Small Watershed Rotating Basin Monitoring Program

Basin Group 4: Washita River and Upper Red River Basins

Final Report

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Submitted by:

Oklahoma Conservation Commission

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

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1.0 INTRODUCTION

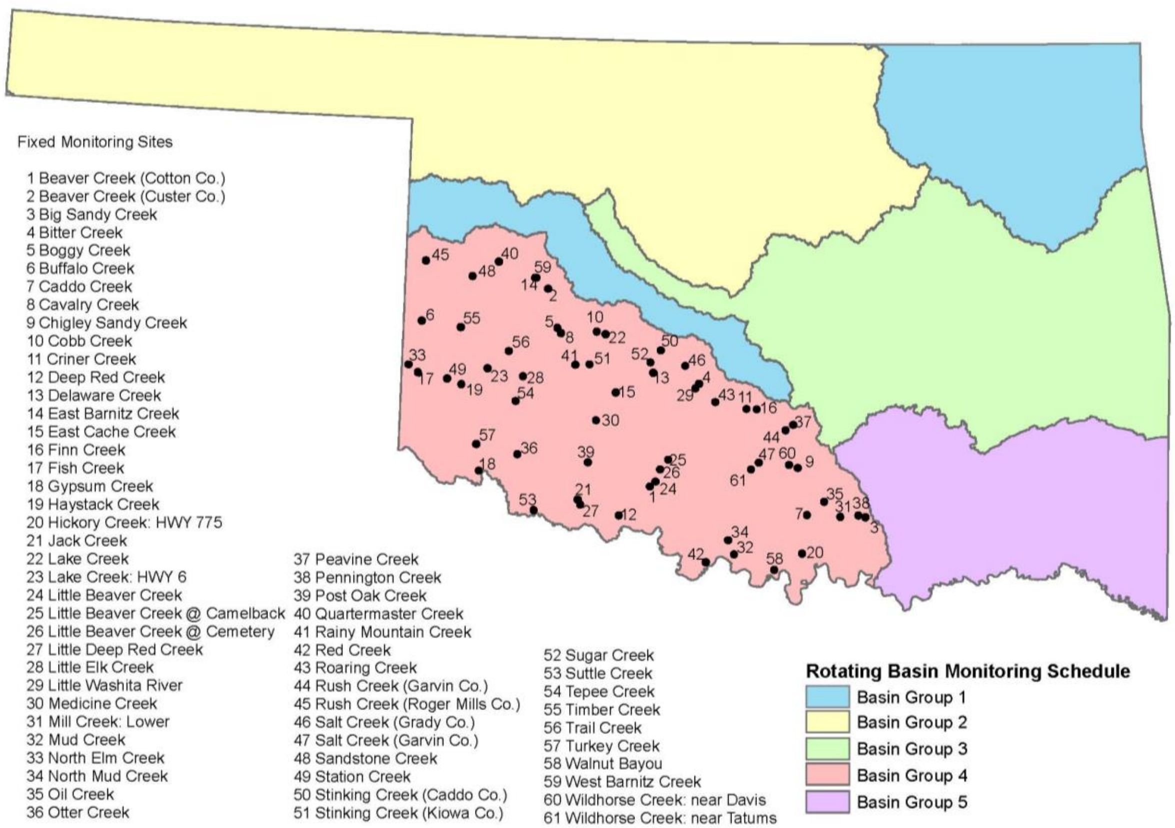
1.1 PROJECT BACKGROUND AND DESCRIPTION

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

In 2000, the Oklahoma Conservation Commission (OCC) initiated a progressive ambient monitoring program to assess NPS issues on a larger spatial and temporal scale than previously done. Known as the *Small Watershed Rotating Basin Monitoring Program* ("Rotating Basin Program"), this effort entails fixed station sampling at or near the outlets of complete eleven digit Hydrologic Unit Code watersheds (HUC-111). Oklahoma contains all or part of 414 U.S. Geological Survey (USGS) 11-digit HUC basins which have been collated into eleven larger planning basins for state water quality management purposes. The sampling units for the Rotating Basin Monitoring Program are based at the outlets of HUC 11 watersheds located entirely in the state, with secondary sites located upstream in selected watersheds where isolation of a particular tributary influence is necessary. Fixed stations are segregated into strategic basin groups and are sampled every five weeks for a period of two years. Each year, sampling is initiated in a new basin group, resulting in a statewide coverage of all sites in five years (Figure 1).

To complement the fixed site monitoring, the OCC added a probabilistic component to the Rotating Basin Monitoring Program for Cycle 2 in 2008. This addition to the Rotating Basin Program provided a statistically qualified assessment of water quality conditions throughout the project basin. To accomplish this, sites were randomly selected from all of the waters of interest in a target area (i.e., basin unit), and the monitoring results were used to estimate water quality conditions in the larger area with known confidence (USGAO 2004). Analysis of the probabilistic component indicated that data collected from the fixed sites accurately represents the water quality of the basin. Probabilistic sites have not been monitored in Cycle 3. The fixed sites monitored in Cycle 3 are shown in Figure 1.

Figure 1. Monitoring sites in "Basin group 4" for third cycle of the Small Watershed Rotating Basin Monitoring Project.



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

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

1. Which HUC 11 waterbodies are not supporting assigned beneficial uses due to NPS or NPS plus point source (PS) pollution?

2. Which waterbodies show elevated or increasing levels of NPS or NPS plus PS pollutants, which may threaten water quality?

3. What are the sources and magnitude of pollution loading within threatened or impaired waterbodies?

4. Which land uses or changes in land use are sources or potential sources for pollutants causing beneficial use impairment?

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

This report discusses the results of the *ambient* (routine physical, chemical, and biological sampling) and *diagnostic* (special parameter sampling) stages of the forth cycle of the Rotating Basin program in the Washita and Upper Red basins (see Figure 1). Data will be discussed. *Implementation* and *success* monitoring are typically accomplished through priority watershed projects and reported on in project-specific final reports.

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

2.0 MATERIALS AND METHODS

2.1 GENERAL

Sampling stations were selected to effectively represent streams of the Washita and Upper Red 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 for a Rotating Basin site if the monitoring being conducted met the project data quality objectives. For most sub-watersheds, the monitoring site was located near the outflow of the primary stream far enough upstream to limit backwater (surface and alluvial) effects of the waterbody to which it drained. For larger sub-watersheds, an additional site was sometimes located upstream to isolate a particularly strong tributary influence. In some cases, sites were specifically chosen to monitor a stream draining an area of landuse different from the majority of the other streams being monitored in that region or sub-watershed.

Reconnaissance of all of the potential sites within the Washita and Upper Red basins was accomplished prior to the first round of monitoring in 2004, and sites which did not meet the sampling criteria were removed from the project. Sixty-one sites were monitored during the first rotating basin cycle, from 2004-2006. The second cycle of the monitoring of 64 sites in these basins occurred from June 2009-May 2011. The third cycle of monitoring in these basins occurred from June 2014-May 2016. Each cycle, several sites changed slightly due to landowner permission issues and several more were removed or added. There were 61 sites during this cycle of monitoring.

The sites monitored in the Washita basin occur in two level-three ecoregions: The Central Great Plains (CGP) and the Cross Timbers (CT). In the Upper Red basin, sites are located in the Cross Timbers (CT), Central Great Plains (CGP), and Southwestern Tablelands (SWT) ecoregions. Eight sites had a heavy influence from a bordering ecoregion (i.e., the sites are very close to the ecoregion border and have water originating in the other ecoregions), so they were grouped with the influencing ecoregions when compared to reference conditions: Medicine Creek (located in CGP but influenced by the "Wichita Mountains"); Stinking Creek (located in CGP, influenced by CT); Mud Creek (located in CT, influenced by CGP); Big Sandy Creek, Caddo Creek, Mill Creek, Oil Creek, and Pennington Creek (all located in CT but influenced by the "Arbuckle Uplift"). These changes are indicated by the "modified ecoregion" column in Table 1.

Table 1. Site list for Rotating Basin Monitoring Program: Basin Group 4, Cycle 3.

Site Name	WBID	Latitude	Longitude	Legal Description	County	Ecoregion	Modified Ecoregion
Beaver Creek	OK311210-00-0010D	34.3913	-98.1828	SW SE 7-2S-9W	Cotton	CGP	
Beaver Creek	OK310830-03-0190C	35.533	-98.958	NW SW NW 12-12N-17W	Custer	CGP	
Big Sandy Creek	OK310800-01-0090G	34.23133	-96.63492	SE SE SE 2-4S-6E	Johnston	CT	Arbuckle
Bitter Creek	OK310820-01-0030D	35.0006	-97.8442	SW SW 9-6N-6W	Grady	CGP	
Boggy Creek	OK310830-03-0100C	35.306	-98.879	SE SE SW 27-10N-16W	Washita	CGP	
Buffalo Creek	OK311510-02-0090D	35.321	-99.867	SW SW SE 20-10N-25W	Beckham	CGP	
Caddo Creek	OK310800-03-0010F	34.24	-97.052	NE SW NW 1-4S-2E	Carter	CT	Arbuckle
Cavalry Creek	OK310830-03-0070D	35.277	-98.853	NE NE NE 11-9N-16W	Washita	CGP	
Chigley Sandy Creek	OK310800-02-0190D	34.514	-97.122	SW SW NW 32-1N-2E	Murray	CT	
Cobb Creek	OK310830-06-0050K	35.2908	-98.5941	SW SE 32-10N-13W	Caddo	CGP	
Criner Creek	OK310810-02-0050D	34.8552	-97.4962	SE SE 34-5N-3W	McClain	CGP	
Deep Red Creek	OK311310-03-0010D	34.218	-98.4	SE SE SE 12-4S-12W	Cotton	CGP	
Delaware Creek	OK310830-01-0030G	35.058	-98.176	NW NE NW 29-7N-9W	Caddo	CT	
East Barnitz Creek	OK310830-03-0210C	35.595	-99.045	SE SW SE 18-13N-17W	Custer	CGP	
East Cache Creek	OK311300-03-0010M	34.9386	-98.4444	SW NW NW 2-5N-12W	Caddo	CGP	
Finn Creek	OK310810-02-0020D	34.855	-97.424	SW SW SW 33-5N-2W	McClain	CGP	
Fish Creek	OK311800-00-0130G	35.0192	-99.8804	NE SE SW 6-6N-25W	Greer	SWT	
Gypsum Creek	OK311600-01-0020F	34.454	-99.412	SE NE SE 20-1S-21W	Jackson	CGP	
Haystack Creek	OK311800-00-0040D	34.958	-99.562	NW NW NE 31-6N-22W	Greer	CGP	
Hickory Creek: HWY 775	OK311100-02-0010M	34.014	-97.084	NW NW NE 27-6S-2E	Love	CT	
Jack Creek	OK311310-03-0030B	34.3043	-98.6984	SE SE 7-3S-14W	Tillman	CGP	

Site Name	WBID	Latitude	Longitude	Legal Description	County	Ecoregion	Modified Ecoregion
Lake Creek	OK310830-06-0040J	35.2762	-98.5306	SE SW 1-9N-13W	Caddo	CGP	
Lake Creek: Hwy 6, Greer Co.	OK311510-01-0040D	35.056	-99.378	SW NW NW 25-7N-21W	Greer	CGP	
Little Beaver Creek	OK311210-00-0050D	34.42	-98.142	SW SE SE 33-1S-9W	Cotton	CGP	
Little Beaver Creek @ Camelback Rd	OK311210-00-0050M	34.5506	-98.0551	SE SE SE 17-1N-8W	Stephens	CGP	
Little Beaver Creek @ Cemetery Rd	OK311210-00-0050H	34.4927	-98.1123	SW SW SE 2-1S-9W	Stephens	CGP	
Little Deep Red Creek	OK311310-03-0040E	34.2772	-98.6793	SE SE 20-3S-14W	Tillman	CGP	
Little Elk Creek	OK311500-03-0040D	35.016	-99.118	NW NE NE 5-6N-18W	Kiowa	CGP	
Little Washita River	OK310820-02-0010A	34.9725	-97.8693	SW SE 19-6N-6W	Grady	CGP	
Medicine Creek	OK311300-04-0060H	34.772	-98.58	NE SE SE 32-4N-13W	Comanche	CGP	Witchita
Mill Creek: Lower	OK310800-01-0190G	34.23069	-96.813083	SE SE 6-4S-5E	Johnston	CT	Arbuckle
Mud Creek	OK311100-04-0010G	34.0039	-97.5695	NW SE 25-6s-4w	Jefferson	CT	CGP
North Elm Creek	OK311800-00-0170G	35.0599	-99.9506	Sections 17/21 7N-26W	Beckham	SWT	
North Mud Creek	OK311100-04-0030C	34.0857	-97.615	SW SW SW 37-5S-4W	Jefferson	CGP	
Oil Creek	OK310800-01-0240P	34.32	-96.931	SW SW 6-3S-4E	Johnston	CT	Arbuckle
Otter Creek	OK311500-01-0080F	34.56	-99.141	SE SE NE 13-1N-19W	Tillman	CGP	
Peavine Creek	OK310810-01-0120M	34.7676	-97.1607	NE NE NE 2-3N-1E	Garvin	CT	
Pennington Creek	OK310800-01-0120G	34.241	-96.682	NE SW NW 4-4S-6E	Johnston	CT	Arbuckle
Post Oak Creek	OK311310-02-0070B	34.5236	-98.6328	SE SE SE 26-1N-14W	Comanche	CGP	
Quartermaster Creek	OK310840-01-0060B	35.6823	-99.3207	SW SW 15-14N-20W	Custer	CGP	
Rainy Mountain Creek	OK310830-02-0060G	35.092	-98.744	SW NW SW 12-7N-15W	Kiowa	CGP	
Red Creek	OK311100-01-0290D	33.955	-97.77	NW NW NW 18-7S-5W	Jefferson	CGP	
Roaring Creek	OK310810-02-0170B	34.893	-97.7233	SW NW 22-5N-5W	Grady	CT	
Rush Creek	OK310810-01-0090G	34.735	-97.214	NE SE NE 17-3N-1E	Garvin	CGP	
Rush Creek	OK310840-02-0210H	35.6738	-99.8548	NE SE 21-14N-25W	Roger Mills	CGP	
Salt Creek	OK310820-01-0140B	35.1022	-97.9454	SE SW 4-7N-7W	Grady	CGP	
Salt Creek	OK310810-03-0080G	34.543	-97.405	NW NW SW 22-1N-2W	Garvin	CT	
Sandstone Creek	OK310840-02-0020C	35.593	-99.509	SW NW NE 23-13N-22W	Roger Mills	CGP	
Station Creek	OK311800-00-0060G	34.9875	-99.667778	NW NW NE 18-6N-23W	Greer	CGP	
Stinking Creek	OK310830-04-0030K	35.18911	-98.1264	NE NE NE 10-8N-9W	Caddo	CGP	CT
Stinking Creek	OK310830-02-0020D	35.097	-98.639	NW SW NW 12-7N-14W	Kiowa	CGP	
Sugar Creek	OK310830-05-0010D	35.117	-98.197	NE NE NE 1-7N-10W	Caddo	CT	
Suttle Creek	OK311310-01-0070H	34.235	-99.011	NW SW SW 5-4S-17W	Tillman	CGP	
Tepee Creek	OK311500-01-0110D	34.87	-99.167	NW NW NW 35-5N-19W	Kiowa	CGP	
Timber Creek	OK311510-01-0090G	35.291	-99.582	SE SW SE 36-10N-23W	Beckham	CGP	
Trail Creek	OK311500-03-0070D	35.16	-99.228	SW SW SE 17-8N-19W	Washita	CGP	
Turkey Creek	OK311600-02-0060J	34.6115	-99.439	NW SW SW 29-2N-21W	Jackson	CGP	
Walnut Bayou	OK311100-03-0010G	33.918	-97.281	NW NW SW 26-7S-1W	Love	CT	
West Barnitz Creek	OK310830-03-0230C	35.595	-99.052	NW NE NW 19-13N-17W	Custer	CGP	
Wildhorse Creek (Davis)	OK310810-01-0020G	34.5331	-97.1871	SE NE NW 27-1N-1E	Garvin	CT	
Wildhorse Creek (Tatums)	OK310810-03-0010R	34.502	-97.457	SW SW NW 6-1S-2W	Carter	CT	

All sampling and analyses performed during this project were conducted under a Quality Assurance Project Plan (QAPP) approved by EPA Region VI and on file at the OCC Water Quality Division, the Oklahoma Secretary of the Environment (OSE), and EPA Region VI in Dallas. The reader is encouraged to obtain and consult the QAPP for specific questions concerning laboratory analytical methods, detection limits, and accuracy and precision limits. All sampling and measurement activities of OCC Water Quality staff followed procedures outlined in the appropriate OCC Standard Operating Procedure (OCC 2014). 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 2014, 61 sites were monitored for physical and chemical parameters on a fixed interval schedule of ten sampling events per year (five-week intervals) through May 2016 (usually 20 total events per sites). This sampling frequency exceeds state data requirements for beneficial use assessment and meets a sample number necessary to provide a 90% level of confidence for principal water quality data (specifically phosphorus, a critical NPS concern) as determined from EPA's DEFT software. Samples were collected during both base flow and high flow conditions as they occurred on predetermined sampling dates. All sampling and measurement activities followed procedures outlined in the appropriate OCC SOP (OCC 2014).

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

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

2.3 BIOLOGICAL MONITORING

2.3.1 Habitat Assessment

In the summer of 2014, OCC staff began conducting instream and riparian habitat assessments at sites concurrent with fish collections; any sites not sampled in 2014 were sampled in the summer of 2015. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP (OCC 2014). The OCC's habitat assessment adheres to a modified version of the EPA Rapid Bioassessment Protocols (RBP) (Plafkin et al., 1989) and is designed to assess habitat quality in relation to its ability to support biological communities in the stream. The assessment is based on particular parameters grouped into three categories for a total of eleven components (Plafkin et al., 1989). The eleven components are discussed in more detail below. The three primary categories assessed include micro scale habitat, macro scale habitat, and riparian/bank structure. Micro scale habitat includes substrate makeup, stable cover, canopy, depth, and velocity. Macro scale assesses the channel morphology, sediment deposits, and other parameters. The third category looks at the riparian zone quality, width, and general makeup (trees, shrubs, vines, and grasses) as well as bank features. Bank erosion and streamside vegetative cover are incorporated into this section.

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

OCC's habitat assessment components include:

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

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

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

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

(5) The **percent of rocky runs and riffles** is calculated for the fifth component. Rocky runs and riffles offer an unique combination of highly oxygenated, turbulent water, flowing over high quality cover and substrate. Turbulence prevents the formation of nutrient concentration gradients from cell membranes outward so that algae and other plants grow at a much higher rate than they would at the same concentration in pools. More food means more growth. Larger crops of algae are translated into larger invertebrate crops. It is these invertebrates, reared in riffle areas, 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 2014 or 2015 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 (2014). The collection of fish follows a modified version of the EPA Rapid Bioassessment Protocol V (Plafkin et al., 1989) supplemented by other documents. Specific techniques and relative advantages of seining and electrofishing vary considerably according to stream type and conductivity. Depending upon workable habitat, seining was performed first at all sites and was accomplished by use of either 6' X 10' or 6' X 20' seines of ¼ inch mesh equipped with 8' brailes. Electroshocking was undertaken at all sites with suitable conductivities (usually < 1000 µS/cm) and involved the use of a Smith Root LR 24 backpack shocker. For sites possessing long pools too deep to seine or backpack shock, OCC field personnel employed a boat electrofishing unit consisting of a Smith-Root GPP 2.5 shocking unit powered by a Honda 5kw generator.

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

Fish data were compiled and analyzed by site using state biocriteria and methods outlined in the state's *Use Support Assessment Protocols* (OWRB 2013). In addition, each site was assessed using a modified version of Karr's Index of Biotic Integrity (IBI) (adapted from Plafkin et al., 1989). Descriptive statistics were determined for each metric using the *Minitab V 17* software. The condition of the fish community was based on indices of species richness, community quality, trophic structure, and by comparison to the average scores of high-quality streams in that ecoregion. The modified IBI score was calculated using the following metrics:

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

(2) The **number of sensitive benthic species (darters, madtoms, sculpins)** decreases with increasing siltation and increasing benthic oxygen demand. Many of these fish actually live within the cobble and gravel interstices and are very good indicators of conditions that make this environment inhospitable.

These species are weak swimmers that do not readily travel up and down a stream, so their presence or absence at a site relates well to both past and present habitat and water quality conditions at that site.

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

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

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

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

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

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

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

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

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

% Comparison to the Reference Score	Integrity Class	Characteristics
97 – 100 %	Excellent	Comparable to pristine conditions, exceptional species assemblage
80 – 87%	Good	Decreased species richness, especially intolerant species
67 – 73%	Fair	Intolerant and sensitive species rare or absent
47 – 57%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
20 – 37%	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

2.3.3 Macroinvertebrates

Collection of macroinvertebrates was attempted at all sites for both winter and summer index periods of July 2014 through March 2016 according to procedures outlined in the OCC SOP (2014). Index periods represent seasons of relative community stability that afford opportunity for meaningful site comparisons. For Oklahoma, the summer index occurs from July 1 to September 15; the winter index occurs from January 1 to March 15. In order for macroinvertebrate collections to be obtained, flowing water must be present. Sampling efforts included attempts to procure animals from all available habitats at a site; thus, total effort at a site may entail up to three total samples with one from each of the following habitats: rocky riffles, streamside vegetation, and woody debris.

Collection methods involved sampling each of the habitats similar to methods outlined in the EPA Rapid Bioassessment Protocols (Plafkin et at., 1989). Riffle sampling effort consisted of three, one meter squared kicknet samples in the areas of rocky substrate reflecting the breadth of the velocity regime at a site. Riffles with substrates of bedrock or tight clay were not sampled. Any streamside vegetation in the current that appeared to offer fine structure was sampled by agitation within a #30 mesh dip net for three minutes total agitation time. Any dead wood with or without bark which was in current fast enough to offer suitable habitat for organisms was sampled by agitation or by scraping/brushing upstream of a #30 mesh dip net for 5 minutes. Woody debris sampled generally ranged in size from ¼” to about 8” in diameter. Each sample type was preserved independently in quart mason jars with ethanol, labeled, and sent to a professional taxonomist for picking and identification.

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

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

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

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

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

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

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

Descriptive statistics of each season-specific sample type (e.g., summer riffle, winter vegetation, summer woody) for each site were determined via *Minitab V. 17* and were compared to the average respective metric of high-quality streams in the ecoregion. A Bioassessment score was calculated similarly to the IBI score for fish. For each site, scores of 6, 4, 2, or 0 were assigned for each metric (according to the criteria in Table 4, below) and then summed to get a total bioassessment score for each site, with a maximum of 36 points. For taxa richness and EPT taxa richness, the percentages used to assign scores were obtained by dividing each monitoring site metric by the average high quality site metric in a particular ecoregion.

For the HBI metric, the high quality site value was divided by the monitoring site value (high quality site metric / monitoring site metric). For the remaining metrics, the score was based on the actual values obtained instead of being relative to the high quality site metric. Each monitoring site's total score was then compared to the average high quality sites' total score (in that ecoregion) and classified according to the condition gradient outlined in Table 5 (adapted from Plafkin et al., 1989).

Table 4. Bioassessment scoring criteria for macroinvertebrates.

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

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

Table 5. Bioassessment score interpretation for macroinvertebrates.

% Comparison to the Reference Score	Biological Condition	Characteristics
>83%	Non-Impaired	Comparable to the best situation expected within the ecoregion. Balanced trophic and community structure for stream size.
54-79%	Slightly Impaired	Community structure less than expected. Species richness is less than expected due to loss of some intolerant forms. Percent contribution of tolerant forms is increased.
21-50%	Moderately Impaired	Fewer species due to the loss of most intolerant forms. Reduction in EPT index.
<17%	Severely Impaired	Few species present. If high densities of organisms occur, they are dominated by 1 or 2 taxa.

2.4 WATERSHED ASSESSMENT

To investigate potential sources of NPS pollution for streams showing beneficial use impairment, relevant data layers were explored using ArcMap 10.1 Geographic Information System (GIS) software. Data explored included the 2011 USGS National Land Cover Dataset (NLCD), oil and gas wells, confined animal feeding operations, national pollution discharge elimination system permit holders, total retention sites, biosolid land application sites and other data layers. The NLCD was explored to determine percent occurrence of particular landuse types such as bare rock/sand/clay, vegetation (broken into several categories, both natural and agricultural), open water, and residential/commercial/industrial uses (divided into several categories).

2.5 BENEFICIAL USE SUPPORT ASSESSMENT

Each fixed site's assigned beneficial uses were evaluated following the protocols outlined in the state's *Continuing Planning Process, Integrated Water Quality Report Listing Methodology* (Oklahoma Department of Environmental Quality, 2012) and per *Oklahoma Administrative Code 785, Chapter 46: Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (OWRB 2013). Streams were considered non-supporting when Oklahoma Water Quality Standards were violated as determined by criteria and rules listed in these documents. Parameters not addressed in OAC 785:46-15 were assessed using applicable state and federal rules and regulations to determine support status. Assessment results were submitted to the ODEQ for final assimilation in the state's 2016 Integrated Report submitted to EPA Region VI.

3.0 RESULTS AND DISCUSSION

3.1 WATER QUALITY MONITORING

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

Table 6. Mean in-situ water quality values for Basin Group 4 monitoring sites, 2014-2016.

Site Name	WBID	DO (mg/L)	DO % Sat	Turbidity (NTU)	Alkalinity ($CaCO_3$)	Conductivity (µS/cm)	Hardness (mg/L)	pH (SU)	Temperature (°C)	Flow (cfs)
Beaver Creek (Cotton)	OK311210-00-0010D	6.32	70.33	83.84	278.5	925.8	444.2	8.18	17.4	8.16
Beaver Creek (Custer)	OK310830-03-0190C	6.87	66.16	11.25	213.5	2485.6	1700.0	7.75	13.6	4.57
Big Sandy Creek	OK310800-01-0090G	7.57	74.29	24.24	147.0	353.3	171.0	8.00	16.7	9.71
Bitter Creek	OK310820-01-0030D	8.63	88.04	30.13	403.8	1253.5	1039.4	8.36	17.6	11.00
Boggy Creek	OK310830-03-0100C	8.50	87.54	102.42	305.6	2075.2	1076.7	8.06	15.5	11.23
Buffalo Creek	OK311510-02-0090D	9.08	95.82	10.23	262.9	3997.4	1404.5	8.08	15.3	5.86
Caddo Creek	OK310800-03-0010F	9.06	95.42	82.77	159.5	662.7	225.1	7.98	18.2	43.31
Cavalry Creek	OK310830-03-0070D	9.17	94.48	75.49	282.9	2471.8	1511.1	8.06	16.1	18.82
Chigley Sandy Creek	OK310800-02-0190D	7.66	74.77	1.92	287.6	697.4	271.1	7.83	15.9	2.33
Cobb Creek	OK310830-06-0050K	9.08	94.55	63.49	235.0	807.2	645.7	8.18	16.5	16.14
Criner Creek	OK310810-02-0050D	7.78	75.31	29.19	385.1	881.2	441.4	8.12	15.7	3.62
Deep Red Creek	OK311310-03-0010D	7.04	74.16	192.71	199.0	1715.4	365.5	8.09	18.9	42.36
Delaware Creek	OK310830-01-0030G	8.93	91.33	5.65	269.1	2210.4	1520.0	7.95	17.0	5.54

Site Name	WBID	DO (mg/L)	DO % Sat	Turbidity (NTU)	Alkalinity ($CaCO_3$)	Conductivity (µS/cm)	Hardness (mg/L)	pH (SU)	Temperature (°C)	Flow (cfs)
East Barnitz Creek	OK310830-03-0210C	7.43	76.75	21.07	204.4	2634.5	1879.4	7.88	15.2	3.57
East Cache Creek	OK311300-03-0010M	7.80	74.26	12.20	227.1	1257.5	444.3	7.82	15.2	20.57
Finn Creek	OK310810-02-0020D	8.43	84.60	25.85	373.8	793.2	439.7	7.83	16.8	3.61
Fish Creek	OK311800-00-0130G	8.16	86.19	69.11	161.4	34898.3	4934.2	7.80	14.3	2.69
Gypsum Creek	OK311600-01-0020F	11.64	129.13	27.02	128.1	16068.3	3852.5	8.07	18.6	5.10
Haystack Creek	OK311800-00-0040D	8.34	84.78	102.08	340.1	6520.2	1701.5	7.88	16.7	0.39
Hickory Creek: HWY 775	OK311100-02-0010M	8.87	90.14	93.61	181.8	886.5	240.0	8.13	17.1	20.07
Jack Creek	OK311310-03-0030B	6.48	65.94	90.35	274.6	3990.4	1012.6	7.70	17.0	5.51
Lake Creek (Caddo)	OK310830-06-0040J	8.57	89.92	54.49	249.0	597.7	471.1	8.15	16.9	10.31
Lake Creek (Greer)	OK311510-01-0040D	8.79	89.59	6.98	284.7	1616.8	625.6	8.00	17.1	1.53
Little Beaver Creek	OK311210-00-0050D	8.98	92.29	80.67	232.0	980.5	455.4	8.14	17.1	7.85
Little Beaver Creek @ Camelback Rd	OK311210-00-0050M	10.49	114.77	29.03	302.9	1130.4	552.5	8.17	18.2	16.93
Little Beaver Creek @ Cemetery Rd	OK311210-00-0050H	10.16	114.84	30.78	272.8	1097.9	502.4	8.18	20.1	16.78
Little Deep Red Creek	OK311310-03-0040E	7.60	78.09	273.41	223.6	3504.4	624.1	8.19	16.6	3.60
Little Elk Creek	OK311500-03-0040D	6.82	64.97	61.07	330.8	1750.6	664.5	7.78	14.7	5.33
Little Washita River	OK310820-02-0010A	8.59	89.56	17.78	216.2	1984.8	1570.1	8.03	16.9	15.27
Medicine Creek	OK311300-04-0060H	8.98	90.53	2.99	141.8	453.4	167.9	8.10	15.6	5.82
Mill Creek: Lower	OK310800-01-0190G	8.03	79.90	13.52	185.9	477.9	246.3	8.18	16.7	44.20
Mud Creek	OK311100-04-0010G	3.70	45.30	572.75	68.8	182.7	93.5	7.41	24.4	0.10
North Elm Creek	OK311800-00-0170G	8.26	81.86	16.50	93.0	27169.2	4543.3	7.33	15.1	1.57
North Mud Creek	OK311100-04-0030C	7.25	68.99	178.33	213.7	1454.5	356.7	7.80	15.5	4.81
Oil Creek	OK310800-01-0240P	7.83	83.39	24.28	250.4	513.7	274.0	7.98	18.3	12.70
Otter Creek	OK311500-01-0080F	6.61	69.36	40.16	231.0	2828.2	624.4	7.98	17.5	2.35
Peavine Creek	OK310810-01-0120M	7.31	66.26	127.04	188.8	417.7	177.2	8.11	12.9	0.87
Pennington Creek	OK310800-01-0120G	8.91	91.69	4.19	214.9	402.1	247.5	8.26	17.4	66.20
Post Oak Creek	OK311310-02-0070B	9.55	96.56	21.16	147.3	480.4	147.0	8.01	16.7	2.44
Quartermaster Creek	OK310840-01-0060B	8.88	92.61	17.61	285.0	3345.1	2379.4	8.06	15.2	1.41
Rainy Mountain Creek	OK310830-02-0060G	7.93	90.83	81.96	233.6	2265.8	1143.9	8.25	20.1	6.41
Red Creek	OK311100-01-0290D	6.30	61.67	207.21	184.8	736.9	221.2	7.80	16.4	1.64
Roaring Creek	OK310810-02-0170B	7.86	73.21	12.56	344.0	905.4	528.5	8.15	16.7	4.00
Rush Creek (Garvin)	OK310810-01-0090G	8.00	82.81	39.51	326.6	1298.2	497.1	8.13	19.0	12.58
Rush Creek (Roger Mills)	OK310840-02-0210H	6.98	72.33	2.36	399.1	1118.6	360.7	7.98	15.6	4.91
Salt Creek (Garvin)	OK310820-01-0140B	8.61	85.13	27.93	327.3	1102.5	488.1	8.01	17.1	4.33
Salt Creek (Grady)	OK310810-03-0080G	7.03	76.30	71.79	240.3	3137.4	707.3	8.18	21.3	0.46
Sandstone Creek	OK310840-02-0020C	9.03	95.35	10.56	320.4	2359.0	1618.0	8.06	15.3	3.63
Station Creek	OK311800-00-0060G	7.73	75.00	14.52	143.2	4824.2	2517.5	7.72	15.2	1.65
Stinking Creek (Caddo)	OK310830-04-0030K	8.80	92.63	23.51	288.0	2502.2	1970.6	7.85	17.4	1.39

Site Name	WBID	DO (mg/L)	DO % Sat	Turbidity (NTU)	Alkalinity ($CaCO_3$)	Conductivity (µS/cm)	Hardness (mg/L)	pH (SU)	Temperature (°C)	Flow (cfs)
Stinking Creek (Kiowa)	OK310830-02-0020D	7.08	75.26	49.54	272.2	1506.1	730.4	8.01	18.5	9.89
Sugar Creek	OK310830-05-0010D	11.46	121.30	18.01	246.0	2237.2	1723.0	8.20	17.3	18.66
Suttle Creek	OK311310-01-0070H	5.17	57.67	37.02	382.2	4022.7	965.0	7.93	19.2	3.33
Tepee Creek	OK311500-01-0110D	9.39	102.58	14.46	199.1	3490.5	1312.2	7.96	18.7	4.20
Timber Creek	OK311510-01-0090G	8.03	85.28	54.38	399.3	1458.4	741.1	8.16	14.4	2.51
Trail Creek	OK311500-03-0070D	7.63	70.12	16.14	286.3	2164.8	1117.7	7.91	13.5	7.99
Turkey Creek	OK311600-02-0060J	10.03	103.91	31.32	158.3	5640.8	2728.8	7.98	17.7	6.12
Walnut Bayou	OK311100-03-0010G	7.90	80.89	103.27	197.5	808.1	261.8	7.96	17.7	22.80
West Barnitz Creek	OK310830-03-0230C	6.77	70.68	17.84	229.6	2611.4	1976.2	7.95	15.1	5.94
Wildhorse Creek: Davis	OK310810-01-0020G	8.84	93.78	28.60	247.5	871.5	341.4	8.26	19.5	14.39
Wildhorse Creek: Tatums	OK310810-03-0010R	9.10	92.16	17.74	295.5	1802.5	742.6	8.16	17.6	4.11

Table 7. Mean water quality values for Basin Group 4 monitoring sites, 2014-2016.

Site Name	WBID	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TKN (mg/L)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
Beaver Creek (Cotton)	OK311210-00-0010D	36.29	247.74	713.3	0.2778	0.2589	0.0656	1.8030	0.0899	0.2223	19.4
Beaver Creek (Custer)	OK310830-03-0190C	26.99	1526.21	2316.3	0.3112	0.1079	0.0558	0.7000	0.0622	0.1144	15.3
Big Sandy Creek	OK310800-01-0090G	11.57	25.73	212.2	0.0190	0.1506	0.0222	0.3837	0.0281	0.0434	14.3
Bitter Creek	OK310820-01-0030D	21.08	162.34	596.7	0.0233	0.1281	0.0310	0.4711	0.0816	0.1058	22.0
Boggy Creek	OK310830-03-0100C	109.93	854.61	1687.4	0.0575	1.5389	0.0500	0.7542	0.0728	0.1224	48.6
Buffalo Creek	OK311510-02-0090D	741.61	1171.44	3010.5	0.1460	0.4737	0.1305	0.5822	0.0239	0.0470	19.1
Caddo Creek	OK310800-03-0010F	78.68	46.96	399.4	0.0376	1.4333	0.0689	0.9224	0.4157	0.4547	45.4
Cavalry Creek	OK310830-03-0070D	98.63	1246.48	2173.7	0.0702	1.5342	0.0500	1.2649	0.1184	0.2021	96.1
Chigley Sandy Creek	OK310800-02-0190D	52.99	17.57	406.7	0.0300	0.2006	0.0428	0.2423	0.0393	0.0464	10.0
Cobb Creek	OK310830-06-0050K	14.67	271.61	586.5	0.0533	1.1875	0.0515	0.7917	0.1359	0.2048	66.3
Criner Creek	OK310810-02-0050D	40.60	55.23	504.4	0.0382	0.3539	0.0600	0.5798	0.0937	0.1174	24.7
Deep Red Creek	OK311310-03-0010D	406.09	143.60	1117.5	0.0610	0.2481	0.1875	1.2723	0.1370	0.2415	84.1
Delaware Creek	OK310830-01-0030G	235.97	820.61	1710.5	0.0745	0.1135	0.0765	0.5743	0.0514	0.0805	26.7
East Barnitz Creek	OK310830-03-0210C	25.06	1662.19	2531.6	0.0303	0.1468	0.0205	0.9386	0.0660	0.1199	29.9
East Cache Creek	OK311300-03-0010M	160.11	224.71	801.6	0.0295	0.3789	0.0200	0.4604	0.0462	0.0709	17.4
Finn Creek	OK310810-02-0020D	36.68	34.64	451.1	0.0713	0.3233	0.0950	0.7321	0.1327	0.1669	14.3
Fish Creek	OK311800-00-0130G	13307.27	2761.65	28000.0	0.1237	0.4869	1.0615	0.7636	0.0405	0.0775	38.5
Gypsum Creek	OK311600-01-0020F	4724.05	2555.21	10786.7	0.0456	1.1640	0.4813	0.5300	0.0166	0.0458	35.5
Haystack Creek	OK311800-00-0040D	1759.41	1415.88	5297.5	0.0482	0.5488	0.3588	1.2434	0.0213	0.0847	26.8
Hickory Creek: HWY 775	OK311100-02-0010M	177.51	44.53	547.3	0.0390	0.1187	0.0560	0.7008	0.0417	0.0935	73.6
Jack Creek	OK311310-03-0030B	966.21	202.86	2021.9	0.0870	0.4713	0.1131	1.3583	0.1008	0.2100	114.1
Lake Creek (Caddo)	OK310830-06-0040J	15.85	66.13	403.0	0.0848	0.6475	0.0590	0.7600	0.1219	0.1796	48.8
Lake Creek (Greer)	OK311510-01-0040D	185.23	268.09	1032.2	0.0347	1.9456	0.1300	0.7421	0.0243	0.0766	11.3
Little Beaver Creek	OK311210-00-0050D	43.93	267.58	685.6	0.2432	0.0813	0.0325	1.9519	0.0997	0.3189	166.1
Little Beaver Creek @ Camelback Rd	OK311210-00-0050M	36.09	309.42	777.0	0.0157	0.3230	0.0520	0.5810	0.0539	0.0835	27.3

Site Name	WBID	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TKN (mg/L)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
Little Beaver Creek @ Cemetery Rd	OK311210-00-0050H	59.40	535.84	748.9	0.0153	0.1678	0.0600	0.6090	0.0476	0.0828	25.3
Little Deep Red Creek	OK311310-03-0040E	841.75	340.32	1995.3	0.0408	0.3882	0.2188	2.3126	0.1761	0.3782	106.7
Little Elk Creek	OK311500-03-0040D	189.14	397.87	1192.5	0.0520	0.6956	0.0875	0.9660	0.1509	0.2520	33.9
Little Washita River	OK310820-02-0010A	90.79	958.97	1675.0	0.0577	0.5150	0.0465	0.5890	0.0658	0.0950	26.6
Medicine Creek	OK311300-04-0060H	46.03	22.96	258.0	0.0612	0.2713	0.0213	0.3845	0.0091	0.0203	10.0
Mill Creek: Lower	OK310800-01-0190G	16.16	46.29	276.5	0.0543	0.2053	0.0241	0.3739	0.0204	0.0374	13.8
Mud Creek	OK311100-04-0010G	12.40	6.37	466.7	0.0193	0.3133	0.0233	2.0900	0.3203	0.5477	209.3
North Elm Creek	OK311800-00-0170G	9335.99	2484.60	18961.1	0.0202	0.4172	0.9389	0.7208	0.0139	0.0426	33.8
North Mud Creek	OK311100-04-0030C	299.58	44.33	970.7	0.0543	0.3253	0.0893	1.8029	0.1491	0.3649	167.4
Oil Creek	OK310800-01-0240P	8.23	17.69	293.2	0.0258	0.7500	0.0247	0.4164	0.0327	0.0577	10.1
Otter Creek	OK311500-01-0080F	690.13	288.77	1751.3	0.0210	0.2206	0.0900	1.0832	0.1741	0.2789	24.5
Peavine Creek	OK310810-01-0120M	18.00	12.32	304.2	0.0170	0.0533	0.0308	1.0860	0.1682	0.2517	29.5
Pennington Creek	OK310800-01-0120G	4.12	7.15	227.2	0.0264	0.1489	0.0206	0.2991	0.0089	0.0203	10.0
Post Oak Creek	OK311310-02-0070B	36.82	46.62	298.3	0.0200	0.4817	0.0200	0.4437	0.0598	0.0810	18.8
Quartermaster Creek	OK310840-01-0060B	53.64	2079.57	3290.0	0.1555	0.1535	0.0240	1.2357	0.0594	0.1285	16.7
Rainy Mountain Creek	OK310830-02-0060G	248.03	690.64	1659.4	0.0180	0.2975	0.0981	0.9361	0.1104	0.1854	70.3
Red Creek	OK311100-01-0290D	127.47	26.99	648.9	0.0612	0.6461	0.0522	1.5880	0.0971	0.2348	81.6
Roaring Creek	OK310810-02-0170B	21.21	149.24	678.3	0.0462	0.2017	0.0444	0.4666	0.0904	0.1119	15.4
Rush Creek (Garvin)	OK310810-01-0090G	170.63	159.62	792.4	0.0435	0.0976	0.0694	0.6577	0.0457	0.0950	25.0
Rush Creek (Roger Mills)	OK310840-02-0210H	108.08	78.60	692.1	0.0163	0.0289	0.0732	0.5377	0.1223	0.1393	10.0
Salt Creek (Garvin)	OK310820-01-0140B	133.24	92.02	645.0	0.0185	0.1133	0.0778	0.5318	0.0186	0.0499	18.4
Salt Creek (Grady)	OK310810-03-0080G	797.48	456.71	2131.1	0.0160	0.0989	0.1333	0.9589	0.1887	0.2533	23.2
Sandstone Creek	OK310840-02-0020C	55.51	1465.68	2263.3	0.0337	0.2408	0.0250	0.5799	0.0173	0.0423	11.9
Station Creek	OK311800-00-0060G	711.65	2011.61	3984.2	0.1107	1.8700	0.2611	0.5812	0.0121	0.0363	13.6
Stinking Creek (Caddo)	OK310830-04-0030K	59.35	1490.44	2494.7	0.0890	0.2505	0.0242	0.6657	0.0418	0.0823	20.2
Stinking Creek (Kiowa)	OK310830-02-0020D	219.71	354.78	1117.2	0.0820	0.4244	0.1217	0.8373	0.0852	0.1376	30.8
Sugar Creek	OK310830-05-0010D	106.64	1174.92	2069.5	0.0165	0.2371	0.0343	0.9430	0.0925	0.1513	21.8

Site Name	WBID	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TKN (mg/L)	Ortho P (mg/L)	Total P (mg/L)	TSS (mg/L)
Suttle Creek	OK311310-01-0070H	1044.03	722.01	2812.5	0.3060	0.2850	0.3475	1.7631	0.2604	0.3579	23.6
Tepee Creek	OK311500-01-0110D	737.40	826.50	2388.9	0.0200	0.6722	0.3533	0.6872	0.0344	0.0819	13.7
Timber Creek	OK311510-01-0090G	76.08	391.01	1179.2	0.0663	0.7608	0.0400	0.6500	0.0673	0.0965	10.4
Trail Creek	OK311500-03-0070D	65.87	888.43	1738.0	0.1362	1.6313	0.0867	0.8923	0.0582	0.1109	11.6
Turkey Creek	OK311600-02-0060J	1024.02	1920.90	4341.2	0.0370	2.7929	0.2776	0.8103	0.0243	0.0706	23.8
Walnut Bayou	OK311100-03-0010G	114.16	60.69	492.2	0.0260	0.0650	0.0372	0.7552	0.1074	0.1578	59.4
West Barnitz Creek	OK310830-03-0230C	28.01	1706.57	2687.7	0.0868	0.3023	0.0246	0.8685	0.0527	0.1059	17.8
Wildhorse Creek: Davis	OK310810-01-0020G	110.33	69.93	516.3	0.0150	0.0456	0.0544	0.4154	0.0134	0.0419	19.4
Wildhorse Creek: Tatums	OK310810-03-0010R	362.61	105.89	975.6	0.0150	0.0433	0.0478	0.4647	0.0129	0.0362	17.9

Most of the sites are designated as Warm Water Aquatic Communities (WWAC) and have a critical dissolved oxygen (DO) level of 5.0 mg/L most of the year (6.0 mg/L from April 1 – June 15). North Mud Creek has a Habitat Limited Aquatic Community (HLAC) designation, with a critical DO level of 3.0 mg/L most of the year (4.0 mg/L from April 1 – June 15). Pennington Creek has a Cool Water Aquatic Community (CWAC) designation, with a critical DO level of 6.0 mg/L most of the year (7.0 mg/L March 1 – May 31). Table 8 shows all instances of criteria exceedance; 43% of the streams in this rotation exceeded the DO standard. Twelve sites [Boggy, Cobb, Fish, Gypsum, Lake (Caddo), Little Beaver at both Camelback and Cemetery Roads, Sandstone, Sugar, Tepee, and Wildhorse (Davis) Creeks] met the DO concentrations each time they were sampled. Fourteen sites [Buffalo, Caddo, Cavalry, Finn, Haystack, Hickory, Oil, Pennington, Rainy Mountain, Rush (Garvin), Salt (Grady), Stinking (Caddo), Turkey, and Wildhorse (Tatums) Creeks] had one low DO sample but met the standards because 10% or fewer samples fell below critical levels.

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

% Samples with Low DO	Site Name	WBID	Date	DO
36%	Beaver Creek (Cotton)	OK311210-00-0010D	7/14/2014	3.90
			7/16/2014	4.02
			1/12/2015	4.00
			8/10/2015	4.92
29%	Beaver Creek (Custer)	OK310830-03-0190C	5/13/2014	4.00
			6/2/2014	2.71
			7/7/2014	3.49
			8/11/2014	4.33
			10/20/2014	4.60
			4/20/2015	5.28
35%	Big Sandy Creek	OK310800-01-0090G	5/27/2014	1.72
			7/15/2014	4.26
			8/19/2014	2.06
			9/9/2014	1.46
			10/14/2014	4.73
			9/1/2015	2.15
			10/6/2015	3.95
14%	Bitter Creek	OK310820-01-0030D	6/3/2014	5.48
			7/8/2014	4.67
			8/11/2014	4.78
5%	Buffalo Creek	OK311510-02-0090D	6/3/2014	5.62
5%	Caddo Creek	OK310800-03-0010F	8/19/2014	4.38
5%	Cavalry Creek	OK310830-03-0070D	5/12/2014	3.67
26%	Chigley Sandy Creek	OK310800-02-0190D	5/29/2014	2.56
			6/2/2014	2.27
			7/7/2014	4.66
			10/21/2014	1.30
			11/24/2014	4.36
11%	Criner Creek	OK310810-02-0050D	6/3/2014	4.38
			8/11/2014	4.93
35%	Deep Red Creek	OK311310-03-0010D	7/14/2014	2.12
			8/14/2014	3.56
			8/18/2014	4.62
			9/22/2014	1.59
			10/27/2014	4.55
			7/7/2015	4.93
14%	Delaware Creek	OK310830-01-0030G	6/3/2014	5.68
			8/4/2014	2.03
			8/11/2014	4.82
20%	East Barnitz Creek	OK310830-03-0210C	7/28/2014	0.11
			8/11/2014	4.76
			9/15/2014	4.38
			11/25/2014	4.45
19%	East Cache Creek	OK311300-03-0010M	7/14/2014	1.90
			8/18/2014	3.62
			9/22/2014	2.03
			8/10/2015	4.75
5%	Finn Creek	OK310810-02-0020D	6/3/2014	4.47
6%	Haystack Creek	OK311800-00-0040D	7/14/2014	4.83

% Samples with Low DO	Site Name	WBID	Date	DO
6%	Hickory Creek	OK311100-02-0010M	9/8/2014	4.49
47%	Jack Creek	OK311310-03-0030B	5/22/2014	2.10
			6/10/2014	3.53
			7/15/2014	0.40
			8/19/2014	0.51
			10/28/2014	3.36
			12/2/2014	3.80
			7/7/2015	4.70
			8/11/2015	4.86
22%	Lake Creek (Greer)	OK311510-01-0040D	8/18/2014	2.30
			8/25/2014	0.45
			9/22/2014	4.72
			10/27/2014	4.27
17%	Little Beaver Creek	OK311210-00-0050D	7/14/2014	3.13
			7/16/2014	4.25
			4/27/2015	5.77
22%	Little Deep Red Creek	OK311310-03-0040E	7/15/2014	2.55
			8/19/2014	1.77
			8/11/2015	4.89
			9/15/2015	4.52
29%	Little Elk Creek	OK311500-03-0040D	6/19/2014	2.73
			7/15/2014	4.10
			8/19/2014	3.06
			9/23/2014	2.27
			10/28/2014	4.24

% Samples with Low DO	Site Name	WBID	Date	DO
20%	Little Washita River	OK310820-02-0010A	6/3/2014	3.64
			7/23/2014	4.28
			8/11/2014	4.41
			4/20/2015	5.82
12%	Medicine Creek	OK311300-04-0060H	5/21/2014	5.23
			7/14/2014	2.00
26%	Mill Creek: Lower	OK310800-01-0190G	6/2/2014	5.34
			7/15/2014	4.27
			8/19/2014	4.19
			9/9/2014	3.05
			9/1/2015	4.83
100%	Mud Creek	OK311100-04-0010G	6/9/2014	4.58
			7/14/2014	2.89
			7/16/2014	3.55
			8/18/2014	3.76
28%	North Elm Creek	OK311800-00-0170G	7/14/2014	4.00
			8/18/2014	3.55
			10/27/2014	4.75
			8/10/2015	3.02
			4/11/2016	5.44
38%	North Mud Creek	OK311100-04-0030C	7/14/2014	2.42
			8/18/2014	4.50
			10/13/2014	3.56
			8/25/2015	4.68
			8/31/2015	3.68
			10/5/2015	4.32

% Samples with Low DO	Site Name	WBID	Date	DO
10%	Oil Creek	OK310800-01-0240P	7/14/2014	4.81
			8/19/2014	2.40
29%	Otter Creek	OK311500-01-0080F	7/15/2014	2.17
			8/19/2014	2.18
			9/23/2014	4.31
			4/28/2015	4.53
			9/15/2015	4.51
15%	Peavine Creek	OK310810-01-0120M	8/24/2015	4.22
			9/9/2015	2.22
5%	Pennington Creek	OK310800-01-0120G	9/9/2014	5.83
14%	Post Oak Creek	OK311310-02-0070B	7/16/2015	4.43
14%	Quartermaster Creek	OK310840-01-0060B	9/16/2014	4.70
			10/21/2014	4.57
			10/21/2014	4.57
6%	Rainy Mountain Creek	OK310830-02-0060G	7/24/2014	4.76
47%	Red Creek	OK311100-01-0290D	6/9/2014	2.76
			7/14/2014	1.52
			8/18/2014	2.34
			9/8/2014	1.27
			11/10/2014	3.00
			4/13/2015	5.44
			7/20/2015	3.96
			8/31/2015	3.46
			10/5/2015	4.02
11%	Roaring Creek	OK310810-02-0170B	7/8/2014	4.32
			7/23/2014	3.03

% Samples with Low DO	Site Name	WBID	Date	DO
6%	Rush Creek (Garvin)	OK310810-01-0090G	8/11/2014	4.09
25%	Rush Creek (Roger Mills)	OK310840-02-0210H	6/3/2014	3.58
			7/8/2014	1.04
			8/12/2014	1.79
			9/16/2014	2.33
			10/21/2014	4.84
11%	Salt Creek (Garvin)	OK310810-03-0080G	8/12/2014	4.34
			10/21/2014	4.80
10%	Salt Creek (Grady)	OK310820-01-0140B	10/20/2014	4.48
32%	Station Creek	OK311800-00-0060G	6/9/2014	5.81
			6/11/2014	2.71
			7/14/2014	2.83
			8/18/2014	3.10
			9/22/2014	3.52
			10/27/2014	3.95
5%	Stinking Creek (Caddo)	OK310830-04-0030K	6/2/2014	5.54
26%	Stinking Creek (Kiowa)	OK310830-02-0020D	6/2/2014	3.07
			7/7/2014	4.06
			7/30/2014	1.71
			8/12/2014	4.86
			4/20/2015	4.39
44%	Suttle Creek	OK311310-01-0070H	7/7/2015	4.46
			8/11/2015	0.64
			9/15/2015	0.99
			10/20/2015	0.70

% Samples with Low DO	Site Name	WBID	Date	DO
15%	Timber Creek	OK311510-01-0090G	4/20/2015	3.17
			9/8/2015	4.72
33%	Trail Creek	OK311500-03-0070D	6/10/2014	5.65
			6/16/2014	3.90
			8/19/2014	2.45
			9/23/2014	2.81
			10/28/2014	2.40
6%	Turkey Creek	OK311600-02-0060J	7/15/2014	3.15

% Samples with Low DO	Site Name	WBID	Date	DO
16%	Walnut Bayou	OK311100-03-0010G	6/3/2014	4.48
			7/14/2014	2.61
			9/8/2014	1.20
29%	West Barnitz Creek	OK310830-03-0230C	6/2/2014	5.36
			2/9/2015	0.67
			3/16/2015	4.28
			6/11/2015	5.86
5%	Wildhorse Creek (Tatums)	OK310810-03-0010R	8/12/2014	4.40

Table 12 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 (SBCR), which allows for a higher bacteria concentration: Beaver (Custer), Delaware, Rainy Mountain, Sugar, and Suttle. All other sites are designated Primary Body Contact Recreation (PBCR). Sixty-nine percent of the streams meet the *E. coli* standard, as denoted by the asterisk in Table 9. None of the sites is fully attaining the Recreation designated use, meeting the standards for both *Enterococcus* and *E. coli*. OCC did not test for *Enterococcus*. To be listed on the state's 303(d) list, the geometric mean must exceed the set criteria for at least one of the bacteria types (OWRB 2013).

Table 9. Geometric mean of bacteria values for Basin Group 4 monitoring sites, 2014-2016 OCC data. An asterisk (*) indicates that the stream meets state standards for *E. coli*. Those highlighted in yellow have a SBCR designation, allowing higher bacteria concentrations.

Site Name	WBID	*E. coli*		Comments
Beaver Creek (Custer)	OK310830-03-0190C	114.49	*	Geometric Mean
Beaver Creek (Cotton)	OK311210-00-0010D	98.15	*	Geometric Mean
Big Sandy Creek	OK310800-01-0090G	44.07	*	Geometric Mean
Bitter Creek	OK310820-01-0030D	63.92	*	Geometric Mean
Boggy Creek	OK310830-03-0100C	106.01	*	Geometric Mean
Buffalo Creek	OK311510-02-0090D	135.14		Geometric Mean

Site Name	WBID	*E. coli*		Comments
Caddo Creek	OK310800-03-0010F	109.34	*	Geometric Mean
Cavalry Creek	OK310830-03-0070D	168.86		Geometric Mean
Chigley Sandy Creek	OK310800-02-0190D	75.55	*	Geometric Mean
Cobb Creek	OK310830-06-0050K	249.80		Geometric Mean
Criner Creek	OK310810-02-0050D	240.41		Geometric Mean
Deep Red Creek	OK311310-03-0010D	64.46	*	Geometric Mean
Delaware Creek	OK310830-01-0030G	77.11	*	Geometric Mean
East Barnitz Creek	OK310830-03-0210C	108.93	*	Geometric Mean
East Cache Creek	OK311300-03-0010M	79.77	*	Geometric Mean
Finn Creek	OK310810-02-0020D	46.61	*	Geometric Mean
Fish Creek	OK311800-00-0130G	46.77	*	Geometric Mean
Gypsum Creek	OK311600-01-0020F	57.21	*	Geometric Mean
Haystack Creek	OK311800-00-0040D	67.59	*	Geometric Mean
Hickory Creek	OK311100-02-0010M	24.68	*	Geometric Mean
Jack Creek	OK311310-03-0030B	81.42	*	Geometric Mean
Lake Creek	OK310830-06-0040J	130.05		Geometric Mean
Lake Creek (Greer)	OK311510-01-0040D	42.70	*	Geometric Mean
Little Beaver Creek	OK311210-00-0050D	100.98	*	Geometric Mean
Little Beaver Creek @ Camelback Rd	OK311210-00-0050M	88.45	*	Geometric Mean
Little Beaver Creek @ Cemetery Rd	OK311210-00-0050H	64.34	*	Geometric Mean
Little Deep Red Creek	OK311310-03-0040E	174.65		Geometric Mean
Little Elk Creek	OK311500-03-0040D	270.96		Geometric Mean
Little Washita River	OK310820-02-0010A	83.73	*	Geometric Mean
Medicine Creek	OK311300-04-0060H	20.40	*	Geometric Mean
Mill Creek: Lower	OK310800-01-0190G	29.92	*	Geometric Mean
Mud Creek	OK311100-04-0010G	862.55		Geometric Mean

Site Name	WBID	*E. coli*		Comments
North Elm Creek	OK311800-00-0170G	70.40	*	Geometric Mean
North Mud Creek	OK311100-04-0030C	159.51		Geometric Mean
Oil Creek	OK310800-01-0240P	34.87	*	Geometric Mean
Otter Creek	OK311500-01-0080F	58.59	*	Geometric Mean
Peavine Creek	OK310810-01-0120M	256.43		Geometric Mean
Pennington Creek	OK310800-01-0120G	32.80	*	Geometric Mean
Post Oak Creek	OK311310-02-0070B	20.00	*	Geometric Mean
Quartermaster Creek	OK310840-01-0060B	288.17		Geometric Mean
Rainy Mountain Creek	OK310830-02-0060G	87.28	*	Geometric Mean
Red Creek	OK311100-01-0290D	154.31		Geometric Mean
Roaring Creek	OK310810-02-0170B	75.25	*	Geometric Mean
Rush Creek (Garvin)	OK310810-01-0090G	1127.92		Geometric Mean
Rush Creek (Roger Mills)	OK310840-02-0210H	102.83	*	Geometric Mean
Salt Creek (Garvin)	OK310810-03-0080G	145.12		Geometric Mean
Salt Creek (Grady)	OK310820-01-0140B	92.60	*	Geometric Mean
Sandstone Creek	OK310840-02-0020C	157.23		Geometric Mean
Station Creek	OK311800-00-0060G	116.57	*	Geometric Mean
Stinking Creek (Kiowa Co.)	OK310830-02-0020D	156.90		Geometric Mean
Stinking Creek (Caddo Co.)	OK310830-04-0030K	85.64	*	Geometric Mean
Sugar Creek	OK310830-05-0010D	115.13	*	Geometric Mean
Suttle Creek	OK311310-01-0070H	232.72	*	Geometric Mean
Tepee Creek	OK311500-01-0110D	125.32	*	Geometric Mean
Timber Creek	OK311510-01-0090G	273.21		Geometric Mean
Trail Creek	OK311500-03-0070D	157.22		Geometric Mean
Turkey Creek	OK311600-02-0060J	78.54	*	Geometric Mean
Walnut Bayou	OK311100-03-0010G	46.07	*	Geometric Mean
West Barnitz Creek	OK310830-03-0230C	338.65		Geometric Mean

Site Name	WBID	*E. coli*		Comments
Wildhorse Creek) (Davis	OK310810-01-0020G	112.91	*	Geometric Mean

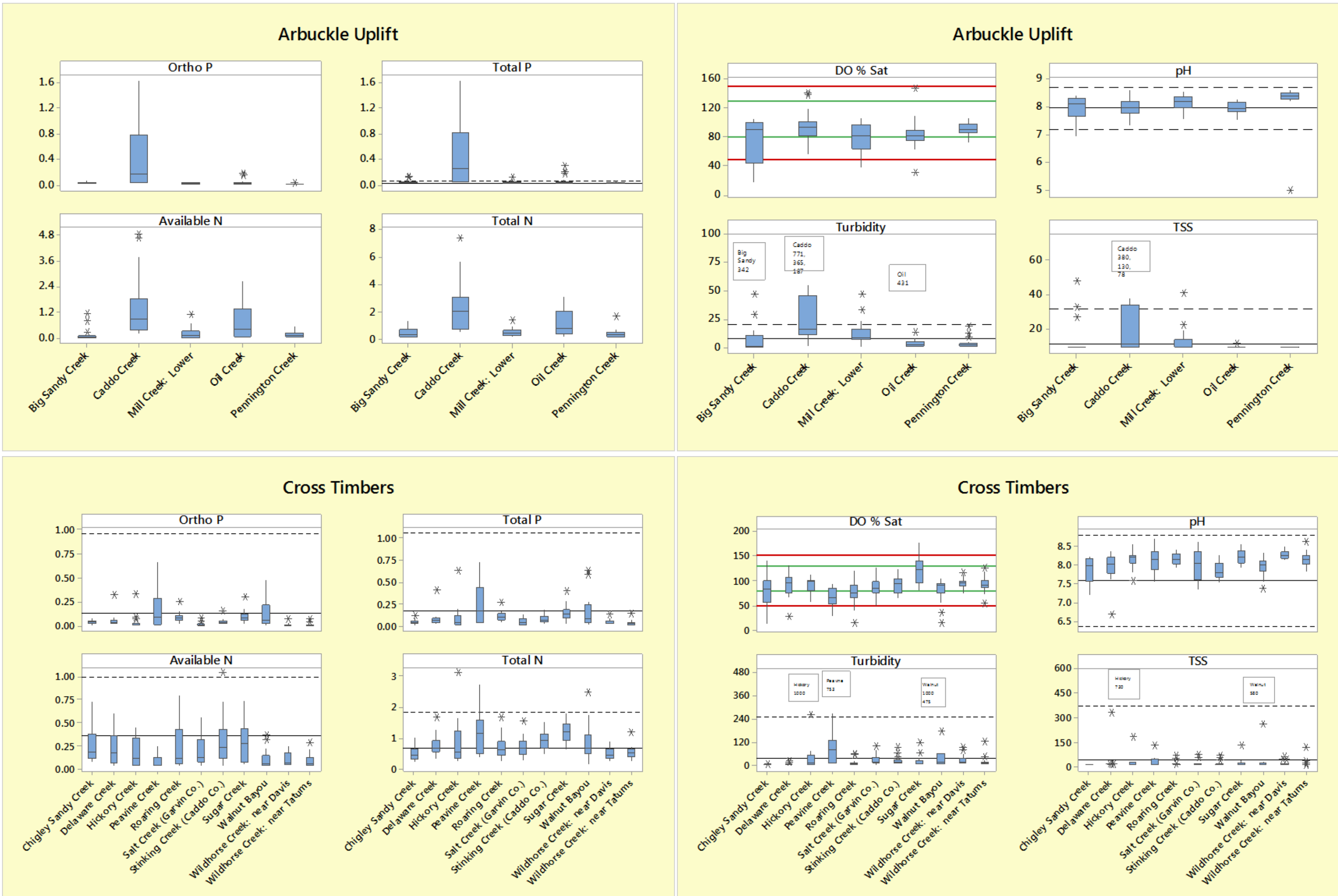
Site Name	WBID	*E. coli*		Comments
Wildhorse Creek (Tatums)	OK310810-03-0010R	73.10	*	Geometric Mean

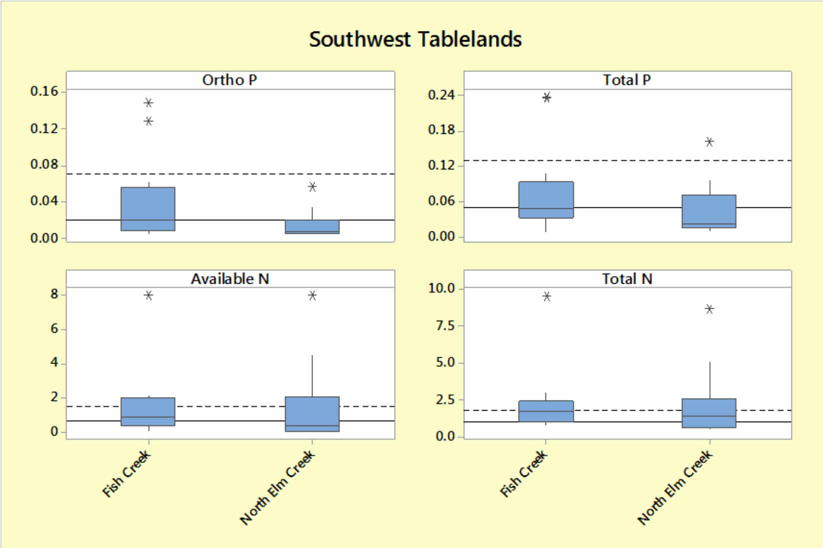
Select water quality parameters are summarized by box plots in Figure 2, below. To account for natural differences, sites were collated and analyzed by Level III ecoregions (Woods et al. 2005). Additionally, sites were compared to streams determined to be "high quality" sites in each ecoregion to determine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

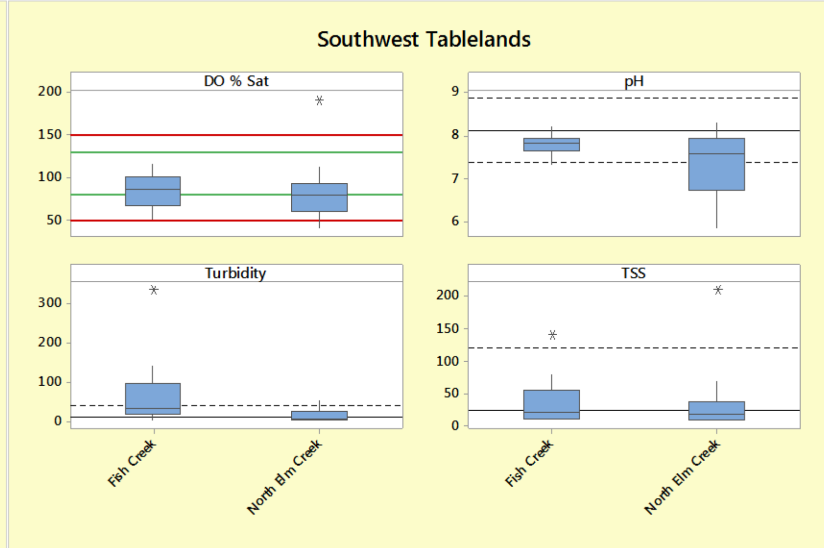
Regarding boxplot composition, the median of each site is shown by a line within the box with most outliers denoted by asterisks. The extreme outliers are denoted by values within a box on the graph. The mean of the high quality stream sites in a particular ecoregion is represented by a solid horizontal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

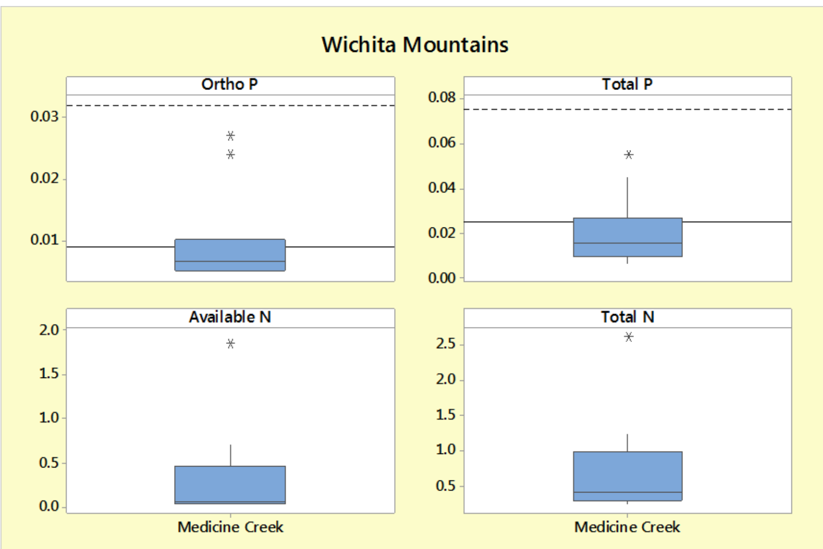
In the Arbuckle Uplift, Caddo Creek had high nutrient values, suspended solids and turbidity relative to the high quality sites for that ecoregion. In the Central Great Plains ecoregion Little Deep Red, Mud, Suttle, and Turkey Creeks had high nutrient values relative to the high quality sites. Sites in Southwestern Tablelands have nitrogen and turbidity values that are often elevated, though the median values for each site still falls within two standard deviations for the high quality sites in the ecoregion. All of the sites in the Cross Timbers and Wichita Mountains ecoregions and most of the sites in the Central Great Plains were within two standard deviations of the high quality sites in the ecoregions, indicating no significant difference from the high quality sites.

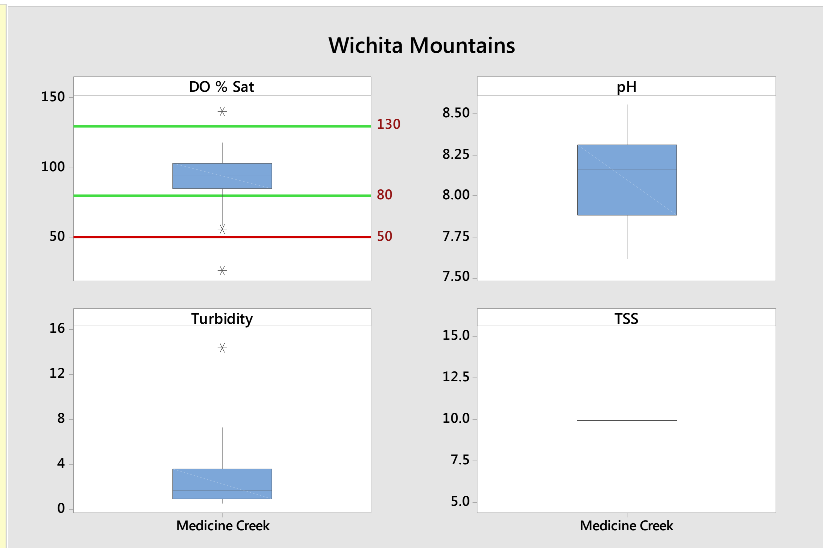
Figure 2. Select parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/1 two standard deviations (if only one dashed line, the lower standard deviation was below zero).

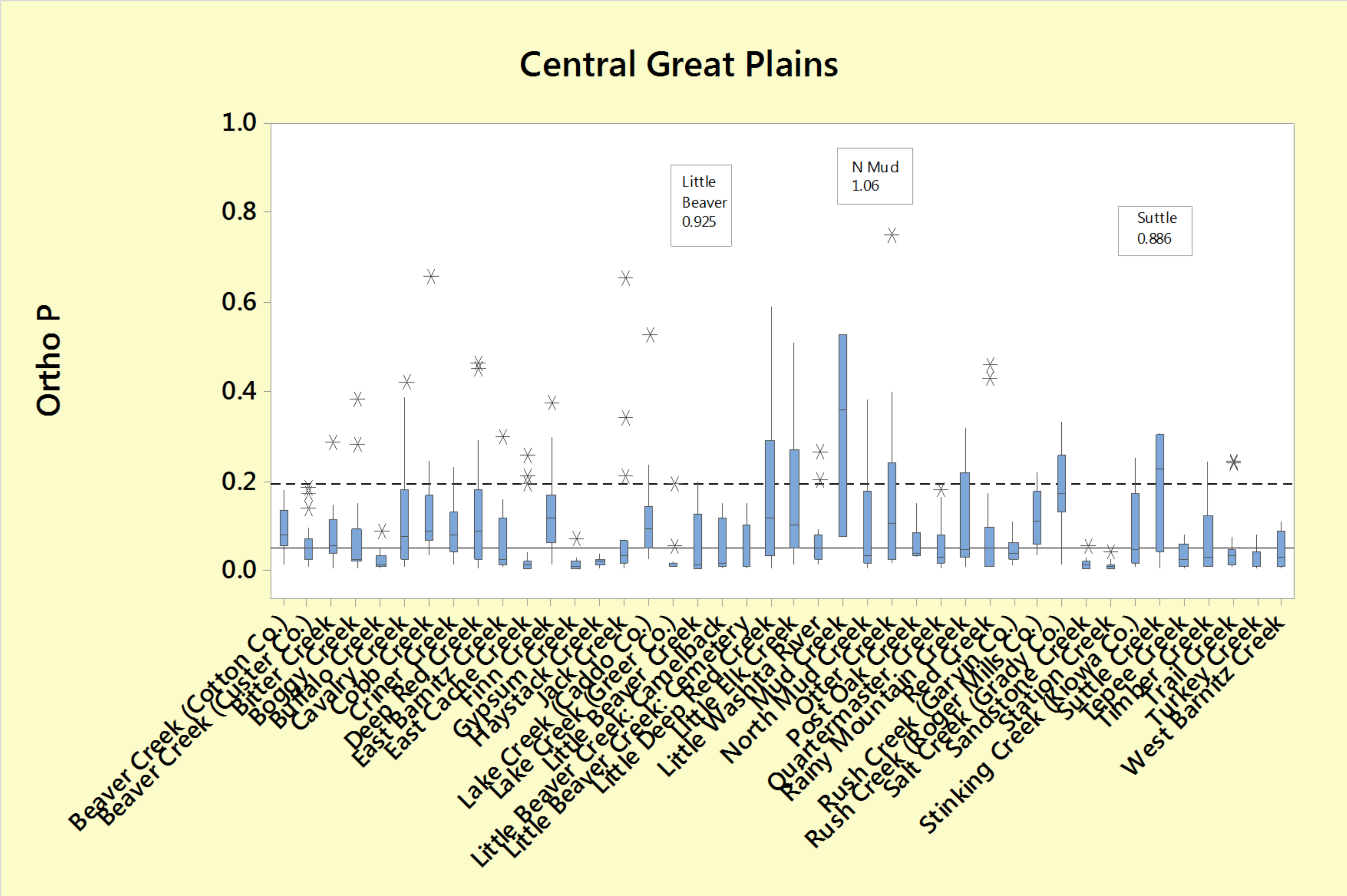


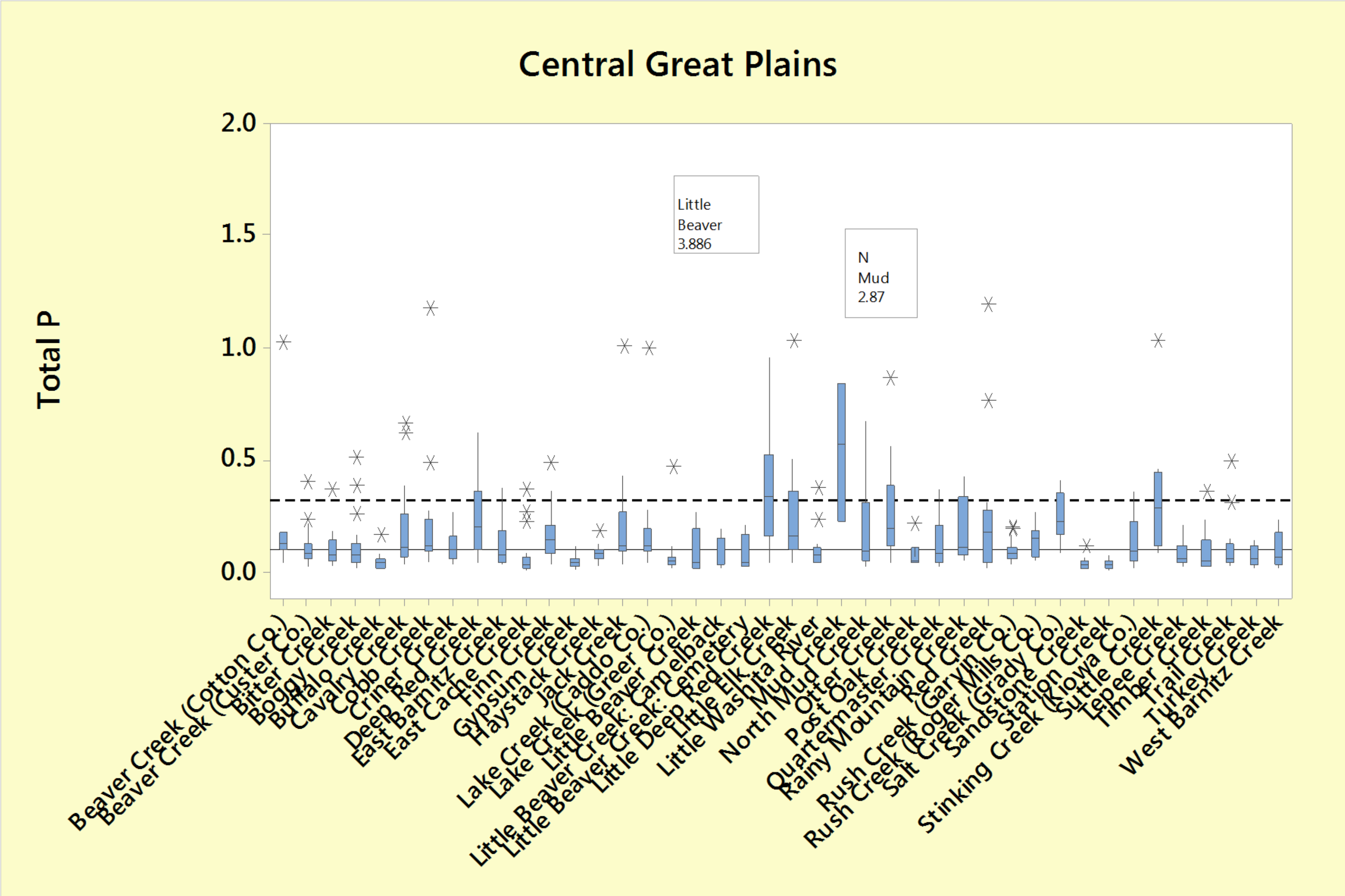

Southwest Tablelands
Ortho P
0.16
0.12
0.08
0.04
0.00
Total P
0.24
0.18
0.12
0.06
0.00
Available N
8
6
4
2
0
Total N
10.0
7.5
5.0
2.5
0.0
Fish Creek
North Elm Creek
Fish Creek
North Elm Creek

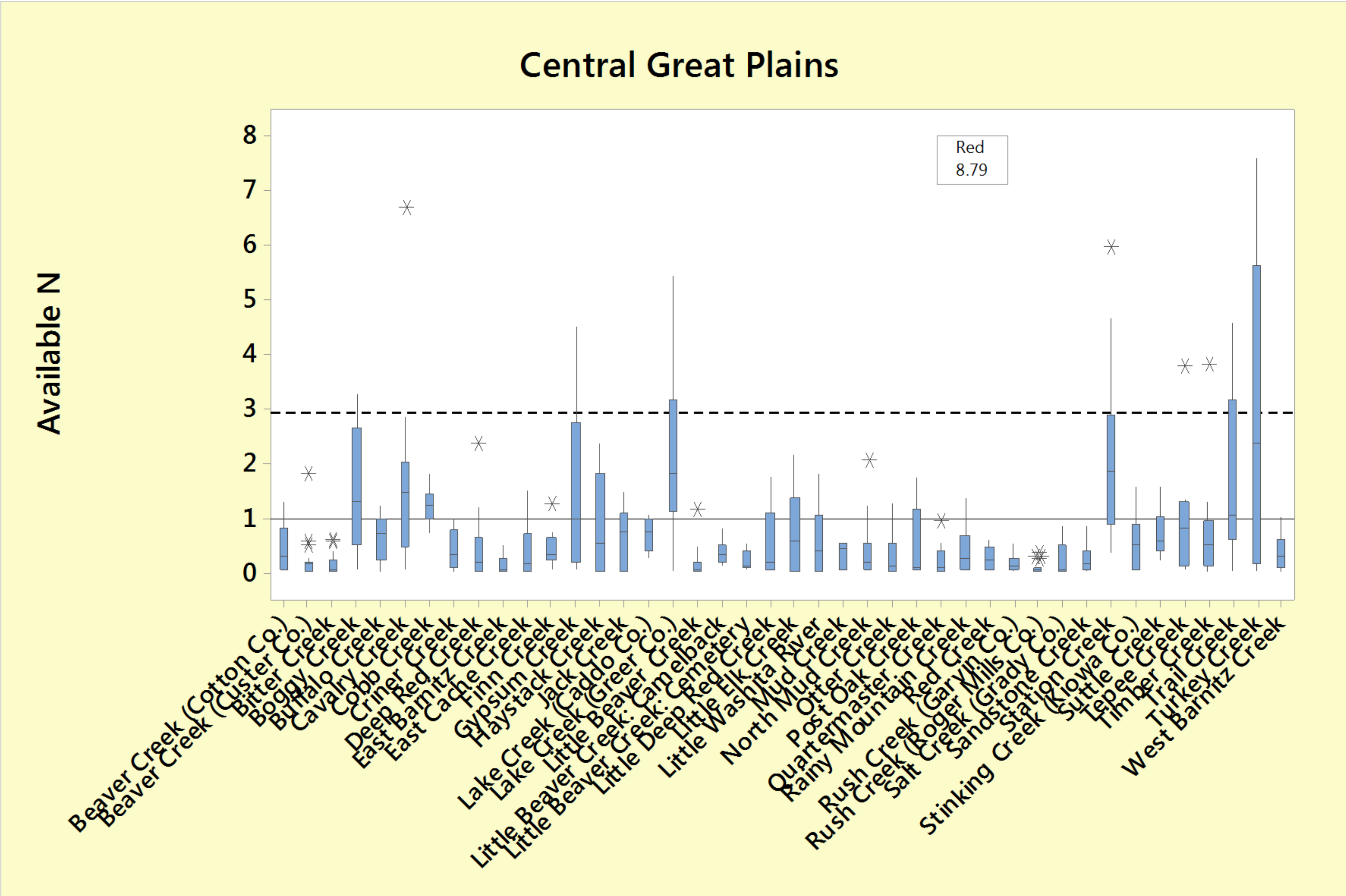

Southwest Tablelands
DO % Sat
200
150
100
50
pH
9
8
7
6
Turbidity
300
200
100
0
TSS
200
150
100
50
0
Fish Creek
North Elm Creek
Fish Creek
North Elm Creek

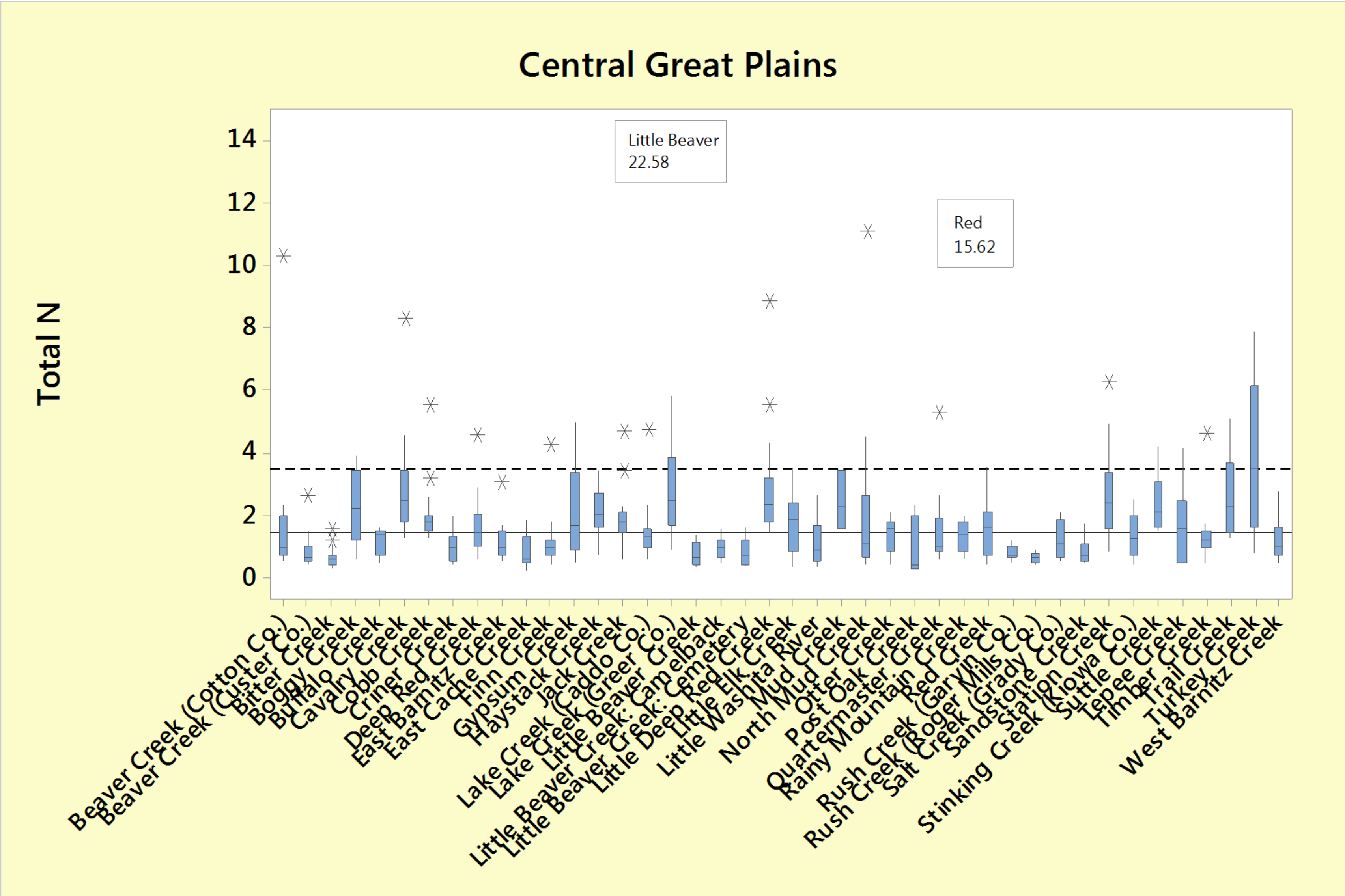

Wichita Mountains
Ortho P
0.03
0.02
0.01
Total P
0.08
0.06
0.04
0.02
0.00
Available N
2.0
1.5
1.0
0.5
0.0
Total N
2.5
2.0
1.5
1.0
0.5
Medicine Creek
Medicine Creek

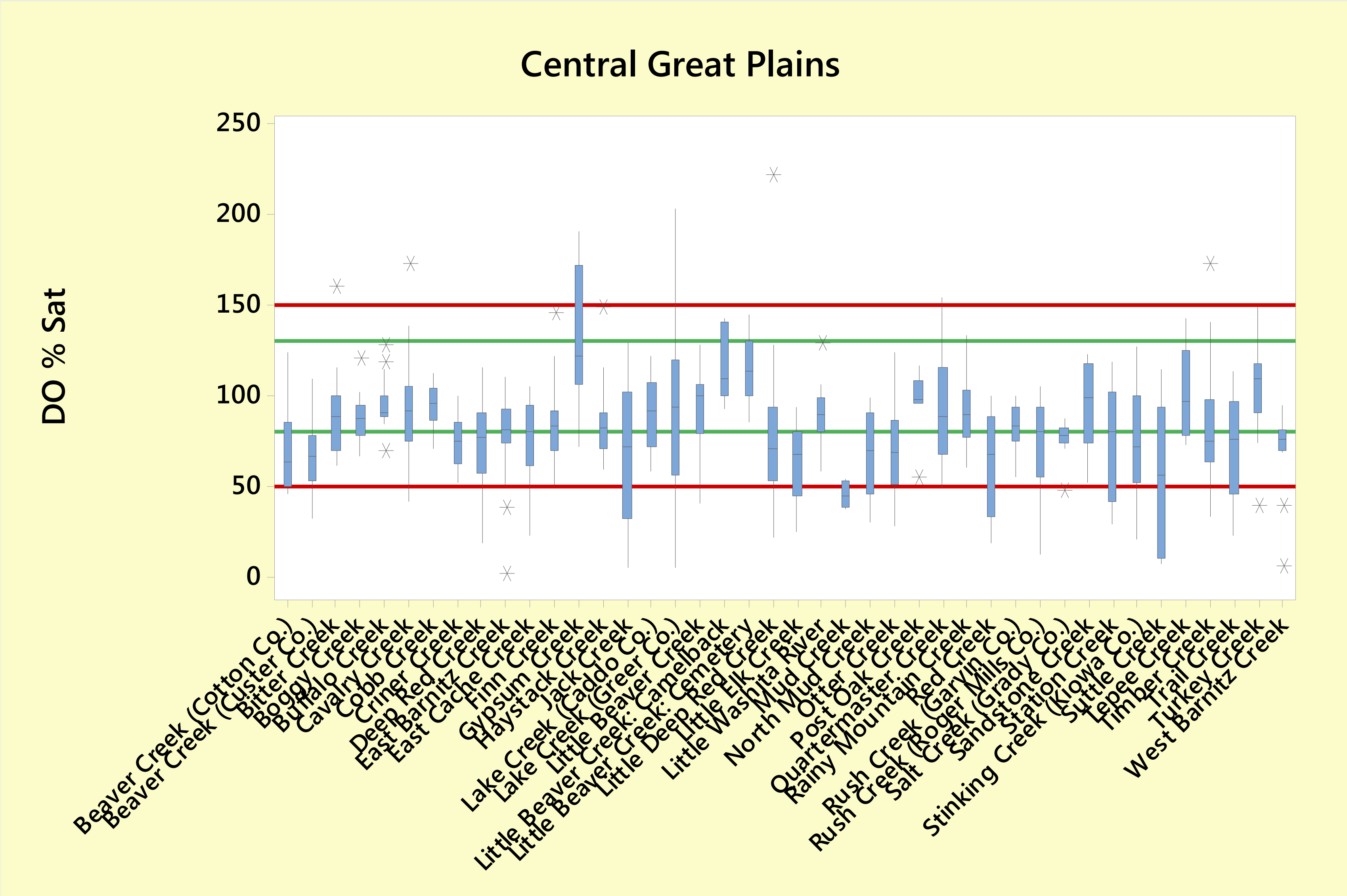

Wichita Mountains
DO % Sat
150
100
50
130
80
50
pH
8.50
8.25
8.00
7.75
7.50
Turbidity
16
12
8
4
0
TSS
15.0
12.5
10.0
7.5
5.0
Medicine Creek
Medicine Creek

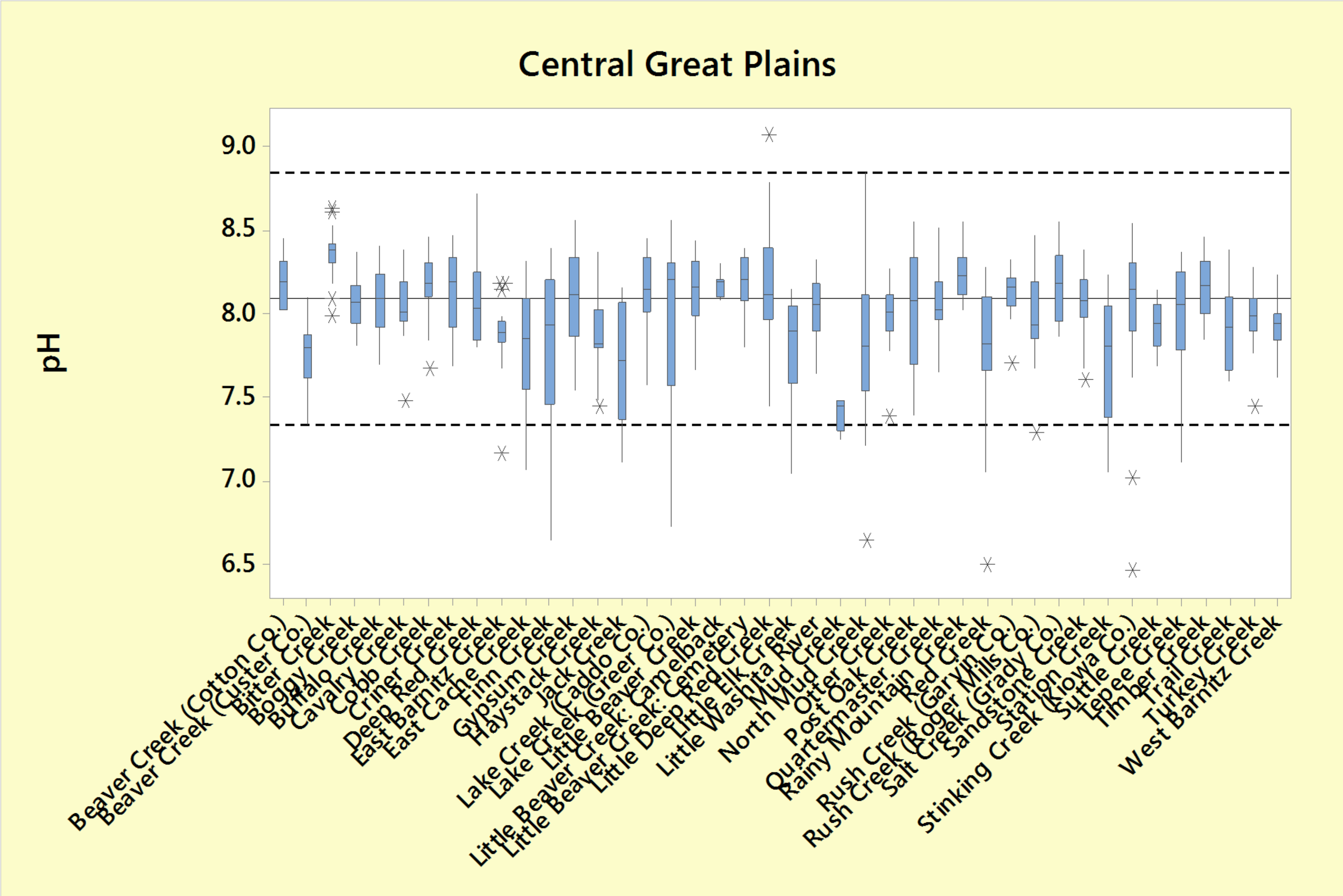

Central Great Plains
Ortho P
1.0
0.8
0.6
0.4
0.2
0.0
Little Beaver 0.925
N Mud 1.06
Suttle 0.886
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Bamitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Bamitz Creek

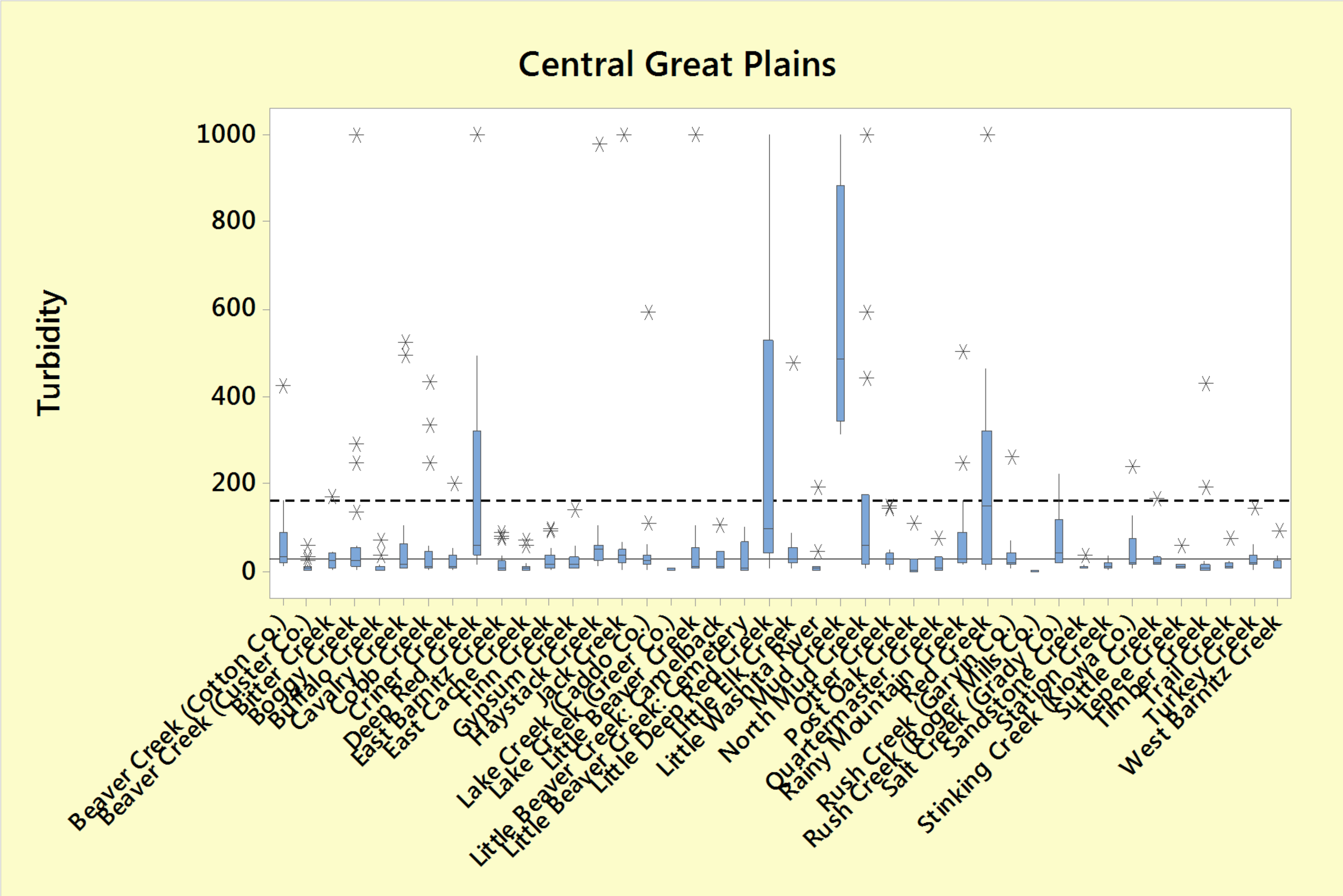

Central Great Plains
Total P
2.0
1.5
1.0
0.5
0.0
Little Beaver 3.886
N Mud 2.87
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek


Central Great Plains
Available N
Red
8.79
0
1
2
3
4
5
6
7
8
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek


Central Great Plains
Total N
14
12
10
8
6
4
2
0
Little Beaver
22.58
Red
15.62
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek


Central Great Plains
DO % Sat
250
200
150
100
50
0
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek


Central Great Plains
pH
9.0
8.5
8.0
7.5
7.0
6.5
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek


Central Great Plains
Turbidity
1000
800
600
400
200
0
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek

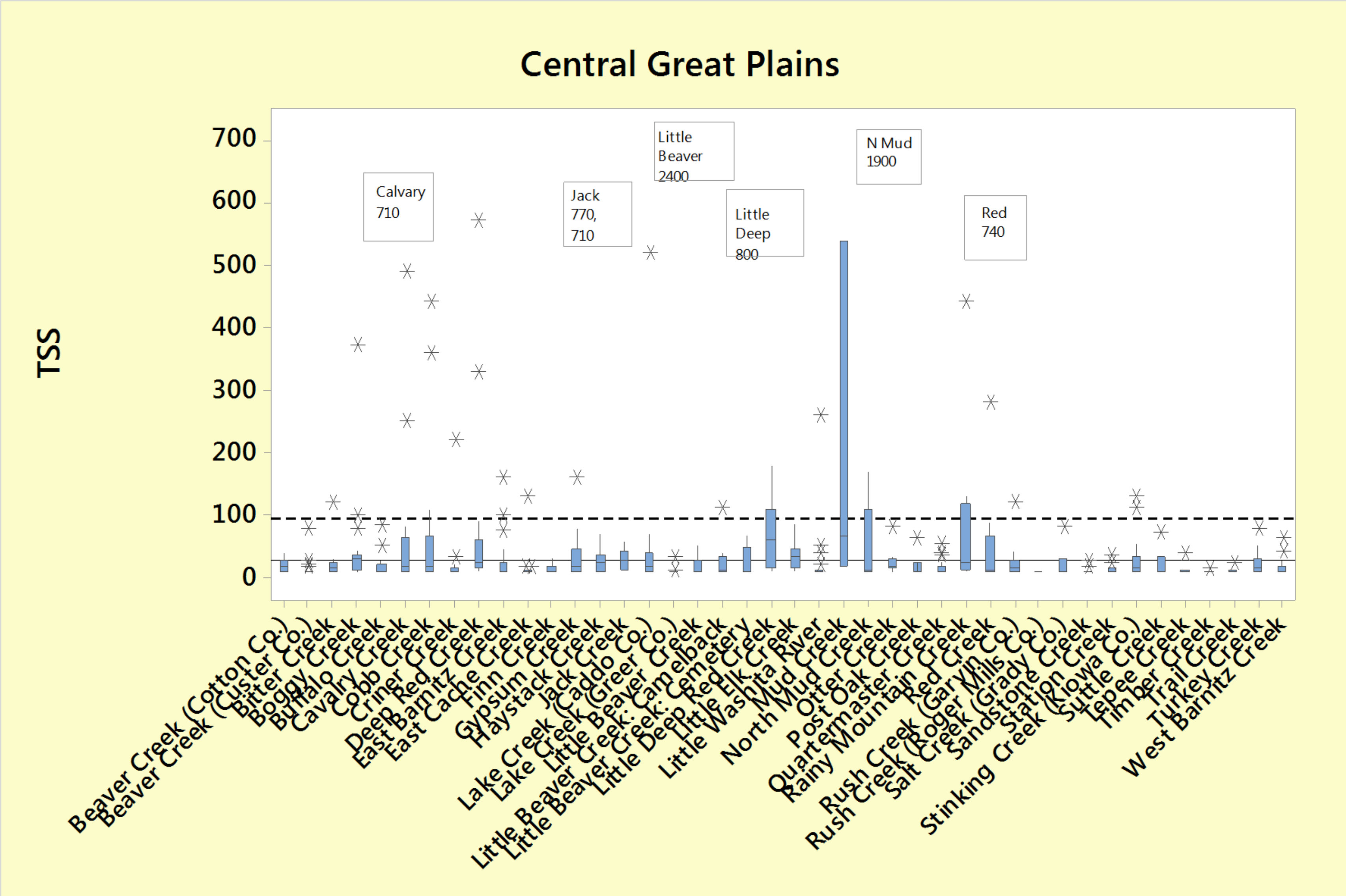

Central Great Plains
TSS
0
100
200
300
400
500
600
700
Calvary 710
Jack 770, 710
Little Beaver 2400
Little Deep 800
N Mud 1900
Red 740
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback
Little Beaver Creek: Cemetery
Little Deep Red Creek
Little Elk Creek
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek

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

All of the parameters had some streams that increased significantly and some that decreased significantly. Ammonia was increased in nine streams and other forms of nitrogen were significantly increased in 34 streams while only six streams showed significant decreases in nitrogen. Alkalinity and/or hardness was significantly higher in 22 streams and reduced in three streams. Seventeen streams exhibited increased salt concentrations (sulfate, chloride, or total dissolved solids) while three showed lower salt concentrations.

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

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
OK310830-03-0190C	Beaver Creek	Dissolved Oxygen	2004-2006	21	9.327	0.003 *	0.009 *	
			2009-2011	21	9.99			
			2014-2016	21	6.867			
		DO % Saturation	2004-2006	21	91.28	0.000 *	0.000 *	
			2009-2011	21	96.17			
			2014-2016	21	66.17			
		Ammonia	2004-2006	20	0.0587	0.023 *	0.007 *	
			2009-2011	20	0.0609			
			2014-2016	6	0.311			
		Nitrate	2004-2006	20	0.249	0.002 *	0.013 *	
			2009-2011	20	0.2295			
			2014-2016	19	0.1079			
		TKN	2004-2006	20	0.468		0.049 *	
			2009-2011	20	0.7315			
			2014-2016	19	0.7			
		Ortho-phosphorus	2004-2006	20	0.03955	0.011 *	0.012 *	
			2009-2011	20	0.0301			
			2014-2016	19	0.0622			
		Total phosphorus	2004-2006	20	0.0841	0.033 *	0.042 *	
			2009-2011	20	0.06625			
			2014-2016	19	0.1144			
		Sulfate	2004-2006	20	1524.4	0.099		
			2009-2011	20	1708.1			
			2014-2016	19	1526.2			
		Alkalinity	2004-2006	21	194.48	0.000 *	0.002 *	
			2009-2011	20	163.85			
			2014-2016	21	213.52			
OK310830-03-0100C	Boggy Creek	Dissolved Oxygen	2004-2006	20	9.135	0.065		
			2009-2011	21	10.174			
			2014-2016	20	8.504			
		DO % Saturation	2004-2006	20	88.71	0.018 *	0.039 *	
			2009-2011	21	99.15			
			2014-2016	20	87.54			
		Sulfate	2004-2006	20	663.8		0.020 *	
			2009-2011	20	867.5			
			2014-2016	19	854.6			
		TDS	2004-2006	20	1275.3	0.009 *	0.002 *	
			2009-2011	20	1390.1			
			2014-2016	19	1687.4			
		Conductivity	2004-2006	20	1733	0.005 *	0.015 *	
			2009-2011	19	1691.8			
			2014-2016	20	2075			
OK311510-02-0090D	Buffalo Creek	Ammonia	2004-2006	20	0.02425	0.019 *	0.002 *	
			2009-2011	20	0.03645			
			2014-2016	6	0.146			
		Nitrate	2004-2006	20	0.739	0.000 *	0.000 *	
			2009-2011	20	0.8785			
			2014-2016	19	0.4737			
		Nitrite	2004-2006	20	0.024	0.028 *	0.007 *	
			2009-2011	19	0.02474			
			2014-2016	19	0.1305			
		Chloride	2004-2006	20	519.7	0.001 *	0.000 *	
			2009-2011	20	355.8			
			2014-2016	19	741.6			
		Sulfate	2004-2006	20	1018.1	0.004 *	0.003 *	
			2009-2011	20	914.8			
			2014-2016	19	1171.4			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Buffalo Creek (continued)	TDS	2004-2006	20	2650.4	0.000 *	0.000 *	
			2009-2011	20	2039.1			
			2014-2016	19	3011			
		Alkalinity	2004-2006	21	228.81		0.063	
			2009-2011	21	260.05			
			2014-2016	21	262.86			
		Hardness	2004-2006	20	1243.5	0.000 *	0.000 *	
			2009-2011	20	1010.5			
			2014-2016	20	1404.5			
		pH	2004-2006	21	8.1143	0.042 *	0.074	
			2009-2011	21	8.1995			
			2014-2016	21	8.0838			
OK310800-03-0010F	Caddo Creek	Dissolved Oxygen	2004-2006	21	7.247		0.055	
			2009-2011	21	7.978			
			2014-2016	20	9.06			
		DO % Saturation	2004-2006	21	75.79	0.004 *	0.000 *	
			2009-2011	21	79.69			
			2014-2016	20	95.42			
		Ammonia	2004-2006	20	1.782		0.001 *	
			2009-2011	20	0.1296			
			2014-2016	5	0.0376			
		Nitrite	2004-2006	20	0.134		0.005 *	
			2009-2011	19	0.02316			
			2014-2016	18	0.0689			
		TKN	2004-2006	20	2.001		0.006 *	
			2009-2011	20	0.701			
			2014-2016	18	0.922			
		Chloride	2004-2006	20	101.51		0.037 *	
			2009-2011	20	62.68			
			2014-2016	18	78.7			
		Sulfate	2004-2006	20	154.25		0.000 *	
			2009-2011	20	43.53			
			2014-2016	18	46.96			
		TDS	2004-2006	20	588.3	0.036 *	0.000 *	
			2009-2011	20	335.9			
			2014-2016	18	399.4			
		Conductivity	2004-2006	21	973.4	0.040 *	0.000 *	
			2009-2011	21	523.5			
			2014-2016	20	662.7			
		Hardness	2004-2006	20	215.3	0.099		
			2009-2011	20	191.6			
			2014-2016	19	225.1			
		pH	2004-2006	19	7.562		0.012 *	
			2009-2011	21	7.9962			
			2014-2016	19	7.9758			
OK310830-03-0070D	Cavalry Creek	TKN	2004-2006	9	0.657		0.061	
			2009-2011	20	0.981			
			2014-2016	19	1.265			
		Chloride	2004-2006	9	70.84		0.028 *	
			2009-2011	20	95.78			
			2014-2016	19	98.63			
		Ortho-phosphorus	2004-2006	9	0.1044	0.037 *		
			2009-2011	20	0.0501			
			2014-2016	19	0.1184			
		Total phosphorus	2004-2006	9	0.1631	0.065		
			2009-2011	20	0.1113			
			2014-2016	19	0.2021			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Cavalry Creek (continued)	Sulfate	2004-2006	9	1121.3	0.000 *	0.000 *	
			2009-2011	20	1740.9			
			2014-2016	19	1246.5			
		TDS	2004-2006	9	1970.7	0.022 *	0.019 *	
			2009-2011	20	2543.6			
			2014-2016	19	2174			
		Alkalinity	2004-2006	21	225.2	0.004 *	0.008 *	
			2009-2011	20	215.4			
			2014-2016	20	282.9			
		Conductivity	2004-2006	21	2105.5	0.023 *	0.001 *	
			2009-2011	19	2825.3			
			2014-2016	20	2472			
		Hardness	2004-2006	21	1422.7	0.029 *	0.057	
			2009-2011	20	1784			
			2014-2016	19	1511			
		pH	2004-2006	21	7.8925	0.077	0.066	
			2009-2011	21	7.9433			
			2014-2016	20	8.0555			
OK310800-02-0190D	Chigley Sandy Creek	DO % Saturation	2004-2006	19	98.2		0.015 *	
			2009-2011	20	83.77			
			2014-2016	19	74.77			
		Ammonia	2004-2006	20	0.01565		0.046 *	
			2009-2011	20	0.02335			
			2014-2016	5	0.03			
		Nitrate	2004-2006	20	0.342		0.008 *	
			2009-2011	20	0.2185			
			2014-2016	18	0.2006			
		Nitrite	2004-2006	20	0.02	0.050	0.020 *	
			2009-2011	19	0.02			
			2014-2016	18	0.0428			
		Ortho-phosphorus	2004-2006	20	0.0395	0.032 *		
			2009-2011	20	0.02695			
			2014-2016	18	0.03933			
		Chloride	2004-2006	20	30.51		0.006 *	
			2009-2011	20	46.06			
			2014-2016	18	52.99			
		Sulfate	2004-2006	20	13.52	0.018 *	0.020 *	
			2009-2011	20	14.435			
			2014-2016	18	17.567			
		TDS	2004-2006	20	336.6		0.056	
			2009-2011	20	386.6			
			2014-2016	18	406.7			
		Alkalinity	2004-2006	19	242.7		0.077	
			2009-2011	20	274.9			
			2014-2016	19	287.63			
		Conductivity	2004-2006	19	530.4		0.015 *	
			2009-2011	20	635.3			
			2014-2016	18	697.4			
		pH	2004-2006	17	7.498		0.060	
			2009-2011	19	7.7763			
			2014-2016	19	7.8316			
OK310830-06-0050K	Cobb Creek	DO % Saturation	2004-2006	21	85.21		0.045 *	
			2009-2011	21	88.94			
			2014-2016	22	94.55			
		TKN	2004-2006	20	0.2147		0.009 *	
			2009-2011	20	0.565			
			2014-2016	20	0.792			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Cobb Creek (Continued)	Alkalinity	2004-2006	20	208.3	0.011 *	0.010 *	
			2009-2011	21	197.9			
			2014-2016	21	235.05			
		Hardness	2004-2006	20	422.8	0.001 *	0.000 *	
			2009-2011	20	443			
			2014-2016	21	645.7			
		pH	2004-2006	21	8.0357	0.056	0.053	
			2009-2011	21	8.04			
			2014-2016	22	8.1782			
OK311310-03-0010D	Deep Red Creek	Nitrite	2004-2006	20	0.022	0.010 *	0.001 *	
			2009-2011	20	0.0255			
			2014-2016	16	0.1875			
		TKN	2004-2006	20	0.726		0.002 *	
			2009-2011	20	0.954			
			2014-2016	16	1.272			
OK310830-01-0030G	Delaware Creek	Dissolved Oxygen	2004-2006	23	9.96	0.044 *		
			2009-2011	21	11.058			
			2014-2016	21	8.93			
		DO % Saturation	2004-2006	23	101.09	0.005 *	0.023 *	
			2009-2011	21	117.32			
			2014-2016	21	91.33			
		Nitrite	2004-2006	20	0.02	0.005 *	0.000 *	
			2009-2011	19	0.02			
			2014-2016	20	0.0765			
		TKN	2004-2006	20	0.535	0.023 *	0.025 *	
			2009-2011	20	0.7605			
			2014-2016	20	0.5743			
		Sulfate	2004-2006	20	709.5	0.061	0.034 *	
			2009-2011	20	873.5			
			2014-2016	20	820.6			
		Turbidity	2004-2006	20	20.8	0.029 *		
			2009-2011	20	12.77			
			2014-2016	21	5.65			
		Alkalinity	2004-2006	19	192.5	0.039 *	0.006 *	
			2009-2011	20	212.8			
			2014-2016	21	269.1			
		Hardness	2004-2006	20	1069.1	0.002 *	0.000 *	
			2009-2011	19	1122.1			
			2014-2016	20	1520			
OK310830-03-0210C	East Barnitz Creek	Dissolved Oxygen	2004-2006	21	9.723	0.003 *	0.005 *	
			2009-2011	21	10.19			
			2014-2016	20	7.426			
		DO % Saturation	2004-2006	21	96.76	0.001 *	0.001 *	
			2009-2011	21	99.74			
			2014-2016	20	76.74			
		TKN	2004-2006	20	0.448		0.006 *	
			2009-2011	20	0.7405			
			2014-2016	19	0.939			
		Sulfate	2004-2006	20	1778.6	0.037 *	0.066	
			2009-2011	20	1922			
			2014-2016	19	1662			
		Alkalinity	2004-2006	20	193.55	0.014 *	0.021 *	
			2009-2011	20	162.75			
			2014-2016	20	204.3			
		Hardness	2004-2006	20	2059.7		0.033 *	
			2009-2011	20	1880.3			
			2014-2016	18	1879			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	East Barnitz Creek (Continued)	pH	2004-2006	21	7.9333	0.010 *	0.025 *	
			2009-2011	21	8.0443			
			2014-2016	20	7.875			
OK310810-02-0020D	Finn Creek	Dissolved Oxygen	2004-2006	21	6.257		0.044 *	
			2009-2011	21	7.906			
			2014-2016	19	8.432			
		DO % Saturation	2004-2006	21	61.59		0.002 *	
			2009-2011	22	76.24			
			2014-2016	19	84.6			
		Nitrite	2004-2006	20	0.028	0.035 *	0.010 *	
			2009-2011	19	0.03			
			2014-2016	18	0.095			
		TKN	2004-2006	20	0.303		0.006 *	
			2009-2011	20	0.559			
			2014-2016	18	0.732			
		Ortho-phosphorus	2004-2006	20	0.1651		0.100	
			2009-2011	20	0.097			
			2014-2016	18	0.1327			
		Total phosphorus	2004-2006	20	0.2268		0.057	
			2009-2011	19	0.1365			
			2014-2016	18	0.1669			
		Alkalinity	2004-2006	21	338.67		0.093	
			2009-2011	22	385.73			
			2014-2016	19	16.8			
		pH	2004-2006	20	7.719	0.081	0.027 *	
			2009-2011	21	8.0271			
			2014-2016	19	7.831			
OK311800-00-0130G	Fish Creek	Dissolved Oxygen	2004-2006	21	9.7	0.058		
			2009-2011	19	10.486			
			2014-2016	13	8.162			
		Nitrite	2004-2006	19	0.735	0.001 *		
			2009-2011	18	0.02			
			2014-2016	13	1.062			
		Ortho-phosphorus	2004-2006	19	0.172	0.050		
			2009-2011	20	0.0173			
			2014-2016	13	0.0405			
		Chloride	2004-2006	19	13614	0.068		
			2009-2011	20	4244			
			2014-2016	13	13307			
		TDS	2004-2006	19	64647	0.056		
			2009-2011	20	9497			
			2014-2016	13	28000			
		Turbidity	2004-2006	17	22.11	0.069	0.026 *	
			2009-2011	21	30.83			
			2014-2016	14	69.1			
		Alkalinity	2004-2006	18	124.53		0.019 *	
			2009-2011	20	172.91			
			2014-2016	14	161.4			
		Conductivity	2004-2006	18	33084	0.095		
			2009-2011	17	13880			
			2014-2016	14	34898			
		Hardness	2004-2006	19	4022	0.022 *	0.095	
			2009-2011	16	2967			
			2014-2016	12	4934			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
OK311600-01-0020F	Gypsum Creek	Nitrite	2004-2006	20	0.1935	0.017 *	0.021 *	
			2009-2011	20	0.02			
			2014-2016	15	0.481			
		TKN	2004-2006	20	0.408	0.086	0.005 *	
			2009-2011	20	0.7535			
			2014-2016	15	0.53			
		Ortho-phosphorus	2004-2006	20	0.0488		0.084	
			2009-2011	20	0.01525			
			2014-2016	15	0.0166			
		Chloride	2004-2006	20	3814		0.019 *	
			2009-2011	20	4787			
			2014-2016	15	4724			
		TDS	2004-2006	20	8810	0.008 *	0.002 *	
			2009-2011	19	9826			
			2014-2016	15	10787			
		TSS	2004-2006	20	101.3		0.088	
			2009-2011	20	22.6			
			2014-2016	15	35.5			
		Turbidity	2004-2006	19	69.41	0.066	0.051	
			2009-2011	21	12.43			
			2014-2016	16	27.02			
		Alkalinity	2004-2006	21	111.63		0.091	
			2009-2011	21	136.57			
			2014-2016	16	128.06			
		Conductivity	2004-2006	20	7066	0.001 *	0.000 *	
			2009-2011	21	14228			
			2014-2016	16	16068			
		Hardness	2004-2006	20	3051.7		0.004 *	
			2009-2011	21	3820.8			
			2014-2016	16	3853			
OK311800-00-0040D	Haystack Creek	Ammonia	2004-2006	20	0.0506	0.093		
			2009-2011	20	0.0221			
			2014-2016	5	0.0482			
		Nitrate	2004-2006	20	0.389	0.063		
			2009-2011	20	0.246			
			2014-2016	16	0.549			
		Nitrite	2004-2006	20	0.029	0.014 *	0.002 *	
			2009-2011	18	0.02			
			2014-2016	16	0.359			
		TKN	2004-2006	20	0.4925		0.005 *	
			2009-2011	20	0.9935			
			2014-2016	16	1.243			
		Sulfate	2004-2006	20	1400.7	0.077	0.098	
			2009-2011	20	1966.9			
			2014-2016	16	1416			
OK311100-02-0010M	Hickory Creek: HWY 775	DO % Saturation	2004-2006	21	89.02	0.073	0.056	
			2009-2011	22	99.8			
			2014-2016	16	90.14			
		Chloride	2004-2006	20	82.03	0.000 *	0.000 *	
			2009-2011	20	79.52			
			2014-2016	15	177.5			
		Ammonia	2004-2006	20	0.01765		0.073	
			2009-2011	20	0.0232			
			2014-2016	3	0.039			
		Nitrate	2004-2006	20	0.111	0.076		
			2009-2011	20	0.054			
			2014-2016	15	0.1187			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Hickory Creek: HWY 775 (Continued)	Nitrite	2004-2006	20	0.02		0.079	
			2009-2011	20	0.02			
			2014-2016	15	0.056			
		TKN	2004-2006	20	0.2095	0.039 *	0.002 *	
			2009-2011	20	0.3565			
			2014-2016	15	0.701			
		TDS	2004-2006	20	395.3	0.000 *	0.000 *	
			2009-2011	20	381.9			
			2014-2016	15	547.3			
		Conductivity	2004-2006	21	509.8	0.013 *	0.001 *	
			2009-2011	22	633.1			
			2014-2016	16	886.5			
OK311510-01-0040D	Lake Creek: Hwy 6, Greer Co.	Dissolved Oxygen	2004-2006	21	10.8	0.030 *	0.044 *	
			2009-2011	19	11.336			
			2014-2016	18	8.792			
		DO % Saturation	2004-2006	21	108.03	0.041 *	0.071	
			2009-2011	19	118.98			
			2014-2016	18	89.6			
		Nitrate	2004-2006	19	1.305	0.023 *	0.058	
			2009-2011	20	0.961			
			2014-2016	18	1.946			
		Nitrite	2004-2006	19	0.0426	0.002	0.001	
			2009-2011	18	0.035			
			2014-2016	18	0.13			
		Sulfate	2004-2006	19	386.8	0.043 *	0.065	
			2009-2011	20	441.6			
			2014-2016	18	268.1			
		Alkalinity	2004-2006	20	251.2	0.096		
			2009-2011	20	260			
			2014-2016	19	284.68			
		pH	2004-2006	21	8.221		0.089	
			2009-2011	21	8.1848			
			2014-2016	19	7.997			
OK311210-00-0050D	Little Beaver Creek	DO % Saturation	2004-2006	21	78.51		0.083	
			2009-2011	21	86.3			
			2014-2016	18	92.29			
		Ammonia	2004-2006	20	0.04005	0.072	0.038 *	
			2009-2011	20	0.0416			
			2014-2016	5	0.243			
		Nitrate	2004-2006	20	0.2215	0.038 *	0.053	
			2009-2011	20	0.1925			
			2014-2016	16	0.0813			
		Sulfate	2004-2006	20	166.73		0.000 *	
			2009-2011	20	230.09			
			2014-2016	16	267.6			
		Alkalinity	2004-2006	20	233.95	0.008 *	0.045 *	
			2009-2011	20	278.4			
			2014-2016	18	232			
		Hardness	2004-2006	20	409.3		0.044 *	
			2009-2011	20	507.4			
			2014-2016	18	455.4			
OK311310-03-0040E	Little Deep Red Creek	Nitrite	2004-2006	17	0.02	0.086	0.030 *	
			2009-2011	19	0.0574			
			2014-2016	17	0.2188			
		TKN	2004-2006	17	1.379	0.017 *	0.022 *	
			2009-2011	19	1.146			
			2014-2016	17	2.313			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Little Deep Red Creek (Continued)	Ortho-phosphorus	2004-2006	17	0.4884		0.054	
			2009-2011	19	0.1109			
			2014-2016	17	0.1761			
		Total phosphorus	2004-2006	17	0.591	0.016 *	0.091	
			2009-2011	18	0.1951			
			2014-2016	17	0.3782			
		Chloride	2004-2006	17	1187.4	0.011 *	0.020 *	
			2009-2011	19	1633.7			
			2014-2016	17	842			
		Sulfate	2004-2006	17	486.5	0.005 *	0.017 *	
			2009-2011	19	677.8			
			2014-2016	17	340.3			
		TDS	2004-2006	17	3033	0.021 *	0.042 *	
			2009-2011	18	3468			
			2014-2016	17	1995			
		Turbidity	2004-2006	16	64	0.012 *	0.004 *	
			2009-2011	20	72			
			2014-2016	18	273.4			
		Alkalinity	2004-2006	18	316.7	0.062		
			2009-2011	20	279.9			
			2014-2016	18	223.6			
		Conductivity	2004-2006	17	7812	0.045 *		
			2009-2011	20	5482			
			2014-2016	18	3504			
		Hardness	2004-2006	17	923	0.011 *	0.021 *	
			2009-2011	19	1145			
			2014-2016	17	624			
		pH	2004-2006	17	7.999	0.039 *		
			2009-2011	20	7.9685			
			2014-2016	18	8.1894			
OK311500-03-0040D	Little Elk Creek	Dissolved Oxygen	2004-2006	21	9.703	0.075	0.014 *	
			2009-2011	19	8.511			
			2014-2016	17	6.825			
		DO % Saturation	2004-2006	21	96.91	0.008 *	0.001 *	
			2009-2011	19	85.18			
			2014-2016	17	64.98			
		Ammonia	2004-2006	20	0.03065		0.078	
			2009-2011	20	0.07335			
			2014-2016	4	0.052			
		Nitrite	2004-2006	20	0.033	0.069	0.038 *	
			2009-2011	18	0.0394			
			2014-2016	16	0.0875			
		TKN	2004-2006	20	0.465		0.005 *	
			2009-2011	20	0.7555			
			2014-2016	16	0.966			
		Ortho-phosphorus	2004-2006	20	0.0603	0.018 *	0.014 *	
			2009-2011	20	0.0665			
			2014-2016	16	0.1509			
		Total phosphorus	2004-2006	20	0.1328	0.045 *		
			2009-2011	19	0.1278			
			2014-2016	16	0.252			
		Chloride	2004-2006	20	118.7	0.019 *	0.008 *	
			2009-2011	20	131.1			
			2014-2016	16	189.1			
		Sulfate	2004-2006	20	284.8		0.098	
			2009-2011	20	358			
			2014-2016	16	397.9			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Little Elk Creek (Continued)	TDS	2004-2006	20	904.3	0.030 *	0.028 *	
			2009-2011	20	937			
			2014-2016	16	1192.5			
		TSS	2004-2006	20	86	0.017 *		
			2009-2011	20	19.05			
			2014-2016	16	33.88			
		Alkalinity	2004-2006	20	272.8	0.065	0.045 *	
			2009-2011	20	275.8			
			2014-2016	17	330.8			
		pH	2004-2006	21	7.86	0.016 *		
			2009-2011	21	8.0176			
			2014-2016	17	7.7788			
OK311300-04-0060H	Medicine Creek	Ammonia	2004-2006	17	0.015	0.066	0.029 *	
			2009-2011	20	0.0192			
			2014-2016	5	0.0612			
		Nitrate	2004-2006	17	0.06	0.042 *	0.029 *	
			2009-2011	20	0.043			
			2014-2016	16	0.271			
		TKN	2004-2006	17	0.3412	0.326		
			2009-2011	20	0.267			
			2014-2016	16	0.3845			
		Chloride	2004-2006	17	25.48	0.050	0.054	
			2009-2011	20	20.5			
			2014-2016	16	46			
OK310800-01-0190G	Mill Creek: Lower	Ammonia	2004-2006	20	0.0184		0.002 *	
			2009-2011	20	0.0335			
			2014-2016	4	0.0542			
		Nitrite	2004-2006	20	0.02	0.082	0.045 *	
			2009-2011	19	0.02			
			2014-2016	17	0.02412			
		TKN	2004-2006	20	0.1975		0.013 *	
			2009-2011	20	0.334			
			2014-2016	17	0.3739			
		TSS	2004-2006	20	31.8		0.037 *	
			2009-2011	20	22.5			
			2014-2016	17	13.82			
		pH	2004-2006	19	7.529		0.001 *	
			2009-2011	21	8.0943			
			2014-2016	19	8.1805			
		Conductivity	2004-2006	21	442	0.058		
			2009-2011	21	419.3			
			2014-2016	19	477.9			
		Hardness	2004-2006	20	231.63	0.063		
			2009-2011	20	217.55			
			2014-2016	18	246.3			
OK311100-04-0010G	Mud Creek	Nitrate	2004-2006	9	0.182	0.006 *		
			2009-2011	20	0.094			
			2014-2016	3	0.313			
		Nitrite	2004-2006	9	0.02444	0.006 *		
			2009-2011	20	0.02			
			2014-2016	3	0.02333			
		TKN	2004-2006	9	0.5111	0.001 *	0.000 *	
			2009-2011	20	1.0195			
			2014-2016	3	2.09			
		Ortho-phosphorus	2004-2006	9	0.0987	0.091	0.087	
			2009-2011	20	0.157			
			2014-2016	3	0.32			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Mud Creek (Continued)	Total phosphorus	2004-2006	9	0.1667	0.012 *	0.008 *	
			2009-2011	20	0.2381			
			2014-2016	3	0.548			
		Chloride	2004-2006	9	86.4	0.054	0.078	
			2009-2011	20	132.9			
			2014-2016	3	12.4			
		Sulfate	2004-2006	9	38.58	0.039 *	0.072	
			2009-2011	20	49.82			
			2014-2016	3	6.37			
		Turbidity	2004-2006	9	78	0.000 *	0.000 *	
			2009-2011	19	93.1			
			2014-2016	4	573			
		Alkalinity	2004-2006	10	227.2	0.007 *	0.026 *	
			2009-2011	20	235.9			
			2014-2016	4	68.8			
		Conductivity	2004-2006	10	796	0.007 *	0.017 *	
			2009-2011	20	970			
			2014-2016	4	182.7			
		Hardness	2004-2006	9	242.5	0.017 *	0.040 *	
			2009-2011	20	284.6			
			2014-2016	4	93.5			
		pH	2004-2006	10	7.85	0.008 *	0.021 *	
			2009-2011	21	7.8362			
			2014-2016	4	7.41			
OK311800-00-0170G	North Elm Creek	Chloride	2009-2011	18	5397	0.088		
			2014-2016	18	9336			
		Nitrite	2009-2011	17	0.02	0.010 *		
			2014-2016	18	0.939			
		TDS	2009-2011	18	9442	0.028 *		
			2014-2016	18	18961			
		Conductivity	2009-2011	14	13637		0.037 *	
			2014-2016	20	27169			
		Hardness	2009-2011	17	3157		0.040 *	
			2014-2016	18	4543			
		pH	2009-2011	19	7.9389		0.002 *	
			2014-2016	19	7.328			
OK310800-01-0240P	Oil Creek	pH	2004-2006	19	7.65		0.005 *	
			2009-2011	21	7.9305			
			2014-2016	21	7.9819			
OK311500-01-0080F	Otter Creek	Nitrate	2004-2006	19	0.3884	0.017 *	0.030 *	
			2009-2011	20	0.639			
			2014-2016	16	0.2206			
		Nitrite	2004-2006	19	0.02842	0.045 *	0.026 *	
			2009-2011	20	0.024			
			2014-2016	16	0.09			
		Chloride	2004-2006	19	403.2	0.002 *	0.004 *	
			2009-2011	20	282.8			
			2014-2016	16	690			
		TDS	2004-2006	19	1128.2	0.001 *	0.002 *	
			2009-2011	19	796.6			
			2014-2016	16	1751			
		TSS	2004-2006	19	104		0.029 *	
			2009-2011	20	21.9			
			2014-2016	16	24.5			
		Conductivity	2004-2006	19	1716	0.002 *	0.003 *	
			2009-2011	21	1366			
			2014-2016	17	2828			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Otter Creek (Continued)	Hardness	2004-2006	19	389.3	0.001 *	0.001 *	
			2009-2011	20	316.6			
			2014-2016	17	624.4			
OK310800-01-0120G	Pennington Creek	Total phosphorus	2004-2006	20	0.0548		0.009 *	
			2009-2011	19	0.02005			
			2014-2016	18	0.02028			
		Sulfate	2004-2006	20	7.892	0.040 *		
			2009-2011	20	8.71			
			2014-2016	18	7.15			
		Alkalinity	2004-2006	21	214.57	0.047 *	0.085	
			2009-2011	21	245.05			
			2014-2016	19	214.9			
		pH	2004-2006	19	7.873		0.062	
			2009-2011	21	8.3129			
			2014-2016	20	8.261			
OK310840-01-0060B	Quartermaster Creek	Dissolved Oxygen	2004-2006	19	10.459	0.008 *	0.015 *	
			2009-2011	19	11.78			
			2014-2016	21	8.883			
		DO % Saturation	2004-2006	19	106.88	0.028 *		
			2009-2011	18	115.76			
			2014-2016	21	92.61			
		Ammonia	2004-2006	9	0.0846	0.083		
			2009-2011	20	0.0714			
			2014-2016	6	0.1555			
		Nitrate	2004-2006	9	0.3322	0.062	0.061	
			2009-2011	19	0.2979			
			2014-2016	20	0.1535			
		TKN	2004-2006	9	0.5022		0.083	
			2009-2011	20	1.031			
			2014-2016	20	1.236			
		Sulfate	2004-2006	9	2233.1	0.020 *	0.037 *	
			2009-2011	20	2568			
			2014-2016	20	2080			
		pH	2004-2006	20	7.8555		0.003 *	
			2009-2011	21	8.0795			
			2014-2016	21	8.0586			
OK310830-02-0060G	Rainy Mountain Creek	Nitrite	2004-2006	20	0.023	0.051	0.021 *	
			2009-2011	18	0.02			
			2014-2016	16	0.0981			
		Hardness	2004-2006	20	758.1	0.003 *	0.004 *	
			2009-2011	19	666.1			
			2014-2016	16	1144			
		pH	2004-2006	22	8.0755	0.078	0.026 *	
			2009-2011	20	8.153			
			2014-2016	18	8.2494			
OK311100-01-0290D	Red Creek	DO % Saturation	2004-2006	21	81.49		0.024 *	
			2009-2011	21	59.87			
			2014-2016	19	61.68			
		Nitrite	2004-2006	20	0.0235	0.097	0.039 *	
			2009-2011	20	0.028			
			2014-2016	18	0.0522			
		TKN	2004-2006	20	0.587		0.009 *	
			2009-2011	20	1.2395			
			2014-2016	18	1.588			
		Sulfate	2004-2006	20	17.95	0.074		
			2009-2011	20	14.26			
			2014-2016	18	26.99			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Red Creek (Continued)	TDS	2004-2006	20	567.8	0.034 *	0.084	
			2009-2011	20	415.7			
			2014-2016	18	649			
		Turbidity	2004-2006	16	61.1		0.048 *	
			2009-2011	19	121			
			2014-2016	18	207.2			
		Alkalinity	2004-2006	21	216.76		0.099	
			2009-2011	21	145.52			
			2014-2016	19	184.8			
OK310810-01-0090G	Rush Creek (Garvin Co.)	Nitrite	2004-2006	19	0.02158		0.074	
			2009-2011	19	0.02526			
			2014-2016	17	0.0694			
		TKN	2004-2006	19	0.3088		0.000 *	
			2009-2011	20	0.538			
			2014-2016	17	0.6577			
		Ortho-phosphorus	2004-2006	19	0.08558		0.074	
			2009-2011	20	0.0305			
			2014-2016	17	0.04571			
		TSS	2004-2006	19	218.5		0.052	
			2009-2011	20	51.9			
			2014-2016	17	25			
OK310810-03-0080G	Salt Creek	Nitrite	2004-2006	20	0.02	0.003 *	0.000 *	
			2009-2011	19	0.02			
			2014-2016	18	0.0778			
		pH	2004-2006	19	7.827		0.071	
			2009-2011	21	8.1424			
			2014-2016	19	8.0053			
OK310840-02-0020C	Sandstone Creek	Nitrate	2004-2006	20	0.384		0.004 *	
			2009-2011	20	0.18			
			2014-2016	12	0.2408			
		Nitrite	2004-2006	20	0.02	0.069	0.033 *	
			2009-2011	19	0.02			
			2014-2016	12	0.025			
		TKN	2004-2006	20	0.271		0.001 *	
			2009-2011	20	0.4755			
			2014-2016	12	0.5799			
		Total phosphorus	2004-2006	20	0.07525		0.059	
			2009-2011	19	0.04895			
			2014-2016	12	0.04225			
		Chloride	2004-2006	20	44.84		0.027 *	
			2009-2011	20	50.64			
			2014-2016	12	55.51			
		Sulfate	2004-2006	20	935.6		0.002 *	
			2009-2011	20	1327.4			
			2014-2016	12	1466			
		TDS	2004-2006	20	1729.7		0.038 *	
			2009-2011	20	2039.7			
			2014-2016	12	2263			
		TSS	2004-2006	20	48.8		0.001 *	
			2009-2011	20	16.3			
			2014-2016	12	11.92			
		Turbidity	2004-2006	19	46.5	0.067	0.060	
			2009-2011	20	21.86			
			2014-2016	13	10.56			
		Alkalinity	2004-2006	20	269.4	0.004 *	0.032 *	
			2009-2011	19	263.37			
			2014-2016	13	320.4			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Sandstone Creek (Continued)	Hardness	2004-2006	19	1155.6		0.007 *	
			2009-2011	18	1369.7			
			2004-2006	19	1155.6			
OK311800-00-0060G	Station Creek	Dissolved Oxygen	2004-2006	22	10.1		0.012 *	
			2009-2011	19	8.045			
			2014-2016	19	7.727			
		DO % Saturation	2004-2006	21	100.94		0.013 *	
			2009-2011	19	81.05			
			2014-2016	19	75			
		Ammonia	2004-2006	20	0.0345	0.006 *	0.001 *	
			2009-2011	20	0.04565			
			2014-2016	6	0.1107			
		Nitrite	2004-2006	20	0.031	0.049 *	0.021 *	
			2009-2011	18	0.02			
			2014-2016	19	0.261			
		TKN	2004-2006	20	0.4515	0.020 *	0.001 *	
			2009-2011	20	0.8555			
			2014-2016	19	0.5812			
		Chloride	2004-2006	20	568.4	0.009 *	0.000 *	
			2009-2011	20	1068.9			
			2014-2016	19	711.6			
		Sulfate	2004-2006	20	1758.4	0.078	0.007 *	
			2009-2011	20	2249.5			
			2014-2016	19	2012			
		Turbidity	2004-2006	20	21.52	0.046 *		
			2009-2011	21	26.9			
			2014-2016	20	14.52			
		Hardness	2004-2006	20	2190.6	0.066	0.069	
			2009-2011	16	2117			
			2014-2016	20	2518			
OK310830-04-0030K	Stinking Creek (Caddo)	Dissolved Oxygen	2004-2006	21	7.469		0.091	
			2009-2011	19	9.546			
			2014-2016	20	8.799			
		DO % Saturation	2004-2006	21	70.38	0.081	0.000 *	
			2009-2011	19	101.77			
			2014-2016	20	92.63			
		Nitrite	2004-2006	19	0.02	0.080	0.039 *	
			2009-2011	17	0.02			
			2014-2016	19	0.02421			
		TKN	2004-2006	19	0.4026		0.000 *	
			2009-2011	18	0.6194			
			2014-2016	19	0.6657			
		Chloride	2004-2006	19	76.4	0.077		
			2009-2011	18	42.48			
			2014-2016	19	59.35			
		TDS	2004-2006	19	2440.7	0.063		
			2009-2011	18	2236.1			
			2014-2016	19	2495			
		Alkalinity	2004-2006	19	232.1	0.004 *	0.001 *	
			2009-2011	19	245.42			
			2014-2016	20	287.9			
		Conductivity	2004-2006	20	2718.1		0.036 *	
			2009-2011	19	2442.7			
			2014-2016	20	2502.2			
		Hardness	2004-2006	19	1701.9	0.031 *	0.041 *	
			2009-2011	18	1613.3			
			2014-2016	19	1971			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	Stinking Creek (Caddo) (Continued)	pH	2004-2006	21	7.7333		0.017 *	
			2009-2011	19	7.92			
			2014-2016	20	7.8545			
OK310830-02-0020D	Stinking Creek (Kiowa)	Nitrite	2004-2006	20	0.02	0.030 *	0.003 *	
			2009-2011	18	0.03389			
			2014-2016	18	0.1217			
		TKN	2004-2006	20	0.404		0.001 *	
			2009-2011	19	0.7216			
			2014-2016	18	0.837			
		Hardness	2004-2006	20	469.4	0.005 *	0.002 *	
			2009-2011	19	462.7			
			2014-2016	19	730.4			
OK310830-05-0010D	Sugar Creek	Dissolved Oxygen	2004-2006	21	9.153	0.013 *	0.011 *	
			2009-2011	20	9.319			
			2014-2016	22	11.46			
		DO % Saturation	2004-2006	21	87.96	0.000 *	0.000 *	
			2009-2011	20	91.3			
			2014-2016	22	121.3			
		Ammonia	2004-2006	20	0.08475	0.001 *	0.000 *	
			2009-2011	19	0.18132			
			2014-2016	6	0.0165			
		Nitrate	2004-2006	20	0.3545	0.003 *	0.070	
			2009-2011	19	0.3989			
			2014-2016	21	0.2371			
		TKN	2004-2006	20	0.662		0.010 *	
			2009-2011	19	0.9489			
			2014-2016	21	0.943			
		Ortho-phosphorus	2004-2006	20	0.0871	0.031 *	0.013 *	
			2009-2011	19	0.14832			
			2014-2016	21	0.0925			
		Total phosphorus	2004-2006	20	0.1554	0.057	0.056	
			2009-2011	19	0.21784			
			2014-2016	21	0.1513			
		TSS	2004-2006	20	29	0.050	0.035 *	
			2009-2011	19	86.3			
			2014-2016	21	21.76			
		Hardness	2004-2006	20	1096.4	0.001 *	0.000 *	
			2009-2011	19	1173.8			
			2014-2016	21	1723			
		pH	2004-2006	21	8.0381	0.000 *	0.007 *	
			2009-2011	20	8.0075			
			2014-2016	22	8.1986			
OK311310-01-0070H	Suttle Creek	Dissolved Oxygen	2004-2006	14	8.73	0.036 *		
			2009-2011	21	7.988			
			2014-2016	9	5.17			
		DO % Saturation	2004-2006	14	88.4	0.062		
			2009-2011	21	81.9			
			2014-2016	9	57.7			
		Ammonia	2004-2006	13	0.0556	0.007 *	0.006 *	
			2009-2011	20	0.08			
			2014-2016	3	0.306			
		Nitrite	2004-2006	13	0.02308	0.003 *	0.001 *	
			2009-2011	19	0.02526			
			2014-2016	8	0.348			
		Alkalinity	2004-2006	14	242.1		0.022 *	
			2009-2011	21	379.5			
			2014-2016	9	382.2			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
OK311500-01-0110D	Tepee Creek	Nitrite	2004-2006	20	0.02	0.030 *	0.007 *	
			2009-2011	19	0.02421			
			2014-2016	9	0.353			
		Alkalinity	2004-2006	20	200.85	0.022 *	0.003 *	
			2009-2011	20	151.45			
			2014-2016	10	199.1			
OK311510-01-0090G	Timber Creek	Nitrate	2004-2006	20	0.393	0.056	0.051	
			2009-2011	20	0.291			
			2014-2016	12	0.761			
		TKN	2004-2006	20	0.349	0.092	0.008 *	
			2009-2011	20	0.4965			
			2014-2016	12	0.65			
		TDS	2004-2006	20	770	0.094	0.041 *	
			2009-2011	20	877.1			
			2014-2016	12	1179			
		Alkalinity	2004-2006	21	322.2	0.064	0.024 *	
			2009-2011	21	348.8			
			2014-2016	13	399.3			
		Hardness	2004-2006	20	544.2	0.094	0.079	
			2009-2011	21	572.2			
			2014-2016	12	741.1			
		pH	2004-2006	21	8.0148	0.097		
			2009-2011	21	7.9943			
			2014-2016	13	8.1562			
OK311500-03-0070D	Trail Creek	Dissolved Oxygen	2004-2006	9	12.35	0.006 *	0.003 *	
			2009-2011	19	11.179			
			2014-2016	15	7.63			
		DO % Saturation	2004-2006	9	121.29	0.000 *	0.000 *	
			2009-2011	19	116.25			
			2014-2016	15	70.11			
		Ammonia	2004-2006	8	0.03575	0.057	0.017 *	
			2009-2011	20	0.0709			
			2014-2016	5	0.1362			
		TKN	2004-2006	8	0.2938	0.074	0.001 *	
			2009-2011	20	0.6595			
			2014-2016	15	0.892			
		Chloride	2004-2006	8	50.16		0.009 *	
			2009-2011	20	73.36			
			2014-2016	15	65.87			
		Sulfate	2004-2006	8	571		0.056	
			2009-2011	20	810			
			2014-2016	15	888.4			
		TDS	2004-2006	8	1263.9		0.050	
			2009-2011	20	1461			
			2014-2016	15	1738			
		Conductivity	2004-2006	9	1810.8	0.060	0.098	
			2009-2011	18	1726			
			2014-2016	17	2165			
		Hardness	2004-2006	8	775.8	0.052	0.021 *	
			2009-2011	16	887.1			
			2014-2016	16	1117.7			
		pH	2004-2006	9	8.22	0.017 *	0.005 *	
			2009-2011	21	8.1176			
			2014-2016	16	7.9144			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
OK311600-02-0060J	Turkey Creek	Dissolved Oxygen	2004-2006	20	7.815	0.031 *	0.059	
			2009-2011	21	7.63			
			2014-2016	17	10.032			
		DO % Saturation	2004-2006	20	76.47	0.000 *	0.000 *	
			2009-2011	21	71.24			
			2014-2016	17	103.91			
		Nitrite	2004-2006	19	0.02	0.006 *	0.001 *	
			2009-2011	20	0.02			
			2014-2016	17	0.2776			
		Chloride	2004-2006	19	866.7	0.017 *	0.002 *	
			2009-2011	20	1417.1			
			2014-2016	17	1024			
		Sulfate	2004-2006	19	1459.9		0.020 *	
			2009-2011	20	2075.2			
			2014-2016	17	1920.9			
		TSS	2004-2006	19	114.5	0.029 *	0.068	
			2009-2011	20	48.7			
			2014-2016	17	23.82			
		Turbidity	2004-2006	19	46.4	0.069		
			2009-2011	21	61.7			
			2014-2016	18	31.32			
		Conductivity	2004-2006	19	3791		0.024 *	
			2009-2011	19	5240			
			2014-2016	19	5641			
		Hardness	2004-2006	19	2049		0.064	
			2009-2011	21	2499			
			2014-2016	17	2729			
		pH	2004-2006	19	7.6584	0.000 *	0.001 *	
			2009-2011	21	7.7233			
			2014-2016	18	7.9778			
OK311100-03-0010G	Walnut Bayou	DO % Saturation	2004-2006	21	94.79		0.098	
			2009-2011	21	92.2			
			2014-2016	19	80.89			
		Nitrite	2004-2006	20	0.02	0.098	0.065	
			2009-2011	20	0.02			
			2014-2016	18	0.0372			
		TKN	2004-2006	20	0.274		0.000 *	
			2009-2011	20	0.5495			
			2014-2016	18	0.755			
		Ortho-phosphorus	2004-2006	20	0.0305	0.022 *	0.005 *	
			2009-2011	20	0.03695			
			2014-2016	18	0.1074			
		Total phosphorus	2004-2006	20	0.064	0.044 *	0.017 *	
			2009-2011	20	0.0684			
			2014-2016	18	0.1578			
		pH	2004-2006	21	8.0776	0.058	0.072	
			2009-2011	21	8.0933			
			2014-2016	19	7.9584			
OK310830-03-0230C	West Barnitz Creek	Dissolved Oxygen	2004-2006	21	9.317	0.006 *	0.018 *	
			2009-2011	21	10.189			
			2014-2016	14	6.769			
		DO % Saturation	2004-2006	21	85.92	0.001 *	0.015 *	
			2009-2011	21	97.19			
			2014-2016	14	70.68			
		Nitrate	2004-2006	20	0.175	0.042 *	0.095	
			2009-2011	20	0.131			
			2014-2016	13	0.3023			

WBID	Site	Variable	RB Cycle	N	Mean	p value Cycle 2 v. Cycle 3	p value (All Cycles)	Result
	West Barnitz Creek (Continued)	Ortho-phosphorus	2004-2006	20	0.0484	0.071		
			2009-2011	20	0.02885			
			2014-2016	13	0.0527			
		Total phosphorus	2004-2006	20	0.1203	0.023 *	0.064	
			2009-2011	20	0.05205			
			2014-2016	13	0.1059			
		Sulfate	2004-2006	20	1860	0.031 *		
			2009-2011	20	2024.5			
			2014-2016	13	1707			
		Alkalinity	2004-2006	20	182.2	0.001 *	0.001 *	
			2009-2011	20	161.1			
			2014-2016	14	229.6			
		Conductivity	2004-2006	20	3049.3		0.031 *	
			2009-2011	20	2824.7			
			2014-2016	14	2611			
OK310810-01-0020G	Wildhorse Creek (Davis)	DO % Saturation	2009-2011	20	99.59	0.062		
			2014-2016	17	93.78			
		Nitrite	2004-2006	20	0.02	0.019 *	0.002 *	
			2009-2011	19	0.02263			
			2014-2016	16	0.0544			
		Ortho-phosphorus	2004-2006	20	0.0409	0.084		
			2009-2011	20	0.025			
			2014-2016	16	0.01344			
OK310810-03-0010R	Wildhorse Creek (Tatums)	Ammonia	2004-2006	20	0.0245	0.046 *		
			2009-2011	20	0.02295			
			2014-2016	6	0.015			
		Nitrate	2004-2006	20	0.1345		0.070	
			2009-2011	20	0.0695			
			2014-2016	18	0.0433			
		Nitrite	2004-2006	20	0.02	0.058	0.013 *	
			2009-2011	19	0.02368			
			2014-2016	18	0.0478			
		TDS	2004-2006	20	832.2	0.003 *	0.016 *	
			2009-2011	20	715.5			
			2014-2016	18	975.6			
		Chloride	2004-2006	20	226.1	0.000 *	0.000 *	
			2009-2011	20	174.2			
			2014-2016	18	362.6			
		Conductivity	2004-2006	21	1452.2	0.000 *	0.001 *	
			2009-2011	19	1148.8			
			2014-2016	19	1802			
		Hardness	2004-2006	20	531.1	0.000 *	0.001 *	
			2009-2011	20	461.4			
			2014-2016	18	742.6			
		pH	2004-2006	19	7.889		0.003 *	
			2009-2011	21	8.1743			
			2014-2016	19	8.1621			

3.2 BIOLOGICAL MONITORING

3.2.1 Habitat Assessment

Total habitat scores for each site and computed metric scores are listed below (Table 11). East Cache and Oil Creeks had the highest habitat scores, while Quartermaster Creek had the lowest habitat score.

Table 11. Habitat assessment metric values for monitoring sites in the Rotating Basin Group 4, Cycle 3.

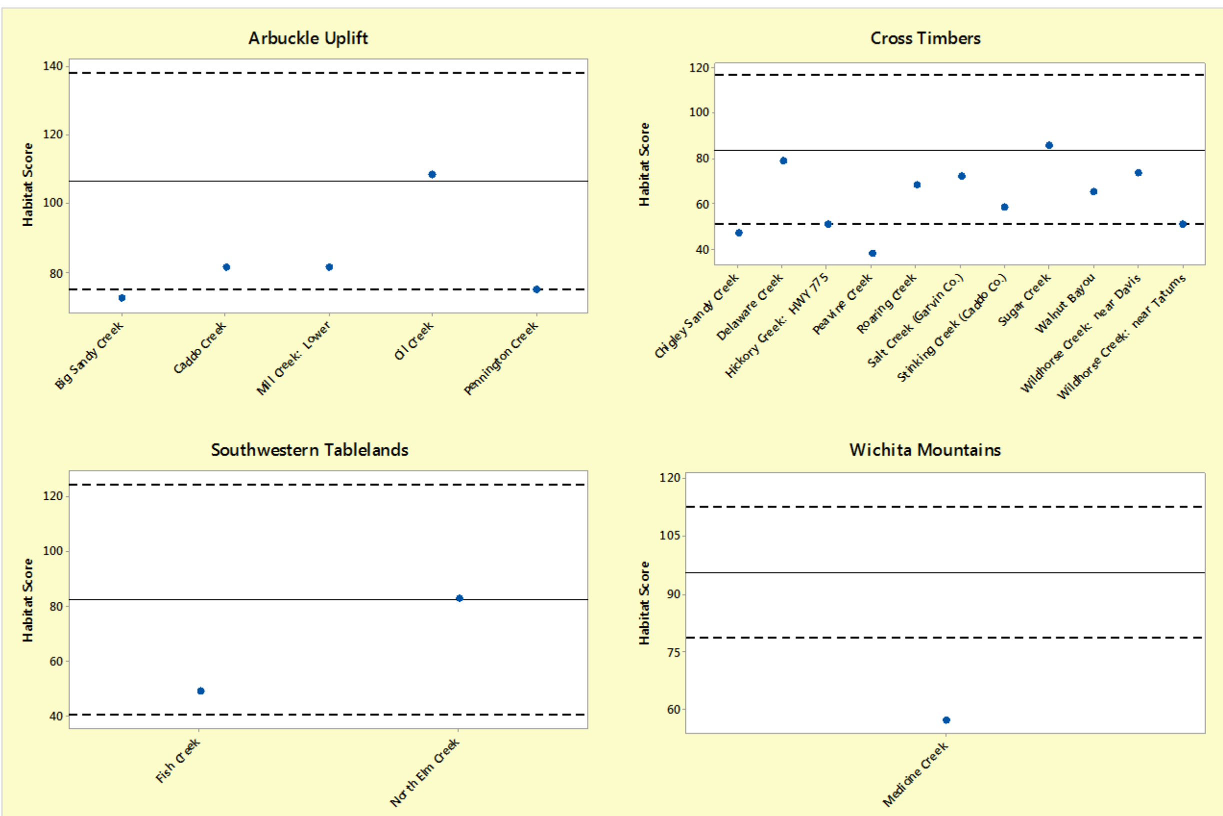
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Beaver Creek (Custer)	OK310830-03-0190C	7.5	6.8	0.0	19.9	0.0	1.4	15.1	4.2	4.2	6.0	10.0	75.1
Beaver Creek (Cotton)	OK311210-00-0010D	0.9	1.7	7.7	7.7	0.0	0.0	16.5	2.9	1.7	4.9	9.6	53.6
Big Sandy Creek	OK310800-01-0090G	2.4	12.6	0.0	20.0	10.3	0.5	0.4	1.2	7.1	7.8	10.0	72.3
Bitter Creek	OK310820-01-0030D	5.7	2.0	19.8	3.8	2.2	11.4	6.7	1.9	6.9	6.5	10.0	76.9
Boggy Creek	OK310830-03-0100C	4.0	0.9	19.8	3.7	0.0	6.0	11.1	2.2	4.6	5.8	4.8	62.9
Buffalo Creek	OK311510-02-0090D	9.2	0.4	0.0	2.7	0.0	4.2	2.8	2.7	6.9	7.6	3.6	40.1
Caddo Creek	OK310800-03-0010F	4.9	3.4	19.7	10.7	4.1	15.2	1.8	-0.1	6.0	5.9	9.6	81.2
Cavalry Creek	OK310830-03-0070D	6.4	2.2	11.8	6.9	0.0	5.7	9.9	3.1	6.7	8.5	4.6	65.8
Chigley Sandy Creek	OK310800-02-0190D	1.5	1.9	2.6	13.8	0.0	0.4	0.4	0.9	7.9	7.1	10.0	46.5
Cobb Creek	OK310830-06-0050K	3.4	1.9	13.0	8.2	0.0	11.4	4.2	0.3	8.9	8.0	4.4	63.7
Criner Creek	OK310810-02-0050D	3.0	1.8	20.2	17.2	12.4	4.8	3.5	1.5	6.1	7.0	8.8	86.3
Deep Red Creek	OK311310-03-0010D	3.5	5.2	14.6	12.6	0.0	0.0	15.1	0.2	4.7	3.3	9.3	68.5
Delaware Creek	OK310830-01-0030G	10.4	4.6	14.6	7.8	0.0	7.0	11.1	2.0	8.1	8.2	4.6	78.4
East Barnitz Creek	OK310830-03-0210C	4.0	2.2	0.0	15.1	0.0	0.0	16.5	5.4	6.5	7.3	3.8	60.8
East Cache Creek	OK311300-03-0010M	7.0	10.2	14.0	3.8	14.1	15.1	16.5	1.8	7.5	8.1	9.5	107.6
Finn Creek	OK310810-02-0020D	2.2	3.4	19.1	19.9	5.9	2.0	7.7	1.9	7.8	4.0	9.7	83.6
Fish Creek	OK311800-00-0130G	3.5	0.4	0.0	1.4	5.9	5.1	13.7	0.6	8.6	5.2	4.4	48.8
Gypsum Creek	OK311600-01-0020F	1.0	0.4	0.0	17.0	0.0	7.7	16.5	0.4	4.2	2.8	10.0	60.0
Haystack Creek	OK311800-00-0040D	1.8	2.7	7.1	4.5	2.2	0.5	16.5	3.1	4.2	2.4	9.7	54.7
Hickory Creek	OK311100-02-0010M	2.5	2.9	3.8	15.9	0.0	0.0	0.4	1.1	7.3	7.2	9.6	50.7
Jack Creek	OK311310-03-0030B	0.5	0.4	0.0	19.1	0.0	0.0	16.5	0.7	1.7	2.9	9.1	50.9
Lake Creek	OK310830-06-0040J	4.4	3.1	20.0	1.9	0.0	2.6	5.8	0.4	9.9	8.7	5.0	61.8
Lake Creek (Greer)	OK311510-01-0040D	2.1	3.5	9.9	8.5	9.0	0.9	6.7	1.5	7.5	4.5	3.8	57.9
Little Beaver Creek	OK311210-00-0050D	1.6	1.4	20.1	0.5	0.0	0.0	9.9	1.4	5.6	5.7	5.0	51.2
Little Deep Red Creek	OK311310-03-0040E	1.2	1.0	13.3	7.5	2.2	11.6	16.5	0.3	5.0	3.5	8.9	71.0
Little Elk Creek	OK311500-03-0040D	5.9	2.3	0.0	18.9	0.0	0.0	1.8	1.1	7.4	7.3	3.2	47.9
Little Washita River	OK310820-02-0010A	8.9	3.5	15.6	4.7	5.9	11.0	1.0	4.0	6.4	6.5	4.8	72.3

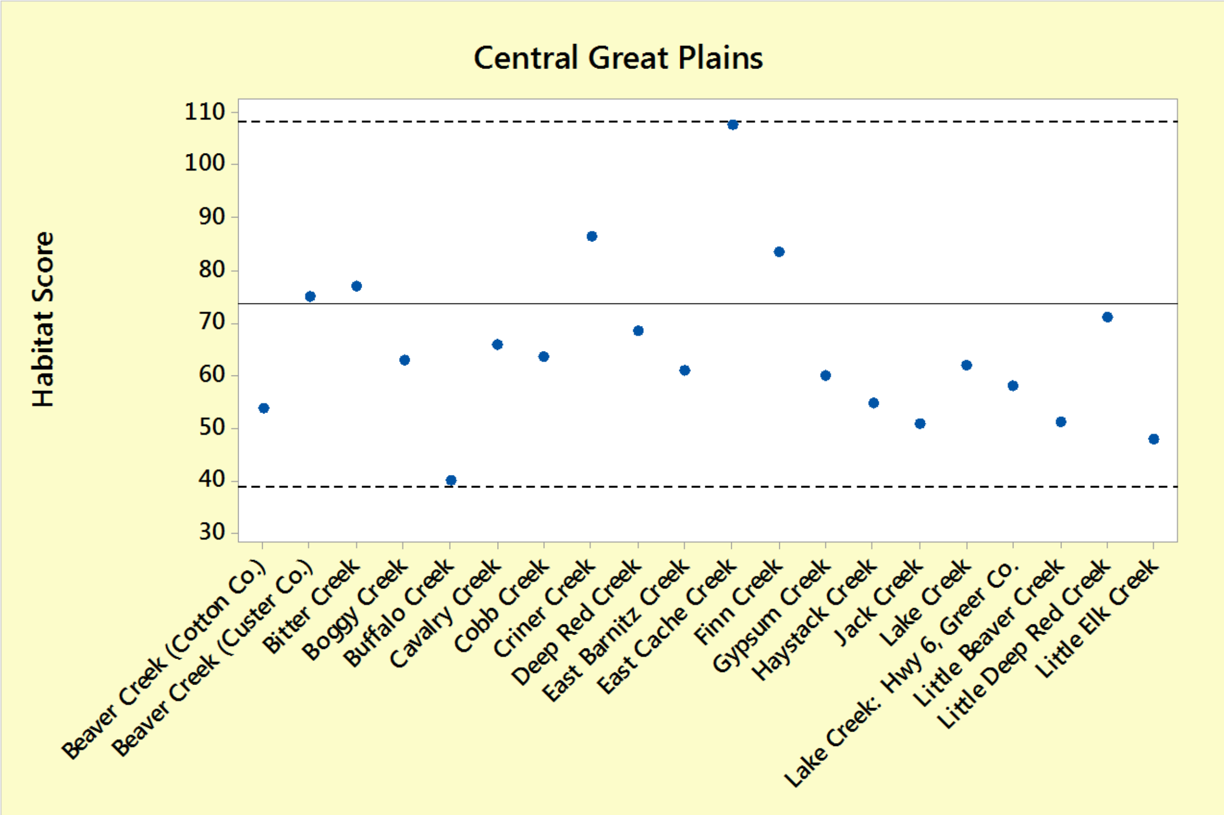
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Medicine Creek	OK311300-04-0060H	13.9	7.6	0.0	2.6	0.0	0.5	3.5	1.4	10.0	7.9	9.9	57.3
Mill Creek: Lower	OK310800-01-0190G	3.0	0.4	17.2	4.2	4.1	10.4	15.1	1.0	9.8	6.9	9.3	81.4
Mud Creek	OK311100-04-0010G	7.7	5.4	20.2	16.1	0.0	0.5	5.0	2.4	3.8	3.4	2.6	67.1
North Elm Creek	OK311800-00-0170G	4.8	10.6	17.2	5.7	13.3	0.4	12.3	2.0	5.9	7.4	3.2	82.8
North Mud Creek	OK311100-04-0030C	4.0	1.2	7.7	16.6	4.1	2.5	5.0	3.1	2.4	3.1	9.1	58.8
Oil Creek	OK310800-01-0240P	14.6	12.4	18.1	17.8	4.1	1.5	13.7	1.9	6.9	7.6	9.5	108.1
Otter Creek	OK311500-01-0080F	5.2	1.9	9.0	12.9	0.0	0.0	0.7	2.4	7.4	5.2	9.2	53.9
Peavine Creek	OK310810-01-0120M	0.9	1.7	0.0	17.7	0.0	1.0	0.4	1.1	3.0	2.2	10.0	38.0
Pennington Creek	OK310800-01-0120G	4.1	1.0	14.6	7.0	0.0	18.9	1.0	0.4	10.0	8.2	9.7	74.9
Post Oak Creek	OK311310-02-0070B	1.2	0.4	0.0	17.7	0.0	0.2	0.4	0.3	9.2	7.2	9.7	46.3
Quartermaster Creek	OK310840-01-0060B	3.7	1.8	0.0	10.2	0.0	0.0	2.8	1.4	0.6	4.4	4.2	29.1
Rainy Mountain Creek	OK310830-02-0060G	7.0	2.6	11.8	6.7	5.9	0.5	0.7	6.7	2.9	3.6	6.0	54.4
Red Creek	OK311100-01-0290D	4.2	2.6	16.3	7.5	0.0	0.0	15.1	2.4	3.7	2.7	9.6	64.1
Roaring Creek	OK310810-02-0170B	3.2	1.3	19.3	7.5	0.0	1.6	6.7	2.9	9.1	7.1	9.1	67.8
Rush Creek (Garvin)	OK310810-01-0090G	9.1	5.2	14.6	4.7	10.3	12.3	6.7	2.4	10.0	6.7	10.0	92.0
Rush Creek (Roger Mills)	OK310840-02-0210H	19.6	18.2	1.1	7.0	0.0	1.5	16.5	0.5	10.0	9.5	4.2	88.1
Salt Creek (Garvin)	OK310810-03-0080G	4.5	1.5	9.0	1.6	5.9	11.1	12.3	0.2	9.2	6.6	10.0	71.9
Salt Creek (Grady)	OK310820-01-0140B	3.6	2.8	18.2	0.2	2.2	11.9	7.7	1.4	4.3	5.0	3.4	60.7
Sandstone Creek	OK310840-02-0020C	3.9	0.5	14.6	19.5	0.0	16.2	9.9	1.2	2.8	3.6	6.2	78.4
Station Creek	OK311800-00-0060G	15.4	0.5	0.0	19.6	0.0	0.4	15.1	3.6	4.9	5.4	3.8	68.7
Stinking Creek (Kiowa)	OK310830-02-0020D	8.2	7.7	14.6	19.9	0.0	0.0	5.0	1.0	7.2	6.5	7.0	77.1
Stinking Creek (Caddo)	OK310830-04-0030K	4.7	1.9	20.2	4.2	0.0	3.8	1.4	0.6	8.2	8.3	5.0	58.3
Sugar Creek	OK310830-05-0010D	4.4	3.5	13.5	4.4	2.2	20.0	15.1	0.5	9.3	7.8	4.4	85.1
Suttle Creek	OK311310-01-0070H	0.6	0.4	0.0	18.6	0.0	5.8	16.5	2.2	4.6	2.8	10.0	61.5
Tepee Creek	OK311500-01-0110D	2.7	0.4	0.0	19.7	0.0	8.6	4.2	1.2	0.4	3.3	7.8	48.3
Timber Creek	OK311510-01-0090G	3.6	1.1	17.2	5.6	2.2	15.7	1.4	3.4	5.8	4.8	8.7	69.5
Trail Creek	OK311500-03-0070D	2.8	0.8	6.1	15.9	4.1	1.4	6.7	2.4	6.3	5.1	9.9	61.5
Turkey Creek	OK311600-02-0060J	4.1	3.1	19.7	13.0	9.0	4.4	8.7	2.9	5.2	4.0	9.2	83.3
Walnut Bayou	OK311100-03-0010G	4.0	3.4	13.0	9.5	0.0	0.5	8.7	1.3	6.8	8.2	9.5	64.9
West Barnitz Creek	OK310830-03-0230C	4.7	3.1	20.2	18.0	0.0	19.6	3.5	4.5	8.0	6.2	3.0	90.8
Wildhorse Creek (Davis)	OK310810-01-0020G	5.9	2.8	15.9	3.6	5.9	9.0	13.7	2.4	3.1	1.7	9.2	73.2
Wildhorse Creek (Tatums)	OK310810-03-0010R	1.6	0.4	0.0	3.0	2.2	4.4	9.9	0.8	9.9	8.8	10.0	51.0

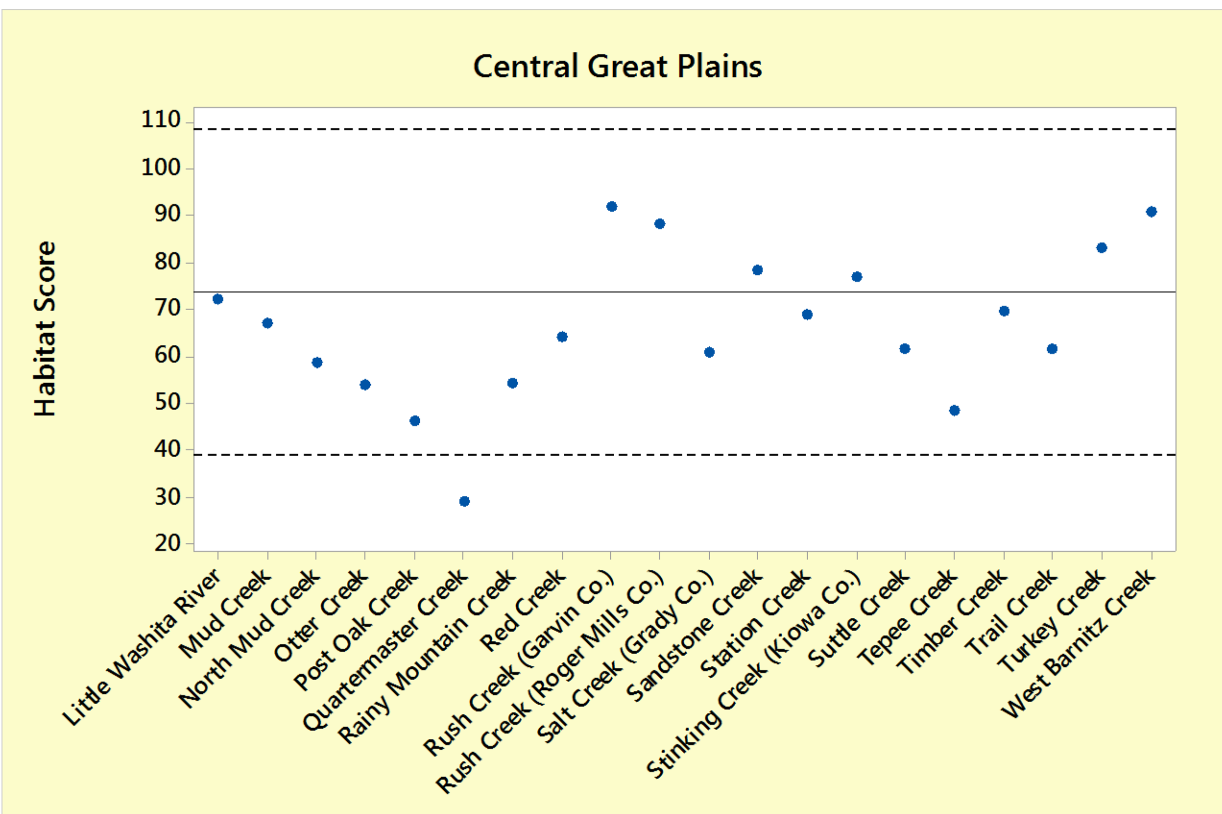
Sites were compared relative to the mean total habitat score of high quality sites in the respective ecoregion and a range determined by +/- two standard deviations (Figure 3). Sites with scores that are within +/- two standard deviations of the mean of the high quality sites do not necessarily have "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.

Most of the sites in this basin fall within two standard deviations of the mean habitat score of high quality sites within each ecoregion. Big Sandy Creek in the Arbuckle Uplift has poor habitat. Chigley Sandy Creek, Peavine Creek, and Wildhorse Creek (Tatums) in the Cross Timbers have poor conditions. Medicine Creek in the Wichita Mountains has extremely poor conditions, a change from the last cycle when it had extremely good habitat. Quartermaster Creek in the Central Great Plains has very poor habitat.

Figure 3. Total habitat score for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.




Central Great Plains
Habitat Score
110
100
90
80
70
60
50
40
30
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek
Lake Creek: Hwy 6, Greer Co.
Little Beaver Creek
Little Deep Red Creek
Little Elk Creek


Central Great Plains
Habitat Score
110
100
90
80
70
60
50
40
30
20
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek

3.2.2 Fish Collections

Fish metrics used to compute IBI scores for the Rotating Basin sites using the OCC method are listed in Table 12. Use of this IBI method allows assessment of streams which lack definite support assignment using the state biocriteria method. For a complete listing of fish collection data, including species and numbers caught, consult Appendix B. All data was compared relative to the same mean of the high quality sites for the respective ecoregion in order to obtain the IBI score (OCC method). Although, ideally, one would use collections from the same years for comparison, multiyear collections at sites deemed "high quality" were not available.

Table 13 presents the results of the fish assessment based on the OCC's modified RBP method compared with the fish assessment based on Oklahoma state biocriteria (as described in Oklahoma Water Resource Board, *Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (USAP), OAC 785:46-15). The state biocriteria are based on older delineations of the level 3 ecoregions, so there were some differences in scoring based on the differences in grouping of sites. The OCC method allowed greater discrimination of the biological condition among sites. Sixteen sites had fish communities that were "excellent" relative to high quality sites in the ecoregion, 14 sites had fish communities that were "good," 17 sites were "fair," 11 sites were "poor", and one site was "very poor" relative to high quality sites in the ecoregion.

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

Site Name	WBID	Date	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent Tolerant	Pecent Insectivorous Cyprinids	Percent Lithophylic Spawners
Beaver Creek (Custer)	OK310830-03-0190C	5/13/2014	735	12	3	2	1	0.84	0.01	0.15
Beaver Creek (Cotton)	OK311210-00-0010D	7/16/2014	162	12	0	5	0	0.99	0.00	0.00
Big Sandy Creek	OK310800-01-0090G	5/27/2014	1346	9	1	4	0	0.03	0.01	0.96
Bitter Creek	OK310820-01-0030D	6/19/2014	1505	17	4	5	2	0.81	0.18	0.01
Boggy Creek	OK310830-03-0100C	5/12/2014	1317	10	2	3	1	1.00	0.00	0.00
Buffalo Creek	OK311510-02-0090D	5/20/2014	409	7	0	1	0	0.45	0.09	0.00
Caddo Creek	OK310800-03-0010F	7/14/2014	925	22	6	8	3	0.57	0.37	0.04
Cavalry Creek	OK310830-03-0070D	5/12/2014	1714	7	0	3	0	1.00	0.00	0.00
Chigley Sandy Creek	OK310800-02-0190D	5/29/2014	206	8	2	1	1	0.97	0.02	0.01
Cobb Creek	OK310830-06-0050K	7/29/2014	914	14	0	5	0	0.99	0.01	0.00
Criner Creek	OK310810-02-0050D	6/26/2014	869	8	2	2	1	0.72	0.28	0.01
Deep Red Creek	OK311310-03-0010D	8/14/2014	132	23	2	5	1	0.73	0.26	0.00
Delaware Creek	OK310830-01-0030G	8/4/2014	497	9	0	5	0	0.99	0.00	0.01
East Barnitz Creek	OK310830-03-0210C	7/28/2014	649	13	2	4	1	0.99	0.00	0.01
East Cache Creek	OK311300-03-0010M	7/1/2014	3024	20	3	6	0	0.50	0.04	0.46

Site Name	WBID	Date	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent Tolerant	Pecent Insectivorous Cyprinids	Percent Lithophylic Spawners
Finn Creek	OK310810-02-0020D	7/3/2014	1224	16	2	6	0	0.96	0.04	0.00
Fish Creek	OK311800-00-0130G	7/15/2015	340	14	1	4	2	0.54	0.04	0.00
Gypsum Creek	OK311600-01-0020F	7/16/2014	330	10	0	1	0	0.68	0.06	0.00
Haystack Creek	OK311800-00-0040D	7/21/2014	264	8	0	2	0	0.90	0.01	0.00
Hickory Creek	OK311100-02-0010M	7/15/2014	449	18	3	5	1	0.86	0.14	0.01
Jack Creek	OK311310-03-0030B	5/22/2014	78	7	0	2	0	1.00	0.00	0.00
Lake Creek	OK310830-06-0040J	7/29/2014	2325	18	1	6	0	0.66	0.33	0.00
Lake Creek (Greer)	OK311510-01-0040D	8/6/2014	1073	19	1	7	1	0.90	0.08	0.01
Little Beaver Creek	OK311210-00-0050D	7/16/2014	995	16	0	6	0	1.00	0.00	0.00
Little Deep Red Creek	OK311310-03-0040E	7/1/2015	199	16	1	3	1	0.97	0.03	0.00
Little Elk Creek	OK311500-03-0040D	6/19/2014	963	13	2	5	1	0.96	0.00	0.03
Little Washita River	OK310820-02-0010A	7/23/2014	1032	14	3	3	1	0.92	0.08	0.01
Medicine Creek	OK311300-04-0060H	5/21/2014	597	15	4	5	2	0.72	0.22	0.06
Mill Creek: Lower	OK310800-01-0190G	6/2/2014	1376	19	5	5	2	0.74	0.02	0.24
Mud Creek	OK311100-04-0010G	7/16/2014	449	17	2	6	2	0.76	0.22	0.00
North Elm Creek	OK311800-00-0170G	7/21/2014	152	5	0	1	0	0.41	0.00	0.00
North Mud Creek	OK311100-04-0030C	8/25/2015	222	12	1	5	1	0.99	0.00	0.00
Oil Creek	OK310800-01-0240P	6/5/2014	2231	14	2	7	1	0.35	0.44	0.65
Otter Creek	OK311500-01-0080F	7/10/2014	1734	22	0	7	0	1.00	0.00	0.00
Peavine Creek	OK310810-01-0120M	8/24/2015	485	13	1	6	1	0.84	0.16	0.00
Pennington Creek	OK310800-01-0120G	5/28/2014	1314	31	7	10	4	0.22	0.58	0.20
Post Oak Creek	OK311310-02-0070B	7/16/2015	165	10	1	1	0	0.92	0.08	0.01
Quartermaster Creek	OK310840-01-0060B	5/20/2014	472	5	0	2	0	1.00	0.00	0.00
Rainy Mountain Creek	OK310830-02-0060G	7/24/2014	1376	16	2	4	1	0.92	0.07	0.00
Red Creek	OK311100-01-0290D	7/15/2014	141	10	0	5	0	1.00	0.00	0.00
Roaring Creek	OK310810-02-0170B	7/23/2014	617	15	2	6	1	0.91	0.07	0.02
Rush Creek (Garvin)	OK310810-01-0090G	7/2/2014	787	15	1	5	1	0.95	0.05	0.00
Rush Creek (Roger Mills)	OK310840-02-0210H	5/19/2014	229	9	2	4	0	0.42	0.00	0.58
Salt Creek (Garvin)	OK310810-03-0080G	6/25/2014	389	17	1	7	1	0.88	0.12	0.00
Salt Creek (Grady)	OK310820-01-0140B	6/26/2014	654	11	1	4	1	1.00	0.00	0.00
Sandstone Creek	OK310840-02-0020C	6/11/2015	191	11	2	4	0	0.97	0.00	0.03
Station Creek	OK311800-00-0060G	6/11/2014	355	8	0	3	0	1.00	0.00	0.00
Stinking Creek (Kiowa)	OK310830-02-0020D	7/30/2014	650	16	2	5	2	0.95	0.01	0.00
Stinking Creek (Caddo)	OK310830-04-0030K	6/17/2014	438	10	0	6	0	1.00	0.00	0.00
Sugar Creek	OK310830-05-0010D	6/30/2014	891	14	1	5	1	0.98	0.02	0.00

Site Name	WBID	Date	Total Number	Total Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent Tolerant	Pecent Insectivorous Cyprinids	Percent Lithophylic Spawners
Suttle Creek	OK311310-01-0070H	7/1/2015	237	11	0	5	0	1.00	0.00	0.00
Tepee Creek	OK311500-01-0110D	7/15/2015	201	13	1	5	1	0.94	0.05	0.01
Timber Creek	OK311510-01-0090G	6/23/2015	406	17	1	8	1	0.96	0.03	0.00
Trail Creek	OK311500-03-0070D	6/16/2014	511	12	0	3	0	0.97	0.03	0.00
Turkey Creek	OK311600-02-0060J	8/6/2014	1127	10	1	3	1	0.99	0.01	0.00
Walnut Bayou	OK311100-03-0010G	6/3/2014	788	15	1	6	1	0.93	0.07	0.00
West Barnitz Creek	OK310830-03-0230C	6/11/2015	190	11	2	4	1	0.75	0.04	0.21
Wildhorse Creek (Davis)	OK310810-01-0020G	7/24/2014	373	14	2	4	0	0.98	0.01	0.01
Wildhorse Creek (Tatums)	OK310810-03-0010R	5/25/2014	320	9	1	3	1	0.99	0.01	0.00

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

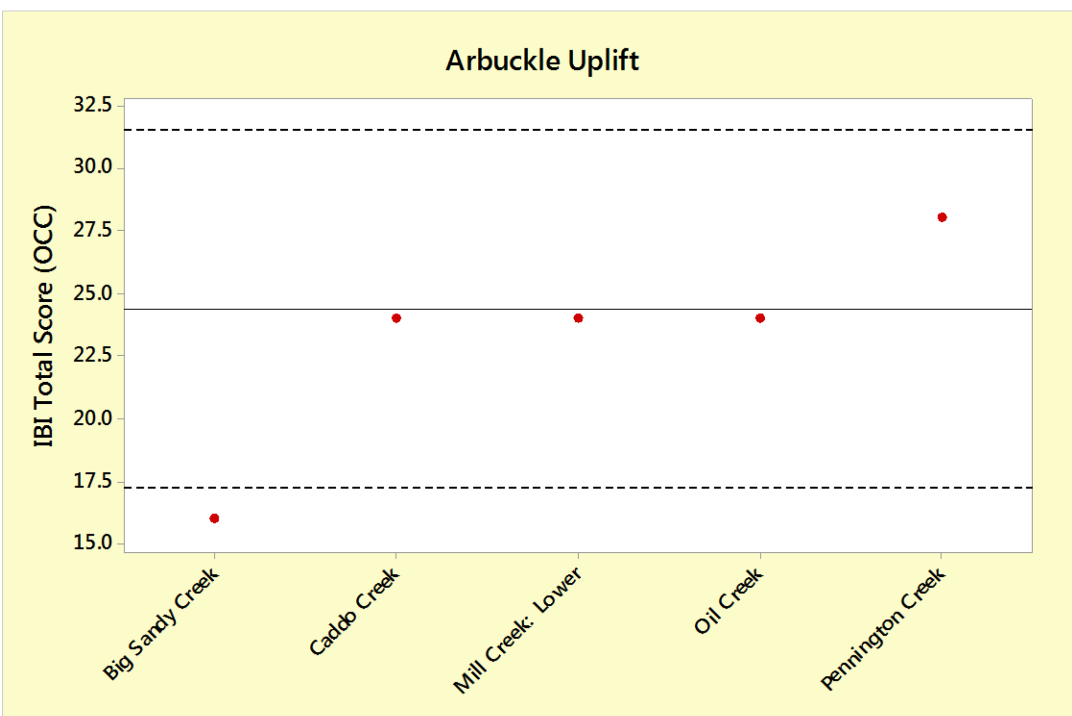
Ecoregion	Site Name	WBID	Use	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
Arbuckle	Big Sandy Creek	OK310800-01-0090G	WWAC	33	S	16	0.62	Poor
Arbuckle	Caddo Creek	OK310800-03-0010F	WWAC	27	S	24	0.92	Excellent
Arbuckle	Mill Creek: Lower	OK310800-01-0190G	WWAC	31	S	24	0.92	Excellent
Arbuckle	Oil Creek	OK310800-01-0240P	WWAC	31	S	24	0.92	Excellent
Arbuckle	Pennington Creek	OK310800-01-0120G	CWAC	35	S	28	1.08	Excellent
CGP	Beaver Creek (Cotton Co.)	OK311210-00-0010D	WWAC	25	S	14	0.64	Fair
CGP	Beaver Creek (Custer Co.)	OK310830-03-0190C	WWAC	22	S	20	0.91	Excellent
CGP	Bitter Creek	OK310820-01-0030D	WWAC	29	S	22	1.00	Excellent
CGP	Boggy Creek	OK310830-03-0100C	WWAC	20	U	22	1.00	Excellent
CGP	Buffalo Creek	OK311510-02-0090D	WWAC	15	N	8	0.36	Very Poor
CGP	Cavalry Creek	OK310830-03-0070D	WWAC	15	U	12	0.55	Poor
CGP	Cobb Creek	OK310830-06-0050K	WWAC	23	S	14	0.64	Fair
CGP	Criner Creek	OK310810-02-0050D	WWAC	23	S	16	0.73	Fair
CGP	Deep Red Creek	OK311310-03-0010D	WWAC	27	S	24	1.09	Excellent

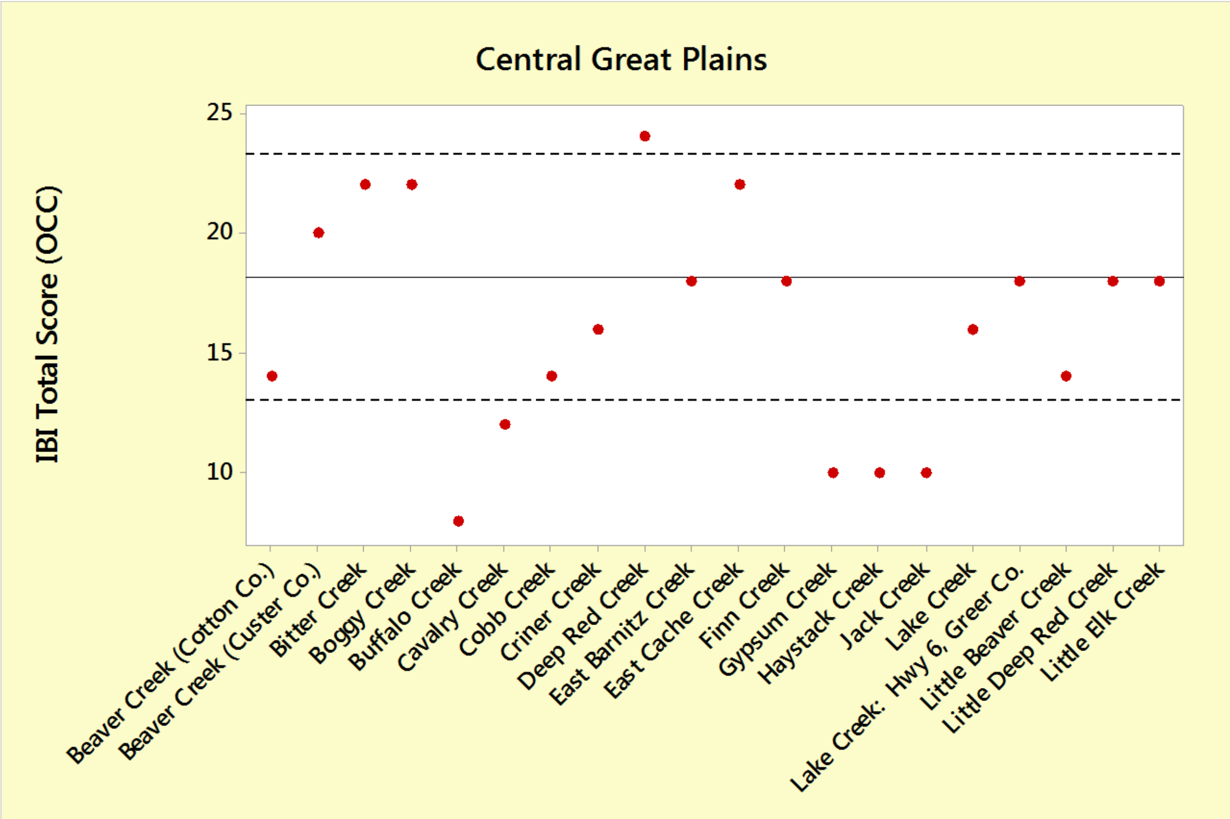
Ecoregion	Site Name	WBID	Use	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CGP	East Barnitz Creek	OK310830-03-0210C	WWAC	26	S	18	0.82	Good
CGP	East Cache Creek	OK311300-03-0010M	WWAC	32	S	22	1.00	Excellent
CGP	Finn Creek	OK310810-02-0020D	WWAC	24	S	18	0.82	Good
CGP	Gypsum Creek	OK311600-01-0020F	WWAC	18	U	10	0.45	Poor
CGP	Haystack Creek	OK311800-00-0040D	WWAC	16	U	10	0.45	Poor
CGP	Jack Creek	OK311310-03-0030B	WWAC	14	U	10	0.45	Poor
CGP	Lake Creek	OK310830-06-0040J	WWAC	25	S	16	0.73	Fair
CGP	Lake Creek: Hwy 6, Greer Co.	OK311510-01-0040D	WWAC	26	S	18	0.82	Good
CGP	Little Beaver Creek	OK311210-00-0050D	WWAC	26	S	14	0.64	Fair
CGP	Little Deep Red Creek	OK311310-03-0040E	WWAC	26	S	18	0.82	Good
CGP	Little Elk Creek	OK311500-03-0040D	WWAC	26	S	18	0.82	Good
CGP	Little Washita River	OK310820-02-0010A	WWAC	20	U	22	1.00	Excellent
CGP	Mud Creek	OK311100-04-0010G	WWAC	25	S	20	0.91	Excellent
CGP	North Mud Creek	OK311100-04-0030C	HLAC	23	S	18	0.82	Good
CGP	Otter Creek	OK311500-01-0080F	WWAC	22	S	14	0.64	Fair
CGP	Post Oak Creek	OK311310-02-0070B	WWAC	15	N	14	0.64	Fair
CGP	Quartermaster Creek	OK310840-01-0060B	WWAC	16	N	10	0.45	Poor
CGP	Rainy Mountain Creek	OK310830-02-0060G	WWAC	28	S	22	1.00	Excellent
CGP	Red Creek	OK311100-01-0290D	WWAC	20	U	14	0.64	Fair
CGP	Rush Creek (Garvin Co.)	OK310810-01-0090G	WWAC	21	U	18	0.82	Good
CGP	Rush Creek (Roger Mills Co.)	OK310840-02-0210H	WWAC	32	S	22	1.00	Excellent
CGP	Salt Creek (Grady Co.)	OK310820-01-0140B	WWAC	19	U	18	0.82	Good
CGP	Sandstone Creek	OK310840-02-0020C	WWAC	22	S	18	0.82	Good
CGP	Station Creek	OK311800-00-0060G	WWAC	20	U	12	0.55	Poor
CGP	Stinking Creek (Kiowa Co.)	OK310830-02-0020D	WWAC	25	S	18	0.82	Good
CGP	Suttle Creek	OK311310-01-0070H	WWAC	20	U	14	0.64	Fair
CGP	Tepee Creek	OK311500-01-0110D	WWAC	28	S	18	0.82	Good
CGP	Timber Creek	OK311510-01-0090G	WWAC	23	S	18	0.82	Good
CGP	Trail Creek	OK311500-03-0070D	WWAC	23	S	14	0.64	Fair
CGP	Turkey Creek	OK311600-02-0060J	WWAC	21	U	18	0.82	Good
CGP	West Barnitz Creek	OK310830-03-0230C	WWAC	20	U	20	0.91	Excellent
CT	Chigley Sandy Creek	OK310800-02-0190D	WWAC	18	N	14	0.64	Fair
CT	Delaware Creek	OK310830-01-0030G	WWAC	21	U	12	0.55	Poor
CT	Hickory Creek: HWY 775	OK311100-02-0010M	WWAC	26	S	20	0.91	Excellent
CT	Peavine Creek	OK310810-01-0120M	WWAC	28	S	16	0.73	Fair

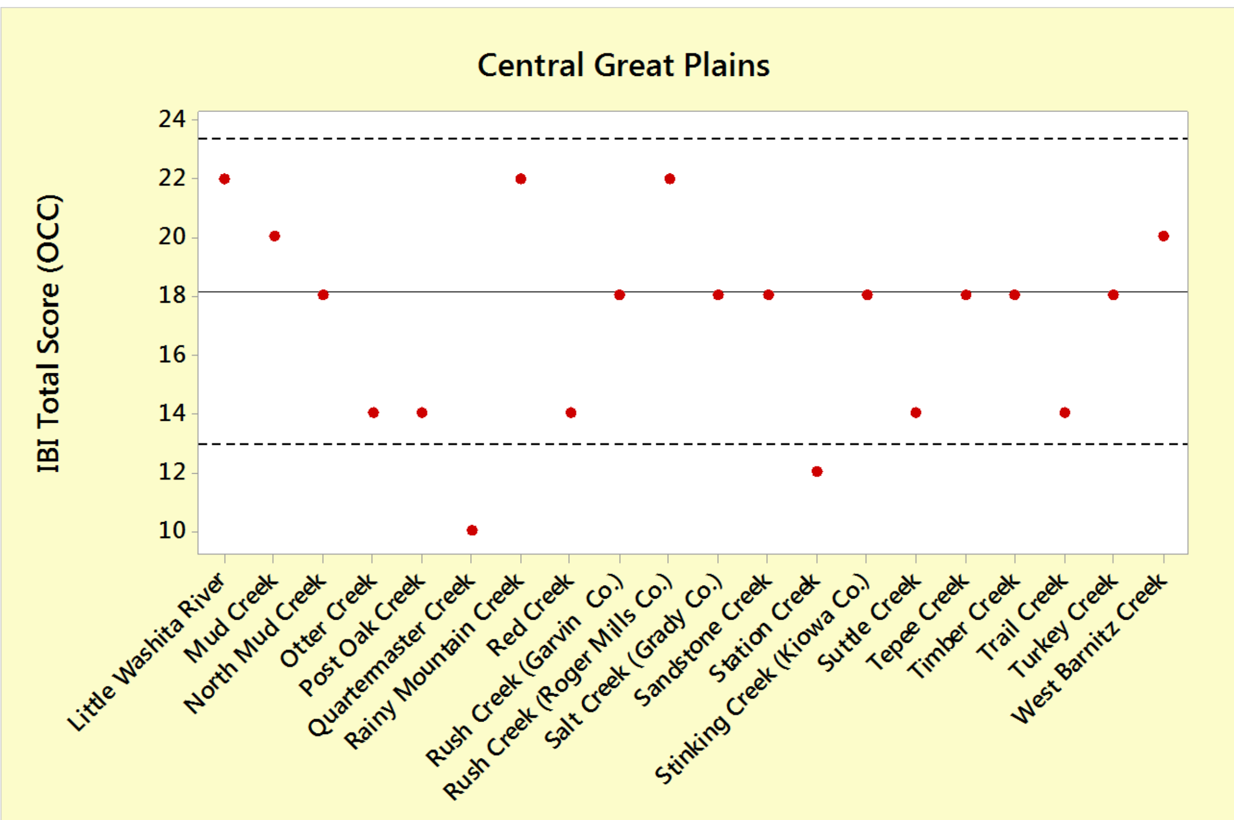
Ecoregion	Site Name	WBID	Use	IBI Score (USAP)	USAP Fish	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CT	Roaring Creek	OK310810-02-0170B	WWAC	26	S	16	0.73	Fair
CT	Salt Creek (Garvin Co.)	OK310810-03-0080G	WWAC	25	S	16	0.73	Fair
CT	Stinking Creek (Caddo Co.)	OK310830-04-0030K	WWAC	20	U	12	0.55	Poor
CT	Sugar Creek	OK310830-05-0010D	WWAC	23	S	16	0.73	Fair
CT	Walnut Bayou	OK311100-03-0010G	WWAC	25	S	16	0.73	Fair
CT	Wildhorse Creek: near Davis	OK310810-01-0020G	WWAC	25	S	16	0.73	Fair
CT	Wildhorse Creek: near Tatums	OK310810-03-0010R	WWAC	17	N	12	0.55	Poor
SWT	Fish Creek	OK311800-00-0130G	WWAC	24	S	18	1.00	Excellent
SWT	North Elm Creek	OK311800-00-0170G	WWAC	17	N	8	0.44	Poor
Wichita	Medicine Creek	OK311300-04-0060H	WWAC	24	S	22	0.85	Good

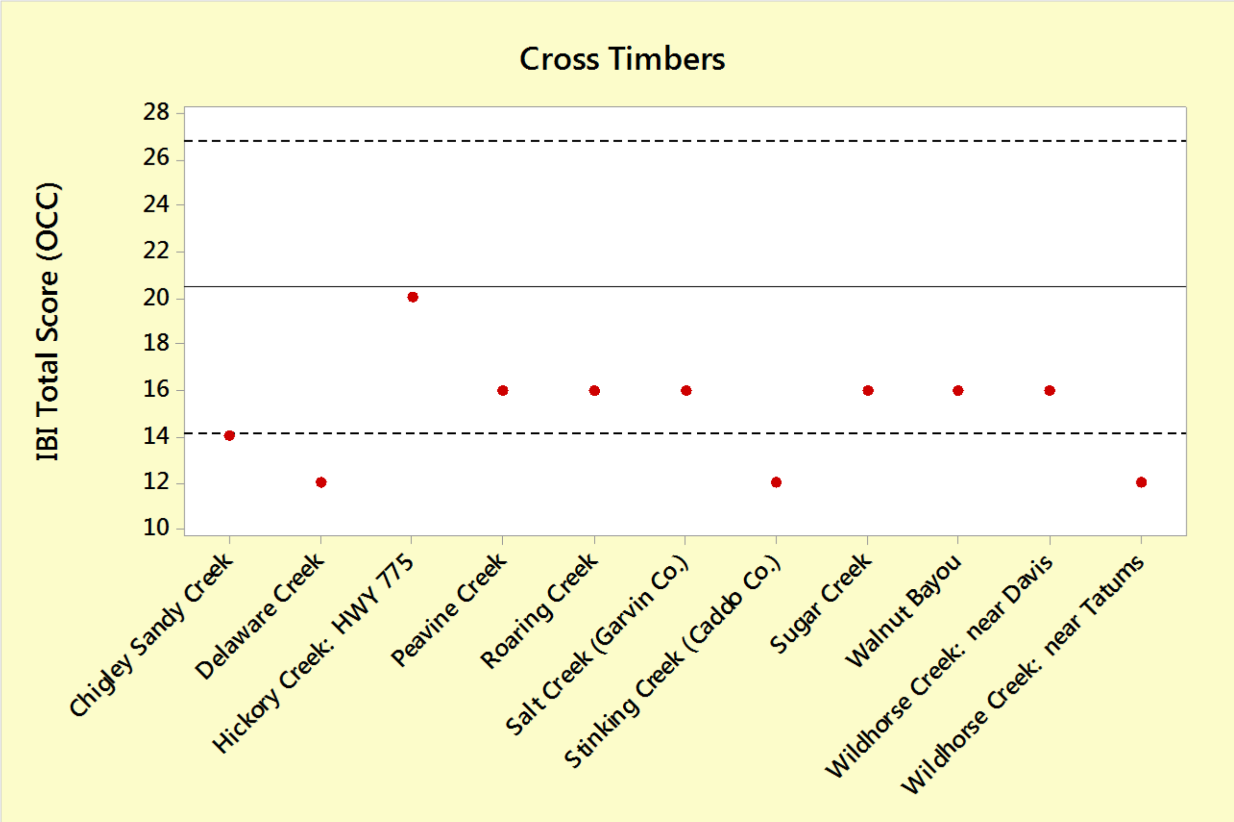
Figure 4 shows the IBI score for each fixed site (indicated by a red dot) relative to the mean value for the high quality sites in that ecoregion (indicated by a solid line). The dashed lines in each graph represent +/- two standard deviations of the mean IBI score of the high quality sites in that ecoregion.

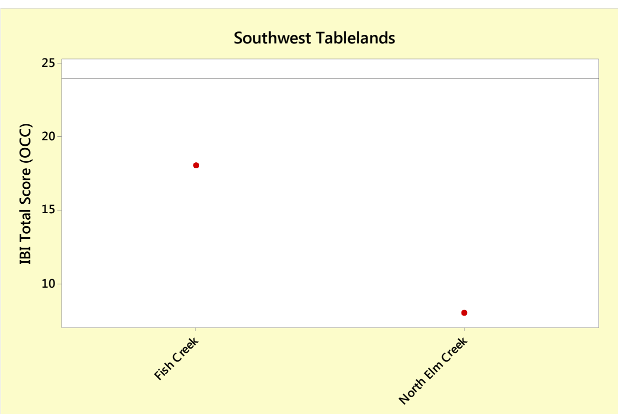
Figure 4. IBI score (fish) for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

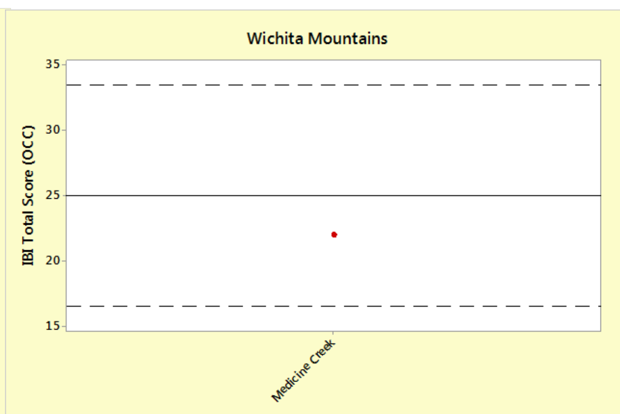



Central Great Plains
IBI Total Score (OCC)
25
20
15
10
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek
Lake Creek: Hwy 6, Greer Co.
Little Beaver Creek
Little Deep Red Creek
Little Elk Creek


Central Great Plains
IBI Total Score (OCC)
24
22
20
18
16
14
12
10
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartemaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Sutle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek







Twenty percent of the sites had significantly lower IBI scores than the high quality sites, as indicated by an IBI score below the bottom dashed line in Figure 4. All of these sites were rated “fair,” “poor,” or “very poor” using the OCC IBI method (Table 13). Conditions have been quite dry during this monitoring cycle, so it is possible that this contributed to low fish scores relative to the high quality site scores, which were collected in previous years.

Table 14 shows a comparison between fish data collected in cycle 1 (2004 or 2005), cycle 2 (2009 or 2010), and cycle 3 (2014 or 2015) of the rotating basin project in order to examine whether biological conditions have improved, worsened, or remained the same at a particular site. IBI scores were calculated relative to the same high quality sites data for all cycles, so any change in condition is due only to a change in the rotating basin cycle 3 collection, not to a change in the high quality sites. When comparing the last two cycles, the fish community remained in the same condition for 11 of the 45 sites. Fourteen streams had worse fish community conditions in cycle 3 relative to cycle 2, while 20 streams had improved fish communities.

Table 14. Comparison of fish data from cycle 1 (2004-2005), cycle 2 (2009-2010), and cycle 3 (2014-2015).

Site Name	WBID	Year	IBI Total Score (OCC)	% of Reference	Condition
Beaver Creek (Custer Co.)	OK310830-03-0190C	2004	21	0.95	Excellent
Beaver Creek (Custer Co.)	OK310830-03-0190C	2009	15	0.68	Fair
Beaver Creek (Custer Co.)	OK310830-03-0190C	2014	20	0.91	Excellent
Big Sandy Creek	OK310800-01-0090G	2004	25	1.00	Excellent
Big Sandy Creek	OK310800-01-0090G	2009	20	0.77	Fair
Big Sandy Creek	OK310800-01-0090G	2014	16	0.62	Poor
Boggy Creek	OK310830-03-0100C	2004	21	0.95	Excellent
Boggy Creek	OK310830-03-0100C	2014	22	1.00	Excellent
Boggy Creek	OK310830-03-0100C	2010	16	0.73	Fair
Buffalo Creek	OK311510-02-0090D	2004	9	0.41	Very Poor
Buffalo Creek	OK311510-02-0090D	2009	14	0.64	Fair
Buffalo Creek	OK311510-02-0090D	2014	8	0.36	Very Poor
Caddo Creek	OK310800-03-0010F	2004	23	0.92	Excellent
Caddo Creek	OK310800-03-0010F	2009	20	0.77	Fair
Caddo Creek	OK310800-03-0010F	2014	24	0.92	Excellent
Cavalry Creek	OK310830-03-0070D	2004	15	0.68	Fair
Cavalry Creek	OK310830-03-0070D	2009	16	0.73	Fair
Cavalry Creek	OK310830-03-0070D	2014	12	0.55	Poor
Chigley Sandy Creek	OK310800-02-0190D	2004	23	1.01	Excellent
Chigley Sandy Creek	OK310800-02-0190D	2009	22	1.00	Excellent
Chigley Sandy Creek	OK310800-02-0190D	2014	14	0.64	Fair
Cobb Creek	OK310830-06-0050K	2014	14	0.64	Fair
Cobb Creek	OK310830-06-0050M	2004	23	1.04	Excellent
Cobb Creek	OK310830-06-0050M	2009	14	0.64	Fair

Site Name	WBID	Year	IBI Total Score (OCC)	% of Reference	Condition
Deep Red Creek	OK311310-03-0010D	2005	15	0.68	Fair
Deep Red Creek	OK311310-03-0010D	2010	20	0.91	Excellent
Deep Red Creek	OK311310-03-0010D	2014	24	1.09	Excellent
Delaware Creek	OK310830-01-0030G	2004	9	0.40	Very Poor
Delaware Creek	OK310830-01-0030G	2009	8	0.36	Very Poor
Delaware Creek	OK310830-01-0030G	2014	12	0.55	Poor
East Barnitz Creek	OK310830-03-0210C	2004	21	0.95	Excellent
East Barnitz Creek	OK310830-03-0210C	2009	10	0.45	Poor
East Barnitz Creek	OK310830-03-0210C	2014	18	0.82	Good
East Cache Creek (upper)	OK311300-02-0010M	2004	19	0.86	Good
East Cache Creek: Upper	OK311300-02-0010M	2009	20	0.91	Excellent
East Cache Creek	OK311300-03-0010M	2014	22	1.00	Excellent
Finn Creek	OK310810-02-0020D	2004	21	0.95	Excellent
Finn Creek	OK310810-02-0020D	2009	22	1.00	Excellent
Finn Creek	OK310810-02-0020D	2014	18	0.82	Good
Fish Creek	OK311800-00-0130G	2004	9	0.38	Very Poor
Fish Creek	OK311800-00-0130G	2009	8	1.33	Excellent
Fish Creek	OK311800-00-0130G	2014	18	1.00	Excellent
Gypsum Creek	OK311600-01-0020F	2004	15	0.68	Fair
Gypsum Creek	OK311600-01-0020F	2009	8	0.36	Very Poor
Gypsum Creek	OK311600-01-0020F	2014	10	0.45	Poor
Haystack Creek	OK311800-00-0040D	2004	23	1.04	Excellent
Haystack Creek	OK311800-00-0040D	2009	18	0.82	Good
Haystack Creek	OK311800-00-0040D	2014	10	0.45	Poor
Hickory Creek	OK311100-02-0010M	2004	21	0.92	Excellent
Hickory Creek: HWY 775	OK311100-02-0010M	2010	20	0.91	Excellent
Hickory Creek: HWY 775	OK311100-02-0010M	2014	20	0.91	Excellent
Lake Creek	OK311510-01-0040D	2004	21	0.95	Excellent
Lake Creek: Hwy 6, Greer Co.	OK311510-01-0040D	2009	20	0.91	Excellent
Lake Creek: Hwy 6, Greer Co.	OK311510-01-0040D	2014	18	0.82	Good
Little Beaver Creek	OK311210-00-0050D	2004	21	0.95	Excellent
Little Beaver Creek	OK311210-00-0050D	2009	18	0.82	Good
Little Beaver Creek	OK311210-00-0050D	2014	14	0.64	Fair
Little Deep Red Creek	OK311310-03-0040D	2004	7	0.32	Very Poor
Little Deep Red Creek	OK311310-03-0040D	2009	12	0.55	Poor
Little Deep Red Creek	OK311310-03-0040E	2014	18	0.82	Good

Site Name	WBID	Year	IBI Total Score (OCC)	% of Reference	Condition
Little Elk Creek	OK311500-03-0040D	2004	23	1.04	Excellent
Little Elk Creek	OK311500-03-0040D	2009	20	0.91	Excellent
Little Elk Creek	OK311500-03-0040D	2014	18	0.82	Good
Medicine Creek	OK311300-04-0060H	2005	27	1.04	Excellent
Medicine Creek	OK311300-04-0060H	2009	20	0.77	Fair
Medicine Creek	OK311300-04-0060H	2014	22	0.85	Good
Mill Creek	OK310800-01-0190G	2004	23	0.92	Excellent
Mill Creek: Lower	OK310800-01-0190G	2009	16	0.62	Poor
Mill Creek: Lower	OK310800-01-0190G	2014	24	0.92	Excellent
Mud Creek	OK311100-04-0010D	2004	17	0.77	Fair
Mud Creek	OK311100-04-0010G	2010	14	0.64	Fair
Mud Creek	OK311100-04-0010G	2014	20	0.91	Excellent
Oil Creek	OK310800-01-0240P	2004	25	1.00	Excellent
Oil Creek	OK310800-01-0240P	2009	28	1.08	Excellent
Oil Creek	OK310800-01-0240P	2014	24	0.92	Excellent
Otter Creek	OK311500-01-0080F	2004	15	0.68	Fair
Otter Creek	OK311500-01-0080F	2009	18	0.82	Good
Otter Creek	OK311500-01-0080F	2014	14	0.64	Fair
Pennington Creek	OK310800-01-0120G	2004	27	1.08	Excellent
Pennington Creek	OK310800-01-0120G	2009	22	0.85	Good
Pennington Creek	OK310800-01-0120G	2014	28	1.08	Excellent
Quartermaster Creek	OK310840-01-0060L	2004	21	0.95	Excellent
Quartermaster Creek	OK310840-01-0060L	2009	8	0.36	Very Poor
Quartermaster Creek	OK310840-01-0060B	2014	10	0.45	Poor
Rainy Mountain Creek	OK310830-02-0060G	2004	21	0.95	Excellent
Rainy Mountain Creek	OK310830-02-0060G	2009	18	0.82	Good
Rainy Mountain Creek	OK310830-02-0060G	2014	22	1.00	Excellent
Red Creek	OK311100-01-0290D	2004	17	0.77	Fair
Red Creek	OK311100-01-0290D	2009	18	0.82	Good
Red Creek	OK311100-01-0290D	2014	14	0.64	Fair
Rush Creek (Garvin Co.)	OK310810-01-0090G	2004	25	1.13	Excellent
Rush Creek (Garvin Co.)	OK310810-01-0090G	2009	21	0.95	Excellent
Rush Creek (Garvin Co.)	OK310810-01-0090G	2014	18	0.82	Good
Salt Creek (Garvin Co.)	OK310810-03-0080G	2004	13	0.57	Poor
Salt Creek (Garvin Co.)	OK310810-03-0080G	2009	12	0.55	Poor
Salt Creek (Garvin Co.)	OK310810-03-0080G	2014	16	0.73	Fair

Site Name	WBID	Year	IBI Total Score (OCC)	% of Reference	Condition
Station Creek	OK311800-00-0060G	2004	15	0.68	Fair
Station Creek	OK311800-00-0060G	2009	14	0.64	Fair
Station Creek	OK311800-00-0060G	2014	12	0.55	Poor
Stinking Creek (Kiowa Co.)	OK310830-02-0020D	2004	21	0.95	Excellent
Stinking Creek (Kiowa Co.)	OK310830-02-0020D	2009	16	0.73	Fair
Stinking Creek (Kiowa Co.)	OK310830-02-0020D	2014	18	0.82	Good
Stinking Creek (Caddo Co.)	OK310830-04-0030K	2004	11	0.48	Poor
Stinking Creek (Caddo Co.)	OK310830-04-0030K	2009	6	0.27	Very Poor
Stinking Creek (Caddo Co.)	OK310830-04-0030K	2014	12	0.55	Poor
Sugar Creek	OK310830-05-0010D	2004	9	0.40	Very Poor
Sugar Creek	OK310830-05-0010D	2009	10	0.45	Poor
Sugar Creek	OK310830-05-0010D	2014	16	0.73	Fair
Suttle Creek	OK311310-01-0070H	2004	21	0.95	Excellent
Suttle Creek	OK311310-01-0070H	2009	14	0.64	Fair
Suttle Creek	OK311310-01-0070H	2014	14	0.64	Fair
Tepee Creek	OK311500-01-0110D	2004	9	0.41	Very Poor
Tepee Creek	OK311500-01-0110D	2009	18	0.82	Good
Tepee Creek	OK311500-01-0110D	2014	18	0.82	Good
Timber Creek	OK311510-01-0090G	2004	25	1.13	Excellent
Timber Creek	OK311510-01-0090G	2009	18	0.82	Good
Timber Creek	OK311510-01-0090G	2014	18	0.82	Good
Trail Creek	OK311500-03-0070D	2004	21	0.95	Excellent
Trail Creek	OK311500-03-0070D	2009	16	0.73	Fair
Trail Creek	OK311500-03-0070D	2014	14	0.64	Fair
Turkey Creek	OK311600-02-0060H	2004	21	0.95	Excellent
Turkey Creek	OK311600-02-0060J	2009	10	0.45	Poor
Turkey Creek	OK311600-02-0060J	2014	18	0.82	Good
Walnut Bayou	OK311100-03-0010G	2004	19	0.84	Good
Walnut Bayou	OK311100-03-0010G	2009	14	0.64	Fair
Walnut Bayou	OK311100-03-0010G	2014	16	0.73	Fair
West Barnitz Creek	OK310830-03-0230C	2004	15	0.68	Fair
West Barnitz Creek	OK310830-03-0230C	2009	14	0.64	Fair
West Barnitz Creek	OK310830-03-0230C	2014	20	0.91	Excellent
Wildhorse Creek near Davis	OK310810-03-0010D	2004	19	0.84	Good
Wildhorse Creek: near Davis	OK310810-03-0010D	2009	16	0.73	Fair
Wildhorse Creek: near Davis	OK310810-01-0020G	2014	16	0.73	Fair

Site Name	WBID	Year	IBI Total Score (OCC)	% of Reference	Condition
Wildhorse Creek near Tatums	OK310810-03-0010R	2004	11	0.48	Poor
Wildhorse Creek: near Tatums	OK310810-03-0010R	2009	10	0.45	Poor
Wildhorse Creek: near Tatums	OK310810-03-0010R	2014	12	0.55	Poor

3.2.3 Macroinvertebrate Collections

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

Table 15 presents the mean values, by season and sample type, for each metric at each site for the two-year cycle 3 monitoring period. Riffle samples were collected at most sites and, generally, best reflect the macroinvertebrate community as a single habitat (Plafkin et al., 1989).

Table 15. Macroinvertebrate metric values determined for each monitoring site, averaged per season and habitat. NI = non-impaired, SI = slightly impaired, MI = moderately impaired.

Site Name	WBID	Habitat	Season	Number of Samples	Total Species	EPT Taxa	Total ID'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition	Average Condition
Beaver Creek (Cotton)	OK311210-00-0010D	Riffle	S	1	8	2	129	0.19	1.18	4.65	0.81	10	0.38	MI	MI
Beaver Creek (Custer)	OK310830-03-0190C	Woody	S	2	12	1	100	0.08	1.62	6.26	0.67	12	0.47	MI	SI
		Woody	W	2	14	2	109	0.07	2.05	7.00	0.50	12	0.60	SI	
Big Sandy Creek	OK310800-01-0090G	Riffle	S	1	16	8	106	0.52	1.99	6.05	0.57	20	0.71	SI	SI
		Riffle	W	1	6	3	118	0.06	0.38	5.75	0.96	6	0.23	MI	
		SVeg	S	1	19	7	121	0.24	2.11	6.34	0.48	22	0.85	NI	
		Woody	W	1	11	8	81	0.31	1.29	5.07	0.77	22	0.85	NI	
Bitter Creek	OK310820-01-0030D	Riffle	S	1	17	4	113	0.27	2.22	5.58	0.50	18	0.69	SI	NI
		Riffle	W	2	14	2	111	0.04	1.22	5.94	0.78	14	0.68	SI	
		SVeg	S	1	22	5	111	0.38	2.43	6.27	0.44	26	1.13	NI	
Boggy Creek	OK310830-03-0100C	Riffle	S	1	11	3	107	0.12	1.45	5.88	0.79	10	0.38	MI	MI
		Woody	W	1	7	1	121	0.02	1.14	6.01	0.81	8	0.40	MI	

Buffalo Creek	OK311510-02-0090D	Riffle	S	2	12	3	103	0.41	1.75	5.57	0.66	16	0.62	SI	SI
		Riffle	W	2	6	1	101	0.03	0.54	5.87	0.94	6	0.29	MI	
		SVeg	S	1	17	5	120	0.43	2.20	5.55	0.42	26	1.13	NI	
Caddo Creek	OK310800-03-0010F	Riffle	S	2	15	6	116	0.15	1.94	5.32	0.56	14	0.50	MI	SI
		Riffle	W	1	9	5	115	0.17	1.01	5.54	0.83	14	0.54	SI	
		SVeg	S	1	22	5	125	0.29	2.31	6.25	0.46	20	0.77	SI	
Cavalry Creek	OK310830-03-0070D	Woody	S	1	7	2	107	0.06	0.54	7.63	0.93	6	0.24	MI	MI
		Woody	W	1	5	2	31	0.10	0.98	5.71	0.81	8	0.40	MI	
Chigley Sandy Creek	OK310800-02-0190D	SVeg	S	1	15	5	114	0.68	1.95	4.99	0.60	20	0.80	NI	SI
		SVeg	W	1	10	3	131	0.79	1.28	2.85	0.77	16	0.71	SI	
Cobb Creek	OK310830-06-0050K	SVeg	W	1	10	0	102	0.00	1.57	6.75	0.73	14	0.68	SI	NI
		Woody	S	1	16	6	108	0.47	2.44	5.15	0.29	30	1.18	NI	
Criner Creek	OK310810-02-0050D	Riffle	S	1	12	4	133	0.65	1.59	4.46	0.63	20	0.77	SI	SI
		Riffle	W	1	9	1	105	0.04	1.04	6.05	0.83	8	0.39	MI	
Deep Red Creek	OK311310-03-0010D	Woody	S	1	12	6	102	0.27	1.72	6.41	0.63	24	0.94	NI	NI
Delaware Creek	OK310830-01-0030G	SVeg	S	1	16	3	107	0.18	1.89	7.26	0.64	12	0.48	MI	SI
		SVeg	W	1	13	3	116	0.25	1.90	6.23	0.51	18	0.79	SI	
East Barnitz Creek	OK310830-03-0210C	Woody	S	1	6	2	98	0.15	1.26	6.06	0.81	10	0.39	MI	SI
		Woody	W	1	7	2	97	0.36	1.49	4.87	0.66	14	0.70	SI	
East Cache Creek	OK311300-03-0010M	Riffle	S	2	13	5	137	0.23	1.93	4.94	0.54	18	0.69	SI	NI
		Riffle	W	1	16	1	102	0.33	2.14	5.91	0.55	20	0.98	NI	
Finn Creek	OK310810-02-0020D	Riffle	S	2	14	5	118	0.62	1.69	5.65	0.63	22	0.85	NI	NI
		Riffle	W	2	16	3	130	0.27	2.23	5.48	0.43	24	1.17	NI	
Fish Creek	OK311800-00-0130G	Riffle	S	1	10	2	133	0.05	1.74	6.37	0.62	12	0.38	MI	MI
		Riffle	W	1	7	0	126	0.00	1.02	6.00	0.84	8	0.29	MI	
Gypsum Creek	OK311600-01-0020F	Riffle	S	2	10	1	103	0.01	1.30	6.87	0.71	4	0.15	SvI	MI
		Riffle	W	1	6	0	112	0.00	0.86	6.36	0.86	6	0.29	MI	
Haystack Creek	OK311800-00-0040D	Riffle	W	1	12	2	89	0.19	2.02	6.02	0.52	16	0.78	SI	SI
Hickory Creek	OK311100-02-0010M	SVeg	W	1	10	2	112	0.05	1.31	7.05	0.84	8	0.35	MI	SI
		Woody	W	1	10	4	96	0.16	1.28	6.15	0.78	16	0.73	SI	
Lake Creek (Caddo)	OK310830-06-0040J	Riffle	S	2	11	3	111	0.26	1.75	5.48	0.59	14	0.54	SI	SI
		Riffle	W	2	16	2	113	0.07	1.75	6.49	0.67	16	0.78	SI	
		SVeg	W	1	14	2	106	0.11	1.92	6.56	0.55	16	0.78	SI	
Lake Creek (Greer)	OK311510-01-0040D	SVeg	S	1	8	2	121	0.61	1.25	7.12	0.81	14	0.61	SI	SI
		SVeg	W	1	12	2	120	0.38	1.91	6.77	0.58	20	0.98	NI	
		Riffle	S	1	10	2	109	0.42	1.68	5.27	0.61	18	0.69	SI	
Little Beaver Creek	OK311210-00-0050D	Riffle	S	1	9	3	123	0.20	1.23	4.52	0.76	12	0.46	MI	MI
		Riffle	W	1	5	0	88	0.00	0.86	7.02	0.93	4	0.20	SvI	
		Woody	S	1	13	7	113	0.12	1.73	6.12	0.61	22	0.86	NI	
Little Beaver Creek: Camelback Rd	OK311210-00-0050M	Riffle	S	1	10	4	102	0.10	1.48	6.41	0.72	10	0.38	MI	MI
Little Beaver Creek: Cemetery Rd	OK311210-00-0050H	Woody	S	1	14	6	128	0.31	1.85	6.09	0.59	26	1.02	NI	NI

Little Deep Red Creek	OK311310-03-0040E	Riffle	S	1	9	1	102	0.04	1.44	7.23	0.68	4	0.15	Svl	MI
		SVeg	S	1	7	1	78	0.13	1.35	7.82	0.73	8	0.35	MI	
Little Elk Creek	OK311500-03-0040D	Riffle	S	2	14	3	105	0.09	1.89	6.21	0.55	12	0.46	MI	SI
		Riffle	W	1	16	0	100	0.00	1.94	5.81	0.55	14	0.68	SI	
Little Washita River	OK310820-02-0010A	Riffle	S	2	14	3	107	0.20	1.81	6.14	0.58	16	0.62	SI	NI
		Riffle	W	2	14	4	120	0.28	1.83	5.59	0.63	24	1.17	NI	
Medicine Creek	OK311300-04-0060H	Riffle	S	1	13	4	105	0.25	1.78	4.15	0.61	20	0.77	SI	SI
Mill Creek: Lower	OK310800-01-0190G	Riffle	S	1	24	10	110	0.36	2.77	5.21	0.30	30	1.07	NI	NI
		Riffle	W	1	16	7	113	0.39	1.96	5.24	0.61	26	1.00	NI	
North Elm Creek	OK311800-00-0170G	Riffle	S	1	10	0	96	0.00	1.53	6.32	0.67	12	0.38	MI	MI
		Riffle	W	1	4	0	99	0.00	0.45	6.00	0.94	6	0.21	MI	
North Mud Creek	OK311100-04-0030C	Riffle	S	1	7	3	116	0.30	1.23	4.20	0.74	14	0.54	SI	MI
		Riffle	W	1	8	0	101	0.00	1.47	7.70	0.65	6	0.29	MI	
Oil Creek	OK310800-01-0240P	Riffle	S	2	19	7	113	0.29	2.27	5.33	0.47	20	0.71	SI	NI
		Riffle	W	2	20	7	105	0.26	2.25	5.71	0.50	24	0.92	NI	
Otter Creek	OK311500-01-0080F	Woody	S	1	13	4	117	0.06	1.35	7.22	0.77	12	0.47	MI	MI
Peavine Creek	OK310810-01-0120M	Riffle	S	1	13	6	105	0.14	1.62	5.73	0.75	16	0.63	SI	SI
		Riffle	W	1	12	1	101	0.31	1.86	7.37	0.53	14	0.56	SI	
Pennington Creek	OK310800-01-0120G	Woody	S	2	19	10	88	0.23	2.22	5.95	0.51	24	0.96	NI	NI
		Woody	W	1	11	6	99	0.38	1.49	5.30	0.75	20	0.77	SI	
Quartermaster Creek	OK310840-01-0060B	Woody	S	1	7	2	106	0.05	0.85	7.48	0.87	6	0.24	MI	MI
		Woody	W	1	12	2	102	0.09	1.32	5.94	0.75	12	0.60	SI	
Rainy Mountain Creek	OK310830-02-0060G	Riffle	S	2	10	1	117	0.14	1.82	6.12	0.54	10	0.38	MI	SI
		Riffle	W	1	13	3	118	0.03	1.60	5.93	0.68	20	0.98	NI	
Red Creek	OK311100-01-0290D	Woody	W	1	4	0	42	0.00	0.53	6.24	0.95	6	0.30	MI	MI
Roaring Creek	OK310810-02-0170B	Riffle	S	1	11	5	127	0.41	1.70	5.09	0.57	20	0.78	SI	MI
		Riffle	W	1	7	2	100	0.05	0.95	6.20	0.87	4	0.16	Svl	
Rush Creek (Garvin)	OK310810-01-0090G	Riffle	S	2	10	3	121	0.06	1.11	6.86	0.86	6	0.23	MI	MI
		Riffle	W	2	13	1	92	0.01	2.05	6.61	0.47	12	0.59	SI	
Rush Creek (Roger Mills)	OK310840-02-0210H	SVeg	S	1	13	4	93	0.29	2.09	5.46	0.45	24	1.04	NI	SI
		SVeg	W	1	5	1	51	0.04	0.52	5.84	0.92	8	0.39	MI	
Salt Creek (Garvin)	OK310810-03-0080G	Riffle	S	1	9	3	121	0.34	1.60	5.83	0.67	14	0.55	SI	SI
		Riffle	W	1	12	3	114	0.32	1.56	5.01	0.74	18	0.72	SI	
Sandstone Creek	OK310840-02-0020C	SVeg	S	1	12	4	121	0.21	1.50	7.02	0.72	20	0.87	NI	SI
		SVeg	W	1	10	2	125	0.02	1.15	6.07	0.88	12	0.59	SI	
Station Creek	OK311800-00-0060G	Riffle	W	1	13	2	84	0.31	2.16	6.35	0.45	22	1.07	NI	NI
Stinking Creek (Caddo)	OK310830-04-0030K	SVeg	S	1	14	1	112	0.14	2.11	5.88	0.42	14	0.56	SI	SI
Stinking Creek (Kiowa)	OK310830-02-0020D	Riffle	S	2	13	4	109	0.24	1.84	5.16	0.63	20	0.77	SI	NI
		Riffle	W	1	13	4	105	0.28	2.15	5.78	0.47	24	1.17	NI	
Sugar Creek	OK310830-05-0010D	SVeg	S	2	14	4	109	0.14	1.74	6.92	0.67	12	0.48	MI	MI

Tepee Creek	OK311500-01-0110D	Riffle	W	1	16	2	96	0.23	2.35	6.60	0.34	20	0.98	NI	NI
		Woody	W	1	9	2	93	0.27	1.72	6.80	0.61	16	0.80	NI	
Timber Creek	OK311510-01-0090G	SVeg	S	1	11	2	98	0.24	2.05	6.95	0.41	16	0.70	SI	NI
		SVeg	W	1	12	3	97	0.16	1.72	6.05	0.64	22	1.07	NI	
Trail Creek	OK311500-03-0070D	Riffle	S	2	12	3	112	0.17	1.36	6.20	0.75	10	0.38	MI	SI
		Riffle	W	1	16	2	115	0.02	1.78	6.17	0.63	16	0.78	SI	
Turkey Creek	OK311600-02-0060J	Riffle	S	2	11	2	99	0.02	1.54	5.17	0.65	12	0.46	MI	MI
		Riffle	W	2	9	1	117	0.07	1.64	5.92	0.63	10	0.49	MI	
Walnut Bayou	OK311100-03-0010G	Riffle	S	1	13	4	99	0.41	2.18	5.03	0.34	20	0.78	SI	SI
		SVeg	W	1	7	1	90	0.01	0.71	6.09	0.89	8	0.35	MI	
West Barnitz Creek	OK310830-03-0230C	Riffle	S	1	11	2	102	0.02	1.26	5.32	0.85	10	0.38	MI	MI
		Woody	S	1	9	1	111	0.04	1.26	6.59	0.84	8	0.31	MI	
		Woody	W	1	10	2	90	0.08	1.65	6.10	0.66	14	0.70	SI	
Wildhorse Creek: Davis	OK310810-01-0020G	Riffle	S	2	15	7	120	0.42	1.98	4.87	0.54	26	1.02	NI	NI
		Riffle	W	2	17	6	110	0.12	1.83	5.52	0.61	18	0.72	SI	
Wildhorse Creek: Tatums	OK310810-03-0010R	Riffle	S	1	11	4	109	0.34	1.83	4.97	0.56	18	0.71	SI	SI
		Riffle	W	2	15	3	112	0.28	1.58	5.94	0.74	18	0.72	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: Beaver (Cotton), Boggy, Cavalry, Fish, Gypsum, Little Beaver, Little Beaver (Camelback), Little Deep Red, North Elm, North Mud, Otter, Quartermaster, Red, Roaring, Rush (Garvin), Sugar, Turkey, and West Barnitz Creeks. Results indicate non-impaired macroinvertebrate communities in 27% of the sites, slightly impaired communities in 41% of the sites, and moderately impaired communities in 32% of the sites.

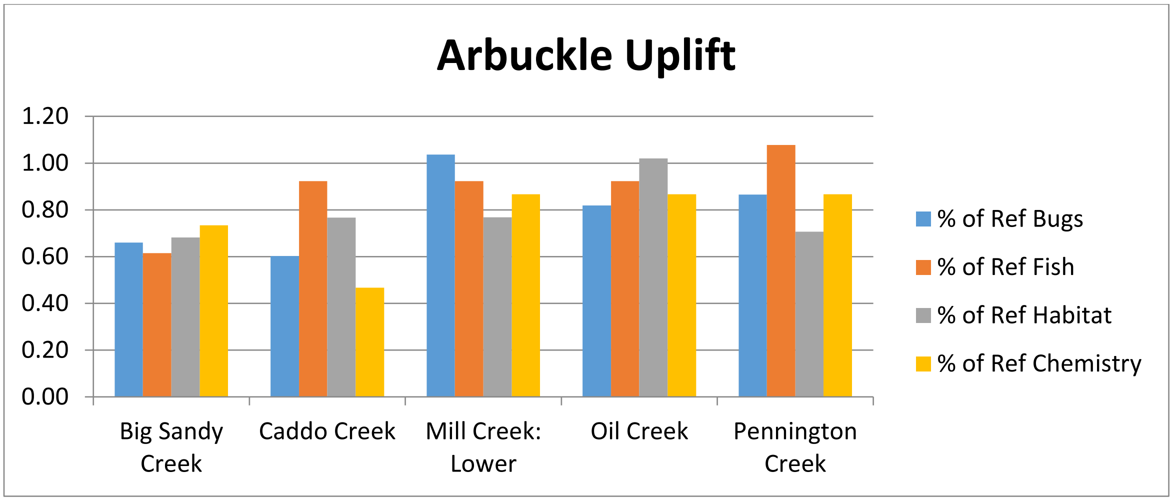
Poor macroinvertebrate scores could indicate water quality problems where habitat scores are acceptable; however, it is possible that the macroinvertebrate collection was not taken at a time which would best represent the community there (i.e., drought influences).

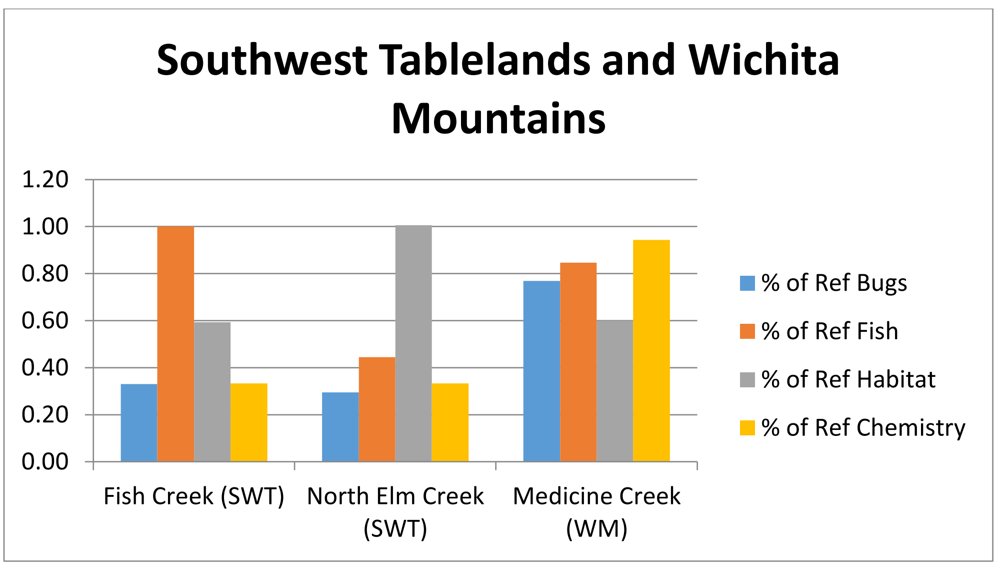
3.2.4 Overall Biological Assessment

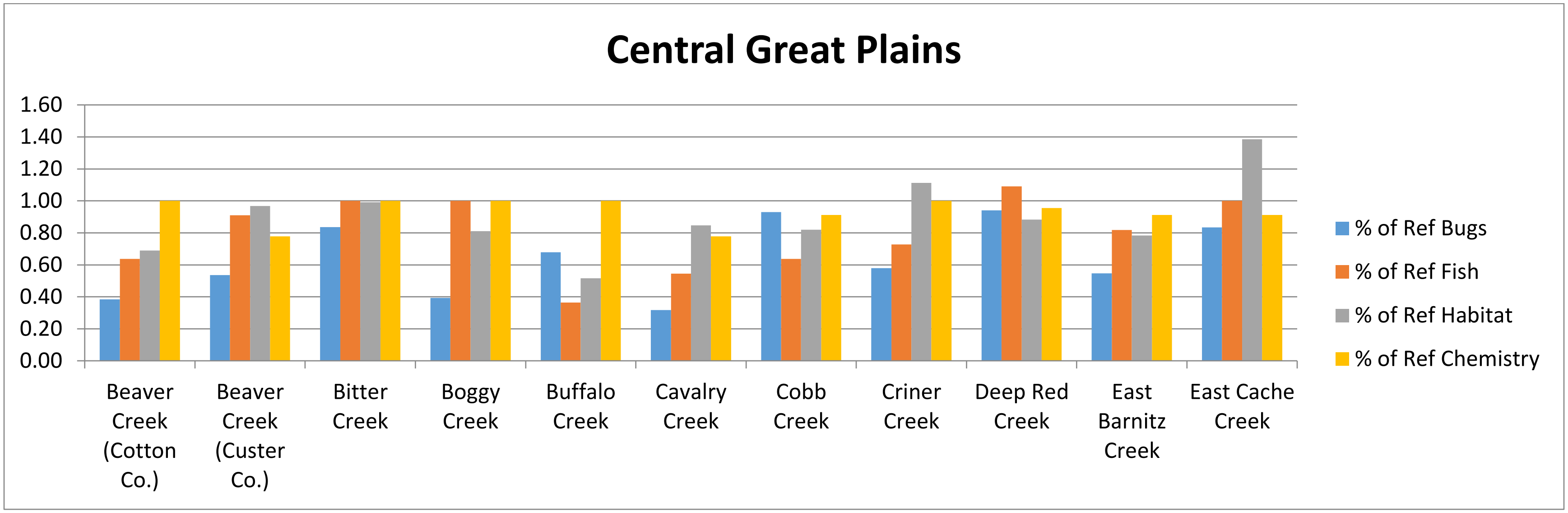
In order to synthesize the biological findings into a meaningful representation of the overall quality of each site, the biological assessments were compared with the habitat and water chemistry results. A water quality score was computed similarly to the other index scores by comparing rotating basin site values relative to high quality site values. The parameters included in this score were phosphorus, nitrogen, DO, turbidity, and salts (TDS, chloride, and sulfate). Then, the habitat, fish, macroinvertebrate, and water quality scores (relative to the mean of high quality sites in the respective ecoregions) were examined in concert with one another (Figure 5).

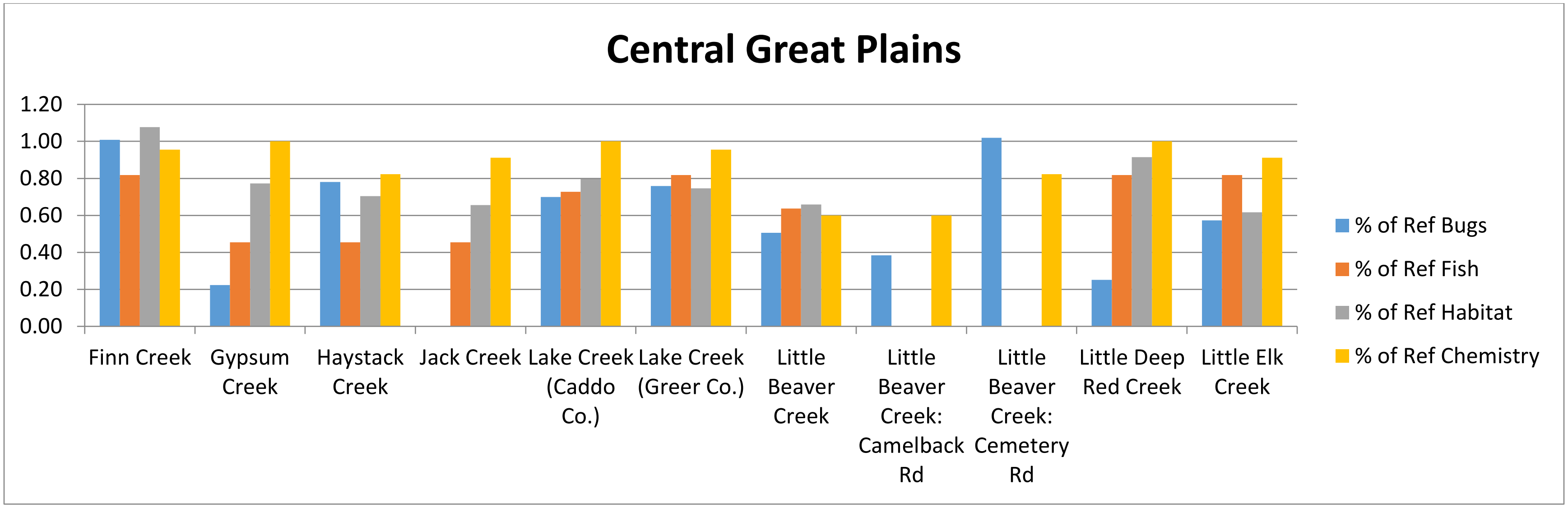
A determination of "good" or "excellent" stream health is indicated by a relatively high score for all categories. Most streams had relatively good agreement among the categories, but there are instances where one score is quite different than the others. It is generally recognized that fish communities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

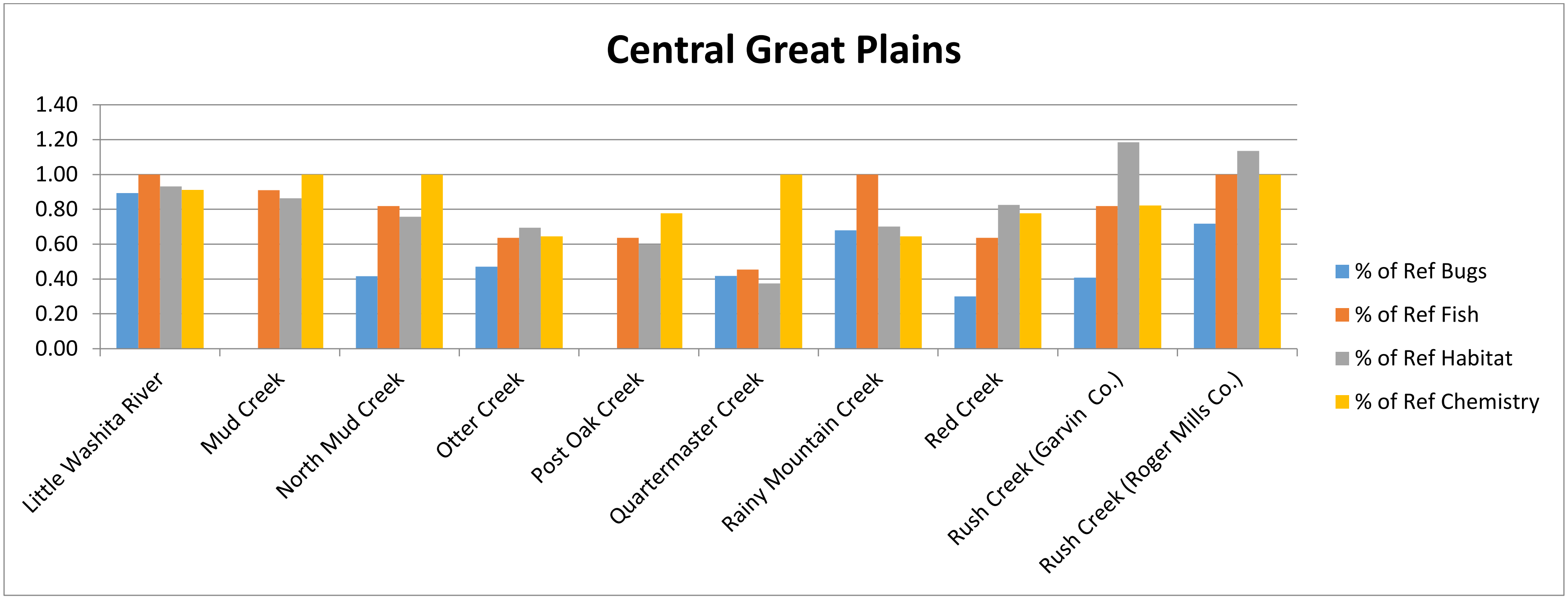
Figure 5. Comparison of habitat, fish, and bug scores relative to the average high quality site in each ecoregion.

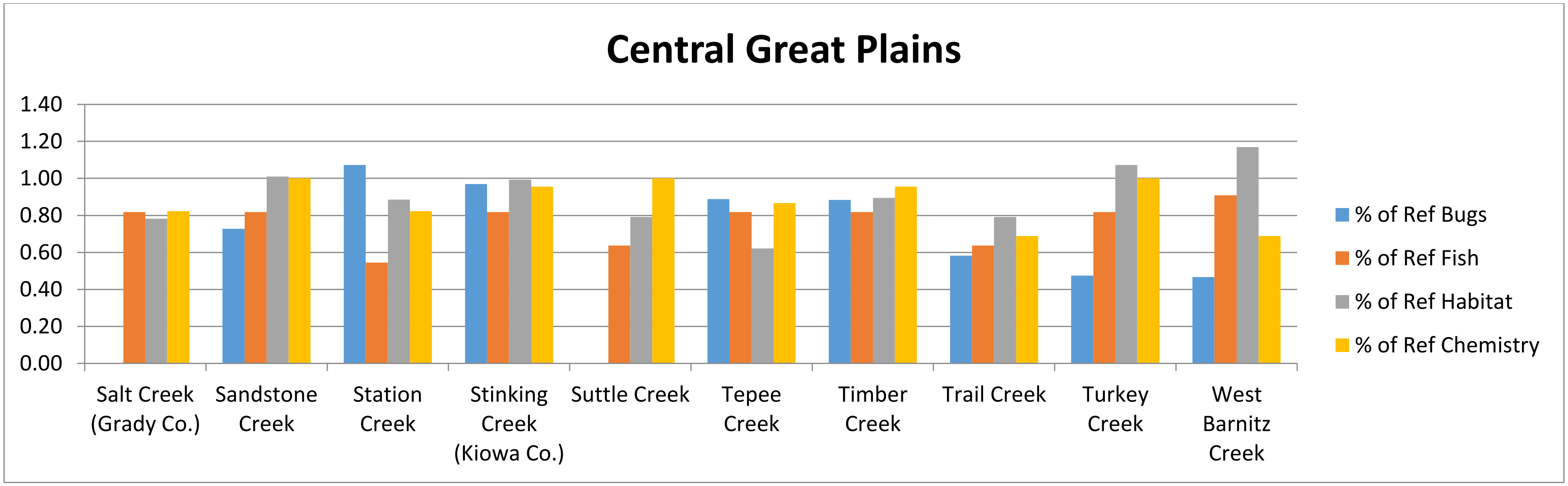


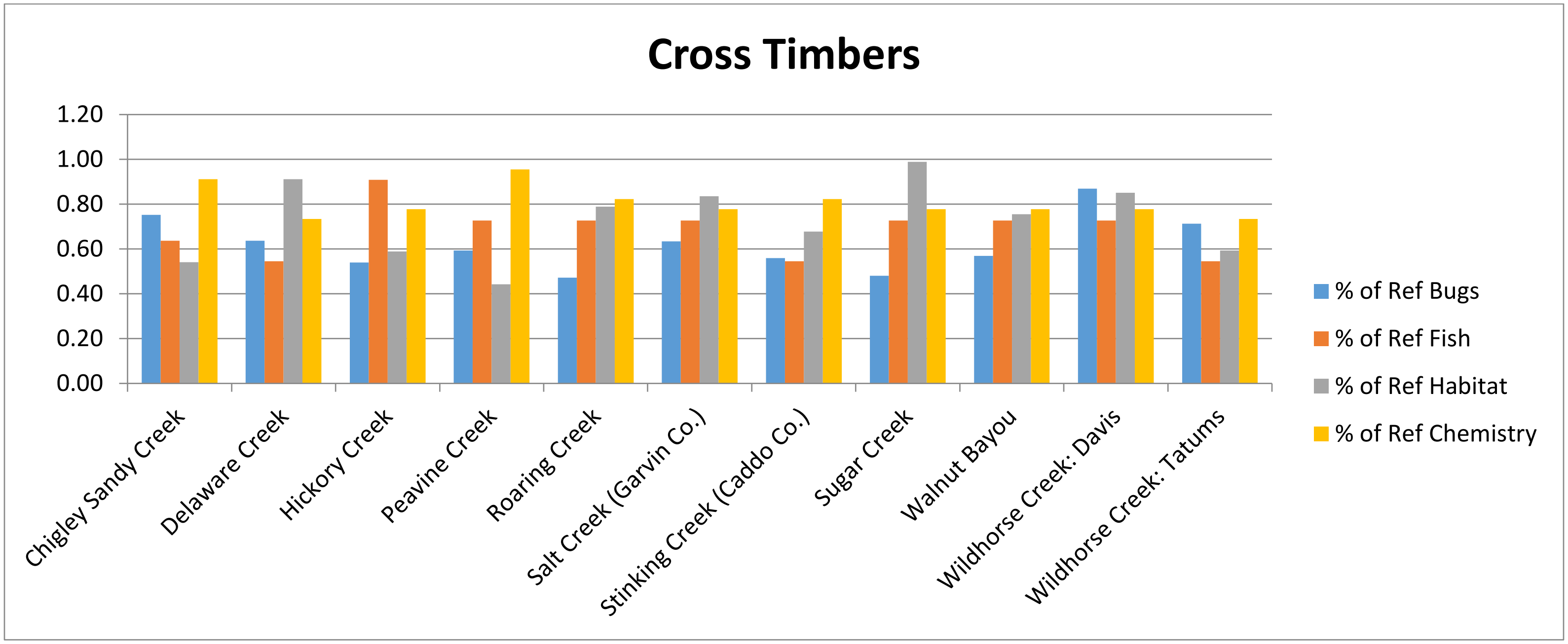



Central Great Plains
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Beaver Creek (Cotton Co.)
Beaver Creek (Custer Co.)
Bitter Creek
Boggy Creek
Buffalo Creek
Cavalry Creek
Cobb Creek
Criner Creek
Deep Red Creek
East Barnitz Creek
East Cache Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry


Central Great Plains
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Finn Creek
Gypsum Creek
Haystack Creek
Jack Creek
Lake Creek (Caddo Co.)
Lake Creek (Greer Co.)
Little Beaver Creek
Little Beaver Creek: Camelback Rd
Little Beaver Creek: Cemetery Rd
Little Deep Red Creek
Little Elk Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry


Central Great Plains
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Little Washita River
Mud Creek
North Mud Creek
Otter Creek
Post Oak Creek
Quartermaster Creek
Rainy Mountain Creek
Red Creek
Rush Creek (Garvin Co.)
Rush Creek (Roger Mills Co.)
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry


Central Great Plains
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Salt Creek (Grady Co.)
Sandstone Creek
Station Creek
Stinking Creek (Kiowa Co.)
Suttle Creek
Tepee Creek
Timber Creek
Trail Creek
Turkey Creek
West Barnitz Creek
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry


Cross Timbers
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Chigley Sandy Creek
Delaware Creek
Hickory Creek
Peavine Creek
Roaring Creek
Salt Creek (Garvin Co.)
Stinking Creek (Caddo Co.)
Sugar Creek
Walnut Bayou
Wildhorse Creek: Davis
Wildhorse Creek: Tatums
% of Ref Bugs
% of Ref Fish
% of Ref Habitat
% of Ref Chemistry

3.3 WATERSHED ASSESSMENT

Table 16 shows the land use upstream of each monitoring site as obtained through GIS using the 2011 NRCS National Land Cover Dataset. Table 17 presents the types and number of permitted activities that occur upstream of each site. The watershed sizes and land uses vary widely, with Washington Creek and Spring Creek in Roger Mills Co. having the smallest watershed areas, each less than 5,000 acres, while the Wildhorse Creek watershed includes more than 400,000 acres. Grasslands make up the largest percentage of land use, on average, in this basin, followed by cultivated crops. Watersheds range from having no grasslands to having 89% in grasslands, and from having no cultivated crops in the watershed to having 83% of the watershed in cultivated crops. Medicine and Pennington Creeks each had only one oil and gas permit and no other permitted land use, though Pennington Creek has one public water intake. Big Sandy, Criner, Jack and Roaring Creeks had no permitted land use.

Table 16. Watershed land use (% of total watershed area) for each Group 4 monitoring site based on the most recent NLCD (USGS 2011).

Site Name	WBID	Total Acres	% Barren Land (Rock/Sand/Clay)	% Cultivated Crops	% Deciduous Forest	% Developed, High Intensity	%Developed, Low Intensity	%Developed, Medium Intensity	% Developed, Open space	% Emergent Herbaceous Wetlands	% Evergreen Forest	% Grasslands/Herbaceous	% Mixed Forest	% Open Water	% Pasture/Hay	% Shrub/Scrub	% Woody Wetlands
Beaver Creek (Custer Co.)	OK310830-03-0190C	50401	0	35	1	0	1	0	5	0	0	57	0	1	0	0	0
Beaver Creek (Cotton Co.)	OK311210-00-0010D	170313	0	24	6	0	0	0	5	0	0	64	0	1	0	0	0
Big Sandy Creek	OK310800-01-0090G	15857	0	2	30	0	0	0	4	0	1	34	0	1	28	0	0
Bitter Creek	OK310820-01-0030D	65867	0	21	7	0	0	0	4	0	0	66	0	0	0	0	0
Boggy Creek	OK310830-03-0100C	74950	0	56	0	0	0	0	5	0	0	25	1	0	0	12	0
Buffalo Creek	OK311510-02-0090D	58019	1	8	0	0	0	0	4	0	0	59	1	0	0	28	0
Caddo Creek	OK310800-03-0010F	207587	0	5	23	0	1	0	3	0	0	53	0	1	12	0	0
Cavalry Creek	OK310830-03-0070D	66556	0	52	0	0	1	0	5	0	0	20	2	0	0	19	0
Chigley Sandy Creek	OK310800-02-0190D	28165	0	4	21	0	1	0	3	0	0	54	0	1	15	0	0
Cobb Creek	OK310830-06-0050K	84705	0	55	1	0	0	0	5	0	1	37	0	1	0	0	0
Criner Creek	OK310810-02-0050D	40535	0	14	14	0	0	0	4	0	0	59	0	1	8	0	0
Deep Red Creek	OK311310-03-0010D	399892	0	48	1	0	0	0	4	0	0	38	0	1	0	6	0
Delaware Creek	OK310830-01-0030G	25751	0	13	11	0	0	0	7	0	1	66	0	0	1	0	0
East Barnitz Creek	OK310830-03-0210C	74238	0	25	0	0	0	0	5	0	3	65	0	0	0	1	0
East Cache Creek	OK311300-03-0010M	42535	0	41	2	0	0	0	4	0	0	51	0	0	0	1	0
Finn Creek	OK310810-02-0020D	41554	0	17	12	0	0	0	4	0	0	52	0	1	14	0	0
Fish Creek	OK311800-00-0130G	20068	0	0	0	0	0	0	1	0	0	33	0	0	0	65	0
Gypsum Creek	OK311600-01-0020F	66197	0	33	0	0	0	0	4	0	0	2	0	0	0	59	0
Haystack Creek	OK311800-00-0040D	87290	1	17	0	0	0	0	3	0	0	15	0	0	0	63	0
Hickory Creek	OK311100-02-0010M	73442	0	1	23	1	4	2	6	0	0	43	0	0	19	0	0

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
Jack Creek	OK311310-03-0030B	44158	0	50	0	0	0	0	4	0	0	38	0	1	0	7	0
Lake Creek (Caddo Co.)	OK310830-06-0040J	40505	0	63	2	0	0	0	5	0	1	28	0	0	0	0	0
Lake Creek (Greer Co.)	OK311510-01-0040D	25620	0	52	0	0	0	0	5	0	0	7	3	0	0	32	0
Little Beaver Creek	OK311210-00-0050D	117050	0	22	9	0	1	0	5	0	0	62	0	1	0	0	0
Little Beaver Creek: Camelback Rd	OK311210-00-0050M	62266	0	25	9	0	1	0	5	0	0	59	0	1	0	0	0
Little Beaver Creek: Cemetery Rd	OK311210-00-0050H	100042	0	22	9	0	1	0	5	0	0	62	0	1	0	0	0
Little Deep Red Creek	OK311310-03-0040E	81443	0	59	0	0	1	0	4	0	0	33	0	2	0	1	0
Little Elk Creek	OK311500-03-0040D	67905	0	67	0	0	1	0	6	0	0	5	2	1	0	17	0
Little Washita River	OK310820-02-0010A	153867	0	19	11	0	1	1	6	0	0	61	0	1	1	0	0
Medicine Creek	OK311300-04-0060H	28261	0	2	4	0	0	0	1	0	1	89	1	0	0	1	0
Mill Creek: Lower	OK310800-01-0190G	61002	3	2	21	0	0	0	3	0	2	50	0	1	18	0	0
Mud Creek	OK311100-04-0010G	293127	0	13	14	0	0	0	2	0	0	65	0	1	5	0	0
North Elm Creek	OK311800-00-0170G	16079	0	0	0	0	0	0	1	0	0	31	0	0	0	68	0
North Mud Creek	OK311100-04-0030C	76062	0	15	11	0	0	0	3	0	0	62	0	0	8	0	0
Oil Creek	OK310800-01-0240P	13587	0	15	9	0	0	0	3	0	0	51	0	0	21	0	0
Otter Creek	OK311500-01-0080F	177739	0	47	1	0	0	0	5	1	0	18	2	3	0	23	0
Peavine Creek	OK310810-01-0120M	35550	0	8	19	0	0	0	3	0	0	50	0	2	17	0	0
Pennington Creek	OK310800-01-0120G	59713	0	0	27	0	0	0	3	0	1	51	0	0	17	0	0
Post Oak Creek	OK311310-02-0070B	85638	0	15	6	0	0	0	3	0	0	69	0	0	0	5	0
Quartermaster Creek	OK310840-01-0060B	110872	0	10	0	0	0	0	3	0	0	66	1	0	0	20	0
Rainy Mountain Creek	OK310830-02-0060G	201388	0	44	0	0	0	0	5	0	0	20	2	0	0	28	0
Red Creek	OK311100-01-0290D	38836	0	12	4	0	0	0	2	0	0	76	0	0	3	2	0
Roaring Creek	OK310810-02-0170B	42000	0	13	12	0	0	0	2	0	0	72	0	1	0	0	0
Rush Creek (Garvin Co.)	OK310810-01-0090G	164542	0	13	19	0	1	0	5	0	0	58	0	1	4	0	0
Rush Creek (Roger Mills Co.)	OK310840-02-0210H	32391	0	2	0	0	0	0	4	0	0	66	0	0	0	27	0
Salt Creek (Garvin Co.)	OK310810-03-0080G	46356	0	4	30	0	0	0	4	0	0	55	0	0	6	0	0
Salt Creek (Grady Co.)	OK310820-01-0140B	51477	0	38	3	0	0	0	4	0	0	54	0	1	0	0	0
Sandstone Creek	OK310840-02-0020C	3	0	25	0	0	0	0	28	0	0	0	0	0	0	46	1
Station Creek	OK311800-00-0060G	8739	0	34	0	0	0	0	4	0	0	19	0	0	0	42	0
Stinking Creek (Kiowa Co.)	OK310830-02-0020D	65267	0	45	2	0	0	0	4	0	0	45	0	0	0	2	0
Stinking Creek (Caddo Co.)	OK310830-04-0030K	13583	0	14	10	0	0	0	4	0	6	66	0	0	1	0	0

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
Sugar Creek	OK310830-05-0010D	148181	0	25	6	0	0	0	5	0	16	48	0	1	0	0	0
Suttle Creek	OK311310-01-0070H	62747	0	83	0	0	1	0	5	0	0	10	0	0	0	0	0
Tepee Creek	OK311500-01-0110D	43115	0	69	0	0	0	0	5	0	0	2	3	0	0	21	0
Timber Creek	OK311510-01-0090G	38593	0	19	0	0	0	0	5	0	0	54	1	0	0	20	0
Trail Creek	OK311500-03-0070D	55777	0	58	0	0	0	0	4	0	0	13	2	0	0	23	0
Turkey Creek	OK311600-02-0060J	184174	0	44	0	0	0	0	4	0	0	4	1	0	0	46	0
Walnut Bayou	OK311100-03-0010G	209312	0	3	34	0	1	0	3	0	0	46	0	1	12	0	0
West Barnitz Creek	OK310830-03-0230C	83806	0	17	0	0	0	0	4	0	1	62	1	0	0	16	0
Wildhorse Creek: Davis	OK310810-01-0020G	403569	0	9	22	0	0	0	4	0	1	57	0	2	5	0	0
Wildhorse Creek: Tatums	OK310810-03-0010R	217507	0	12	22	0	0	0	4	0	0	56	0	2	4	0	0

Table 17. Permitted land use for each Group 4 monitoring site. For the NPDES category, the total number of NPDES in the watershed is given, followed by the number of major NPDES in parentheses, if applicable. The number of O&G permits is currently being updated: these numbers are from the previous report.

Site Name	WBID	#CAFO	# Landfill	#NPDES Permits	# O&G* (*currently being updated)	#Total Retention Lagoon	# Land Application	# Public Water Intakes	# Storage Disposal
Beaver Creek (Custer Co.)	OK310830-03-0190C	1			148	6			
Beaver Creek (Cotton Co.)	OK311210-00-0010D					8	3		
Big Sandy Creek	OK310800-01-0090G								
Bitter Creek	OK310820-01-0030D	1							
Boggy Creek	OK310830-03-0100C				130	3			
Buffalo Creek	OK311510-02-0090D				345				
Caddo Creek	OK310800-03-0010F		1	8 (6 M)	5598	2	4		1
Cavalry Creek	OK310830-03-0070D			1	60				
Chigley Sandy Creek	OK310800-02-0190D				347	1			
Cobb Creek	OK310830-06-0050K	2			110				
Criner Creek	OK310810-02-0050D								

Site Name	WBID	#CAFO	# Landfill	#NPDES Permits	# O&G* (*currently being updated)	#Total Retention Lagoon	# Land Application	# Public Water Intakes	# Storage Disposal
Deep Red Creek	OK311310-03-0010D		2	1	194	4	1	1	
Delaware Creek	OK310830-01-0030G			1	950				
East Barnitz Creek	OK310830-03-0210C				203				
East Cache Creek	OK311300-03-0010M				642				
Finn Creek	OK310810-02-0020D				467				
Fish Creek	OK311800-00-0130G				44				
Gypsum Creek	OK311600-01-0020F				30				
Haystack Creek	OK311800-00-0040D				253				
Hickory Creek	OK311100-02-0010M			4	1043	1	3		
Jack Creek	OK311310-03-0030B								
Lake Creek (Caddo Co.)	OK310830-06-0040J	1	1						
Lake Creek (Greer Co.)	OK311510-01-0040D				186	1			
Little Beaver Creek	OK311210-00-0050D		1		1408	7	1		
Little Beaver Creek: Camelback Rd	OK311210-00-0050M					6	1		
Little Beaver Creek: Cemetery Rd	OK311210-00-0050H		1			7	1		
Little Deep Red Creek	OK311310-03-0040E		1	1	224	1			
Little Elk Creek	OK311500-03-0040D				152	6			
Little Washita River	OK310820-02-0010A		1	2		2			1
Medicine Creek	OK311300-04-0060H				1				
Mill Creek: Lower	OK310800-01-0190G	1		19	29	2			
Mud Creek	OK311100-04-0010G		2		7820	4		1	
North Elm Creek	OK311800-00-0170G				63				
North Mud Creek	OK311100-04-0030C	1		1					
Oil Creek	OK310800-01-0240P	1			7				
Otter Creek	OK311500-01-0080F	1		2	63	5	1	2	
Peavine Creek	OK310810-01-0120M					5			
Pennington Creek	OK310800-01-0120G				1			1	
Post Oak Creek	OK311310-02-0070B					3			
Quartermaster Creek	OK310840-01-0060B				235				
Rainy Mountain Creek	OK310830-02-0060G	2		1	2815	1	1		
Red Creek	OK311100-01-0290D				340				
Roaring Creek	OK310810-02-0170B								
Rush Creek (Garvin Co.)	OK310810-01-0090G			1		1	1		
Rush Creek (Roger Mills Co.)	OK310840-02-0210H					1			

Site Name	WBID	#CAFO	# Landfill	#NPDES Permits	# O&G* (*currently being updated)	#Total Retention Lagoon	# Land Application	# Public Water Intakes	# Storage Disposal
Salt Creek (Garvin Co.)	OK310810-03-0080G			1	1334				
Salt Creek (Grady Co.)	OK310820-01-0140B		1			3			
Sandstone Creek	OK310840-02-0020C				272				
Station Creek	OK311800-00-0060G				11				
Stinking Creek (Kiowa Co.)	OK310830-02-0020D				284				
Stinking Creek (Caddo Co.)	OK310830-04-0030K				59				
Sugar Creek	OK310830-05-0010D	1			591				
Suttle Creek	OK311310-01-0070H	3		3	312	1	1		
Tepee Creek	OK311500-01-0110D				38	2	1		
Timber Creek	OK311510-01-0090G				175				
Trail Creek	OK311500-03-0070D				269				
Turkey Creek	OK311600-02-0060J		1	1	68				
Walnut Bayou	OK311100-03-0010G			4	5973	1		1	
West Barnitz Creek	OK310830-03-0230C				249				
Wildhorse Creek: Davis	OK310810-01-0020G			5	10394	10		2	
Wildhorse Creek: Tatums	OK310810-03-0010R			2	7027	7		2	

3.4 DESIGNATED USE SUPPORT ASSESSMENT

The designated uses assessed for the monitoring sites are presented in Table 18 below, along with the current attainment status of each use based on the proposed 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 all its designated uses.

Table 18. Designated use support assessment. F = fully supporting, N = not supporting, I = insufficient information, X = use not assessed, * = antidegradation designation.

Site Name	WBID	Size (Stream Miles)	Aesthetics	Agriculture	Cool Water Aquatic Comm.	Habitat Limited Aquatic Comm.	Warm Water Aquatic Comm.	Fish Consumption	High Quality Water	Primary Body Contact Recreation	Public/Private Water Supply	Secondary Body Contact Recreation	Sensitive Water Supply
Beaver Creek (Custer Co.)	OK310830-03-0190C	22.54	F	N			N	X				F	
Beaver Creek (Cotton Co.)	OK311210-00-0010D	46.89	I	I			I	X		X	I		*

Site Name	WBID	Size (Stream Miles)	Aesthetics	Agriculture	Cool Water Aquatic Comm.	Habitat Limited Aquatic Comm.	Warm Water Aquatic Comm.	Fish Consumption	High Quality Water	Primary Body Contact Recreation	Public/Private Water Supply	Secondary Body Contact Recreation	Sensitive Water Supply
Big Sandy Creek	OK310800-01-0090G	13.57	F	F			N	X		N			
Bitter Creek	OK310820-01-0030D	6.02	F	F			I	X		N	I		
Boggy Creek	OK310830-03-0100C	24.89	F	F			F	X		N			
Buffalo Creek	OK311510-02-0090D	135.14	F	N			N	X		N	I		
Caddo Creek	OK310800-03-0010F	44.08	I	F			F	X		N	I		
Cavalry Creek	OK310830-03-0070D	20.30	F	N			I	X		N	I		
Chigley Sandy Creek	OK310800-02-0190D	14.31	I	F			N	X		N	I		
Cobb Creek	OK310830-06-0050K	8.13	X	X			I	X		X	X		*
Criner Creek	OK310810-02-0050D	11.76	F	I			I	X		X	F		
Deep Red Creek	OK311310-03-0010D	57.29	I	N			N	F		N	I		
Delaware Creek	OK310830-01-0030G	11.68	I	N			N	X				F	
East Barnitz Creek	OK310830-03-0210C	26.48	I	N			I	X		N	X		
East Cache Creek	OK311300-03-0010M	28.40	X	X			N	X		X	X		*
Finn Creek	OK310810-02-0020D	14.15	F	F			I	X		N	I		
Fish Creek	OK311800-00-0130G	16.84	F	N			N	X		N	I		
Gypsum Creek	OK311600-01-0020F	28.10	I	N			N	X		N	I		
Haystack Creek	OK311800-00-0040D	43.06	F	N			N	X		N	I		
Hickory Creek: HWY 775	OK311100-02-0010M	37.28	I	F			F	I		N	I		
Jack Creek	OK311310-03-0030B	23.87	I	I			N	X		X	X		
Lake Creek (Caddo Co.)	OK310830-06-0040J	16.27	F	F			I	X		X	I		*
Lake Creek (Greer Co.)	OK311510-01-0040D	13.33	F	F			I	X		N			
Little Beaver Creek	OK311210-00-0050D	39.49	F	N			I	X		N	I		*
Little Beaver Creek @ Camelback Rd	OK311210-00-0050M	39.49	F	N			I	X		N	I		*
Little Beaver Creek @ Cemetery Rd	OK311210-00-0050H	39.49	F	N			I	X		N	I		*
Little Deep Red Creek	OK311310-03-0040E	33.57	I	N			N	X		N	I		
Little Elk Creek	OK311500-03-0040D	15.40	F	F			N	X		N	I		
Little Washita River	OK310820-02-0010A	36.98	F	N			N	X		N	F		
Medicine Creek	OK311300-04-0060H	17.71	F	F			I	X		N	I		*
Mill Creek: Lower	OK310800-01-0190G	37.86	I	F			I	X		N	I		
Mud Creek	OK311100-04-0010G	49.53	I	F			N	N		N	I		
North Elm Creek	OK311800-00-0170G	12.77	F	N			N	X		N	I		
North Mud Creek	OK311100-04-0030C	27.87	I	I		I		X		I	I		
Oil Creek	OK310800-01-0240P	19.47	F	F			N	X		N	I		
Otter Creek	OK311500-01-0080F	23.13	I	N			N	X		N	I		
Peavine Creek	OK310810-01-0120M	3.81	I	I			I	X		X	I		

Site Name	WBID	Size (Stream Miles)	Aesthetics	Agriculture	Cool Water Aquatic Comm.	Habitat Limited Aquatic Comm.	Warm Water Aquatic Comm.	Fish Consumption	High Quality Water	Primary Body Contact Recreation	Public/Private Water Supply	Secondary Body Contact Recreation	Sensitive Water Supply
Pennington Creek	OK310800-01-0120G	36.93	F	F	I			X	F	N	F		
Post Oak Creek	OK311310-02-0070B	24.86	I	X			I	X		X	X		
Quartermaster Creek	OK310840-01-0060B	32.98	I	N			N	X		N	I		
Rainy Mountain Creek	OK310830-02-0060G	32.33	F	N			N	X				F	
Red Creek	OK311100-01-0290D	17.42	F	F			N	X		N	I		
Roaring Creek	OK310810-02-0170B	18.27	F	F			N	X		N	F		
Rush Creek (Garvin Co.)	OK310810-01-0090G	10.30	I	N			F	X		N			
Rush Creek (Roger Mills Co.)	OK310840-02-0210H	16.33	I	I			N	X		X	X		
Salt Creek (Garvin Co.)	OK310810-03-0080G	19.05	I	N			N	X		N	I		
Salt Creek (Grady Co.)	OK310820-01-0140B	18.52	I	I			I	X		X			
Sandstone Creek	OK310840-02-0020C	14.59	F	N			F	X		N	I		
Station Creek	OK311800-00-0060G	10.58	F	N			F	X		N			
Stinking Creek (Kiowa Co.)	OK310830-02-0020D	18.36	F	N			N	X		N	I		
Stinking Creek (Caddo Co.)	OK310830-04-0030K	11.33	F	N			I	X		N	I		
Sugar Creek	OK310830-05-0010D	32.40	I	N			N	X				F	
Suttle Creek	OK311310-01-0070H	19.41	I	N			N	X				I	
Tepee Creek	OK311500-01-0110D	19.44	I	N			F	X		N			
Timber Creek	OK311510-01-0090G	12.01	F	F			N	X		N	I		
Trail Creek	OK311500-03-0070D	19.15	F	N			N	X		N	I		
Turkey Creek	OK311600-02-0060J	51.64	I	N			N	X		N	N		
Walnut Bayou	OK311100-03-0010G	10.82	I	F			N	F		N	F		
West Barnitz Creek	OK310830-03-0230C	38.35	F	N			N	X		N	I		
Wildhorse Creek (Davis)	OK310810-01-0020G	8.97	I	F			I	X		N	I		
Wildhorse Creek (Tatums)	OK310810-03-0010R	22.30	I	N			N	X		N	I		

4.0 SUMMARY

This southwestern Oklahoma basin of mixed grasslands and crop lands has been experiencing drought conditions for the last several years. The changes in stream conditions since the last monitoring cycle appear to confirm lower flows, a higher percentage of contributions from point sources, and lower levels of dissolved oxygen. The biological community, while struggling in places, is maintaining similar levels as was found in previous cycles.

In general, water chemistry for the rotating Basin Group 4 monitoring sites showed some changes when compared with the first two cycles: nitrogen, alkalinity and/or hardness, and salts all increased though other parameters were about the same. Many sites did not show significant differences between cycles

2 and 3, but did show significant differences when all three cycles were compared. Many of these differences could be indicative of lower flow conditions, where point source inputs play a larger role in water quality than nonpoint source, as evident by higher nitrogen and salts.

Low dissolved oxygen continues to be a problem in this basin: 43% of the sites were below the state criteria. Lower flow conditions could also be affecting the dissolved oxygen.

While 69% of the sites in Basin 4 are meeting the state *E. coli* standard, none is fully attaining the Recreational designated use because they are listed for *Enterococcus* and OCC only tests for *E. coli*.

Habitat at 90% of the sites in Basin 4 falls within two standard deviations of the mean habitat score of high quality sites in the same ecoregion. Comparisons of fish collections with collections in Cycle 2 indicate that about 1/3 of the sites showed improved conditions, 1/3 of the sites showed worse conditions, and 1/3 indicated the same conditions. Overall, approximately 27% of the sites scored excellent, 24% were good, 29% were fair, 19% were poor, and 1% was very poor. Four of the sites with poor fish collections also had poor habitat.

Most sites had either non-impaired (27%) or slightly impaired (41%) macroinvertebrate communities overall; 32% of the sites had collections that indicate moderately impaired communities.

The next cycle of monitoring in Basin 4 is scheduled to begin in June, 2019.

5.0 LITERATURE CITED

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