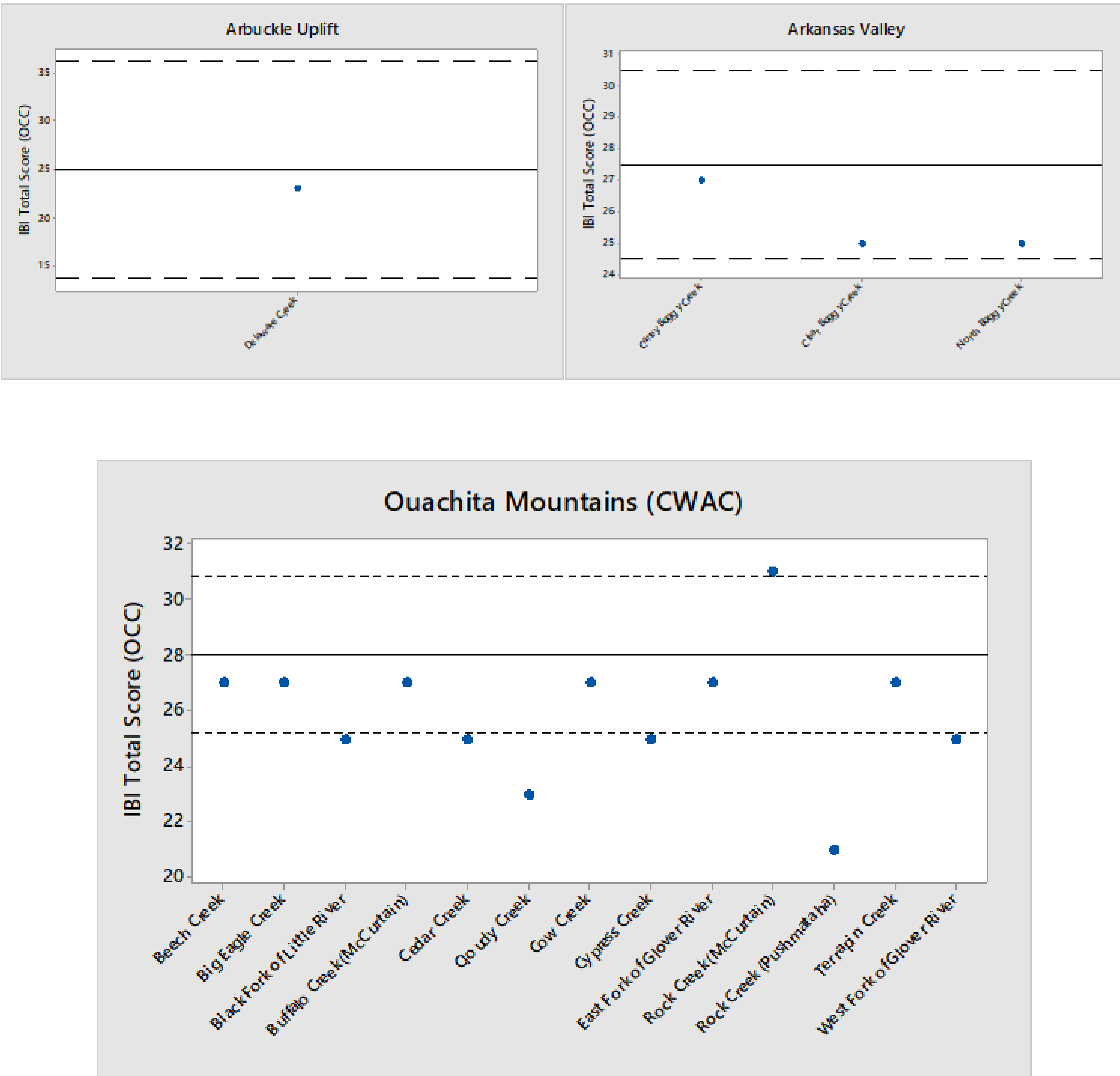
Table 13. IBI scores based on Use Support Assessment Protocol biocriteria (OWRB 2013) and OCC's modified RBP method. WWAC = warm water aquatic community, CWAC = cool water aquatic community. S = supporting, N = not supporting, U = undetermined.

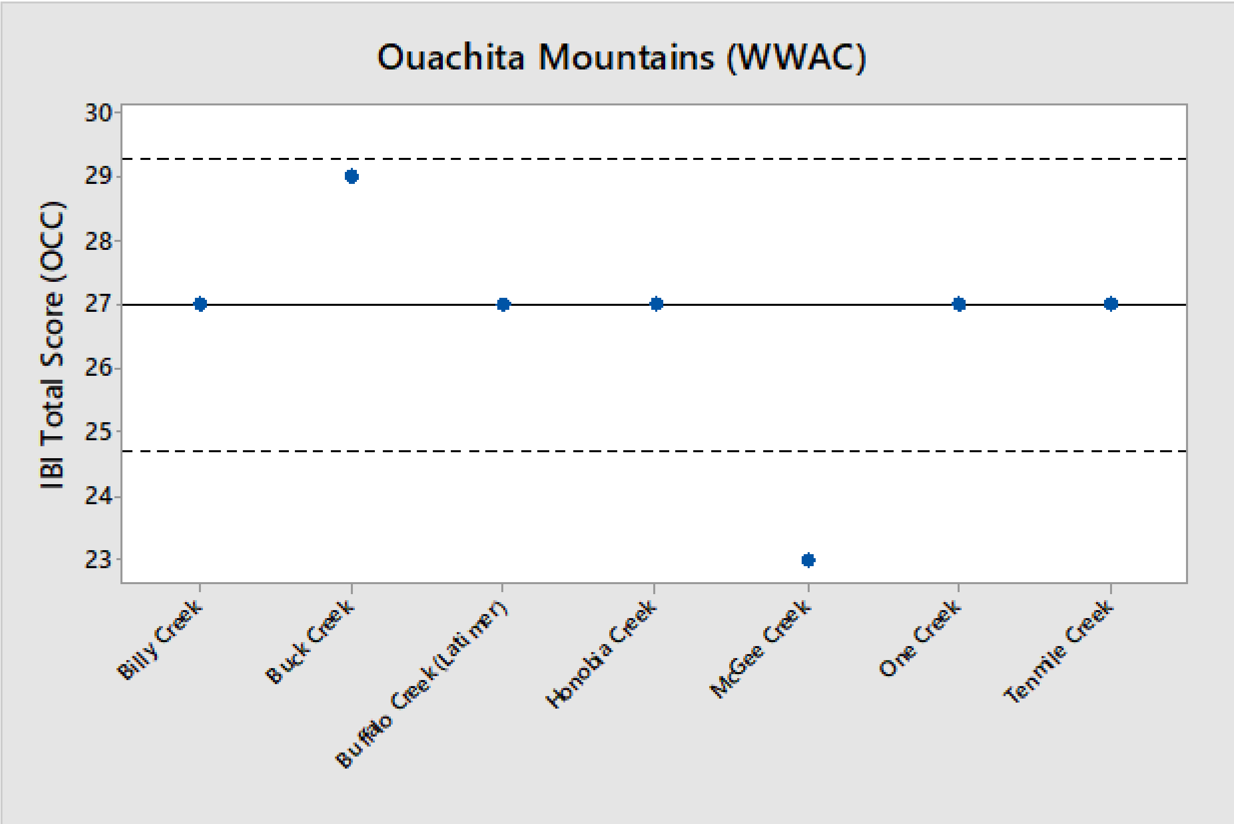
Modified Ecoregion	Site Name	WBID	FWProp	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
Arbuckle	Delaware Creek	OK410400-03-0240M	WWAC	37	S	23	0.9	Excellent
AV	Caney Boggy Creek	OK410400-06-0120G	WWAC	41	S	27	1	Excellent
AV	Clear Boggy Creek	OK410400-03-0230K	WWAC	35	S	25	0.9	Excellent
AV	North Boggy Creek	OK410400-08-0010E	WWAC	39	S	25	0.9	Excellent
ECTP	Island Bayou	OK410700-00-0040G	WWAC	35	S	NR		
ECTP	Sand Creek	OK410700-00-0260G	WWAC	33	S	NR		
OM	Beech Creek	OK410210-06-0320G	CWAC	41	S	27	1	Excellent
OM	Big Eagle Creek	OK410210-06-0160I	CWAC	33	U	27	1	Excellent
OM	Black Fork of Little River	OK410210-03-0020C	CWAC	35	S	25	0.9	Excellent
OM	Buffalo Creek (McCurtain)	OK410210-06-0020G	CWAC	33	U	27	1	Excellent
OM	Cedar Creek	OK410300-03-0020M	CWAC	35	S	25	0.9	Excellent
OM	Cloudy Creek	OK410210-02-0300C	CWAC	33	U	23	0.9	Good
OM	Cow Creek	OK410210-06-0350G	CWAC	37	S	27	1	Excellent
OM	Cypress Creek	OK410210-01-0070D	CWAC	39	S	25	0.9	Excellent
OM	East Fork of Glover River	OK410210-09-0010G	CWAC	41	S	27	1	Excellent
OM	Rock Creek (McCurtain)	OK410200-03-0010G	CWAC	41	S	31	1.1	Excellent
OM	Rock Creek (Pushmataha)	OK410300-02-0190G	CWAC	31	S	21	0.8	Fair
OM	Terrapin Creek	OK410210-02-0150G	CWAC	35	S	27	1	Excellent
OM	West Fork of Glover River	OK410210-08-0010M	CWAC	35	S	25	0.9	Excellent

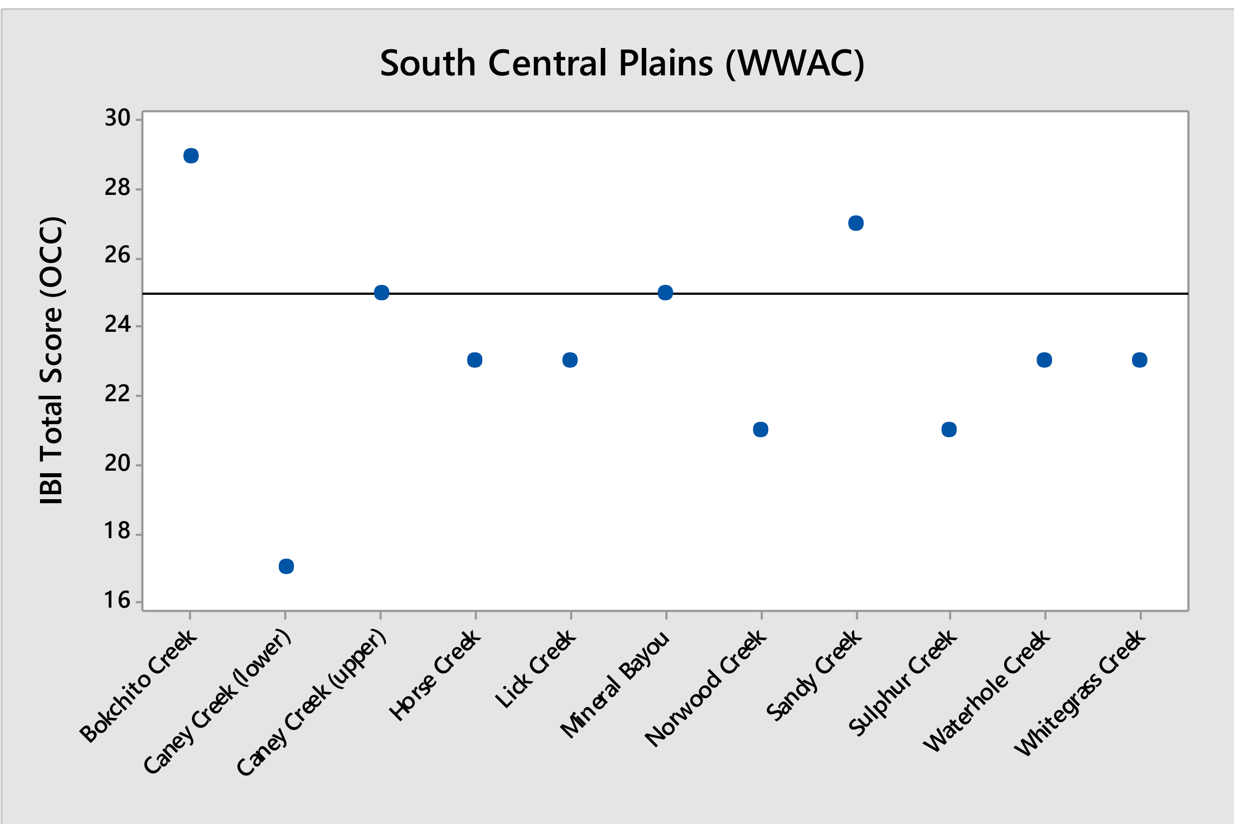
Modified Ecoregion	Site Name	WBID	FWProp	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
OM	Billy Creek	OK410310-02-0070C	WWAC	37	S	27	1.1	Excellent
OM	Buck Creek	OK410300-03-0420C	WWAC	35	S	29	1.2	Excellent
OM	Buffalo Creek (Latimer)	OK410310-03-0030N	WWAC	43	S	27	1.1	Excellent
OM	Honobia Creek	OK410210-03-0150H	WWAC	31	U	27	1.1	Excellent
OM	McGee Creek	OK410400-07-0010L	WWAC	31	U	23	0.9	Excellent
OM	One Creek	OK410300-03-0060F	WWAC	37	S	27	1.1	Excellent
OM	Tenmile Creek	OK410300-03-0270C	WWAC	35	S	27	1.1	Excellent
SCP	Lukfata Creek	OK410210-07-0010G	CWAC	39	S	27	1.2	Excellent
SCP	Bokchito Creek	OK410600-01-0090G	WWAC	39	S	29	1.2	Excellent
SCP	Caney Creek (lower)	OK410400-02-0200G	WWAC	27	S	17	0.7	Fair
SCP	Caney Creek (upper)	OK410400-03-0020C	WWAC	35	S	25	1	Excellent
SCP	Horse Creek	OK410400-01-0040G	WWAC	37	S	23	0.9	Excellent
SCP	Lick Creek	OK410400-01-0130G	WWAC	37	S	23	0.9	Excellent
SCP	Mineral Bayou	OK410600-01-0300G	WWAC	31	S	25	1	Excellent
SCP	Norwood Creek	OK410100-01-0050H	WWAC	32	No criteria	21	0.8	Good
SCP	Sandy Creek	OK410600-02-0020G	WWAC	37	S	27	1.1	Excellent
SCP	Sulphur Creek	OK410600-01-0030G	WWAC	31	S	21	0.8	Good
SCP	Waterhole Creek	OK410100-01-0340D	WWAC	37	S	23	0.9	Excellent
SCP	Whitegrass Creek	OK410400-01-0210G	WWAC	33	S	23	0.9	Excellent

Figure 5 shows the IBI score for each fixed site (indicated by a blue dot) relative to the mean value for the high quality sites in that ecoregion (indicated by a solid line). The dashed lines in each graph represent +/- two standard deviations of the mean IBI score of the high quality sites in that ecoregion. There was only one high quality site in the SCP ecoregion for the WWAC designation and the CWAC designation, so no range is indicated. There were no high quality sites in the East Central Texas Plains ecoregion, so that data is not shown in Figure 5.

Figure 5. IBI score (fish) for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.




Ouachita Mountains (WWAC)
IBI Total Score (OCC)
30
29
28
27
26
25
24
23
Billy Creek
Buck Creek
Buffalo Creek (Latimer)
Honobia Creek
McGee Creek
One Creek
Tenmile Creek


South Central Plains (WWAC)
IBI Total Score (OCC)
30
28
26
24
22
20
18
16
Bokchito Creek
Caney Creek (lower)
Caney Creek (upper)
Horse Creek
Lick Creek
Mineral Bayou
Norwood Creek
Sandy Creek
Sulphur Creek
Waterhole Creek
Whitegrass Creek

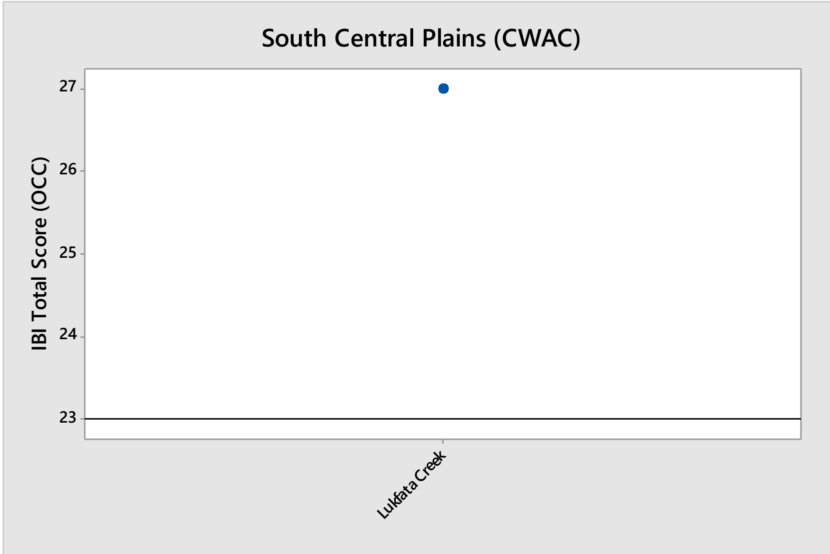


Table 14 shows a comparison between fish data collected in cycle 1 (2005 or 2006), cycle 2 (2010 or 2011), and cycle 3 (2015 or 2016) of the rotating basin project in order to examine whether biological conditions have improved, worsened, or remained the same at a particular sites. IBI scores were calculated relative to the same high quality sites data for all cycles, so any change in condition is due only to a change in the rotating basin cycle 3 collection, not to a change in the high quality sites. When comparing the last two cycles, the fish community remained in the same condition for 25 of the 32 sites with IBI scores to be compared. Four streams had worse fish community conditions in cycle 3 relative to cycle 2, while three streams had improved fish communities.

Table 14. Comparison of fish data from cycle 1 (2005-2006), cycle 2 (2010-2012), and cycle 3 (2015-2017).

Site Name	WBID	Cycle	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Proportion Tolerant Individuals	Proportion Insectivorous Cyprinid Individuals	Proportion Lithophylic Spawner Individuals	Total Score	IBI	Condition
Beech Creek	OK410210-06-0320G	2005-2006	343	10	2	2	4	0.08	0.74	0.22	27	1.00	Excellent
Beech Creek	OK410210-06-0320G	2010-2012	450	13	4	3	5	0.22	0.26	0.55	29	1.07	Excellent
Beech Creek	OK410210-06-0320G	2015-2017	914	17	5	5	8	0.25	0.11	0.71	27	1.00	Excellent
Big Eagle Creek	OK410210-06-0160L	2005-2006	340	13	2	3	5	0.15	0.14	0.78	25	0.93	Excellent
Big Eagle Creek	OK410210-06-0160L	2010-2012	522	11	4	3	5	0.25	0.13	0.44	25	0.93	Excellent
Big Eagle Creek	OK410210-06-0160I	2015-2017	420	18	7	5	7	0.55	0.21	0.29	27	1.00	Excellent

Site Name	WBID	Cycle	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Proportion Tolerant Individuals	Proportion Insectivorous Cyprinid Individuals	Proportion Lithophylic Spawner Individuals	Total Score	IBI	Condition
Billy Creek	OK410310-02-0070C	2005-2006	357	18	4	5	5	0.27	0.19	0.17	23	0.85	Good
Billy Creek	OK410310-02-0070C	2010-2012	617	17	4	6	3	0.34	0.43	0.37	27	1.08	Excellent
Billy Creek	OK410310-02-0070C	2015-2017	400	16	5	4	4	0.56	0.19	0.38	27	1.08	Excellent
Black Fork of Little River	OK410210-03-0020C	2005-2006	239	21	5	6	6	0.48	0.18	0.33	25	0.93	Excellent
Black Fork of Little River	OK410210-03-0020C	2010-2012	425	23	8	7	8	0.68	0.17	0.26	25	0.93	Excellent
Black Fork of Little River	OK410210-03-0020C	2015-2017	357	22	4	7	5	0.61	0.18	0.24	25	0.93	Excellent
Bokchito Creek	OK410600-01-0090G	2005-2006	714	19	2	6	4	0.36	0.06	0.52	25	1.04	Excellent
Bokchito Creek	OK410600-01-0090G	2010-2012	525	14	2	6	2	0.51	0.26	0.43	25	1.00	Excellent
Bokchito Creek	OK410600-01-0090G	2015-2017	789	23	4	8	3	0.39	0.28	0.48	29	1.16	Excellent
Buck Creek	OK410310-03-0420C	2005-2006	239	17	6	4	4	0.34	0.15	0.43	27	1.00	Excellent
Buck Creek	OK410310-03-0420C	2010-2012	153	17	4	4	4	0.49	0.37	0.22	27	1.08	Excellent
Buck Creek	OK410300-03-0420C	2015-2017	743	24	6	7	5	0.46	0.21	0.50	29	1.16	Excellent
Buffalo Creek (McCurtain)	OK410210-06-0020G	2005-2006	448	15	3	5	4	0.18	0.22	0.48	31	1.15	Excellent
Buffalo Creek (McCurtain)	OK410210-06-0020G	2010-2012	473	18	5	6	2	0.32	0.07	0.40	25	0.93	Excellent
Buffalo Creek (McCurtain)	OK410210-06-0020G	2015-2017	987	18	3	7	5	0.47	0.26	0.38	27	1.00	Excellent
Caney Boggy Creek	OK410400-06-0120G	2005-2006	275	23	6	8	5	0.48	0.07	0.35	25	0.91	Good
Caney Boggy Creek	OK410400-06-0120G	2010-2012	284	18	1	7	2	0.96	0.03	0.02	17	0.63	Fair
Caney Boggy Creek	OK410400-06-0120G	2015-2017	871	27	7	9	6	0.42	0.13	0.46	27	1.00	Excellent
Caney Creek (lower)	OK410400-02-0200G	2005-2006	523	25	7	9	6	0.81	0.07	0.07	23	0.96	Excellent
Caney Creek (lower)	OK410400-02-0200G	2010-2012	395	21	3	9	4	0.82	0.01	0.03	23	0.92	Excellent
Caney Creek (lower)	OK410400-02-0200G	2015-2017	453	18	1	9	2	0.87	0.00	0.02	17	0.68	Fair
Caney Creek (upper)	OK410400-03-0020C	2005-2006	277	17	4	7	2	0.45	0.15	0.39	25	1.04	Excellent
Caney Creek (upper)	OK410400-03-0020C	2010-2012	483	24	6	7	7	0.52	0.31	0.15	25	1.00	Excellent
Caney Creek (upper)	OK410400-03-0020C	2015-2017	1087	30	5	9	5	0.56	0.26	0.08	25	1.00	Excellent
Cedar Creek	OK410300-03-0020M	2005-2006	137	18	5	5	6	0.45	0.13	0.25	25	0.93	Excellent
Cedar Creek	OK410300-03-0020M	2010-2012	429	20	5	6	5	0.64	0.16	0.19	25	0.93	Excellent
Cedar Creek	OK410300-03-0020M	2015-2017	781	27	5	7	7	0.55	0.16	0.26	25	0.93	Excellent
Cloudy Creek	OK410210-02-0300C	2005-2006	206	21	6	5	7	0.34	0.34	0.27	27	1.00	Excellent
Cloudy Creek	OK410210-02-0300C	2010-2012	284	14	3	4	4	0.53	0.12	0.30	21	0.78	Fair
Cloudy Creek	OK410210-02-0300C	2015-2017	474	19	3	9	6	0.63	0.01	0.34	23	0.85	Good
Cow Creek	OK410210-06-0350G	2005-2006	51	8	3	2	4	0.43	0.14	0.55	23	0.85	Good

Site Name	WBID	Cycle	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Proportion Tolerant Individuals	Proportion Insectivorous Cyprinid Individuals	Proportion Lithophylic Spawner Individuals	Total Score	IBI	Condition
Cow Creek	OK410210-06-0350G	2010-2012	360	12	5	4	7	0.22	0.53	0.45	31	1.15	Excellent
Cow Creek	OK410210-06-0350G	2015-2017	905	13	5	2	6	0.17	0.14	0.74	27	1.00	Excellent
Cypress Creek	OK410210-01-0070G	1991	237	19	3	7	6	0.26	0.47	0.52	27	1.00	Excellent
Cypress Creek	OK410210-01-0070G	1994	410	23	4	8	7	0.46	0.17	0.40	27	1.00	Excellent
Cypress Creek	OK410210-01-0070G	2005-2006	201	22	4	7	7	0.50	0.25	0.19	27	1.00	Excellent
Cypress Creek	OK410210-01-0070G	2010-2012	186	13	3	4	2	0.43	0.41	0.44	25	0.93	Excellent
Cypress Creek	OK410210-01-0070D	2015-2017	312	27	5	11	9	0.51	0.19	0.31	25	0.93	Excellent
Delaware Creek	OK410400-03-0240M	2005-2006	248	22	7	7	6	0.40	0.32	0.26	27	1.08	Excellent
Delaware Creek	OK410400-03-0240M	2010-2012	345	17	6	3	4	0.34	0.32	0.37	27	1.08	Excellent
Delaware Creek	OK410400-03-0240M	2015-2017	841	31	11	8	8	0.63	0.18	0.14	23	0.92	Excellent
East Fork of Glover River	OK410210-09-0010G	2005-2006	737	23	6	7	9	0.21	0.10	0.64	29	1.07	Excellent
East Fork of Glover River	OK410210-09-0010G	2010-2012	972	21	8	5	9	0.27	0.27	0.56	29	1.07	Excellent
East Fork of Glover River	OK410210-09-0010G	2015-2017	1276	22	6	6	9	0.56	0.12	0.41	27	1.00	Excellent
Horse Creek	OK410400-01-0040G	2005-2006	303	22	4	8	5	0.55	0.35	0.06	25	1.04	Excellent
Horse Creek	OK410400-01-0040G	2010-2012	500	25	7	7	4	0.74	0.19	0.05	23	0.92	Excellent
Horse Creek	OK410400-01-0040G	2015-2017	1503	33	6	9	6	0.75	0.12	0.05	23	0.92	Excellent
Island Bayou	OK410700-00-0040G	2005-2006	233	25	4	7	2	0.67	0.12	0.10	NR		
Island Bayou	OK410700-00-0040G	2010-2012	432	23	6	7	3	0.68	0.25	0.05	NR		
Island Bayou	OK410700-00-0040G	2015-2017	757	27	6	7	5	0.62	0.21	0.10	NR		
Lick Creek	OK410400-01-0130G	2005-2006	193	17	3	4	5	0.32	0.25	0.24	23	0.96	Excellent
Lick Creek	OK410400-01-0130G	2010-2012	137	21	4	7	6	0.50	0.26	0.04	25	1.00	Excellent
Lick Creek	OK410400-01-0130G	2015-2017	375	30	6	8	8	0.71	0.05	0.07	23	0.92	Excellent
Lukfata Creek	OK410210-07-0010G	1991	150	20	5	8	4	0.68	0.03	0.05	23	0.96	Excellent
Lukfata Creek	OK410210-07-0010G	2005-2006	467	25	5	7	5	0.29	0.57	0.22	29	1.21	Excellent
Lukfata Creek	OK410210-07-0010G	2010-2012	464	24	9	5	8	0.41	0.28	0.45	29	1.26	Excellent
Lukfata Creek	OK410210-07-0010G	2015-2017	405	32	8	11	11	0.51	0.22	0.33	27	1.17	Excellent
Mineral Bayou	OK410600-01-0300G	1994	777	18	5	6	2	0.42	0.34	0.23	23	0.96	Excellent
Mineral Bayou	OK410600-01-0300G	2005-2006	397	21	7	4	4	0.27	0.29	0.44	27	1.13	Excellent
Mineral Bayou	OK410600-01-0300G	2010-2012	281	20	6	7	4	0.43	0.16	0.36	25	1.00	Excellent
Mineral Bayou	OK410600-01-0300G	2015-2017	1016	31	7	10	4	0.53	0.43	0.11	25	1.00	Excellent
North Boggy Creek	OK410400-08-0010M	2005-2006	181	18	1	7	3	0.65	0.24	0.17	19	0.70	Fair

Site Name	WBID	Cycle	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Proportion Tolerant Individuals	Proportion Insectivorous Cyprinid Individuals	Proportion Lithophylic Spawner Individuals	Total Score	IBI	Condition
North Boggy Creek	OK410400-08-0010M	2010-2012	392	23	4	9	4	0.60	0.19	0.28	25	1.00	Excellent
North Boggy Creek	OK410400-08-0010E	2015-2017	1365	31	3	9	6	0.29	0.02	0.65	25	0.93	Excellent
Norwood Creek	OK410100-01-0050H	2005-2006	103	17	1	5	1	0.86	0.03	0.03	15	0.63	Poor
Norwood Creek	OK410100-01-0050H	2010-2012	207	24	3	8	4	0.78	0.07	0.11	23	0.92	Excellent
Norwood Creek	OK410100-01-0050H	2015-2017	1111	30	2	11	7	0.93	0.00	0.00	21	0.84	Good
One Creek	OK410300-03-0060F	2005-2006	167	15	4	5	5	0.50	0.17	0.48	27	1.00	Excellent
One Creek	OK410300-03-0060F	2010-2012	486	27	5	8	6	0.43	0.15	0.22	25	1.00	Excellent
One Creek	OK410300-03-0060F	2015-2017	1305	31	8	8	9	0.56	0.40	0.31	27	1.08	Excellent
Rock Creek (McCurtain)	OK410200-03-0010G	2005-2006	258	14	3	6	6	0.20	0.43	0.73	31	1.15	Excellent
Rock Creek (McCurtain)	OK410200-03-0010G	2010-2012	191	13	3	4	6	0.36	0.32	0.63	27	1.00	Excellent
Rock Creek (McCurtain)	OK410200-03-0010G	2015-2017	1872	28	7	7	13	0.18	0.30	0.76	31	1.15	Excellent
Rock Creek (Pushmataha)	OK410300-02-0190G	2005-2006	213	16	3	6	2	0.43	0.16	0.25	23	0.85	Good
Rock Creek (Pushmataha)	OK410300-02-0190G	2010-2012	149	14	3	6	1	0.61	0.01	0.38	21	0.78	Fair
Rock Creek (Pushmataha)	OK410300-02-0190G	2015-2017	309	24	5	10	4	0.84	0.01	0.12	21	0.78	Fair
Sand Creek	OK410700-00-0260G	2005-2006	596	17	4	5	3	0.29	0.24	0.38	NR		
Sand Creek	OK410700-00-0260G	2010-2012	457	17	4	6	2	0.65	0.18	0.15	NR		
Sand Creek	OK410700-00-0260G	2015-2017	3176	34	5	11	4	0.76	0.16	0.05	NR		
Sandy Creek	OK410600-02-0020G	2005-2006	320	14	4	5	1	0.33	0.23	0.43	25	1.04	Excellent
Sandy Creek	OK410600-02-0020G	2010-2012	264	17	4	6	2	0.28	0.23	0.11	23	0.92	Excellent
Sandy Creek	OK410600-02-0020G	2015-2017	746	22	6	6	4	0.28	0.53	0.18	27	1.08	Excellent
Sulphur Creek	OK410600-01-0030G	2005-2006	361	21	3	5	3	0.66	0.07	0.18	19	0.79	Good
Sulphur Creek	OK410600-01-0030G	2010-2012	469	17	3	5	2	0.70	0.21	0.06	23	0.92	Excellent
Sulphur Creek	OK410600-01-0030G	2015-2017	637	23	3	5	2	0.79	0.15	0.06	21	0.84	Good
Tenmile Creek	OK410300-03-0270C	2005-2006	160	14	4	3	2	0.29	0.21	0.50	25	0.93	Excellent
Tenmile Creek	OK410300-03-0270C	2010-2012	158	21	4	5	5	0.49	0.27	0.39	29	1.16	Excellent
Tenmile Creek	OK410300-03-0270C	2015-2017	455	20	5	5	5	0.42	0.17	0.55	27	1.08	Excellent
Terrapin Creek	OK410210-02-0150G	2005-2006	179	13	2	5	3	0.26	0.06	0.62	23	0.85	Good
Terrapin Creek	OK410210-02-0150G	2010-2012	194	14	2	5	3	0.30	0.36	0.51	25	0.93	Excellent
Terrapin Creek	OK410210-02-0150G	2015-2017	388	18	3	5	5	0.32	0.26	0.63	27	1.00	Excellent
Waterhole Creek	OK410100-01-0340D	2005-2006	78	13	1	6	1	0.78	0.12	0.01	13	0.54	Poor
Waterhole Creek	OK410100-01-0340D	2010-2012	195	26	4	10	3	0.86	0.08	0.01	23	0.92	Excellent

Site Name	WBID	Cycle	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Proportion Tolerant Individuals	Proportion Insectivorous Cyprinid Individuals	Proportion Lithophylic Spawner Individuals	Total Score	IBI	Condition
Waterhole Creek	OK410100-01-0340D	2015-2017	347	28	4	11	7	0.78	0.00	0.01	23	0.92	Excellent
West Fork of Glover River	OK410210-08-0010M	2003	772	16	5	5	6	0.30	0.47	0.66	27	1.00	Excellent
West Fork of Glover River	OK410210-08-0010M	2005-2006	536	19	5	7	8	0.53	0.30	0.30	27	1.00	Excellent
West Fork of Glover River	OK410210-08-0010M	2010-2012	675	14	2	4	5	0.48	0.24	0.45	27	1.00	Excellent
West Fork of Glover River	OK410210-08-0010M	2015-2017	1254	16	3	5	6	0.61	0.18	0.38	25	0.93	Excellent
Whitegrass Creek	OK410400-01-0210G	2005-2006	262	19	3	6	3	0.54	0.34	0.09	21	0.88	Good
Whitegrass Creek	OK410400-01-0210G	2010-2012	107	11	3	4	4	0.88	0.02	0.05	19	0.76	Fair
Whitegrass Creek	OK410400-01-0210G	2015-2017	319	22	6	6	5	0.79	0.05	0.07	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 collections periods prevented collection of all planned samples over the cycle.

Table 15 presents the mean values, by season and sample type, for each metric at each site for the two year cycle 3 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, averaged per season and habitat. 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
Beech Creek	OK410210-06-0320G	Riffle	S	2	15	7	111	0.50	2.12	4.06	0.46	20	0.70	SI	NI
		Riffle	W	1	24	14	115	0.71	2.50	3.22	0.43	26	0.91	NI	
Big Eagle Creek	OK410210-06-0160I	Riffle	S	2	14	7	115	0.38	2.03	4.06	0.51	20	0.70	SI	NI

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	20	15	93	0.90	2.33	3.10	0.48	26	0.91	NI	
Billy Creek	OK410310-02-0070C	Riffle	S	2	17	8	127	0.26	2.10	5.85	0.51	16	0.56	SI	SI
		Riffle	W	1	13	6	106	0.45	1.98	3.60	0.55	18	0.63	SI	
Black Fork of Little River	OK410210-03-0020C	Riffle	S	2	20	8	117	0.37	2.42	4.36	0.41	24	0.84	NI	NI
		Riffle	W	1	34	20	232	0.58	3.02	3.07	0.23	32	1.12	NI	
Bokchito Creek	OK410600-01-0090G	Riffle	S	1	9	3	118	0.04	1.47	5.27	0.70	8	0.31	MI	SI
		Riffle	W	2	15	9	114	0.54	1.91	4.38	0.58	26	1.08	NI	
Buck Creek	OK410300-03-0420C	Riffle	S	2	18	10	117	0.42	2.28	4.84	0.40	24	0.84	NI	NI
		Riffle	W	1	17	8	111	0.32	2.15	4.97	0.52	22	0.77	SI	
Buffalo Creek (Latimer)	OK410310-03-0030N	Riffle	S	2	18	7	169	0.28	1.89	4.90	0.56	18	0.63	SI	SI
		Riffle	W	1	18	9	104	0.66	1.91	2.88	0.65	24	0.84	NI	
Buffalo Creek (McCurtain)	OK410210-06-0020G	Riffle	S	2	21	11	115	0.37	2.45	4.83	0.41	26	0.91	NI	NI
		Riffle	W	1	17	12	94	0.74	2.21	3.35	0.48	24	0.84	NI	
Caney Boggy Creek	OK410400-06-0120G	Riffle	S	2	15	7	103	0.41	1.65	3.73	0.60	26	1.00	NI	NI
		Riffle	W	1	15	6	153	0.22	1.97	5.36	0.55	20	0.77	SI	
Caney Creek (upper)	OK410400-03-0020C	Riffle	S	1	12	5	117	0.19	1.61	5.01	0.69	18	0.69	SI	SI
		Riffle	W	1	13	4	102	0.09	1.66	4.48	0.65	12	0.50	MI	
Cedar Creek	OK410300-03-0020M	Riffle	S	1	8	2	116	0.21	1.35	6.13	0.72	8	0.28	MI	MI
		Riffle	W	1	16	6	110	0.30	2.42	4.70	0.36	18	0.63	SI	
		Woody	W	1	15	5	114	0.11	1.89	5.96	0.65	14	0.54	SI	
Clear Boggy Creek	OK410400-03-0230K	Woody	S	1	13	4	111	0.46	2.11	4.97	0.46	22	0.85	NI	NI
		Woody	W	2	16	8	124	0.27	1.92	5.23	0.55	24	0.96	NI	
Cloudy Creek	OK410210-02-0300C	Riffle	S	1	20	8	116	0.39	2.47	4.70	0.38	26	0.91	NI	NI
		Riffle	W	1	19	11	113	0.55	2.44	3.63	0.38	28	0.98	NI	
Cow Creek	OK410210-06-0350G	Riffle	S	1	15	8	128	0.70	2.06	3.71	0.53	22	0.77	SI	SI
		Riffle	W	1	13	10	113	0.81	2.20	3.25	0.45	20	0.70	SI	
Cypress Creek	OK410210-01-0070D	Riffle	S	1	16	7	106	0.33	1.72	4.20	0.72	20	0.70	SI	SI
		Riffle	W	1	14	10	100	0.74	2.18	2.71	0.39	24	0.84	NI	
Delaware Creek	OK410400-03-0240M	Riffle	S	2	17	9	114	0.22	1.84	4.40	0.62	22	0.79	SI	NI
		Riffle	W	2	17	8	118	0.44	1.97	5.44	0.59	26	1.00	NI	
East Fork of Glover River	OK410210-09-0010G	Riffle	S	2	18	7	112	0.59	2.25	4.18	0.47	22	0.77	SI	SI
		Riffle	W	1	19	9	127	0.31	2.37	4.14	0.41	22	0.77	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
Honobia Creek	OK410210-03-0150H	Riffle	S	2	19	8	120	0.57	2.57	4.32	0.33	26	0.91	NI	NI
		Riffle	W	1	23	14	110	0.57	2.65	3.57	0.34	30	1.05	NI	
Island Bayou	OK410700-00-0040G	Woody	W	1	14	3	108	0.06	1.86	6.39	0.57		NR		
Lukfata Creek	OK410210-07-0010G	Riffle	S	1	16	8	126	0.30	1.93	4.15	0.60	26	1.00	NI	NI
		Riffle	W	1	12	7	97	0.39	1.78	4.67	0.59	24	1.00	NI	
Mineral Bayou	OK410600-01-0300G	Riffle	S	1	13	3	112	0.10	1.90	5.93	0.53	12	0.46	MI	SI
		Woody	W	1	14	5	119	0.32	1.92	6.41	0.54	22	0.85	NI	
North Boggy Creek	OK410400-08-0010E	Riffle	S	1	9	3	112	0.04	1.02	4.31	0.84	8	0.31	MI	MI
One Creek	OK410300-03-0060F	Riffle	S	2	17	9	119	0.36	2.28	4.16	0.41	22	0.77	SI	NI
		Riffle	W	2	22	11	124	0.33	2.30	4.78	0.49	26	0.91	NI	
Rock Creek (McCurtain)	OK410200-03-0010G	Riffle	W	1	16	12	86	0.67	2.19	3.70	0.50	24	0.84	NI	NI
		Riffle	S	1	21	8	105	0.36	2.63	4.56	0.30	28	0.98	NI	
Rock Creek (Pushmataha)	OK410300-02-0190G	Riffle	W	1	10	7	109	0.74	1.47	3.15	0.76	14	0.49	MI	MI
		Riffle	S	1	15	3	119	0.15	1.94	5.37	0.55	12	0.42	MI	
Sand Creek	OK410700-00-0260G	Riffle	S	1	12	4	132	0.10	1.91	5.73	0.58		NR		
		Riffle	W	2	20	12	119	0.52	2.51	4.37	0.34		NR		
Sandy Creek	OK410600-02-0020G	Sveg	S	1	18	8	105	0.38	2.24	4.15	0.44	26	0.93	NI	NI
		Sveg	W	1	18	7	127	0.47	2.24	5.06	0.46	26	1.08	NI	
		Woody	S	1	25	11	101	0.50	2.69	4.82	0.40	30	1.07	NI	
Tenmile Creek	OK410300-03-0270C	Riffle	S	2	11	5	124	0.14	1.16	4.19	0.80	10	0.35	MI	MI
		Riffle	W	1	12	5	122	0.20	1.86	4.62	0.60	12	0.42	MI	
		Woody	S	1	10	4	112	0.28	1.56	4.73	0.62	14	0.64	SI	
Terrapin Creek	OK410210-02-0150G	Riffle	S	2	30	16	202	0.50	2.83	4.59	0.31	30	1.05	NI	NI
		Riffle	W	1	18	12	113	0.60	2.11	3.86	0.51	26	0.91	NI	
Waterhole Creek	OK410100-01-0340D	Riffle	W	1	6	2	100	0.45	1.22	4.08	0.79	12	0.50	MI	MI
West Fork of Glover River	OK410210-08-0010M	Riffle	S	2	18	10	114	0.54	2.40	4.36	0.41	26	0.91	NI	NI
		Riffle	W	1	17	12	115	0.53	2.35	3.48	0.35	26	0.91	NI	

Most sites had either non-impaired or slightly impaired macroinvertebrate communities overall (when averaging the scores across sample types). The following sites were moderately impaired overall: Cedar, North Boggy, Rock (Pushmataha), Tenmile, and Waterhole Creeks. Results indicate non-impaired macroinvertebrate communities in 52% of the sites, slightly impaired communities in 26% of the sites, and moderately impaired communities in 16% of the sites. 2 sites had no reference data to compare. Macroinvertebrates were not collected from seven sites (Caney (lower), Horse, Lick, McGee, Norwood, Sulfur, and Whitegrass Creeks) due to lack of flow or elevated flow.

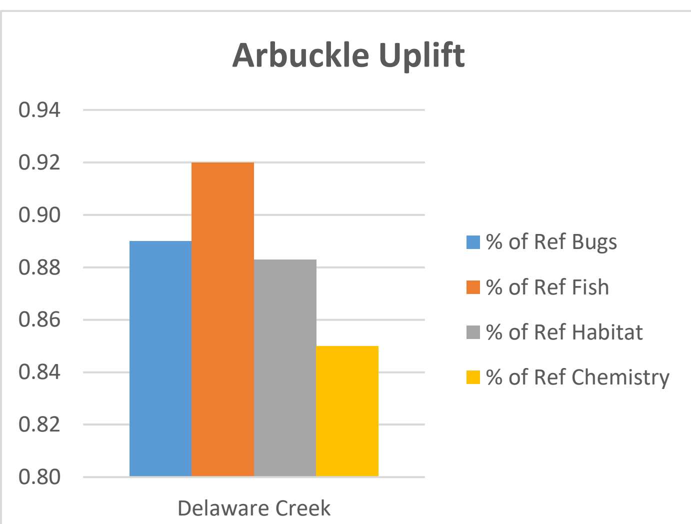
Poor macroinvertebrate scores could indicate water quality problems where habitat scores are acceptable; however, it is possible that the macroinvertebrate collection was not taken at a time which would best represent the community there (i.e., drought influences).

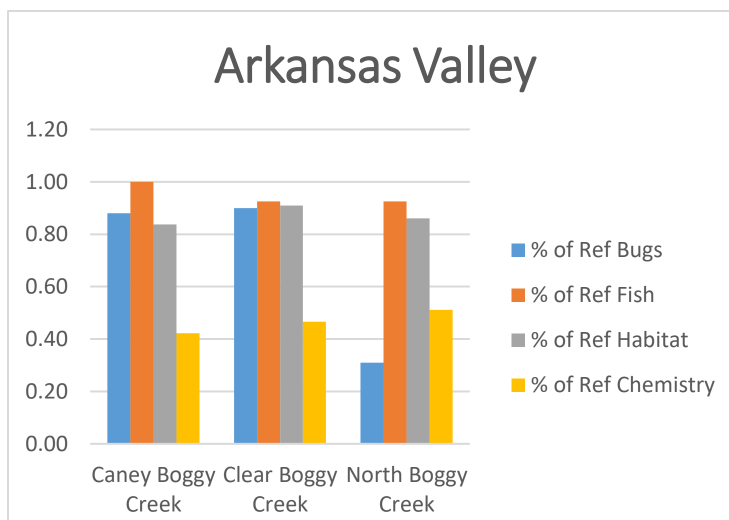
3.2.4 Overall Biological Assessment

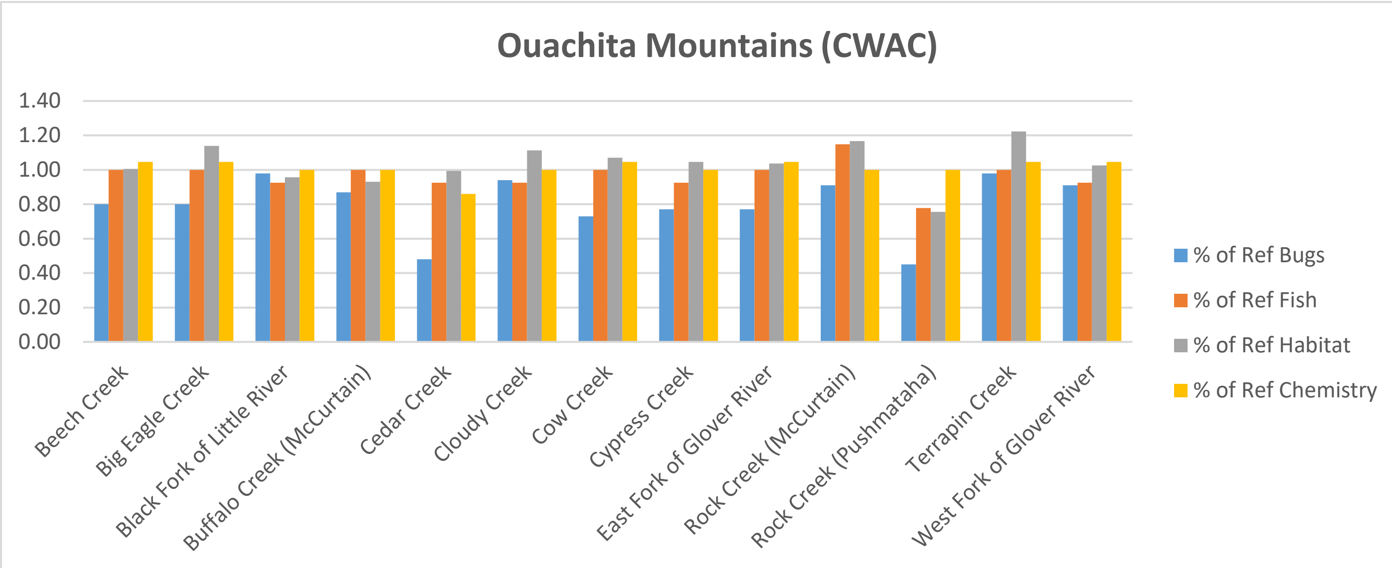
In order to synthesize the biological findings into a meaningful representation of the overall quality of each site, the biological assessments were compared with the habitat and water chemistry results. A water quality score was computed similarly to the other index scores by comparing rotating basin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

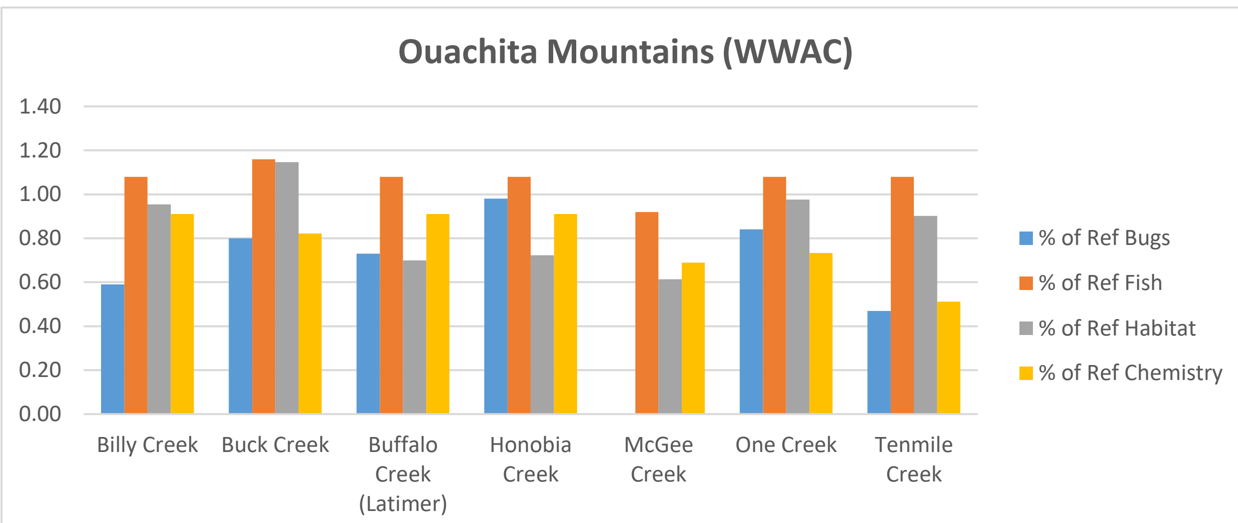
A determination of "good" or "excellent" stream health is indicated by a relatively high score for all categories. Most streams had relatively good agreement among the categories, but there are instances where one score is quite different than the others. It is generally recognized that fish communities 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.

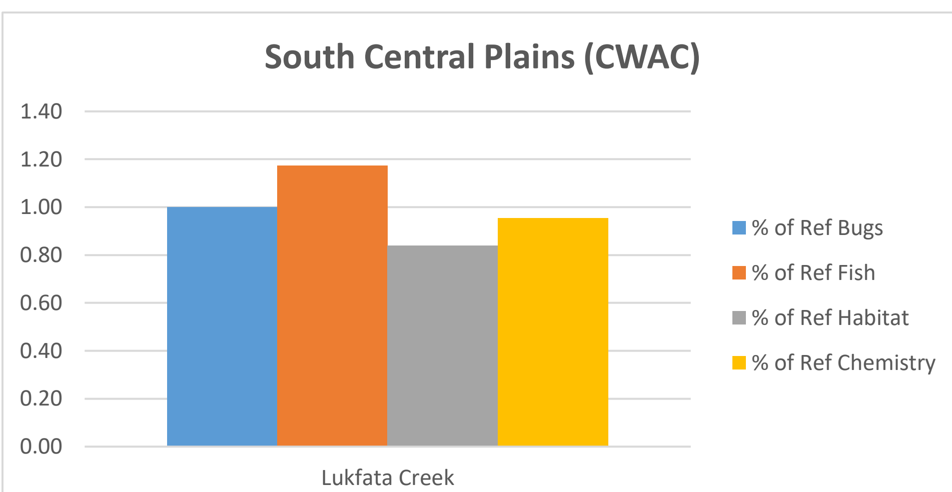
Figure 6. Comparison of habitat, fish, and bug scores relative to the average high quality site in each ecoregion.

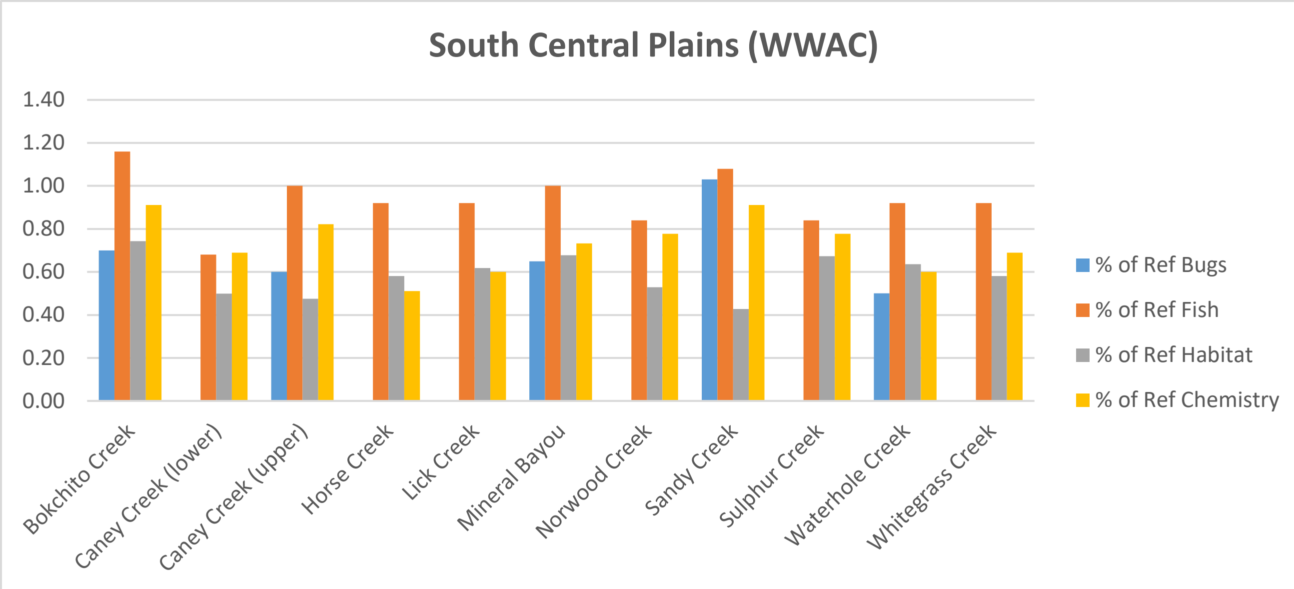





Ouachita Mountains (CWAC)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Beech Creek
Big Eagle Creek
Black Fork of Little River
Buffalo Creek (McCurtain)
Cedar Creek
Cloudy Creek
Cow Creek
Cypress Creek
East Fork of Glover River
Rock Creek (McCurtain)
Rock Creek (Pushmataha)
Terrapin Creek
West Fork of Glover River
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry


Ouachita Mountains (WWAC)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Billy Creek
Buck Creek
Buffalo Creek (Latimer)
Honobia Creek
McGee Creek
One Creek
Tenmile Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry


South Central Plains (CWAC)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Lukfata Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry



3.3 WATERSHED ASSESSMENT

Table 16 shows the land use upstream of each monitoring site as obtained through GIS using the 2011 NRCS National Land Cover Dataset. Table 17 presents the types and number of permitted activities that occur upstream of each site. The watershed sizes and land uses vary widely, with Cow Creek in having the smallest watershed areas, less than 8,000 acres, while the Clear Boggy Creek watershed includes more than 200,000 acres. Deciduous forest makes up the largest percentage of land use, on average, in this basin, followed by evergreen forest and grasslands. Watersheds range from having 10% deciduous forest to having 51% in deciduous forest, and from having no evergreen forest in the watershed to having 75% of the watershed in evergreen forest. Table 17 presents the types and number of permitted activities that occur in the watershed upstream of each site. Eighteen sites had no permitted activities in the watershed: Beech, Big Eagle, Black Fork of Little River, Bokchito, Buffalo (McCurtain), Caney (lower), Cedar, Cloudy, Cow, Cypress, Honobia, Lick, Lukfata, Norwood, One, Rock (McCurtain), Terrapin, Waterhole, and Whitegrass Creeks.

Five sites had permitted discharges 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 a permitted discharge to sites with no permitted discharge. Table 18 shows the results: nearly all of the parameters are significantly lower in the sites with no permitted discharge.

Table 16. Watershed land use (% of total watershed area) for each Group 5 monitoring site based on the most recent NLCD (USGS 2011).

Site Name	WBID	Total Acres	% Barren Land (Rock/Sand/Clay)	% Cultivated Crops	% Deciduous Forest	% Developed, High Intensity	% Developed, Low Intensity	% Developed, Medium Intensity	% Developed, Open space	% Emergent Herbaceous Wetlands	% Evergreen Forest	% Grasslands/Herbaceous	% Mixed Forest	% Open Water	% Pasture/Hay	% Shrub/Scrub	% Woody Wetlands
Beech Creek	OK410210-06-0320G	14777.35			0.51				0.02		0.37	0.03	0.06			0.02	0.00
Big Eagle Creek	OK410210-06-0160I	54696.33	0.00		0.46		0.00	0.00	0.03	0.00	0.28	0.07	0.08	0.00	0.01	0.07	0.01
Billy Creek	OK410310-02-0070C	13760.10			0.15		0.00		0.02		0.75	0.01	0.04	0.00	0.04	0.00	0.00
Black Fork of Little River	OK410210-03-0020C	45153.18	0.00		0.27		0.00	0.00	0.03		0.46	0.06	0.07	0.00	0.05	0.07	0.00
Bokchito Creek	OK410600-01-0090G	15371.49		0.01	0.20		0.00	0.00	0.04		0.00	0.32		0.00	0.42		
Buck Creek	OK410300-03-0420C	67007.46	0.00		0.32		0.00	0.00	0.02	0.00	0.36	0.05	0.07	0.00	0.15	0.03	0.01
Buffalo Creek (Latimer)	OK410310-03-0030N	29188.82	0.00		0.49		0.00	0.00	0.02	0.00	0.11	0.06	0.07	0.00	0.22	0.03	0.00
Buffalo Creek (McCurtain)	OK410210-06-0020G	40727.17	0.00		0.31		0.00		0.05	0.00	0.34	0.09	0.11	0.00	0.06	0.05	0.00
Caney Boggy Creek	OK410400-06-0120G	57840.61	0.00	0.01	0.46	0.00	0.00	0.00	0.03	0.00	0.01	0.22		0.01	0.25		0.00
Caney Creek (lower)	OK410400-02-0200G	19251.68	0.00	0.00	0.41		0.00	0.00	0.04	0.00	0.00	0.24		0.00	0.31		
Caney Creek (upper)	OK410400-03-0020C	30235.10	0.00	0.01	0.41	0.00	0.01	0.00	0.03	0.00	0.00	0.39		0.01	0.15		
Cedar Creek	OK410300-03-0020M	64280.07			0.25		0.00		0.03	0.00	0.40	0.11	0.08	0.00	0.07	0.05	0.01
Clear Boggy Creek	OK410400-03-0230K	233214.50	0.00	0.02	0.35	0.00	0.01	0.00	0.04	0.00	0.00	0.36		0.01	0.20	0.00	0.00
Cloudy Creek	OK410210-02-0300C	36265.56	0.00		0.23		0.00		0.03		0.41	0.17	0.04	0.00	0.01	0.11	0.00
Cow Creek	OK410210-06-0350G	7235.75			0.36				0.03		0.53	0.03	0.03	0.00	0.02	0.00	
Cypress Creek	OK410210-01-0070D	20833.50			0.18		0.01	0.00	0.05	0.00	0.39	0.12	0.08		0.01	0.17	0.00
Delaware Creek	OK410400-03-0240M	31040.29	0.00	0.02	0.39		0.00	0.00	0.03	0.00	0.00	0.36		0.01	0.19		
East Fork of Glover River	OK410210-09-0010G	36392.75			0.18		0.00	0.00	0.06		0.52	0.06	0.07	0.00	0.04	0.07	0.00

Site Name	WBID	Total Acres	% Barren Land (Rock/Sand/Clay)	% Cultivated Crops	% Deciduous Forest	% Developed, High Intensity	% Developed, Low Intensity	% Developed, Medium Intensity	% Developed, Open space	% Emergent Herbaceous Wetlands	% Evergreen Forest	% Grasslands/Herbaceous	% Mixed Forest	% Open Water	% Pasture/Hay	% Shrub/Scrub	% Woody Wetlands
Honobia Creek	OK410210-03-0150H	27220.19			0.43		0.00		0.01		0.36	0.03	0.10	0.00		0.06	
Horse Creek	OK410400-01-0040G	12833.89	0.00		0.10	0.00	0.03	0.01	0.09		0.01	0.02	0.04	0.00	0.69		0.00
Island Bayou	OK410700-00-0040G	84972.36	0.00	0.02	0.17	0.00	0.00	0.00	0.03	0.00	0.00	0.34	0.05	0.01	0.36	0.00	0.00
Lick Creek	OK410400-01-0130G	19968.88			0.27	0.00	0.00	0.00	0.05	0.00	0.00	0.13	0.01	0.00	0.54		0.00
Lukfata Creek	OK410210-07-0010G	29150.11	0.00	0.00	0.26		0.00	0.00	0.06		0.32	0.06	0.07	0.00	0.19	0.04	0.00
McGee Creek	OK410400-07-0010L	43340.28	0.00	0.00	0.40		0.00	0.00	0.01	0.00	0.10	0.13	0.03	0.00	0.23	0.08	0.01
Mineral Bayou	OK410600-01-0300G	24869.75	0.00	0.01	0.22	0.02	0.07	0.02	0.10		0.00	0.33		0.01	0.22		0.00
North Boggy Creek	OK410400-08-0010E	51454.79	0.00	0.00	0.50	0.00	0.00	0.00	0.04		0.00	0.28	0.00	0.00	0.16	0.01	0.00
Norwood Creek	OK410100-01-0050H	38430.30	0.00	0.01	0.19	0.00	0.00	0.00	0.03	0.01	0.32	0.07	0.08	0.01	0.21	0.01	0.06
One Creek	OK410300-03-0060F	27493.97			0.27	0.00	0.00		0.03		0.35	0.09	0.09	0.00	0.04	0.12	0.01
Rock Creek (McCurtain)	OK410200-03-0010G	29712.83			0.31		0.01	0.00	0.05		0.22	0.09	0.25	0.00		0.07	0.00
Rock Creek (Pushmataha)	OK410300-02-0190G	21207.19			0.30		0.00	0.00	0.02		0.21	0.29	0.05	0.00	0.01	0.10	0.00
Sand Creek	OK410700-00-0260G	11750.31	0.01	0.09	0.23	0.00	0.01	0.00	0.05	0.00	0.01	0.34		0.02	0.24		
Sandy Creek	OK410600-02-0020G	25090.65	0.00	0.04	0.39	0.00	0.00	0.00	0.03		0.00	0.36		0.00	0.18		0.00
Sulphur Creek	OK410600-01-0030G	15897.65	0.00	0.01	0.31		0.00	0.00	0.06		0.00	0.28		0.01	0.34		
Tenmile Creek	OK410300-03-0270C	63630.62	0.00		0.29		0.00	0.00	0.03	0.00	0.15	0.12	0.06	0.00	0.31	0.02	0.00
Terrapin Creek	OK410210-02-0150G	32793.95			0.17		0.00		0.04	0.00	0.57	0.09	0.05	0.00		0.07	0.00
Waterhole Creek	OK410100-01-0340D	19029.28	0.00	0.05	0.13		0.00	0.00	0.05		0.01	0.01	0.03	0.01	0.70	0.00	0.00
West Fork of Glover River	OK410210-08-0010M	115233.07	0.00		0.18		0.00	0.00	0.06	0.00	0.50	0.06	0.07	0.00	0.07	0.06	0.00

Site Name	WBID	Total Acres	% Barren Land (Rock/Sand/Clay)	% Cultivated Crops	% Deciduous Forest	% Developed, High Intensity	% Developed, Low Intensity	% Developed, Medium Intensity	% Developed, Open space	% Emergent Herbaceous Wetlands	% Evergreen Forest	% Grasslands/Herbaceous	% Mixed Forest	% Open Water	% Pasture/Hay	% Shrub/Scrub	% Woody Wetlands
Whitegrass Creek	OK410400-01-0210G	40878.22	0.00	0.00	0.37		0.00	0.00	0.03	0.00	0.00	0.21	0.00	0.00	0.38		0.00

Table 17. Permitted land use for each Group 5 monitoring sites. For the NPDES category, the total number of NPDES in the watershed is given, followed by the number of major NPDES in parentheses, if applicable.

Site Name	WBID	# CAFO	# Landfill	# Permitted Discharge	# O & G	# Total Retention Lagoon	# Land Application	# Public Water Intakes
Beech Creek	OK410210-06-0320G							
Big Eagle Creek	OK410210-06-0160I							
Billy Creek	OK410310-02-0070C				1			
Black Fork of Little River	OK410210-03-0020C							
Bokchito Creek	OK410600-01-0090G							
Buck Creek	OK410300-03-0420C				61			
Buffalo Creek (Latimer)	OK410310-03-0030N				17			
Buffalo Creek (McCurtain)	OK410210-06-0020G							
Caney Boggy Creek	OK410400-06-0120G	3			381			
Caney Creek (lower)	OK410400-02-0200G							
Caney Creek (upper)	OK410400-03-0020C				2	2		
Cedar Creek	OK410300-03-0020M							
Clear Boggy Creek	OK410400-03-0230K	1	2	3	1440		3	
Cloudy Creek	OK410210-02-0300C							
Cow Creek	OK410210-06-0350G							
Cypress Creek	OK410210-01-0070D							
Delaware Creek	OK410400-03-0240M	1		1				
East Fork of Glover River	OK410210-09-0010G	1						
Honobia Creek	OK410210-03-0150H							
Horse Creek	OK410400-01-0040G			3			1	
Island Bayou	OK410700-00-0040G			2	2			
Lick Creek	OK410400-01-0130G							
Lukfata Creek	OK410210-07-0010G							
McGee Creek	OK410400-07-0010L				54			
Mineral Bayou	OK410600-01-0300G		2	1	14	1		1
North Boggy Creek	OK410400-08-0010E				146			
Norwood Creek	OK410100-01-0050H							
One Creek	OK410300-03-0060F							
Rock Creek (McCurtain)	OK410200-03-0010G							
Rock Creek (Pushmataha)	OK410300-02-0190G				1			

Site Name	WBID	# CAFO	# Landfill	# Permitted Discharge	# O & G	# Total Retention Lagoon	# Land Application	# Public Water Intakes
Sand Creek	OK410700-00-0260G				1			
Sandy Creek	OK410600-02-0020G	1				1		
Sulphur Creek	OK410600-01-0030G					1		
Tenmile Creek	OK410300-03-0270C				12			
Terrapin Creek	OK410210-02-0150G							
Waterhole Creek	OK410100-01-0340D							
West Fork of Glover River	OK410210-08-0010M	1						
Whitegrass Creek	OK410400-01-0210G							

Table 18. Comparison of sites with and without permitted discharge based on one-way ANOVAs.

Parameter	Permitted Discharge	N	Mean	StDev	P Value	Result
Alkalinity	No	591	71.85	72.02	0.000	Lower
	Yes	89	193.85	66.02		
Conductivity	No	584	181.99	199.7	0.000	Lower
	Yes	87	639	427.2		
DO	No	580	7.262	2.896	0.047	Lower
	Yes	87	7.91	2.406		
DO %	No	580	75.516	22.949	0.003	Lower
	Yes	87	83.29	18.8		
Hardness	No	571	98.8	97.37	0.000	Lower
	Yes	86	264.52	88.47		
pH	No	576	7.0038	0.837	0.000	Lower
	Yes	87	7.8362	0.3863		
Turbidity	No	618	15.56	25.5	0.927	No Significant Difference
	Yes	89	16.3	16.15		

Parameter	Permitted Discharge	N	Mean	StDev	P Value	Result
Ammonia	No	256	0.0491	0.1656	0.814	No Significant Difference
	Yes	35	0.0424	0.0291		
Chloride	No	562	12.842	16.564	0.000	Lower
	Yes	84	80.1	125.9		
TDS	No	562	114.13	106.91	0.000	Lower
	Yes	84	372.4	236		
TKN	No	562	0.4301	0.4075	0.039	Lower
	Yes	84	0.5255	0.2899		
Nitrate	No	562	0.1154	0.2965	0.000	Lower
	Yes	84	0.4963	0.7976		
Nitrite	No	562	0.0509	0.1072	0.000	Lower
	Yes	84	0.1481	0.2681		
Ortho P	No	562	0.0204	0.0645	0.000	Lower
	Yes	84	0.118	0.197		
Total P	No	562	0.0478	0.0835	0.000	Lower
	Yes	84	0.1476	0.2009		
Sulfate	No	562	12.342	13.513	0.000	Lower
	Yes	84	37.28	30.83		
TSS	No	562	19.08	156.03	0.754	No Significant Difference
	Yes	84	13.74	12.06		
Available N	No	562	0.1887	0.3386	0.000	Lower
	Yes	84	0.6621	0.821		
Total N	No	562	0.5964	0.556	0.000	Lower
	Yes	84	1.17	0.943		
Flow	No	524	8.861	19.268	0.921	No Significant Difference
	Yes	68	8.62	15.72		

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 2016 Integrated Report (ODEQ). The causes and potential source(s) (if known) of any impairments can be found in the Integrated Report. No stream is in full attainment of its designated uses.

Table 19. Designated use support assessment. F = fully supporting, N = not supporting, I = insufficient information, X = use not assessed, * = antidegradation designation.

Site Name	WBID	Size (Stream Miles)	Aesthetics	Agriculture	Cool Water Aquatic Community	Habitat limited aquatic community	Warm Water Aquatic Community	Fish Consumption	High Quality Water	Primary Body Contact Recreation	Public/Private Water Supply	Secondary Body Contact Recreation	Sensitive Water Supply
Beech Creek	OK410210-06-0320G	12.71	F	F	N			X		F	X		
Big Eagle Creek	OK410210-06-0160I	20.50	F	F	N			X		F	X		
Billy Creek	OK410310-02-0070C	8.91	I	F			N	X		N			
Black Fork of Little River	OK410210-03-0020C	31.00	I	F	N			X	*	N	X		
Bokchito Creek	OK410600-01-0090G	16.78	F	F			F	X		N			
Buck Creek	OK410300-03-0420C	35.60	I	F			F	X		N	X		
Buffalo Creek (Latimer)	OK410310-03-0030N	10.72	X	X			X	X		X	X		*
Buffalo Creek (McCurtain)	OK410210-06-0020G	23.38	F	F	N			X		F	X		*
Caney Boggy Creek	OK410400-06-0120G	26.49	F	F			N	X		N	X		
Caney Creek (lower)	OK410400-02-0200G	11.67	F	N			N	X		N			
Caney Creek (upper)	OK410400-03-0020C	12.42	I	F			F	X				F	
Cedar Creek	OK410300-03-0020M	23.36	F	F	N			X	*	N	X		
Clear Boggy Creek	OK410400-03-0230K	10.74	X	X			F	X		X	X		
Cloudy Creek	OK410210-02-0300C	25.63	F	F	N			X	*	F	X		
Cow Creek	OK410210-06-0350G	11.03	F	F	N			X		F	X		
Cypress Creek	OK410210-01-0070D	20.73	I	F	N			X	*	F	X		
Delaware Creek	OK410400-03-0240M	29.01	I	F			F	X		N	X		
East Fork of Glover River	OK410210-09-0010G	21.90	F	F	N			F	*	F	F		
Honobia Creek	OK410210-03-0150H	22.20	I	I			I	X		X			
Horse Creek	OK410400-01-0040G	7.76	I	F			F	X		N	X		
Island Bayou Creek	OK410700-00-0040G	41.20	I	F			F	F				I	
Lick Creek	OK410400-01-0130G	20.19	F	F			N	X		N	X		
Lukfata Creek	OK410210-07-0010G	17.80	F	F	N			X		N	X		
McGee Creek	OK410400-07-0010L	32.08	I	F			F	X		F	X		*
Mineral Bayou Creek	OK410600-01-0300G	15.53	F	F			N	X		N			
North Boggy Creek	OK410400-08-0010E	27.84	X	X			F	X		X	X		*
Norwood Creek	OK410100-01-0050H	20.15	F	F			N	X		N	X		
One Creek	OK410300-03-0060F	17.42	I	F			N	X		N			
Rock Creek (McCurtain)	OK410200-03-0010G	12.35	I	F	N			X		N	X		
Rock Creek (Pushmataha)	OK410300-02-0190G	13.96	I	F	N			X		N			
Sand Creek	OK410700-00-0260G	12.01	F	F			F	X		N			
Sandy Creek	OK410600-02-0020G	15.35	I	F			N	X		N	X		
Sulphur Creek	OK410600-01-0030G	14.61	F	F			N	X		N			
Tenmile Creek	OK410300-03-0270C	35.75	I	F			N	X		F	I		
Terrapin Creek	OK410210-02-0150G	13.47	F	F	F			X	*	F	X		
Waterhole Creek	OK410100-01-0340D	16.61	F	F			N	X		N	X		

Site Name	WBID	Size (Stream Miles)	Aesthetics	Agriculture	Cool Water Aquatic Community	Habitat limited aquatic community	Warm Water Aquatic Community	Fish Consumption	High Quality Water	Primary Body Contact Recreation	Public/Private Water Supply	Secondary Body Contact Recreation	Sensitive Water Supply
West Fork of Glover River	OK410210-08-0010M	33.95	F	F	N			F	*	F			
Whitegrass Creek	OK410400-01-0210G	29.71	F	F			N	X		N	X		

4.0 SUMMARY

In general, water chemistry for the rotating Basin Group 5 monitoring sites showed some changes when compared with the first two cycles: nitrogen, alkalinity and/or hardness, and salts all increased though other parameters were about the same.

Low dissolved oxygen continues to be a problem in this basin: 76% of the sites were below the state criteria. This is most likely due to the fact that these systems, particularly those in McCurtain, LeFlore, and Pushmataha Counties, naturally tend toward sluggish, organically enriched conditions which promote high biological demand. Biological communities have developed under these naturally occurring conditions and are well adapted to the significantly lower DO trends.

While 61% of the sites in Basin 5 are meeting the state *E. coli* standard, none (except for East Fork of Glover River) is fully attaining the Recreational designated use because they are listed for *Enterococcus* and OCC only tests for *E. coli*.

Habitat at 45% of the sites in Basin 5 falls within two standard deviations of the mean habitat score of high quality sites in the same ecoregion. Comparisons of fish collections with collections in Cycle 2 indicate that about three of the sites showed improved conditions, four of the sites showed worse conditions, and 2/3 indicated the same conditions. Overall, approximately 82% of the sites scored excellent, 8% were good, 5% were fair, and 2 sites had no reference data to compare.

Most sites had either non-impaired (52%) or slightly impaired (26%) macroinvertebrate communities overall; 16% of the sites had collections that indicate moderately impaired communities. 2 sites had no reference data to compare.

The next cycle of monitoring in Basin 5 is scheduled to begin in June, 2020.

5.0 LITERATURE CITED

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