Small Watershed Rotating Basin Monitoring Program

Basin Group 1: Neosho-Grand and Upper Canadian Basins

Final Report

FY 15/16 §319(h), EPA Grant C9-996100-18
Project 7, Output 7.1.4

Submitted by:

Oklahoma Conservation Commission

Water Quality Division
2800 N. Lincoln Blvd., Suite 200
Oklahoma City, OK 73105

January 2019

Table of Contents

LIST OF TABLES 3
LIST OF FIGURES 3
1.0 INTRODUCTION 4
1.1 PROJECT BACKGROUND AND DESCRIPTION 4
2.0 MATERIALS AND METHODS 6
2.1 GENERAL 6
2.2 WATER QUALITY MONITORING 9
2.3 BIOLOGICAL MONITORING 10
2.3.1 Habitat Assessment 10
2.3.2 Fish 12
2.3.3 Macroinvertebrates 14
2.4 WATERSHED ASSESSMENT 16
2.5 BENEFICIAL USE SUPPORT ASSESSMENT 17
3.0 RESULTS AND DISCUSSION 17
3.1 WATER QUALITY MONITORING 17
3.2 BIOLOGICAL MONITORTING 59
3.2.1 Habitat Assessment 59
3.2.2 Fish Collections 65
3.2.3 Macroinvertebrate Collections 76
3.2.4 Overall Biological Assessment 80
3.3 WATERSHED ASSESSMENT 83
3.4 DESIGNATED USE SUPPORT ASSESSMENT 89
4.0 SUMMARY 91
5.0 LITERATURE CITED 92

LIST OF TABLES

Table 1. Site list for Rotating Basin Monitoring Program: Basin Group 1, Cycle 4 7
Table 2. Index of Biotic Integrity (IBI) scoring criteria for fish. 14
Table 3. Index of Biotic Integrity (IBI) score interpretation for fish. 14
Table 4. Bioassessment scoring criteria for macroinvertebrates 16
Table 5. Bioassessment score interpretation for macroinvertebrates 16
Table 6. Mean in-situ water quality values for Basin Group 1 monitoring sites, 2016-2018 17
Table 7. Mean water quality values for Basin Group 1 monitoring sites, 2016-2018 19
Table 8. Low dissolved oxygen values 21
Table 9. Geometric mean of bacteria values for Basin 1 monitoring sites. 23
Table 10. Statistical comparisons of cycles one, two, three, and four. 34
Table 11. Habitat assessment values. 59
Table 12. Metric values for calculations of fish IBI scores 65
Table 13. IBI scores based on USAP (OWRB 2014) and OCC's modified RBP method 67
Table 14. Comparison of fish data from cycle 1, 2, 3, and 4. 73
Table 15. Macroinvertebrate metric values 77
Table 16. Watershed land use (% of total watershed area) 84
Table 17. Permitted land use 87
Table 18. Comparison of sites with and without NPDES 88
Table 19. Designated use support assessment. 90

LIST OF FIGURES

Figure 1. Monitoring sites 5
Figure 2. Select nutrients for each site by ecoregion 25
Figure 3. Select physical parameters for each site by ecoregion. 29
Figure 4. Total habitat score for each site by ecoregion 61
Figure 5. IBI score (fish) for each site by ecoregion 69
Figure 6. Comparison of habitat, fish, macroinvertebrate, and chemistry scores by ecoregion 81

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 plans to implement to correct identified problems. In addition, each state's NPS agency is tasked with the identification of all programs which are actively planning or enforcing NPS controls in order to reduce NPS pollution through 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 assigned as the NPS Program technical lead by Oklahoma state statute and therefore must monitor to determine the occurrence, nature and extent of NPS impacts to state waters. Robust and meaningful assessment of the state's water quality is the foundation for meeting the long-term goals of the Oklahoma NPS program and water quality management in general.

In 2000, the Oklahoma Conservation Commission (OCC) initiated a progressive ambient monitoring program to assess NPS issues on a larger spatial and temporal scale than previously done. Known as the *Small Watershed Rotating Basin Monitoring Program* ("Rotating Basin Program"), this effort entails fixed station sampling at or near the outlets of complete eleven digit Hydrologic Unit Code watersheds (HUC-11). Oklahoma contains all or part of 414 U.S. Geological Survey (USGS) 11-digit HUC basins which have been collated into eleven larger planning basins for state water quality management purposes. The sampling units for the Rotating Basin Monitoring Program are based at the outlets of HUC 11 watersheds located entirely in the state, 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. Therefore, probabilistic sites have not been monitored in Cycle 4. The fixed sites monitored in Cycle 4 are shown in Figure 1.

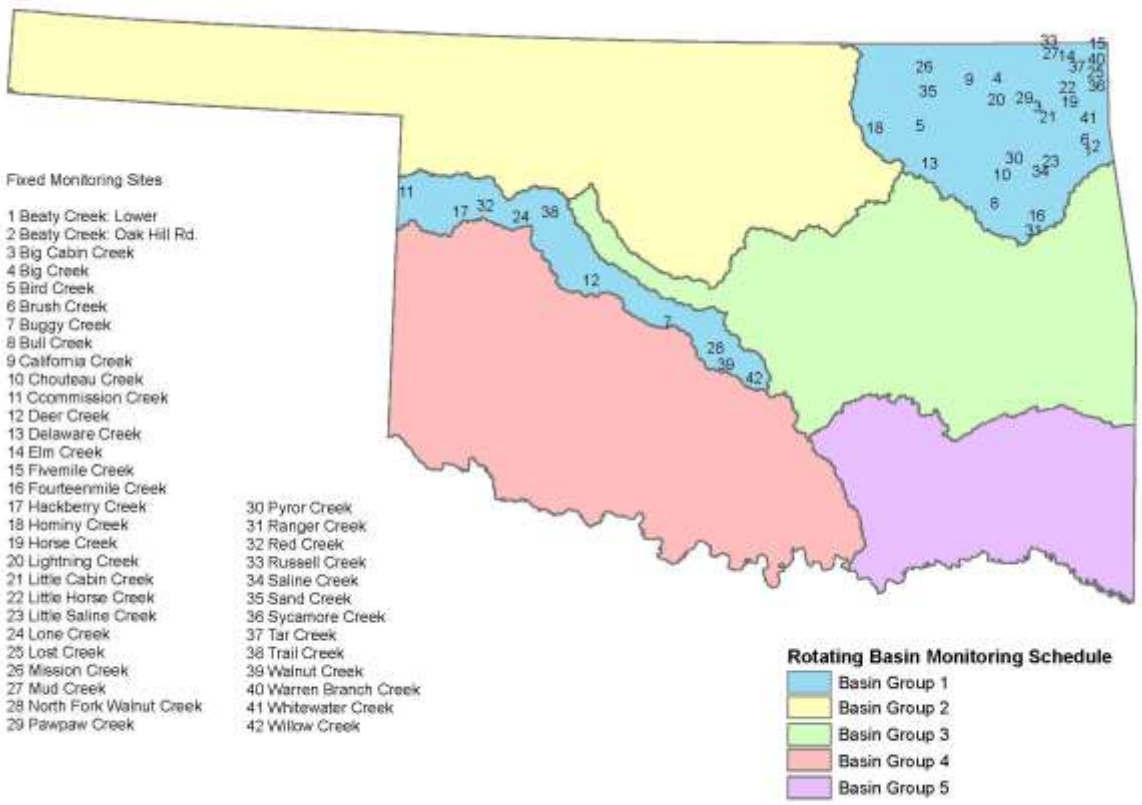


Figure 1. Monitoring sites in "Basin Group 1" for the fourth cycle of the Small Watershed Rotating Basin Monitoring Project.

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

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

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

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

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

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

2.0 MATERIALS AND METHODS

2.1 GENERAL

Sampling stations were selected to effectively represent streams of the Neosho-Grand and Upper Canadian basins. Candidate streams were selected from sub-watersheds within these basins located entirely within the state of Oklahoma having perennial water. Watersheds that did not have perennial water or were actually a segment of a larger river being sampled by another agency were not chosen. Where a particular watershed was monitored by another entity, the stream was dropped from consideration as a Rotating Basin site, if the 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 land use different from the majority of the other streams being monitored in that region or sub-watershed.

Reconnaissance of all of the potential sites within the Neosho-Grand and Upper Canadian basins was accomplished prior to the first round of monitoring in 2001, and sites which did not meet the sampling criteria were removed from the project. Thirty-four sites were monitored during the first rotating basin cycle, from 2001-2003. Thirty-one of the original 34 streams were monitored in the second cycle from June 2006-May 2008. Thirty-seven sites were monitored during the third cycle from June 2011-May 2013. The fourth cycle of monitoring in these basins occurred from June 2016-May 2018. There were 42 fixed sites during this cycle of monitoring.

The sites monitored in the Neosho-Grand basin occur in three level III ecoregions: Central Irregular Plains (CIP), Cross Timbers (CT), and Ozark Highlands (OH) (Woods et al., 2005). In the Upper Canadian basin, one site is located in the Southwestern Tablelands (SWT), while the other sites are in the Central Great Plains (CGP) ecoregion.

Table 1. Site list for Rotating Basin Monitoring Program: Basin Group 1 (Neosho-Grand and Upper Canadian Basins), Cycle 4. WBID is a unique waterbody identifier for each monitoring site. Ecoregions include Ozark Highlands (OH), Central Irregular Plains (CIP), Cross Timbers (CT), Central Great Plains (CGP), and Southwest Tablelands (SWT).

Site Name	WBID	Latitude	Longitude	Legal Description	County	Ecoregion	Modified Ecoregion
Beaty Creek: Lower	OK121600-05-0160G	36.35544	-94.776	NE SE 30-22N-24E	Delaware	OH	OH
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	36.367	-94.7261	SW SE 22-22N-24E	Delaware	OH	OH
Big Cabin Creek	OK121600-06-0220I	36.61417	-95.16172	NW 34-25N-20E	Craig	CIP	CIP
Big Creek	OK121510-03-0010D	36.7853	-95.4634	NW 35-27N-17E	Nowata	CIP	CIP
Bird Creek	OK121300-02-0010C	36.48522	-96.061	NW 7-23N-12E	Osage	CT	CT
Brush Creek	OK121600-05-0140J	36.4054	-94.7956	NE 12-22N-23E	Delaware	OH	OH
Buggy Creek	OK520610-02-0120G	35.2949	-97.9537	32/33-10N-7W	Grady	CGP	CGP
Bull Creek	OK121500-02-0090D	36.02981	-95.494	NW 22-18N-17E	Wagoner	CIP	CIP
California Creek	OK121510-02-0050C	36.7861	-95.6735	36/35 27N-15E	Nowata	CIP	CIP
Chouteau Creek	OK121600-01-0430P	36.223	-95.4047	SE 8-20N-18E	Mayes	CIP	CIP
Commission Creek	OK520620-05-0160C	36.03356	-99.917	NW NE NW 18-18N-25W	Ellis	SWT	SWT
Deer Creek	OK520620-06-0010F	35.5365	-98.5174	NW NW NW 7-12N-12W	Caddo	CGP	CGP
Delaware Creek	OK121300-01-0150H	36.27714	-95.99239	E.B. Section 25-21N-12E	Tulsa	CIP	CT
Elm Creek	OK121600-04-0150G	36.9217	-94.9181	SE NE 10-28N-22E	Ottawa	CIP	CIP

Site Name	WBID	Latitude	Longitude	Legal Description	County	Ecoregion	Modified Ecoregion
Fivemile Creek	OK121600-07-0110G	36.9835	-94.6919	NW NE 22-29N-24E	Ottawa	OH	OH
Fourteenmile Creek	OK121600-01-0100G	35.9591	-95.1825	S.B. Section 9-17N-20E	Cherokee	OH	OH
Hackberry Creek	OK520620-04-0050D	35.932	-99.52372	SE NE SE 22-17N-22W	Ellis	CGP	CGP
Hominy Creek	OK121300-04-0280G	36.481	-96.398	SE 12-23N-8E	Osage	CT	CT
Horse Creek	OK121600-03-0160G	36.683	-94.9273	3-25N-22E	Ottawa	CIP	CIP
Lightning Creek	OK121510-01-0130N	36.6554	-95.4645	NW 14-25N-17E	Nowata	CIP	CIP
Little Cabin Creek	OK121600-06-0080C	36.5975	-95.1385	N.B. Section 2-24N-20E	Craig	CIP	CIP
Little Horse Creek	OK121600-03-0190G	36.6977	-94.9093	E.B. 35-26N-22E	Ottawa	CIP	CIP
Little Saline Creek	OK121600-02-0070G	36.2791667	-95.077	SW 21-21N-21E	Mayes	OH	OH
Lone Creek	OK520620-03-0020C	35.90619	-99.065	S.B. SW SE NE 36-17N-18W	Dewey	CGP	CGP
Lost Creek	OK121600-03-0560G	36.80195	-94.70095	SE Section 22-27N-24E	Ottawa	OH	OH
Mission Creek	OK121400-02-0190B	36.86841	-96.0253	NW NW NW 33-28N-12E	Osage	CT	CT
Mud Creek	OK121600-04-0175M	36.9433	-95.0441	N.B. 3-28N-21E	Craig	CIP	CIP
North Fork Walnut Creek	OK520610-03-0080E	35.1316	-97.5849	SE SE 26-8N-4W	McClain	CGP	CGP
PawPaw Creek	OK121600-06-0240G	36.65512	-95.23397	W Section 13-25N-19E	Craig	CIP	CIP
Pryor Creek	OK121610-00-0050D	36.3074	-95.3472	NE NE 14-21N-18E	Mayes	CIP	CIP
Ranger Creek	OK121600-01-0060D	35.88436	-95.20011	NW NW 9-16N-20E	Cherokee	BM	OH
Red Creek	OK520620-03-0110F	35.9778	-99.3492	NE SE 5-17N-20W	Dewey	CGP	CGP
Russell Creek	OK121600-04-0200F	36.9879	-95.065	SW SW SW 17-29N-21E	Craig	CIP	CIP
Saline Creek	OK121600-02-0030D	36.282	-95.09292	SW 20-21N-21E	Mayes	OH	OH
Sand Creek	OK121400-04-0010F	36.71919	-96.0074	E.B. Section 21-26N-12E	Osage	CT	CT
Sycamore Creek	OK121600-03-0510D	36.76853	-94.692	NE NW2-26N-24E	Ottawa	OH	OH
Tar Creek	OK121600-04-0060D	36.87481	-94.862	SE SE SE 30-28N-23E	Ottawa	CIP	CIP
Trail Creek	OK520620-02-0090G	35.9565492	-98.848	NW NW NW 18-17N-15W	Dewey	CGP	CGP
Walnut Creek	OK520610-03-0010G	35.0634	-97.4854	SE 23-7N-3W	McClain	CGP	CGP
Warren Branch Creek	OK121600-07-0050G	36.90163	-94.7072	W.B. Section 15-28N-24E	Ottawa	OH	OH
Whitewater Creek	OK121600-03-0320G	36.539	-94.7596389	NW NE NE 29-24N-24E	Delaware	OH	OH
Willow Creek	OK520610-01-0080H	34.9716	-97.2937	SE SW 22-6N-1W	Cleveland	CGP	CGP

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 Energy & Environment (OSEE), and EPA Region VI in Dallas. All sampling and measurement activities of OCC Water Quality staff followed procedures outlined in the appropriate OCC

Standard Operating Procedure (OCC 2016). 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 2016, 42 sites were monitored for physical and chemical parameters on a fixed interval schedule of ten sampling events per year (five-week intervals) through May 2018 (usually 20 total events per site). This sampling frequency exceeds state data requirements for beneficial use assessment and meets a sample number necessary to provide a 90% level of confidence for principal water quality data (specifically phosphorus, a critical NPS concern) as determined from EPA's DEFT software. 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 2016).

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.

For each site a water quality index was computed 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). For each of these parameters, a score of 5 (best), 3, or 1 was assigned based on the comparison with high quality sites in that ecoregion. High quality sites were determined by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005). Each parameter score was added together for a total score. This score was then compared to the average high quality sites' total score in that ecoregion.

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 2016, OCC staff began conducting instream and riparian habitat assessments at sites concurrent with fish collections (described in Section 2.3.2); any sites not sampled in 2016 were sampled in the summer of 2017. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP (OCC 2016). The OCC's habitat assessment adheres to a modified version of the EPA Rapid Bioassessment Protocols (RBP) (Plafkin et al., 1989) and is designed to assess habitat quality in relation to its ability to support biological communities in the stream. The assessment is based on particular parameters grouped into three categories for a total of eleven components (Plafkin et al., 1989). The eleven components are discussed in more detail below. The three primary categories assessed include micro scale habitat, macro scale habitat, and riparian/bank structure. Micro scale habitat includes substrate composition, stable cover, canopy, depth, and velocity. Macro scale assesses the channel morphology, sediment deposits, and other parameters. The third category looks at the riparian zone quality, width, and 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 submerged logs, cobble and boulders, root wads, and beds of aquatic plants. Cover required by smaller members of the stream community will consist of gravel, cobbles, small woody debris, and dense beds of fine aquatic plants. At least 50% of the stream's area should be occupied by a mixture of stable cover types for this category to be considered optimal.

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

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

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

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

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

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

(8) **Channel sinuosity** measures how far a channel deviates from a straight line. More sinuous channels tend to have more undercut banks, root wads, submerged logs, etc. Index of Biotic Integrity (IBI) scores should be higher as channels become more sinuous. Sinuosity is calculated by dividing the length of the assessment (400 meters) by the distance between the GPS location of the start point and end point of the assessment.

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

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

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

2.3.2 Fish

Fish collections were obtained in the summer of 2016 or 2017 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 (2016). 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 2014). In addition, each site was assessed using OCC's modified RBP method, which is a modified version of Karr’s Index of Biotic Integrity (IBI) (adapted from Plafkin et al., 1989). Descriptive statistics were determined for each metric using the *Minitab V 17* software. The condition of the fish community was based on indices of species richness, community quality, trophic structure, and by comparison to the average scores of high-quality streams in that ecoregion. High quality sites were determined by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005). The modified IBI score was calculated using the following metrics:

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

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

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

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

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

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

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

For each of these seven metrics, a score of 5, 3, or 1 was assigned (Table 2), and these scores were summed to get a total IBI score (35 point maximum) for each site. For all “proportion” metrics, the score was based on the actual metric. For all non–proportion metrics, the score was determined by dividing the monitoring site’s metric by the average high quality site metric of the same ecoregion. Each monitoring site’s total score was then compared to the high quality site total score in that ecoregion and given an integrity rating (as established and suggested by the EPA RBP; see Table 3, below). 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
90 – 100 %	Excellent	Comparable to pristine conditions, exceptional species assemblage
78 – 89%	Good	Decreased species richness, especially intolerant species
62 – 77%	Fair	Intolerant and sensitive species rare or absent
42 – 61%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
0 – 41%	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

2.3.3 Macroinvertebrates

Collection of macroinvertebrates was attempted at all sites for both winter and summer index periods of July 2016 through March 2018 according to procedures outlined in the OCC SOP (2016). 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 five minutes. Woody debris sampled generally ranged in size from ¼" to about 8" in diameter. Each sample type was preserved independently in quart mason jars with ethanol, labeled, and sent to a professional taxonomist for picking and identification.

Data 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 taxa are found in the collection and as individual taxa become less dominant. The metric increases with increasing biotic quality (Plafkin et al., 1989).

Descriptive statistics of each season-specific sample type (e.g., summer riffle, winter vegetation, summer woody) for each site were determined via *Minitab V. 17* and were compared to the average respective metric of high-quality streams in the ecoregion. High quality sites were determined by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005). A Bioassessment score was calculated similarly to the IBI score for fish. For each site,

scores of 6, 4, 2, or 0 were assigned for each metric (according to the criteria in Table 4, below) and then summed to get a total Bioassessment score for each site, with a maximum of 36 points. For taxa richness and EPT taxa richness, the percentages used to assign scores were obtained by dividing each monitoring site metric by the average high quality site metric in a particular ecoregion. For the HBI metric, the high quality site value was divided by the monitoring site value (high quality site metric / monitoring site metric). For the remaining metrics, the score was based on the actual values obtained instead of being relative to the high quality site metric. Each monitoring site's total score was then compared to the average high quality sites' total score (in that ecoregion) and classified according to the condition gradient outlined in Table 5 (adapted from Plafkin et al., 1989).

Table 4. Bioassessment scoring criteria for macroinvertebrates

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

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

Table 5. Bioassessment score interpretation for macroinvertebrates

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

2.4 WATERSHED ASSESSMENT

To investigate potential sources of NPS pollution for streams showing beneficial use impairment, relevant data layers were explored using ArcMap 10.1 Geographic Information System (GIS) software.

Data explored included the 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 land-use 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 2014). 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 1 (Neosho-Grand and Upper Canadian) monitoring sites, 2016-2018. WBID is a unique waterbody identifier for each monitoring site.

Site Name	WBID	Alkalinity (CaCO3)	Conductivity (µS/cm)	DO (mg/L)	DO % Saturation	Hardness (mg/L)	pH (SU)	Water Temp (°C)	Turbidity (NTU)	Flow (cfs)
Beaty Creek: Lower	OK121600-05-0160G	135.2	260.9	9.46	97.01	171.8	7.37	17.4	1.50	51.48
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	138.9	282.1	8.05	83.30	179.0	7.27	17.2	1.57	11.20
Big Cabin Creek	OK121600-06-0220I	106.6	797.8	8.96	92.25	504.2	7.71	18.6	35.26	121.03
Big Creek	OK121510-03-0010D	163.5	351.7	8.36	82.49	195.8	7.72	16.8	38.27	39.75
Bird Creek	OK121300-02-0010C	97.5	293.1	8.77	89.60	137.0	7.78	18.3	29.08	135.50
Brush Creek	OK121600-05-0140J	151.0	296.2	9.84	101.15	190.4	7.40	16.3	1.70	10.76
Buggy Creek	OK520610-02-0120G	261.3	1671.5	9.82	110.44	726.3	8.17	19.5	15.86	5.64

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)
Bull Creek	OK121500-02-0090D	105.5	312.8	5.59	54.13	170.4	7.04	17.5	33.70	0.00
California Creek	OK121510-02-0050C	124.6	410.5	7.67	73.52	201.8	7.11	15.8	47.21	7.77
Chouteau Creek	OK121600-01-0430P	131.3	261.5	6.28	61.14	174.5	7.15	16.8	27.48	0.81
Commission Creek	OK520620-05-0160C	234.8	914.9	9.40	100.29	383.6	8.32	16.8	16.07	4.58
Deer Creek	OK520620-06-0010F	168.4	1216.9	8.88	94.73	771.9	8.17	17.5	164.99	31.90
Delaware Creek	OK121300-01-0150H	105.8	601.7	7.27	73.43	183.0	6.95	17.8	25.14	18.99
Elm Creek	OK121600-04-0150G	83.0	581.6	7.70	74.21	315.1	7.47	15.7	11.80	0.71
Fivemile Creek	OK121600-07-0110G	128.2	274.8	9.36	95.06	154.7	7.20	17.3	0.71	15.26
Fourteenmile Creek	OK121600-01-0100G	97.0	173.3	9.73	101.51	130.6	7.28	18.6	14.04	24.63
Hackberry Creek	OK520620-04-0050D	314.7	2070.1	9.70	105.97	1378.5	8.24	18.0	204.48	0.70
Hominy Creek	OK121300-04-0280G	130.3	954.3	9.58	92.64	289.7	7.36	16.0	52.27	30.19
Horse Creek	OK121600-03-0160G	97.9	326.4	7.37	68.69	153.0	7.29	15.7	18.47	3.48
Lightning Creek	OK121510-01-0130N	204.9	2627.1	9.13	90.90	2215.0	7.98	15.1	13.92	24.97
Little Cabin Creek	OK121600-06-0080C	80.4	275.5	7.25	73.92	151.1	6.85	18.1	46.62	39.28
Little Horse Creek	OK121600-03-0190G	128.5	312.5	7.29	69.25	184.9	7.36	15.3	8.62	2.38
Little Saline Creek	OK121600-02-0070G	100.2	201.1	8.43	86.08	143.3	7.07	16.9	1.67	35.93
Lone Creek	OK520620-03-0020C	200.5	2698.6	10.02	108.73	1791.0	8.12	17.3	24.26	2.60
Lost Creek	OK121600-03-0560G	128.6	284.8	10.11	101.96	159.1	7.81	16.5	4.30	89.39
Mission Creek	OK121400-02-0190B	92.7	232.5	5.70	54.99	131.9	7.22	16.3	44.26	22.96
Mud Creek	OK121600-04-0175M	69.3	254.7	6.22	58.64	122.5	6.59	15.3	35.00	0.05
North Fork Walnut Creek	OK520610-03-0080E	328.1	762.2	9.99	116.04	445.1	8.33	21.9	7.53	6.59
Pawpaw Creek	OK121600-06-0240G	85.6	253.3	6.31	62.33	132.3	7.44	16.6	20.43	1.03
Pryor Creek	OK121610-00-0050D	99.4	319.3	5.98	61.89	177.2	6.98	16.8	36.46	2.66
Ranger Creek	OK121600-01-0060D	118.1	246.2	8.99	92.87	166.3	7.52	18.7	7.94	5.76
Red Creek	OK520620-03-0110F	218.8	2526.8	9.92	102.99	1905.5	8.11	17.5	25.51	0.45
Russell Creek	OK121600-04-0200F	137.9	410.8	8.81	88.85	230.2	7.74	17.7	10.24	3.07
Saline Creek	OK121600-02-0030D	107.0	224.9	9.52	97.99	150.6	7.25	17.0	2.18	49.58
Sand Creek	OK121400-04-0010F	109.5	394.7	8.30	83.09	172.9	7.43	17.7	51.03	80.31
Sycamore Creek	OK121600-03-0510D	114.6	269.6	9.53	95.34	140.0	7.13	16.5	1.42	32.77
Tar Creek	OK121600-04-0060D	121.1	1390.7	9.72	94.63	848.8	7.63	15.6	29.14	8.80
Trail Creek	OK520620-02-0090G	171.9	2583.2	10.15	106.31	1735.1	8.09	17.2	17.67	3.70
Walnut Creek	OK520610-03-0010G	331.8	788.8	10.54	114.84	398.9	8.31	20.5	19.74	16.99
Warren Branch Creek	OK121600-07-0050G	128.6	279.8	10.61	107.50	156.3	7.55	15.9	15.92	9.73
Whitewater Creek	OK121600-03-0320G	151.7	286.9	7.42	76.44	178.8	7.34	17.3	1.34	2.07
Willow Creek	OK520610-01-0080H	271.7	684.0	10.24	110.76	327.6	8.15	18.9	13.71	3.92

Table 7. Mean water quality values for Basin Group 1 (Neosho- Grand and Upper Canadian Basins) monitoring sites, 2016-2018. WBID is a unique waterbody identifier for each monitoring site.

Site Name	WBID	Ammonia (mg/L)	Chloride (mg/L)	TDS (mg/L)	TKN (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	OrthoP (mg/L)	Total P (mg/L)	Sulfate (mg/L)	TSS (mg/L)
Beaty Creek: Lower	OK121600-05-0160G	0.0157	8.24	156.3	0.130	2.701	0.062	0.0595	0.0612	5.19	10.4
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	0.0153	8.96	163.7	0.139	3.208	0.066	0.0732	0.0746	5.16	11.3
Big Cabin Creek	OK121600-06-0220I	0.0281	8.59	560.0	0.567	0.725	0.041	0.0933	0.1272	307.15	13.4
Big Creek	OK121510-03-0010D	0.0231	4.52	211.2	0.450	0.111	0.043	0.0266	0.0542	16.72	11.2
Bird Creek: Avant	OK121300-02-0010C	0.0164	28.31	168.5	0.521	0.062	0.138	0.0134	0.0450	13.68	15.8
Brush Creek	OK121600-05-0140J	0.0150	10.98	168.1	0.127	1.687	0.079	0.0305	0.0317	7.67	10.0
Buggy Creek	OK520610-02-0120G	0.1040	61.52	1146.3	0.622	0.699	0.085	0.0846	0.1145	521.37	17.8
Bull Creek	OK121500-02-0090D	0.0677	21.97	188.4	0.832	0.092	0.036	0.0310	0.0854	43.12	17.6
California Creek	OK121510-02-0050C	0.0410	23.02	248.5	0.511	0.082	0.039	0.0325	0.0620	50.50	10.6
Chouteau Creek	OK121600-01-0430P	0.7173	9.03	158.9	1.346	0.129	0.063	0.0225	0.0931	22.42	15.5
Commission Creek	OK520620-05-0160C	0.0167	126.30	576.5	0.427	0.327	0.142	0.0200	0.0382	41.02	24.5
Deer Creek	OK520620-06-0010F	0.1015	21.54	944.5	1.203	1.821	0.045	0.2224	0.3546	469.10	235.2
Delaware Creek	OK121300-01-0150H	0.0233	115.13	347.5	0.539	0.042	0.065	0.0177	0.0509	18.87	13.1
Elm Creek	OK121600-04-0150G	0.0318	5.65	416.8	0.534	0.140	0.032	0.0296	0.0594	208.71	11.6
Fivemile Creek	OK121600-07-0110G	0.0421	8.82	155.0	0.111	0.307	0.053	0.0120	0.0127	6.44	10.0
Fourteenmile Creek	OK121600-01-0100G	0.0173	6.66	90.9	0.147	0.388	0.033	0.0350	0.0397	9.27	10.0
Hackberry Creek	OK520620-04-0050D	0.0188	71.12	1689.2	0.605	0.027	0.020	0.0436	0.0748	831.25	39.3
Hominy Creek	OK121300-04-0280G	0.0177	208.63	545.5	0.414	0.042	0.120	0.0140	0.0390	24.96	17.3
Horse Creek	OK121600-03-0160G	0.0707	21.15	195.8	1.289	0.662	0.115	0.2482	0.3166	31.15	10.8
Lightning Creek	OK121510-01-0130N	0.0223	11.84	2675.0	0.273	0.108	0.035	0.0285	0.0412	1657.35	10.5
Little Cabin Creek	OK121600-06-0080C	0.0293	9.14	193.5	0.827	0.211	0.052	0.0649	0.1157	51.02	13.6
Little Horse Creek	OK121600-03-0190G	0.0372	14.52	187.4	0.663	0.232	0.056	0.1571	0.1919	16.61	10.0
Little Saline Creek	OK121600-02-0070G	0.0150	10.24	108.4	0.113	0.653	0.070	0.0104	0.0116	4.61	10.4
Lone Creek	OK520620-03-0020C	0.0323	39.91	2585.0	0.678	0.497	0.034	0.0312	0.0599	1508.30	47.1
Lost Creek	OK121600-03-0560G	0.0421	9.32	160.9	0.169	1.481	0.048	0.0564	0.0640	9.36	11.0
Mission Creek	OK121400-02-0190B	0.0651	14.46	146.3	0.858	0.100	0.063	0.0380	0.0973	9.77	16.9
Mud Creek	OK121600-04-0175M	0.2516	9.44	146.6	0.956	0.197	0.040	0.0539	0.1043	32.99	15.3
North Fork Walnut Creek	OK520610-03-0080E	0.1890	26.22	408.0	0.516	0.203	0.098	0.0358	0.0629	38.06	11.2
PawPaw Creek	OK121600-06-0240G	0.1202	6.52	165.8	0.683	0.105	0.033	0.0234	0.0608	44.09	14.3
Pryor Creek	OK121610-00-0050D	0.0691	40.98	205.3	0.838	0.154	0.059	0.0599	0.1154	28.59	21.4

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)
Ranger Creek	OK121600-01-0060D	0.0165	4.84	141.6	0.295	0.188	0.035	0.0357	0.0594	15.74	10.6
Red Creek	OK520620-03-0110F	0.0150	29.74	2416.9	0.432	0.169	0.023	0.0177	0.0525	1397.31	25.2
Russell Creek	OK121600-04-0200F	0.0322	7.32	255.3	0.396	0.097	0.047	0.0464	0.0681	71.69	12.5
Saline Creek	OK121600-02-0030D	0.0154	10.09	128.2	0.115	0.608	0.044	0.0092	0.0122	6.88	10.5
Sand Creek	OK121400-04-0010F	0.0257	40.78	235.5	0.561	0.054	0.129	0.0230	0.0602	23.54	31.1
Sycamore Creek	OK121600-03-0510D	0.0421	8.33	151.6	0.125	1.962	0.040	0.0229	0.0262	5.39	10.0
Tar Creek	OK121600-04-0060D	0.0675	17.22	1195.0	0.477	0.122	0.036	0.0370	0.0573	676.78	37.2
Trail Creek	OK520620-02-0090G	0.0680	29.61	2359.0	0.510	0.138	0.032	0.0333	0.0592	1427.00	33.7
Walnut Creek	OK520610-03-0010G	0.0938	28.12	434.5	0.449	0.134	0.113	0.0438	0.0693	42.82	20.4
Warren Branch Creek	OK121600-07-0050G	0.0423	4.66	156.0	0.129	1.238	0.046	0.0183	0.0233	6.25	10.0
Whitewater Creek	OK121600-03-0320G	0.0181	9.65	157.8	0.124	0.999	0.076	0.0182	0.0210	6.72	10.0
Willow Creek	OK520610-01-0080H	0.0513	16.39	393.8	0.660	2.122	0.081	0.1291	0.1549	50.21	11.9

Dissolved Oxygen criteria depend on the use designation of the waterbody. Twenty-nine of the fixed sites are designated as Warm Water Aquatic Communities (WWAC) and have a critical DO level of 5.0 mg/L most of the year (6.0 mg/L from April 1 – June 15). Eleven of the sites are designated as Cool Water Aquatic Communities (CWAC), with a critical DO level of 6.0 mg/L most of the year (7.0 mg/L from March 1 – May 31). Tar Creek and Trail Creek are designated as Habitat Limited Aquatic Community. Twenty-two sites exhibited dissolved oxygen levels which were always above criteria values: Buggy Creek, Hackberry Creek, Lone Creek, North Fork Walnut Creek, Red Creek, Trail Creek, Walnut Creek, Willow Creek, Big Cabin Creek, Fourteenmile Creek, Lightning Creek, Tar Creek, Bird Creek, Hominy Creek, Sand Creek, Brush Creek, Fivemile Creek, Lost Creek, Saline Creek, Sycamore Creek, Warren Branch Creek, and Commission Creek. Six sites were consistently above the criteria levels: Deer Creek, Big Creek, Russell Creek, Beaty Creek: Lower, Beaty Creek: Oak Hill Rd, and Ranger Creek. Table 8 (below) reflects the DO values at the 14 sites with low dissolved oxygen values and the total percentage of low DO samples.

Table 9 shows the geometric mean of *E. coli* bacteria samples for each site over the two-year monitoring period. Creeks highlighted in yellow are designated Secondary Body Contact Recreation (SBRC), which allows for a higher bacteria concentration: Big Cabin Creek, Tar Creek, and Trail Creek. All other sites are designated Primary Body Contract Recreation (PBCR). Sixty 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 2014).

Table 8. Low dissolved oxygen values (based on OAC 785:46-15; OWRB 2014) at rotating basin sites in the Neosho Grand and Upper Canadian Basins 2016-2018. WBID is a unique waterbody identifier for each monitoring site. Each site is designated as a warm water (WWAC) or cool water aquatic community (CWAC) for the fish and wildlife propagation (FWP) beneficial use.

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
52%	Bull Creek	OK121500-02-0090D	WWAC	6/20/2016	2.41
				7/12/2016	3.5
				7/26/2016	1.62
				8/25/2016	3.28
				10/3/2016	4.93
				10/31/2016	4.63
				6/6/2017	2.11
				7/10/2017	4.82
				8/14/2017	3.49
				9/18/2017	4.35
				10/16/2017	4.88
20%	California Creek	OK121510-02-0050C	WWAC	6/21/2016	4.78
				7/26/2016	4.22
				8/30/2016	3.1
				9/19/2017	2.9
48%	Chouteau Creek	OK121600-01-0430P	WWAC	6/20/2016	3.91
				6/30/2016	2.6
				7/26/2016	1.92
				8/23/2016	4.24
				10/3/2016	2.72
				2/22/2017	4.53
				6/6/2017	0.04
				8/14/2017	3.44
				9/18/2017	2.81
				10/16/2017	4.73

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
21%	Elm Creek	OK121600-04-0150G	WWAC	6/14/2016	3.94
				8/22/2016	4.91
				9/26/2016	4.52
				5/30/2017	5.78
32%	Horse Creek	OK121600-03-0160G	WWAC	6/13/2016	2.28
				7/18/2016	3.33
				5/30/2017	3.77
				8/7/2017	2.98
				9/11/2017	2.54
				10/16/2017	3.55
29%	Little Cabin Creek	OK121600-06-0080C	WWAC	7/19/2016	4.93
				7/26/2016	4.12
				8/30/2016	2.6
				7/11/2017	4.38
				9/19/2017	2.98
				11/28/2017	1.75
32%	Little Horse Creek	OK121600-03-0190G	WWAC	6/13/2016	5.54
				7/18/2016	4.84
				8/22/2016	3.3
				5/30/2017	5.82
				8/7/2017	4.75
				9/11/2017	2.25
14%	Little Saline Creek	OK121600-02-0070G	CWAC	8/22/2016	5.49
				7/11/2017	5.98
				8/15/2017	5.95

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
62%	Mission Creek	OK121400-02-0190B	WWAC	6/20/2016	4.4
				7/11/2016	1.74
				7/25/2016	4.15
				8/26/2016	2.5
				10/3/2016	4.82
				11/7/2016	3.72
				12/5/2016	4.97
				6/5/2017	4.62
				7/10/2017	4.25
				8/14/2017	4.01
				9/18/2017	2.81
				10/23/2017	4.54
				11/27/2017	4.53
45%	Mud Creek	OK121600-04-0175M	WWAC	6/6/2016	4.05
				6/15/2016	2.25
				7/18/2016	2.2
				8/22/2016	4.39
				9/26/2016	1.82
				5/30/2017	5.44
				6/26/2017	4.52
				8/7/2017	3.04
				9/11/2017	1.2
45%	PawPaw Creek	OK121600-06-0240G	WWAC	6/16/2016	0.92
				7/26/2016	2.87
				8/30/2016	3.5
				10/4/2016	1.59
				11/8/2016	1.85
				12/6/2016	4.85
				7/11/2017	4.05
				8/15/2017	2.6
				11/28/2017	3.6

% Samples with Low DO	Site Name	WBID	FWP	Date	DO
43%	Pryor Creek	OK121610-00-0050D	WWAC	6/20/2016	4.92
				7/26/2016	3.14
				8/18/2016	1.85
				12/6/2016	3.71
				6/6/2017	5.17
				7/10/2017	4.15
				8/14/2017	3.81
				10/16/2017	3.64
				11/13/2017	2.38
25%	Whitewater Creek	OK121600-03-0320G	CWAC	8/22/2016	3.33
				10/4/2016	4.23
				11/1/2016	3.99
				9/19/2017	3.71
				10/17/2017	5.99
29%	Delaware Creek	OK121300-01-0150H	WWAC	6/20/2016	4.4
				6/20/2016	4.4
				8/29/2016	4.28
				11/7/2016	3.6
				9/18/2017	3.43
				11/27/2017	4

Table 9. Geometric mean of bacteria values for Basin 1 (Neosho-Grand and Upper Canadian Basins) monitoring sites, 2016-2018. An asterisk (*) indicates that the stream meets state standards for E. coli. Those highlighted in yellow have a secondary body contact recreation (SBCR) designation, allowing for higher bacteria concentrations.

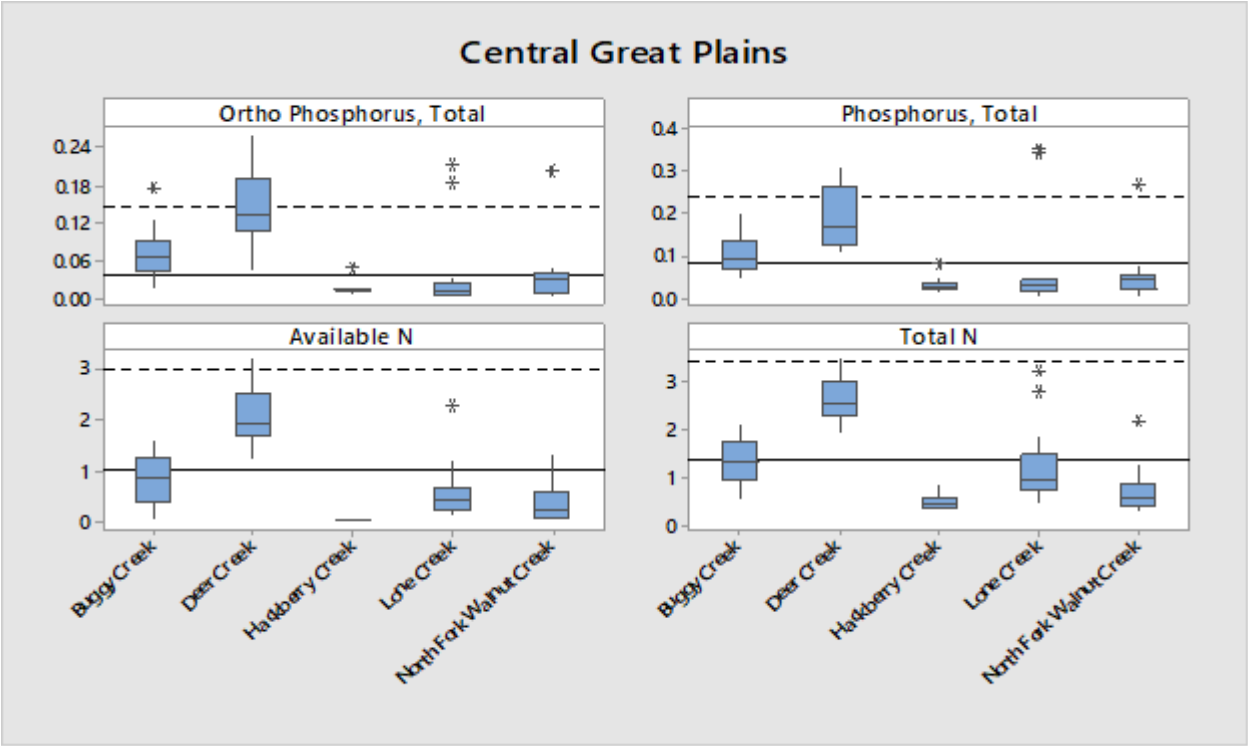
Site Name	WBID	E. coli		Comments
Beaty Creek: Lower	OK121600-05-0160G	15.96	*	Geometric Mean
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	13.39	*	Geometric Mean
Big Cabin Creek	OK121600-06-0220I	115.28	*	Geometric Mean
Big Creek	OK121510-03-0010D	238.95		Geometric Mean
Bird Creek	OK121300-02-0010C	57.04	*	Geometric Mean
Brush Creek	OK121600-05-0140J	24.82	*	Geometric Mean
Buggy Creek	OK520610-02-0120G	156.49		Geometric Mean
Bull Creek	OK121500-02-0090D	289.81		Geometric Mean
California Creek	OK121510-02-0050C	106.74	*	Geometric Mean
Chouteau Creek	OK121600-01-0430P	275.25		Geometric Mean
Commission Creek	OK520620-05-0160C	210.89		Geometric Mean
Deer Creek	OK520620-06-0010F	89.10	*	Geometric Mean
Delaware Creek	OK121300-01-0150H	99.23	*	Geometric Mean
Elm Creek	OK121600-04-0150G	395.32		Geometric Mean
Fivemile Creek	OK121600-07-0110G	12.34	*	Geometric Mean
Fourteenmile Creek	OK121600-01-0100G	25.85	*	Geometric Mean
Hackberry Creek	OK520620-04-0050D	981.55		Geometric Mean
Hominy Creek	OK121300-04-0280G	199.22		Geometric Mean
Horse Creek	OK121600-03-0160G	360.70		Geometric Mean
Lightning Creek	OK121510-01-0130N	123.34	*	Geometric Mean
Little Cabin Creek	OK121600-06-0080C	221.44		Geometric Mean
Little Horse Creek	OK121600-03-0190G	154.51		Geometric Mean
Little Saline Creek	OK121600-02-0070G	13.98	*	Geometric Mean
Lone Creek	OK520620-03-0020C	900.34		Geometric Mean
Lost Creek	OK121600-03-0560G	66.10	*	Geometric Mean
Mission Creek	OK121400-02-0190B	149.27		Geometric Mean
Mud Creek	OK121600-04-0175M	116.05	*	Geometric Mean
North Fork Walnut Creek	OK520610-03-0080E	69.94	*	Geometric Mean
PawPaw Creek	OK121600-06-0240G	100.15	*	Geometric Mean
Pryor Creek	OK121610-00-0050D	72.79	*	Geometric Mean
Ranger Creek	OK121600-01-0060D	31.93	*	Geometric Mean
Red Creek	OK520620-03-0110F	625.22		Geometric Mean
Russell Creek	OK121600-04-0200F	103.54	*	Geometric Mean
Saline Creek	OK121600-02-0030D	8.92	*	Geometric Mean
Sand Creek	OK121400-04-0010F	151.73		Geometric Mean
Sycamore Creek	OK121600-03-0510D	62.83	*	Geometric Mean
Tar Creek	OK121600-04-0060D	426.50	*	Geometric Mean
Trail Creek	OK520620-02-0090G	191.02	*	Geometric Mean
Walnut Creek	OK520610-03-0010G	160.33		Geometric Mean
Warren Branch Creek	OK121600-07-0050G	16.09	*	Geometric Mean
Whitewater Creek	OK121600-03-0320G	6.50	*	Geometric Mean
Willow Creek	OK520610-01-0080H	257.74		Geometric Mean

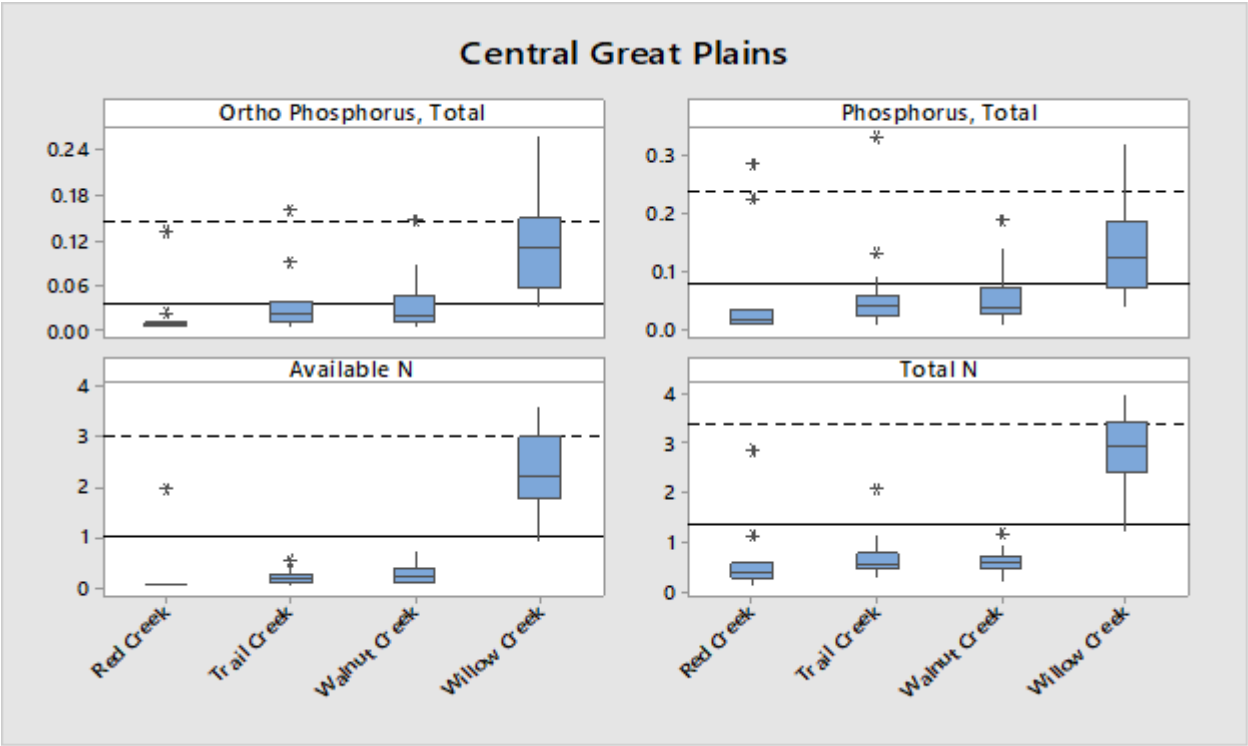
Select water quality parameters for each site during the sample period are summarized by box plots in Figure 2 and Figure 3, below. Figure 2 shows interquartile range plots by site for four important indicators of pollution: orthophosphorus, total phosphorus, estimated total nitrogen (TKN plus nitrate-nitrite),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

In the Central Great Plains, Deer Creek had higher orthophosphorus and total phosphorus values than the high quality sites. In the Central Irregular Plains, Horse Creek and Little Horse Creek had higher orthophosphorus and total phosphorus values than the high quality sites. Also, Horse Creek had higher total nitrogen values. Streams in the Cross Timbers, Ozark Highlands, and Southwest Tablelands had some high outliers, but most of the values were well within two standard deviations of the mean for high quality sites.

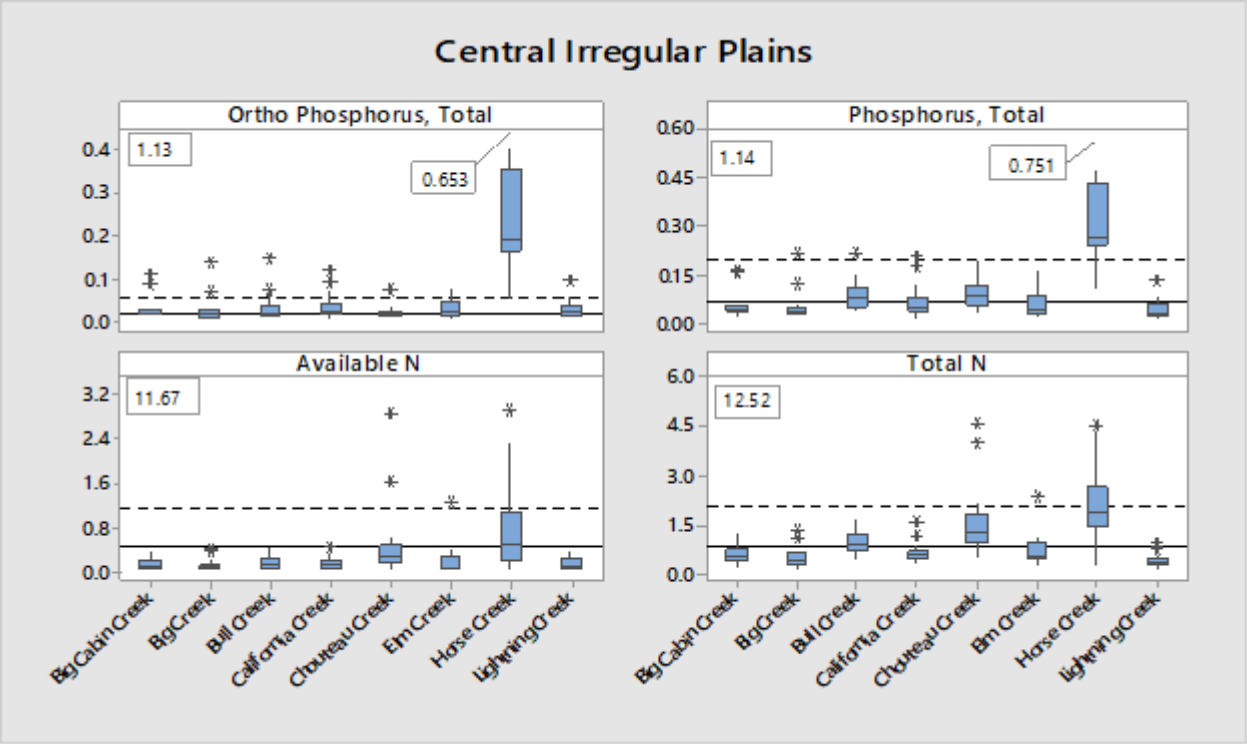
Figure 3 shows interquartile range plots for four physical parameters (all high flow data excluded): dissolved oxygen (percent saturation), pH, turbidity, and total suspended solids. Deer Creek in the Central Great Plains shows high values for turbidity and total suspended solids. In the Ozark Highlands, Lost Creek and Ranger Creek had turbidity values higher than the high quality sites. Dissolved oxygen in the Cross Timbers and Central Irregular Plains streams is naturally low at high quality reference sites. Although many of the streams in these two ecoregions exhibited low dissolved oxygen saturation, the values generally fell within two standard deviations of mean oxygen saturation at high quality sites.

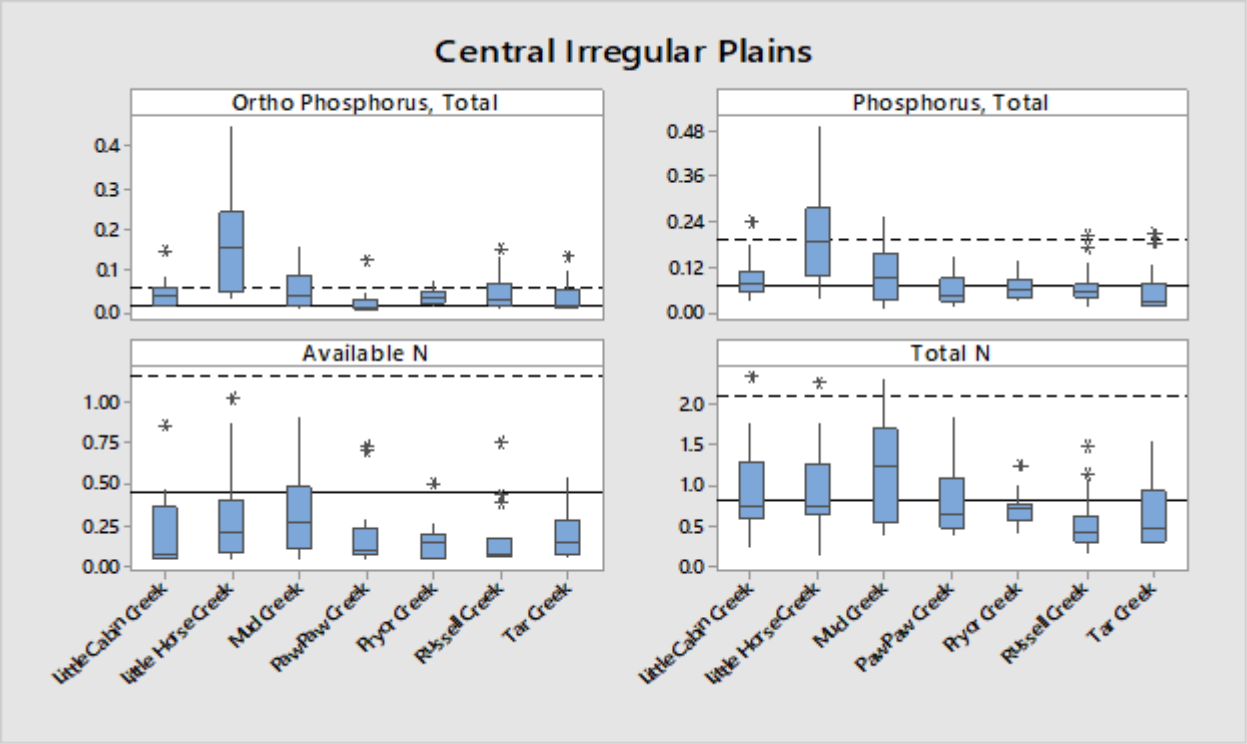
(a)


Central Great Plains
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Biggy Creek
Deer Creek
Hackberry Creek
Lone Creek
North Fork Walnut Creek

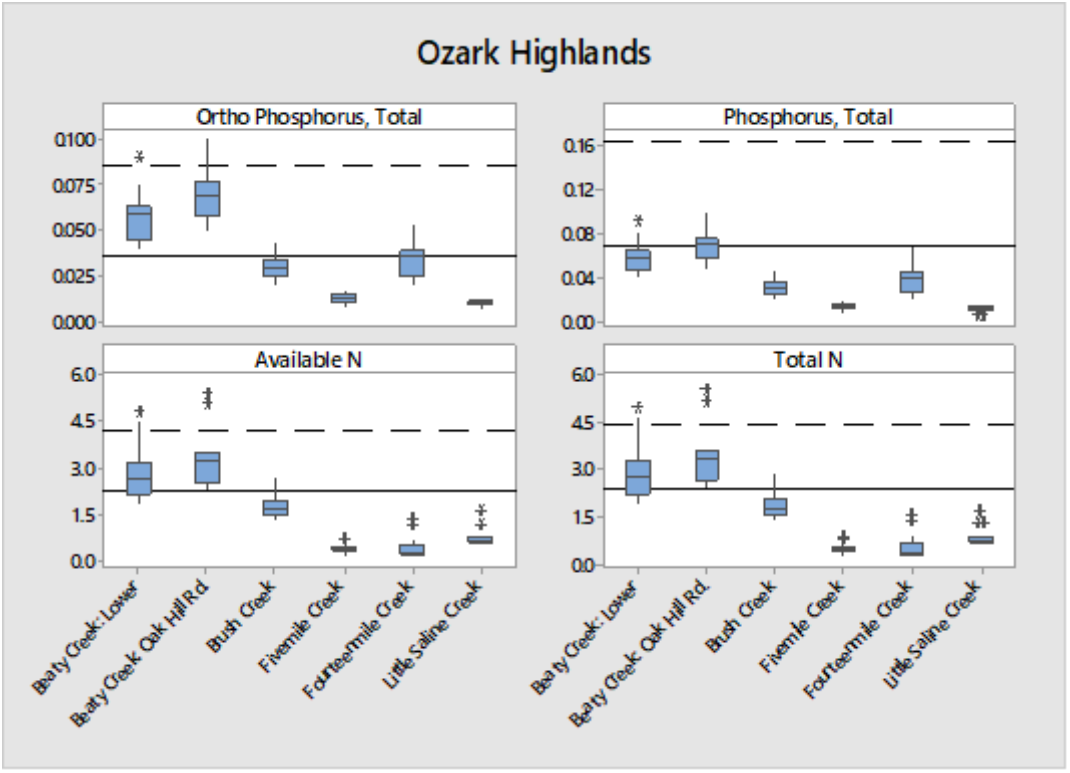

Central Great Plains
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Red Creek
Trail Creek
Walnut Creek
Willow Creek

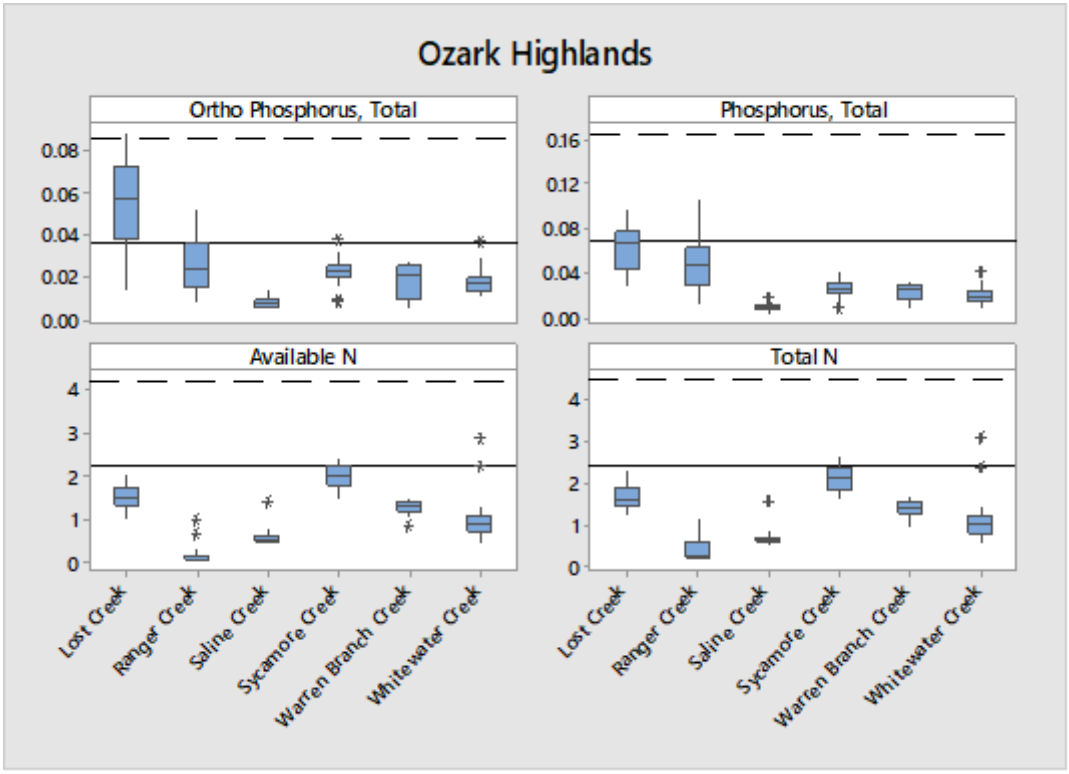
(b)


Central Irregular Plains
Ortho Phosphorus, Total
1.13
0.653
Phosphorus, Total
1.14
0.751
Available N
11.67
Total N
12.52
BigCabinCreek
BigCreek
BillCreek
CaliforniaCreek
ChouteauCreek
ElmCreek
HorseCreek
LightningCreek

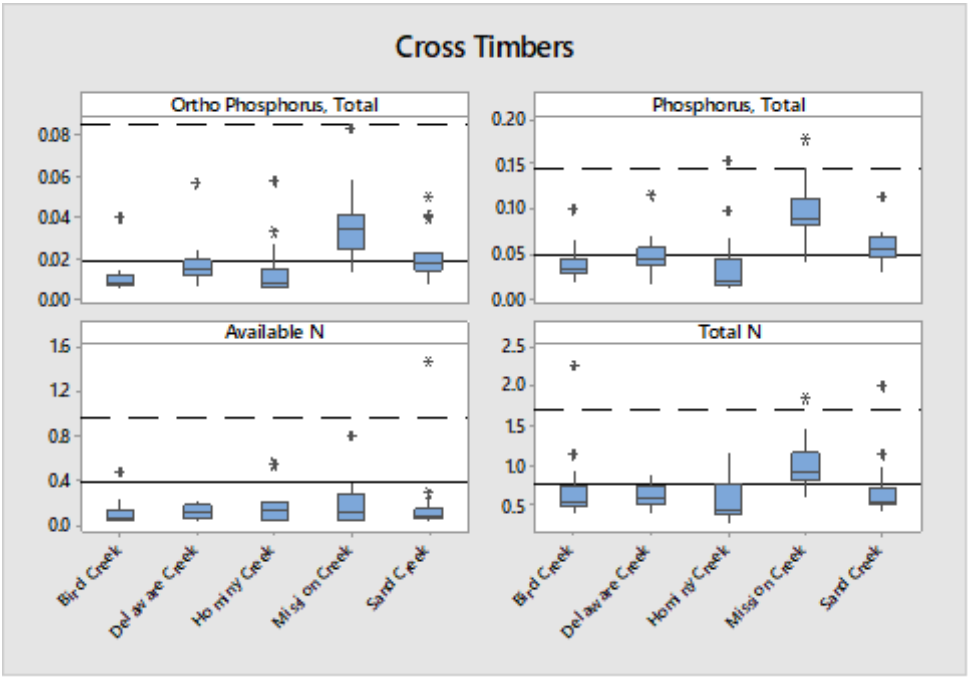

Central Irregular Plains
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
LittleCabinCreek
LittleHorseCreek
MudCreek
PawPawCreek
RyanCreek
RussellCreek
TarCreek

(c)


Ozark Highlands
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Beaty Creek: Lower
Beaty Creek: Oak Hill Rd.
Brush Creek
Fivemile Creek
Fourteenmile Creek
Little Saline Creek


Ozark Highlands
Ortho Phosphorus, Total
Phosphorus, Total
Available N
Total N
Lost Creek
Ranger Creek
Saline Creek
Sycamore Creek
Warren Branch Creek
Whitewater Creek

(d)



(e)

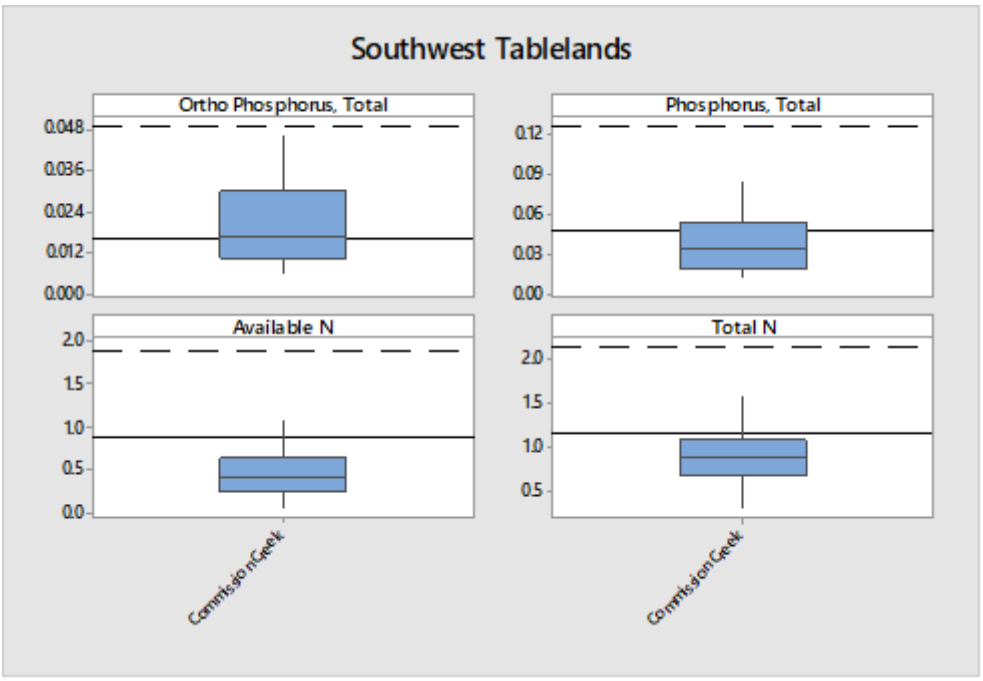
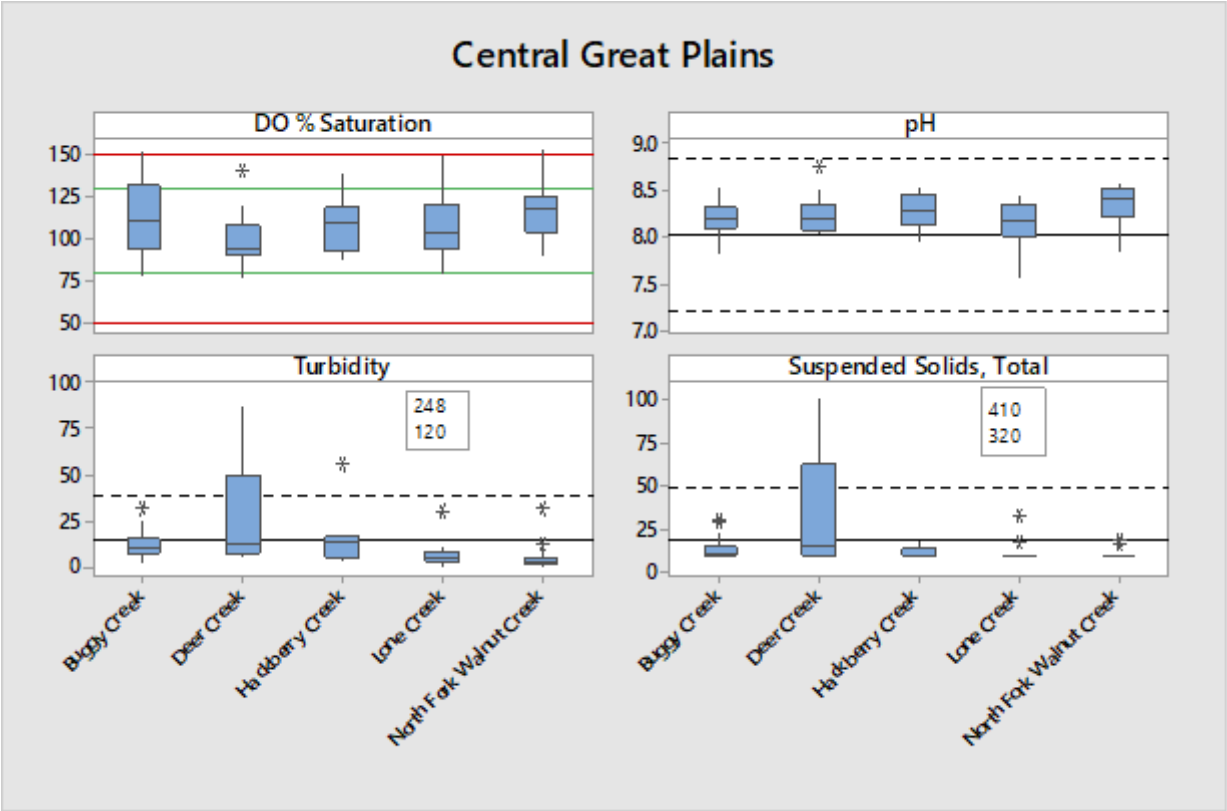
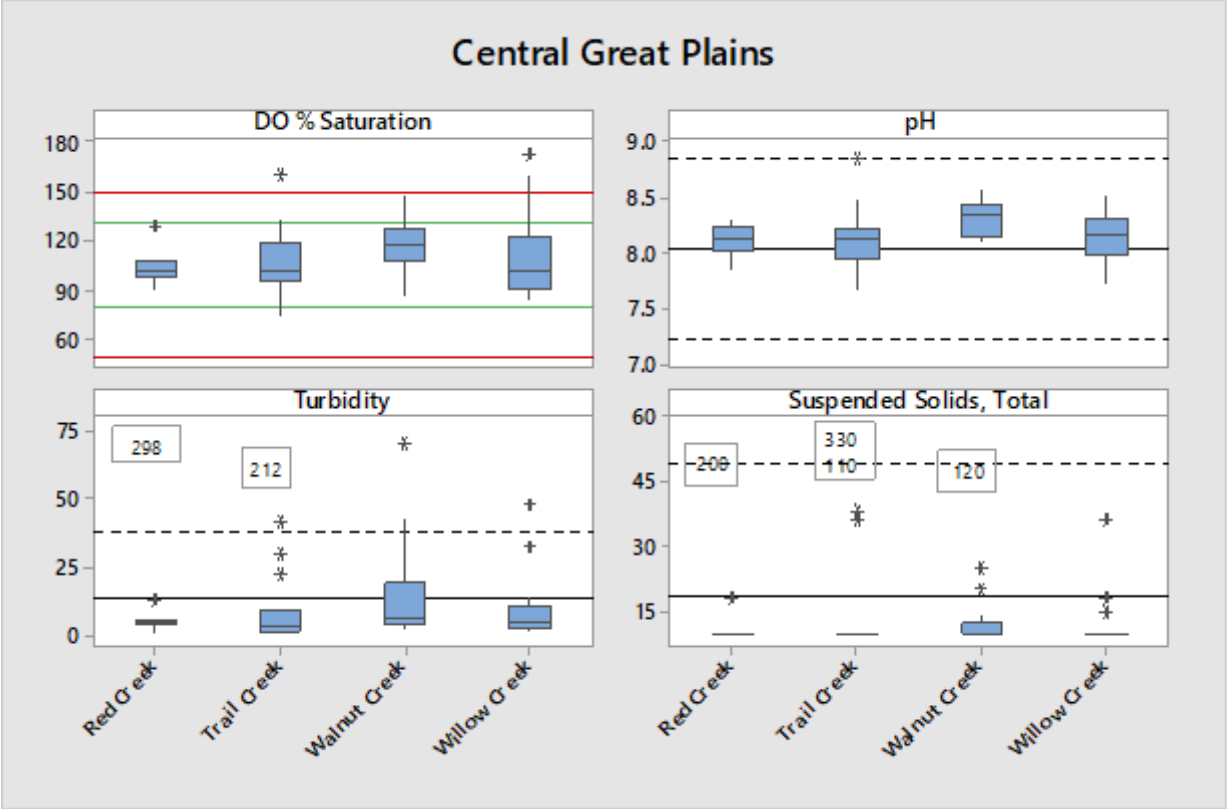


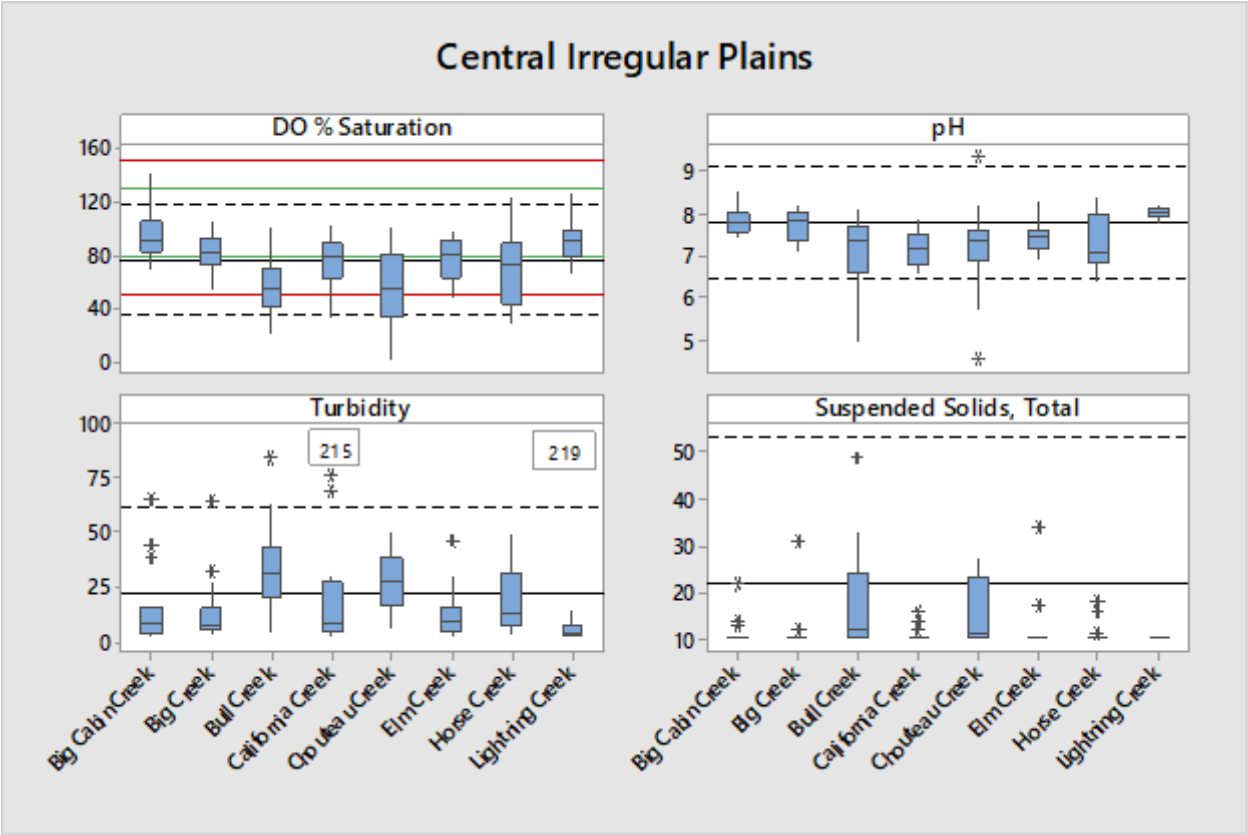
Figure 2. Select nutrients (orthophosphorous, total phosphorous, available nitrogen and total nitrogen) for each site in the (a) Central Great Plains, (b) Central Irregular Plains, (c) Ozark Highlands, (d) Cross Timbers and (e) Southwest Tablelands. The median of each site is shown by a line within the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

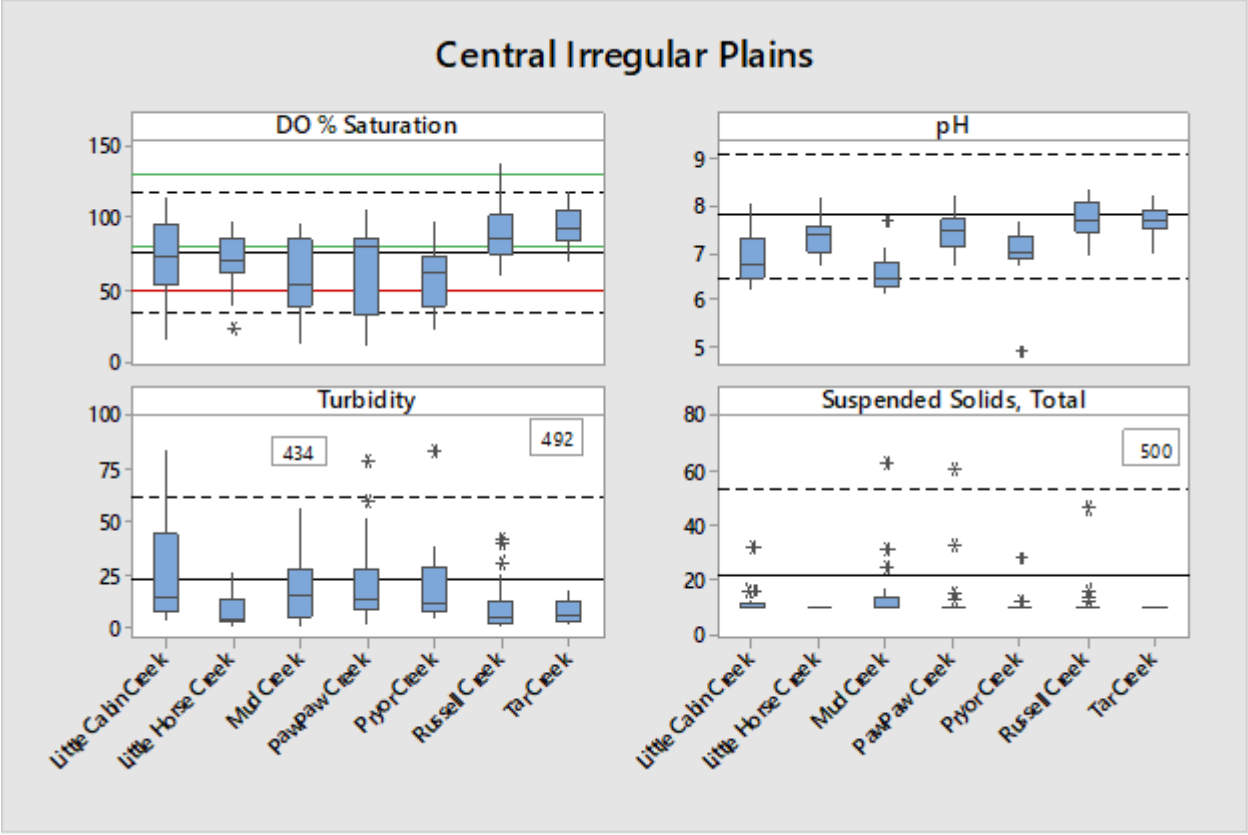
(a)


Central Great Plains
DO % Saturation
pH
Turbidity
248
120
Suspended Solids, Total
410
320
Buggy Creek
Deer Creek
Hackberry Creek
Lone Creek
North Fork Walnut Creek

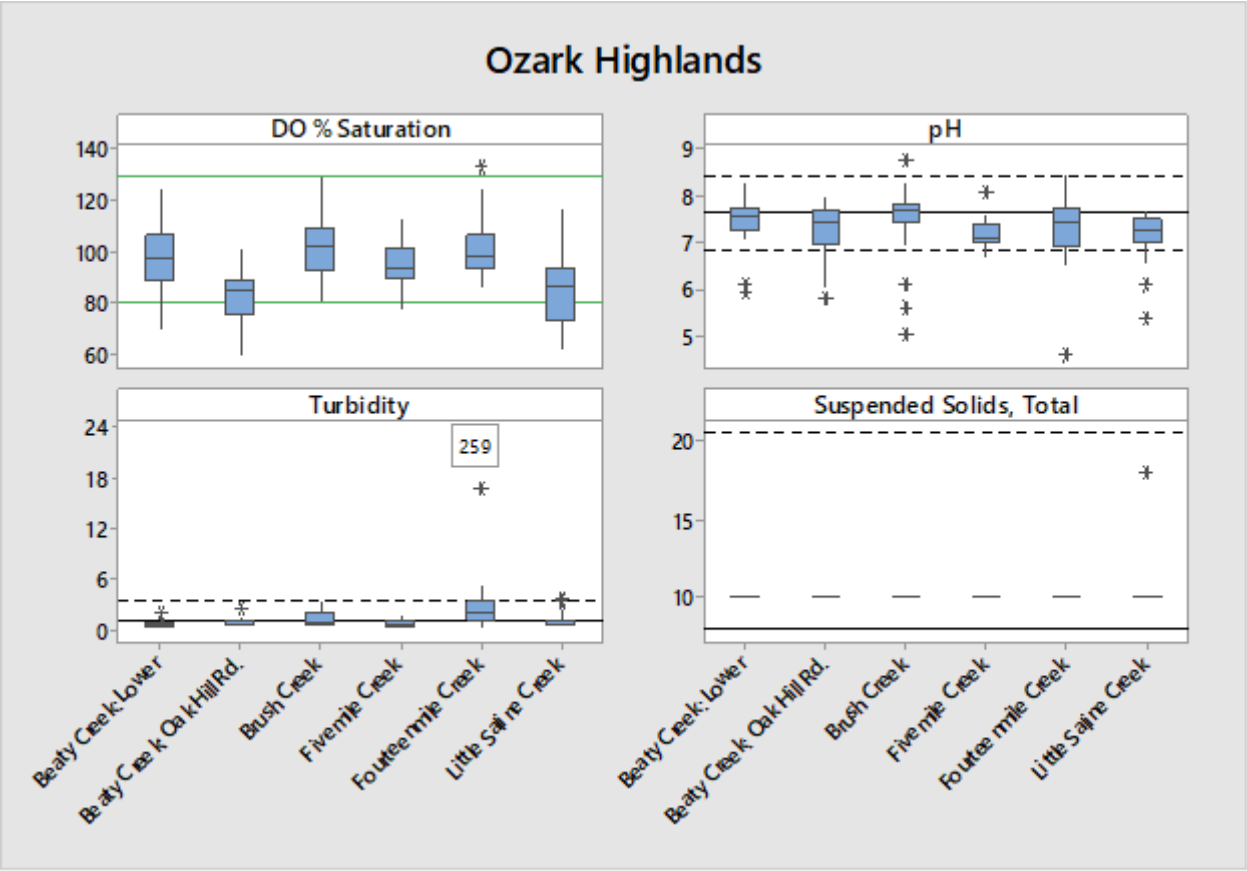

Central Great Plains
DO % Saturation
pH
Turbidity
298
212
Suspended Solids, Total
330
120
Red Creek
Trail Creek
Walnut Creek
Willow Creek

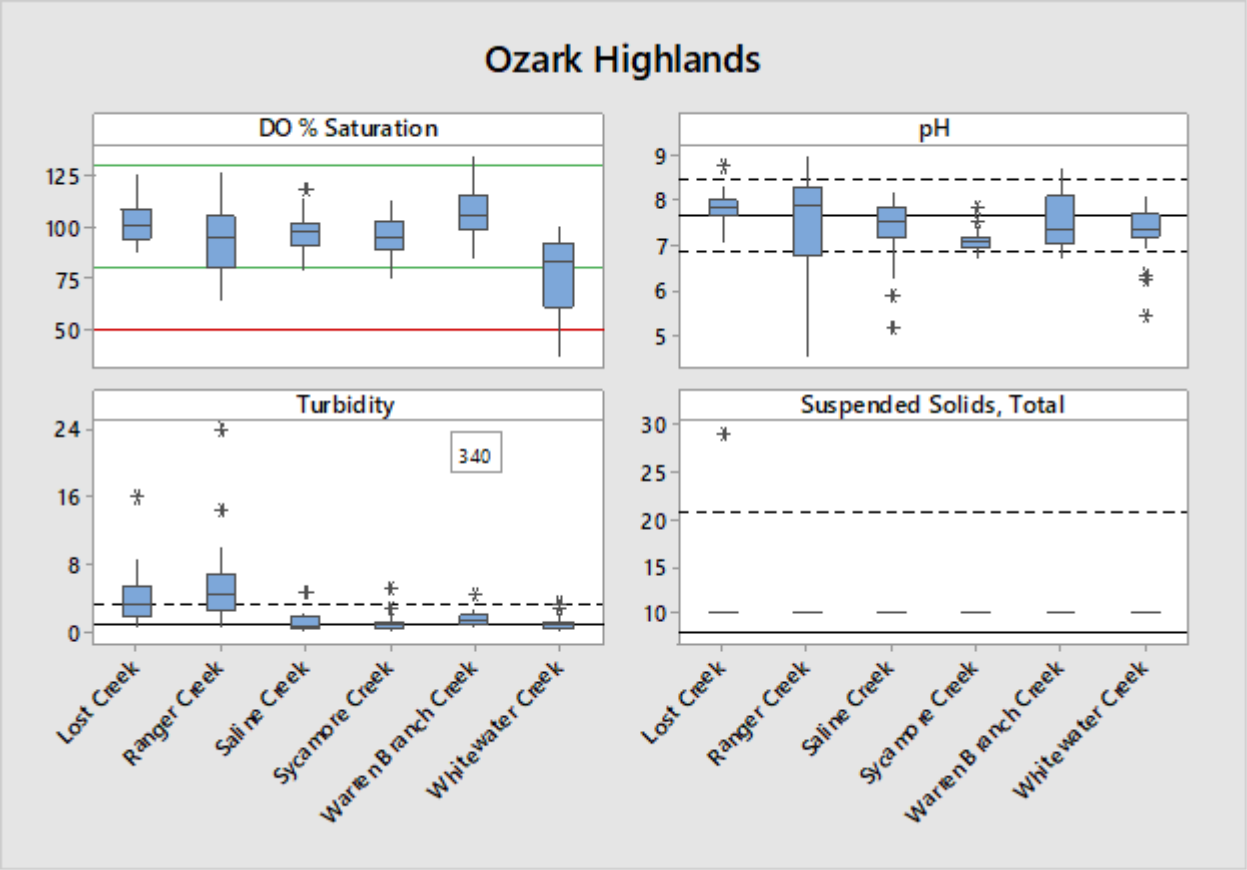
(b)


Central Irregular Plains
DO % Saturation
pH
Turbidity
215
219
Suspended Solids, Total
Big Cabin Creek
Big Creek
Bull Creek
California Creek
Choteau Creek
Elm Creek
Horse Creek
Lightning Creek

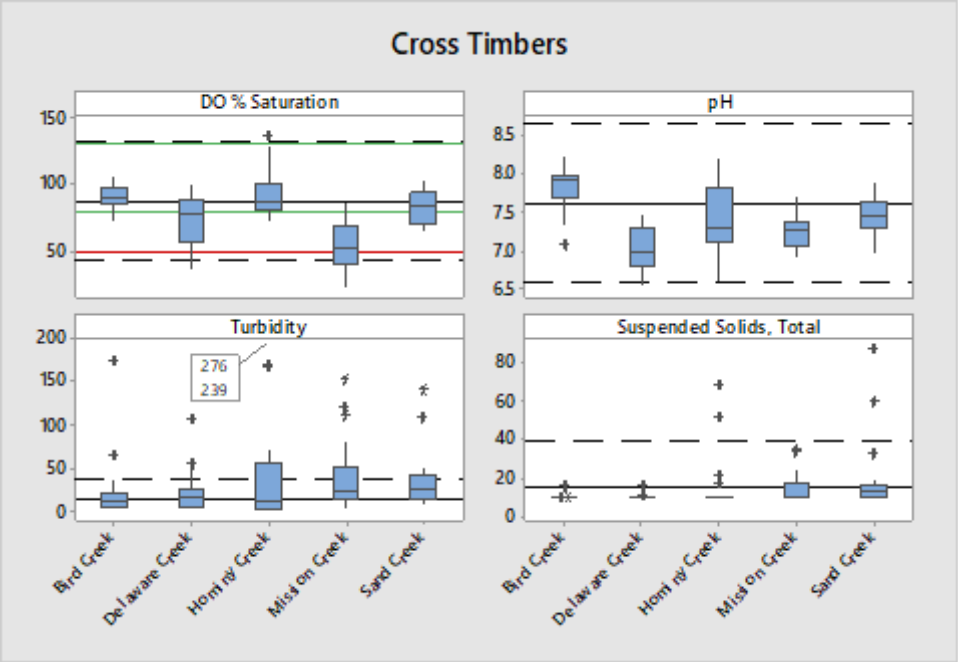

Central Irregular Plains
DO % Saturation
pH
Turbidity
434
492
Suspended Solids, Total
500
Little Cabin Creek
Little Horse Creek
Mud Creek
Paw Paw Creek
Pryor Creek
Russell Creek
Tar Creek

(C)


Ozark Highlands
DO % Saturation
pH
Turbidity
259
Suspended Solids, Total
Beaty Creek: Lower
Beaty Creek: Oak Hill Rd.
Brush Creek
Fivemile Creek
Fourteenmile Creek
Little Saline Creek


Ozark Highlands
DO % Saturation
pH
Turbidity
340
Suspended Solids, Total
Lost Creek
Ranger Creek
Saline Creek
Sycamore Creek
Warren Branch Creek
Whitewater Creek

(d)



(e)

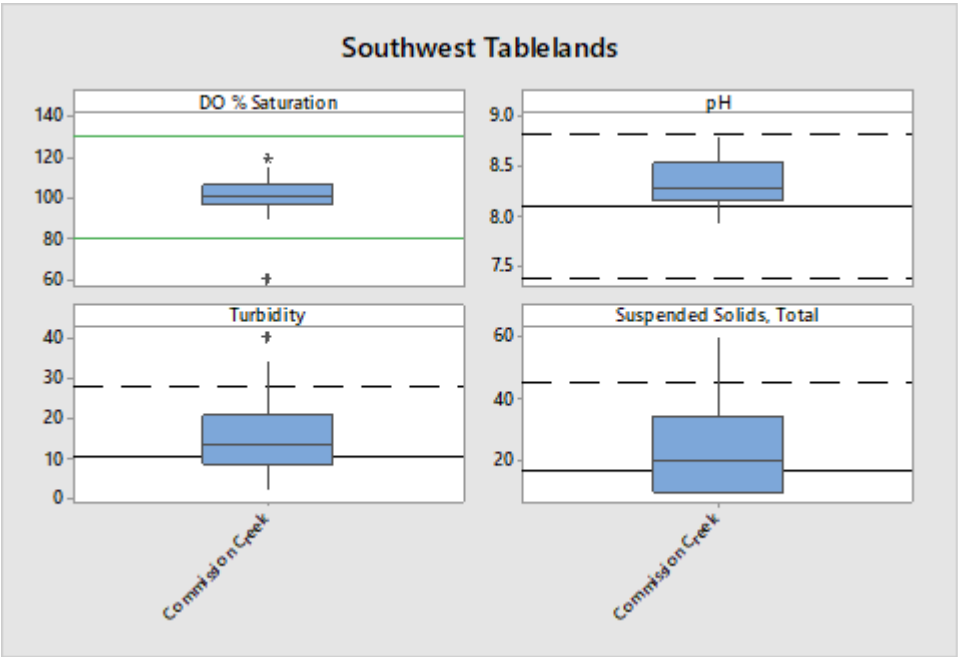


Figure 3. Select physical parameters by ecoregion (DO % Saturation, pH, turbidity, total suspended solids) for each site in the (a) Central Great Plains, (b) Central Irregular Plains, (c) Ozark Highlands, (d) Cross Timbers and (e) Southwest Tablelands. The median of each site is shown by a line within the box with most outliers denoted by asterisks. The extreme outliers are denoted by values within a box on the graph. The solid line indicates the mean value of that parameter at high quality sites in each ecoregion, while the dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero). Oxygen charts use a green line to indicate 80% and 130% and a red line to indicate 50% and 150% DO saturation. The Central Irregular Plains and Cross Timbers ecoregions have high quality sites with oxygen saturations lower than the other ecoregions included in these basins. In the Central Irregular Plains and Cross Timbers the dissolved oxygen charts show both oxygen saturation lines and the lines marking +/- two standard deviations from the high quality mean.

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

Three streams: Big Cabin Creek, Mission Creek, and Saline Creek were sampled in cycles 1 and 2 but not 3. Lightning Creek and Willow Creek were first sampled in cycle 3. Cycle 3 of Hackberry Creek and Red Creek were not included in the comparison since they were suffering drought conditions and few samples were collected. Ten streams had significantly higher levels of dissolved oxygen percent saturation, but nine streams had reduced DO % saturation. Ammonia was decreased in 13 streams and other forms of nitrogen were significantly decreased in 17 streams. Seven streams showed significant increases in nitrogen. Phosphorus decreased in nine streams. Turbidity and/or total suspended solids (TSS) was significantly lower in nine streams; alkalinity and/or hardness was significantly higher in 22 streams and reduced in two streams; eight streams exhibited increased salt concentrations (sulfate, chloride, or total dissolved solids) while 14 showed lower salt concentrations.

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

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Big Cabin Creek	OK121600-06-0220I	Alkalinity	1	20	88.8		0.079	
			2	20	86.9			
			4	17	113.94			
		Conductivity	1	19	640.6		0.003 *	
			2	20	652.9			
			4	17	886.6			
		DO % Saturation	1	20	71.89		0.001 *	
			2	20	76.2			
			4	16	94.23			
		Hardness	1	20	353.9		0.000 *	
			2	20	298.2			
			4	17	562.1			
		pH	1	20	8.079		0.060	
			2	20	7.602			
			4	17	7.787			
		Turbidity	1	20	25.22		0.037 *	
			2	20	78.9			
			4	19	10.89			
		Ammonia	1	20	0.1746		0.000 *	
			2	20	0.0282			
			4	7	0.0281			
		TDS	1	20	526.7		0.042 *	
			2	20	449.9			
			4	16	627.5			
		Sulfate	1	20	243.4		0.006 *	
			2	20	193.3			
			4	16	351			
Big Creek	OK121510-03-0010D	Alkalinity	1	20	110.8	0.070	0.001 *	
			2	19	144.6			
			3	21	141			
			4	18	166.1			
		Conductivity	1	20	336.5	0.097		
			2	19	332.9			
			3	21	312.2			
			4	18	358.5			
		DO % Saturation	1	20	72.21	0.073	0.006 *	
			2	19	78.55			
			3	20	92.5			
			4	18	81.47			
		Ammonia	1	20	0.1413		0.018 *	
			2	19	0.0226			
			3	9	0.0366			
			4	7	0.0231			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Big Creek (cont.)		Chloride	1	20	7.19	0.066	0.035 *	
			2	19	10.02			
			3	20	8.72			
			4	17	4.67			
		TKN	1	20	0.544	0.006 *	0.027 *	
			2	19	0.354			
			3	20	0.707			
			4	17	0.401			
		Nitrate	1	20	0.3691	0.079	0.079	
			2	19	0.3069			
			3	20	0.956			
			4	17	0.0512			
		Nitrite	1	20	0.0661	0.089	0.064	
			2	19	0.0273			
			3	20	0.025			
			4	17	0.0447			
		Sulfate	1	20	114.9	0.006 *		
			2	19	25.07			
			3	20	22.41			
			4	17	16.58			
		Available N	1	20	0.5764	0.085	0.093	
			2	19	0.3567			
			3	20	0.997			
			4	17	0.1054			
		Total N	1	20	0.979	0.028 *	0.015 *	
			2	19	0.688			
			3	20	1.688			
			4	17	0.4965			
		Flow	1	20	14.71	0.063	0.064	
			2	15	34.5			
			3	21	7.26			
			4	18	22.55			
Bird Creek	OK121300-02-0010C	Alkalinity	1	19	65.47		0.000 *	
			2	20	82.45			
			3	21	94.48			
			4	17	102.41			
		Hardness	1	19	106.09		0.010 *	
			2	20	107.79			
			3	13	135.5			
			4	17	140.9			
		pH	1	19	7.3968		0.000 *	
			2	18	7.6917			
			3	21	7.8543			
			4	17	7.8588			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Bird Creek (cont.)		Ammonia	1	19	0.1184		0.008 *	
			2	20	0.0179			
			3	9	0.015			
			4	6	0.0167			
		TKN	1	19	0.572	0.027 *		
			2	20	0.419			
			3	20	0.5965			
			4	16	0.4719			
		Nitrate	1	19	0.3937		0.000 *	
			2	20	0.1232			
			3	20	0.042			
			4	16	0.0319			
		Sulfate	1	19	13.93	0.061		
			2	20	15.76			
			3	20	16.95			
			4	16	13.83			
		Available N	1	19	0.544		0.000 *	
			2	20	0.1581			
			3	20	0.0688			
			4	15	0.0753			
		Total N	1	19	0.998		0.078	
			2	20	0.559			
			3	20	0.6585			
			4	16	0.652			
Buggy Creek	OK520610-02-0120G	Conductivity	1	20	1309.1		0.000 *	
			2	18	1103.2			
			3	20	1681			
			4	14	1723.1			
		DO % Saturation	1	20	109.65		0.043 *	
			2	18	90.87			
			3	19	99.42			
			4	13	112.05			
		Hardness	1	20	548.2		0.000 *	
			2	19	515.7			
			3	13	687.7			
			4	17	745			
		pH	1	20	8.115		0.015 *	
			2	19	8.033			
			3	20	8.234			
			4	14	8.201			
		Turbidity	1	20	62.5		0.041 *	
			2	19	160			
			3	20	18			
			4	18	12.17			
		Chloride	1	20	39		0.000 *	
			2	19	37.82			
			3	20	67.05			
			4	17	63.19			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Buggy Creek (Cont.)		TDS	1	20	1004.1		0.009 *	
			2	19	834.7			
			3	20	1501			
			4	17	1172.9			
		TKN	1	20	0.644	0.011 *		
			2	19	1.064			
			3	20	0.896			
			4	17	0.5812			
		Nitrate	1	20	0.925	0.000 *	0.000 *	
			2	19	0.903			
			3	20	0.2255			
			4	17	0.69			
		Nitrite	1	20	0.0074	0.006 *	0.000 *	
			2	19	0.037			
			3	20	0.0275			
			4	17	0.0929			
		Ortho P	1	17	0.1084		0.031 *	
			2	19	0.2089			
			3	20	0.0766			
			4	17	0.0718			
		Total P	1	17	0.1605		0.041 *	
			2	19	0.38			
			3	20	0.128			
			4	17	0.0991			
		Sulfate	1	20	431.6	0.030 *	0.000 *	
			2	19	301.2			
			3	20	709.1			
			4	17	568.4			
		TSS	1	20	39.9		0.031 *	
			2	19	443			
			3	20	19.6			
			4	17	14.24			
		Available N	1	20	1.121	0.000 *	0.000 *	
			2	18	1.049			
			3	20	0.2724			
			4	17	0.807			
		Total N	1	20	1.576		0.029 *	
			2	19	2.004			
			3	20	1.149			
			4	17	1.364			
		Flow	1	20	9.31		0.045 *	
			2	17	33			
			3	19	5.16			
			4	11	5.639			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Bull Creek	OK121500-02-0090D	Alkalinity	1	20	72.7	0.077	0.000 *	
			2	19	62.63			
			3	21	87.05			
			4	21	105.48			
		Conductivity	1	20	327.4	0.054	0.027 *	
			2	19	274.9			
			3	21	372.6			
			4	21	312.8			
		DO % Saturation	1	20	52.71	0.084	0.023 *	
			2	19	69.28			
			3	21	64.83			
			4	20	54.13			
		Hardness	1	20	121.74		0.000 *	
			2	19	97.21			
			3	13	180.54			
			4	21	170.43			
		pH	1	19	8.349		0.000 *	
			2	16	7.303			
			3	21	7.22			
			4	21	7.04			
		Ammonia	1	20	0.2719		0.000 *	
			2	19	0.0337			
			3	9	0.0392			
			4	7	0.0677			
		TDS	1	20	220.1	0.004 *	0.005 *	
			2	19	185.84			
			3	20	237.2			
			4	19	188.4			
		TKN	1	20	0.979	0.019 *	0.005 *	
			2	19	0.6329			
			3	20	1.1055			
			4	19	0.8321			
		Nitrate	1	20	0.562	0.079	0.000 *	
			2	19	0.3502			
			3	20	0.229			
			4	19	0.0921			
		Sulfate	1	20	65.45	0.002 *	0.028 *	
			2	19	54.1			
			3	20	69.62			
			4	19	43.12			
		Available N	1	20	0.891		0.000 *	
			2	19	0.4247			
			3	20	0.2692			
			4	19	0.1528			
		Total N	1	20	1.598	0.017 *	0.002 *	
			2	19	1.024			
			3	20	1.357			
			4	19	0.96			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
California Creek	OK121510-02-0050C	Alkalinity	1	20	99		0.004 *	
			2	19	106.74			
			3	21	148.8			
			4	21	124.62			
		DO	1	20	5.986	0.012 *	0.034 *	
			2	19	7.469			
			3	20	5.221			
			4	20	7.67			
		DO % Saturation	1	20	59.75	0.002 *	0.008 *	
			2	19	70.71			
			3	20	49.38			
			4	21	73.52			
		pH	1	20	8.06	0.009 *	0.000 *	
			2	15	7.525			
			3	19	7.409			
			4	21	7.108			
		Ammonia	1	19	0.1539		0.000 *	
			2	19	0.0165			
			3	9	0.0357			
			4	7	0.041			
		Chloride	1	20	44.96		0.073	
			2	19	37.41			
			3	20	31.6			
			4	20	23.02			
		TKN	1	19	0.5164	0.001 *	0.000 *	
			2	19	0.4181			
			3	20	1.088			
			4	20	0.5105			
		Nitrate	1	20	0.3716	0.006 *	0.000 *	
			2	19	0.2575			
			3	20	0.057			
			4	20	0.082			
		Available N	1	20	0.5558		0.000 *	
			2	19	0.2935			
			3	20	0.0931			
			4	20	0.1349			
		Total N	1	20	0.9	0.004 *	0.007 *	
			2	19	0.695			
			3	20	1.165			
			4	20	0.631			
		Flow	1	20	2.77	0.032 *	0.061	
			2	17	6.46			
			3	21	0.348			
			4	22	7.77			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Chouteau Creek	OK121600-01-0430P	Alkalinity	1	18	74.83	0.024 *	0.000 *	
			2	19	69.11			
			3	21	102.2			
			4	19	135.7			
		Conductivity	1	19	255		0.034 *	
			2	19	219.6			
			3	21	417.4			
			4	19	369.6			
		Hardness	1	19	93.31		0.000 *	
			2	19	79.88			
			3	12	162.3			
			4	19	175.21			
		pH	1	18	8.092		0.000 *	
			2	16	7.142			
			3	21	7.1633			
			4	19	7.153			
		Ammonia	1	19	0.2147		0.010 *	
			2	19	0.0675			
			3	9	0.197			
			4	7	0.717			
		TDS	1	19	170.7	0.006 *	0.001 *	
			2	19	166.1			
			3	20	236.8			
			4	17	160			
		TKN	1	19	0.852		0.001 *	
			2	19	0.5948			
			3	20	1.336			
			4	17	1.401			
		Nitrate	1	19	0.6435		0.000 *	
			2	19	0.2225			
			3	20	0.227			
			4	17	0.1194			
		Nitrite	1	19	0.0644	0.078		
			2	19	0.0238			
			3	20	0.025			
			4	17	0.0682			
		Sulfate	1	19	37.79	0.007 *	0.001 *	
			2	19	25.29			
			3	20	61.5			
			4	17	20.41			
		Available N	1	19	0.923		0.000 *	
			2	19	0.3139			
			3	20	0.3408			
			4	17	0.483			
		Total N	1	19	1.56		0.006 *	
			2	19	0.8411			
			3	20	1.588			
			4	17	1.589			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Chouteau Creek (Cont.)		Flow	1	15	42.9		0.018 *	
			2	12	12.61			
			3	20	1.888			
			4	20	0.814			
Commission Creek	OK520620-05-0160C	Conductivity	1	19	819.5		0.086	
			2	18	858.1			
			3	20	912			
			4	19	914.9			
		DO	1	19	9.995	0.056		
			2	18	10.109			
			3	19	10.538			
			4	18	9.397			
		DO % Saturation	1	19	103.71		0.023 *	
			2	18	95.44			
			3	19	107.47			
			4	18	100.29			
		Hardness	1	19	233.1		0.000 *	
			2	18	258.04			
			3	11	317.3			
			4	19	383.6			
		pH	1	18	8.2939		0.070	
			2	18	8.1611			
			3	20	8.296			
			4	19	8.3163			
		Ammonia	1	19	0.0323		0.050 *	
			2	18	0.0106			
			3	9	0.0169			
			4	6	0.0167			
		Chloride	1	19	103.76		0.000 *	
			2	18	103.13			
			3	20	137.79			
			4	20	126.3			
		TDS	1	19	482.97		0.035 *	
			2	18	494.83			
			3	20	539.3			
			4	20	576.5			
		TKN	1	19	0.3138		0.095	
			2	18	0.3028			
			3	20	0.4335			
			4	20	0.427			
		Nitrate	1	19	0.6356	0.012 *	0.000 *	
			2	18	0.3556			
			3	20	0.2045			
			4	20	0.3265			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Commission Creek (Cont.)		Nitrite	1	19	0.0074	0.004 *	0.000 *	
			2	18	0.0376			
			3	20	0.02			
			4	20	0.142			
		Ortho P	1	18	0.0118	0.018 *	0.039 *	
			2	18	0.0188			
			3	20	0.0105			
			4	20	0.0199			
		Total P	1	18	0.0365	0.033 *		
			2	18	0.0362			
			3	20	0.0219			
			4	20	0.0382			
		Sulfate	1	19	30.44	0.072	0.017 *	
			2	18	55.4			
			3	20	33.72			
			4	20	41.02			
		Available N	1	19	0.6753	0.001 *	0.000 *	
			2	18	0.4037			
			3	20	0.2321			
			4	20	0.4735			
		Total N	1	19	0.9569	0.011 *	0.001 *	
			2	18	0.696			
			3	20	0.658			
			4	20	0.8955			
Deer Creek	OK520620-06-0010F	Alkalinity	1	20	167.15		0.093	
			2	18	194.11			
			3	20	172.2			
			4	17	174.35			
		Hardness	1	20	615.5		0.053	
			2	19	680.9			
			3	13	668.5			
			4	16	817.4			
		Turbidity	1	20	39.7	0.009 *		
			2	19	99.7			
			3	21	8.91			
			4	17	27.58			
		Sulfate	1	20	456.9	0.012 *		
			2	19	480.4			
			3	20	402.8			
			4	16	514.4			
		Flow	1	20	41.61		0.023 *	
			2	14	68.1			
			3	19	27.39			
			4	8	31.9			
Delaware Creek	OK121300-01-0150H	Alkalinity	1	18	76.94	0.002 *	0.002 *	
			2	19	80.53			
			3	21	82.25			
			4	20	108.95			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Delaware Creek (Cont.)		Conductivity	1	19	837	0.001 *	0.001 *	
			2	19	472			
			3	21	415.8			
			4	20	623.9			
		DO % Saturation	1	19	59.11		0.097	
			2	18	62.75			
			3	20	73.95			
			4	20	72.47			
		Hardness	1	19	191.9	0.060	0.029 *	
			2	19	132.8			
			3	13	148.8			
			4	20	189.2			
		pH	1	19	7.922	0.019 *	0.000 *	
			2	15	7.0547			
			3	21	7.1862			
			4	20	6.97			
		Turbidity	1	19	36.74	0.090		
			2	19	50.2			
			3	22	36.27			
			4	23	22.65			
		Ammonia	1	19	0.1087		0.000 *	
			2	19	0.0129			
			3	9	0.0553			
			4	7	0.0233			
		Chloride	1	19	201.1	0.001 *	0.001 *	
			2	19	89.1			
			3	20	65.92			
			4	19	120.5			
		TDS	1	19	497.1	0.001 *	0.002 *	
			2	19	307.5			
			3	20	250.4			
			4	19	358.9			
		TKN	1	19	0.5156	0.000 *	0.000 *	
			2	19	0.4548			
			3	20	0.951			
			4	19	0.5337			
		Nitrate	1	19	0.4086		0.000 *	
			2	19	0.1051			
			3	20	0.0675			
			4	19	0.0395			
		Nitrite	1	19	0.0074	0.003 *	0.006 *	
			2	19	0.0369			
			3	20	0.02			
			4	19	0.0674			
		Total P	1	19	0.0596	0.005 *	0.064	
			2	19	0.0726			
			3	20	0.079			
			4	19	0.0485			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Delaware Creek (Cont.)		Sulfate	1	19	23.48		0.000 *	
			2	19	57.5			
			3	20	20.84			
			4	19	19.17			
		TSS	1	19	32.76		0.043 *	
			2	19	23.03			
			3	20	16.55			
			4	19	10.47			
		Available N	1	19	0.5248		0.000 *	
			2	19	0.1549			
			3	20	0.1124			
			4	19	0.1154			
		Total N	1	19	0.9317	0.000 *	0.000 *	
			2	19	0.5967			
			3	20	1.0385			
			4	19	0.6405			
Fivemile Creek	OK121600-07-0110G	Alkalinity	1	20	106.55		0.025 *	
			2	20	109.25			
			3	21	119.71			
			4	21	128.24			
		DO	1	20	10.382		0.097	
			2	20	9.826			
			3	21	8.831			
			4	20	9.355			
		DO % Saturation	1	20	104.54		0.001 *	
			2	20	98.62			
			3	21	90.25			
			4	20	95.05			
		Hardness	1	20	138.51		0.008 *	
			2	20	135.87			
			3	13	165.92			
			4	20	154.7			
		pH	1	18	7.944	0.000 *	0.000 *	
			2	20	7.703			
			3	21	7.733			
			4	21	7.199			
		Turbidity	1	19	0.799	0.059		
			2	19	1.991			
			3	21	1.465			
			4	24	0.7058			
		Ammonia	1	20	0.0117		0.000 *	
			2	20	0.0106			
			3	9	0.0213			
			4	7	0.0421			
		TKN	1	20	0.085	0.026 *		
			2	20	0.215			
			3	20	0.16			
			4	20	0.1105			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Fivemile Creek (Cont.)		Nitrate	1	20	0.589		0.000 *	
			2	20	0.3485			
			3	20	0.3915			
			4	20	0.3065			
		Nitrite	1	20	0.0097	0.001 *	0.000 *	
			2	20	0.0197			
			3	20	0.02			
			4	20	0.0525			
		Ortho P	1	18	0.0088	0.002 *		
			2	20	0.02			
			3	20	0.0092			
			4	20	0.012			
		Available N	1	20	0.6105		0.001 *	
			2	20	0.3788			
			3	20	0.4211			
			4	20	0.3737			
Fourteenmile Creek	OK121600-01-0100G	Alkalinity	1	20	68.6	0.000 *	0.000 *	
			2	20	72.05			
			3	20	77.2			
			4	20	98.4			
		Conductivity	1	20	190.65	0.047 *		
			2	20	174.57			
			3	20	192.26			
			4	19	177.12			
		DO % Saturation	1	20	100.5		0.036 *	
			2	20	92.34			
			3	20	105.33			
			4	19	101.57			
		Hardness	1	20	82.59		0.000 *	
			2	20	79.31			
			3	13	116.85			
			4	20	133.4			
		pH	1	18	7.6833	0.034 *		
			2	20	7.617			
			3	20	7.7355			
			4	19	7.3			
		Nitrite	1	20	0.0126	0.006 *	0.002 *	
			2	20	0.0174			
			3	20	0.02			
			4	18	0.0339			
		Ortho P	1	19	0.0212	0.000 *	0.013 *	
			2	20	0.0322			
			3	20	0.0224			
			4	18	0.0332			
		Total P	1	19	0.0464	0.010 *	0.025 *	
			2	20	0.0538			
			3	20	0.0275			
			4	18	0.0371			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Hackberry Creek	OK520620-04-0050D	Alkalinity	1	18	253.2		0.025 *	
			2	13	242.9			
			4	9	321.2			
		DO % Saturation	1	18	103.53		0.000 *	
			2	12	87.51			
			4	8	108.7			
		pH	1	17	8.107		0.013 *	
			2	13	8.033			
			4	9	8.279			
		Ammonia	1	18	0.0677		0.014 *	
			2	13	0.0106			
			4	3	0.016			
		Nitrate	1	18	0.3177		0.002 *	
			2	13	0.1508			
			4	9	0.02			
		Available N	1	18	0.3929		0.002 *	
			2	13	0.2037			
			4	9	0.0453			
		Total N	1	18	0.8008		0.037 *	
			2	13	0.5482			
			4	9	0.5133			
		Flow	1	18	3.456		0.000 *	
			2	11	3.21			
			4	18	0.704			
Hominy Creek	OK121300-04-0280G	Alkalinity	1	20	109.85	0.052		
			2	20	113.75			
			3	21	110.71			
			4	20	131.85			
		Conductivity	1	20	1189	0.003 *	0.016 *	
			2	17	1163			
			3	21	1602			
			4	20	987			
		DO % Saturation	1	20	102.33	0.005 *	0.000 *	
			2	20	84.91			
			3	20	70.8			
			4	20	92.38			
		Hardness	1	20	309.9	0.028 *	0.062	
			2	20	292			
			3	14	407.4			
			4	20	297.1			
		pH	1	20	7.86		0.005 *	
			2	18	7.65			
			3	21	7.54			
			4	20	7.38			
		Turbidity	1	20	38.2	0.023 *		
			2	20	77			
			3	22	10.56			
			4	23	51.4			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Hominy Creek (Cont.)		Ammonia	1	18	0.0758	0.020 *	0.003 *	
			2	20	0.0133			
			3	9	0.0384			
			4	7	0.0177			
		Chloride	1	20	280.2	0.000 *	0.000 *	
			2	20	262.7			
			3	20	503.2			
			4	19	218.3			
		TDS	1	20	694.5	0.001 *	0.004 *	
			2	20	702.6			
			3	20	985.9			
			4	19	563.7			
		TKN	1	20	0.4129	0.096	0.047 *	
			2	20	0.3239			
			3	20	0.539			
			4	19	0.4053			
		Nitrate	1	20	0.285		0.000 *	
			2	20	0.1735			
			3	20	0.0485			
			4	19	0.0389			
		Nitrite	1	20	0.0081	0.004 *	0.000 *	
			2	20	0.0282			
			3	20	0.02			
			4	19	0.1247			
		Ortho P	1	20	0.0144	0.056		
			2	20	0.0238			
			3	20	0.0069			
			4	19	0.0129			
		Available N	1	20	0.3613	0.026 *	0.001 *	
			2	20	0.215			
			3	20	0.0858			
			4	19	0.1702			
		Flow	1	20	15.45	0.065		
			2	18	12.68			
			3	18	1.706			
			4	20	11.7			
Lightning Creek	OK121510-01-0130N	Alkalinity	3	20	168	0.001 *		
			4	20	208			
		pH	3	18	7.796	0.000 *		
			4	20	7.989			
		Ammonia	3	9	0.015	0.035 *		
			4	7	0.0223			
		TKN	3	20	0.5225	0.011 *		
			4	19	0.27			
		Total N	3	20	0.611	0.049 *		
			4	19	0.3863			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Little Cabin Creek	OK121600-06-0080C	Alkalinity	1	19	73.47	0.005 *	0.001 *	
			2	20	99.55			
			3	20	114.1			
			4	18	84.22			
		DO	1	19	6.012	0.098		
			2	19	6.461			
			3	20	5.325			
			4	18	7.014			
		DO % Saturation	1	19	56.14	0.015 *	0.041 *	
			2	20	60.25			
			3	20	51.81			
			4	18	72.84			
		pH	1	19	7.918	0.024 *	0.000 *	
			2	20	7.425			
			3	20	7.209			
			4	18	6.898			
		Ammonia	1	19	0.1645		0.000 *	
			2	20	0.0422			
			3	9	0.0408			
			4	7	0.0293			
		TDS	1	19	213.1	0.057		
			2	20	258.2			
			3	20	245.2			
			4	17	198.8			
		TKN	1	19	0.6776	0.061	0.025 *	
			2	20	0.666			
			3	20	1.072			
			4	17	0.7553			
		Nitrate	1	19	0.625	0.034 *	0.012 *	
			2	20	0.4232			
			3	20	0.481			
			4	17	0.1312			
		Available N	1	19	0.876	0.047 *	0.001 *	
			2	20	0.5001			
			3	20	0.53			
			4	17	0.1956			
		Total N	1	19	1.389	0.038 *	0.079	
			2	20	1.124			
			3	20	1.584			
			4	17	0.939			
Little Horse Creek	OK121600-03-0190G	Alkalinity	1	20	93.25		0.005 *	
			2	18	104.22			
			3	20	113.6			
			4	20	128.45			
		DO % Saturation	1	20	69.48	0.049 *	0.090	
			2	18	65.93			
			3	20	53.23			
			4	19	69.25			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Little Horse Creek (Cont.)		Hardness	1	20	144.2		0.004 *	
			2	18	128.72			
			3	12	183.8			
			4	20	184.9			
		pH	1	17	6.992		0.073	
			2	18	7.461			
			3	20	7.298			
			4	20	7.355			
		Turbidity	1	19	14.59	0.053	0.040 *	
			2	18	43.9			
			3	20	17.96			
			4	23	8.62			
		TKN	1	20	0.6858	0.003 *	0.006 *	
			2	18	0.854			
			3	19	1.26			
			4	19	0.6632			
		Nitrate	1	20	1.27		0.049 *	
			2	18	0.571			
			3	19	0.506			
			4	19	0.2321			
		Ortho P	1	20	0.1121		0.020 *	
			2	18	0.2762			
			3	19	0.1795			
			4	19	0.1571			
		Total P	1	20	0.1609		0.013 *	
			2	18	0.3553			
			3	19	0.2397			
			4	19	0.1919			
		Sulfate	1	20	27.86	0.041 *		
			2	18	23.73			
			3	19	28.74			
			4	19	16.61			
		TSS	1	20	11.54		0.094	
			2	18	48.3			
			3	19	11.26			
			4	19	10			
		Available N	1	20	2.07	0.077	0.096	
			2	18	0.655			
			3	19	0.679			
			4	19	0.2996			
		Total N	1	20	2.575	0.005 *		
			2	18	1.452			
			3	19	1.802			
			4	19	0.951			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Lone Creek	OK520620-03-0020C	DO	1	20	9.552	0.063	0.021 *	
			2	17	10.404			
			3	13	12.07			
			4	18	10.018			
		Chloride	1	20	38.15	0.003 *	0.001 *	
			2	17	42.27			
			3	13	31.3			
			4	19	39.91			
		TDS	1	20	2501	0.081		
			2	17	2638			
			3	13	2324			
			4	20	2585			
		Nitrate	1	20	0.7095	0.034 *	0.000 *	
			2	17	0.3094			
			3	13	0.1862			
			4	20	0.497			
		Nitrite	1	20	0.0096		0.025 *	
			2	17	0.0231			
			3	13	0.0239			
			4	20	0.0335			
		Sulfate	1	20	1619	0.033 *		
			2	17	1454.7			
			3	13	1734			
			4	20	1508.3			
		Available N	1	20	0.8183	0.027 *	0.000 *	
			2	17	0.3875			
			3	13	0.2138			
			4	20	0.54			
		Total N	1	20	1.352		0.062	
			2	17	0.699			
			3	13	0.925			
			4	20	1.208			
Mission Creek	OK121400-02-0190B	DO	1	20	6.571		0.096	
			2	20	7.275			
			4	20	5.51			
		DO % Saturation	1	20	67.73		0.017 *	
			2	20	70.64			
			4	20	53.18			
		Ammonia	1	20	0.1497		0.000 *	
			2	20	0.013			
			4	7	0.0651			
		TKN	1	20	0.7114		0.000 *	
			2	20	0.4552			
			4	19	0.85			
		Nitrate	1	20	0.4036		0.000 *	
			2	20	0.1213			
			4	19	0.1011			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Mission Creek (Cont.)		Available N	1	20	0.6099		0.000 *	
			2	20	0.1503			
			4	19	0.1903			
		Total N	1	20	1.172		0.000 *	
			2	20	0.5924			
			4	19	1.0163			
Pryor Creek	OK121610-00-0050D	Alkalinity	1	16	73.81		0.000 *	
			2	19	62.92			
			3	21	90.48			
			4	14	110.43			
		Conductivity	1	18	472.2	0.041 *	0.001 *	
			2	19	259.8			
			3	21	291.2			
			4	14	379.9			
		DO	1	18	5.436		0.065	
			2	19	7.357			
			3	21	5.793			
			4	14	5.273			
		DO % Saturation	1	18	53.56		0.030 *	
			2	19	71.11			
			3	21	55.74			
			4	14	57.06			
		Hardness	1	18	111.94	0.003 *	0.000 *	
			2	19	82.74			
			3	13	151.15			
			4	14	195.79			
		pH	1	17	7.952		0.000 *	
			2	16	7.278			
			3	21	7.028			
			4	14	6.959			
		Ammonia	1	18	0.197		0.000 *	
			2	19	0.0524			
			3	9	0.0473			
			4	5	0.0572			
		Chloride	1	18	86	0.021 *	0.002 *	
			2	19	22.13			
			3	20	28.69			
			4	12	58.2			
		TDS	1	18	303.5		0.001 *	
			2	19	175			
			3	20	196			
			4	12	230.8			
		TKN	1	18	0.8163	0.010 *	0.007 *	
			2	19	0.5437			
			3	20	0.8645			
			4	12	0.5975			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Pryor Creek (Cont.)		Nitrate	1	18	0.5461	0.064	0.000 *	
			2	19	0.2586			
			3	20	0.198			
			4	12	0.0683			
		Nitrite	1	18	0.0352	0.021 *		
			2	19	0.0259			
			3	20	0.0235			
			4	12	0.065			
		Total P	1	17	0.1033	0.030 *	0.067	
			2	19	0.1294			
			3	20	0.1199			
			4	12	0.07			
		TSS	1	18	29.62		0.086	
			2	19	41.2			
			3	20	16			
			4	12	11.67			
		Available N	1	18	0.7783		0.000 *	
			2	19	0.337			
			3	20	0.2428			
			4	12	0.1572			
		Total N	1	18	1.398	0.032 *	0.001 *	
			2	19	0.828			
			3	20	1.086			
			4	12	0.7308			
Ranger Creek	OK121600-01-0060D	DO % Saturation	1	20	85.48		0.055	
			2	20	75.19			
			3	21	90.6			
			4	19	92.97			
		Hardness	1	20	133.87		0.012 *	
			2	20	140.92			
			3	13	156.9			
			4	19	169.89			
		Ammonia	1	20	0.0646		0.007 *	
			2	20	0.0129			
			3	9	0.0243			
			4	5	0.0168			
		TKN	1	20	0.3013	0.050 *	0.003 *	
			2	20	0.1866			
			3	20	0.43			
			4	17	0.2876			
		Nitrate	1	20	0.4211	0.054	0.045 *	
			2	20	0.2606			
			3	20	0.669			
			4	17	0.1406			
		Nitrite	1	20	0.0432	0.004 *		
			2	20	0.0182			
			3	20	0.02			
			4	17	0.0371			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Ranger Creek (Cont.)		Available N	1	20	0.5288	0.058	0.042 *	
			2	20	0.2917			
			3	20	0.7			
			4	17	0.1826			
		Total N	1	20	0.7655	0.016 *	0.003 *	
			2	20	0.4655			
			3	20	1.119			
			4	17	0.4653			
Saline Creek	OK121600-02-0030D	Alkalinity	1	20	98.25		0.006 *	
			2	20	87.75			
			4	19	113.16			
		Conductivity	1	20	230.58		0.041 *	
			2	20	210.91			
			4	19	235.29			
		DO % Saturation	1	20	106.71		0.051	
			2	20	103.72			
			4	19	97.1			
		Hardness	1	20	108.42		0.000 *	
			2	20	97.11			
			4	19	155.11			
		Ammonia	1	20	0.0273		0.081	
			2	20	0.0106			
			4	7	0.0154			
		Chloride	1	20	8.271		0.013 *	
			2	20	8.48			
			4	17	10.753			
		TDS	1	20	133.25		0.016 *	
			2	20	118.8			
			4	17	132.94			
		TKN	1	20	0.0896		0.089	
			2	20	0.0956			
			4	17	0.1141			
		Nitrite	1	20	0.0119		0.000 *	
			2	20	0.0202			
			4	17	0.0471			
		Ortho P	1	20	0.0059		0.002 *	
			2	20	0.0099			
			4	17	0.0083			
		Total P	1	20	0.0145		0.001 *	
			2	20	0.023			
			4	17	0.01012			
		TSS	1	20	6.768		0.001 *	
			2	20	7.918			
			4	17	10			
		Flow	1	20	31.16		0.067	
			2	17	67.3			
			4	17	17.2			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Sand Creek	OK121400-04-0010F	Alkalinity	1	20	93.45		0.002 *	
			2	20	98.8			
			3	21	123.95			
			4	18	116.89			
		Conductivity	1	20	442.2	0.023 *		
			2	17	488.6			
			3	21	517.9			
			4	18	417.3			
		pH	1	20	7.313		0.048 *	
			2	19	7.4305			
			3	21	7.5419			
			4	18	7.4583			
		Ammonia	1	20	0.1034		0.002 *	
			2	20	0.0213			
			3	9	0.0477			
			4	7	0.0257			
		Chloride	1	20	53.47	0.016 *		
			2	20	69.3			
			3	20	73.19			
			4	17	43.78			
		TDS	1	20	239.9	0.015 *	0.024 *	
			2	20	303.4			
			3	20	309.9			
			4	17	244.1			
		TKN	1	20	0.5345	0.001 *	0.001 *	
			2	20	0.4424			
			3	20	0.8835			
			4	17	0.5153			
		Nitrate	1	20	0.3356	0.061	0.000 *	
			2	20	0.1047			
			3	20	0.122			
			4	17	0.0329			
		Nitrite	1	20	0.0127		0.083	
			2	20	0.0202			
			3	20	0.0215			
			4	17	0.1353			
		Available N	1	20	0.4517		0.001 *	
			2	20	0.1462			
			3	20	0.165			
			4	17	0.1788			
		Total N	1	20	0.883	0.033 *	0.012 *	
			2	20	0.567			
			3	20	1.027			
			4	17	0.6835			
		Flow	1	20	38	0.038 *		
			2	15	57			
			3	19	5.52			
			4	18	23.96			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Sycamore Creek	OK121600-03-0510D	DO % Saturation	1	19	109.45		0.000 *	
			2	20	91.63			
			3	21	88.31			
			4	20	95.34			
		Hardness	1	19	124.95		0.002 *	
			2	20	117.39			
			3	13	144.85			
			4	20	140			
		pH	1	16	7.7194	0.000 *	0.002 *	
			2	20	7.57			
			3	21	7.621			
			4	21	7.1262			
		Ammonia	1	19	0.0177	0.099		
			2	20	0.0175			
			3	9	0.0151			
			4	7	0.0421			
		Chloride	1	19	8.379	0.070	0.093	
			2	20	9.891			
			3	20	9.38			
			4	20	8.33			
		TKN	1	19	0.1287	0.001 *	0.054	
			2	20	0.1344			
			3	20	0.207			
			4	20	0.125			
		Nitrate	1	19	1.886	0.091	0.031 *	
			2	20	1.677			
			3	20	2.414			
			4	20	1.962			
		Nitrite	1	19	0.0365	0.012 *		
			2	20	0.0159			
			3	20	0.02			
			4	20	0.04			
		Ortho P	1	16	0.0084		0.025 *	
			2	20	0.026			
			3	20	0.0196			
			4	20	0.0229			
		Total P	1	17	0.022		0.078	
			2	20	0.0445			
			3	20	0.0272			
			4	20	0.0262			
		Sulfate	1	19	5.682	0.002 *		
			2	20	6.202			
			3	20	6.03			
			4	20	5.385			
		Available N	1	19	1.94		0.036 *	
			2	20	1.711			
			3	20	2.44			
			4	20	2.016			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Sycamore Creek (Cont.)		Total N	1	19	2.051	0.059	0.016 *	
			2	20	1.828			
			3	20	2.641			
			4	20	2.127			
		Flow	1	19	25.97	0.041 *		
			2	17	30			
			3	20	10.14			
			4	21	32.8			
Tar Creek	OK121600-04-0060D	pH	1	18	7.354	0.095		
			2	19	7.626			
			3	20	7.452			
			4	19	7.629			
		Ammonia	1	19	0.1809		0.010 *	
			2	19	0.0799			
			3	9	0.075			
			4	6	0.0675			
		Chloride	1	20	37.05	0.001 *	0.006 *	
			2	19	34.33			
			3	20	30.23			
			4	18	17.22			
		TKN	1	19	0.6249	0.007 *	0.006 *	
			2	19	0.422			
			3	20	0.826			
			4	18	0.4772			
		Nitrate	1	20	1.635	0.018 *	0.000 *	
			2	19	0.3589			
			3	20	0.386			
			4	18	0.1217			
		Ortho P	1	19	0.2539		0.000 *	
			2	19	0.0556			
			3	20	0.0483			
			4	18	0.037			
		Total P	1	19	0.3255		0.000 *	
			2	19	0.0949			
			3	20	0.0883			
			4	18	0.0573			
		Available N	1	20	1.82	0.030 *	0.000 *	
			2	19	0.4597			
			3	20	0.45			
			4	18	0.1803			
		Total N	1	20	2.242	0.004 *	0.000 *	
			2	19	0.802			
			3	20	1.242			
			4	18	0.635			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Trail Creek	OK520620-02-0090G	Hardness	1	19	1714.7	0.022 *	0.005 *	
			2	19	1917.8			
			3	12	2076			
			4	19	1735.1			
		pH	1	18	8.043		0.046 *	
			2	19	7.866			
			3	21	7.969			
			4	19	8.094			
		Chloride	1	19	25.254	0.037 *	0.081	
			2	19	27.21			
			3	20	24.52			
			4	20	29.61			
		TKN	1	19	0.2939		0.058	
			2	19	0.449			
			3	20	0.666			
			4	20	0.51			
		Nitrate	1	19	0.4185	0.019 *	0.000 *	
			2	19	0.1604			
			3	20	0.062			
			4	20	0.1375			
		Nitrite	1	19	0.0074		0.001 *	
			2	19	0.0181			
			3	20	0.02			
			4	20	0.0315			
		Sulfate	1	19	1532.5	0.001 *	0.009 *	
			2	19	1411.4			
			3	20	1679.8			
			4	20	1427			
		Available N	1	19	0.5088	0.008 *	0.000 *	
			2	19	0.2431			
			3	20	0.0942			
			4	20	0.1894			
Walnut Creek	OK520610-03-0010G	Conductivity	1	20	685.6	0.024 *		
			2	19	757			
			3	22	692.1			
			4	16	828.1			
		DO % Saturation	1	20	95.62		0.001 *	
			2	17	87.66			
			3	21	106.62			
			4	16	116.97			
		Hardness	1	20	318.1		0.031 *	
			2	19	356.2			
			3	14	428.6			
			4	15	418.7			
		pH	1	19	8.1258		0.000 *	
			2	19	8.0016			
			3	22	8.3095			
			4	16	8.32			

Site Name	WBID	Variable	RB Cycle	N	Mean	p value Cycle 3 vs Cycle 4	p value (all cycles)	Result
Walnut Creek (Cont.)		Chloride	1	20	25.59	0.040 *	0.018 *	
			2	19	39.74			
			3	20	36.83			
			4	18	29.72			
		TKN	1	20	0.629	0.060		
			2	19	0.87			
			3	20	0.742			
			4	18	0.3722			
		Nitrate	1	20	0.56	0.098	0.022 *	
			2	19	0.543			
			3	20	0.061			
			4	18	0.1244			
		Nitrite	1	20	0.0444	0.002 *	0.028 *	
			2	19	0.0631			
			3	20	0.024			
			4	18	0.1233			
		Ortho P	1	19	0.1257		0.056	
			2	19	0.2291			
			3	20	0.0505			
			4	18	0.0362			
		Total P	1	19	0.217		0.063	
			2	19	0.312			
			3	20	0.108			
			4	18	0.055			
		Available N	1	20	0.751	0.003 *		
			2	19	1.129			
			3	20	0.0929			
			4	18	0.2533			
Willow Creek	OK520610-01-0080H	Conductivity	3	22	576.2	0.088		
			4	19	684			
		Nitrate	3	20	1.769	0.035 *		
			4	20	2.202			
		Available N	3	20	1.851	0.037 *		
			4	20	2.291			
		Total N	3	20	2.475	0.053		
			4	20	2.877			
		Flow	3	18	0.829	0.000 *		
			4	13	3.922			

3.2 BIOLOGICAL MONITORTING

3.2.1 Habitat Assessment

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

Table 11. Habitat assessment values for monitoring sites in the Rotating Basin Group 1 (Neosho-Grand and Upper Canadian Basins), Cycle 4. Each site is assigned a unique waterbody identifier (WBID). The total habit score (Total Points) is calculated by aggregating the eleven metrics listed below for a maximum of 180 points.

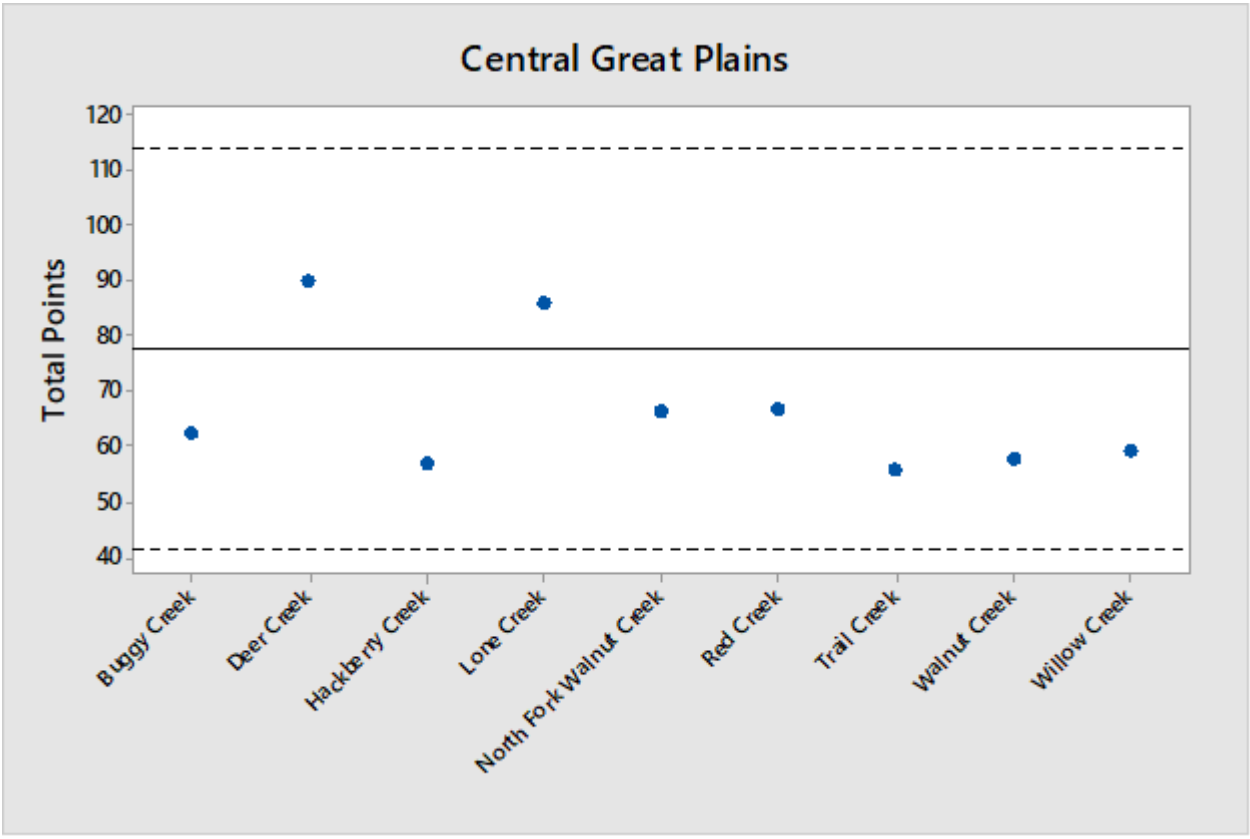
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Beaty Creek: Lower	OK121600-05-0160G	17.8	17.3	17.2	7	16.1	16.2	2.8	0.6	7.6	4.4	7.4	114.4
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	18.6	16.2	13.2	14.9	16.2	10	2.8	2	8.6	7.4	9.6	119.5
Big Cabin Creek	OK121600-06-0220I	13.4	11.4	14.6	15.7	16.1	20	5	0.5	7.1	7.4	9.3	120.5
Big Creek	OK121510-03-0010D	6.6	4.6	17.2	17.6	4.1	0.5	9.9	0.5	7.6	5.6	9.3	83.5
Bird Creek	OK121300-02-0010C	8.9	2.5	0	8.4	0	19.7	0.4	0.3	10	8.9	10	69.1
Brush Creek	OK121600-05-0140J	18.8	18.7	19.8	19.9	16.3	12.2	0.5	3.3	7.4	6.3	9.6	132.8
Buggy Creek	OK520610-02-0120G	1.6	0.4	14.6	2.1	0	12.6	2.8	0.4	9.2	8.9	10	62.6
Bull Creek	OK121500-02-0090D	6.3	8.9	14.2	3.8	0	0	5	3.7	6.2	3.3	9.1	60.5
California Creek	OK121510-02-0050C	14.8	12.2	13	19.5	9	1.5	1	1.9	7.6	6.3	9.1	95.9
Chouteau Creek	OK121600-01-0430P	3.2	0.4	0	14.8	11.4	0	5	6	3.8	2.5	7	54.1
Commission Creek	OK520620-05-0160C	6.1	0.4	0	3.3	11.4	12.2	16.5	2	8.3	8.5	4.8	73.5
Deer Creek	OK520620-06-0010F	6.9	3.7	19.3	6.3	4.1	18.7	0.4	2	9.8	8.7	10	89.9
Delaware Creek	OK121300-01-0150H	8.5	3.1	13.5	12.6	2.2	3.7	8.7	4.8	7.6	6	3.4	74.1
Elm Creek	OK121600-04-0150G	19.6	16.9	15.4	19.7	13.3	3.5	2.8	0.6	9.7	8.3	8.7	118.5
Fivemile Creek	OK121600-07-0110G	19.6	15.7	17.2	15.4	16.2	15.5	2.8	0.5	10	7.3	10	130.2
Fourteenmile Creek	OK121600-01-0100G	18.8	14.6	14	9.9	16.1	20	0.4	2	6	5	4.2	111
Hackberry Creek	OK520620-04-0050D	3.5	0.4	0	18.6	0	8.9	1.8	4.7	7.2	7.3	4.6	57
Hominy Creek	OK121300-04-0280G	12.1	10.3	17.2	8.1	16.2	15.3	6.7	0.8	7.4	6.3	9.3	109.7
Horse Creek	OK121600-03-0160G	15	9.9	19.9	17.6	5.9	2	1.4	1.7	8	6.1	3.8	91.3
Lightning Creek	OK121510-01-0130N	2.7	1.8	13.6	13	0	0	16.5	2	10	6.7	10	76.3
Little Cabin Creek	OK121600-06-0080C	7.2	4.6	13.2	19.5	5.9	16.8	5	0.4	6.3	5.1	9.9	93.9
Little Horse Creek	OK121600-03-0190G	14.5	15.9	0	19.9	10.3	1.2	5	0.3	6.6	3.9	6.2	83.8
Little Saline Creek	OK121600-02-0070G	17.6	16.8	19.1	15	15.6	12.2	1	0.6	7.9	3.9	9.9	119.6
Lone Creek	OK520620-03-0020C	6.2	0.4	20.2	20	5.9	9.6	0.5	1.1	6.1	6.6	9.3	85.9
Lost Creek	OK121600-03-0560G	19.5	12.1	17.2	8.6	16.1	20	0.5	2.5	7.4	6.6	10	120.5
Mission Creek	OK121400-02-0190B	14.3	10.8	13.3	19.7	10.3	1	1.8	3.1	8.5	6.1	10	98.9

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
Mud Creek	OK121600-04-0175M	4.9	8.3	17.6	19.3	0	0.5	13.7	4.4	4.7	5.6	7	86
North Fork Walnut Creek	OK520610-03-0080E	4.6	1.4	14.6	3.8	0	15.9	0.4	0.1	8.5	7.1	9.9	66.3
PawPaw Creek	OK121600-06-0240G	9.7	8.8	15.4	19.5	9	0.2	0.4	3.4	6.8	5.5	10	88.7
Pryor Creek	OK121610-00-0050D	9.8	3.5	14.2	16.4	2.2	0.5	7.7	0.5	5.2	3.4	9.3	72.7
Ranger Creek	OK121600-01-0060D	18.7	16.5	14.3	19.4	15.2	16.6	0.4	3.8	8.9	6.5	9.6	129.9
Red Creek	OK520620-03-0110F	0.8	0.4	0	20	0	0.8	16.5	2	8.1	8	10	66.6
Russell Creek	OK121600-04-0200F	4	12.6	19.6	10.4	11.4	1.2	0.4	0.4	5.7	2.9	9.6	78.2
Saline Creek	OK121600-02-0030D	18.1	10.9	8.7	3	14.7	20	0.5	0.9	6.3	4.6	9.2	96.9
Sand Creek	OK121400-04-0010F	12.1	5.3	13.8	15.1	10.3	20	0.5	0.7	9.3	8.1	10	105.2
Sycamore Creek	OK121600-03-0510D	19.6	18.6	14.6	16.4	16.1	16.8	1.4	0.7	10	4.9	9.1	128.2
Tar Creek	OK121600-04-0060D	7.6	8.6	6.1	11.5	9	17.6	6.7	0.4	9.1	7.5	9.7	93.8
Trail Creek	OK520620-02-0090G	1.2	0.4	17.2	5.8	0	8	0.7	1.4	8.5	7.8	4.8	55.8
Walnut Creek	OK520610-03-0010G	0.7	0.4	0	7.2	0	20	5.8	0.3	9.8	3.6	10	57.8
Warren Branch Creek	OK121600-07-0050G	18.1	11.9	19.3	19.8	14.7	16.5	2.3	1.2	9.4	7.4	10	130.6
Whitewater Creek	OK121600-03-0320G	18	17	20.2	19.4	16.1	0	0.4	0.1	7.5	4.7	8.8	112.2
Willow Creek	OK520610-01-0080H	1.5	0.4	0	19.7	0	10.1	2.3	0.7	10	5.1	9.6	59.4

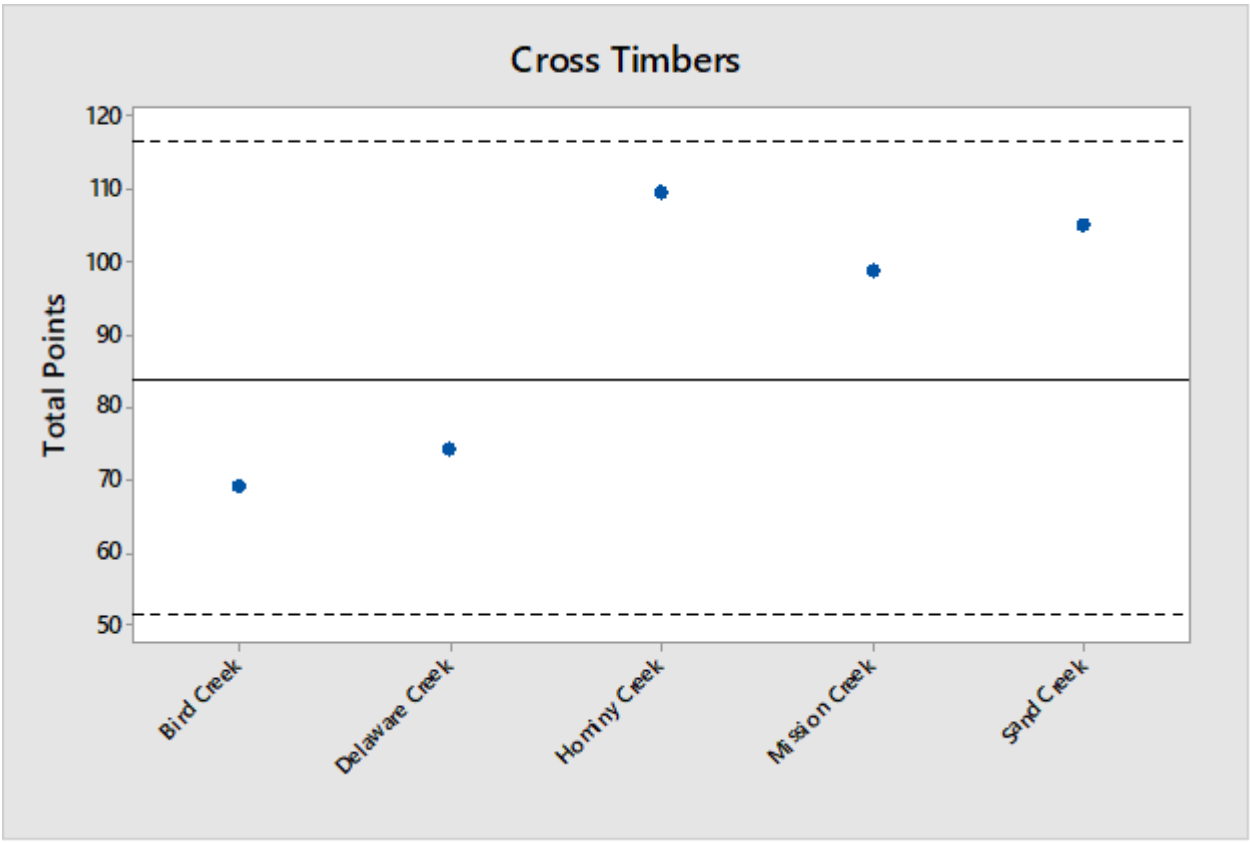
Sites were compared relative to the mean total habitat score of high quality sites in the respective ecoregion and a range determined by +/- two standard deviations (Figure 4). Sites with scores that are within +/- two standard deviations of the mean of the high quality sites do not necessarily have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

Habitat scores for all of the sites in all of the ecoregions were within two standard deviations of the high quality sites with the exception of Big Cabin Creek and Elm Creek in the Central Irregular Plains, which received good habitat scores.

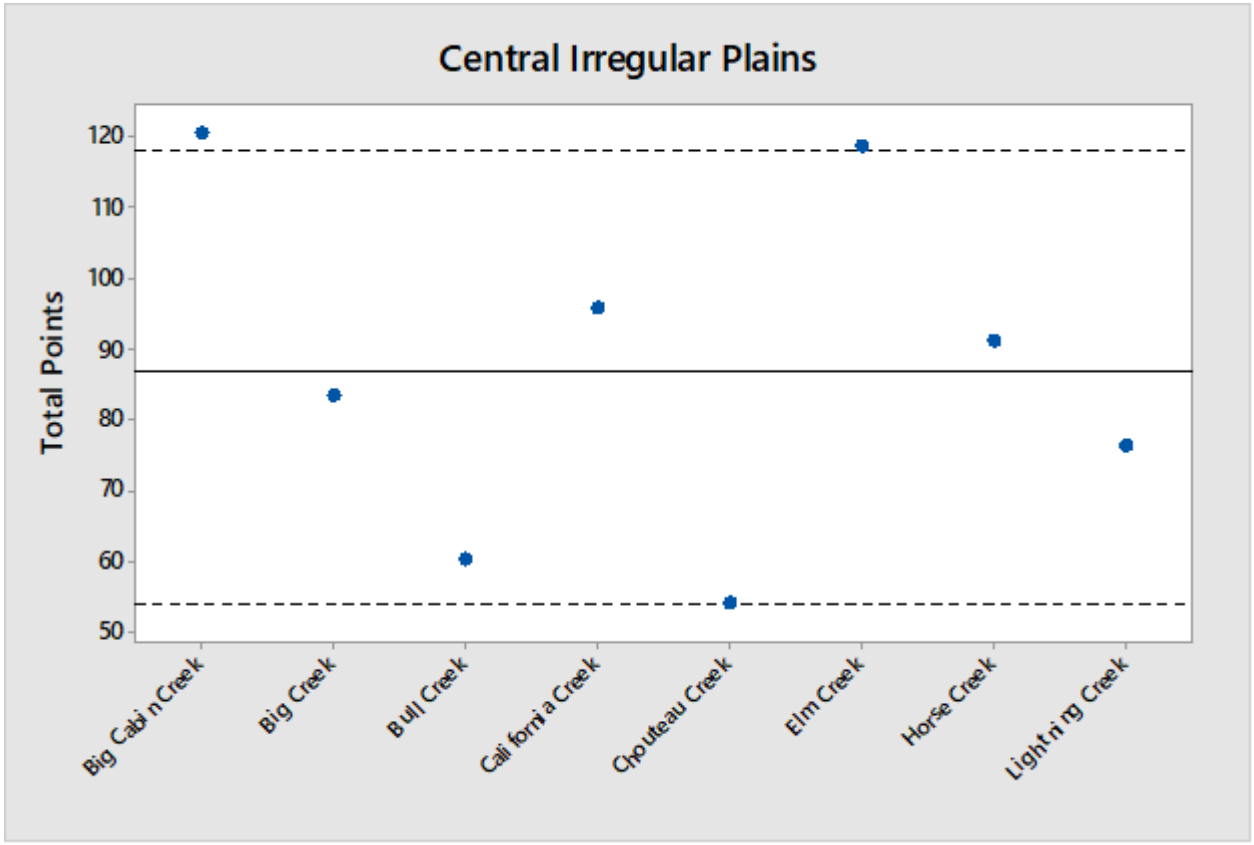
(a)

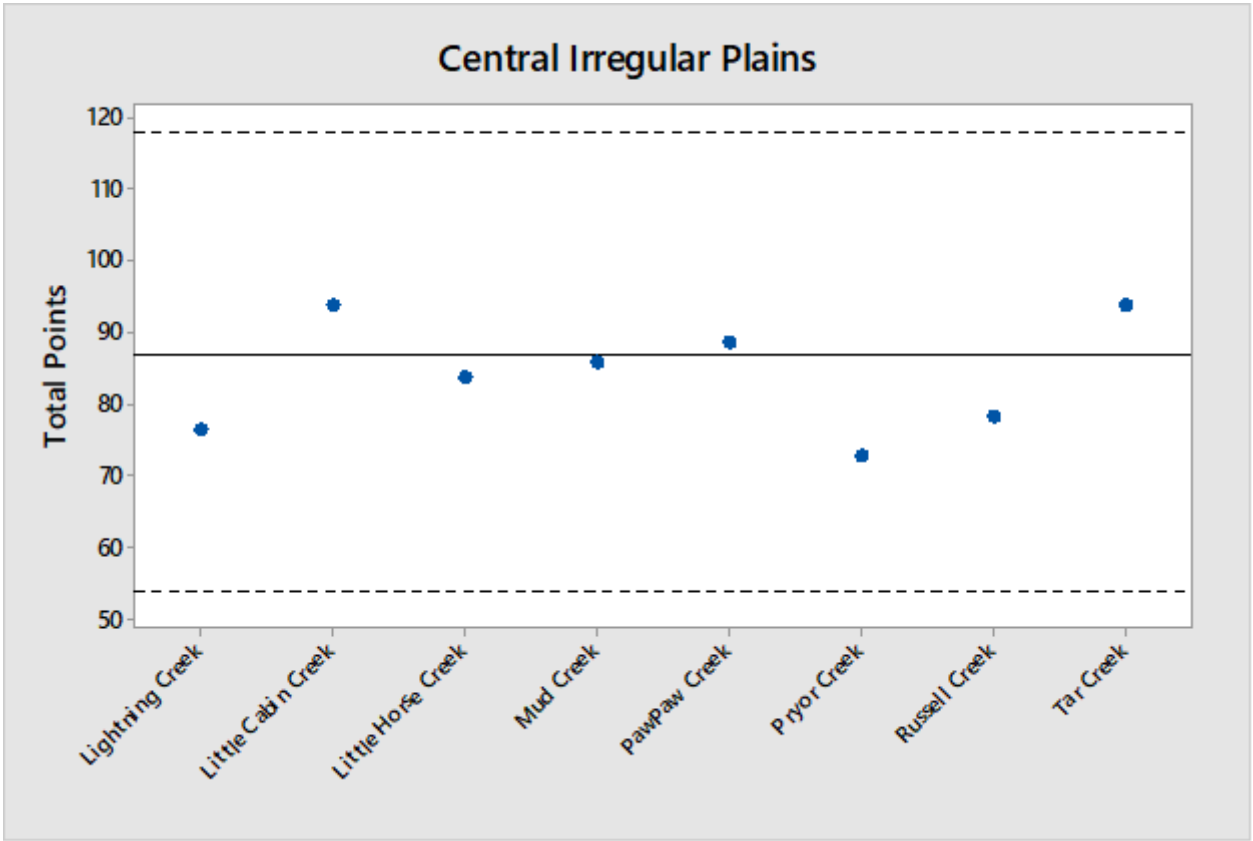

Central Great Plains
Total Points
120
110
100
90
80
70
60
50
40
Buggy Creek
Deer Creek
Hackberry Creek
Lone Creek
North Fork Walnut Creek
Red Creek
Trail Creek
Walnut Creek
Willow Creek

(b)

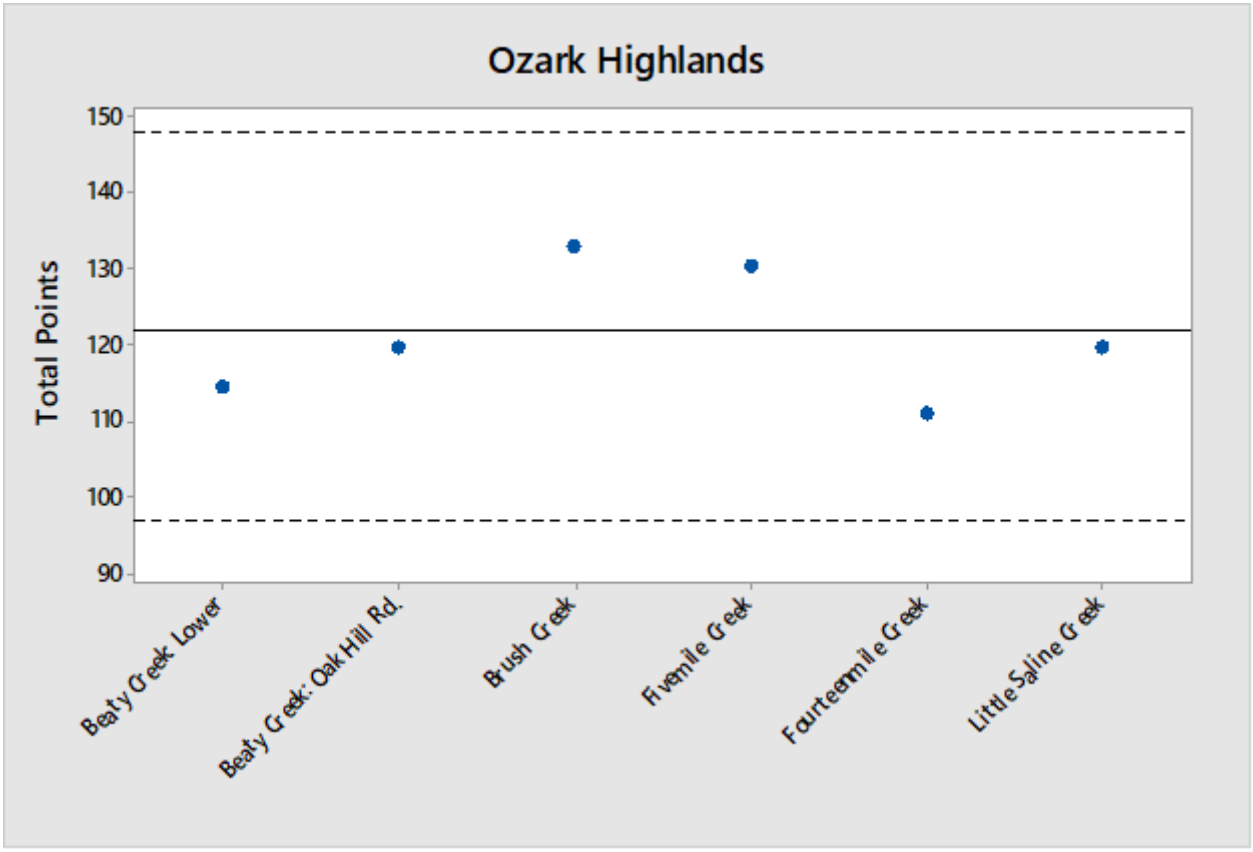

Cross Timbers
Total Points
120
110
100
90
80
70
60
50
Bird Creek
Delaware Creek
Hominy Creek
Mission Creek
Sand Creek

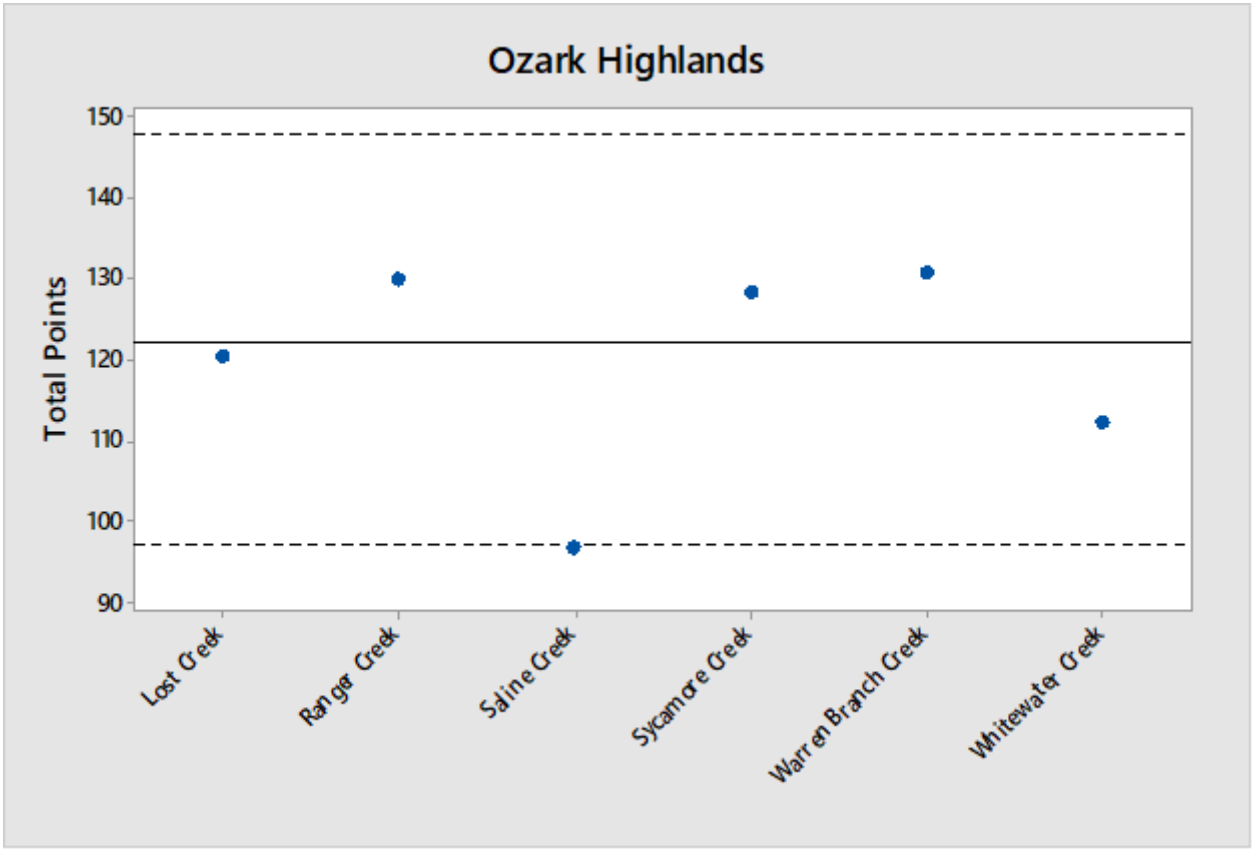
(c)


Central Irregular Plains
Total Points
120
110
100
90
80
70
60
50
Big Cabin Creek
Big Creek
Bull Creek
California Creek
Cpouteau Creek
Elm Creek
Horse Creek
Lightning Creek


Central Irregular Plains
Total Points
120
110
100
90
80
70
60
50
Lightning Creek
Little Cabin Creek
Little Horse Creek
Mud Creek
PawPaw Creek
Pryor Creek
Russell Creek
Tar Creek

(d)


Ozark Highlands
Total Points
150
140
130
120
110
100
90
Beaty Creek Lower
Beaty Creek: Oak Hill Rd.
Brush Creek
Fivemile Creek
Fourteenmile Creek
Little Saline Creek


Ozark Highlands
Total Points
150
140
130
120
110
100
90
Lost Creek
Ranger Creek
Saline Creek
Sycamore Creek
Warren Branch Creek
Whitewater Creek

(e)

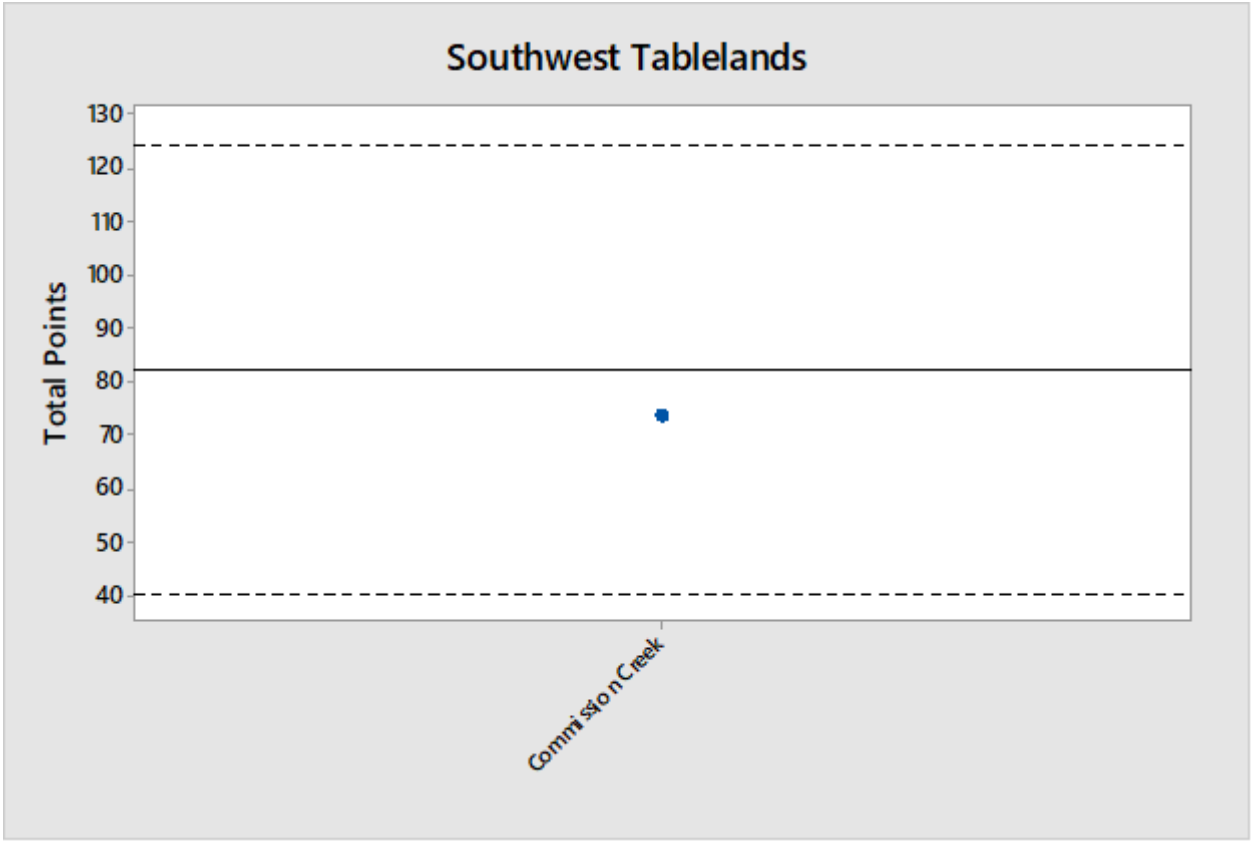


Figure 4. Total habitat score for sites monitoring in Basin 1 (Neosho-Grand and Upper Canadian Basins) during 2016-2018 for (a) Central Great Plains, (b) Cross Timbers, (c) Central Irregular Plains, (d) Ozark Highlands and (e) Southwest Tablelands Ecoregions. Habitat scores aggregate 11 different measures of habitat conditions with a maximum score of 180. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

3.2.2 Fish Collections

Fish metrics used to compute IBI scores for the Rotating Basin sites using the OCC method are listed in Table 12. Use of this IBI method allows assessment of streams which lack definite support assignment using the state biocriteria method. For a complete listing of fish collection data, including species and numbers caught, consult Appendix B. All data 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 calculations of fish IBI scores (OCC method) for Rotating Basin Group 1 (Neosho-Grand and Upper Canadian), cycle 4 monitoring sites collected between 2016 and 2018. Each site is assigned a unique waterbody identifier (WBID).

Site Name	WBID	Total Number Individuals	Total Species	Sensitive Benthic Species	Sunfish Species	Intolerant Species	Percent tolerant (Individuals)	Percent insectivorous Cyprinid (Individuals)	Percent lithophylic spawners (Individuals)
Beaty Creek: Lower	OK121600-05-0160G	725	19	8	5	11	0.02	0.15	0.95
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	1053	18	6	4	13	0.01	0.15	0.99
Big Cabin Creek	OK121600-06-0220I	642	28	7	9	4	0.31	0.02	0.66
Big Creek	OK121510-03-0010D	2059	31	10	8	8	0.34	0.15	0.60
Bird Creek	OK121300-02-0010C	762	25	7	7	4	0.80	0.06	0.09
Brush Creek	OK121600-05-0140J	1317	14	6	1	9	0.00	0.32	1.00
Buggy Creek	OK520610-02-0120G	347	17	1	6	1	0.78	0.22	0.00
Bull Creek	OK121500-02-0090D	973	37	6	10	6	0.61	0.02	0.11
California Creek	OK121510-02-0050C	797	26	6	7	4	0.42	0.03	0.53
Chouteau Creek	OK121600-01-0430P	1038	24	1	10	2	0.86	0.00	0.07
Commission Creek	OK520620-05-0160C	279	9	1	5	1	0.40	0.60	0.00
Deer Creek	OK520620-06-0010F	1984	16	1	4	1	0.89	0.12	0.00
Delaware Creek	OK121300-01-0150H	408	23	3	10	1	0.57	0.01	0.24
Elm Creek	OK121600-04-0150G	368	16	3	8	1	0.54	0.00	0.38
Fivemile Creek	OK121600-07-0110G	560	23	7	8	12	0.23	0.30	0.77
Fourteenmile Creek	OK121600-01-0100G	414	27	9	7	12	0.14	0.36	0.82
Hackberry Creek	OK520620-04-0050D	113	10	1	2	1	0.84	0.16	0.00
Hominy Creek	OK121300-04-0280G	1028	29	6	9	3	0.65	0.06	0.29
Horse Creek	OK121600-03-0160G	543	14	3	8	0	0.66	0.00	0.27
Lightning Creek	OK121510-01-0130N	692	13	2	6	0	0.72	0.00	0.15
Little Cabin Creek	OK121600-06-0080C	572	32	10	10	8	0.48	0.03	0.24
Little Horse Creek	OK121600-03-0190G	1225	13	3	6	0	0.23	0.00	0.76

Site Name	WBID	Total Number Individuals	Total Species	Sensitive Benthic Species	Sunfish Species	Intolerant Species	Percent tolerant (Individuals)	Percent insectivorous Cyprinid (Individuals)	Percent lithophylic spawners (Individuals)
Little Saline Creek	OK121600-02-0070G	793	13	7	2	9	0.00	0.18	1.00
Lone Creek	OK520620-03-0020C	525	13	1	5	1	0.38	0.62	0.00
Lost Creek	OK121600-03-0560G	986	31	12	9	14	0.10	0.38	0.87
Mission Creek	OK121400-02-0190B	649	37	8	10	6	0.65	0.14	0.15
Mud Creek	OK121600-04-0175M	107	14	2	7	0	0.45	0.00	0.42
North Fork Walnut Creek	OK520610-03-0080E	349	12	0	5	0	0.82	0.15	0.00
PawPaw Creek	OK121600-06-0240G	411	18	3	8	1	0.28	0.01	0.56
Pryor Creek	OK121610-00-0050D	772	32	7	9	5	0.59	0.01	0.21
Ranger Creek	OK121600-01-0060D	1718	22	8	6	9	0.10	0.11	0.90
Red Creek	OK520620-03-0110F	89	6	0	2	0	0.99	0.01	0.00
Russell Creek	OK121600-04-0200F	1979	28	5	7	4	0.40	0.05	0.52
Saline Creek	OK121600-02-0030D	1021	20	12	4	14	0.04	0.09	0.95
Sand Creek	OK121400-04-0010F	1056	31	9	8	8	0.56	0.08	0.36
Sycamore Creek	OK121600-03-0510D	577	21	7	8	10	0.14	0.38	0.85
Tar Creek	OK121600-04-0060D	1095	23	5	10	3	0.71	0.00	0.27
Trail Creek	OK520620-02-0090G	693	16	1	5	1	0.60	0.40	0.00
Walnut Creek	OK520610-03-0010G	701	12	2	4	1	0.95	0.04	0.00
Warren Branch Creek	OK121600-07-0050G	594	23	7	7	12	0.26	0.18	0.74
Whitewater Creek	OK121600-03-0320G	666	23	8	7	11	0.10	0.15	0.89
Willow Creek	OK520610-01-0080H	625	17	1	8	1	0.90	0.08	0.03

Table 13 presents the results of the fish assessment based on the OCC's modified RBP method compared with the fish assessment based on Oklahoma state biocriteria (as described in Oklahoma Water Resource Board, *Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (USAP), OAC 785:46-15). The state biocriteria are based on older delineations of the level III ecoregions, so there were some differences in scoring based on the differences in grouping of sites. The OCC method allowed greater discrimination of the biological condition among sites. Of the 42 sites, 32 were "excellent" when compared with high quality sites with the same FWP use in the ecoregion, five were "good", four were "fair", and one was "poor".

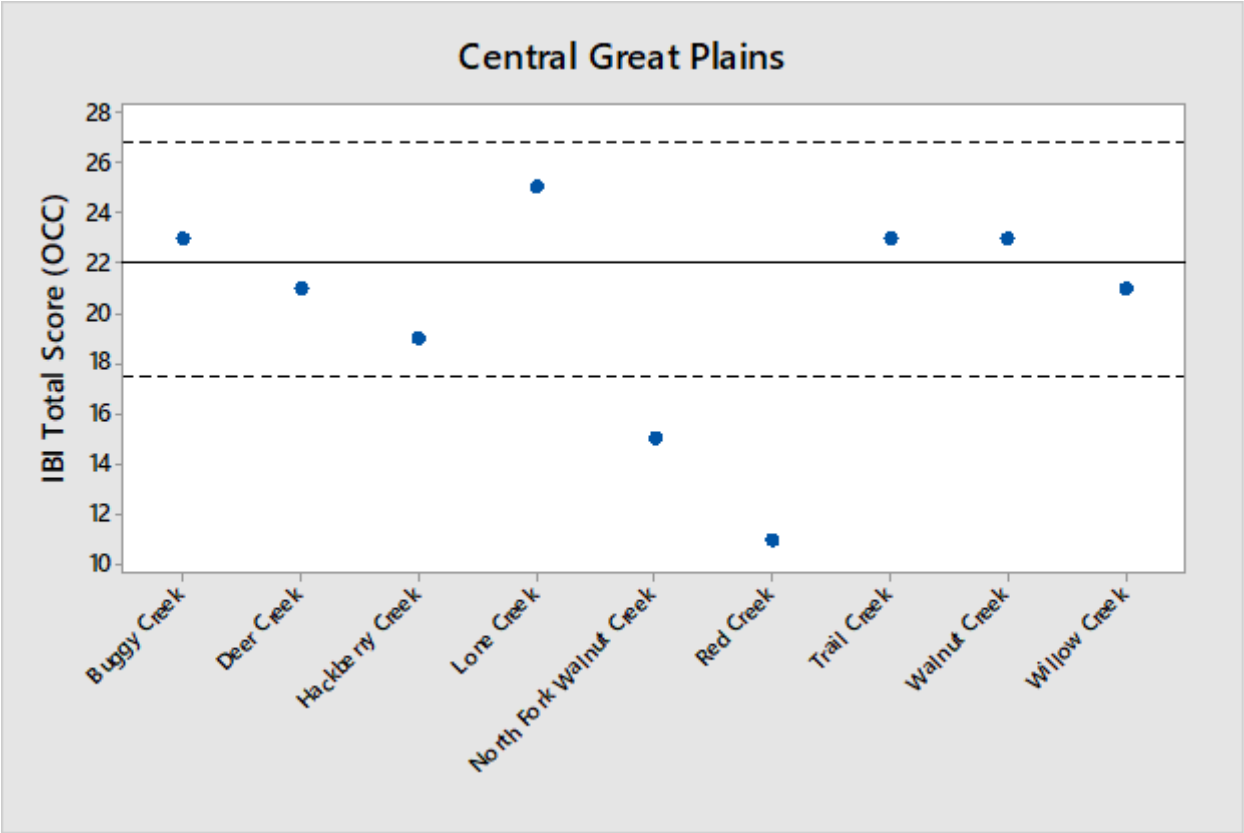
Table 13. IBI scores for fish communities at sites in Basin 1 (Neosho-Grand and Upper Canadian Basins) during 2016-2018. Each site is given a unique waterbody identifier (WBID). The designation of the streams for the Fish and Wildlife Propagation beneficial use include: WWAC = warm water aquatic community, CWAC = cool water aquatic community and HLAC = habitat limited aquatic community. Results are based on Use Support Assessment Protocol (USAP) biocriteria (OWRB 2014) and OCC's modified RBP method (OCC). The use determinations based on the fish community (USAP Fish) are as follows: S = supporting, N = not supporting, U = undetermined. For OCC's modified method the value of the IBI score relative to reference is provided (% of reference) as well as a condition category of the community (Score Interpretation).

Modified Ecoregion	Site Name	WBID	Fish and Wildlife Propagation	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CGP	Buggy Creek	OK520610-02-0120G	WWAC	27	S	23	1.05	Excellent
CGP	Deer Creek	OK520620-06-0010F	WWAC	23	S	21	0.95	Excellent
CGP	Hackberry Creek	OK520620-04-0050D	WWAC	21	S	19	0.86	Good
CGP	Lone Creek	OK520620-03-0020C	WWAC	25	S	25	1.14	Excellent
CGP	North Fork Walnut Creek	OK520610-03-0080E	WWAC	27	S	15	0.68	Fair
CGP	Red Creek	OK520620-03-0110F	WWAC	17	N	11	0.50	Poor
CGP	Trail Creek	OK520620-02-0090G	HLAC	27	S	23	1.05	Excellent
CGP	Walnut Creek	OK520610-03-0010G	WWAC	23	S	23	1.05	Excellent
CGP	Willow Creek	OK520610-01-0080H	WWAC	29	S	21	0.95	Excellent
CIP	Big Cabin Creek	OK121600-06-0220I	WWAC	37	S	27	1.15	Excellent
CIP	Big Creek	OK121510-03-0010D	WWAC	43	S	27	1.15	Excellent
CIP	Bull Creek	OK121500-02-0090D	WWAC	37	S	23	0.98	Excellent
CIP	California Creek	OK121510-02-0050C	WWAC	37	S	27	1.15	Excellent
CIP	Chouteau Creek	OK121600-01-0430P	WWAC	29	S	17	0.73	Fair
CIP	Elm Creek	OK121600-04-0150G	WWAC	35	S	23	0.98	Excellent
CIP	Horse Creek	OK121600-03-0160G	WWAC	29	S	17	0.73	Fair
CIP	Lightning Creek	OK121510-01-0130N	WWAC	27	U	15	0.64	Fair
CIP	Little Cabin Creek	OK121600-06-0080C	WWAC	39	S	25	1.07	Excellent
CIP	Little Horse Creek	OK121600-03-0190G	WWAC	31	S	21	0.90	Good
CIP	Mud Creek	OK121600-04-0175M	WWAC	31	S	19	0.81	Good
CIP	PawPaw Creek	OK121600-06-0240G	WWAC	35	S	23	0.98	Excellent
CIP	Pryor Creek	OK121610-00-0050D	WWAC	35	S	25	1.07	Excellent
CIP	Russell Creek	OK121600-04-0200F	WWAC	37	S	27	1.15	Excellent
CIP	Tar Creek	OK121600-04-0060D	HLAC	33	S	25	1.07	Excellent
CT	Bird Creek	OK121300-02-0010C	WWAC	31	S	23	1.01	Excellent
CT	Delaware Creek	OK121300-01-0150H	WWAC	35	S	23	1.01	Excellent
CT	Hominy Creek	OK121300-04-0280G	WWAC	33	S	25	1.10	Excellent

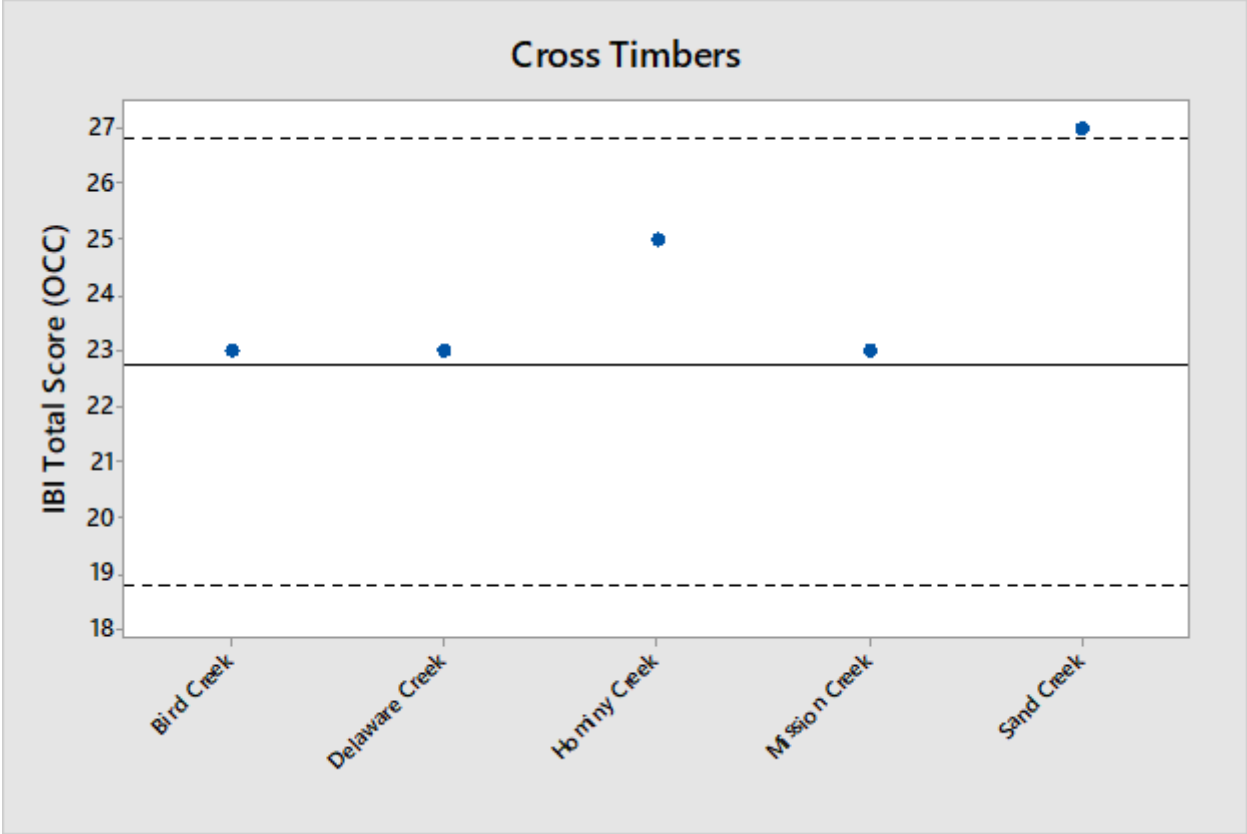
Modified Ecoregion	Site Name	WBID	Fish and Wildlife Propagation	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CT	Mission Creek	OK121400-02-0190B	WWAC	37	S	23	1.01	Excellent
CT	Sand Creek	OK121400-04-0010F	WWAC	41	S	27	1.19	Excellent
OH	Beaty Creek: Lower	OK121600-05-0160G	CWAC	41	S	31	0.94	Excellent
OH	Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	CWAC	39	S	31	0.94	Excellent
OH	Brush Creek	OK121600-05-0140J	CWAC	35	U	31	0.94	Excellent
OH	Fivemile Creek	OK121600-07-0110G	CWAC	43	S	31	0.94	Excellent
OH	Fourteenmile Creek	OK121600-01-0100G	CWAC	43	S	31	0.94	Excellent
OH	Little Saline Creek	OK121600-02-0070G	CWAC	37	S	29	0.88	Good
OH	Lost Creek	OK121600-03-0560G	CWAC	37	S	33	1.00	Excellent
OH	Ranger Creek	OK121600-01-0060D	WWAC	37	S	31	0.94	Excellent
OH	Saline Creek	OK121600-02-0030D	CWAC	39	S	31	0.94	Excellent
OH	Sycamore Creek	OK121600-03-0510D	CWAC	43	S	31	0.94	Excellent
OH	Warren Branch Creek	OK121600-07-0050G	CWAC	43	S	27	0.82	Good
OH	Whitewater Creek	OK121600-03-0320G	CWAC	41	S	31	0.94	Excellent
SWT	Commission Creek	OK520620-05-0160C	WWAC	23	No criteria	27	1.17	Excellent

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

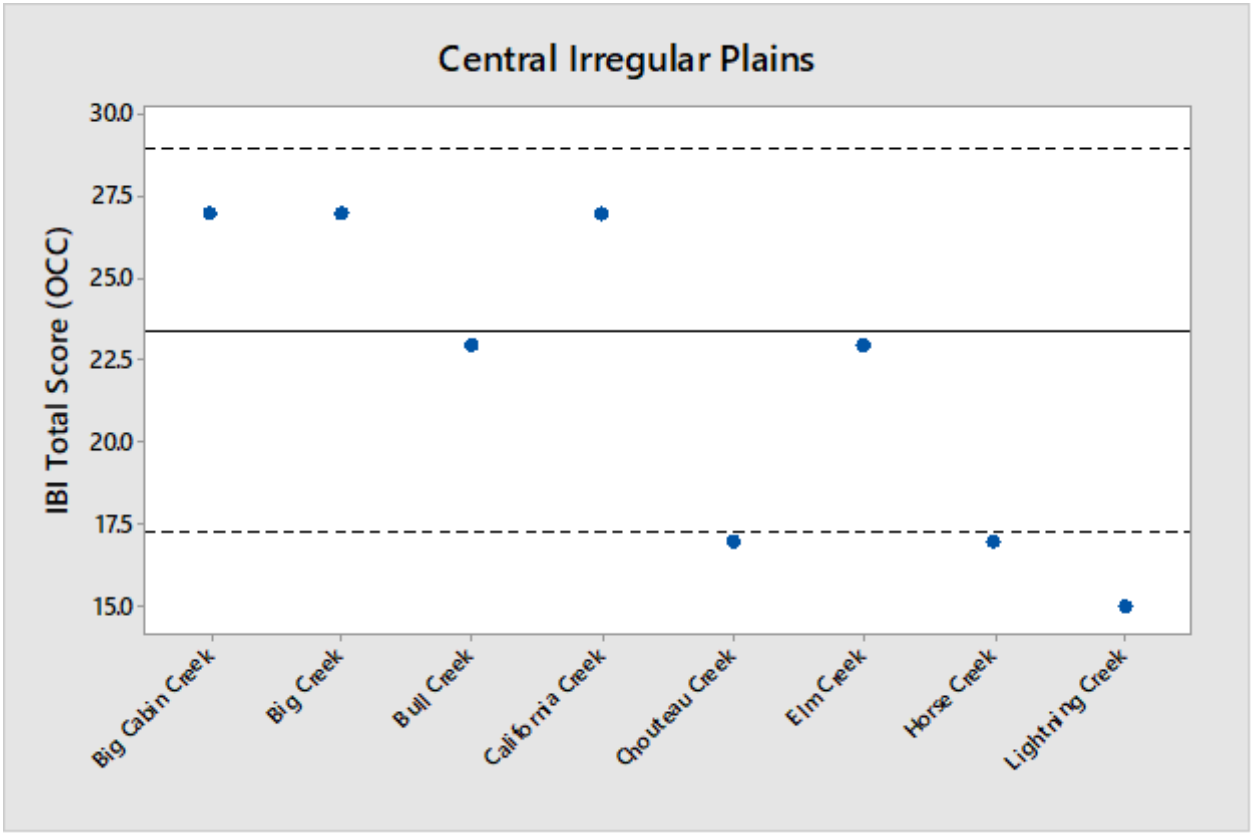
(a)

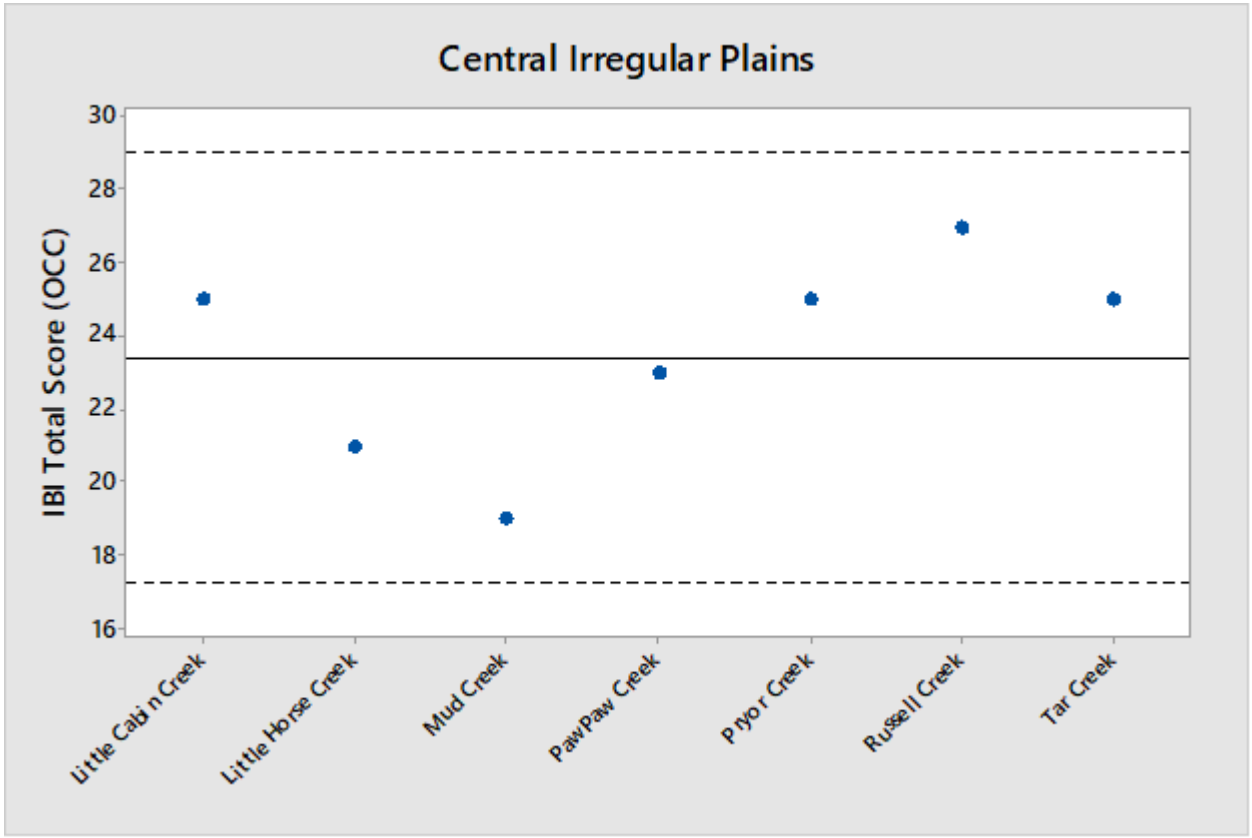

Central Great Plains
IBI Total Score (OCC)
28
26
24
22
20
18
16
14
12
10
Buggy Creek
Deer Creek
Hackberry Creek
Lone Creek
North Fork Walnut Creek
Red Creek
Trail Creek
Walnut Creek
Willow Creek

(b)

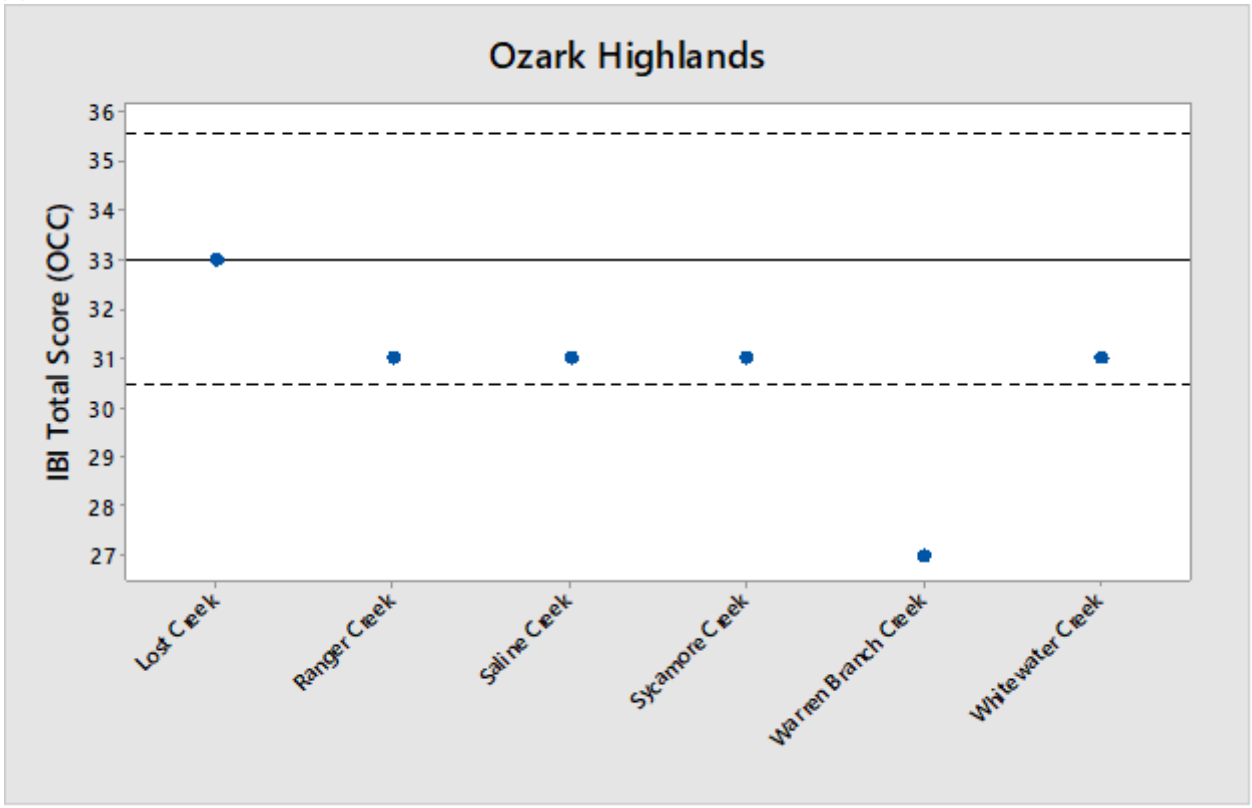

Cross Timbers
IBI Total Score (OCC)
27
26
25
24
23
22
21
20
19
18
Bird Creek
Delaware Creek
Hominy Creek
Mission Creek
Sand Creek

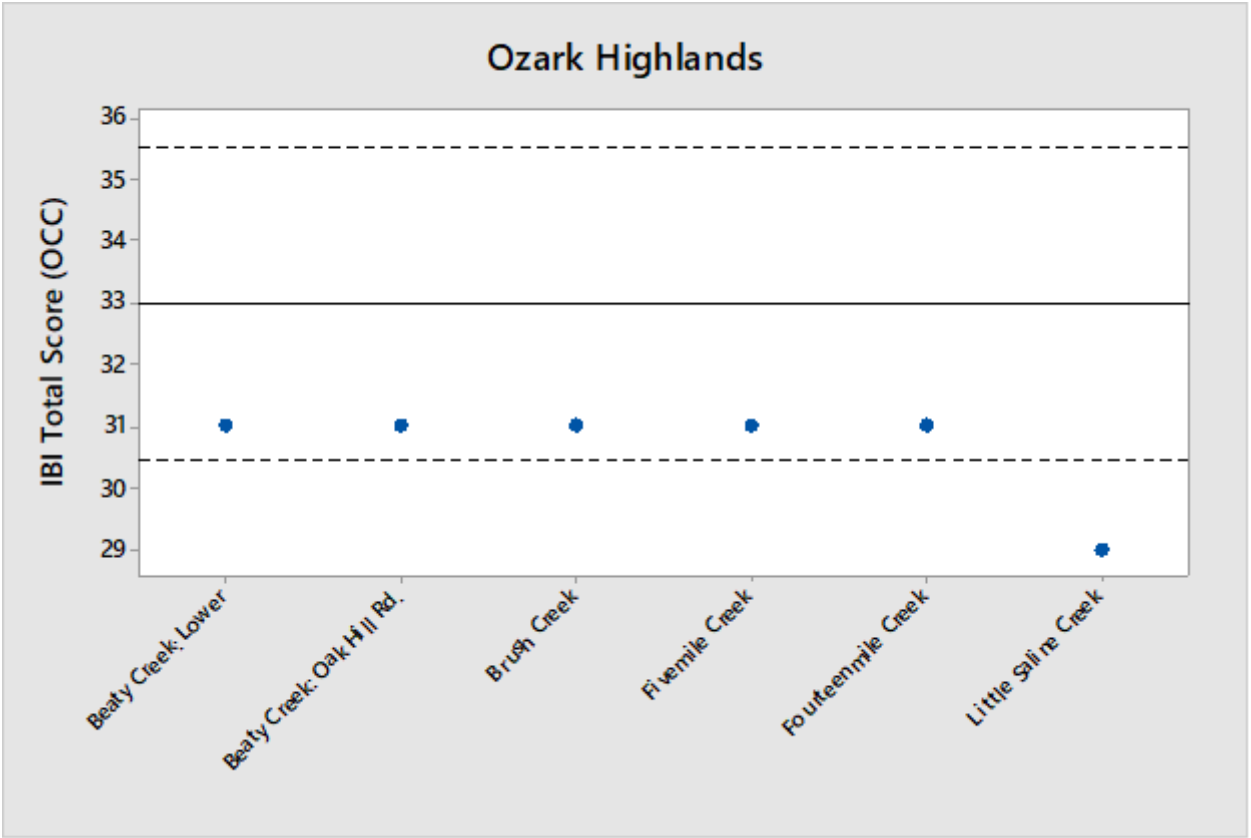
(c)


Central Irregular Plains
IBI Total Score (OCC)
30.0
27.5
25.0
22.5
20.0
17.5
15.0
Big Cabin Creek
Big Creek
Bull Creek
California Creek
Chouteau Creek
Elm Creek
Horse Creek
Lightning Creek


Central Irregular Plains
IBI Total Score (OCC)
30
28
26
24
22
20
18
16
Little Cabin Creek
Little Horse Creek
Mud Creek
PawPaw Creek
Pryor Creek
Russell Creek
Tar Creek

(d)


Ozark Highlands
IBI Total Score (OCC)
36
35
34
33
32
31
30
29
28
27
Lost Creek
Ranger Creek
Saline Creek
Sycamore Creek
Warren Branch Creek
Whitewater Creek


Ozark Highlands
IBI Total Score (OCC)
36
35
34
33
32
31
30
29
Beaty Creek: Lower
Beaty Creek: Oak Hill Rd.
Brush Creek
Fivemile Creek
Fourteenmile Creek
Little Saline Creek

(e)

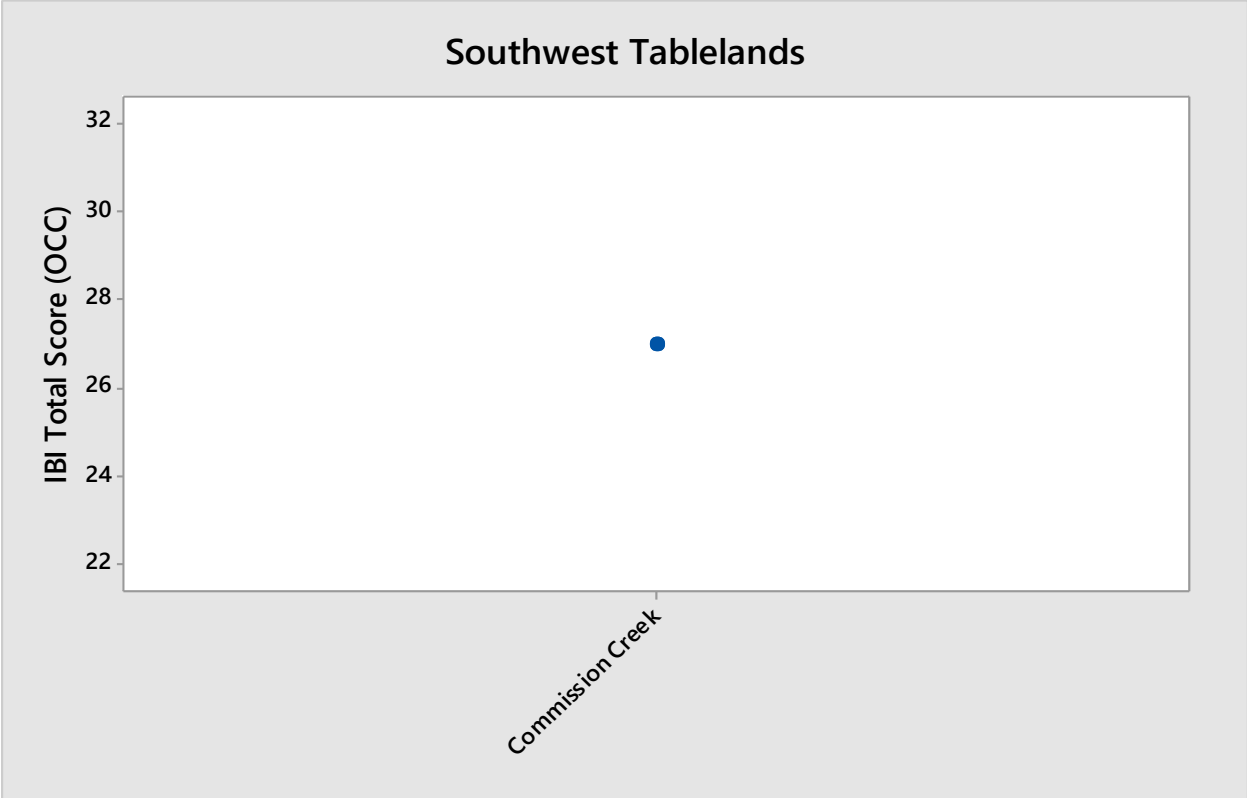


Figure 5. IBI scores for fish communities for monitoring sites in Basin 1 (Neosho-Grand and Upper Canadian Basins) assessed between 2016 and 2018 in (a) Central Great Plains, (b) Cross Timbers, (c) Central Irregular Plains, (d) Ozark Highlands and (e) Southwest Tablelands Ecoregions. IBI scores were calculated using the modified OCC Rotating Basin Method. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

Table 14 shows a comparison between fish data collected in cycle 1 (2000 or 2002), cycle 2 (2006 or 2008), cycle 3 (2011 or 2013), and cycle 4 (2016 or 2018) 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 4 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 13 of the 28 sites with IBI scores to be compared. Two streams had worse fish community conditions, while 13 streams had improved fish communities.

Table 14. Comparison of fish IBIs from cycle 1 (2000-2002), cycle 2 (2006-2008), cycle 3 (2011-2013), and cycle 4 (2016-2018) at sites in Basin 1 (Neosho-Grand and Upper Canadian Basins). Each site is given a unique waterbody identifier (WBID). Results are based on OCC's modified RBP method (OCC). IBI scores relative to reference are provided (% of reference) as well as a condition category of the community (Score Interpretation).

Site Name	WBID	Year	Total Number (Individuals)	Total Species	Darter Species	Sunfish Species	Intolerant Species	Percent tolerant (Individuals)	Percent insectivorous Cyprinid (individuals)	Percent lithophylic spawners (individuals)	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
Big Cabin Creek	OK121600-06-0220I	2001	426	25	4	8	5	0.49	0.12	0.26	25	0.96	Excellent
Big Cabin Creek	OK121600-06-0220I	2006	324	18	3	7	1	0.75	0.00	0.19	21	0.81	Good
Big Cabin Creek	OK121600-06-0220I	2016	642	28	5	9	4	0.31	0.02	0.66	27	1.15	Excellent
Big Creek	OK121510-03-0010D	2001	886	28	1	7	4	0.26	0.04	0.39	23	0.88	Good
Big Creek	OK121510-03-0010D	2006	242	24	1	10	3	0.62	0.07	0.13	21	0.81	Good
Big Creek	OK121510-03-0010D	2011	389	21	0	6	2	0.47	0.27	0.38	25	1.07	Excellent
Big Creek	OK121510-03-0010D	2016	2059	31	5	8	8	0.34	0.15	0.60	27	1.15	Excellent
Bird Creek	OK121300-02-0010C	2001	2146	24	3	7	4	0.83	0.75	0.13	23	1.00	Excellent
Bird Creek	OK121300-02-0010C	2006	784	18	2	6	3	0.55	0.04	0.40	27	1.17	Excellent
Bird Creek	OK121300-02-0010C	2011	1221	17	2	5	4	0.95	0.02	0.04	23	1.01	Excellent
Bird Creek	OK121300-02-0010C	2016	762	25	4	7	4	0.80	0.06	0.09	23	1.01	Excellent
Buggy Creek	OK520610-02-0120C	2001	948	13	0	3	1	0.85	0.15	0.00	19	0.86	Good
Buggy Creek	OK520610-02-0120C	2006	234	12	0	4	0	0.96	0.04	0.00	15	0.68	Fair
Buggy Creek	OK520610-02-0120C	2011	1321	9	0	3	1	0.70	0.30	0.00	23	1.05	Excellent
Buggy Creek	OK520610-02-0120G	2016	347	17	0	6	1	0.78	0.22	0.00	23	1.05	Excellent
Bull Creek	OK121500-02-0090D	2001	671	25	2	8	3	0.66	0.00	0.13	19	0.73	Fair
Bull Creek	OK121500-02-0090D	2006	395	23	0	10	0	0.74	0.25	0.76	15	0.58	Poor
Bull Creek	OK121500-02-0090D	2011	467	20	0	8	1	0.95	0.00	0.02	19	0.81	Good
Bull Creek	OK121500-02-0090D	2016	973	37	5	10	6	0.61	0.02	0.11	23	0.98	Excellent
California Creek	OK121510-02-0050C	2001	971	24	2	6	4	0.40	0.02	0.49	23	0.88	Good
California Creek	OK121510-02-0050C	2006	168	27	1	8	2	0.66	0.10	0.20	23	0.88	Good
California Creek	OK121510-02-0050C	2011	504	19	0	5	3	0.68	0.10	0.28	23	0.98	Excellent
California Creek	OK121510-02-0050C	2016	797	26	4	7	4	0.42	0.03	0.53	27	1.15	Excellent
Chouteau Creek	OK121600-01-0430M	2001	351	23	0	8	1	0.41	0.03	0.04	17	0.65	Fair
Chouteau Creek	OK121600-01-0430M	2006	232	14	0	8	1	0.93	0.00	0.02	15	0.58	Poor
Chouteau Creek	OK121600-01-0430P	2011	340	21	0	8	1	0.86	0.03	0.07	19	0.81	Good
Chouteau Creek	OK121600-01-0430P	2016	1038	24	2	10	2	0.86	0.00	0.07	17	0.73	Fair
Commission Creek	OK520620-05-0160C	2001	117	10	0	4	1	0.57	0.43	0.00	21	0.88	Good
Commission Creek	OK520620-05-0160C	2006	339	7	0	2	1	0.27	0.73	0.00	23	0.96	Excellent

Site Name	WBID	Year	Total Number (Individuals)	Total Species	Darter Species	Sunfish Species	Intolerant Species	Percent tolerant (Individuals)	Percent insectivorous Cyprinid (individuals)	Percent lithophylic spawners (individuals)	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
Commission Creek	OK520620-05-0160C	2011	475	7	0	2	1	0.27	0.73	0.00	23	1.00	Excellent
Commission Creek	OK520620-05-0160C	2016	279	9	0	5	1	0.40	0.60	0.00	27	1.17	Excellent
Deer Creek	OK520620-06-0010F	2001	3451	21	0	6	2	0.90	0.19	0.00	19	0.86	Good
Deer Creek	OK520620-06-0010F	2006	3632	15	0	3	1	0.88	0.12	0.00	21	0.95	Excellent
Deer Creek	OK520620-06-0010F	2011	2342	20	0	5	1	0.94	0.07	0.00	21	0.95	Excellent
Deer Creek	OK520620-06-0010F	2016	1984	16	0	4	1	0.89	0.12	0.00	21	0.95	Excellent
Delaware Creek	OK121300-01-0150H	2001	261	26	1	9	3	0.49	0.03	0.11	21	0.91	Good
Delaware Creek	OK121300-01-0150H	2006	131	22	2	9	3	0.84	0.05	0.05	23	1.00	Excellent
Delaware Creek	OK121300-01-0150H	2011	152	16	1	6	1	0.87	0.00	0.05	19	0.81	Good
Delaware Creek	OK121300-01-0150H	2016	408	23	2	10	1	0.57	0.01	0.24	23	1.01	Excellent
Fivemile Creek	OK121600-07-0110G	2001	1557	24	2	6	9	0.13	0.39	0.85	29	0.88	Good
Fivemile Creek	OK121600-07-0110G	2006	704	20	3	6	11	0.05	0.43	0.95	33	1.00	Excellent
Fivemile Creek	OK121600-07-0110G	2011	500	21	4	7	13	0.06	0.43	0.94	33	1.00	Excellent
Fivemile Creek	OK121600-07-0110G	2016	560	23	3	8	12	0.23	0.30	0.77	31	0.94	Excellent
Fourteenmile Creek	OK121600-01-0100G	2001	2690	31	5	8	16	0.11	0.34	0.89	27	0.82	Good
Fourteenmile Creek	OK121600-01-0100G	2006	726	20	3	7	11	0.10	0.40	0.90	33	1.00	Excellent
Fourteenmile Creek	OK121600-01-0100G	2011	490	26	6	6	13	0.38	0.21	0.60	29	0.88	Good
Fourteenmile Creek	OK121600-01-0100G	2016	414	27	4	7	12	0.14	0.36	0.82	31	0.94	Excellent
Hackberry Creek	OK520620-04-0050D	2001	265	6	0	1	1	0.76	0.48	0.00	17	0.77	Good
Hackberry Creek	OK520620-04-0050D	2007	288	9	0	2	0	0.89	0.10	0.00	11	0.50	Poor
Hackberry Creek	OK520620-04-0050D	2011	250	12	0	2	0	0.99	0.01	0.00	13	0.59	Poor
Hackberry Creek	OK520620-04-0050D	2016	113	10	0	2	1	0.84	0.16	0.00	19	0.86	Good
Hominy Creek	OK121300-04-0280G	2001	802	18	1	6	1	0.71	0.62	0.26	19	0.83	Good
Hominy Creek	OK121300-04-0280G	2006	316	20	2	4	2	0.70	0.08	0.21	23	1.00	Excellent
Hominy Creek	OK121300-04-0280G	2011	777	18	0	6	1	0.80	0.10	0.16	19	0.84	Good
Hominy Creek	OK121300-04-0280G	2016	1028	29	3	9	3	0.65	0.06	0.29	25	1.10	Excellent
Lightning Creek	OK121500-01-0130N	2011	134	13	1	4	0	0.81	0.00	0.11	13	0.56	Poor
Lightning Creek	OK121510-01-0130N	2016	692	13	1	6	0	0.72	0.00	0.15	15	0.64	Fair
Little Cabin Creek	OK121600-06-0080C	2001	348	25	3	8	4	0.52	0.11	0.14	23	0.88	Good
Little Cabin Creek	OK121600-06-0080C	2006	167	21	2	8	3	0.75	0.05	0.13	21	0.81	Good
Little Cabin Creek	OK121600-06-0080C	2011	421	22	3	6	3	0.86	0.01	0.07	23	0.98	Excellent
Little Cabin Creek	OK121600-06-0080C	2016	572	32	7	10	8	0.48	0.03	0.24	25	1.07	Excellent

Site Name	WBID	Year	Total Number (Individuals)	Total Species	Darter Species	Sunfish Species	Intolerant Species	Percent tolerant (Individuals)	Percent insectivorous Cyprinid (individuals)	Percent lithophylic spawners (individuals)	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
Little Horse Creek	OK121600-03-0190A	2001	428	22	2	5	10	0.10	0.47	0.88	31	1.19	Excellent
Little Horse Creek	OK121600-03-0190A	2006	40	10	1	5	2	0.85	0.00	0.05	19	0.73	fair
Little Horse Creek	OK121600-03-0190A	2011	716	21	2	7	1	0.56	0.00	0.41	23	0.98	Excellent
Little Horse Creek	OK121600-03-0190G	2016	1225	13	2	6	0	0.23	0.00	0.76	21	0.90	Good
Lone Creek	OK520620-03-0020C	2001	858	13	0	2	2	0.76	0.24	0.00	19	0.86	Good
Lone Creek	OK520620-03-0020C	2006	625	8	0	0	1	0.65	0.35	0.00	17	0.77	Good
Lone Creek	OK520620-03-0020C	2011	628	11	0	4	1	0.87	0.13	0.00	21	0.95	Excellent
Lone Creek	OK520620-03-0020C	2016	525	13	0	5	1	0.38	0.62	0.00	25	1.14	Excellent
Mission Creek	OK121400-02-0190B	2001	765	25	1	8	1	0.64	0.03	0.15	17	0.74	Fair
Mission Creek	OK121400-02-0190B	2006	227	26	3	8	4	0.63	0.11	0.16	23	1.00	Excellent
Mission Creek	OK121400-02-0190B	2016	649	37	5	10	6	0.65	0.14	0.15	23	1.01	Excellent
Pryor Creek	OK121610-00-0050D	2001	467	27	1	7	4	0.64	0.04	0.27	23	0.88	Good
Pryor Creek	OK121610-00-0050D	2006	306	18	1	7	2	0.81	0.02	0.14	21	0.81	Good
Pryor Creek	OK121610-00-0050D	2011	457	16	2	6	3	0.87	0.00	0.12	21	0.90	Good
Pryor Creek	OK121610-00-0050D	2016	772	32	5	9	5	0.59	0.01	0.21	25	1.07	Excellent
Ranger Creek	OK121600-01-0060D	2001	552	17	1	6	3	0.39	0.16	0.53	21	0.64	Fair
Ranger Creek	OK121600-01-0060D	2006	200	18	1	6	3	0.48	0.20	0.50	23	0.70	Fair
Ranger Creek	OK121600-01-0060D	2011	640	21	2	7	5	0.72	0.14	0.20	23	0.70	Fair
Ranger Creek	OK121600-01-0060D	2016	1718	22	4	6	9	0.10	0.11	0.90	31	0.94	Excellent
Saline Creek	OK121600-02-0030D	2001	1139	21	3	6	12	0.01	0.26	0.99	29	0.88	Good
Saline Creek	OK121600-02-0030D	2006	360	19	4	5	12	0.02	0.23	0.96	33	1.00	Excellent
Saline Creek	OK121600-02-0030D	2016	1021	20	5	4	14	0.04	0.09	0.95	31	0.94	Excellent
Sand Creek	OK121400-04-0010F	2001	378	21	1	7	4	0.40	0.15	0.28	21	0.91	Good
Sand Creek	OK121400-04-0010F	2006	601	27	2	8	5	0.84	0.01	0.11	23	1.00	Excellent
Sand Creek	OK121400-04-0010F	2011	434	18	0	6	3	0.96	0.01	0.01	23	1.01	Excellent
Sand Creek	OK121400-04-0010F	2016	1056	31	5	8	8	0.56	0.08	0.36	27	1.19	Excellent
Sycamore Creek	OK121600-03-0510D	2001	1261	26	2	8	13	0.06	0.52	0.93	31	0.94	Excellent
Sycamore Creek	OK121600-03-0510D	2006	649	24	3	9	10	0.14	0.40	0.85	31	0.94	Excellent
Sycamore Creek	OK121600-03-0510D	2011	390	22	3	9	11	0.26	0.29	0.67	29	0.88	Good
Sycamore Creek	OK121600-03-0510D	2016	577	21	4	8	10	0.14	0.38	0.85	31	0.94	Excellent
Tar Creek	OK121600-04-0060D	2001	160	16	0	5	0	0.74	0.09	0.03	15	0.58	Poor
Tar Creek	OK121600-04-0060D	2006	10	6	0	2	0	0.80	0.00	0.20	11	0.42	Very poor

Site Name	WBID	Year	Total Number (Individuals)	Total Species	Darter Species	Sunfish Species	Intolerant Species	Percent tolerant (Individuals)	Percent insectivorous Cyprinid (individuals)	Percent lithophylic spawners (individuals)	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
Tar Creek	OK121600-04-0060D	2011	498	16	0	6	1	0.88	0.00	0.08	19	0.81	Good
Tar Creek	OK121600-04-0060D	2016	1095	23	3	10	3	0.71	0.00	0.27	25	1.07	Excellent
Trail Creek	OK520620-02-0090G	2001	845	12	1	2	1	0.93	0.07	0.00	19	0.86	Good
Trail Creek	OK520620-02-0090G	2006	269	8	0	2	1	0.51	0.49	0.00	21	0.95	Excellent
Trail Creek	OK520620-02-0090G	2011	1023	6	0	0	1	0.77	0.23	0.00	17	0.77	Fair
Trail Creek	OK520620-02-0090G	2016	693	16	0	5	1	0.60	0.40	0.00	23	1.05	Excellent
Walnut Creek	OK520610-03-0010C	2001									21	0.95	Excellent
Walnut Creek	OK520610-03-0010F	2006	1496	11	0	4	0	0.61	0.39	0.00	17	0.77	Good
Walnut Creek	OK520610-03-0010F	2011	1106	15	0	6	0	0.94	0.08	0.00	15	0.68	Fair
Walnut Creek	OK520610-03-0010G	2016	701	12	0	4	1	0.95	0.04	0.00	23	1.05	Excellent
Willow Creek	OK520610-01-0080H	2011	1051	14	0	6	1	0.741	0.247	0.011	25	1.136	Excellent
Willow Creek	OK520610-01-0080H	2016	625	17	0	8	1	0.90	0.08	0.03	21	0.95	Excellent

3.2.3 Macroinvertebrate Collections

The complete macroinvertebrate dataset, including species and numbers captured per site, can be found in Appendix C. Macroinvertebrates were collected for most sites at least once during the project period. Lack of flow during the collection periods prevented acquisition of all planned samples over the cycle.

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

Table 15. Macroinvertebrate metric values determined for each monitoring site in Basin 1 (Neosho-Grand and Upper Canadian Basins) collected from 2016-2018, averaged per season (S=Spring and W=Winter) and habitat (Riffle, Sveg=Submerged Aquatic Vegetation, and Woody=Woody Debris). Each site is given a unique waterbody identifier (WBID). Each of the six metrics (Total Species, Number EPT Species, Percent EPT species, Shannon Diversity, Modified HBI and Percent Dominant 2 Taxa) are scaled from 0-6 and summed to calculate Total Points, which ranges from 0 to 36. Total Points are then compared to scores at reference sites (% of Reference) to determine the average condition (NI = non-impaired, SI = slightly impaired, MI = moderately impaired).

Site Name	WBID	Habitat	Season	Number of Samples	Number of individuals Identified	Total species	Number of Ephemeroptera, Plecoptera and Tricoptera Taxa	Percent Ephemeroptera, Plecoptera and Tricoptera Taxa	Shannon Diversity	Modified Hilsenhoff Biotic Index (HBI)	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
Beaty Creek: Lower	OK121600-05-0160G	Riffle	S	2	128	15	6.5	0.44	1.93	5.28	0.61	18	0.69	SI	NI
		Riffle	W	2	98	22	15	0.61	2.54	4.14	0.38	30	1.02	NI	
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	Riffle	S	2	108	22	13	0.42	2.57	3.99	0.38	30	1.15	NI	NI
		Riffle	W	2	105	22	12	0.37	2.44	4.62	0.46	26	0.89	NI	
Big Cabin Creek	OK121600-06-0220I	Riffle	S	2	116	11	3	0.07	1.44	4.23	0.77	10	0.38	MI	MI
		Riffle	W	2	95.5	16	2	0.04	2.25	7.11	0.4	14	0.62	SI	
Big Creek	OK121510-03-0010D	Riffle	S	2	109	12	4	0.1	1.88	4.64	0.59	12	0.46	MI	SI
		Riffle	W	2	106	18	5.5	0.14	2.32	6.48	0.45	20	0.89	NI	
		Sveg	S	2	116	12	2	0.04	1.86	5.95	0.53	12	0.48	MI	
Bird Creek	OK121300-02-0010C	Riffle	S	2	119	19	10	0.36	2.4	4.74	0.4	26	1.02	NI	NI
		Sveg	W	1	124	20	5	0.12	2.18	6.15	0.53	22	0.97	NI	
		Woody	W	1	94	9	2	0.17	1.17	5.73	0.82	12	0.55	SI	
Brush Creek	OK121600-05-0140J	Riffle	S	2	107	12	4	0.26	2	5.43	0.51	14	0.54	SI	SI
		Riffle	W	2	107	17	11	0.41	2.14	4.38	0.5	22	0.75	SI	
Buggy Creek	OK520610-02-0120G	Riffle	S	1	80	14	5	0.29	2.39	5.88	0.34	22	0.85	NI	NI
		Riffle	W	1	92	12	1	0.03	1.16	6.1	0.8	12	0.59	SI	
		Sveg	S	2	119	17	6.5	0.37	2.33	5.73	0.42	26	1.13	NI	
		Sveg	W	1	102	10	1	0.16	1.05	6.18	0.87	14	0.68	SI	
California Creek	OK121510-02-0050C	Riffle	S	1	122	13	3	0.02	1.63	4.66	0.69	14	0.54	SI	SI
		Riffle	W	2	109	13	4	0.07	1.83	5.59	0.59	14	0.62	SI	
Chouteau Creek	OK121600-01-0430P	Riffle	S	1	110	12	3	0.08	1.64	6.55	0.69	10	0.38	MI	MI
Commission Creek	OK520620-05-0160C	Riffle	S	2	85.5	16	6.5	0.53	2.11	3.86	0.53	26	0.93	NI	NI
		Riffle	W	1	96	14	4	0.11	1.19	5.49	0.8	14	0.5	MI	
		Sveg	S	1	88	18	7	0.67	2.35	4.47	0.44	26	0.93	NI	
		Sveg	W	1	100	20	9	0.63	2.71	4.43	0.25	32	1.33	NI	
Deer Creek	OK520620-06-0010F	Riffle	W	1	93	15	1	0.01	1.85	5.77	0.61	14	0.68	SI	SI

Site Name	WBID	Habitat	Season	Number of Samples	Number of individuals Identified	Total species	Number of Ephemeroptera, Plecoptera and Tricoptera Taxa	Percent Ephemeroptera, Plecoptera and Tricoptera Taxa	Shannon Diversity	Modified Hilsenhoff Biotic Index (HBI)	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
Delaware Creek	OK121300-01-0150H	Riffle	S	2	112	13	5	0.16	1.86	4.57	0.6	16	0.63	SI	SI
		Riffle	W	2	104	16	4.5	0.1	2.09	5.76	0.51	18	0.72	SI	
Fivemile Creek	OK121600-07-0110G	Riffle	S	2	111	18	11	0.73	2.29	4.38	0.43	26	1	NI	NI
		Riffle	W	2	101	18	8.9	0.66	2.34	4.27	0.44	20	0.68	SI	
		Sveg	S	2	95	22	9	0.38	2.69	4.65	0.34	30	1.25	NI	
		Sveg	W	1	113	21	8	0.39	2.47	5.62	0.39	20	0.77	SI	
Fourteenmile Creek	OK121600-01-0100G	Riffle	S	1	102	15	8	0.72	1.78	4.43	0.65	22	0.85	NI	SI
		Riffle	W	2	114	16	8.5	0.38	2.15	4.8	0.47	16	0.55	SI	
Hackberry Creek	OK520620-04-0050D	Sveg	S	2	103	12	3.5	0.55	1.72	5.15	0.6	20	0.87	NI	SI
		Sveg	W	1	80	9	2	0.08	1.11	6.03	0.79	14	0.68	SI	
Hominy Creek	OK121300-04-0280G	Riffle	S	2	126	20	8	0.39	2.5	4.29	0.36	28	1.1	NI	SI
		Riffle	W	2	114	19	6	0.22	2.34	6.11	0.44	24	0.96	NI	
Horse Creek	OK121600-03-0160G	Riffle	S	2	113	10	0.5	0.07	1.54	6.25	0.68	10	0.38	MI	MI
		Riffle	W	2	107	14	1.5	0.04	2.05	6.73	0.47	12	0.53	SI	
Lightning Creek	OK121510-01-0130N	Sveg	S	1	91	17	2	0.04	2.3	5.95	0.45	14	0.56	SI	SI
		Sveg	W	1	117	12	2	0.28	2.04	6.68	0.47	18	0.82	NI	
		Woody	W	1	121	17	4	0.12	2.32	6.55	0.41	20	0.91	NI	
Little Cabin Creek	OK121600-06-0080C	Riffle	S	2	112	15	4.5	0.06	1.63	4.71	0.68	14	0.54	SI	SI
		Riffle	W	2	102	15	2.5	0.08	2.04	6.45	0.56	12	0.53	SI	
Little Horse Creek	OK121600-03-0190G	Riffle	S	2	126	13	3.5	0.18	1.78	4.99	0.61	17	0.65	SI	SI
		Riffle	W	2	111	10	1	0.06	1.62	6.35	0.64	10	0.44	MI	
		Sveg	W	1	121	12	1	0.01	1.41	7.12	0.77	12	0.55	SI	
Little Saline Creek	OK121600-02-0070G	Riffle	S	2	113	15	6	0.61	1.8	4.46	0.67	18	0.69	SI	SI
		Riffle	W	2	99	21	13	0.42	2.4	4.29	0.4	26	0.89	NI	
Lone Creek	OK520620-03-0020C	Riffle	S	2	106	14	2.5	0.19	1.8	4.94	0.63	16	0.62	SI	NI
		Sveg	S	1	115	16	6	0.4	2.26	5.57	0.42	26	1.13	NI	
Lost Creek	OK121600-03-0560G	Riffle	S	2	117	18	9	0.52	2.3	4.33	0.43	26	1	NI	NI
		Riffle	W	2	101	24	12	0.58	2.52	4.38	0.42	28	0.95	NI	
Mission Creek	OK121400-02-0190B	Riffle	S	2	98.5	13	3	0.07	1.91	5.73	0.58	12	0.47	MI	SI
		Riffle	W	2	122	16	5	0.16	1.91	6.3	0.58	20	0.8	NI	
		Woody	S	1	119	9	1	0.05	1.61	5.97	0.61	10	0.4	MI	
North Fork Walnut Creek	OK520610-03-0080E	Sveg	W	2	111	12	2.3	0.14	1.56	6.2	0.7	20	0.98	NI	NI

Site Name	WBID	Habitat	Season	Number of Samples	Number of individuals Identified	Total species	Number of Ephemeroptera, Plecoptera and Tricoptera Taxa	Percent Ephemeroptera, Plecoptera and Tricoptera Taxa	Shannon Diversity	Modified Hilsenhoff Biotic Index (HBI)	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
PawPaw Creek	OK121600-06-0240G	Riffle	W	1	129	9	2	0.16	1.29	4.64	0.79	10	0.44	MI	MI
Pryor Creek	OK121610-00-0050D	Riffle	S	1	96	12	3	0.07	2	6.1	0.5	10	0.38	MI	SI
		Riffle	W	2	94.5	16	4	0.23	2.19	5.91	0.47	20	0.89	NI	
Ranger Creek	OK121600-01-0060D	Riffle	S	1	105	11	4	0.63	1.69	4.35	0.64	16	0.62	SI	SI
		Riffle	W	2	94.5	17	8.5	0.27	1.82	5.34	0.65	14	0.48	MI	
Red Creek	OK520620-03-0110F	Sveg	S	1	89	12	3	0.57	1.69	5.31	0.67	18	0.78	SI	SI
Russell Creek	OK121600-04-0200F	Riffle	S	1	111	9	3	0.11	1.65	5.82	0.62	10	0.38	MI	SI
		Riffle	W	2	99	13	1.5	0.07	1.75	6.49	0.62	13	0.58	SI	
		Sveg	W	1	117	12	2	0.03	1.74	6.9	0.63	14	0.64	SI	
Saline Creek	OK121600-02-0030D	Riffle	S	2	128	15	7.5	0.33	1.56	6.38	0.75	18	0.69	SI	SI
		Riffle	W	2	94.5	20	11	0.25	2.21	5.4	0.54	20	0.68	SI	
Sand Creek	OK121400-04-0010F	Riffle	S	2	112	15	7.5	0.19	1.79	4.55	0.66	22	0.86	NI	NI
		Riffle	W	2	105	15	5	0.07	1.61	5.03	0.71	20	0.8	NI	
Sycamore Creek	OK121600-03-0510D	Riffle	S	2	114	22	10	0.54	2.43	5	0.46	26	1	NI	NI
		Riffle	W	2	113	17	9	0.67	2.15	4.77	0.51	18	0.61	SI	
Tar Creek	OK121600-04-0060D	Riffle	S	2	99	8.5	1.5	0.02	1.59	6.24	0.62	8	0.31	MI	MI
		Riffle	W	2	96	8	0.5	0	0.66	5.92	0.91	8	0.36	MI	
		Sveg	S	1	98	12	2	0.02	1.73	5.73	0.65	12	0.48	MI	
		Woody	S	1	110	10	2	0.04	1.49	6.21	0.73	10	0.42	MI	
Trail Creek	OK520620-02-0090G	Riffle	S	1	92	15	4	0.25	2.23	5.27	0.42	18	0.69	SI	SI
		Sveg	W	1	102	10	2	0.18	1.56	5.89	0.69	18	0.88	NI	
Walnut Creek	OK520610-03-0010G	Sveg	S	2	111	9.5	3.5	0.55	1.46	4.85	0.72	16	0.7	SI	SI
		Sveg	W	2	105	11	1	0.01	1.23	6.22	0.79	12	0.59	SI	
Warren Branch Creek	OK121600-07-0050G	Riffle	S	1	120	15	5	0.13	2.04	6.16	0.49	12	0.46	MI	SI
		Riffle	W	1	128	19	7	0.27	2.4	4.86	0.38	18	0.61	SI	
		Sveg	S	1	104	17	3	0.22	2.35	5.44	0.38	20	0.83	NI	
		Sveg	W	1	88	20	6	0.09	2.4	5.74	0.38	12	0.46	MI	
Whitewater Creek	OK121600-03-0320G	Riffle	S	2	112	19	7	0.31	2.22	4.84	0.49	22	0.85	NI	SI
		Riffle	W	2	97.5	16	6	0.2	1.52	5.66	0.65	14	0.48	MI	
Willow Creek	OK520610-01-0080H	Sveg	S	1	101	17	7	0.23	2.07	6.5	0.59	24	1.04	NI	NI
		Sveg	W	2	108	10	1.5	0.05	1.52	6.24	0.7	14	0.68	SI	

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: Big Cabin, Chouteau, Horse, Pawpaw, and Tar Creeks. Results indicate non-impaired macroinvertebrate communities in 31% of the sites, slightly impaired communities in 56% of the sites, and moderately impaired communities in 13% of the sites. Macroinvertebrates were not collected from three sites (Bull, Elm, and Mud Creeks) due to lack of 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).

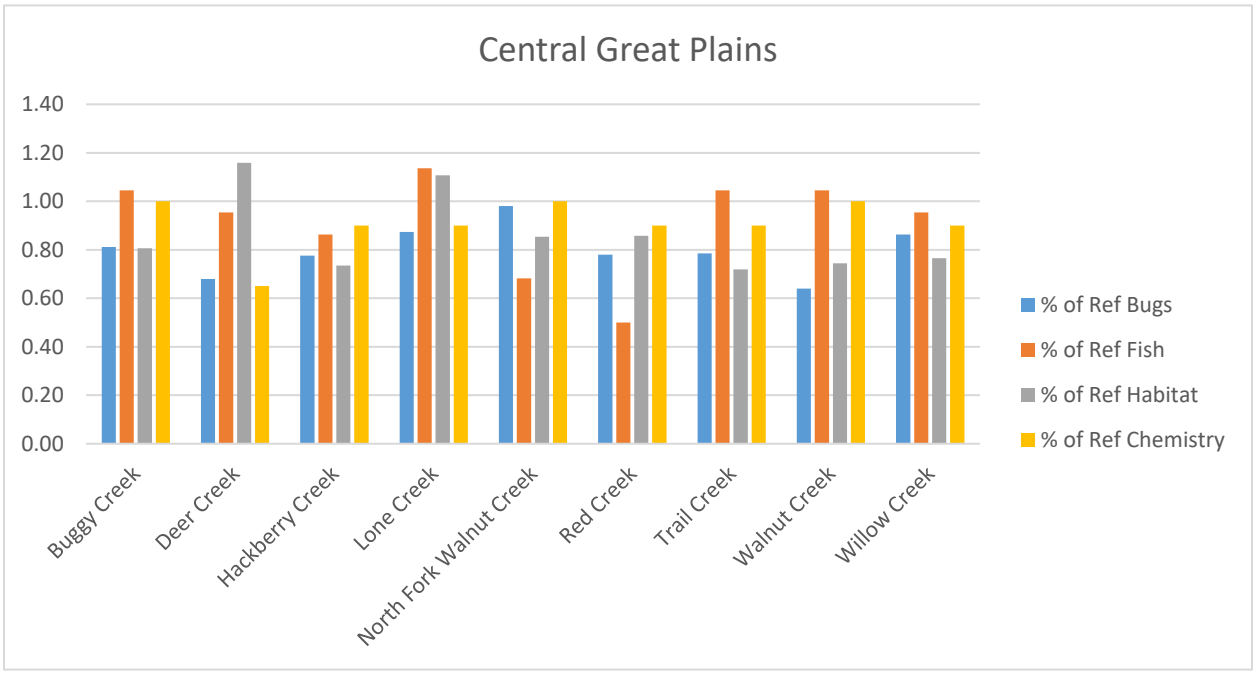
3.2.4 Overall Biological Assessment

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

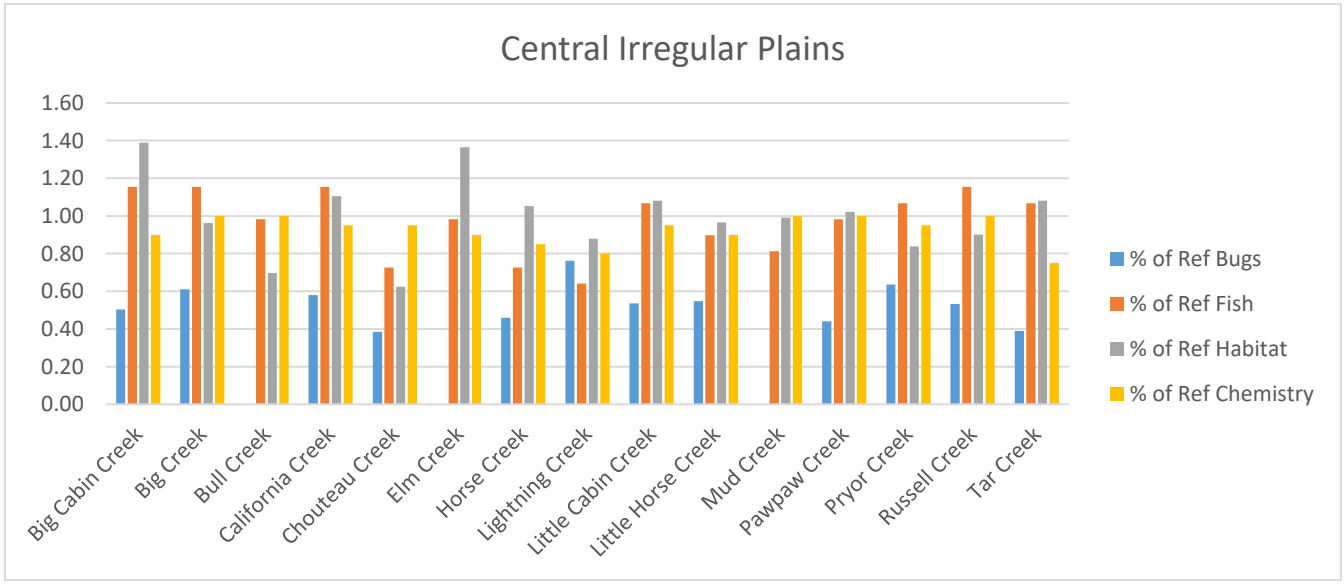
A determination of “good” or “excellent” stream health is indicated by a relatively high score for all categories. Most streams had relatively good agreement among the categories, but there are instances where one score is quite different than the others. It is generally recognized that fish communities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

Many of the sites sampled during this rotation have macroinvertebrate collections that indicate poorer conditions than the rest of the parameters. This could be due to extreme weather conditions such as the drought in 2016 and the abundant rainfall in 2017. This is especially true for the Central Irregular Plains ecoregion. The low fish score for Red Creek may be due to difficulties during the fish collection. There was significant deep silt along the entire stretch of the creek, hampering the ability to make an adequate fish collection.

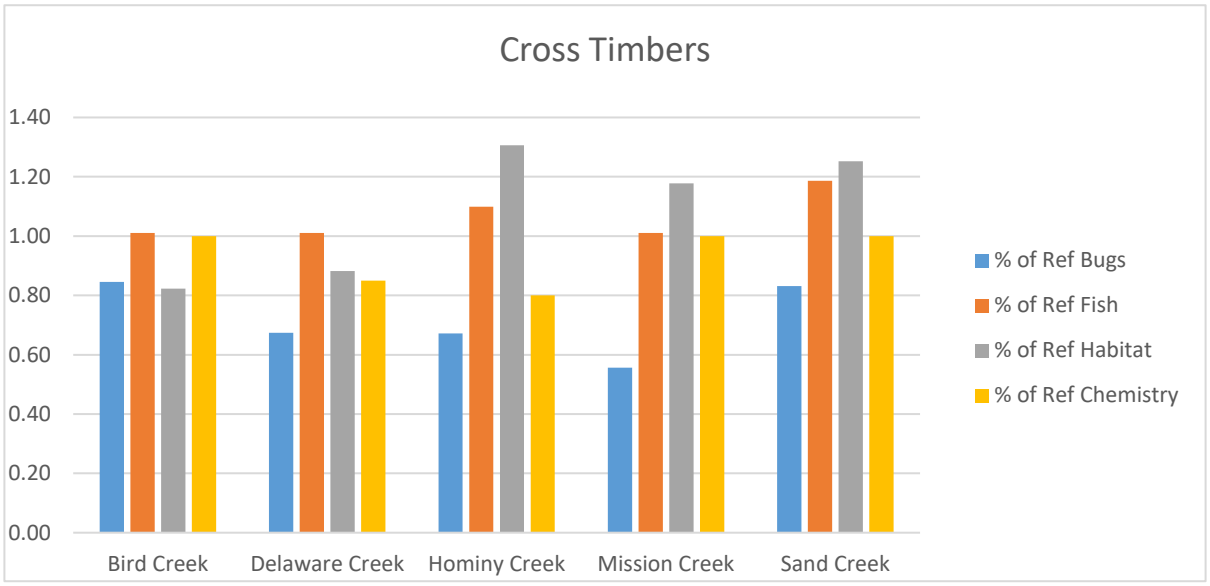
(a)


Central Great Plains
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Buggy Creek
Deer Creek
Hackberry Creek
Lone Creek
North Fork Walnut Creek
Red Creek
Trail Creek
Walnut Creek
Willow Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry

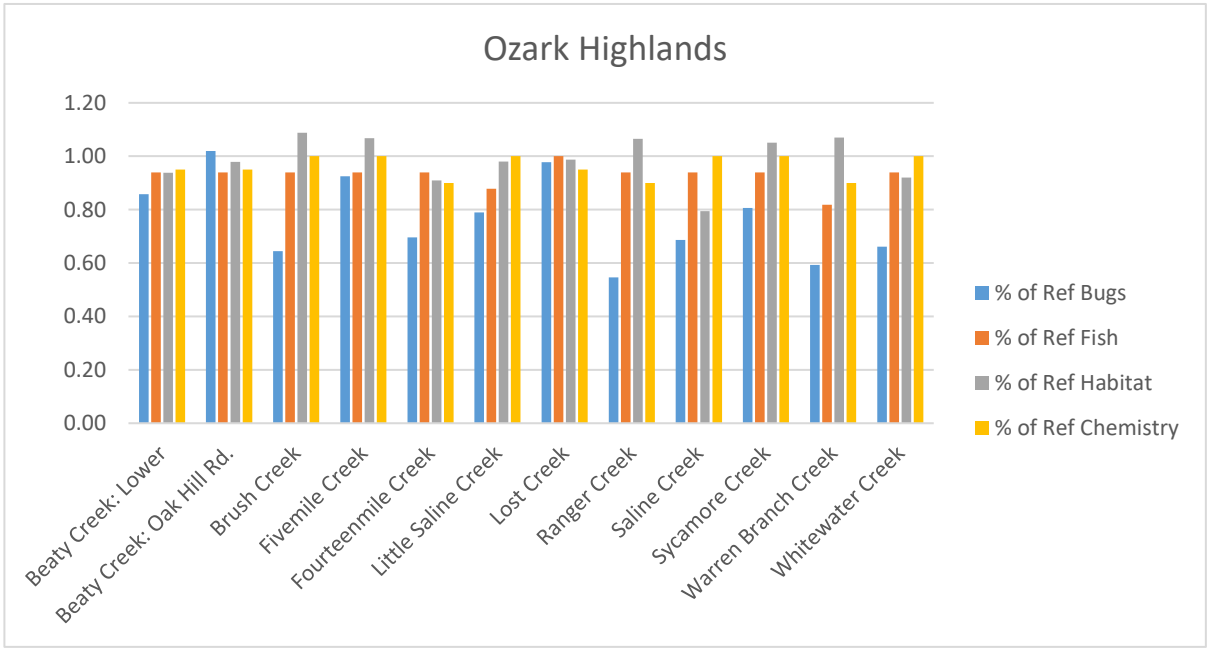
(b)


Central Irregular Plains
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Big Cabin Creek
Big Creek
Bull Creek
California Creek
Chouteau Creek
Elm Creek
Horse Creek
Lightning Creek
Little Cabin Creek
Little Horse Creek
Mud Creek
Pawpaw Creek
Pryor Creek
Russell Creek
Tar Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry

(c)


Cross Timbers
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Bird Creek
Delaware Creek
Hominy Creek
Mission Creek
Sand Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry

(d)


Ozark Highlands
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Beaty Creek: Lower
Beaty Creek: Oak Hill Rd.
Brush Creek
Fivemile Creek
Fourteenmile Creek
Little Saline Creek
Lost Creek
Ranger Creek
Saline Creek
Sycamore Creek
Warren Branch Creek
Whitewater Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry

(e)

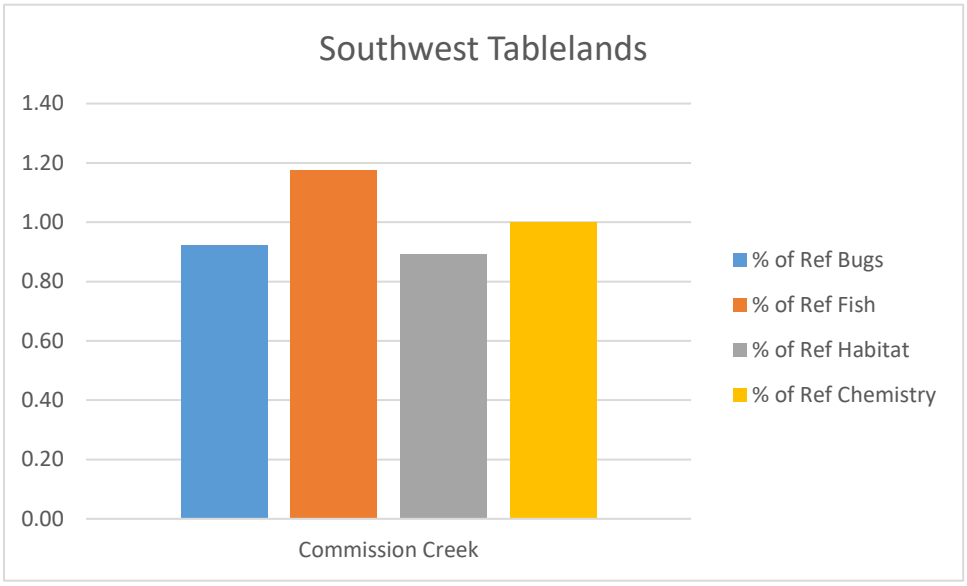


Figure 6. Comparison of habitat, fish, macroinvertebrate, and chemistry scores relative to the average high quality site in for rotating basin monitoring sites in Basin 1 (Neosho-Grand and Upper Canadian Basins) collected in 2016-2018 for (a) Central Great Plains, (b) Central Irregular Plains, (c) Cross Timbers, (d) Ozark Highlands and (e) Southwest Tablelands.

3.3 WATERSHED ASSESSMENT

Table 16 shows the land-use upstream of each monitoring site calculated from the 2011 NRCS National Land Cover Dataset in Geographic Information Systems (GIS). The watershed sizes and land uses vary widely, with Red Creek having the smallest watershed area, less than 7,000 acres, while the Bird Creek watershed includes more than 200,000 acres. Pasture/Hay make up the largest percentage of land use, on average, in this basin, followed by grasslands. Watersheds range from having 0.03% cultivated crop to having 62% in cultivated crop, and from having no deciduous forest in the watershed to having 59% of the watershed in deciduous forest. Table 17 presents the types and number of permitted activities (e.g. Concentrated Animal Feeding Operations [CAFOs], landfills, National Pollution Discharge Elimination System[NPDES] permits) that occur upstream of each site. Eight sites had no permitted activities in the watershed: Beaty: Lower, Beaty: Oak Hill Rd., Fivemile, Little Horse, Little Saline, Mud, Sycamore, and Warren Branch Creeks.

Twelve sites had national pollution discharge elimination systems (NPDES) in the watershed. To examine the effects of point source versus non-point source pollution on the parameters at the monitoring sites, one-way ANOVAs were performed comparing sites with a permitted discharge to sites with no permitted discharge. Table 18 shows the results: most 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 1 (Neosho-Grand and Upper Canadian Basins) monitoring sites based on the most recent National Land Cover Dataset (NLCD; USGS 2011). Each site is given a unique waterbody identifier (WBID).

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
Beaty Creek: Lower	OK121600-05-0160G	37831	0.01%	1.17%	29.25%	0.14%	0.55%	0.24%	4.13%		0.41%	2.15%	0.11%	0.02%	61.70%	0.06%	0.06%
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	31981	0.02%	1.39%	21.53%	0.17%	0.63%	0.28%	4.32%		0.01%	1.29%	0.04%	0.02%	70.19%	0.07%	0.06%
Big Cabin Creek	OK121600-06-0220I	149532	0.01%	2.84%	13.26%	0.02%	0.40%	0.07%	4.15%		0.28%	18.37%		0.49%	60.10%	0.02%	
Big Creek	OK121510-03-0010D	94970	0.01%	2.81%	12.70%		0.08%		3.11%	0.01%	0.25%	26.80%		0.24%	53.87%	0.10%	0.02%
Bird Creek	OK121300-02-0010C	235610	0.03%	0.84%	27.21%	0.06%	0.53%	0.16%	4.89%	0.01%		60.22%		1.22%	4.82%		
Brush Creek	OK121600-05-0140J	17396			37.50%	0.19%	0.85%	0.41%	3.57%		0.46%	4.49%	0.06%	0.01%	52.37%	0.02%	0.08%
Buggy Creek	OK520610-02-0120G	53844		23.81%	5.65%	0.01%	0.23%	0.02%	3.97%	0.03%	9.11%	56.66%	0.06%	0.22%	0.22%		
Bull Creek	OK121500-02-0090D	29953		11.21%	6.00%	0.02%	0.61%	0.15%	4.16%		0.06%	19.52%		0.37%	57.90%		
California Creek	OK121510-02-0050C	25517	0.03%	1.32%	6.23%		0.05%		3.05%		0.03%	42.33%		0.45%	46.51%		
Chouteau Creek	OK121600-01-0430P	19654		2.67%	17.66%	0.02%	0.17%	0.18%	3.21%			29.65%		1.01%	45.43%		
Commission Creek	OK520620-05-0160C	31612	0.20%	1.73%	0.05%		0.15%	0.01%	2.13%			60.30%	0.34%	0.07%		34.96%	0.05%
Deer Creek	OK520620-06-0010F	204529		61.39%	1.19%	0.26%	1.20%	0.61%	4.87%		1.60%	28.49%	0.23%	0.14%			
Delaware Creek	OK121300-01-0150H	28720			57.40%		0.27%	0.02%	3.58%		0.01%	22.02%		0.28%	16.42%		
Elm Creek	OK121600-04-0150G	11882	2.30%	62.35%	1.29%	0.03%	0.63%	0.16%	3.05%	0.20%		0.02%		0.50%	27.72%	0.02%	1.72%
Fivemile Creek	OK121600-07-0110G	17214	0.23%	0.69%	48.50%	0.48%	1.87%	0.85%	7.47%		0.07%	1.21%	0.04%	0.09%	35.88%	2.12%	0.52%
Fourteenmile Creek	OK121600-01-0100G	42232	0.01%	0.03%	31.43%		0.15%	0.04%	3.95%		0.38%	2.09%	0.06%	0.08%	61.19%	0.36%	0.23%
Hackberry Creek	OK520620-04-0050D	63659	0.01%	5.24%			0.04%	0.01%	3.54%		0.29%	54.47%	0.01%	0.10%		36.30%	
Hominy Creek	OK121300-04-0280G	45437		0.81%	21.74%		0.16%		3.19%		0.06%	72.57%		0.12%	1.35%		
Horse Creek	OK121600-03-0160G	18501	0.04%	20.97%	1.52%	0.08%	2.78%	0.52%	6.74%	0.10%		1.08%		0.64%	65.14%	0.03%	0.36%

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
Lightning Creek	OK121510-01-0130N	23536	0.18%	0.15%	14.26%	0.06%	0.26%	0.05%	5.11%		0.19%	29.35%		0.54%	49.82%	0.02%	
Little Cabin Creek	OK121600-06-0080C	80909	0.13%	8.32%	8.16%	0.04%	0.92%	0.18%	4.45%	0.05%	0.04%	5.53%	0.04%	0.46%	71.08%	0.40%	0.21%
Little Horse Creek	OK121600-03-0190G	10335		11.41%	2.37%	0.16%	2.38%	0.64%	5.69%			0.75%		0.29%	75.63%	0.53%	0.14%
Little Saline Creek	OK121600-02-0070G	14857		0.45%	49.78%	0.01%	0.36%	0.15%	2.71%		1.26%	8.49%	0.07%		34.55%	2.18%	
Lone Creek	OK520620-03-0020C	17724		1.26%			0.02%	0.01%	3.97%		22.59%	67.62%	0.01%	0.08%		4.44%	
Lost Creek	OK121600-03-0560G	55307	0.14%	0.45%	35.67%	0.14%	1.32%	0.38%	4.49%		0.42%	0.85%	0.03%	0.09%	55.37%	0.58%	0.07%
Mission Creek	OK121400-02-0190B	26244		0.15%	24.85%		0.15%	0.01%	4.19%		0.04%	37.29%		0.35%	32.97%		
Mud Creek	OK121600-04-0175M	8245		12.12%	3.64%		1.05%	0.02%	4.99%			0.67%		0.54%	76.88%	0.02%	0.09%
North Fork Walnut Creek	OK520610-03-0080E	37183		11.99%	15.11%	0.11%	1.84%	0.70%	6.86%	0.04%	0.07%	62.51%		0.49%	0.27%		
PawPaw Creek	OK121600-06-0240G	31157		1.77%	13.12%		0.19%	0.01%	4.09%		0.09%	22.81%		0.49%	57.40%	0.01%	
Pryor Creek	OK121610-00-0050D	127096	0.01%	3.37%	20.24%	0.08%	0.66%	0.29%	5.16%	0.01%	0.02%	14.34%		0.32%	55.49%	0.01%	
Ranger Creek	OK121600-01-0060D	21861	0.01%	0.13%	28.45%	0.15%	0.92%	0.38%	5.76%		0.17%	2.27%	0.20%	0.06%	60.82%	0.52%	0.15%
Red Creek	OK520620-03-0110F	6988	0.24%	2.96%			0.02%		2.01%		0.06%	46.90%	6.75%			41.07%	
Russell Creek	OK121600-04-0200F	20497		11.92%	9.43%		0.18%		3.94%	0.02%	0.04%	10.49%	0.22%	0.31%	63.43%		0.03%
Saline Creek	OK121600-02-0030D	66674	0.02%	0.16%	59.04%	0.06%	0.32%	0.14%	3.46%		0.96%	7.60%	0.10%		26.28%	1.72%	0.14%
Sand Creek	OK121400-04-0010F	144883	0.01%	0.54%	34.18%		0.11%	0.01%	4.68%		0.19%	48.91%		0.36%	11.02%		
Sycamore Creek	OK121600-03-0510D	31134	0.01%	0.53%	30.93%		0.58%	0.03%	4.07%		0.18%	1.32%	0.01%	0.02%	62.18%	0.09%	0.04%
Tar Creek	OK121600-04-0060D	32819	6.27%	40.75%	4.17%	1.17%	7.74%	3.12%	6.01%	0.22%	0.01%	0.39%		1.16%	26.73%	0.03%	2.23%
Trail Creek	OK520620-02-0090G	28660	0.01%	12.40%	1.08%		0.08%	0.01%	4.63%		9.73%	69.09%	1.92%	0.15%		0.91%	
Walnut Creek	OK520610-03-0010G	99192		12.86%	16.62%	0.09%	1.17%	0.43%	5.93%	0.02%	0.04%	59.95%		0.52%	2.36%		
Warren Branch Creek	OK121600-07-0050G	14689	0.20%	1.58%	40.93%		0.34%	0.03%	3.25%			3.14%			49.62%	0.61%	0.29%

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
Whitewater Creek	OK121600-03-0320G	19109		0.09%	44.43%	0.16%	0.27%	0.15%	3.27%		0.05%	1.31%	0.01%	0.01%	50.11%	0.10%	0.03%
Willow Creek	OK520610-01-0080H	13790	0.01%	21.96%	7.14%	0.06%	1.26%	0.25%	4.12%			29.72%		0.69%	34.78%		

Table 17. Permitted land use for each Group 1 (Neosho-Grand and Upper Canadian Basins) monitoring sites. Each site is given a unique identifier (WBID).

Site Name	WBID	# Concentrated Animal Feeding Operations	# Landfill	# National Pollution Discharge Elimination System Permits	# Oil and Gas Wells	# Total Retention Lagoon	# Land Application	# Public Water Intakes
Beaty Creek: Lower	OK121600-05-0160G							
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E							
Big Cabin Creek	OK121600-06-0220I			3	398			
Big Creek	OK121510-03-0010D				300			
Bird Creek	OK121300-02-0010C			8	6606			2
Brush Creek	OK121600-05-0140J			1				
Buggy Creek	OK520610-02-0120G	2			74			
Bull Creek	OK121500-02-0090D				156			
California Creek	OK121510-02-0050C				718		1	
Chouteau Creek	OK121600-01-0430P				87			
Commission Creek	OK520620-05-0160C				74			
Deer Creek	OK520620-06-0010F	2	1	3	316	4	3	
Delaware Creek	OK121300-01-0150H				1167		2	
Elm Creek	OK121600-04-0150G				1			
Fivemile Creek	OK121600-07-0110G							
Fourteenmile Creek	OK121600-01-0100G		1					1
Hackberry Creek	OK520620-04-0050D				126			
Hominy Creek	OK121300-04-0280G				1583			
Horse Creek	OK121600-03-0160G			1	1			
Lightning Creek	OK121510-01-0130N			38	80			
Little Cabin Creek	OK121600-06-0080C	1		2	23			
Little Horse Creek	OK121600-03-0190G							
Little Saline Creek	OK121600-02-0070G							
Lone Creek	OK520620-03-0020C				84			
Lost Creek	OK121600-03-0560G			2				
Mission Creek	OK121400-02-0190B				537			
Mud Creek	OK121600-04-0175M							
North Fork Walnut Creek	OK520610-03-0080E			1	78			
PawPaw Creek	OK121600-06-0240G				47			
Pryor Creek	OK121610-00-0050D			8	474		1	

Site Name	WBID	# Concentrated Animal Feeding Operations	# Landfill	# National Pollution Discharge Elimination System Permits	# Oil and Gas Wells	# Total Retention Lagoon	# Land Application	# Public Water Intakes
Ranger Creek	OK121600-01-0060D		1		1	1		
Red Creek	OK520620-03-0110F				4			
Russell Creek	OK121600-04-0200F				13			
Saline Creek	OK121600-02-0030D					1		
Sand Creek	OK121400-04-0010F		1		3585			
Sycamore Creek	OK121600-03-0510D							
Tar Creek	OK121600-04-0060D			1				
Trail Creek	OK520620-02-0090G				57			
Walnut Creek	OK520610-03-0010G			1	350	11		
Warren Branch Creek	OK121600-07-0050G							
Whitewater Creek	OK121600-03-0320G		1		1			
Willow Creek	OK520610-01-0080H				11			

Table 18. Comparison of site chemistry at rotating Basin 1 (Neosho-Grand and Upper Canadian Basins) monitoring sites with and without National Pollution Discharge Elimination System (NPDES) permits based on one-way ANOVAs. Comparisons where p-values were less than 0.05 were considered significantly different.

Parameter	NPDES Permit	Sample Size (N)	Mean	Standard Deviation	P Value	Result
Alkalinity	No	577	142.69	65.06	<0.001	Lower
	Yes	225	165.06	91.97		
Conductivity	No	572	659.9	763.6	0.015	Lower
	Yes	217	807.2	734.8		
DO	No	555	8.394	2.873	0.028	Lower
	Yes	214	8.905	2.918		
DO %	No	553	85.5	24.75	0.001	Lower
	Yes	213	92.16	24.38		
Hardness	No	569	369.8	509.8	<0.001	Lower
	Yes	220	532.9	620.1		
pH	No	567	7.4592	0.6555	<0.001	Lower

Parameter	NPDES Permit	Sample Size (N)	Mean	Standard Deviation	P Value	Result
	Yes	217	7.6996	0.6294		
Turbidity	No	643	16.52	38.39	0.868	No significant difference
	Yes	250	16.05	38.16		
Ammonia	No	187	0.0694	0.2412	0.460	No significant difference
	Yes	75	0.0478	0.1194		
Chloride	No	544	31.83	54.52	0.003	
	Yes	212	20.46	17.99		Lower
TDS	No	545	506.1	738.2	0.032	Lower
	Yes	212	635.1	755.2		
TKN	No	545	0.4612	0.4266	0.235	No significant difference
	Yes	212	0.5014	0.3941		
Nitrate	No	545	0.5894	0.8934	0.718	No significant difference
	Yes	212	0.617	1.0713		
Nitrite	No	545	0.05905	0.1011	0.154	No significant difference
	Yes	212	0.0728	0.1566		
Ortho P	No	545	0.0368	0.046	<0.001	Lower
	Yes	212	0.0664	0.111		
Total P	No	545	0.0609	0.0612	<0.001	Lower
	Yes	212	0.0931	0.1235		
Sulfate	No	545	200.7	452.8	0.016	Lower
	Yes	212	291.8	501.5		
TSS	No	545	15.13	28.23	0.930	No significant difference
	Yes	212	15.35	35.77		
Available N	No	545	0.6722	0.9035	0.707	No significant difference
	Yes	211	0.7014	1.081		
Total N	No	545	1.1096	0.8871	0.297	No significant difference
	Yes	212	1.1913	1.1453		
Flow	No	574	8.661	23.494	<0.001	Lower
	Yes	197	29.73	81.57		

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 for rotating basin monitoring sites in Basin 1 (Neosho-Grand and Upper Canadian Basins). Each site was assigned a unique waterbody identifier (WBID). Beneficial uses are listed along with the support status (F = fully supporting, N = not supporting, I = insufficient information, X = use not assessed, * = antidegradation designation). Blanks indicate that a particular beneficial use was not designated for a waterbody.

Site Name	WBID	Size (stream miles)	Aesthetic	Agriculture	Cool Water Aquatic Community	Habitat Limited Aquatic Community	Warm Water Aquatic Community	Fish Consumption	Primary Body Contact Recreation	Secondary Body Contact Recreation	Public/Private Water Supply	Emergency Water Supply	High Quality Water	Sensitive Water Supply
Beaty Creek: Lower	OK121600-05-0160G	12.44	F	I	F			X	N		I		*	
Beaty Creek: Oak Hill Rd.	OK121600-05-0160E	12.44	F	I	F			X	N		I		*	
Big Cabin Creek	OK121600-06-0220I	11.58	I	N			F	X		F				
Big Creek	OK121510-03-0010D	34.74	F	F			F	X	N		I			
Bird Creek	OK121300-02-0010C	35.63	F	F			F	X	N		I			
Brush Creek	OK121600-05-0140J	16.51	I	I	F			X	X		X		*	
Buggy Creek	OK520610-02-0120G	26.51	F	N			N	X	N			F		
Bull Creek	OK121500-02-0090D	17.55	F	F			N	X	N					
California Creek	OK121510-02-0050C	25.39	F	F			N	X	N		I			
Chouteau Creek	OK121600-01-0430P	22.25	I	F			N	X	N		I			
Commission Creek	OK520620-05-0160C	12.13	I	F			F	X	N		I			
Deer Creek	OK520620-06-0010F	55.58	I	F			I	X	N		F			
Delaware Creek	OK121300-01-0150H	26.26	F	F			N	X	N		I			
Elm Creek	OK121600-04-0150G	10.76	X	X			X	X	X					
Fivemile Creek	OK121600-07-0110G	5.81	F	F	F			F	N		F			
Fourteenmile Creek	OK121600-01-0100G	25.45	F	F	F			F	N		F		*	
Hackberry Creek	OK520620-04-0050D	14.33	I	N			F	X	N		I			
Hominy Creek	OK121300-04-0280G	33.89	I	N			I	X	N		I			*
Horse Creek	OK121600-03-0160G	10.06	I	N			N	X	N			F		
Lightning Creek	OK121510-01-0130N	14.40	I	N			F	X	F		I			
Little Cabin Creek	OK121600-06-0080C	32.31	F	F			N	X	N					
Little Horse Creek	OK121600-03-0190G	6.46	I	F			N	X	N					
Little Saline Creek	OK121600-02-0070G	10.50	F	I	F			X	N		I		*	
Lone Creek	OK520620-03-0020C	13.18	F	N			F	X	N		I			
Lost Creek	OK121600-03-0560G	10.23	F	F	F			X	I		I			
Mission Creek	OK121400-02-0190B	18.22	F	F			F	X	N					
Mud Creek	OK121600-04-0175M	10.00	X	X			X	X	X					

Site Name	WBID	Size (stream miles)	Aesthetic	Agriculture	Cool Water Aquatic Community	Habitat Limited Aquatic Community	Warm Water Aquatic Community	Fish Consumption	Primary Body Contact Recreation	Secondary Body Contact Recreation	Public/Private Water Supply	Emergency Water Supply	High Quality Water	Sensitive Water Supply
North Fork Walnut Creek	OK520610-03-0080E	16.84	F	F			N	X	N		I			
PawPaw Creek	OK121600-06-0240G	18.40	F	N			N	X	I					
Pryor Creek	OK121610-00-0050D	4.97	I	F			N	X	N		I			
Ranger Creek	OK121600-01-0060D	7.94	F	F			F	X	N		X			
Red Creek	OK520620-03-0110F	11.82	I	N			F	X	N		I			
Russell Creek	OK121600-04-0200F	11.48	F	N			N	X	I					
Saline Creek	OK121600-02-0030D	28.12	F	I	F			F	N		F		*	
Sand Creek	OK121400-04-0010F	59.85	I	F			N	X	N		I			
Sycamore Creek	OK121600-03-0510D	7.36	I	F	I			X	N		I			
Tar Creek	OK121600-04-0060D	11.67				N		X		F				
Trail Creek	OK520620-02-0090G	14.34	F	N		F		X	N	X		F		
Walnut Creek	OK520610-03-0010G	28.44	I	F			F	X	N					
Warren Branch Creek	OK121600-07-0050G	9.10	I	F	F			X	I		I		*	
Whitewater Creek	OK121600-03-0320G	14.74	I	F	F			X	I		I			
Willow Creek	OK520610-01-0080H	9.06	F	F			F	X	F					

4.0 SUMMARY

In general, water chemistry for the Rotating Basin Group 1 monitoring sites showed some changes when compared with the first three cycles: Ammonia and other forms of nitrogen decreased while alkalinity and/or hardness increased.

Habitat at 95% of the sites in Basin 1 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 the previous cycle indicate that about 13 of the sites showed improved conditions, two of the sites showed worse conditions, and 13 indicated the same conditions. Overall, approximately 76% of the sites scored excellent, 12% were good, 9% were fair, and one site was poor.

Most sites had either non-impaired (31%) or slightly impaired (56%) macroinvertebrate communities overall; 13% of the sites had collections that indicate moderately impaired communities. Three sites did not have macroinvertebrate collections due to lack of flow.

The next cycle of monitoring in Basin 1 is scheduled to begin in June, 2021.

5.0 LITERATURE CITED

Minitab, Inc. 2016. *Minitab*, Release 17 for Windows.

OCC (Oklahoma Conservation Commission). 2016. Water Quality Division: *Standard Operating Procedures*. Oklahoma Conservation Commission, Oklahoma City, Oklahoma

OCC (Oklahoma Conservation Commission). 2005. Analysis of Oklahoma Conservation Commission Physicochemical and Biological Data toward Determination of High Quality Sites.

ODEQ (Oklahoma Department of Environmental Quality). 2016. *Water Quality in Oklahoma: 2016 Integrated Report.*

OWRB (Oklahoma Water Resource Board). 2014. *Implementation of Oklahoma's Water Quality Standards, Chapter 46, Subchapter 15: Use Support Assessment Protocols (USAP)*. OAC 785:46-15.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, R.M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers*. USEPA/444/4-89-001. U.S. E.P.A., Assessment and Watershed Protection Division, Washington, D.C.

USGS (United States Geological Survey). 2011. National Land Coverage Dataset. http://landcover.usgs.gov.

Woods, A.J., Omernik, J.M., Butler, D.R., Ford, J.G., Henley J.E., Hoagland, B.W., Arndt, D.S., and Moran, B.C. 2005. *Ecoregions of Oklahoma* (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,250,000).