CRITICAL REVIEW OF US ENVIRONMENTAL PROTECTION AGENCY NUMERICAL NUTRIENT CRITERIA WITH RESPECT TO CULTURALLY SIGNIFICANT WATERS AS A DESIGNATED USE

By

CARA AILENE COWAN WATTS

Bachelor of Science in Mechanical Engineering
Oklahoma State University
Stillwater, OK
1997

Master of Science in Telecommunications
Management
Oklahoma State University
Stillwater, OK
2002

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Oklahoma State University
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CRITICAL REVIEW OF US ENVIRONMENTAL PROTECTION AGENCY NUMERICAL NUTRIENT CRITERIA WITH RESPECT TO CULTURALLY SIGNIFICANT WATERS AS A DESIGNATED USE

Dissertation Approved:

Dr. Dan Storm

Dissertation Adviser

Dr. Mike Smolen

Dr. Garey Fox

Dr. Mark Payton

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Note, this dissertation does not represent the official views or actions of the Cherokee Nation and was completed by me as an individual Cherokee Nation citizen.

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Abstract: The Cherokee Nation, a Federally-recognized Tribal government in Northeastern Oklahoma lacks Tribal water quality standards for numerical nutrient standards based on baseline conditions in the Cherokee Nation. Lotic waters are of special significance in Cherokee Nation culture and ceremonies. Three water quality standard priorities within the Tribe include defining Culturally Significant Waters as a designated use, identifying Culturally Significant Waterbodies and determining applicable numerical nutrient standards. Culturally Significant Water as a designated use was defined based on community surveys. Twelve rivers and streams were identified as a portion of the Culturally Significant Waters of the Cherokee Nation based on a tribal community survey using a Use Attainability Analysis. To address excess nutrients in the Cherokee Nation, a total phosphorus numerical nutrient criterion was determined using data for Culturally Significant Water bodies, literature guidance and the US Environmental Protection Agency recommended nutrient criteria process for the respective Aggregate Nutrient Ecoregion. The Oklahoma Scenic Rivers criterion of 0.037 mg/L total phosphorus for a 90-day geometric mean was evaluated and determined not to be protective of Cherokee Nation's Culturally Significant Waters. A total phosphorus criterion of 0.016 mg/L was recommended to protect Cherokee Nation Culturally Significant Waters from benthic algae greater than 100 mg/m^2 Chlorophyll *a*.

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CHAPTER I

INTRODUCTION

Background

The Cherokee Nation, a Federally-recognized Tribe, lacks numerical nutrient criteria specific to Tribal waters (Cherokee Nation, 2007; Environmental Protection Agency (US EPA), 2008a). The Tribe has adopted the State of Oklahoma's Scenic Rivers Criterion and other Oklahoma Water Quality Standards (WQS). The Tribe does not have Treatment in the Same Manner as a State (TAS) status with the US EPA for WQS. Therefore, the Tribally-approved WQS (TWQS) were not US EPA-approved. The lack of US EPA-approved TWQS leaves approximately 23,916 km^2 of Cherokee Nation Tribal jurisdiction including 106,878 acres of Tribal trust and fee simple land, individual restricted lands and associated surface waters in northeastern Oklahoma at risk from excess nutrients (Cherokee Nation Comprehensive Annual Financial Report (CNCAFR), 2012). TWQS were important to fill the void in applicable State law on Tribal lands where the State does not have jurisdiction. In addition, Tribes have a governmental duty to protect public health, natural resources, waters, plants and animals important to Tribal culture and ceremonies within their jurisdiction. Tribes have the right to safeguard water resources which they depend upon for economic, spiritual and cultural survival (US EPA, 2001a). Tribes with Federally-approved WQS have the legal enforcement ability to protect Tribal resources and communities from upstream pollution sources not on Tribal lands as well as downstream waters (US EPA, 2001a).

Of particular importance to the Cherokee Nation were culturally significant running waters which support daily Cherokee activities and ceremonies throughout the year. Waters for these uses were designated Culturally Significant Waters (CSWs) by both individual Tribal citizens and/or the community. Generally, CSWs were defined as water bodies used in Tribal cultural events, ceremonies, community activities, traditional gathering sites and other activities relating to daily and/or traditional Tribal life.

A review of historical records provided the following information. Duncan and Riggs (2003) stated on page 11:

> "*Every day began with the going-to-water ceremony, when everyone entered a stream near their village, faced east, and prayed to the seven directions: the four cardinal points, the sky, the earth, and the center – the spirit. They gave thanks for a new day, and washed away any feelings that might separate them from their neighbors or from the Creator, emerging cleansed physically, mentally, and spiritually*."

James Mooney's 1900 account of *Myths of the Cherokee* on page 431, and the 1932 *The Swimmer Manuscript: Cherokee Sacred Formulas and Medical Prescriptions* on pages 22 and 23, describes "going to water" as "bathing in the running stream" requiring full immersion and ingestion. The Payne-Butrick Papers (2010), which were likely written between 1847 and 1851, references "full body immersion," "pure water," "free…from all pollution," and "ingestion of water" in at least fifteen places where Cherokees traditional use of water was described.

CSWs require pristine conditions to maintain their Designated Uses protected by the U.S. Clean Water Act for Tribal citizens. Excess nutrients can cause nuisance algal growth in rivers and streams (Carpenter et al., 1998). In addition, the development of numerical nutrient criteria by Tribes was a US EPA priority (US EPA, 1998a). The Federal Water Pollution Control Amendments of 1972, the Clean Water Act of 1977, the Water Quality Act of 1987, as well as all amendments pertaining to those Acts are commonly referred to as the U.S. Clean Water Act (CWA). The CWA defines 'Existing Uses' as water uses on or after November 28, 1975 and 'Designated Uses' as social, economic or political classifications of water use (US EPA, 1990; US EPA, 2000a). The Tribe was established by fee patent on September 6, 1839 in northeastern Oklahoma which was a much earlier historical baseline for water uses. A timeline showing 'Existing Uses' baseline dates to consider as possible reference points for Cherokee Nation water quality standards, see Figure 1.

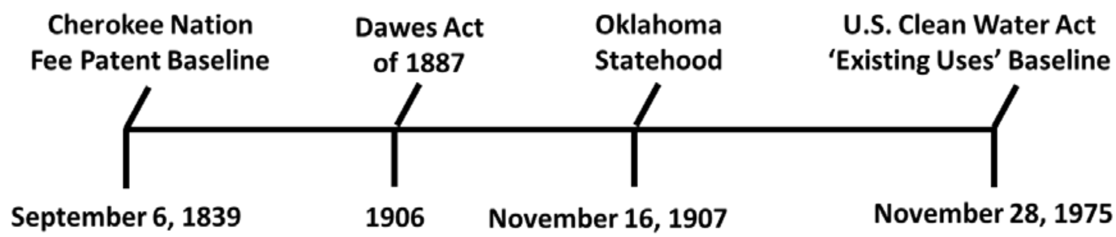


Figure 1. Clean Water Act 'Existing Uses' historical baseline dates for the Cherokee Nation (Cherokee Nation, 2007; US EPA, 1990; US EPA, 2000a).

Today, some of Cherokee Nation's waters including CSWs were threatened by excess nutrients (Pickup et al., 2003; Tortorelli and Pickup, 2006). Current Tribal standards often lack numerical nutrient criteria and do not designate specific water bodies to protect (US EPA, 2001a). The Cherokee Nation lacks designated CSW bodies as well as regional or water body specific numerical nutrient criteria to support those uses. The Tribe provides for CSW in Tribal legislation Title 63: Public Health and Safety, Chapter 3: Cherokee Nation Environmental Code, Article 9: Water Quality and Section 901(F). "Identify and protect waters and resources of the (Cherokee) Nation with special cultural or historical significance, and develop and enforce such standards and anti-degradation provisions as may be appropriate for such purposes." The Tribe does promulgate the Oklahoma's Scenic Rivers Criterion for Total Phosphorus (TP) of 0.037 mg/L 30-day geometric mean (Cherokee Nation, 2007).

Tribal 'Treatment in the Same Manner as a State' (TAS)

Section 303 (c)(2)(A) of the CWA requires WQS "to protect the public health or welfare,…public water supplies, propagation of fish and wildlife, recreational purposes, and also taking into consideration their use and value for navigation" of all "waters of the U.S." In 1987, amendments creating Section 518 of the CWA created U.S. Environmental Protection Agency (US EPA) authorization of Tribal water quality programs and standards to protect Tribal waters known as 'Treatment in the Same Manner as a State' (TAS) (US EPA, 1986; US EPA, 2001a). TAS requirements were Federal recognition, a governing body with substantial duties and powers as well as jurisdiction and capability to carry out the proposed activities (US EPA, 1990; US EPA 1998b; US EPA, 2001a). After 20 years, only 36 of more than 580 Federally-recognized Tribal governments have obtained US EPA-authorized WQS (US EPA, 2006a). An additional eleven Tribes have applied and received TAS as described in 40 CFR § 131.4(c) and § 131.8 (US EPA, 2001a; US EPA, 2006a; US EPA, 2015). Other Tribes may have WQS adopted by the Tribe, but not submitted to the US EPA. Without US EPA-approved standards, Tribal waters and their downstream neighbors may lack protection from upstream pollutants. The US EPA estimates an area approximately the size of the New England States and New Jersey combined was without US EPA-approved TWQS (US EPA, 2001a). The lack of US EPA-approved TWQS leaves a significant void in the protection of Tribal and downstream U.S. waters (US EPA, 2001a).

In 2005, Senator James Inhofe (Republican - Oklahoma) successfully attached a last minute amendment to the *Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2005* (SAFE-TEA) eliminating Oklahoma Tribes' right to TAS without input from Tribal Nations within Oklahoma or senate committees with jurisdiction over tribal issues; the amendment later became known as Inhofe's 'Midnight Rider'. For an Oklahoma Tribe to seek US EPA-approved environmental regulation, the "Midnight Rider" requires Tribes to compact with the State of Oklahoma. Inhofe's Midnight Rider' creates a unique barrier for Oklahoma Tribes to create US EPA-authorized WQS as described by Hobbs, Straus, Dean, & Walker, LLP (2005). The validity of the "Midnight Rider" has not been challenged in court or otherwise as of this paper. Only the Pawnee Nation has TAS status in Oklahoma for water as they had approval before the 2005 "Midnight Rider" was submitted (US EPA, 2006a; US EPA, 2015).

Cherokee Nation

The Cherokee Nation was a sovereign nation since time immemorial with twenty-three treaties between the British and the United States governments. In 1838, Cherokees were forced to move from the Southeastern United States to Oklahoma on the infamous "Trail of Tears". Many Cherokees known as the "Old Settlers" had established a government in Oklahoma prior to the forced exodus. Both nations comprise the Cherokee Nation, today. Currently, the Cherokee Nation was the second largest Native American Tribe in the U.S. with more than 320,000 Tribal citizens (Cherokee Nation, 2007). The Cherokee Nation was a sovereign nation with a tripartite government including an executive, legislative and judicial branch (Cherokee Nation, 2007; Cherokee Nation CAFR, 2012).

Headquartered in Tahlequah, Oklahoma, the Cherokee Nation's jurisdictional boundaries include all or part of 14-counties in northeastern Oklahoma with approximately 23,916 km^2 of Tribal jurisdiction including 154.5

kilometers of Arkansas River (Cherokee Nation, 2007). The Cherokee Nation was all or part of the following counties: Adair, Cherokee, Craig, Delaware, Mayes, McIntosh, Muskogee, Nowata, Ottawa, Rogers, Sequoyah, Tulsa, Wagoner and Washington (Cherokee Nation, 2007). Five of the six Oklahoma Scenic Rivers were within the Cherokee Nation: Barren Fork Creek, Flint Creek, Illinois River, Lee Creek and Little Lee Creek (Oklahoma Scenic Rivers Website, 2007; OWRB, 2002). Barren Fork Creek may have an alternative spelling in the sampling data, literature and maps as Baron Fork Creek.

As of the *2012 Cherokee Nation Comprehensive Annual Report* (CAFR), the Tribe and Tribal citizens hold in trust, restricted status or fee simple more than 106,878 acres. The 14-counties included in the jurisdiction of the Cherokee Nation were environmentally diverse with five US EPA Level III Ecoregions and five 6-digit Hydrologic Unit Codes (HUCs), shown in Figure 2 (Cherokee Nation Geo Data Center (Cherokee Nation GDC), 2007). Figure 2 was created by the Cherokee Nation GDC on October 1, 2007 using Tribal GIS data, Omernik's US EPA Level III Ecoregions and US EPA HUC data (US EPA, 2008a).

The Cherokee Nation exercises self-determination with respect to the environment through the Cherokee Nation Environmental Programs (CNEP) team and the Cherokee Nation Environmental Protection Commission (CNEPC). Established by Cherokee Nation Legislative Act (LA) 31-04 and 35-04 titled "Cherokee Nation Environmental Quality Code Amendments Act of 2004" and "Cherokee Nation Environmental Quality Code: Water Quality Amendment Act of 2004," respectively, the CNEPC provides independent oversight of the Cherokee

Nation environment such as business activities, government activities and private actions within the Tribal jurisdictional service area (Cherokee Nation, 2007).

Although the Cherokee Nation has developed significant environmental infrastructure compared to most Tribes, room for growth and improvement exists. The Cherokee Nation has promulgated neighboring US EPA-approved State and Tribal TWQS, rather than developing their own standards, but lacks US EPA TAS status and thus Federally-approved WQS (US EPA, 2015). The Act creating the Cherokee Nation EPC does not create unique Tribal numerical nutrient WQS. The Act does include the adoption of the State of Oklahoma’s Scenic River Act for the same scenic rivers within the jurisdiction of the Cherokee Nation and responsibility for enforcement by the Cherokee Nation within Tribal jurisdiction (Cherokee Nation, 2007).

Only one Oklahoma Tribe, the Pawnee Nation, has applied for and received TAS. Pawnee’s TAS application was submitted to the US EPA on March 2, 1998. Pawnee’s TAS application was approved on November 4, 2004. None of the Oklahoma Tribes has US EPA-approved WQS including the Pawnee Nation (US EPA, 2006a; US EPA, 2015).

In addition to the CNEPC and CNEP, the Cherokee Nation serves as the “agent” for the Inter-Tribal Environmental Council (ITEC) whose mission was “to protect the health of Native Americans, their natural resources and their environment as it relates to air, land and water.” As the agent for ITEC, the Cherokee Nation receives and administers US EPA grant monies for the 41 member Tribes of which 32 were Oklahoma Tribes (ITEC Website, 2007).

Oklahoma has 39 federally-recognized sovereign Tribal Nations. Separate from ITEC, the Cherokee Nation and other Oklahoma Tribes formed an ad hoc group to write the *Model Tribal Water Quality Standards* for Oklahoma Tribes. The ad hoc work group was known as the Inter-Tribal Water Task Force with no set membership as relayed in an email December 31, 2007 from Jeannine Hale, Cherokee Nation Environmental Justice (CNEJ). The ad hoc group no longer actively meets.

One goal of the *Model TWQS wa*s to reach consensus with the State of Oklahoma's WQS whenever possible as stated by Jeannine Hale, CNEJ. The designation of CSW as a Designated Use was a major concern for the State of Oklahoma as stated in a 2007 email from Jeannine Hale, CNEJ. Tribal governments tend to value cooperation and coordinated efforts with local, State and Federal governments. Tribes may bring additional Federal resources to the State which would benefit both Tribal citizens and their neighbors.

The State of Oklahoma has included CSW in the Anti-Degradation section of the Oklahoma WQS code (State of Oklahoma, 2007). However, CSWs were not given the status of a Designated Use, which provides enforcement (State of Oklahoma, 2013). Section 303 (c)(2)(a) of the Clean Water Act provides for Designated Uses as "public water supplies, propagation of fish and wildlife, recreational, agricultural, industrial and other purposes." CSWs were not given explicit consideration as a Designated Use in the Clean Water Act. Therefore, Tribes were likely to shoulder the entire responsibility for creating a scientifically defensible Designated Use implicit to the Clean Water Act.

Overall US Environmental Protection Agency Nutrient Strategy

In President Clinton's *1998 Clean Water Action Plan* announcement, numerical nutrient standards were mandated for all States and Tribes to address nutrient enrichment in all U.S. waters by 2004 (US EPA, 1998c). The 2004 deadline has passed. The US EPA, States and Tribes still consider numeric nutrient criteria a priority for US waters with more than half of the reported U.S. waters unable to fully support aquatic life due to excess nutrients (Carpenter, Caraco et al., 1998; US EPA, 1998a; US EPA, 2000a; US EPA 2000b; US EPA, 2000c; US EPA, 2001a; Reckhow et al., 2005). Numerical nutrient criteria were a priority due to the continued severity of anthropogenic eutrophication from excessive nitrogen (N) and phosphorous (P) in U.S. rivers and streams (US EPA, 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2001b; Carpenter et al.., 1998). Dodds et al. (2008) estimated the annual revenue loss from decreased recreational use in the U.S. due to surface water eutrophication as much as $1.16 billion. The US EPA has determined numerical nutrient criteria were essential for supporting aquatic life uses and maintaining the integrity of a water body (US EPA, 1998a; US EPA, 1998c; US EPA, 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2000d; US EPA, 2000e; US EPA, 2000f; US EPA, 2001a). Numerical nutrient criteria establish an objective measurement for determining attainment of Designated Uses (US EPA 1998a; US EPA, 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2001b; Reckhow et al., 2005).

The US EPA has recommended baseline ecoregion and sub-ecoregion numeric nutrient criteria for rivers and streams based on 14 'Draft Aggregations of Level III Ecoregions for the National Nutrient Strategy' (Nutrient Ecoregions) as shown in Figure 3 (US EPA, 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2001b; US EPA, 2008a). The Cherokee Nation was part of three Level III Nutrient Ecoregions: (IV) Great Plains Grass and Shrublands, (IX) Southeastern Temperate Forested Plains and Hills and (XI) Central and Eastern Forested Uplands as shown in Figure 4 (CNGDC, 2008; US EPA, 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2001b; US EPA, 2007; US EPA, 2008a).

The US EPA suggested numerical nutrient criteria for ecoregions and sub-ecoregions were reference points for States and Tribes to use in developing criteria specific to local conditions (US EPA 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2000d; US EPA, 2000e; US EPA, 2000f; US EPA, 2001b; US EPA, 2001c).

Objectives

The following research questions were studied.

1. Are Culturally Significant Waters a definable Designated Use by the Cherokee Nation under the U.S. Clean Water Act?

2. Which rivers and/or streams in the Cherokee Nation were CSW?

3. What numerical nutrient criterion was protective of Cherokee Nation's culturally significant waters?

4. Does US EPA numerical nutrient criteria guidance analysis adequately protect Cherokee Nation's Culturally Significant Waters?

To meet the Clean Water Act intent to protect Tribal waters from excess nutrients and exercise Cherokee Nation's sovereign right to regulate their environment; CSW must be defined, identified and documented. Once the designated and existing uses of CSW were documented, numerical nutrient criteria sufficient to protect those uses must be determined. A survey of Cherokee citizens was conducted to identify some of the Cherokee Nation's CSW and their uses. Existing publicly available water quality data for identified CSW were gathered and analyzed per US EPA guidance. These data were then compared to applicable US EPA-recommended regional nutrient criteria, literature findings, algal response theory, and existing State of Oklahoma standards. Multiple tests were utilized including evaluating the US EPA-recommended procedure to determine numerical nutrient criteria using the reference condition approach (US EPA, 2000c) and statistical analysis of available water quality data. Using publicly available water quality data, a reference condition was calculated using the US EPA-recommended 25th percentile of all data (reference and impacted sites) or 75th percentile of reference conditions when available. The calculated local reference condition was then compared to the US EPA-recommended regional criteria for the applicable Aggregate Nutrient Ecoregion and Sub-Ecoregions, literature values for nuisance benthic chlorophyll *a* (Chl *a*) and/or periphyton response to total nitrogen (TN) and total P (TP), findings from other studies of TN, TP and Chl *a* within streams and rivers as well as other State and Tribal numerical nutrient criteria.

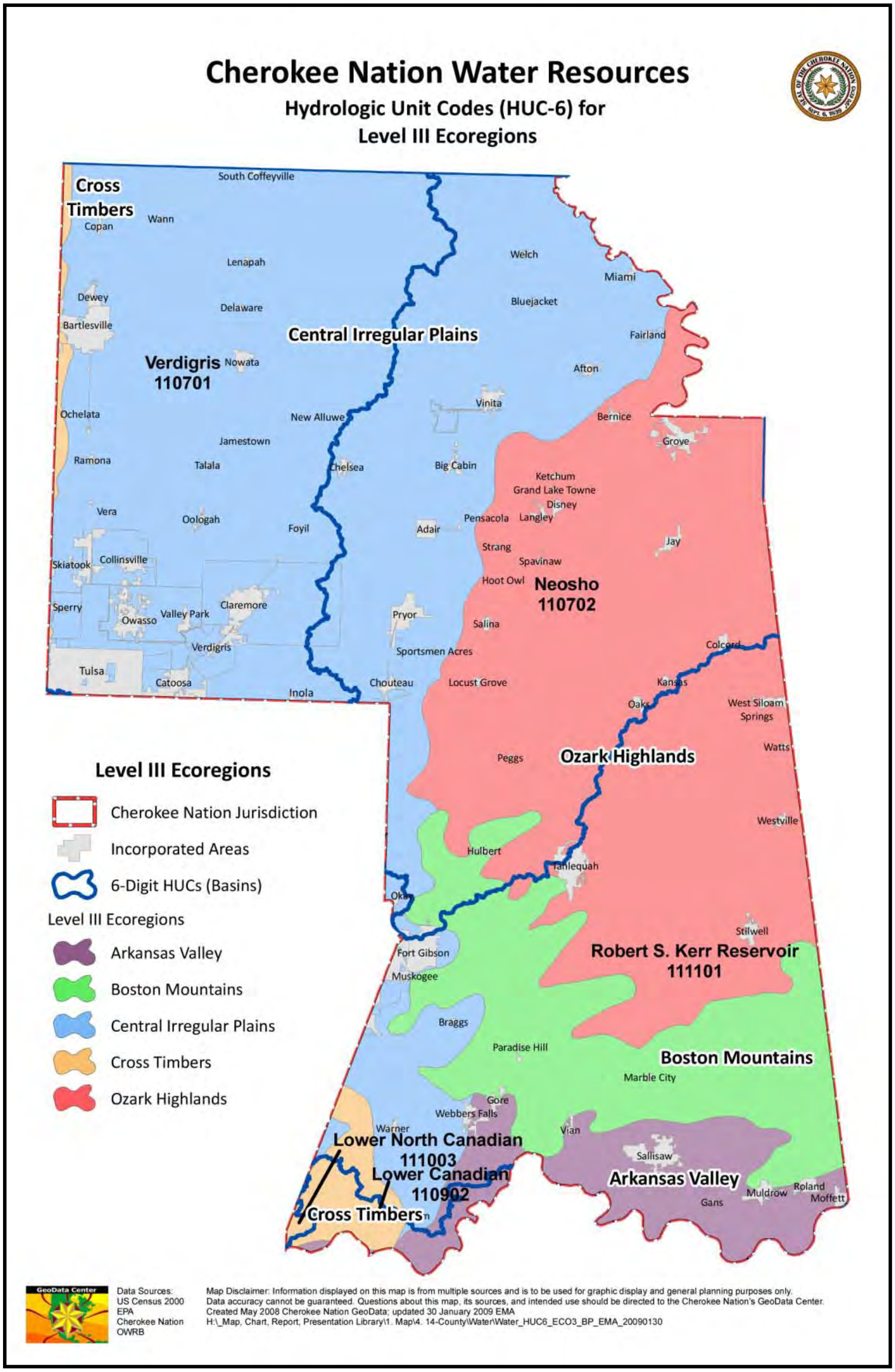


Figure 2. Six-digit Hydrological Unit Codes (HUC) and Omernik Level III Ecoregions within the Cherokee Nation jurisdiction (Cherokee Nation GDC, 2007; US EPA, 2008a).

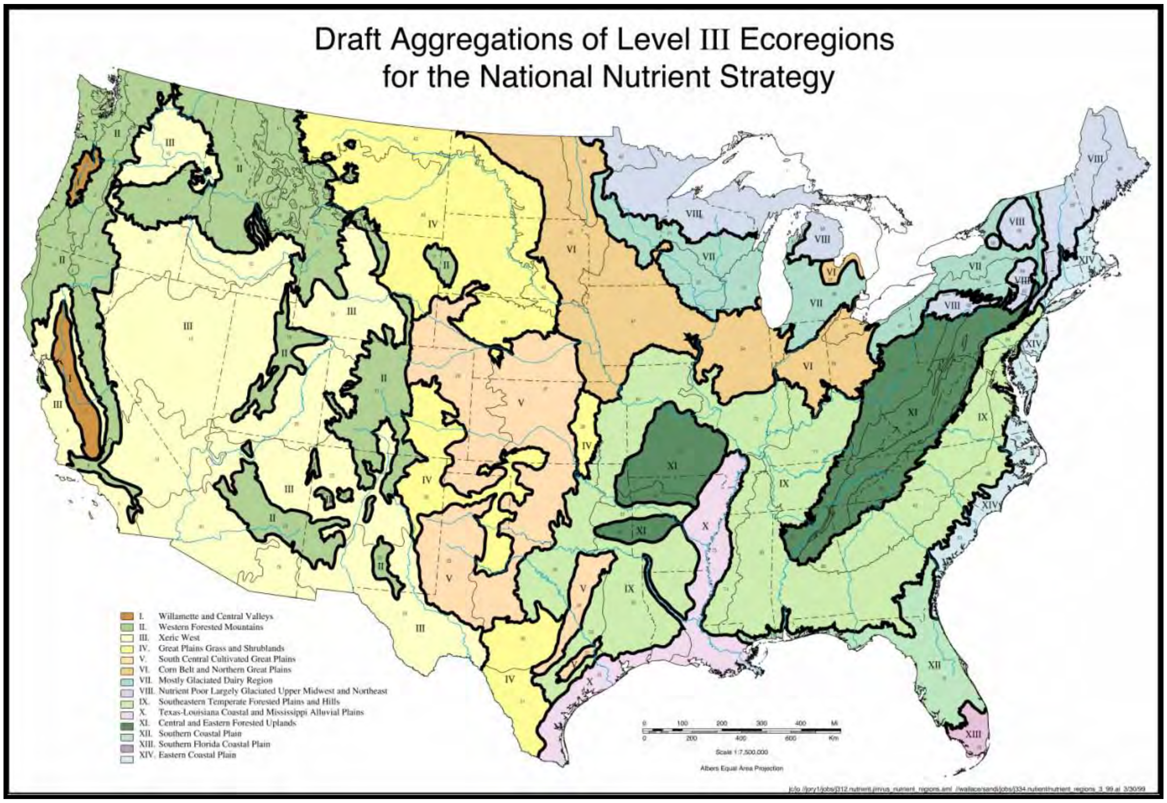


Figure 3. Draft aggregations of United States Level III Ecoregions for the National Nutrient Strategy (US EPA, 2008a; Smith et al., 2003).

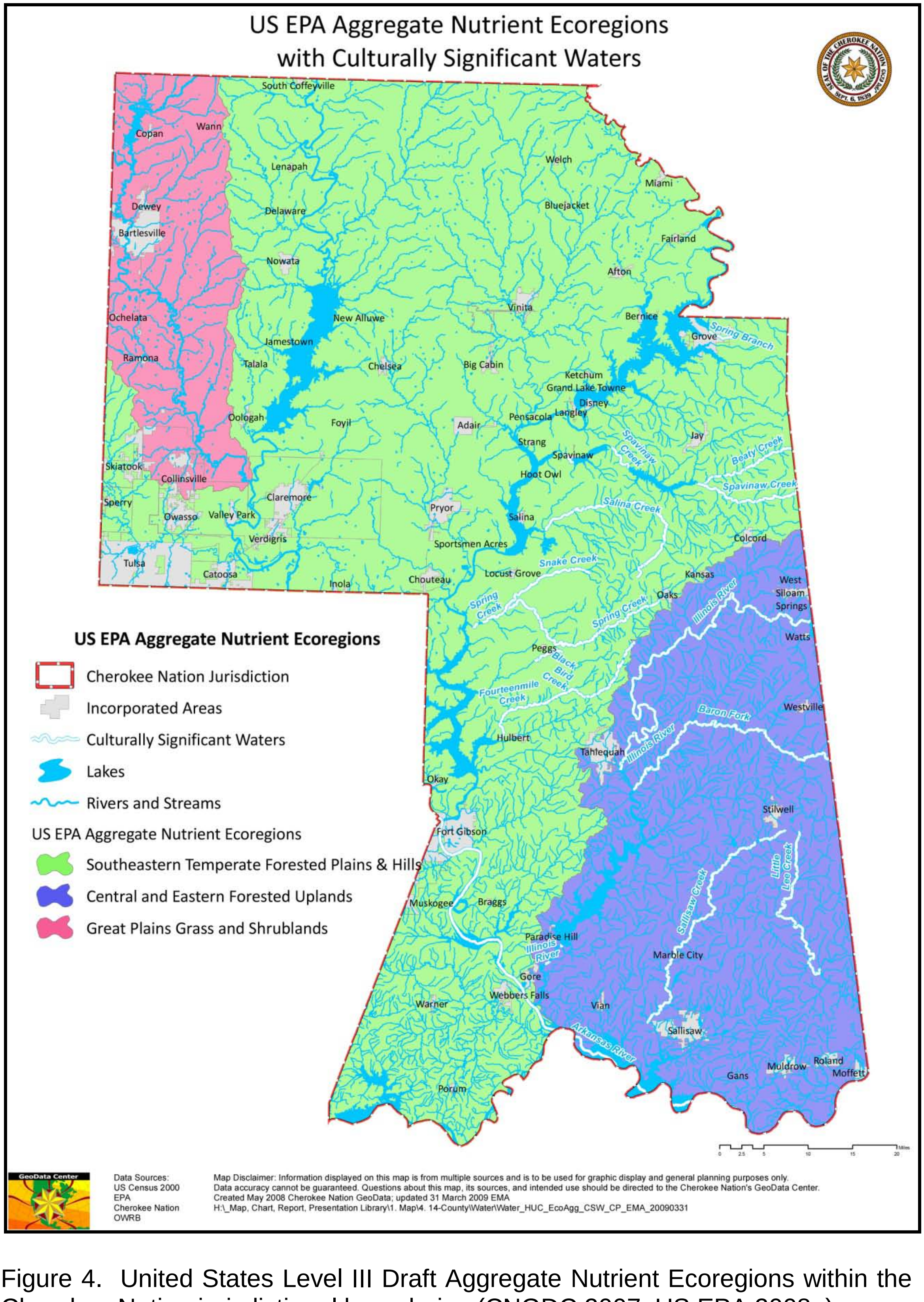


Figure 4. United States Level III Draft Aggregate Nutrient Ecoregions within the Cherokee Nation jurisdictional boundaries (CNGDC 2007; US EPA 2008a).

CHAPTER II

REVIEW OF LITERATURE

'Culturally Significant Waters' Designated Use

US Environmental Protection Agency Approved Tribal Water Quality Standards

In 1987, Section 518 of the CWA created US EPA authorization of Tribal water quality programs and standards to protect Tribal waters. Section 518 of the CWA is also known as Treatment in the Same Manner as States (TAS) (US EPA, 1998b; US EPA, 2001a). More than 20 years later only 36 of more than 580 Federally-recognized Tribes in the U.S. have US EPA-approved Tribal WQS (TWQS). None of the Oklahoma Tribes have US EPA-approved TWQS (DOI, 2015; US EPA 2006a; US EPA, 2015), and only the Pawnee tribe has submitted water quality standards to US EPA for approval. Most of the 36 Tribes with US EPA-approved TWQS include nationally-significant waters often designated 'Culturally Significant Waters' (CSW) or some variation of CSW. After reviewing the US EPA-approved TWQS for Designated Uses addressing CSWs, a single accepted definition for CSW as a Designated Use was not found. All US EPA-approved TWQS can be found on the US EPA website at '*Tribal Water Quality Standards approved by US EPA.'* A summary of U.S. Tribal TAS and TWQS approval status as of November 10, 2015 was provided in Appendix A.

Designated Use under the CWA was defined as “a use…specified in water quality standards as a goal for a water body segment, whether or not it is currently being attained (National Indian Justice Center (NIJC), 2001; US EPA, 1990; US EPA, 2000d).” The US EPA (1990; 2000a) requires Designated Uses protect downstream waters in addition to the stream segment under consideration. Designated Uses must also consider Existing Uses and Beneficial Uses as illustrated in Figure 5. Existing Uses were “all uses actually attained in the water body on or after *September 6, 1839*, whether or not they are explicitly stated as Designated Uses in the water quality standards or presently existing uses” (Cherokee Nation, 2007; NIJC, 2001). Note, the US EPA (1990; 2000a) established November 28, 1975 as the baseline reference date for Existing Uses, where September 6, 1839 was the baseline for the establishment of the modern Cherokee Nation in northeastern Oklahoma (Cherokee Nation, 2007). When the Cherokee Nation purchased their land in fee patent, the Tribe’s Designated Uses should be protective of Existing Uses at a minimum (US EPA, 1990; US EPA, 2000c). Beneficial Uses consist of, but were “not limited to, domestic, commercial, industrial, agricultural, traditional, cultural and recreational” uses as well as “uses by fish and wildlife for habitat or propagation” established by Tribal law for the Tribal jurisdiction (NIJC, 2001; US EPA, 1990; US EPA, 2000a). Figure 5 illustrates the Designated, Existing and Beneficial Uses as they pertain to WQS.

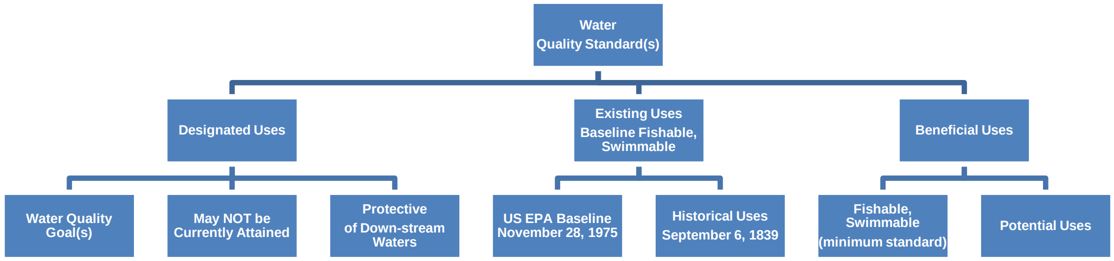


Figure 5. Clean Water Act water quality standard use types within the Cherokee Nation (US EPA 1990; US EPA 2000a).

The US EPA (1990; 2000a) requires water quality standards to "provide for the protection and propagation of fish, shellfish, and wildlife, and for the recreation in and on the water." Public water supply and navigation were additional uses, not already listed (US EPA, 1990; US EPA, 2000a). Other uses, subcategories and their criteria must "enhance the quality of water and serve the purposes of the *(Clean Water)* Act" (US EPA 1990; US EPA 2000a). Designated Use, Existing Use and Beneficial Use can be the same water body use(s) or different. Ultimately, a water body criteria or goals must be protective of 'fishable and swimmable' uses at the level of water quality attained on November 28, 1975, including downstream use(s) (US EPA 1990; US EPA 2000a).

The Confederated Tribes of the Colville Reservation (2005) in Oregon promulgated Federal Water Quality recommended standards. The Colville did not adopt WQS developed by the Tribe based on local data and conditions. Included in the Colville's promulgated standards was the US EPA's definition for CSW called "Ceremonial and Religious water use" defined as waters "involving traditional Native American spiritual practices which involve, among other things, primary (direct) contact with water." Colville Confederated Tribes was the sole tribe with US EPA recognized and promulgated water quality standards without being given TAS status. Several other Tribes with US EPA-approved Tribal WQS have adopted the US EPA's definition of CSW. The US EPA definition lacks acknowledgement of aquatic biota connected to Tribal practices, intentional or incidental ingestion of water during ceremony and the importance of cultural sites near the water body (US EPA, 2000a).

A few of the Tribes with US EPA-approved Tribal WQS did not provide for cultural uses of water as a separate Designated Use or were only mentioned within Tiers or Classes of Waters designated 'Outstanding Waters.' 'Outstanding Waters' might be named "Outstanding Reservation Resource Waters", "Outstanding Tribal Resource Waters" or the US EPA designation of "Outstanding National Resource Waters." All of these waters should require an anti-degradation policy. Most of the Tribes did not identify water bodies as CSW after establishing the Designated Use while others broadly designated all of their jurisdictional waters as CSW.

Several of the Tribe's with US EPA-approved Tribal WQS begin with statements similar to the Pueblo of Acoma (2005). "Water is essential to all life at Acoma and is indispensable to the practice of age-old traditions and to our cultural preservation." Definitions of CSW range from a brief mention in an existing US EPA Designated Use, such as "Primary Contact Recreation" or "Water Contact Recreation," to any activity pertinent to the Tribal community's traditional way of life. Traditional way of life may include "culture", "ceremonial uses", "way of life", "maintain the way of life", "traditional value system", "preservation of habitat" and "unique sacred and cultural resource." CSW may be referred to as "Primary Contact Ceremonial Use," "Cultural Beneficial Uses," "Cultural Water Use," "Traditional Cultural Place" or "Ceremonial and Cultural Water Use" in the US EPA-approved TWQS reviewed.

Identifying or defining a CSW varied from Tribe to Tribe, as expected. Every Tribe had their own unique culture, language, government, ceremonies and way of life. Tribes included "exclusive harvest areas," "religious gatherings and sensitive ceremonial activities," "consumption of salmonid fish," "ingestion likely," "wild rice growing areas" or activities as specific as the Hoopa Valley Tribe's (2001) Boat Ceremony. None of the ingestion descriptions indicated the waters were used for daily drinking water direct from the source without treatment. All of the Tribal uses may be classified within existing US EPA's CWA Designated Uses; "propagation of fish and wildlife, recreational, agricultural, industrial, and other purposes" (US EPA, 2006b; US EPA, 2006c). In general, the Designated Uses involving cultural activities, such as ceremonial events and traditional daily activities, of a Tribal community are referred to as 'Culturally Significant Waters' (CSW).

Two unique Tribal perspectives on Designated Uses were found in the Hualapai (2004) and Hoopa (2001) standards. Hualapai Existing Uses were based on water quality at the time U.S. President Chester Arthur signed the Executive Order establishing the Hualapai Reservation on January 4, 1883 rather than the Clean Water Act's November 28, 1975 baseline reference policy

(Kappler, 1904, US EPA, 2006b; US EPA, 2006c). By setting the baseline date in terms of Hualapai historical context, the reference date itself is an act of Tribal self-determination. The Hoopa Valley Indians include “adequate flows for the Boat Dance ceremony” with their CSW provisions. The minimum flow standard for the Boat Dance ceremony was based on the *American Indian Religious Freedom Act* (P.L. 95 – 341). A few additional Tribes required minimum flows to support their CSWs. Only the Hoopa Boat Dance ceremony was tied to a specific ceremony and/or time of year for minimum flow standard requirements.

Although all US EPA-approved TWQS recognize CSWs, Tribal waters relating to Tribal life require protection and none present a clear and comprehensive CSW Designated Use for other Tribes to model. All lack one or more of the following aspects: incidental or intentional ingestion, aquatic biota important to the Tribe’s identified water bodies and identification of culturally significant sites associated with a water body.

The Cherokee Nation lacks approved legislation identifying CSW bodies under an approved Designated Use. However, Tribal Legislative Act (LA) 31-04 and 35-04 established the goal for the Tribe to protect culturally and historically important water bodies.

<u>Draft Oklahoma Tribal Water Quality Standards</u>

Five of the six Oklahoma Scenic Rivers were within the Cherokee Nation. The Tribe has adopted the State of Oklahoma’s Scenic River Act designating the same rivers scenic with the same level of protection from maximum TP 0.037 mg/L 30-day geometric mean throughout the year (Cherokee Nation Legislative

Act (LA) 35-04; Oklahoma Scenic Rivers, 2007; OWRB, 2002). As of 2015, the Scenic Rivers were not designated for cultural or ceremonial use by the Cherokee Nation or the State of Oklahoma. In addition, the approved Cherokee Nation legislation lacks unique numeric WQS and was not US EPA approved (US EPA, 2006a; US EPA, 2015).

The July 9, 2007 Draft *Model Oklahoma Tribal Water Quality Standards,* provided by Jeannine Hale (CNEJ), were the product of an ad hoc group of Oklahoma Tribes, which included the Cherokee Nation., CSWs were defined and criteria set in Section 5-27, given as:

> *(a) Waterbodies or segments of waterbodies designated as culturally significant waters (CSWs) are listed separately in Appendix I.*
>
> *(b) CSW waters, their tributaries and associated wetlands shall be protected at all times for use in Native American traditional, cultural, religious, or ceremonial purposes.*
>
>> *(1) The CSW designation shall apply to any waterbodies where ceremonial use will involve partial or complete immersion with water, intentional ingestion or incidental ingestion of water.*
>>
>> *(2) The CSW designation may also be applied by the Nation to other waters with traditional, cultural, religious, historical or other special significance regardless of whether ingestion or immersion may occur.*
>>
>> *(3) The CSW designation may be applied when the traditional, cultural, religious, historical or other special significance relates to uses of the water itself, or to fish, wildlife or plant species associated with the waterbody, or to a particular site where the waterbody is.*
>
> *(c) Waters with the CSW designation have the following specific standards:*
>
>> *(1) Water quality in CSW waters shall be maintained and improved. No degradation shall be allowed in CSW waters.*

(2) CSW waters shall not contain chemical, physical, or biological substances in concentrations that are irritating to skin, and/or sense organs, or are toxic, or cause illness by ingestion or contact.

(3) The open water shall be free from algae in concentrations causing a nuisance condition or causing gastrointestinal or skin disorders.

(4) The waters with the CSW designation will have the following limits for bacteria set forth and these limits will apply throughout the calendar year. Provided, where concurrent data exist for multiple bacterial indicators on the same waterbody or waterbody segment, no criteria exceedances shall be allowed for any indicator group.

> *A. Coliform Bacteria: The bacteria of the fecal coliform group shall not exceed a monthly geometric mean of 200 CFU/100 ml, as determined by multiple-tube fermentation or membrane filter procedures based on a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. Further, a single sample during the thirty (30) day period shall not exceed 400 CFU/100 ml.*
>
> *B. Escherichia coli (E. coli): E. coli shall not exceed a monthly geometric mean of 126 CFU/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. No single sample during the thirty (30) day period shall exceed 235 CFU/100 ml.*
>
> *C. Enterococci: Enterococci shall not exceed a monthly geometric mean of 33 CFU/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. No single sample during the thirty (30) day period shall exceed 61 CFU/100 ml.*

(5) CSW waters shall not be subject to significant physical alterations such as impoundment, channelization or consumptive uses that would result in a diminished flow or adverse impacts to water quality, or that would result in adverse impacts to the special purposes for which the CSW designation was applied.

(6) No new discharges, except for temporary discharges of stormwater associated with construction activities, shall be allowed in CSW waters.

(7) Discharges of stormwater from point sources existing as of June 25, 1992, whether or not such were permitted prior to that date, are exempt from the prohibition of new point source discharges but are prohibited from having any increased load of any pollutant.

(d) The Tribe may establish special procedures for granting a variance or exception to CSW standards, or for deleting the CSW designation.

Designation of water bodies as CSWs was left to each individual Tribal government per Section (a), above. Therefore, a Tribe exercises CSW as a Designated Use when specifying applicable water bodies. The *Draft Model TWQS* under consideration by the Cherokee Nation includes provisions for incidental and intentional ingestion, primary body contact, culturally significant biota and sites as well as 'free from' language for algae. The *Draft Model TWQS* encompasses almost all of the CSW uses identified in the review of the 36 US EPA-approved TWQS except for wild rice, boat ceremonies, and other unique foods, ceremonies or sites applicable to specific Tribal Nations. The *Draft Model TWQS* appear sufficient for Cherokee Nation CSW as a Designated Use under the CWA assuming a numerical nutrient criterion to protect those uses was specified based on local conditions and CSW bodies were designated.

Numerical standards for excessive nutrients were not provided. However, narrative 'free from' language addressing anthropogenic eutrophication was often included. Numerical nutrient criteria would provide an objective measure to support the anti-degradation policy for CSWs and Scenic Rivers as well as the 'free from' algae narrative with respect to excess nutrients.

The State of Oklahoma acknowledges Tribal CSW in Oklahoma Administrative Code 785:45-5-25, *Implementation Policies for the Antidegradation Policy* Statement, shown below. The Oklahoma definition does not conflict with the Oklahoma Model TWQS for CSW or any of the CSW definitions for other Tribes reviewed.

> *(A) Waters designated as CSW in Appendix A of this Chapter are those identified by recognized Tribal authorities as critical to maintaining the waters' utility for cultural, historic, recreational or ceremonial uses and which may require more stringent protection measures to protect human health or aquatic life or both.*
>
> *(B) All activities associated with a CSW may require consultation with the duly authorized Tribal authority to assure that the proposed activity is consistent with applicable Tribal environmental laws.*

Since CSW was provided as 'Designated Waters' and not a Designated Use under State law, protections for CSWs were limited within the existing code for the State of Oklahoma. In a December 31, 2007 email from Jeannine Hale, Oklahoma statutes (82 O.S.) and Federal Regulations (40 CFR §130) would not apply unless CSW was given Designated Use status. If the State language was for a Designated Use, all of the *Draft Model TWQS* categories would fall within the State language.

Anthropogenic Eutrophication of Streams and Rivers

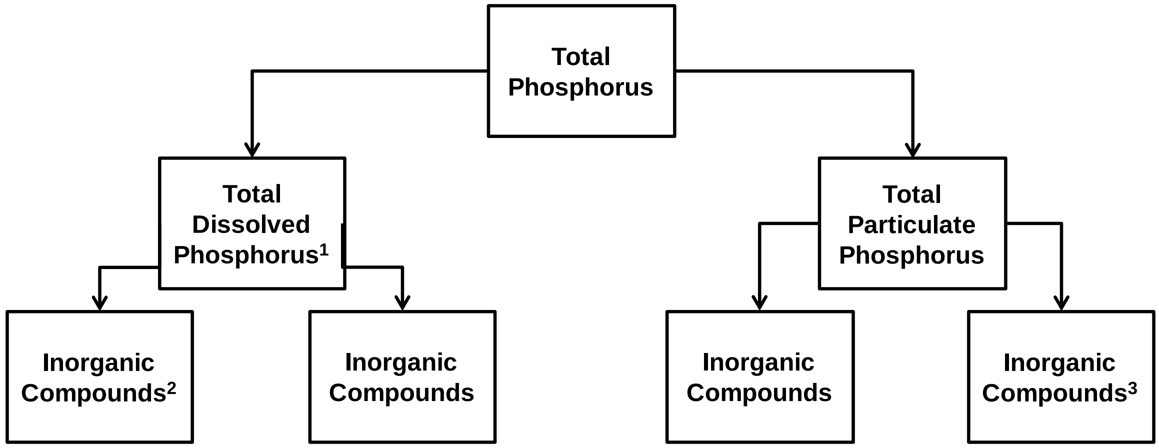
Anthropogenic eutrophication is "the excessive growth of aquatic plants" created by human input of organic and/or inorganic nutrients to water bodies (Thomann and Mueller, 1987). Aquatic plants include phytoplankton, i.e. free floating plants, and periphyton which are attached and rooted plants (Thomann and Mueller, 1987). Some nutrients are necessary to maintain a diverse and healthy biotic community. However, excessive growth occurs when aquatic plants interfere with designated water uses (Thomann and Mueller, 1987). Excessive algae interference with water uses may include “algal mats, decaying algal clumps, odors, discoloration and low dissolved oxygen” (Thomann and Mueller, 1987). In addition, algae can clog water supply intake pipes and filters, create bad taste and odor in drinking water and interfere with recreation, such as swimming and fishing (Thomann and Mueller, 1987).

<u>Algae</u>

Benthic Chl *a* is an indirect measure of the in-stream plant biomass and is directly proportional to in stream algal biomass (Ji, 2008; Barbour, 1999). Chl *a* is the primary response variable typically measured to quantify anthropogenic eutrophication in lotic waters (US EPA, 2000a). Chlorophyll *a* is a measure of the benthic or periphyton biomass per unit area (US EPA, 1999; USGS, 2007).

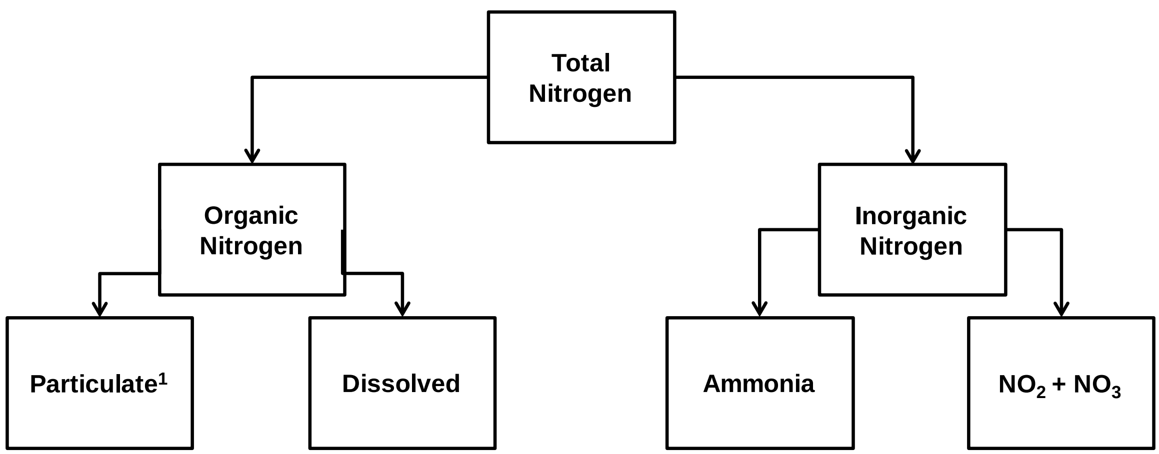
<u>Nutrients</u>

Aquatic plants utilize inorganic nutrients to grow and multiply, and through photosynthesis inorganic nutrients are converted to organic plant material (Thomann and Mueller, 1987). Figures 6 and 7 illustrate the in-stream forms of P and N, respectively. Both P and N are macronutrients required by plants (Calow and Petts, 1992; Chin, 2000; Dodds, 2003; Yen, 2005). P is important for the reproductive growth of plants and N for the vegetative rate of growth (Calow and Petts, 1992; Chin, 2000; Chin, 2006; Wang, Gorsuch, and Hughes, 1997).



[1]Passed through a 0.45 µm filter.
[2]Dissolved or soluble reactive phosphorous.
[3]Includes detritus and phytoplankton.

Figure 6. Composition of total phosphorus in lotic waters (Chin, 2000; Chin, 2006; Downes et al., 2000; Maidment, 1993; Thomann and Mueller, 1987; Yen, 2005)



[1]Includes detritus and phytoplankton.

Figure 7. Composition of total nitrogen in lotic waters (Chin, 2000; Chin, 2006; Maidment, 1993; Thomann and Mueller, 1987; Yen, 2005; Thomann and Mueller, 1987)

For freshwater rivers and streams, P tends to be the limiting nutrient before N (Calow and Petts, 1992; Chin, 2000; Thomann and Mueller, 1987; Yen, 2005; Wang et al., 1997). Studies have determined P and N thresholds in lotic ecosystems which significantly increase the risk of eutrophication and nuisance algal growth, but P and N may often be co-limited (Elwood et al., 198; Biggs, 2000; Francoeur et al., 1999; Downes et al., 2002; Dodds et al., 1997; Dodds and Welch, 2000; Nijboer and Verdonschot, 2004; Stevenson et al., 2006).

Using both TP and TN were recommended in the US EPA (2000a) guidance for numerical nutrient criteria to keep waters ‘free from’ nuisance algae. However, not all findings were conclusive about using TP and TN, or even nutrients to control algae growth (Biggs, 2000; Bourassa and Cattaneo, 1998; Dodds and Welch 2000; Thomas, 1978; Zimmerman and Campo, 2007). For example, Bourassa, and Cattaneo’s (1998) studied 12 streams in Quebec, Canada and found stream velocity and depth controlled periphyton biomass more than nutrient concentrations.

Dissolved nutrients are quickly utilized by aquatic plants and thus require frequent sampling programs (Dodds, 2003; Dodds et al., 1997; Downes et al., 2002). Soluble reactive phosphorus (SRP) is available for algae uptake and thus is highly variable in the water column (Dodds, 2003; Horner et al., 1983; Welch et al., 1988). Use of TP should avoid differences in filter sizes when data were compiled from multiple agencies that likely have different sampling standards and methods (US EPA, 2000a).

Variables other than nutrient concentrations can have significant control of the eutrophication of rivers and streams, but are unlikely to be controlled by human actions.

Trophic status was best determined by TP and TN according to Ji (2008) on page 254 (Biggs, 2000; Carpenter et al., 1998; Chin, 2000; Dodds, 2003; Dodds et al., 2002; Dodds et al., 1997; Dodds and Welch, 2000). TP and TN were best used in controlling benthic Chl *a* response (Biggs, 2000; Chetelat et al., 1999; Dodds, 2003; Dodds et al., 1997; Dodds and Welch, 2000; Nijboer and Verdonschot, 2004). Total nutrients measure the "potential nutrient supply" (Biggs, 2000). A widely accepted predictive relationship between the causal variables (TP and TN) and the response variable periphyton (benthic) Chl *a* does not exist. However, TP and TN numerical criteria were often considered the most protective of water bodies from excess nutrients (Bourassa and Cattaneo, 1998; Clark et al., 2000; Dodds, 2003; Dodds et al., 2002; Dodds et al., 1997; Dodds and Welch, 2000; Dojlido and Best, 1993; Ice and Binkley, 2003). Yet, Taylor et al. (2004) analyzed 16 streams near Melbourne, Australia for a benthic algal response to different forms of P and N. Taylor et al. (2004) found TP and TN explained less variation in benthic chlorophyll compared to filterable reactive P and dissolved inorganic N. Dodds et al. (2002) reviewed data including eight Oklahoma streams from the National Stream Water-Quality Monitoring Networks and other data sets for TP, TN and benthic Chl *a*. Water column TP and TN accounted for more variation in benthic chlorophyll compared to SRP and DIN (Dodds et al., 1997). Stevenson et al. (2006) two month study of 1st through 4th order streams in northwest Kentucky and Michigan in 1996 and 1997 found TP and TN explained the Cladophora benthic algae response the same as dissolved nutrients. In addition, land use models were likely to use TP and TN if a comparison to available data were needed (Dodds and Welch, 2000).

Fate and Transport

Fate processes are the "transformation of substances," such as "chemical and biological processes" (Chin, 2000). Transport processes were "advection and mixing" (Chin, 2000). For the nutrients nitrogen (N) and phosphorous (P), the fate processes are chemical changes, such as the mineralization of N and P. The biological processes for both N and P involve consumption by organisms (Maidment, 1993; Novotny, 2003). The transport processes were conducted by surface and subsurface runoff which transport sediment and organic matter containing N and P, dissolved N and P, and living materials, such as algae, to streams and rivers (Maidment, 1993; Novotny, 2003). Land use, soil texture, drainage, climate, rate and timing of fertilizer application, land management practices, municipal sewage outflow, and others were major factors contributing to N and P load to streams and rivers (Maidment, 1993; Chin, 2000; Dingman, 2002; Novotny, 2003).

The physical path for luxury consumption was illustrated in Figure 6. Luxury consumption where P was stored in algae cells during times of excess may allow algal growth even when in-stream P was low (Dodds and Welch, 2000). Luxury consumption may explain some of the differences seen in the literature for the relationship between in-stream phosphorous and benthic Chl *a*. When luxury consumption of P occurs, N concentration may become more important as driven by the Redfield Ratio balance (Dodds and Welch, 2000).

Chemical Reaction 2.1 describes the in-stream fates of organic N after the nutrient enters the water body and travels downstream (Chin, 2000; Chin, 2006; Yen, 2005). Organic nitrogen becomes ammonia then nitrite and finally nitrate. Organic nitrogen in the form of urea, amino acids or proteins was transformed to ammonia (NH_3) as shown in Chemical Reaction 2.2 then broken down into nitrite (NO_2) as shown in Chemical Reaction 2.3 and finally turns to nitrate (NO_3) as shown in Chemical Reaction 2.4.

$$N_{organic} + O_2 \rightarrow NH_3 nitrogen + O_2 \rightarrow NO_2 nitrogen + O_2 \rightarrow NO_3 nitrogen \quad \textbf{(2.1)}$$

Organic N $\longrightarrow$ *Ammonia* $\longrightarrow$ *Nitrite* $\longrightarrow$ *Nitrate*

$$NH_4^+ + OH^- \Leftrightarrow NH_3 + H_2O \quad \textbf{(2.2)}$$

Ammonium ions $\leftrightarrows$ dissolved ammonia gas

Chemical Reaction 2.2 details the process of ammonification. Ammonium ions (NH_4^+) and dissolved ammonia gas (NH_3) exist in equilibrium (Chin, 2006; Yen, 2005).

$$NH_4^+ + 2O_2 \Leftrightarrow NO_3 + 2H^+ + H_2O \quad \textbf{(2.3)}$$

Ammonium ions $\rightleftarrows$ nitrate ions

Nitrification as shown in Chemical Reaction 2.3 was where ammonium ions were converted to nitrate ions by bacteria (Chin, 2006; Yen, 2005).

Nitrification was the process and pathways by which nitrogen, N, was retained and transformed within streams. Nitrate (NO_3) was the most soluble form of nitrogen and found more abundantly in surface waters such as streams (Chin, 2000). Denitrification as shown in Chemical Reaction 2.4, or the release of nitrogen gas into the atmosphere from the water body, can occur under anoxic conditions (Chin, 2006; Yen, 2005).

$$5CH_2O + 4NO_3^- + 4H^+ \rightarrow 2CO_2 + 2H_2O + H_2S \qquad \textbf{(2.4)}$$

Chemical Reaction 2.1 through 2.4 illustrates the in-stream fate processes for N. Figure 8 combines the pathways for Chemical Reaction 2.1 through 2.4 and shows the lotic ecosystem fate of N and conditions which control the rate of reactions. N was transported to the stream or river by rain, run-off, ground water, storm water drains and waste water treatment plants. The only loss of N from a stream or river was via denitrification or physical removal of plant mass. Plants uptake NH_4^+ (ammonium ions) or NO_3^- (nitrate) via biological nitrogen fixation. Animals eat plants and excrete ammonium which was converted to nitrates via bacteria.

Figure 9 illustrates the in-stream fate of P as P cycles downstream. P lacks exchange with the atmosphere and thus resembles a closed system more so than N. Sources of P include elemental P derived from rock or soil as it breaks down, Organic P in plants or dissolved and colloidal organic P (Maidment, 1993; Thomann and Mueller, 1987; Yen, 2005). Figure 10 illustrates the diffusion or physical pathway between the in-stream flow boundary layer and algal cells or film. When the difference between the in-stream nutrient concentration and the algal film nutrient concentration was great, nutrient uptake by the algal cells will increase (Singh, 1995).

Overall nutrient fate and transport in streams and rivers may be described via Nutrient Spiraling (Nijboer and Verdonschot, 2004). Nutrient Spiraling treats rivers and streams as open systems whereas lakes and reservoirs were treated as closed systems. Since cycling infers a closed system, Nutrient Spiraling was used to describe downstream unidirectional nutrient cycling as waters flow downstream (Nijboer and Verdonschot, 2004; Wang et al., 1997). Although the system was open, the long-term net change in P as the nutrient moves downstream will go relatively unchanged due to P's lack of atmospheric exchange (Nijboer and Verdonschot, 2004). The biological assimilation of dissolved inorganic nutrients to organic nutrients by organisms as water moves downstream represents a single nutrient cycle (Nijboer and Verdonschot, 2004). The 'average downstream distance associated with one complete cycle of a nutrient atom' was the spiral length quantifying the Nutrient Spiral and thus the transport of the nutrient via organisms (Nijboer and Verdonschot, 2004; Wang et al., 1997). Organisms consume and return nutrients as the water moves downstream, thus cycling (Nijboer and Verdonschot, 2004). The in-stream nutrient transport mechanisms were advection and dispersion (Nijboer and Verdonschot, 2004; Singh, 1995).

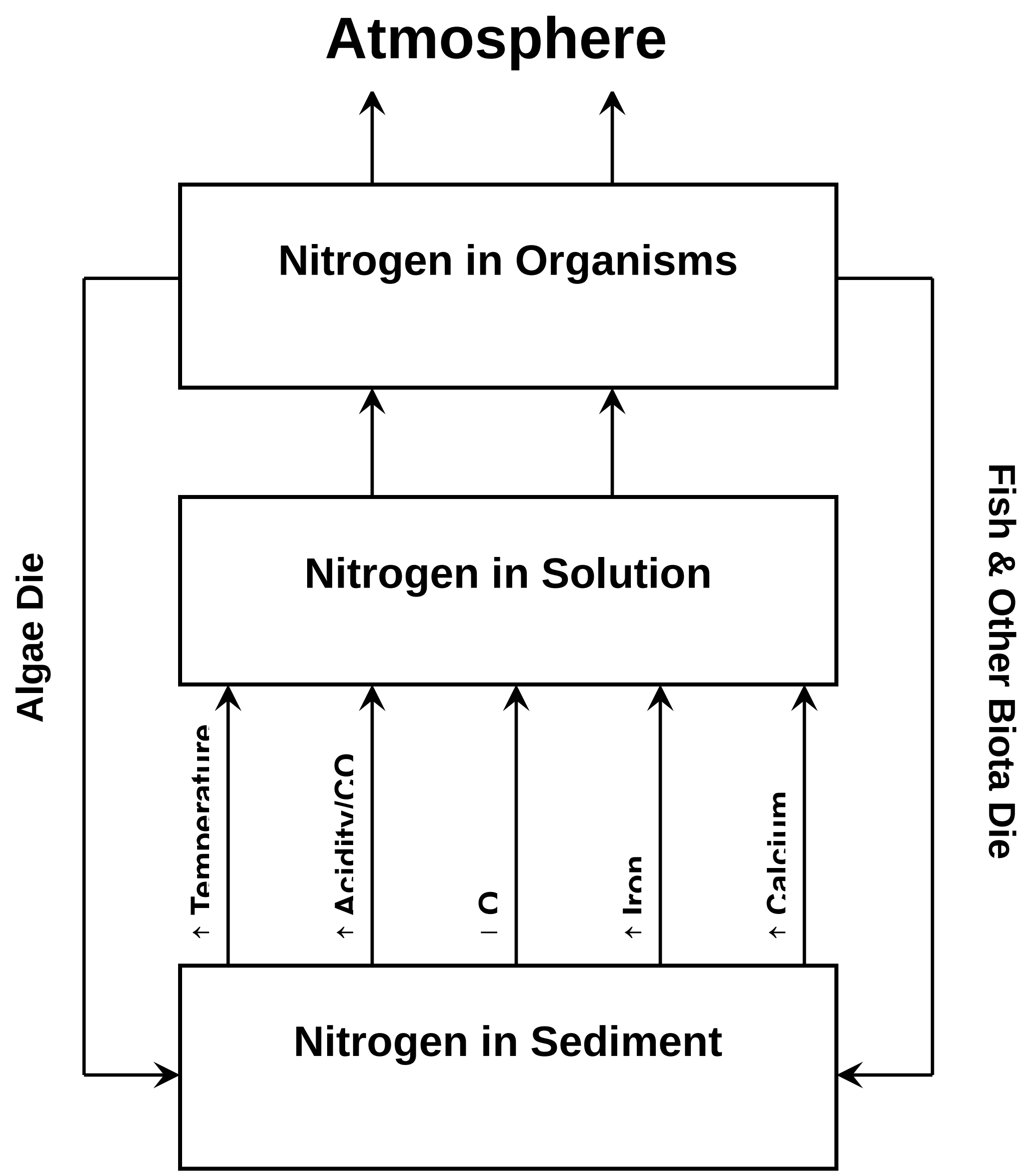


Figure 8. In-stream fate cycle of nitrogen in lotic waters (Maidment, 1993; Thomann and Mueller, 1987; Yen, 2005)

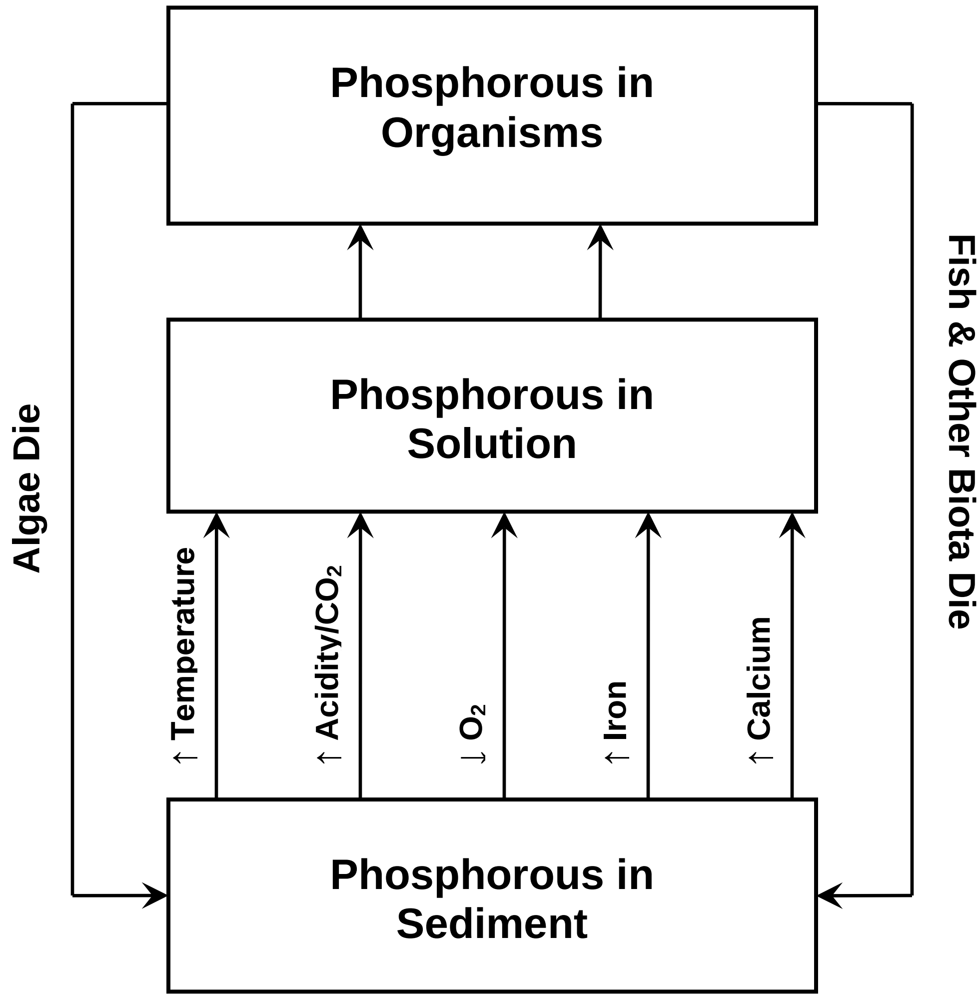


Figure 9. In-stream fate cycle of phosphorus in lotic waters (Maidment 1993; Thomann and Mueller, 1987; Yen 2005).

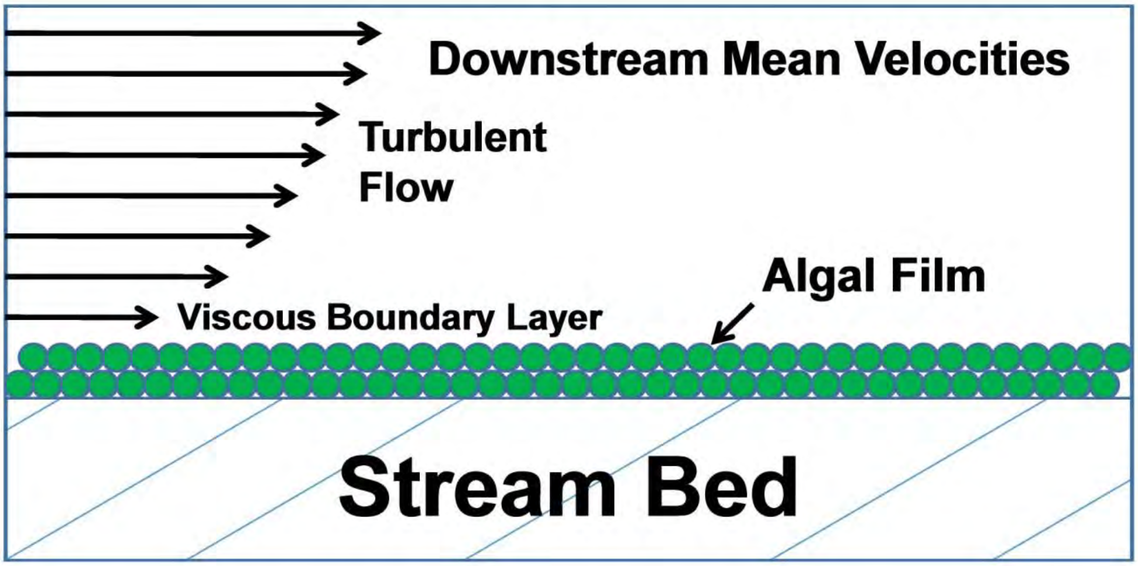


Figure 10. Mechanics of nutrient diffusion into algae at in-stream boundary layer (Singh, 1995)

Numerical Nutrient Criteria

<u>US Environmental Protection Agency Recommended Numerical Nutrient Guidance</u>

Cherokee Nation Nutrient Ecoregions

The Cherokee Nation contains portions of the Lower Canadian (110902), Lower North Canadian (111003), Robert S. Kerr Reservoir (111101), Neosho (110702) and Verdigris (110701) six-digit Basin/Accounting Unit Hydrological Unit Code (HUC) as shown earlier in Figure 2. A six-digit HUC was a 'basin' and not a true topographic watershed (Omernik and Bailey, 1997). Table 1 identifies the two-digit, four-digit, six-digit and eight-digit HUCs within the Cherokee Nation and provides their approximate area in hectares. There were six US EPA Level III Ecoregions within the Cherokee Nation, which are referred to as Level III Ecoregions. The Level III Ecoregions were 28 – Flint Hills, 29 – Central

Oklahoma/Texas Plains, 37 – Arkansas Valley, 38 – Boston Mountains, 39 – Ozark Highlands and 40 – Central Irregular Plains, and are shown in Figures 2 and 4 (Cherokee Nation GDC, 2007; US EPA, 2007).

US EPA recommended numerical nutrient criteria apply to US EPA Draft Aggregate Level III Nutrient Ecoregions as well as Subecoregions. The US EPA Draft Aggregate Nutrient Ecoregions are referred to as Nutrient Ecoregions. The U.S. has 14 Nutrient Ecoregions based on the 84 Level III Ecoregions (Rohm et al., 2002). The Cherokee Nation contains parts of three Nutrient Ecoregions: IV - Great Plains Grass and Shrublands, IX - Southeastern Temperate Forested Plains and Hills and XI - Central and Eastern Forested Uplands (Figure 4) (US EPA, 2008a). The Nutrient Ecoregions were based on data from 928 stream sites in the National Eutrophication Survey (NES) taken between 1972 and 1975 (Rohm et al., 2002). The NES data established the Nutrient Ecoregion boundaries by regions with similar nutrient concentrations of similar ecology and land use (Rohm et al., 2002).

Table 1. Two-digit to eight-digit Hydrological Unit Codes (HUC) within the Cherokee Nation jurisdictional service area (Cherokee Nation GDC, 2008; USGS, 2008).

Hydrological Unit Codes Cherokee Nation Jurisdictional Service Area			
Number	**Name**	**Unit Type**	**Area (hectares)**
11	Arkansas-White-Red	Region	-
1107	Neosho-Verdigris	Subregion	5,309,476
1109	Canadian	Subregion	4,351,180
1110	North Canadian	Subregion	4,532,479
1111	Lower Arkansas	Subregion	4,040,382
110701	Verdigris	Basin/Accounting Unit	2,097,890
110702	Neosho	Basin/Accounting Unit	3,211,585
110902	Lower Canadian	Basin/Accounting Unit	1,748,242
111003	Lower North Canadian	Basin/Accounting Unit	1,595,433
111101	Robert S. Kerr Reservoir	Basin/Accounting Unit	1,901,051
11070209	Lower Neosho	Subbasin/Cataloging (Watershed)	562,027
11110102	Dirty-Greenleaf	Subbasin/Cataloging (Watershed)	199,170
11110103	Illinois	Subbasin/Cataloging (Watershed)	419,578
11110104	Robert S. Kerr Reservoir	Subbasin/Cataloging (Watershed)	461,018

US Environmental Protection Agency Recommended Numerical Nutrient Process

The US EPA's (2000a) *Nutrient Criteria Technical Guidance Manual: Rivers and Streams* provide the framework for States and Tribes to determine numerical nutrient standards for lotic waterbodies. The US EPA (2000a) made a number of assumptions in their nutrient criteria manual. Nutrient Ecoregions were assumed to represent an area of similar nutrient conditions due to both natural and anthropogenic conditions with little variance across the Nutrient Ecoregion (US EPA, 2000a). If adequate reference sites within the watershed were unavailable for the Nutrient Ecoregion or Subecoregion, the 25th percentile of all data, which includes both reference and impacted sites, were recommended as reference criteria (US EPA, 2000a). If the number of available reference sites was considered adequate, the 75th percentile of reference data was recommended (US EPA, 2000a).

Reference streams or stream reaches were defined by the US EPA (2000a) as "relatively undisturbed" stream, stream segments or location which "can serve as examples of the natural biological integrity of a region." In practice, reference streams or stream reaches are determined by "best professional judgment" using US EPA (2000a). US EPA guidance requires each Subecoregion within a state to have a minimum of three streams with "low-impact" or reference streams for 'sufficient' reference conditions (US EPA, 2000a). In addition, the US EPA suggests sampling of 30 streams within the same stream class to guarantee adequate sample size (US EPA, 2000a).

Smith et al. (2003) suggests adequate reference sites were often not available for analysis in the US EPA's recommended nutrient criteria analysis for Oklahoma. Dodds and Oakes (2004) reviewed alternate reference condition methods including the US EPA nutrient criteria guidance. Dodds and Oakes (2004) and Smith et al. (2003) concluded no reference condition method was better than another. Both studies were conducted on forested areas considered unaffected by humans to validate nutrient reference conditions recommended by the US EPA for those regions. Both Dodds and Oakes (2004) and Smith et al. (2003), also, concluded "pristine reference sites" were unlikely to exist in the U.S. If reference watersheds are not available, the 25th percentile of all data would apply per US EPA guidance for Oklahoma, and thus for the Cherokee Nation (US EPA, 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2001b).

The US EPA numerical nutrient guidance is illustrated in Figure 11, 12 and 13 (US EPA, 2000a; US EPA, 2000c). Note the figures do not illustrate the full reduction process. The final median is a decadal annual median for the quartile chosen. The selected quartile is a management choice based on the water quality objective and data availability. Decadal annual median quartiles are the water quality data reduced to seasonal percentiles for each river and stream by water year, and then reduced to a median percentile for every ten years of data. First, all water quality samples are grouped by water body. Then, samples are reduced to a water season median by year, and the four-seasonal percentiles are reduced to water year medians of percentiles. The final decadal medians of percentiles are based on ten years of data. If additional decades of data are available, a median of the decadal medians for each water body is used.

The US EPA (2000a) recommends the median of the four seasonal 25th or 75th percentile medians for Fall (September through November), Winter (December through February), Spring (March through May) and Summer (June through August) for a decade as a final recommended numeric nutrient criterion for Nutrient Ecoregions IV, IX and XI. US EPA's recommended guidance suggests the combined 25th percentile or 75th percentile of four seasonal median concentrations for the year as shown in Figures 9, 10 and 11 depending on availability of reference sites (US EPA, 2000a).

Once the distributions of the water quality data are calculated for the Nutrient Ecoregion and Subecoregion(s), the final recommended nutrient criteria reference condition is determined. If reference conditions are available, the upper 25th percentile is recommended. If reference conditions were not available, the lower 25th percentile of all streams was recommended (US EPA, 2000a). The use of either the 75th percentile of reference streams or 25th percentile of all data suggests a correlation between the two populations (Suplee et al., 2007). The assumption of a correlation may be based on lake studies such as the Van Nieuwenhuyse and Jones (1996) study. If neither condition was acceptable, the median of the two may be chosen, as shown in Figure 11. No statistical or biological basis was provided by the US EPA to justify the assumption that the 25th percentile of the general population of data approximates the 75th percentile of the reference population.

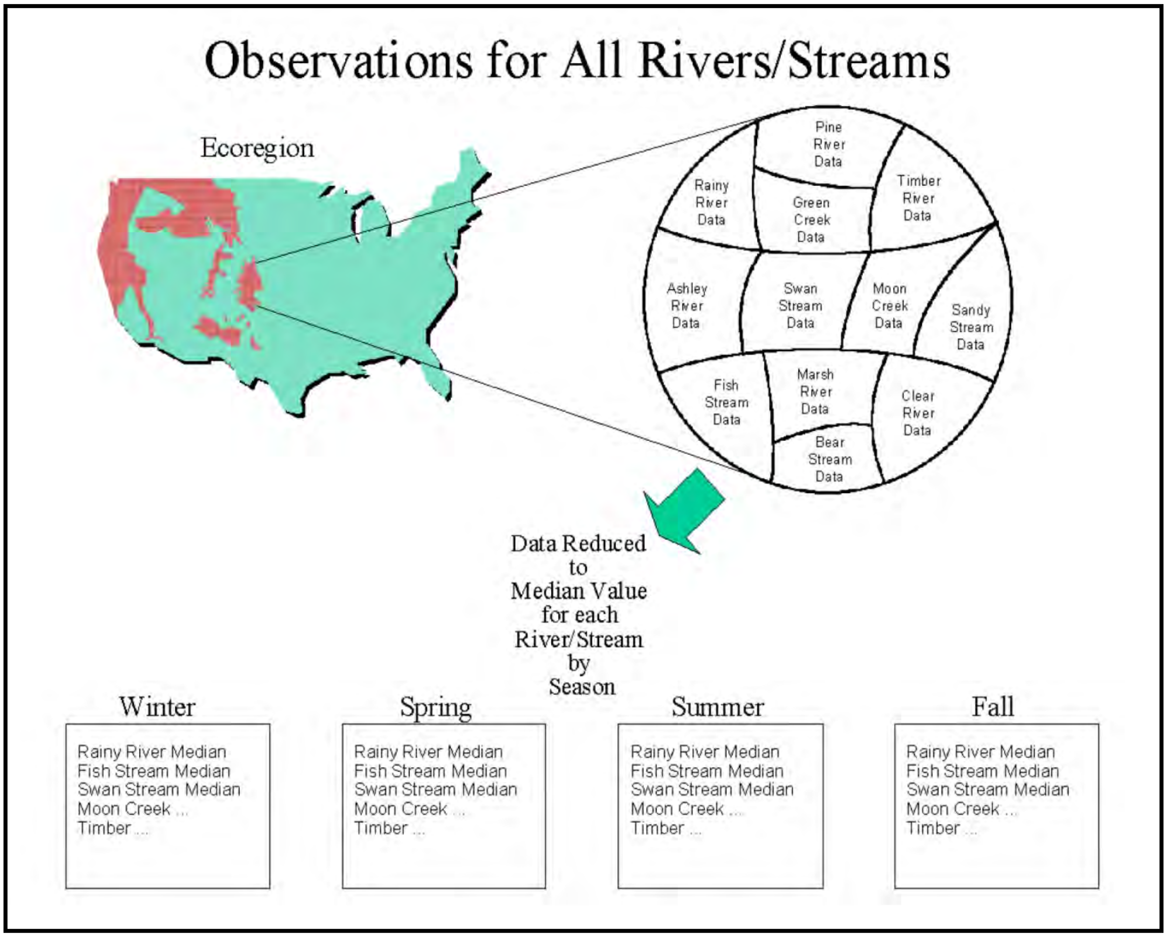


Figure 11. US Environmental Protection Agency numerical nutrient reference criteria guidance data reduction method to a single water year median for each river and stream based on a single reduced median for each river and stream from the four water seasons (US EPA, 2000a)

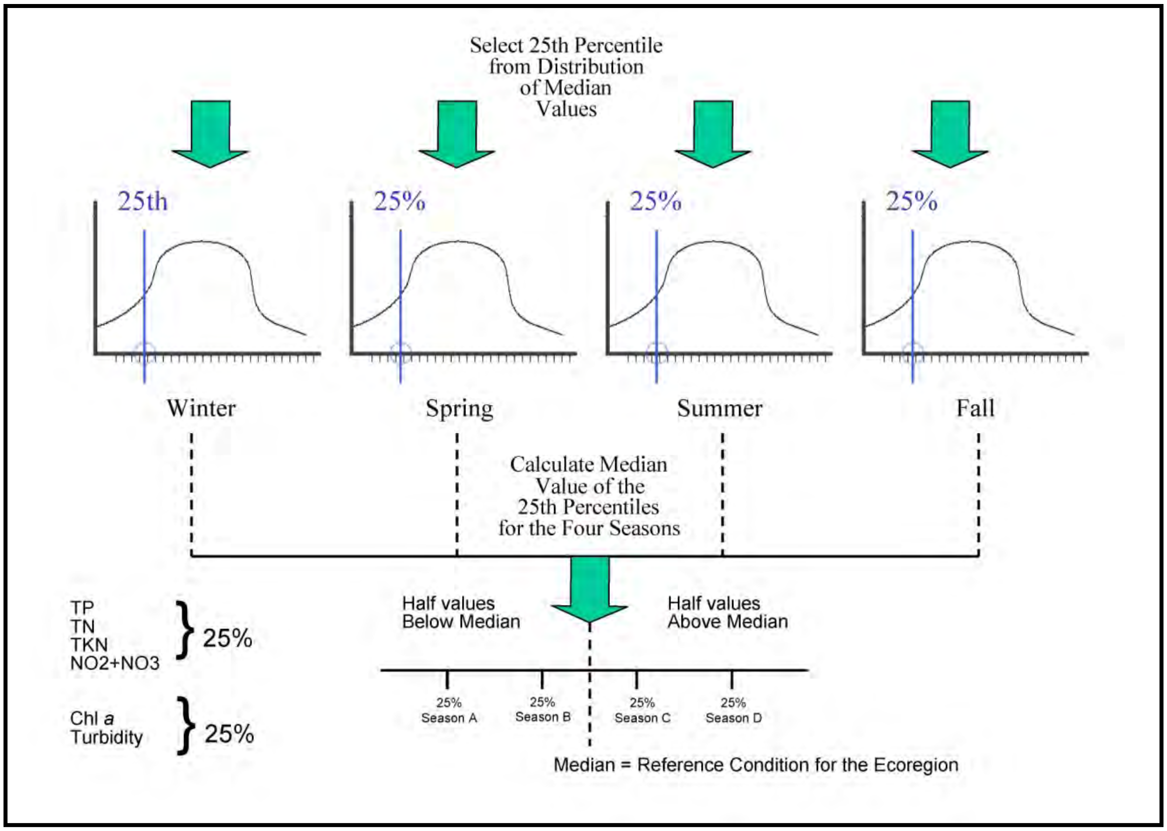


Figure 12. US Environmental Protection Agency numerical nutrient criteria guidance reference condition reduction method by seasons and water year to a single decadal annual median (US EPA, 2000a)

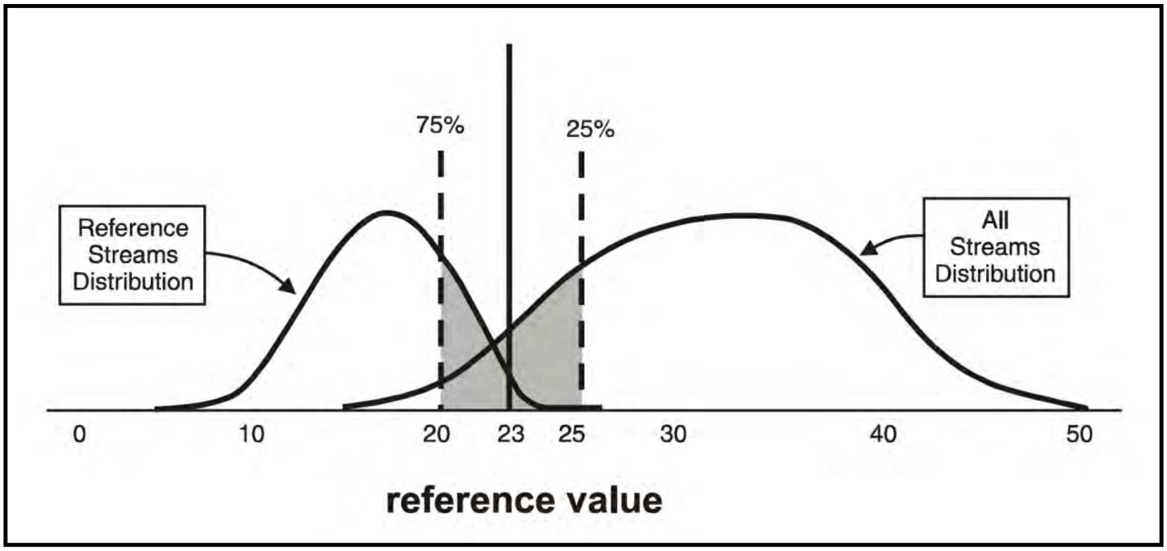


Figure 13. US Environmental Protection Agency suggested method for numerical nutrient criteria reference condition selection by reference stream distribution (US EPA, 2000a)

US Environmental Protection Agency Recommended Reference Conditions

Smith et al. (2003) analyzed data from 63 ‘minimally-impacted’ US Geological Survey (USGS) reference basins. For Nutrient Ecoregions IV, IX and XI, the predicted frequency distribution of TN concentration was found to be lower than the US EPA-recommendation and predicted frequency distribution of TP concentration was found to be higher after corrections for human inputs. In addition, Smith et al. (2003) determined the 25th percentile for areas heavily impacted by anthropogenic eutrophication may be too high to provide adequate reference criteria for healthy waters. Dodds and Oakes (2004) agreed the 25th percentile of heavily polluted areas was not an appropriate reference condition. Both studies indicate the use of the 25th percentile for all data may not be protective of water uses. Stevenson et al. (2008) regression analysis reported

TP of approximately 0.010 mg/L in relatively un-impacted streams and recreational aesthetics were impacted at 30 mg/L.

Suplee et al. (2007) examined five Level III Ecoregions in Montana. Reference site data were compared to general population (all data) percentiles to determine actual relationships between the reference sites and all data combined. For reference data across all seasons in the five Level III Ecoregions, the 75th percentile for TP reference data mapped to the general population across a wide range, 4th to 86th percentile (Suplee et al., 2007). The 90th percentile for TP reference data mapped to the general population across an even wider range, 4th to 96th percentile (Suplee et al., 2007). For TN in all seasons, the 75th percentile for TN reference data mapped to the general population across a smaller range, 62nd to 74th percentile. The 90th percentile for TN reference data mapped to the general population for a different range, 77th to 95th percentile. Only 11% of the 75th percentiles for reference data were within ±5% of the 25th percentiles of the general population data (Suplee et al., 2007). Case-study nutrient concentrations were mapped to reference population percentiles ranging from 73rd to 99th percentile for TP and TN criteria. Suplee et al. (2007) suggests the 86th percentile of median and means for a reference population on the five Level III Ecoregions in Montana studied equate to impact criteria for anthropogenic eutrophication based on 100 mg/m^2 benthic Chl *a* as a benchmark. The median results on the forested reference stream studies almost all exceeded the US EPA-recommended criteria for TP and TN for each Nutrient Ecoregion recommendation. TN was much lower than the recommendation after corrected for wet deposition of N (Dodds and Oakes, 2004; Smith et al., 2003). In the Smith et al. (2003) study, N was 15 to 100% higher than the recommended reference without correction for deposition. Suplee et al. (2007) found the 75th percentile for reference data does not always correlate closely to the 25th percentile of all data as assumed by the US EPA recommended guidance. Suplee et al. (2007) found the 86th percentile for Montana reference streams was correlated with the 25th percentile of negatively impacted streams better than the 75th percentile. However, the Suplee et al. (2007) analysis was different from the US EPA guidance as data were divided by three seasons, winter, runoff and growing, and not four.

US Environmental Protection Agency Recommended Numerical Nutrient Criteria

Data gathered for the US EPA-recommended numerical nutrient criteria were evaluated by an independent consultant, Indus Corporation (US EPA, 2001d), for proper sampling to ensure scientific reliability (US EPA, 2000a; US EPA, 2000b; US EPA, 2000c; US EPA, 2001b; Zhang, 2007). The Indus Corporation Report (US EPA, 2001d) detailed data migration methods for legacy data to be compiled into US EPA's STORET database (http://www.US EPA.gov/storet/). Outliers were omitted (US EPA, 2001d), and minimum detection limits for TP and TN were 10 mg/L TP and 0.1 mg/L TN, respectively (Clark et al., 2000; Dodds and Oakes, 2004; US EPA, 2000a; US EPA, 2001d). US EPA recommended statistical analysis addresses varied sampling frequency and sample size by using the seasonal median for a stream (US EPA, 2000a).

Using the mean might create bias due to variations between data sets (Clark et al., 2000). Ice and Brinkley (2003) found the median of the combined seasonal medians would address the natural variation of nutrient concentrations between seasons and reduce the probability of exceeding criterion more than 10% of the year, which is a criterion often found in water quality standards.

The Nutrient Ecoregion and Subecoregion US EPA-recommended numerical nutrient criteria for TP, TN and Chl *a* river and stream criteria applicable to the Cherokee Nation jurisdiction are provided in Tables 2, 5 and 7. For comparison, the US EPA recommended numerical nutrient criteria for lakes and reservoirs for the same Ecoregions are provided in Tables 3, 4 and 6. Generally, the lakes and reservoirs recommended criteria were lower than the rivers and streams due to the significant differences in lotic and lentic ecosystems. Therefore, the lakes and reservoirs criteria should not be used for rivers and streams (Chin, 2000; US EPA, 2000a).

<u>US Environmental Protection Agency Nutrient Ecoregion IV – Great Plains Grass and Shrublands</u>

Nutrient Ecoregion IV (Great Plains Grass and Shrublands) used data between 1990 and 2000 from US EPA's Legacy STORET, USGS National Stream Quality Accounting Network (NASQAN), USGS National Water-Quality Assessment (NAWQA), US EPA Region 7's Central Plains Center for BioAssessment (CPCB), US EPA Region 7's CPCB 2, US EPA Region 7's Regional Environmental Monitoring and Assessment Program (REMAP), US EPA Region 8 data for Montana and Wyoming, US EPA Region 8 data for South

Dakota and US EPA Region 8 data for North Dakota. The Great Plains Nutrient Ecoregion was primarily "disjunct grassy rolling high plains, hills, plateaus, buttes, stabilized sand dunes and badlands (US EPA, 2001b; Rohm et al., 2002)." All data sources, except for the State of New Mexico and Tribal Nations of Nutrient Ecoregion IV, responded and verified US EPA-approved methods for data gathering were met (US EPA, 2001b).

Each Subecoregion and Nutrient Ecoregion was reviewed for adequate data. All four seasons were reported in each Nutrient Ecoregion and Subecoregion indicating adequate data were available throughout the sampling year. The recommended reference condition was based on the 25th percentile of all nutrient data available for Nutrient Ecoregion IV indicating no reference sites were available (US EPA, 2001b). Reference sites would be from basins minimally impacted by human activity (US EPA, 2000a). If the 75th percentile was reported as the recommended numerical nutrient criteria, US EPA had sufficient data from minimally impacted sites (US EPA, 2000a).

The Aggregate Reference Condition 25th percentile Median Range reported for Nutrient Ecoregion IV streams and rivers was 0.008 to 0.157 mg/L TP with a 25th percentile recommendation of 0.023 mg/L TP (Table 4). The 0.157 mg/L TP was much larger than expected for reference conditions and may indicate some of the streams were not suitable as reference streams. The Aggregate Reference Condition Median Range reported for Nutrient Ecoregion IV streams and rivers was 0.36 to 0.65 mg/L TN with 0.56 mg/L TN (25th percentile) recommended. No periphyton was reported (US EPA, 2001b).

Table 2. US EPA Nutrient Ecoregion IV recommended streams and rivers numerical nutrient criteria reference conditions for all seasons over a decade based on water years 1990 to 2000 (US EPA, 2001b)

Nutrient Ecoregion (NE) IV - Great Plains Grass & Shrublands							
	Aggregate				Subecoregion 28 - Flint Hills		
Nutrient Parameter	**25^{th} Percentile**	**25^{th} Percentile Range**	**Minimum Value**	**Maximum Value**	**25^{th} Percentile**	**Minimum Value**	**Maximum Value**
Total Phosphorus (TP) (mg/L)	0.023	0.008 - 0.157[1]	0.00	2.070	0.060	0.002	0.465
Number of TP Samples	10,035	-	-	-	1,788	-	-
Total Nitrogen (TN) (mg/L)	0.56	0.36 - 0.65	0.12	5.63	0.36	0.32	1.75
Number of TN Samples	740[2]	-	-	-	43	-	-
Combined Phytoplankton Chl *a* (µg/L)	2.4	2 – 4.4					
Phytoplankton Chl *a* (µg/L) [F]	-	-	1.3	36.5	4	3.5	34.6
Phytoplankton Chl *a* (µg/L) [S]	-	-	0.2	46.6	-	-	-
Phytoplankton Chl *a* (µg/L) [T]	-	-	-	-	-	-	-
Periphyton Chl *a* (mg/m^2)	-	-	-	-	-	-	-
Number of all Chl *a* Samples	1,009	-	-	-	15	-	-
Number of Named Streams	430	-	-	-	69	-	-
Number of Stream Stations	850	-	-	-	109	-	-

[1] US EPA indicates further investigation needed to determine high TP concentrations.
[2] Fluorometric method (US EPA, 2001b).

Table 3. US EPA Nutrient Ecoregion IV recommended lakes and reservoirs numerical nutrient criteria reference conditions (US EPA 2001c)

	Ecoregion IV - Great Plains Grass and Shrublands					
	Lakes & Reservoirs Aggregate			**Lakes & Reservoirs Subecoregion 28 (Flint Hills)**		
Nutrient Parameter	**Number of Records**	**25th Percentile**	**Range**	**Number of Records**	**25th Percentile**	**Range**
Total Phosphorus (TP) (mg/L)	0.007	0.020	0.002 – 0.580[1]	0.480	0.031	0.004 - 0.550
Total Nitrogen (TN) (mg/L)	2,247	0.44[2]	0.44-0.49[1]	-	-	-
Periphyton Chl *a* (mg/m^2)	-	-	-	-	-	-

[1] US EPA indicates further investigation was needed to determine high TP and TN values.
[2] Fewer than two lakes were used to determine value.

<u>US EPA Nutrient Ecoregion IX – Southeastern Temperate Forested Plains and Hills</u>

Nutrient Ecoregion IX (Southeastern Temperate Forested Plains and Hills) used data between 1990 and 1999 from US EPA's Legacy STORET, USGS NASQAN, USGS NAWQA, US EPA Regions III, V and VII and Auburn University research (US EPA, 2000c). None of the Tribes within Nutrient Ecoregion IX responded to requests for data (US EPA, 2000c). The Southeastern Temperate Forested Plains were "irregular plains and hills, forest, cropland and pasture, poultry operations and municipal waste water treatment plants" threatened by anthropogenic eutrophication (US EPA, 2000c; Rohm et al., 2002). Half of the

20 states, including Oklahoma, and none of the Tribes for Nutrient Ecoregion IX responded to verify the US EPA-approved methods for data gathering were met (US EPA, 2000c). Each Subecoregion and Nutrient Ecoregion was reviewed for adequate data (US EPA, 2000c). Every season in each Subecoregion and Nutrient Ecoregion were reported (US EPA, 2000c). The recommended reference condition was based on the 25th percentile of all nutrient data available for Nutrient Ecoregion IX implying inadequate reference data were available (US EPA, 2000c) which was consistent with Smith et al. (2003) and Dodds and Oakes (2004) findings for Nutrient Ecoregion IX.

The Subecoregions of Nutrient Ecoregion IX were described as follows. Subecoregion 29 'Central Oklahoma/Texas Plains' was primarily "bluestem grassland with scattered blackjack oak and post oak trees" (US EPA, 2000c). Subecoregion 37 'Arkansas Valley' was about one-fourth grazing lands and one-tenth croplands (US EPA, 2000c). In Subecoregion 37, streams may have naturally low oxygen levels (US EPA, 2000c).

The recommended US EPA (2000c) numerical nutrient criteria for Nutrient Ecoregion IX lakes and reservoirs were included in Table 4 for a perspective on findings within other water bodies within the same watersheds. The 25th percentile recommended criteria for TP was 20 mg/L TP and for TN was 0.358 mg/L TN. Nutrient Ecoregion IX had a median of 0.040 mg/L TP and 0.881 mg/L TN over 227 sample sites (Rohm et al., 2002; US EPA, 2000c). The aggregate 25th percentile for periphyton Chl *a* was 20.4 mg/m^2.

Subecoregion 29 (Central Oklahoma/Texas Plains) had 25th percentiles of 37.5 mg/L TP, 0.68 mg/L TN and 1.238 mg periphyton Chl *a*/m^2. Subecoregion 37 (Arkansas Valley) had 25th percentiles of 42.5 mg/L TP, 0.683 mg/L TN and no periphyton. Subecoregion 40 (Central Irregular Plains) had 25th percentiles of 92.5 mg/L TP, 0.712 mg/L TN and no periphyton (US EPA, 2000c).

Nutrient Ecoregion IX Subecoregion 40 'Central Irregular Plains' was a mix of grassland and forest with wide forested riparian corridors along streams (US EPA 2000b). Subecoregion 40 was highly impacted by 'high sulfur…coal mining."

US EPA Nutrient Ecoregion XI - Central and Eastern Forested Uplands

Nutrient Ecoregion XI (Central and Eastern Forested Uplands) used data between 1990 and 1998 from US EPA's Legacy STORET, Auburn University research, New York State DU Department of Environmental Conservation (NYSDEC) and US EPA Regions III and IV (US EPA, 2000b). Nine of the 15 states and none of the Tribes for Nutrient Ecoregion XI responded to verify US EPA-approved or standard methods for sampling were met (US EPA, 2000b). Oklahoma and Arkansas were two of the six states who did not respond (US EPA, 2000b). Each Subecoregion and Nutrient Ecoregion was reviewed for adequate data (US EPA, 2000b). Every season in each Subecoregion and Nutrient Ecoregion were reported (US EPA, 2000b). The recommended reference conditions were based on the 25th percentile of all nutrient data available for Nutrient Ecoregion XI implying inadequate reference data (US EPA, 2000b).

Nutrient Ecoregion XI had a median of 0.040 mg/L TP and 0.881 mg/L TN over 227 sample sites. Nutrient Ecoregion XI was "mostly unglaciated, forested low mountains and upland plateaus in the central and eastern U.S. (Rohm et al., 2002; US EPA, 2000b)." Subecoregion 38 'Boston Mountains' was mostly forested valleys and ridges dominated by red oak, white oak and hickory trees (US EPA, 2000b). Recreation was a primary use in the Subecoregion 38 (US EPA, 2000b). The US EPA Level III Ozark Highlands ecoregion was primarily forested, limestone plateau with less than 25% used for agriculture (US EPA, 2000b).

The recommended US EPA (2000d) numerical nutrient criteria for Nutrient Ecoregion XI lakes and reservoirs were included in Table 6 for a perspective on findings within other water bodies within the same watersheds. Nutrient Ecoregion XI had a median of 0.022 mg/L TP and 0.894 mg/L TN over 164 sample sites for rivers and streams (Rohm et al., 2002; US EPA, 2000b).

Table 4. US EPA Nutrient Ecoregion IX recommended lakes and reservoirs numerical nutrient criteria reference conditions (US EPA 2000e)

	Ecoregion IX – Southeastern Temperate Forested Plains and Hills		
	Lakes and Reservoirs Aggregate		
Nutrient Parameter	**Number of Records**	**25^{th} Percentile**	**Range**
Total Phosphorus (TP) (mg/L)	23,261	0.020	0.0 – 1.145
Total Nitrogen (TN) (mg/L)	1,492	0.358	0.238 - 2.025
Periphyton Chl *a* (mg/m^2)	-	-	-

Table 5. US EPA Nutrient Ecoregion IX streams and rivers numerical nutrient criteria reference conditions for all seasons over a decade from 1990 to 1999 (US EPA, 2000c; Rohm et al., 2002)

Nutrient Ecoregion (NE) IX - Southeastern Temperate Forested Plains and Hills							
	Aggregate NE IX				**Subecoregion 29 - Central OK/TX Plains**		
Nutrient Parameter	**25th Percentile**	**25th Percentile Range**	**Minimum Value**	**Maximum Value**	**25th Percentile**	**Minimum Value**	**Maximum Value**
Total Phosphorus (TP) (mg/L)	0.037	0.023 – 0.10	0.0	2.40	0.038	0.003	1.33
Number of TP Samples	164,145	-	-	-	2,412	-	-
Total Nitrogen (TN) (mg/L)	0.69	0.07 - 1.0	0.24	12.4	0.68	0.39	3.23
Number of TN Samples	13,749	-	-	-	351	-	-
Combined Phytoplankton Chl *a* (µg/L)	0.93	0.05 - 5.74					
Phytoplankton Chl *a* (µg/L) [Fluorometric]	-	-	1.3	36.5	13	13	13
Phytoplankton Chl *a* (µg/L) [Spectro-photometric]	-	-	0.2	46.6	32	0.25	33.8
Phytoplankton Chl *a* (µg/L) [Trichromatic]	-	-	-	-	-	-	-
Periphyton Chl *a* (mg/m^2)	20.4	3.13 - 20.4	11	62	1.24	-	-
Number of all Chl *a* Samples	16,756	-	-	-	698	-	-
Number of Named Streams	3,278	-	-	-	160	-	-
Number of Stream Stations	-	-	-	-	256	-	-

Table 5…..continued.

Nutrient Ecoregion IX - Southeastern Temperate Forested Plains and Hills						
	Subecoregion 37 - Arkansas Valley			Subecoregion 40 - Central Irregular Plains		
Nutrient Parameter	**25^{th} Percentile**	**Minimum Value**	**Maximum Value**	**25^{th} Percentile**	**Minimum Value**	**Maximum Value**
Total Phosphorus (TP) (mg/L)	0.043	0.005	1.41	0.093	0.01	2.09
Number of TP Samples	2,421	-	-	5,305	-	-
Total Nitrogen (TN) (mg/L)	0.68	0.55	1.75	0.71	0.28	6.23
Number of TN Samples	123	-	-	390	-	-
Combined Phytoplankton Chl *a* (µg/L)						
Phytoplankton Chl *a* (µg/L) [Fluorometric]	-	-	-	2.75	0.65	24.8
Phytoplankton Chl *a* (µg/L) [Spectro-photometric]	4.5	4.5	4.5	5.5	2.025	22.6
Phytoplankton Chl *a* (µg/L) [Trichromatic]	-	-	-	-	-	-
Periphyton Chl *a* (mg/m^2)	-	-	-	-	-	-
Number of all Chl *a* Samples	2	-	-	229	-	-
Number of Named Streams	56	-	-	220	-	-
Number of Stream Stations	93	-	-	445	-	-

Table 6. US EPA Nutrient Ecoregion XI recommended lakes and reservoirs numerical nutrient criteria reference conditions (US EPA, 2000d)

	Ecoregion XI - Central and Eastern Forested Uplands								
	Aggregate Lakes and Reservoirs			**Subecoregion 38 (Boston Mountains)**			**Subecoregion 39 (Ozark Highlands)**		
Nutrient Parameter	**Number of Records**	**25th Percentile**	**Range**	**Number of Records**	**25th Percentile**	**Range**	**Number of Records**	**25th Percentile**	**Range**
Total Phosphorus (mg/L)	8,285	0.008	0.002 – 0.41	190	0.005	0.003 – 0.055	1,112	0.024	0.008 -0.16
Total Nitrogen (mg/L)	58	0.46	0.44 - 1.04	-	-	-	-	-	-
Periphyton Chl *a* (mg/m^2)	-	-	-	-	-	-	-	-	-

Table 7. US EPA Nutrient Ecoregion XI streams and rivers numerical nutrient criteria reference conditions for all seasons over a decade from 1990 to 1999 (US EPA, 2000b)

	Nutrient Ecoregion (NE) XI - Central & Eastern Forested Uplands			
	Aggregate NE XI			
Nutrient Parameter	**25^{th} Percentile**	**25^{th} Percentile Range**	**Minimum Value**	**Maximum Value**
Total Phosphorus (TP) (mg/L)	0.010	0.006 – 0.010	0.0	2.16
Number of TP Samples	80,708	-	-	-
Total Nitrogen (TN) (mg/L)	0.31	0.21 - 0.58	0.059	6.67
Number of TN Samples	13,749	-	-	-
Combined Phytoplankton Chl *a* (µg/L)	1.61	0.25 - 3.26	-	-
Phytoplankton Chl *a* (µg/L) [Fluorometric]	0.45	-	0.125	8.55
Phytoplankton Chl *a* (µg/L) [Spectrophotometric]	1.61	-	0.25	45.7
Phytoplankton Chl *a* (µg/L) [Trichromatic]	1.56	-	0.25	43.4
Periphyton Chl *a* (mg/m^2)	32.5	-	32.5	45.5
Number of all Chl *a* Samples	8,588	-	-	-
Number of Named Streams	2,685	-	-	-
Number of Stream Stations	6,136	-	-	-

Table 7…..continued.

Nutrient Parameter	Nutrient Ecoregion XI - Central & Eastern Forested Uplands					
	Subecoregion 38 - Boston Mountains			Subecoregion 39 - Ozark Highlands		
	25th Percentile	Minimum Value	Maximum Value	25th Percentile	Minimum Value	Maximum Value
Total Phosphorus (TP) (mg/L)	0.006	0.003	0.16	0.007	0.003	2.15
Number of TP Samples	1,644	-	-	8,166	-	-
Total Nitrogen (TN) (mg/L)	1.38	1.38	2.29	0.38	0.15	3.89
Number of TN Samples	46	-	-	826	-	-
Combined Phytoplankton Chl *a* (µg/L)	-	-	-	-	-	-
Phytoplankton Chl *a* (µg/L) [Fluorometric]	-	-	-	0.35	0.20	4.60
Phytoplankton Chl *a* (µg/L) [Spectrophotometric]	0.25	0.25	0.25	0.90	0.435	10.9
Phytoplankton Chl *a* (µg/L) [Trichromatic]	-	-	-	-	-	-
Periphyton Chl *a* (mg/m^2)	-	-	-	32.5	32.5	32.5
Number of all Chl *a* Samples	3	-	-	214	-	-
Number of Named Streams	67	-	-	258	-	-
Number of Stream Stations	117	-	-	560	-	-

Case Study Findings

Nuisance Algae

Case studies in the literature indicate a natural breakpoint for a nuisance threshold for benthic chlorophyll in rivers and streams, as well as breakpoints for classification of trophic status. Studies were reviewed for possible numerical nutrient criteria for TP, TN and benthic Chl *a* and possible response relationships for benthic chlorophyll to both TP and TN in rivers and streams. The reviewed findings are explored in this section and summarized in Appendix B.

Suplee et al. (2009) determined by field and mail surveys of Montana river users a 150 to 200 mg Chl a/m^2 maximum benthic Chl *a* as a threshold for tolerable recreational use on Montana rivers. Using eight randomly ordered pictures showing algal cover of 44, 112, 152, 202, 235, 299, 404 and 1276 mg Chl a/ m^2, Suplee et al. (2009) conducted in-person and by mail surveys asking Montana river users if the level of benthic algae shown in the pictures was acceptable or unacceptable for recreation. A simple majority or 50% acceptability was the baseline for acceptable recreation levels, and used a 95% confidence level with 5% or less error (Suplee et al., 2009). Although differences were found between groups, such as residents and non-residents, different geographic areas or regions surveyed and in-person or mailed surveys, a majority favored the 150 mg benthic Chl a/m^2 as a breakpoint for acceptable benthic algae for recreational river users (Suplee et al., 2009). Benthic Chl *a* levels above 150 mg Chl a/m^2 were determined to be eutrophic (Suplee et al., 2009).

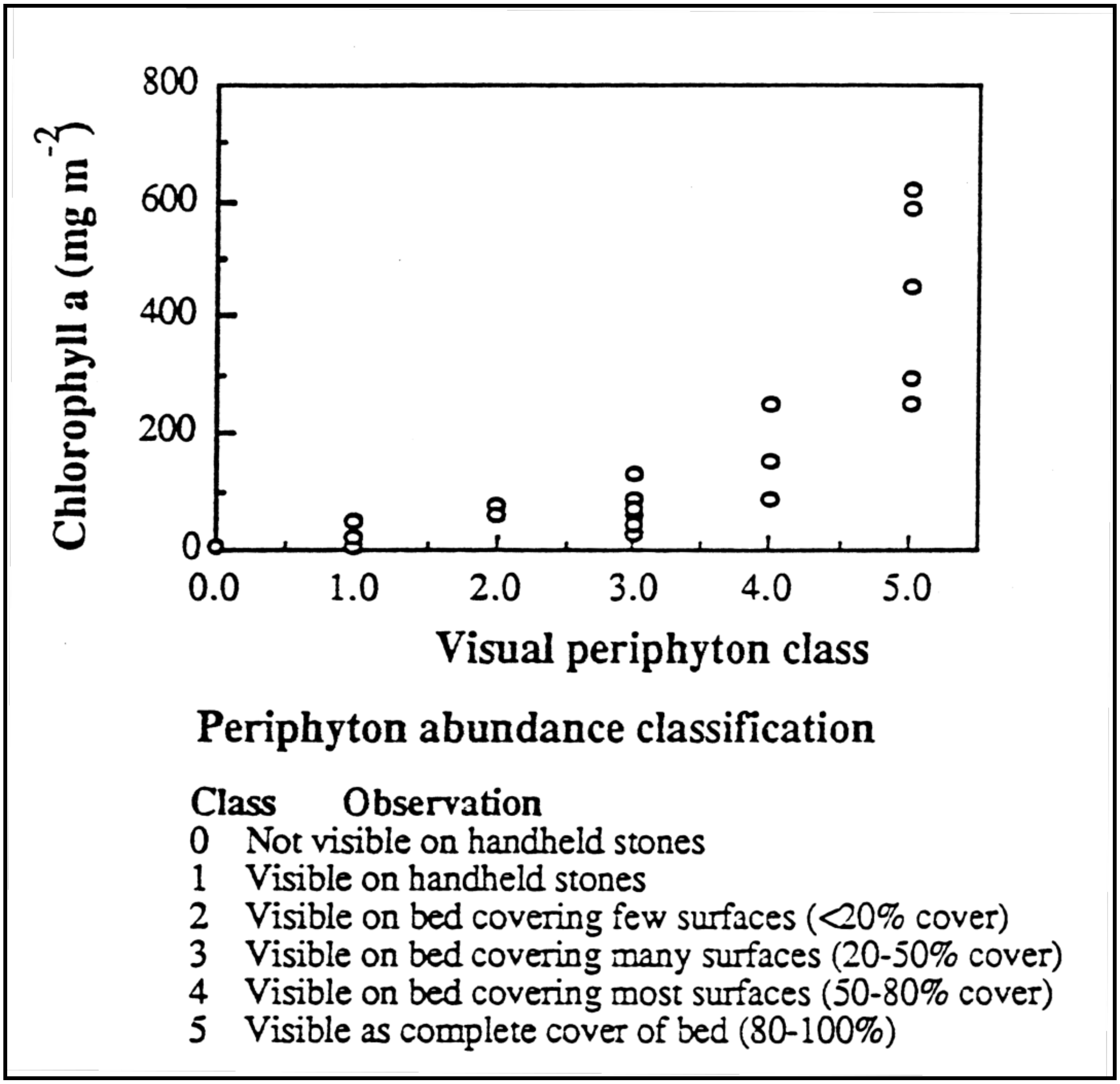


Figure 14. Classification values assigned to periphyton biomass correlated to visual periphyton abundance (Thomas, 1978)

Thomas (1978) equated periphyton (benthic algae biomass) to percent of visible coverage. Figure 14 shows periphyton 100 mg Chl *a*/m^2 likely for 'Class 2' observations would represent less than 20% visible algae (Thomas, 1978). 'Class 3' observations show 150 mg Chl *a*/m^2 likely with visible algal cover ranging from 20 to 50% (Thomas, 1978) which was the breakpoint for recreational Montana river users in the Suplee et al. (2009) study. 'Class 4' estimated at 250 mg Chl *a*/m^2 and 50 to 80% cover (Thomas, 1978). Figure 15 provides a visual idea of the numbered classes in Figure 14 such as ‘Class 2’ for periphyton on row A, column 2 (Thomas, 1978) which should visually approximate the Suplee et al. (2007) study breakpoint for acceptable benthic algae coverage. Welch et al. (1988) found filamentous periphytic algae cover remained less than 20% when biomass was less than 100 to 150 mg Chl *a*/m^2 for 22 northwest U.S. and Swedish streams which was somewhat consistent with Figures 14 and 15. Biggs (1996) analysis of 16 New Zealand streams determined the benthic Chl *a* threshold for moderately enriched streams as 100 mg Chl *a*/m^2.

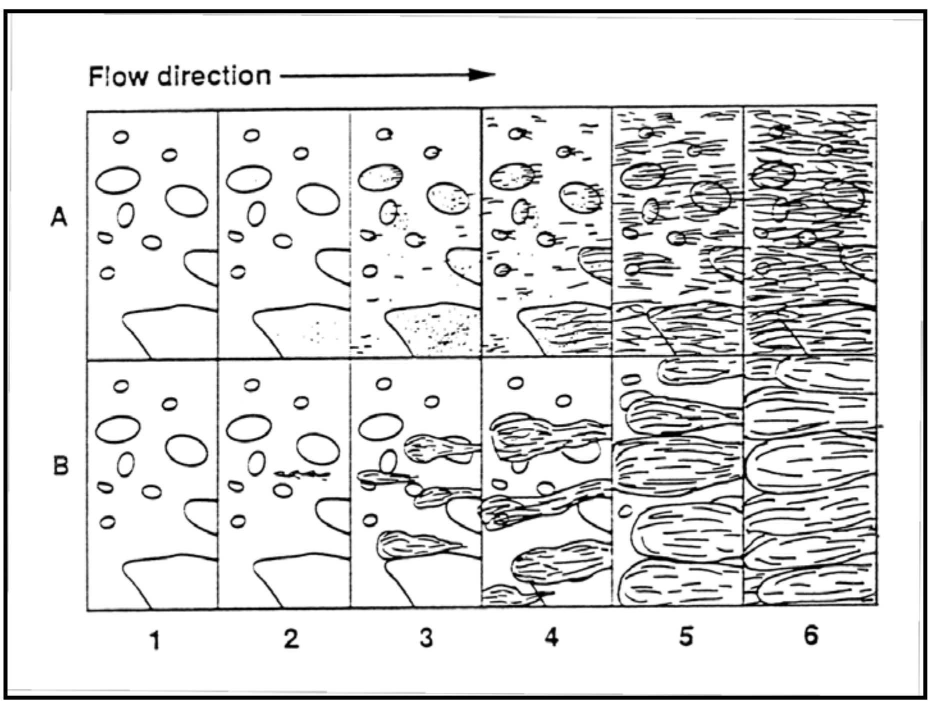


Figure 15. Visual scale for estimation of algal growth in streams and rivers; Flow direction was unexplained; A was periphyton or microphytes and B was macrophytes; 1 through 6 was the observed class for periphyton abundance (Thomas, 1978)

As a general guideline, the US EPA (2000a) *Nutrient Criteria Technical Guidance Manual: Rivers and Streams* considers a stream periphyton dominated if the current was less than 10 cm/s with low turbidity, an open canopy, shallow depth, minimal scouring, gravel size substrata and a small depth to width ration. Stevenson et al., (2006) northwest Kentucky and Michigan findings suggest 1st to 4th order reference stream conditions should be less than or equal to 0.011 mg/L TP, 0.400 mg/L TN and 10 to 20 mg Chl *a*/m^2 for benthic algae. To avoid increased risk of excessive benthic algae defined as 100 mg/m^2 benthic Chl *a*, TP should be less than 0.030 mg/L and TN should be less than 1.000 mg/L. To minimize the likelihood of benthic Chl *a* being greater than 100 mg/m^2 most of the time, TN should be less than 0.470 mg/L and TP less than 0.060 mg/L (Dodds and Welch, 2000). Dubrovsky et al. (2010) estimated national reference conditions for streams as 0.58 mg/L TN and 0.034 mg/L TP. Stevenson et al. (2012) found 0.027 mg/L TP in the Illinois River watershed resulted in an average of 36 percent filamentous green algae cover.

Chetelat et al. (1999) found periphyton diversity diminishes at 0.020 mg/L TP and Cladophora does not grow if TP was less than 0.011 mg/L TP. Stevenson et al. (2008) found nuisance Cladophora was avoided for average TP less than 0.030 mg/L and Justus et al. (2009) found biotic indices were best when TP was less than 0.018 mg/L. Using the weight of evidence approach, Smith and Tran (2010) recommended 0.03 mg/L TP to protect aquatic life in large rivers. Rosemarin (1983) found Cladophora maximum growth rates occurred between 0.025 and 0.040 mg/L TP. Critical breakpoints of 0.023 mg/L

TP and 0.048 mg/L TN were established for benthic Chl *a* response (Dodds et al., 2002). Chetelat et al., (1999) found periphyton diversity was lost when TP was 0.020 mg /L or greater and no Cladophora present if less than or equal to 0.011 mg/L.

Artificial substrates used in some studies may produce lower than expected benthic Chl *a* response (Thomas, 1978; Dodds et al., 2002). The Chl *a* response may only be slightly lower than natural substrate results, but caution should still be used when including research data from artificial substrates (Dodds et al., 2002).

The Chl *a* response was influenced by solar radiation, the geometry of the water body, flow, velocity, dispersion, water temperature as well as nutrients (Thomann and Mueller, 1987). The water velocity for optimum periphyton growth identified in case studies ranges from 9 to 50 cm/s (0.295 to 1.640 ft/s) (Gosh and Gauir, 1994; Horner and Welch, 1981; Nijboer and Verdonschot, 2004).

Nutrients

Before the US EPA recommended nutrient criteria guidance, the US EPA (1986) on page 240 of *The US EPA Gold Book* (1986) recommended a general threshold of 0.100 mg/L TP for flowing waters and maximum of 0.050 mg/L TP for streams and rivers entering a lake or reservoir to avoid nuisance pests and excess eutrophication. The US EPA (1986) suggests the lotic waters numeric TP criterion was based on Mackenthum (1973) involving algal response to nutrients in sewage pond sludge (Allen, 1955).

Several State nutrient standards refer to the US EPA (1986) *Gold Book* standards which reference Mackenthum (1973) guidance for water supplies in setting TP standards. To avoid “interfere with coagulation in water treatment plants”, unspecified P should not exceed 0.100 mg/L (Mackenthum, 1973). In the same context, Mackenthum (1973) states 0.050 mg P/L was the threshold to avoid excessive algal growth.

Bothwell (1989) suggested 0.050 mg/L dissolved P created maximum biomass and 100 mg Chl *a*/m^2 was a breakpoint for significant increased growth. Later in the US EPA guidance, Mackenthum (1973) refers to a study of maximum algal growth on pages 11 through 34 in the General Features of Algae Growth in Sewage Oxidation Ponds by M. B. Allen (1955). Mackenthum (1973) suggests the Allen study determines “total phosphorus should not exceed 0.100 mg/L TP at any point within the flowing stream, nor should 0.050 mg /L TP be exceeded where waters enter a lake” to avoid “biological nuisances.” The Allen (1955) study was of sewage oxidation pond algae, primarily chlorella and scenedesmus, at the Central Contra Costa Sanitary District and City of Santa Rosa, California. In addition to P and N, carbon inputs for algae growth were studied (Allen, 1955). Allen (1955) never indicates the nutrient input study on sewage algae was applicable to other algae types such as benthic algae or lotic waters.

Appendix B contains numerical nutrient criteria for TP, TN and Chl *a* found within the literature recommended to prevent nuisance algal growth and the negative effects due to anthropogenic eutrophication as reviewed in the literature.

Wong and Clark (1976) calculated two different critical levels (saturation) for in-stream TP, 0.060 and 0.070 mg/L TP. The 0.060 mg/L TP was based on plant (Cladophora) tissue analysis (Wong and Clark, 1976). The 0.070 mg/L TP was based on actual water quality data analysis and the assumption the Cladophora growth curve follows the Michael-Mentis growth equation with rapid growth followed by a saturation level or critical level (Wong and Clark, 1976).

Dodds et al. (1997) studied Clark Fork on the Columbia River in western Montana to determine numerical nutrient objectives needed to prevent nuisance algal growth. Nuisance benthic algal growth was defined as mean Chl *a* in excess of 100 mg/m^2 (Dodds et al., 1997). Note, Suplee et al. (2007) suggests a breakpoint of 150 Chl *a* mg/m^2. The study used mean values and not medians as suggested and used by the US EPA in determining recommended nutrient criteria (US EPA, 2000a). Prominent land uses identified within the Clark Fork area were forest, rangeland and agriculture. Using regression analysis for more than 200 sampling sites in North America, Europe and New Zealand, Dodds et al. (1997) found mean in-stream nutrients needed to minimize risk of nuisance algae should be less than 0.350 mg/L TN and 0.030 mg/L TP. An analysis of reference reaches for mean summer conditions needed to avoid nuisance algae yielded 0.318 mg/L TN and 0.021 mg/L TP (Dodds et al., 1997). The reference site data seem to validate the regression analysis findings.

Vollenweider (1971) trophic classifications should not be used to characterize running waters as Vollenweider (1971) analyzed lake and reservoir data. Vollenweider (1971) may be used inappropriately to describe lotic waters in some literature. Van Nieuwenhuyse and Jones (1996) analyzed data from 115 northern temperate streams and one southern temperate stream using regression analysis. Van Nieuwenhuyse and Jones (1996) does not apply to benthic algae (Dodds et al., 1997). Suggested trophic breakpoints in the literature for the oligotrophic to mesotrophic and mesotrophic to eutrophic boundaries for benthic algae are summarized in Table 8.

Table 8. Suggested trophic classification boundary breakpoints based on cumulative frequency distribution for general (or all) rivers and streams data (US EPA, 2000f; Haggard et al., 2003; Dodds, Jones and Welch, 1998)

Variable (Units)	**Oligotrophic-Mesotrophic Boundary**	**Mesotrophic -Eutrophic Boundary**	**Sample Size**
Mean Benthic Chlorophyll (mg/m^2)[b]	20	70	286
Maximum Benthic Chlorophyll (mg/m^2)[a, b]	60	200	176
Total Nitrogen (TN) (mg/L)[b, d]	0.70	1.50	1070
Total Phosphorus (TP) (mg/L)[b, d, e]	0.025	0.075	1366
TP (mg/L)[c]	0.010	0.035	Annual Mean in Conjunction with phytoplankton Chl *a* response for Lakes and Reservoirs

[a]Biggs (2000) for New Zealand streams.
[b]Dodds et al. (1998).
[c]Dojlido and Best (1993).
[d]Omernik (1977).
[e]Van Nieuwenhuyse and Jones (1996)

Table 9. Trophic state analysis for total nitrogen (TN) and total phosphorus (TP) based on 100 mg Chl *a*/m^2 by Dodds (2006)

Nutrient Parameter	Autotrophic Boundary	Concentration (mg/m^3) Smith et al. (2003)	Dodds and Oakes (2004)	Cases Exceeding 100 mg/m^2 Chl *a* (%) Mean	Maximum
Total Nitrogen (TN) (mg/L)	Lower Third	0.285	0.370	7	27
TN (mg/L)	Upper Third	0.714	0.659	10	29
Total Phosphorus (TP) (mg/L)	Lower Third	0.029	0.023	5	17
TP (mg/L)	Upper Third	0.071	0.048	13	25

In comparison, the trophic boundaries of lakes were proposed as 0.010 mg/L TP for the transition from oligotrophic to mesotrophic and 0.020 mg/L TP for the transition from mesotrophic to eutrophic (Thomann and Mueller, 1987). The boundary analysis by Thomann and Mueller (1987) was based on the National Eutrophication Survey Working Paper No. 23 published by the U.S. US EPA in 1974.

Dodds (2006) reviewed Smith et al. (2003) and Dodds and Oakes (2004) for trophic state classification with respect to nuisance algae response. Shown in Table 9, Dodds (2006) determines the upper third boundary should be avoided as nuisance algae response of 100 mg Chl *a*/m^2 will likely occur 30% of the time. Note, Dodds (2006) numbers corrected the Dodds and Oakes (2004) analysis for data entered incorrectly in earlier papers.

Thomann and Mueller (1987) determined the Redfield ratio breakpoint for P and N limitation algae in rivers and streams as 10. Thomann and Mueller

(1987) concluded streams and rivers were N-limited if the Redfield Ratio was less than 5 and P-limited if the Redfield Ratio was greater than 20. A Redfield Ratio less than 5 may risk a blue-green algae response in order to fix N for the ecosystem. Hauer and Lamberti (2006) suggest a Redfield ratio breakpoint for benthic algae was 18 N:P by molar with 32 plus required for P-limitation (Francoeur et al., 1999). A Redfield Ratio of 7.23g N: 1g P may provide for balanced growth (Dodds et al., 1997). The Redfield Ratio of 7.2 N:P by weight was based on the stoichometric ratio for P and N with Liebig's Law of the Minimum (Droop, 1973; Dodds, 2003; Ji, 2008).

Theoretical Algal Response

The Michaelis-Menten equation (2.3) describes the theoretical saturation or uptake kinetics of algae lacking nutrients (Droop, 1973; Hauer and Lamberti, 2006; Stevenson et al., 2006; Wang et al., 1997). The Monod equation (2.4) describes the empirical growth rate of nutrient limited algae (Droop, 1973). Understanding the half-saturation constant for nutrient uptake or growth and the critical saturation point where growth stops and the curve were flat may provide a basis for a numerical nutrient criteria and reference conditions.

$$G(N) = \frac{N}{K_{mN} + N} \qquad \textbf{(2.3)}$$

$G(N)$ = growth rate

N = nutrient concentration

K_{mN} = "Michaelis" constant or half saturation constant

$$\mu = \mu_{\max} \frac{S}{K_S + S} \tag{2.4}$$

μ = specific growth rate of algae

μ_{max} = maximum specific growth rate of algae

S = concentration of limiting substrate

K_s = "half-velocity constant"

Rhee (1978), as referenced in Elwood et al. (1981), determined $P_{critical}$ was less than or equal to 0.060 mg/L TP for periphyton (Thomann and Mueller, 1987). In a P study of a woodland stream, Elwood et al., (1981) found P (PO_4•P) uptake saturated at 0.060 mg/L. Miltner (2010) found the approximate upper limit for the change point in benthic Chl *a* density in small rivers and streams of Ohio was 0.038 mg/L TP. Thomann and Mueller (1987) suggests the critical nutrient concentration (saturation) should be approximately five times the Michaelis constant, K_{mN}, given as (Agren, 1988):

$$G(N) = \frac{N}{K_{mN} + N} = \frac{5 \cdot K_{mN}}{K_{mN} + 5 \cdot K_{mN}} = \frac{5 \cdot K_{mN}}{6 \cdot K_{mN}} = 0.83 \tag{2.5}$$

Past case study analysis shows a significant decrease in TP does not necessarily bring a significant decrease in Chl *a* (Chin, 2006; Nijboer and Verdonschot, 2004; Thomann and Mueller, 1987). The appearance of hysteresis may be due to temporary nutrient storage in the hyporheic zone and sediment as well as luxury storage in the algae (Droop, 1973; Dodds and Welch, 2000; Nijboer and Verdonschot, 2004). The concentration may need to be much less than K_{mN} before a visible decline in algal growth occurs due to both temporary storage in the lotic ecosystem and the slope of the curve above K_{mN} (Thomann and Mueller, 1987).

In addition, Stevenson et al. (2006) estimates the rate of periphyton growth was 0.6 µg Chl *a*/cm^2 for every ln (µg TN/L or µg TP /L) and P_c was 0.030 mg/L TP for diatoms. Bothwell (1985) suggests lotic periphyton growth are saturated as low as 0.003 to 0.004 mg SRP/L where Horner et al. (1983) documents chlorophyll accrual becomes saturated between 0.015 and 0.025 mg dissolved P/L. Toetz et al. (1999) found SRP less than 0.010 mg/L was significant for lotic periphyton for eight Oklahoma subbasins in the Illinois River basin. Chetelat et al. (1999) and King et al. (2009) found periphyton algae diversity was lost when TP became greater than 0.020 mg/L. If TP was less than or equal to 0.011 mg/L TP, no Cladophora was present (Chetelat et al. 1999). However, Rosemarin (1983) determined the maximum growth rates for Cladophora was when TP was 0.025 to 0.040 mg/L.

The form of the Dodds (2006) corrected regression equation predicting benthic algae response based on TP or TN is given below with parameter values given in Table 10.

$$\log_{10}\left(\frac{mg \cdot chl\_a}{m^2}\right) = Intercept + B_1 \cdot \log_{10}\left(TotalNutrient\left(\frac{\mu g}{L}\right)\right) - B_2 \cdot \left[\log_{10}\left(TotalNutrient\left(\frac{\mu g}{L}\right)\right)\right]^2 \tag{2.6}$$

Table 10. Corrected regression equation parameters for predicting benthic algae response for trophic state based on either total phosphorus (TP) or total nitrogen (TN) (Dodds, 2006). Equations are of the form $\log_{10}$(mg chlorophyll m^{-2}) = Intercept + B_1 $\log_{10}$(mg m^{-3} total N or total P) + B_2 [$\log_{10}$(mg m^{-3} total N or total P)]^2

Relationship	Intercept	B_1	B_2	R^2	Expected Chl *a* Response (mg/m^2) Lower 1/3	Upper 1/3
Mean Chl *a* versus TN (mg/m^3)	-2.638	2.460	-0.320	0.401	30	60
Maximum Chl *a* versus TN (mg/m^3)	0.438	0.613	-	0.295	88	154
Mean Chl *a* versus TP (mg/m^3)	-0.608	1.486	-0.255	0.402	36	65
Maximum Chl *a* versus TP (mg/m^3)	0.216	1.680	-0.297	0.371	109	204

US Environmental Protection Agency Approved Numerical Nutrient Standards

Tribal Nations

Most of the US EPA-approved Tribal WQS include only narrative “free from” statements as criteria for prevention of anthropogenic eutrophication. Three of the 36 Tribes mention the US EPA’s recommended Nutrient Ecoregion criteria. Only the Isleta Pueblo (2002) adopts the Nutrient Ecoregion III Criteria for TP and TN for rivers and streams as suggested by the US EPA in the recommended numerical nutrient criteria. The Grand Portage Band of the Minnesota Chippewa Tribe (2006) adopted the US EPA recommended TP and TN numeric criteria until the Tribe can evaluate further. The Miccosukee (1999) set TP at 0.010 mg/L TP to attain “natural oligotrophic levels.” The Acoma (2005) and Sandia Pueblos (1991) set TP limits at 0.100 mg/L TP in streams. No basis for the criteria was stated. Many of the Tribes have adopted the US EPA’s *National Recommended Water Quality Criteria* (2006b) for P and N in respect to Human Health Criteria, but not numeric criteria for the prevention of excess nutrients. The *National Recommended Water Quality Criteria* (2006b) utilized were nitrates 10 mg/L, nitrites 1.0 mg/L and pH, temperature and life stage dependent ammonia criterion.

Oklahoma Scenic River Criterion

The Oklahoma Scenic River numeric phosphorous criterion was reviewed. The Oklahoma Scenic Rivers criterion aesthetic criterion for TP was a 30-day rolling geometric mean of 0.037 mg/L TP (Oklahoma Water Resource Board (OWRB), 2001; OWRB, 2002). The available US EPA nutrient guidance for the 75th percentile for non-reference conditions was not used by OWRB to determine the criterion because “acquisition and manipulation of data necessary to determine such a value became problematic” (OWRB, 2001; OWRB, 2002). The US EPA-recommended Nutrient Ecoregion or Subecoregion nutrient reference criterion for TP was not used; instead, the 75th percentile of all data in Clark et al. (2000) was used. The 75th percentile for all basin data in Clark’s Study (2000) for TP was 0.037 mg/L TP. The summary of findings with respect to TP and TN for the Clark et al. (2000) was provided in Table 11. Of the basins studied in the Clark et al. (2000), seven basins were in or near Oklahoma as shown in Figure 13. No basins appeared to be in the Cherokee Nation. Flow conditions were not known for all data used in the State's analysis of existing conditions (OWRB, 2001; OWRB, 2002).

Figure 16. Hydrological Benchmark Network (HBN), National Water-Quality Assessment (NAWQA) and research water quality sites utilized in the Clark et al. (2000) study utilized by the State of Oklahoma to justify the Oklahoma Scenic Rivers criterion.

The Illinois River seems to be the focus of the Oklahoma Scenic Rivers TP criterion. The Illinois River was within the US EPA Nutrient Ecoregion XI (Central and Eastern Forested Uplands) and the US EPA Level III Ecoregion Ozark Highlands. For the Nutrient Ecoregion XI and Ozark Highlands ecoregion, the US EPA-recommended TP criteria was 0.010 mg/L and 0.007 mg/L, respectively (US EPA, 2000b). Oklahoma's Scenic River TP criterion was almost four times the US EPA-recommended nutrient criterion for the greater Nutrient

Ecoregion and five times for the smaller, local Subecoregion. When compared with the two reference condition studies in forested areas, Oklahoma's Scenic River TP criterion appears reasonable (Dodds and Oakes, 2004; Smith et al., 2003).

Table 11. Clark et al. (2000) Recommended Reference Numerical Nutrient Criteria for total phosphorus (TP) and total nitrogen (TN)

Study Unit	Sample Number	Percentile					
		25th		50th		75th	
		TP	TN	TP	TN	TP	TN
		(mg/L)					
All	63	0.014	0.20	0.022	0.26	0.037	0.50
Hydrological Benchmark Network (HBN)	41	0.014	0.19	0.020	0.24	0.030	0.52
National Water-Quality Assessment Program (NAWQA)	22	0.013	0.20	0.037	0.32	0.052	0.49

The approved OWRB criterion for Oklahoma Scenic Rivers applies to the Illinois River, Barren Fork, Flint Creek, Lee Creek, Little Lee Creek and Upper Mountain Fork River. Of the six Scenic Rivers, five were within the jurisdictional service area of the Cherokee Nation. The criterion, 0.037 mg/L TP, was representative of the upper 25% (75^{th} percentile) of the flow-weighted TP concentration for 'relatively undeveloped' streams as determined by Clark et al. (2000). Clark et al. (2000) identified data from 85 "relatively undeveloped basins," but found Oklahoma lacked data in undeveloped areas. Davis et al.

(1996) assessed the Ozark Plateau study unit from 1970 to 1992 for nutrients. The assessment indicated the Ozark Plateau study unit, which was used by Clark et al. (2000) from 1990 to 1995 was more than minimally impacted. The long-term average was used since flow at the time of sampling was unknown for data utilized by Clark et al. (2000).

In a 2002 OWRB PowerPoint presentation addressing the Oklahoma's Scenic Rivers criterion for TP, Dr. Riley Needham's 2002 Report submitted to the OWRB was included as technical justification for the 0.037 mg/L TP criteria. The Needham (2002) report initially recommends 0.010 to 0.020 mg/L TP as the maximum allowable TP concentration to maintain high quality waters. Ultimately, Needham (2002) recommends 0.020 mg/L TP as a maximum TP concentration allowable to control algal growth in lotic waters. The Needham (2002) 0.020 mg/L TP recommendation appears to be based on Clark et al. (2000) indicating an algal growth response at 0.0205 mg/L TP. In addition, Needham (2002) notes 46% of all samples collected by the US EPA for Nutrient Ecoregion analysis of Subecoregions 36, 38 and 39 which fall within the Cherokee Nation were less than 0.020 mg/L TP (US EPA 2000b). The 0.020 mg/L TP was much higher than the US EPA-recommended 25th percentile of all river and stream data for US EPA Nutrient Ecoregion XI of 0.0066 mg/L TP ranging from 0.0056 to 0.0105 mg/L TP (US EPA, 2000b). The 25th percentile of all data was assumed to be equivalent to the 75th percentile of reference condition data by US EPA *Nutrient Criteria Technical Guidance Manual: Rivers and Streams* (2000a) when no reference sites were available. Clark et al. (2000) found a median flow-weighted concentration of 0.022 mg/L TP and 0.260 mg/L TN was needed to maintain high quality waters free from excessive algae for the rivers and streams studied which was not the 75th percentile.

Both Needham's (2002) report and the OWRB (2002) presentation included the Clark et al. (2000) findings as justification for the Oklahoma Scenic Rivers TP criterion. Clark et al. (2000) was based on USGS data collected between 1990 and 1995 from 85 U.S. stream sites in 'relatively undeveloped basins.' 'Relatively undeveloped' was not pristine reference conditions as described in the US EPA (2000a) technical guidance needed to justify the use of the 75th percentile. The three USGS data sets utilized in the study were the Hydrological Benchmark Network (HBN), NAWQA and research data from several USGS programs including the Water, Energy and Biochemical Budgets (WEBB) project data (Clark et al., 2000; Murdoch et al., 2005). Oklahoma was found to be, too, developed for use as a reference area and thus poorly represented in Clark et al. (2000). From the HBN data set, the 43 basins included ranged from 6.1 to about 2,500 km^2. HBN basins were, typically, protected areas such as national forests and data were collected between 1976 and 1997 (Clark et al., 2000; Mast et al., 2005). From the NAWQA data set, the 22 'fairly undeveloped basins' included ranged from 18 to approximately 2,700 km^2 and data were collected between 1992 and 1995 (Clark et al., 2000). From the USGS research programs, 20 basins located primarily in the Appalachian and Rocky Mountains ranging in size from 0.1 to roughly 22 km^2 were included (Clark et al., 2000).

Clark et al. (2000) data included TP sampled, directly, and TN as the sum of the sampled nitrate (NO_3) and Total Keijdal Nitrogen (TKN). TKN was the sum of ammonia (NH_4) and organic N which was sampled for in most data sets utilized by Clark et al. (2000). The USGS research data included only nitrate (NO_3) data (Clark et al., 2000).

Clark et al. (2000) assumed the US EPA (1986) suggested TP threshold of 0.100 mg/L TP for flowing surface waters to prevent nuisance benthic algae in streams and rivers. Clark et al. (2000) stated the study outcomes were never intended to determine regional numeric nutrient criteria.

Both the OWRB (2002) and Needham (2002) analysis assume the 25th percentile of all stream data approximates the 75th percentile of reference conditions streams to determine numerical nutrient criteria as suggested by the US EPA *Nutrient Criteria Technical Guidance Manual: Rivers and Streams* (2000a). Since the Cherokee Nation jurisdiction was highly impacted by human activities, some studies suggest the 25th percentile of general population data may be too high (Suplee et al., 2007). If valid, the 25th percentile of the general population was not protective and the 5th percentile of all data should be considered.

Needham (2002), also, considers lake studies for justification of his recommended scenic river TP criterion, 0.020 mg/L TP. Needham's (2002) report references a study of Lake Taneycomo in Missouri. Needham (2002) notes preliminary findings for Lake Taneycomo indicate 0.040 mg/L TP was not low enough to limit excessive algal growth. The Knowlton and Jones (1990)

Lake Taneycomo modeling indicates 0.019 mg/L TP creates visible algal growth in approximately one week. Another comparison by Needham (2002) was the US EPA-recommended Ecoregion XI Lake reference criterion of 0.008 mg/L TP (US EPA 2000d). Needham (2002), also, cites a Carlson (1977) study of Lake Washington which concluded lake restoration required TP levels between 0.015 and 0.020 mg/L TP. No relationship between lotic and lentic nutrients concentrations was established or mentioned by Needham (2002) to consider the associated significance. Needham's (2002) report does not provide clear references for all studies or findings.

The OWRB presentation (2002) also includes the US EPA-recommended criteria of 0.010 mg/L TP for consideration. Note, the Oklahoma Scenic Rivers Commission (OSRC) recommended 0.020 mg/L TP in a resolution submitted to the OWRB. The basis for the 0.020 mg/L TP OSRC recommendation was undocumented.

Actual river data presented on the OWRB PowerPoint (2002) indicated the Barren Fork (0.040 mg/L TP), Illinois River (lower 0.121 mg/L TP; upper 0.271 mg/L TP) and Flint Creek (0.165 mg/L TP) 30-day rolling geometric mean for TP were all in violation of the final, approved Oklahoma Scenic River criterion, 0.037 mg/L TP.

Pickup et al. (2003) studied Oklahoma Scenic Rivers in the Illinois River basin in Oklahoma and Arkansas from 1997 to 2001. Five stations on the Illinois River, Baron Fork (should be Barren Fork) and Flint Creek were investigated for three-year periods between 1997 and 2001: 1997-1999, 1998-2000 and 1999-

2001. The mean flow-weighted TP concentration for all three Illinois River stations three-year means ranged from 0.120 to 0.339 mg/L TP from 1997 to 2001. ‘Flint Creek near Kansas’ ranged from 0.186 mg/L TP to 0.362 mg/L TP, in the same period. ‘Baron Fork at Eldon’ (Barren Fork) ranged from 0.045 to 0.190 mg/L TP, in the same period. None of the three Oklahoma Scenic Rivers studied by Pickup et al. (2003) appear to meet the Oklahoma’s Scenic Rivers criterion.

The Oklahoma Scenic Rivers criterion was reviewed by a US EPA convened Technical Advisory Group (TAG) in 2012 who reviewed the magnitude, duration and frequency of the current total phosphorus criterion. The majority of the TAG supported no change in the criterion. The “best scientific information available” was determined (OWRB, 2012).

Oklahoma Use Support Assessment Protocols (USAP)

In addition to the Oklahoma’s Scenic Rivers criterion, the State of Oklahoma provides a dichotomous decision matrix for stream and river nutrient criteria in the implementation section of the Oklahoma State water quality code Use Support Assessment Protocols (USAP) (OK Statute 785: 46-15-10) as detailed next.

> *785:46-15-10. Nutrients*
>
> *(a) General. OAC 785:45-3-2(c) prohibits water quality degradation by nutrients which will interfere with the attainment or maintenance of any existing or designated beneficial use. OAC 785:46-13-3(a)(1) requires maintenance of any existing or designated beneficial use. This Section provides a framework which shall be used in assessing threats or impairments to beneficial uses and waterbodies and watersheds caused by nutrients, and the consequences of such assessments.*

(b) Determining whether a stream is nutrient-threatened. The dichotomous process stated in this subsection shall be used in the determination of whether a stream is nutrient-threatened.

(1) The stream order shall be identified. If the stream order is 1, 2 or 3, then proceed to paragraph (2). If the stream order is not 1, 2 or 3, then proceed to paragraph (9).

(2) The stream slope shall be identified. If the stream slope is greater than or equal to 17 feet per mile, then proceed to paragraph (3). If the stream slope is less than 17 feet per mile, then proceed to paragraph (4).

(3) Subject to the application of the foregoing paragraphs of this subsection, if phosphorus concentrations in the stream are greater than 0.24 mg/L or if nitrite plus nitrate concentrations in the stream are greater than 4.95 mg/L, then proceed to paragraph (5). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(4) Subject to the application of the foregoing paragraphs of this subsection, if phosphorus concentrations in the stream are greater than 0.15 mg/L or if nitrite plus nitrate concentrations in the stream are greater than 2.4 mg/L, then proceed to paragraph (5). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(5) Subject to the application of the foregoing paragraphs of this subsection, if the percentage of canopy shading is greater than or equal to 80%, then the stream is not threatened by nutrients. If the percentage of canopy shading is less than 80%, then proceed to paragraph (6).

(6) Subject to the application of the foregoing paragraphs of this subsection, if the stream's turbidity is organic, then proceed to paragraph (7). If the stream's turbidity is inorganic, then proceed to paragraph (8).

(7) Subject to the application of the foregoing paragraphs of this subsection, if turbidity measured at seasonal base flow conditions is less than 20 NTU, then the stream is not threatened by nutrients. If turbidity measured at seasonal base flow conditions is 20 or more NTU, then the stream is threatened by nutrients.

(8) Subject to the application of the foregoing paragraphs of this subsection, if turbidity measured at seasonal base flow conditions is less than 20 NTU, then the stream is threatened by nutrients. If

turbidity measured at seasonal base flow conditions is 20 or more NTU, then the stream is not threatened by nutrients.

(9) Subject to the application of the foregoing paragraphs of this subsection, if the stream slope is greater than or equal to 17 feet per mile, then proceed to paragraph (10). If the stream slope is less than 17 feet per mile, then proceed to paragraph (11).

(10) Subject to the application of the foregoing paragraphs of this subsection, if phosphorus concentrations in the stream are greater than 1.00 mg/L, or if nitrite plus nitrate concentrations in the stream are greater than 4.65 mg/L, then proceed to paragraph (12). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(11) Subject to the application of the foregoing paragraphs of this subsection, if phosphorus concentrations in the stream are greater than 0.36 mg/L, or if nitrite plus nitrate concentrations in the stream are greater than 5.0 mg/L, then proceed to paragraph (12). If such nutrient concentrations are less than the levels specified in this paragraph, then the stream is not threatened by nutrients.

(12) Subject to the application of the foregoing paragraphs of this subsection, if the stream's inorganic turbidity measured at seasonal base flow conditions is greater than or equal to 20 NTU, then the stream is not threatened by nutrients. If the stream's inorganic turbidity measured at seasonal base flow conditions is less than 20 NTU, then the stream is threatened.

(c) Alternative to dichotomous process for streams.

(1) A wadable stream shall be deemed threatened by nutrients if the arithmetic mean of benthic chlorophyll-a data exceeds 100 mg per square meter under seasonal base flow conditions, or if two or more benthic chlorophyll-a measurements exceed 200 mg per square meter under seasonal base flow conditions. A non-wadable stream shall be deemed threatened by nutrients if planktonic chlorophyll-a values in the water column indicate it has a Trophic State Index of 62 or greater.

(2) If clear and convincing evidence indicates a result for a stream different from that obtained from application of the dichotomous process in (b) of this Section, then the appropriate state environmental agency may, after completing the public participation process developed by the Secretary of Environment pursuant to

27A O.S. 1-2-101, accordingly identify the stream as threatened or not threatened by nutrients.

(d) Demonstration that nutrients may be adversely impacting a beneficial use. If it is demonstrated by the Trophic State Index or by other relevant data as provided in 785:46-15-1(c) that nutrient loading in a waterbody may be adversely impacting a beneficial use designated for that waterbody, then the Board may determine that the waterbody and its watershed is an NLW (Nutrient Limited Watershed), and shall identify the waterbody and watershed as NLW in Appendix A of OAC 785:45.

(e) Consequence of identification as NLW. If a waterbody or its watershed is identified as NLW in Appendix A of OAC 785:45, then the Board or other appropriate state environmental agency may cause an impairment study to be performed. Provided, if an impairment study demonstrates that the uses are not threatened, then the Board shall consider deleting the NLW identification.

(f) Consequence of assessment that use is threatened by nutrients. If it is determined that one or more beneficial uses designated for a waterbody are threatened by nutrients, then that waterbody shall be presumed to be nutrient-threatened. If it is determined or presumed, in accordance with this Section, that a waterbody is nutrient-threatened, then before the waterbody is determined to be nutrient-impaired, an impairment study must be completed by the appropriate state environmental agency.

(g) Result of impairment study.

(1) Impaired. If, independent of or in addition to the process set forth in this Section, an impairment study of a waterbody demonstrates that any beneficial use designated for a waterbody is impaired by nutrients, then the appropriate state environmental agency shall initiate the appropriate listing procedure developed by the Secretary of Environment pursuant to 27A O.S. 1-2-101 for each such beneficial use.

(2) Not impaired. If, independent of or in addition to the process set forth in this Section, an impairment study of a waterbody demonstrates that all beneficial uses designated for that waterbody are not impaired by nutrients, then the appropriate state environmental agency shall initiate the appropriate de-listing procedure developed by the Secretary of Environment pursuant to 27A O.S. 1-2-101.

[Source: Added at 17 Ok Reg 1775, eff 7-1-00; Amended at 18 Ok Reg 171, eff 10-25-00 (emergency); Amended at 18 Ok Reg 3379, eff 8-13-01;

Amended at 21 Ok Reg 1910, eff 7-1-04; Amended at 22 Ok Reg 1607, eff 7-1-05; Amended at 25 Ok Reg 1455, eff 7-1-08]

The Oklahoma USAP is based on a study of the Netherlands' surface water standards by Peeters and Gardeniers (1998) whose results for TP are shown in Tables 12 and 13. The Netherlands' shallow surface water nutrient criteria for all 'shallow surface waters' including ditches were 0.150 mg/L TP annual average and 2.2 mg/L TN maximum summer average (Peeters and Gardeniers 1998). Both streams and ditches were studied for ecological quality based on macroinvertebrate and diatom community data. Only ditch sites provided Chl *a* data (Peeters and Gardeniers, 1998). Peeters and Gardeniers (1998) recommended a single phosphorus criterion of 0.15 mg/L TP for all surface waters in the Netherlands. In comparison, Oklahoma's USAP uses TP breakpoints of 0.15, 0.24, 0.36 and 1.00 mg/L which were all significantly greater than 0.037 mg/L TP (Haggard et al., 2003).

Figure 17 and Table 14 illustrates the dichotomous decision-making process for the Oklahoma USAP used to apply numerical nutrient criteria for Oklahoma streams and rivers other than the designated Scenic Rivers (Haggard et al., 2003). Haggard et al. (2003) analyzed existing TP and TN data from US EPA's STORET, OWRB and the Oklahoma Conservation Commission (OCC) from 1973 to 2001 for 563 Oklahoma and four Arkansas sites using the Oklahoma USAP classifications as shown in Figure 18. Median concentration percentiles for four geographic regions were determined using the US EPA's Level Ecoregions. Eight stream categories based on the USAP division of stream order and stream slope were identified using the stream characteristics of stream order and slope as determined in Masoner et al. (2002). No specific relationship to Peeters and Gardeniers (1998) or stream order and stream slope was established to justify Oklahoma's USAP breakpoints for TP. However, the Oklahoma USAP breakpoints correspond to findings in Table 14 for "derived from 50th percentile of III - "nearly highest level" trophic waters or IV - "highest level" for "Hill Stream Upper Reach," "Hill Stream Lower Reach," "Lowland Stream Upper Reach," and "Lowland Stream Lower Reach." Oklahoma USAP stream categories as applied to Oklahoma water quality sampling data were presented in Table 15 to determine the applicability of Peeters and Gardeniers (1998) to Oklahoma water bodies (Haggard et al., 2003).

U.S. States and Territories

Five territories and states have one or more nutrient parameters (TP, TN or Benthic Chl *a*) for all rivers and streams (US EPA, 2008b). Nine territories and states have one or more nutrient parameters for specific rivers and streams (US EPA, 2008b). Table 16 summarizes all of the approved State and Territory US EPA-approved TP and TN criteria as described on the US EPA website as of December 2009 (US EPA, 2008b). Hawaii and the Northern Mariana Islands were the only two numerical nutrient criteria for TP less than the Oklahoma's Scenic Rivers criterion.

Table 12. Frequency analysis by Peeters and Gardeniers (1998) for the upper reaches of lowland streams in the Netherlands.

Trophic Classification	Number of Samples	Mean	Minimum	Maximum	Percentile Distribution of Total Phosphate (mg/L)						
					5th	10th	25th	50th	75th	90th	95th
I - All available data	353	0.99	0.02	18.0	0.05	0.07	0.13	0.25	0.66	2.08	3.96
II - "Middle level" trophic degree	155	0.41	0.02	8.50	0.04	0.06	0.10	0.18	0.40	0.77	1.33
III - 'Nearly highest level" trophic degree	40	0.20	0.02	0.77	0.03	0.06	0.09	0.15	0.22	0.52	0.75
IV - "Highest level" trophic degree	10	0.23	0.05	0.77	-	0.05	0.09	0.17	0.27	0.74	-

Table 13. Peeters and Gardeniers (1998) proposed total phosphorus standards for Netherlands streams and ditches used to determine the Oklahoma Use Support Assessment Protocol (OK Statute 785: 46-15-10) numerical criteria decision path breakpoints (Haggard et al., 2003)

Waterbody Type	**General Environmental Quality derived from 75th percentile of "middle level" trophic waters (mg/L)**	**Specific Environmental Quality derived from 50th percentile of Level III - "nearly highest level" trophic waters or IV - "highest level" (mg/L)**
Hill Stream Upper Reach	0.38	0.24
Hill Stream Middle Reach	1.03	0.72
Hill Stream Lower Reach	1.35	1.00
Lowland Stream Upper Reach	0.40	0.15
Lowland Stream Middle Reach	0.76	0.18
Lowland Stream Lower Reach	0.76	0.36
Sandy Bottom Ditch	0.32	0.08
Clayish Bottom Ditch	0.66	0.17
Peaty Bottom Ditch	0.28	0.14
Acid Ditch	0.05	-
Brackish Ditch	0.42	-
Slightly Brackish Ditch	1.90	-

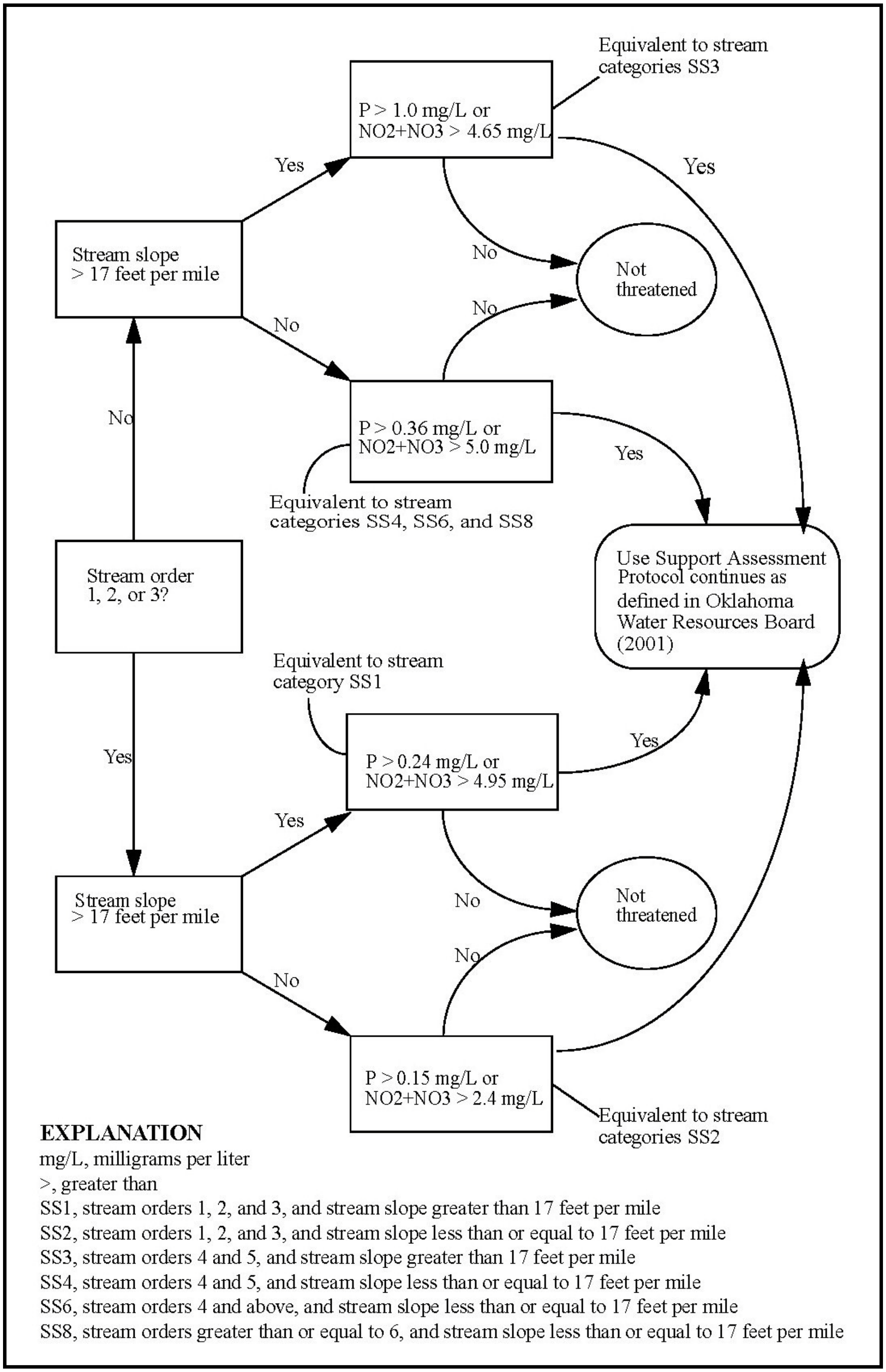


Figure 17. Oklahoma Use Support Assessment Protocol (USAP) implementation of (OK Statute 785: 46-15-10) numerical criteria decision path as provided by Haggard et al. (2003)

Table 14. Oklahoma Use Support Assessment Protocol (USAP) implementation of (OK Statute 785: 46-15-10) numerical criteria decision criteria (Haggard et al., 2003)

Stream Order	Stream Slope (m/km)	Phosphorus Criteria (mg/L)	$NO_2 + NO_3$ Criteria (mg/L)	USAP Determination
1, 2 or 3	> 3.2	> 0.24	> 4.95	If greater than either nutrient criterion, stream is threatened.
1, 2 or 3	< 3.2	> 0.15	> 2.40	If greater than either nutrient criterion, stream is threatened.
Other	> 3.2	> 1.0	> 4.65	If greater than either nutrient criterion, stream is threatened.
Other	< 3.2	> 0.36	> 5.00	If greater than either nutrient criterion, stream is threatened.

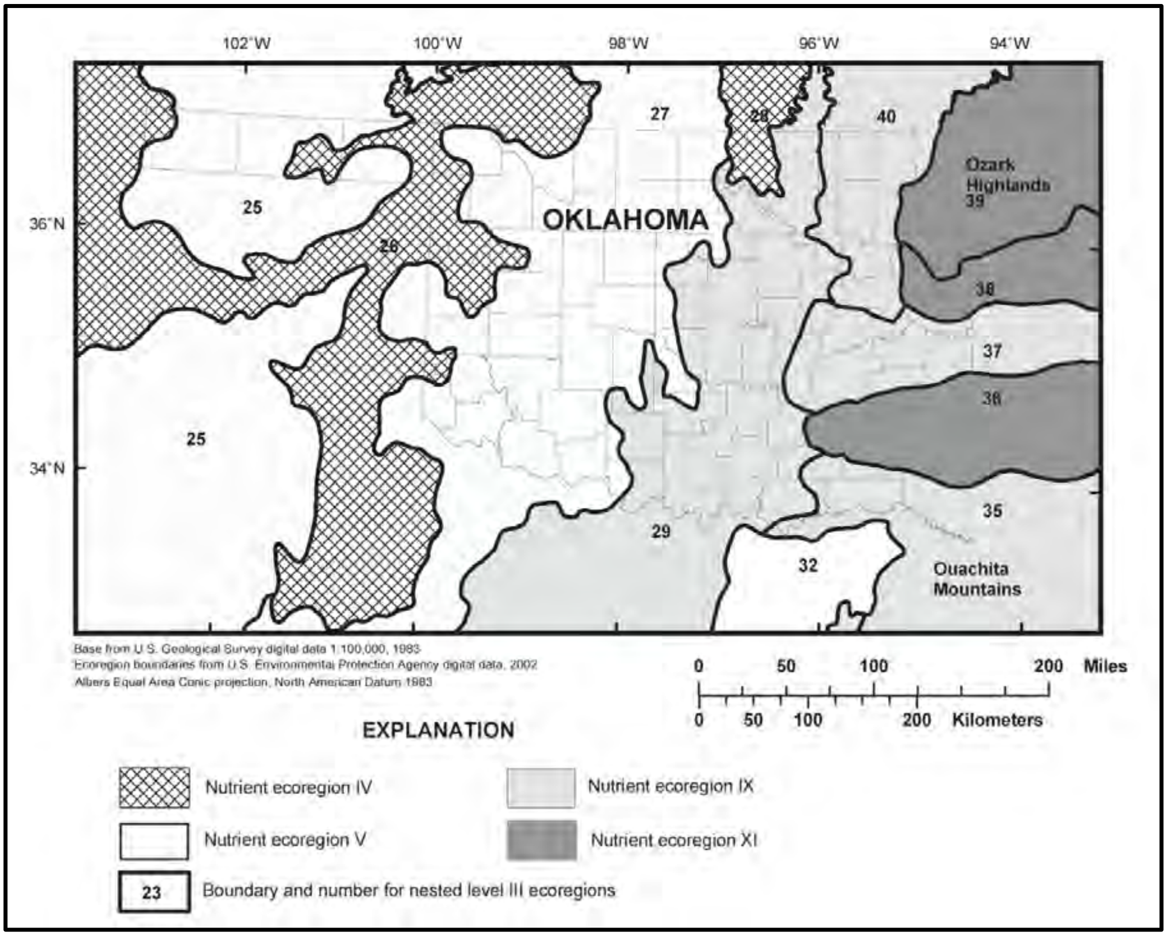


Figure 18. Haggard et al. (2003) geographic regions used to analyze percentile distributions of total phosphorus for Oklahoma streams from 1973 to 2001 in support of the Oklahoma Use Support Assessment Protocol (OK Statute 785: 46-15-10)

Table 15. Haggard et al. (2003) percentile distributions of Total Phosphorus for Oklahoma streams in the Ozark Highland Ecoregion Geographic Region 1, Ouachita Mountains Ecoregion in Oklahoma, Geographic Region 2, Oklahoma and Partial Arkansas Region Geographic 3 (Excluding Ozark Highland and Ouachita Mountains Ecoregions) and Oklahoma and Partial Arkansas Geographic Region 4 as shown in Figure 18 from 1973 to 2001 in support of the Oklahoma Use Support Assessment Protocol (USAP) implementation of (OK Statute 785: 46-15-10) numerical criteria decision path

Stream Category[1]	Number of Sites[2]	Mean	Percentiles of Median Total Phosphorus (mg/L)							Minimum	Maximum
			10	25	33	50	67	75	90		
Ozark Highland Ecoregion in Oklahoma, Geographic Region 1											
SS1	59	0.068	0.003	0.003	0.010	0.020	0.030	0.040	0.100	0.000	0.770
SS2	17	0.119	0.018	0.035	0.049	0.070	0.101	0.118	0.434	0.010	0.670
SS3	4	0.074	-	-	-	0.073	-	-	-	0.003	0.150
SS4	10	0.129	0.044	0.103	0.110	0.118	0.170	0.179	0.189	0.040	0.190
SS5	14	0.113	0.022	0.070	0.104	0.110	0.151	0.168	0.185	0.003	0.190
SS6	14	0.122	0.040	0.088	0.110	0.118	0.158	0.175	0.187	0.040	0.190
SS7	16	0.110	0.029	0.050	0.095	0.110	0.144	0.161	0.183	0.003	0.190
SS8	2	0.090	-	-	-	-	-	-	-	0.040	0.140
Ouachita Mountains Ecoregion in Oklahoma, Geographic Region 2											
SS1	46	0.023	0.008	0.010	0.013	0.020	0.023	0.030	0.040	0.003	0.110
SS2	16	0.042	0.019	0.020	0.20	0.030	0.040	0.048	0.097	0.016	0.160
SS3	4	0.047	-	-	-	0.045	-	-	-	0.020	0.080
SS4	17	0.059	0.018	0.021	0.024	0.030	0.040	0.072	0.177	0.010	0.255
SS5	21	0.057	0.020	0.021	0.025	0.030	0.058	0.072	0.156	0.010	0.255
SS6	18	0.061	0.019	0.021	0.026	0.030	0.058	0.078	0.167	0.010	0.255
SS7	22	0.058	0.020	0.021	0.025	0.030	0.065	0.078	0.155	0.010	0.255
SS8	0	-	-	-	-	-	-	-	-	-	-

Table 15…..continued.

Stream Category[1]	Number of Sites[2]	Mean	Percentiles of Median Total Phosphorus (mg/L) 10	25	33	50	67	75	90	Minimum	Maximum
Oklahoma and Partial Arkansas Region Geographic 3 (Excluding Ozark Highland and Ouachita Mountains Ecoregions)											
SS1	87	0.077	0.006	0.020	0.028	0.040	0.065	0.080	0.168	0.003	1.315
SS2	133	0.083	0.025	0.040	0.041	0.060	0.085	0.100	0.168	0.006	0.476
SS3	5	0.107	-	-	-	0.060	-	-	-	0.030	0.290
SS4	68	0.140	0.030	0.055	0.065	0.088	0.138	0.158	0.331	0.003	0.850
SS5	91	0.138	0.030	0.055	0.062	0.086	0.136	0.158	0.320	0.003	0.850
SS6	151	0.156	0.030	0.060	0.075	0.110	0.155	0.190	0.333	0.003	0.850
SS7	156	0.154	0.030	0.060	0.075	0.110	0.155	0.190	0.329	0.003	0.850
SS8	65	0.176	0.045	0.071	0.099	0.133	0.186	0.223	0.352	0.021	0.790
Oklahoma and Partial Arkansas Geographic Region 4											
SS1	192	0.061	0.003	0.010	0.018	0.026	0.040	0.050	0.121	0.000	1.315
SS2	166	0.083	0.020	0.030	0.040	0.055	0.080	0.100	0.162	0.006	0.670
SS3	13	0.079	0.010	0.027	0.036	0.060	0.090	0.110	0.234	0.003	0.290
SS4	113	0.127	0.024	0.047	0.060	0.084	0.129	0.156	0.228	0.003	0.850
SS5	126	0.122	0.023	0.040	0.055	0.080	0.118	0.151	0.227	0.003	0.850
SS6	68	0.172	0.043	0.069	0.095	0.132	0.179	0.214	0.339	0.021	0.790
SS7	181	0.144	0.030	0.055	0.066	0.106	0.150	0.178	0.292	0.003	0.850
SS8	68	0.172	0.043	0.069	0.095	0.132	0.179	0.214	0.339	0.021	0.790

[1] SS1, stream orders 1, 2, and 3, and stream slope greater than 3.2 meters per kilometer
SS2,stream orders 1, 2, and 3, and stream slope less than or equal to 3.2 meters per kilometer
SS3,stream orders 4 and 5, and stream slope greater than 3.2 meters per kilometer
SS4,stream orders 4 and 5, and stream slope less than or equal to 3.2 meters per kilometer
SS5 stream orders 4 and 5, without slope criteria
SS6,stream orders 4 and above, and stream slope less than or equal to 3.2 meters per kilometer
SS7,stream orders 4 and above, without slope criteria
SS8,stream orders greater than or equal to 6, and stream slope less than or equal to 3.2 meters per kilometer

[2] Number of water-quality sites with median concentration

Table 16. U.S. State and Territory streams and rivers numerical nutrient criteria for total phosphorus and total nitrogen (US EPA, 2008b).

U.S. State or Territory	Total Phosphorus		Total Nitrogen	
	(mg/L)	Description	(mg/L)	Description
Arizona	**0.050–1.00**		**0.50 – 10**	
Puerto Rico	0.070	**Monthly Median Low Flow[2]**		
Utah	**0.050**			
Oklahoma USAP[1]	0.150–1.00	**Decision-tree Range**	**2.4 – 5.0**	**Decision-tree Range**
American Samoa	0.150	**Maximum Average**		
Oklahoma Scenic Rivers	0.037	**30-day Geometric Mean**		
Hawaii Wet Season[2]	**0.030**	**Geometric Mean Maximum**	**0.18**	**Geometric Mean Maximum**
	0.060	**< 90%**	**0.38**	**< 90%**
	0.080	**< 98%**	**0.60**	**< 98%**
Hawaii	**0.050**	**Geometric Mean Maximum**	**0.25**	**Geometric Mean Maximum**

Dry Season[3]	0.100 0.150	< 90% < 98%	0.52 0.80	< 90% < 98%
Nevada	0.040–1.00		0.60 – 1.4	
Northern Mariana Islands	0.025 – 0.100		0.4 – 1.5	Maximum
Vermont	0.010	Low Median Monthly Flow		

[1]Use Support Assessment Protocols

[2]November 1 through April 30

[3]May 1 through October 30

CHAPTER III

METHODOLOGY

Research Questions

The research questions were:

1. Are Culturally Significant Waters a definable Designated Use by the Cherokee Nation under the U.S. Clean Water Act?

2. Which rivers and/or streams in the Cherokee Nation were CSW?

3. What numerical nutrient criterion was protective of Cherokee Nation's culturally significant waters?

4. Does US EPA numerical nutrient criteria guidance analysis adequately protect Cherokee Nation's Culturally Significant Waters?

CSWs of the Cherokee Nation were first identified and nutrient goals established via a Use Attainability tool. Existing publicly available nutrient data as well as characterization of water sites and water bodies were identified, gathered, compiled and qualified for the Cherokee Nation's CSW bodies identified.

CSWs data were analyzed to determine if the Oklahoma Scenic Rivers three-month rolling geometric mean, three-month rolling arithmetic mean and single sample percent exceedance were analyzed for comparison. Next, reference streams and reference conditions were determined and the decadal annual median quartiles per US EPA guidance calculated (US EPA, 2000a). Finally, the weight of evidence with respect to all findings was evaluated using existing standards, algal response theory and literature findings.

US EPA Numerical Nutrient Criteria Guidance

The US EPA's *Nutrient Criteria Technical Guidance Manual for Rivers and Streams* (US EPA, 2000a) suggested the following actions for criteria development:

- Determine nutrient goals for identified water body Designated Uses.
- Identify variables to evaluate and measure nutrient goals.
- Determine available data, gather and compile into a single data set.
- Identify reference water bodies, reference conditions for the study area and/or nutrient goals.
- Consider weight of evidence including benthic algae response and risk, existing State and Tribal numerical nutrient criteria and established trophic breakpoint boundaries.
- Establish nutrient criteria based on reference condition and Designated Uses goals.

Culturally Significant Waters as a Designated Use

To define CSW as a Designated Use in the Cherokee Nation, a Use Attainability Analysis (UAA) was developed and interviews were conducted with Cherokee Elders, Cherokee artisans who gather traditional materials from river and stream areas and Traditionalists who continue to practice the traditional Cherokee way of life. Reckhow et al. (2005) stated "designated uses reflects public values;" thus the survey requested examples of personal and community water use as well as the significance of water to the Cherokee Nation citizen, their local Cherokee community and/or Cherokee ceremonial traditions, and specific rivers and streams in use today by Cherokee Nation culture keepers. The *Sample Use Survey* used for the interviews was adapted from a Kansas Use Attainability Analysis survey (US EPA, 2006d) and is provided in Appendix C.

Supporting criteria were developed using ‘Best Expert Judgment’ (BEJ) based on designated uses determined from the UAA results. “A UAA is a scientific assessment of the physical, chemical, biological and economic factors which affect the attainment of a beneficial use” (US EPA 1991). US EPA (1991) notes UAA surveys may be used to determine possible uses of a water body and were required when Designated Uses were outside of the CWA fishable and swimmable goals. Reckhow et al. (2005) also supported a structured approach to defining a Designated Use and respective supporting criteria through formal scientific (expert) interviews, which were adapted to fit the Cherokee Nation’s needs.

The Designated Use of CSW was defined in terms of existing Clean Water Act Beneficial Uses, e.g. public health or welfare, public water supplies, propagation of fish and wildlife, and recreational purposes (US EPA 2001b). The surveys were supplemented with a review of historical Cherokee Nation literature to determine baseline historical uses and conditions. Cherokee historical documents were reviewed for references to water use and meaning to consider the historical baselines of both the US EPA November 28, 1975 context and the Cherokee Nation Fee Patent date of September 6, 1839. Once the interviews and historical research were complete, CSWs were defined based on the survey results to ensure the Designated Use reflected Cherokee Nation cultural values.

Zhang (2007) defined 'legally defensible' as having controls on sampling, fully documented procedures and traceability or repeatability of data and analysis. To be valid, CSW must have each aspect of 'legally defensible,' including Cherokee Nation values. To determine adequately protected, the surveys were summarized and reviewed for specific uses, which determined the water body goals, risk, and acceptable water body conditions for CSWs including numerical nutrient goal(s). If provided, the surveys captured community feedback to determine perceived reference conditions by Cherokee community members. The work of Suplee et al. (2009) on benthic algae cover tolerance for recreational users of Montana rivers and streams was used to establish acceptable conditions in the form of a numerical nutrient criteria. The aesthetic criterion developed by Suplee et al. (2009) findings for recreational users tolerance to benthic Chl *a* cover was assumed to apply to Cherokee Nation's CSW needs.

<u>Classify and Describe Streams</u>

Descriptions of the rivers and streams identified as CSWs of the Cherokee Nation were provided in the UAA survey to assess nutrient criteria specific to the CSWs rivers and streams. All of the identified Cherokee Nation CSWs from the UAA surveys along with any Oklahoma Scenic Rivers not identified were classified as Cherokee Nation CSW. Cherokee Nation CSW was evaluated as one class of water bodies. To further describe and classify the water bodies, their Cherokee names in both English and Cherokee syllabary were identified as well as applicable HUC, stream order, stream slope, county(s), US EPA Nutrient Ecoregion(s), US EPA Level III Ecoregion(s) and trophic status. State of Oklahoma classification of waters was reviewed including the Oklahoma Department of Environmental Quality 303d list as submitted to the US EPA, Oklahoma Scenic Rivers designations, High Quality Waters anti-degradation designation and OCC's High Quality water site determinations.

Nutrient Variable Selection

For freshwater rivers and streams, P tends to be the limiting nutrient before N (Calow and Petts, 1992; Chin, 2000; Thomann and Mueller, 1987; Yen, 2005; Wang et al., 1997). Although both N and P contribute to benthic algal growth, P is the nutrient variable most likely controlled by humans and impacting the stream with regards to a closed-loop nutrient spiraling. TP was chosen to represent P since it represents all available forms of P and avoids differences in filter sizes used in sampling. Specifically, STORET Code 00665 samples were chosen for consistency in data across multiple databases. TP was the causal variable evaluated to meet nutrient goals since benthic Chl *a* and periphyton lacked consistent publicly available data as a response variable.

Build Database

Publicly available data were chosen to reflect the reality for most Tribes who often lack the finances and staff resources needed to create sufficient sampling programs. TP data from the following sources were gathered and compiled for all available years and all identified Cherokee Nation CSW plus Oklahoma Scenic Rivers within the 14 counties of the Cherokee Nation: US EPA Legacy STORET, US EPA STORET, USGS, OWRB, Clark et al. (2000) and the data sets associated with the US EPA Nutrient Ecoregion IV, IX and XI Reference Guides (2000b; 2000c; 2001b). In addition, OCC High Quality Water Sites data for Oklahoma was obtained to determine a potential reference conditions or reference streams. Since OCC data are entered into US EPA STORET, these data were not combined into the overall Cherokee Nation CSW data set.

Data available for TP, benthic Chl *a* and periphyton for all rivers and streams in the 14 counties of NE Oklahoma, which included portions of the Cherokee Nation, were acquired from public data bases and other public sources. The 14 counties comprising all or part of the Cherokee Nation were Adair, Cherokee, Craig, Delaware, Mayes, McIntosh, Muskogee, Ottawa, Nowata, Rogers, Sequoyah, Tulsa, Wagoner and Washington. Data from water quality stations in the 14 counties of the Cherokee Nation for the CSWs were utilized for the analysis.

After the USGS, OWRB, US EPA L-STORET and US EPA STORET data were compiled into one data set, the samples were reviewed for duplicates. To ensure consistent data quality across the different sources, duplicate records were removed if the station or waterbody, date and value matched.

Data Analysis

Statistical analysis of these compiled data for equality of medians, comparison of the combined data set to Clark et al. (2000) data and the three applicable US EPA Nutrient Ecoregions (2000b; 2000c; 2001b) reference guidance data sets and the weight of evidence guidance per US EPA (2000a) were considered. Statistical analysis was completed using Minitab 17®. ‘Sample Season’ was calculated per US EPA guidance as Fall (September through November), Winter (December through February), Spring (March through May) and Summer (June through August). Table 17 outlines the seasons used for the decadal median reduction calculations. The US EPA states the median reduction process prevents the “over-representation of individual waterbodies with a great deal of data versus those with fewer data points” (US EPA, 2000b; US EPA, 2000c; US EPA, 2001b).

Table 17. Water seasons as defined and recommended by the US EPA (2000a).

Season	**Months**
Fall	September - November
Winter	December - February
Spring	March - May
Summer	June - August

Sample size, i.e. the number of streams/rivers and number of samples for each water body, was determined for the Cherokee Nation CSW. To further describe and analyze these data, descriptive statistics such as the interquartile range, 25^{th} percentile, median percentile and 75^{th} percentile were calculated for each sample by season and year.

Using these descriptive data, the reduced decadal annual median for the 25th, 50th and 75th percentiles were calculated per the US EPA nutrient reference criteria guidance. Specifically, all site data for a water body were combined after removing duplicates. The water body samples were reduced to percentiles by season and year. The seasonal and year percentiles for a single water body were reduced to one annual median of percentiles. The annual median percentiles were reduced to one decadal annual median percentile for each percentile distribution. When a full decade was not available, the median of the remaining years was used even though it was not a complete decadal median. The single decadal annual median by water body was reduced to a single decadal median for the aggregate Cherokee Nation CSW data set. The decadal medians of each river and stream are further reduced to a single median. US EPA (2000a) guidance on the reduction process required three seasons to calculate water year medians and four samples per season. If four samples were not available, the minimum value was used in place of the median value for that water year median. The decadal median calculated using the minimum values are referred to as the 'alternative' decadal median.

Descriptive statistical data for each waterbody and an alternative to the full decadal annual median of percentiles reduction were provided for comparison. Rather than conduct the extensive calculations required for the medians each year, the decadal median and median of decades for all data by waterbody for the 25th, 50th and 75th percentiles were calculated based on the season and years for all waterbodies without additional reduction.

Develop Criteria

Reference Conditions

Ultimately, development of numerical nutrient criteria required identifying a reference condition if possible for each water body, possible reference waterbodies, evaluating local conditions compared to the reference condition, and evaluating criteria in support of the Designated Use within the literature (US EPA, 2000d). Reference water bodies or reference conditions, are two methods to establish baseline conditions which may set the goals for the Designated Uses constituting CSWs of the Cherokee Nation. Establishing reference conditions for local conditions using US EPA guidance requires data from at least three streams (US EPA 2000d).

When using reference stream data to set the criterion, the US EPA recommends a minimum of three reference streams. To identify at least three possible reference streams, the Cherokee Nation CSW water bodies were ranked by the calculated US EPA decadal annual medians, by the Oklahoma Scenic Rivers criterion calculated three-month Rolling Geometric Means and by the Oklahoma Scenic Rivers criterion for calculated three-month Rolling Arithmetic Mean. The lowest three 25th percentiles by stream for each method streams were chosen as a set of reference streams to evaluate against the Cherokee Nation CSW data set. In addition, the OCC High Quality Waters (HQW) data set for all of Oklahoma and HQWs only in the 14 counties of the Cherokee Nation were compared to the Cherokee Nation CSW as separate reference conditions.

The Cherokee Nation water body with the lowest TP 25th percentile and the Illinois River were examined using an alternative analysis to the US EPA guidance for a single decadal median. Medians of all annual 25th, 50th and 75th percentiles were calculated by reducing the medians to percentiles by season and year. Next, the seasonal and year percentiles for a single water body were reduced to one annual median of percentiles. The single decadal median for the water body with the lowest 25th percentile, the Illinois River and the aggregate Cherokee Nation CSW data set were included for comparison.

A second alternative method to the EPA Guidance was evaluated using an alternative median for the most recent decade. To calculate the median for the recent decade, the water body samples were first reduced to percentiles by season and year. Next, the seasonal and year percentiles for a single water body were then reduced to one annual median of percentiles. Finally, the annual median percentiles were reduced to one decadal annual median percentile for each percentile distribution for the most recent ten years of data for the water body.

The US EPA recommends a corrected alternative median of annual percentiles if four samples were not available for a given water year. If the minimum samples were not met, the minimum value was used in place of the median value for that water year. To compare to the US EPA guidance, the median of all annual water body percentiles, including the alternative minimum value when applicable, was calculated as an alternative to the US EPA guidance for a single decadal median.

Predictive Relationships and Established Thresholds

The Michaelis-Menten, Dodds (2006) and Suplee et al. (2006) relationships were investigated to determine the appropriate numerical nutrient criteria for TP if 100 mg Chl a/m^2 was the acceptable benthic Chl *a* breakpoint. Literature findings for widely used thresholds were reviewed for comparison to determine if the calculated US EPA decadal annual median guidance findings protect the Cherokee Nation CSW water bodies or risk excessive eutrophication.

Oklahoma Scenic Rivers Criterion

Existing Conditions

Before the US EPA guidance, the Cherokee Nation CSW was analyzed for current conditions with respect to the Oklahoma Scenic Rivers criterion, 0.037 mg/L TP. Exceedance by sample was calculated to determine percent exceedance by water body and the overall data set. The three-month rolling geometric mean and three-month rolling arithmetic mean were calculated for each month. To calculate the three-month rolling geometric and arithmetic means, Microsoft Excel® was utilized. To illustrate the calculation, the three-month rolling geometric mean for January 2003 would be the geometric mean of all samples taken in October, November and December 2002. For the three-month arithmetic mean, the same sample period would be used but the arithmetic mean calculated. The two Virtual Basic functions created for Microsoft Excel® to calculate the rolling geometric mean and rolling arithmetic mean are included in Appendix D.

Clark et al. (2000)

The null hypothesis assumes the Clark et al. (2000) population median is equal to Oklahoma's Scenic River population median. Clark et al. (2000) 75th percentile was the basis for the Oklahoma Scenic Rivers numeric Total Phosphorus (TP) criterion, 0.037 mg/L TP. To avoid Type II errors, the confidence interval is set at 90% or $\alpha = 0.10$ to protect CSWs. The Mann-Whitney test was used in Minitab 17® to test the equality of medians of the Clark et al. (2000) population against the Cherokee Nation CSW data set. The null and alterative hypothesis was:

H_o: $\eta_1 = \eta_2$

H_a: $\eta_1 \neq \eta_2$, η = population median and $\alpha = 0.10$

The OCC High Quality Water (HQW) sites data set percentiles were compared to the Clark et al. (2000) data set to evaluate the assumption that Clark et al. (2000) represented reference conditions for Oklahoma and specifically the Oklahoma Scenic Rivers in Eastern Oklahoma. The Mann-Whitney test was used with a 90% confidence interval to test the equality of medians for OCC HQW for all of Oklahoma as well as the subset of HQW sites within the 14 counties of the Cherokee Nation.

Oklahoma Use Support Assessment Protocol

The Cherokee Nation CSW data set was evaluated using the Oklahoma Use Support Assessment Protocol (OK USAP) which required streams to be differentiated by stream orders 1, 2 and 3 or stream order 4 or greater. Then, streams were differentiated by stream slope of less than or greater than 3.2

meters per kilometer. Each water quality sample was evaluated for pass or fail on the aesthetic standards created by the Oklahoma USAP. Although the Oklahoma USAP requires data to be five years old or less, all available water years were evaluated. To better understand the OK USAP, analysis and comparison of the background research by Peeters and Gardeniers (1998) used to determine the TP breakpoints for the decision-making matrix were completed.

The OK USAP assumption of breakpoints for stream orders greater than three and stream slope greater than 3.2 meters per kilometer were tested using one-way ANOVA in Minitab 17® with a 90% confidence interval. OK USAP was based on stream order and stream slope. Data for equal means were analyzed based on different stream orders and stream slope. Specifically, the OK USAP differentiates 1st, 2nd and 3rd order streams from 4th, 5th and 6th order streams. Then, stream slope is differentiated if the slope is 3.2 meters per kilometer or less or greater than 3.2 meters per kilometer. The OK USAP Total Phosphorus breakpoints are 0.24 mg/L for stream orders 1, 2 and 3 and slope greater than 3.2 meters per kilometer, 0.15 mg/L for stream orders 1, 2 and 3 and slope greater less than or equal to 3.2 meters per kilometer, 1.0 mg/L for stream orders 4 and 5 and slope greater than 3.2 meters per kilometer, 0.36 mg/L for stream orders 4 and above and slope less than or equal to 3.2 meters per kilometer. Haggard et al. (2003), also, grouped sites into four geographic regions for their analysis to determine nutrient breakpoints used in the OK USAP.

US EPA Nutrient Ecoregion Recommendations

The US EPA Nutrient Ecoregions IV, IX and XI data sets were compared to the Cherokee Nation CSW data set. The Mann-Whitney test was used with a 90% confidence interval to test the equality of medians for each individual Nutrient Ecoregion.

Weight of Evidence

Weight of evidence per US EPA (2000a) guidance included six factors: literature findings, historical data and trends, reference conditions, models, Regional Technical Advisory Group (RTAG) recommendations and downstream effects. Literature based TP recommendations were also considered, i.e. the Michaelis-Menten algae growth rate equation and the Dodds (2006) corrected regression equations predicting minimum and maximum Chl *a* (mg/m^2) benthic algal growth. Downstream effects were not considered when determining the magnitude of the numerical nutrient criteria required to protect Cherokee Nation's CSWs, because the modeling tools and skills needed to determine downstream effects were beyond the existing capacity of most Tribal Nations.

CHAPTER IV

RESULTS AND DISCUSSION

US EPA Numerical Nutrient Criteria Guidance

Culturally Significant Waters as a Designated Use

Cherokee Nation CSW is a definable designated use under the Clean Water Act. Cherokee Nation citizens continue to use Tribal waters for cultural and ceremonial uses throughout the year. The waters must be free from excessive visible anthropogenic eutrophication based upon the community survey responses. CSW as a designated use is sufficiently defined in the Draft Oklahoma Tribal Water Quality Standards section. Although today's Cherokee Nation citizens do not recall conditions in the 1800s when the Cherokee Nation purchased their current jurisdiction, the surveys do indicate individuals remember lotic waters free from visible algae and other human impacts within their lifetimes. The surveys indicate reference conditions differ from current water conditions.

A total of 21 responses, given in Appendixes E through W, were completed by 17 adult Cherokee Nation citizens living inside the jurisdiction of the Cherokee Nation. In the Cherokee Nation, the community, tradition keepers, artisans, Elders and spiritual leaders are the experts. The surveys identified eight streams and four rivers as 'culturally significant waters'. A total of 15 separate communities associated with 12 individual rivers and streams were identified as CSWs of the Cherokee Nation in completed surveys. The surveys were not designed or intended to be all inclusive in identifying CSWs. Therefore, there may be additional CSWs that were not identified in the surveys.

CSWs were defined as traditional Cherokee gigging and crawdad gathering areas, water used for ingestion or submersion, and areas used for ceremonies. All surveys indicated Cherokee citizens expected high quality waters with little to no visible algae or turbidity to the naked eye. Some surveys indicated only moving waters are a source of drinking water during ceremonies and should be "pure from any human contamination." Other surveys indicated a wide variety of activities important to Cherokees, which included "going to water" ceremonies, fishing, crawdad gathering, gigging, cooking with stream water, gathering of macrophytes, such as watercress, for human ingestion, Christian baptisms, swimming and bathing. The traditional ceremonies of "going to water" involve primary body contact, and incidental and intentional human ingestion of water. The waterbodies identified as Cherokee Nation CSW are shown by eight-digit HUC watersheds in Figures 19, 20, 21 and 22 within the Cherokee Nation and the Cherokee Nation water sampling sites.

Repeated concerns in the surveys about degradation of streams and rivers in the Cherokee Nation included anecdotal evidence of eutrophication, such as increased water "weeds" and fish kills, which implies a need for in-stream nutrient reductions. One survey specifically asked for "clean gravel bottoms" and no "rocks…covered with slime," indicating the need to control benthic algae. If periphyton is limited to 100 mg Chl *a*/m^2, the stream would likely have less than 20% visible algae (Thomas, 1978).

The Cherokee Nation currently has running waters of national significance used by traditional Cherokees for ceremonies year round. Water uses include full body immersion and incidental or intentional ingestion, which requires protection from eutrophication or excess algal growth. The surveys established expectations, which were assumed to equate to a baseline criteria of 100 mg Chl *a*/m^2. The Oklahoma Scenic Rivers criterion was established to protect waters that should be "better than average" (OWRB, 2001). Although the Cherokee Nation has promulgated the Oklahoma Scenic Rivers criterion, Cherokee Nation CSWs require pristine conditions, so the numerical nutrient criteria protecting CSWs will likely be the same or lower.

Classify and Describe Streams

Table 18 lists the streams and rivers identified by the surveys as a CSW, their Cherokee name in both English and Cherokee syllabary, their associated USGS HUC, watershed name and county. The Illinois River, Barren Fork Creek (a.k.a. Baron Fork Creek), and Little Lee Creek were designated as Oklahoma Scenic Rivers by the State of Oklahoma in 1970. Although Flint Creek and Lee Creek were not identified in the surveys, they were included in data gathering and analysis since they were designated as Oklahoma Scenic Rivers within the jurisdiction of the Cherokee Nation.

Table 18. Use Attainability Analysis community survey results for Cherokee Nation Culturally Significant Waters.

Waterbody Name	Cherokee Name	Hydrologic Unit Code (HUC)	Watershed Name	Oklahoma County(s)
Beaty Creek	Not Available	11070209	Lower Neosho	Delaware
Spavinaw Creek	ᎨᏓᎵ ᏍᏙᏍᎩᎢ ᎤᏪᏴᎢ (ge-da-li s-do-s -gi-lu-we-yv-i)	11070209	Lower Neosho	Delaware Mayes
Saline Creek	ᏌᎳᎯᎢ ᎤᏪᏴᎢ (sa-la-hi-I u-we-yv-i)	11070209	Lower Neosho	Delaware Mayes
Snake Creek	ᎢᎾᏛᎩ ᎤᏪᏴᎢ (i-na-dv-gi u-we-yv-i)	11070209	Lower Neosho	Mayes
Spring Creek	ᎦᏅᎪᎬᎢ ᎤᏪᏴᎢ (ga-nv-go-gv-I u-we-yv-i)	11070209	Lower Neosho	Mayes
Blackbird Creek	ᏥᏆᎵᏍᏛ ᎤᏪᏴᎢ (tsi-qua-li-s-dv u-we-yv-i)	11070209	Lower Neosho	Cherokee
Fourteen Mile Creek	ᏂᎦᏚ ᎢᏳᏟᎶᏛᎢ (ni-ga-du i-yu-tli-lo-dv-i)	11070209	Lower Neosho	Cherokee
Illinois River*	ᎠᏥᏍᎬᏅᎨᏍᏛᎢ (a-tsi-s-gv-hna-ge-s-dv-i)	11110103	Illinois	Adair Cherokee Delaware Sequoyah
Barren Fork* (a.k.a Barren Fork)	ᎢᏲᏟᎢ ᎤᏪᏴᎢ (i-yo-tli-i u-we-yv-i)	11110103	Illinois	Cherokee
Sallisaw Creek	ᏌᎷᏂᎨᏴᎢ ᎤᏪᏴᎢ (sa-lu-ni-ge-yv-i u-we-yv-i)	11110104	Robert S. Kerr Reservoir	Adair Sequoyah
Little Lee Creek*	ᎤᏍᏗᎪ ᎤᏪᏴᎢ (u-s-di-go u-we-yv-i)	11110104	Robert S. Kerr Reservoir	Adair Sequoyah
Arkansas River	ᏲᏁᎬ ᎤᏪᏴᎢ (yo-ne-gv u-we-yv-i)	11110102 11110104	Robert S. Kerr Reservoir	Wagoner Cherokee Sequoyah

*Designated Scenic River by the State of Oklahoma and the Cherokee Nation.

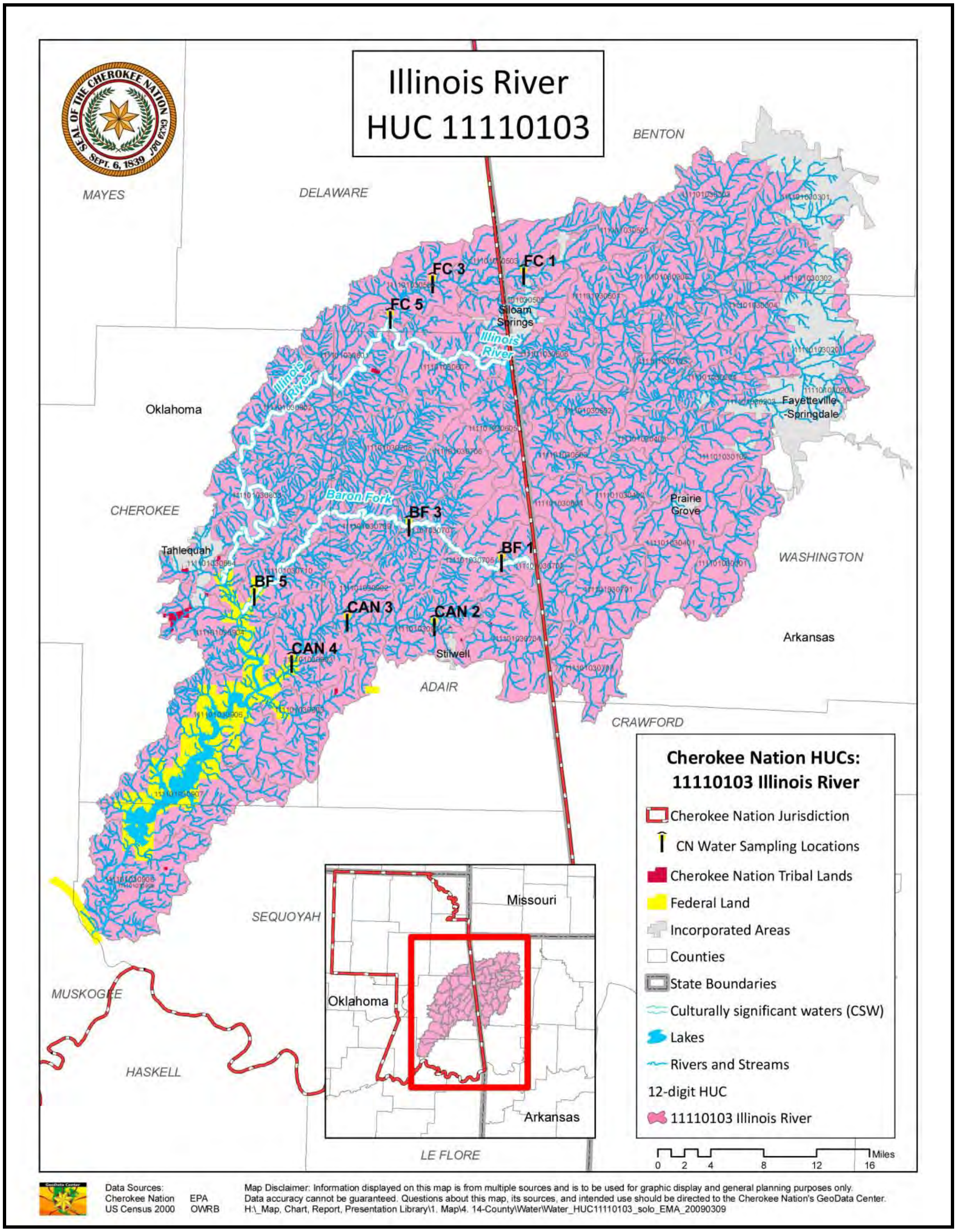


Figure 19. Hydrological Unit Code (HUC) 11110103 Illinois River watershed within the Cherokee Nation with the Illinois River and Barren Fork identified as Culturally Significant Waters with respect to Cherokee Nation Tribal Lands and Cherokee Nation water sampling locations (Cherokee Nation GDC, 2007).

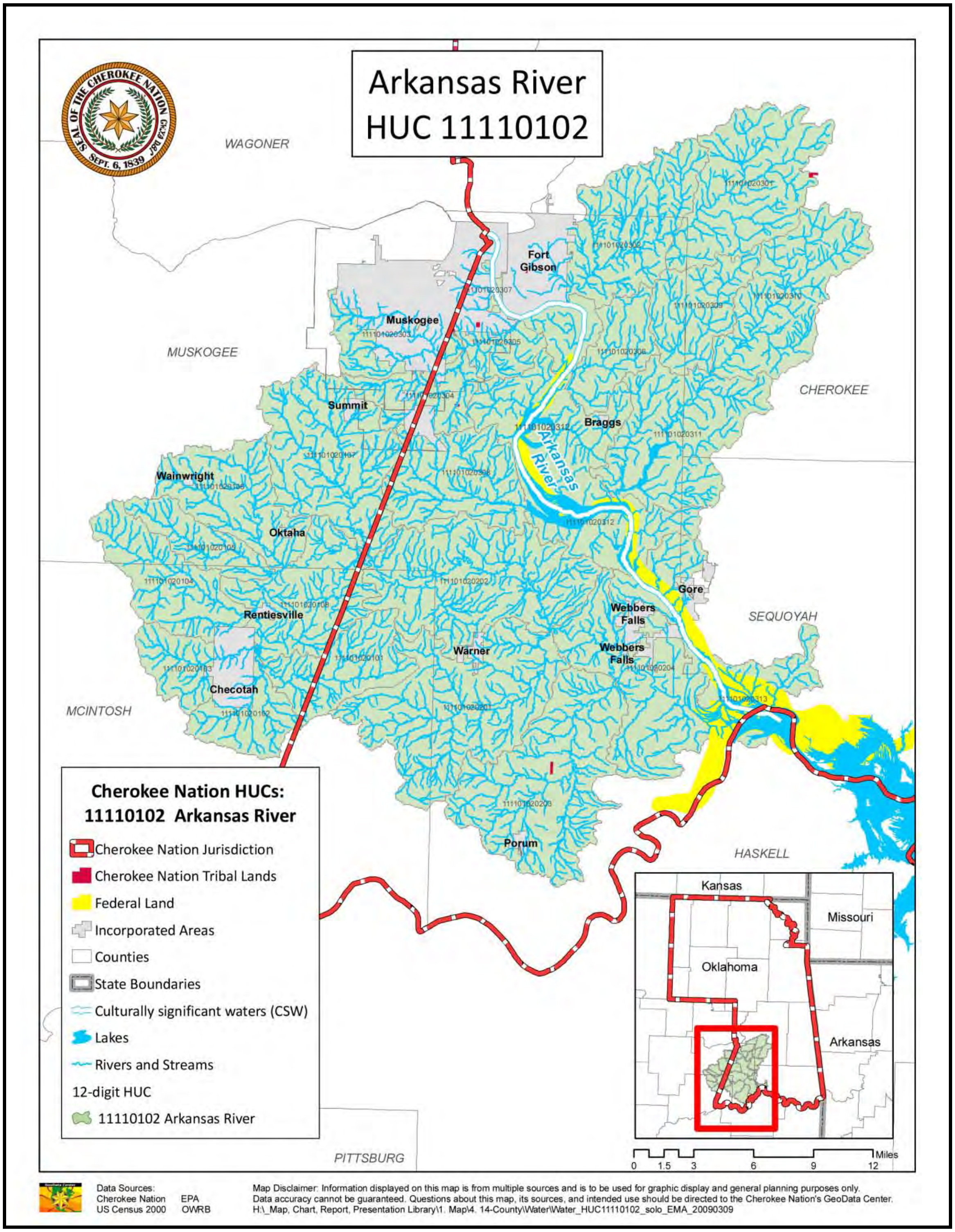


Figure 20. Hydrological Unit Code (HUC) 11110102 Arkansas River Watershed within the Cherokee Nation with the Arkansas River identified as a Culturally Significant Water with respect to Cherokee Nation Tribal Lands. No Cherokee Nation water sampling locations were located in the Arkansas River watershed (Cherokee Nation GDC, 2007).

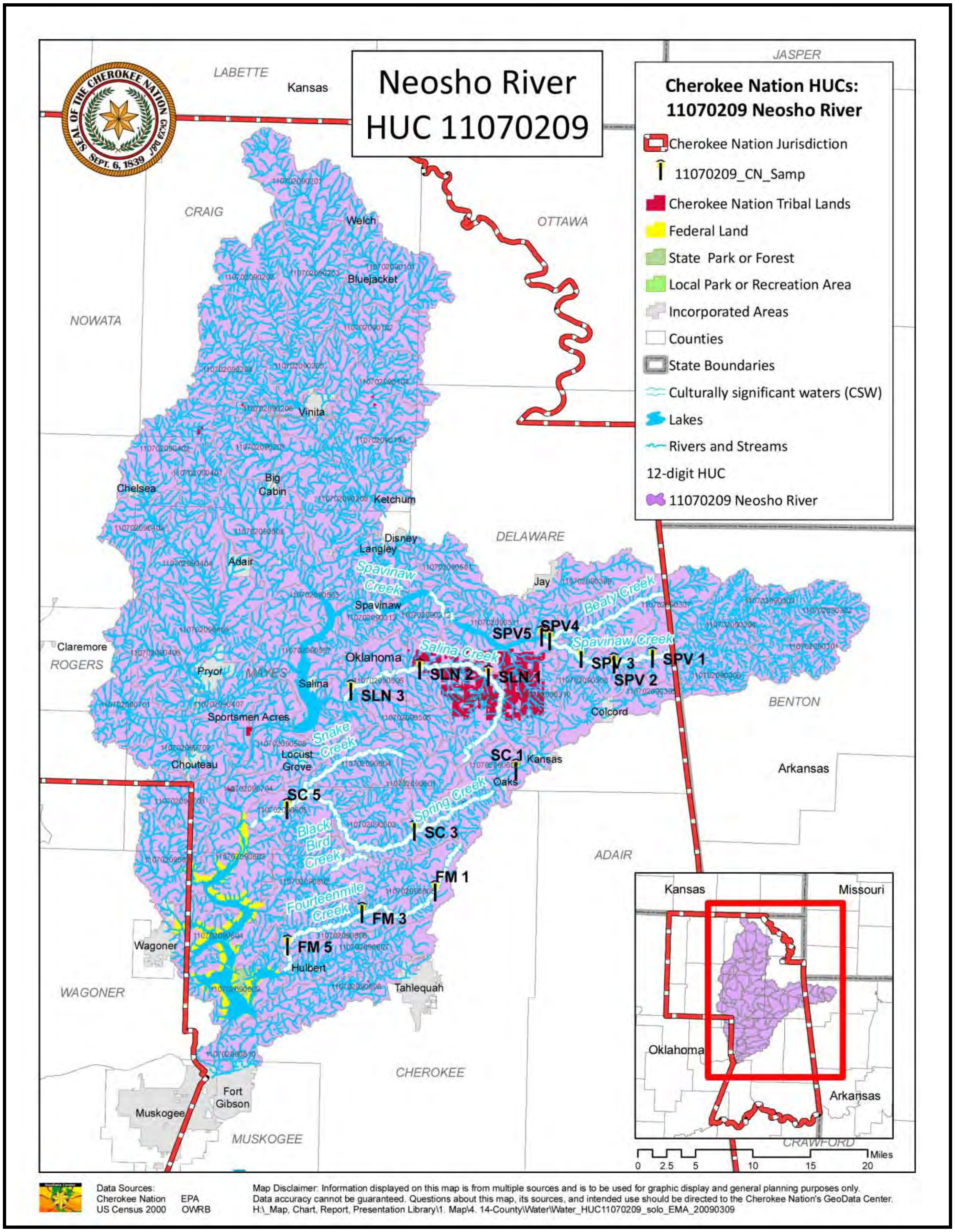


Figure 21. Hydrological Unit Code (HUC) 11070209 Neosho River Watershed within the Cherokee Nation with the Spavinaw Creek, Beaty Creek, Salina Creek, Snake Creek, Spring Creek, Black Bird Creek and Fourteen mile Creek identified as a Culturally Significant Waters with respect to Cherokee Nation Tribal Lands and Cherokee Nation water sampling locations (Cherokee Nation GDC, 2007).

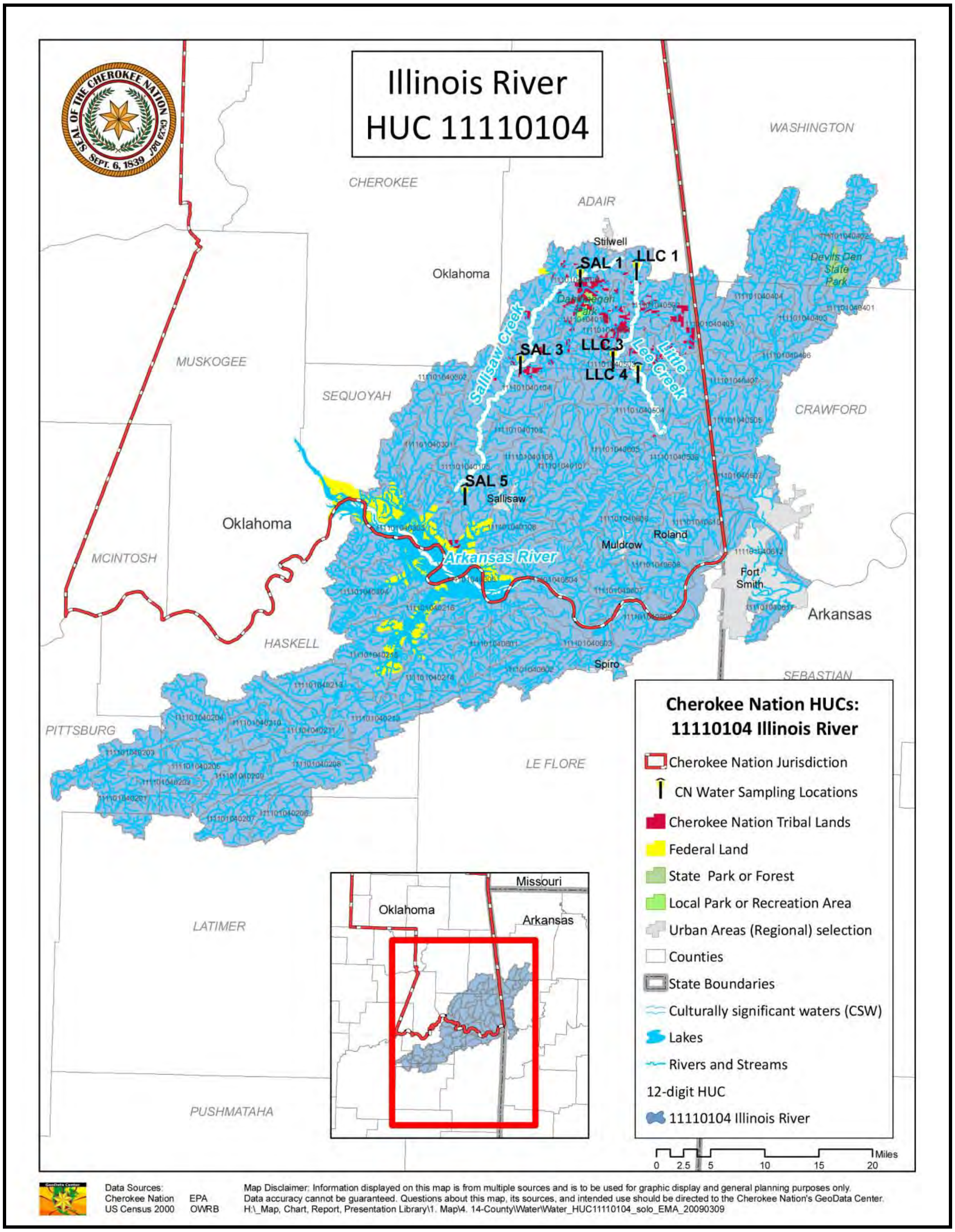


Figure 22. Hydrological Unit Code (HUC) 11110104 Illinois River Watershed within the Cherokee Nation with the Arkansas River, Sallisaw Creek and Little Lee Creek identified as Culturally Significant Waters with respect to Cherokee Nation Tribal Lands and Cherokee Nation water sampling locations (Cherokee Nation GDC, 2007).

To characterize the Cherokee Nation and the CSWs identified, Table 21 lists all of the HUCs up to eight digits within the Cherokee Nation. The stream order, stream slope, US EPA Nutrient Ecoregion and US EPA Level III Ecoregion applicable to each water quality site in the Cherokee Nation CSW data set are provided in Appendix X. Figure 23 shows the spatial distribution of the Cherokee Nation CSW water quality sites. Land use and basin characteristics from Mason et al. (2002), such as stream slope, stream order and percent farmland, are included in Appendix Y for several of the sampling sites included in the Cherokee Nation CSW data set.

The Oklahoma Department of Environmental Quality 2014 303(d) list was reviewed for impairment of CSWs with respect to nutrients. Table 19 lists portions of three Oklahoma Scenic Rivers identified as CSWs that were aesthetically impaired by TP: Flint Creek, Illinois River and Barren Fork Creek. Oklahoma determined aesthetic impairment of Scenic Rivers by TP based on the State of Oklahoma Water Quality Standards 785:46-15-14(b).

Build Database

The possible study years for samples by data set are given in Table 20. The actual sample dates ranged by water body are given in Table 21. A summary of the duplicates removed by data set and the combined data set are provided in Table 22. Samples available by season for each contributing data set are listed in Table 23. A key for duplicate sites across the contributing databases is given in Appendix Z.

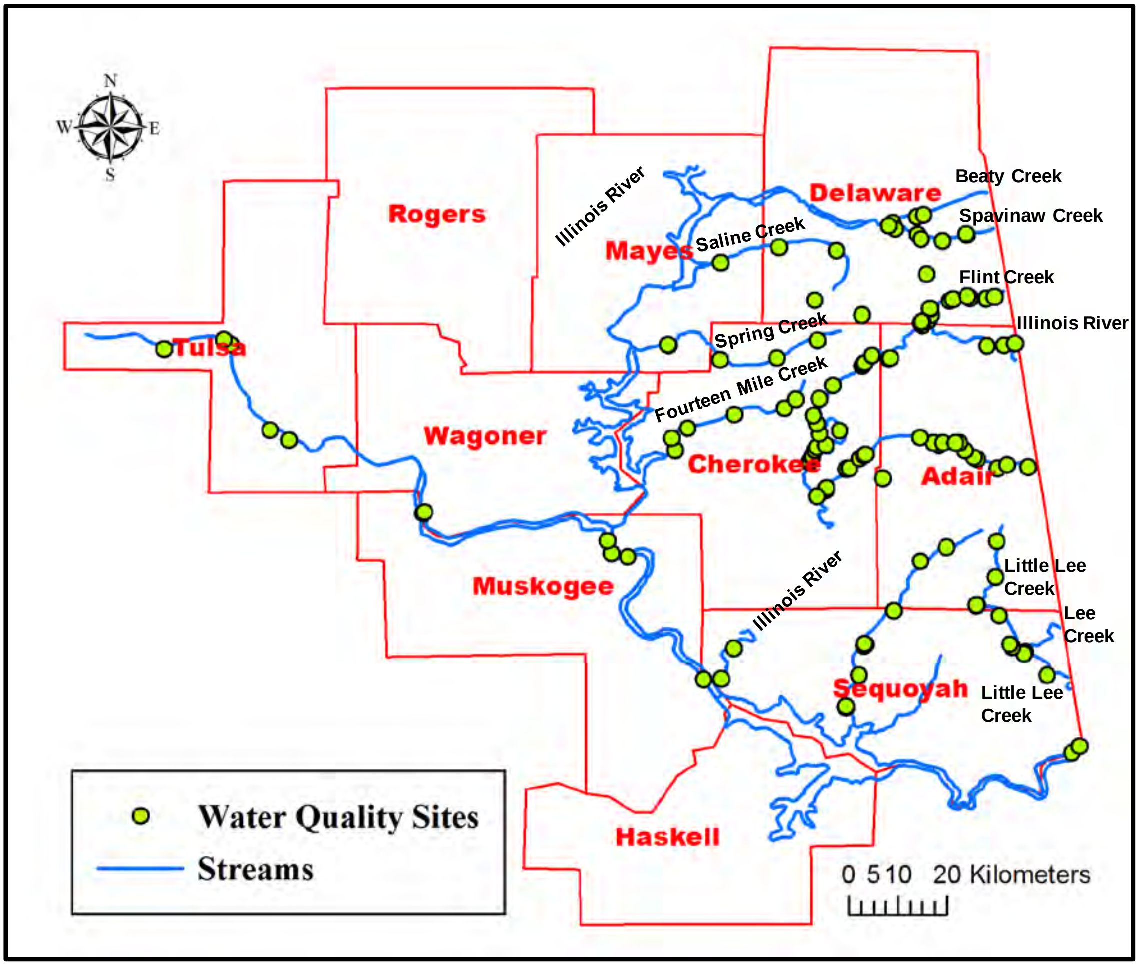


Figure 23. Spatial distribution of Cherokee Nation water quality sites and water bodies for Cherokee Nation Culturally Significant Waters data set.

Table 19. Oklahoma Department of Environmental Quality 2014 Oklahoma 303(d) list of impaired waters (ODEQ, 2014).

Waterbody				
Identification Code	Name	Size (km)	Cause of Impairment	Cause Category
OK121700030290_00	Flint Creek	2.6	Phosphorus (Total)	Aesthetics
OK121700060010_00	Flint Creek	12.5	Phosphorus (Total)	Aesthetics
OK121700030010_00	Illinois River	12.4	Phosphorus (Total)	Aesthetics
OK121700030080_00	Illinois River	51.0	Phosphorus (Total)	Aesthetics
OK121700030280_00	Illinois River	25.3	Phosphorus (Total)	Aesthetics
OK121700030350_00	Illinois River	8.3	Phosphorus (Total)	Aesthetics
OK121700050010_00	Barren Fork Creek	40.6	Phosphorus (Total)	Aesthetics

Table 20. Summary of databases and data sets used to determine a total phosphorus criterion for Cherokee Nation's Culturally Significant Waters.

Database or Data Set	Beginning Year	Ending Year	Notes
US Environmental Protection Agency (EPA) Legacy STORET	1900	1998	All conditions
US EPA STORET	1999	2015	All conditions
US Geological Survey	1900	2015	All conditions
Oklahoma Water Resources Board	1998	2015	All conditions
Clark et al. (2000)	1990	1995	Assumed reference conditions
US EPA Nutrient Ecoregion IV Recommended Criteria for Rivers and Streams (USEPA, 2001b)	1990	2000	Assumed no reference sites
US EPA Nutrient Ecoregion IX Recommended Criteria for Rivers and Streams (US EPA, 2000c)	1990	1998	Assumed no reference sites
US EPA Nutrient Ecoregion XI Recommended Criteria for Rivers and Streams (US EPA, 2000b)	1990	1998	Assumed no reference sites
Oklahoma Conservation Commission High Quality Water Sites	1990	2005	High Quality Sites: reference conditions and reaches

In addition to Table 22, Cherokee Nation reported sample data to the US EPA STORET database from 1930. Note that future sample years, such as 2020, had not yet occurred and were removed. The Cherokee Nation was not monitoring water in the 1930s, and thus the 29 sample reporting dates which were implausible were removed from the data set. Cherokee Nation was also reporting a large number of samples under the minimum detection limit of 0.010 mg/L TP; all data below 0.010 mg P/L were retained. One Cherokee Nation sample was removed since it was reported as a negative value. Thirty-one duplicate data points were found after identifying four L-STORET sites were aliases for four USGS sites. In addition, one Arkansas River site was removed with 97 data points since it was located west of Tulsa, Oklahoma (120420010130-001). A total of 158 additional data points were removed.

Table 21. Data availability by water body for Cherokee Nation's Culturally Significant Waters.

	Sample Date		Available Data (years)
Water Body	**Beginning**	**Ending**	
Arkansas River	March-1974	January-2015	39
Spring Creek	November-1998	January-2015	16
Spavinaw Creek	October-1972	December-2014	21
Sallisaw Creek	November-1976	September-2013	13
Saline Creek	January-2000	September-2013	10
Little Lee Creek	October-1991	January-2015	13
Lee Creek	November-1991	January-2015	13
Illinois River	July-1969	March-2015	45
Fourteen Mile Creek	January-2000	September-2013	10
Flint Creek	April-1973	January-2015	41
Beaty Creek	April-1993	June-2014	11
Barren Fork	November-1998	January-2015	17

Table 22. Summary of duplicate removal outcomes by database for the Cherokee Nation Culturally Significant Waters data set.

Data Set	Raw Data Appendix	Water Quality Site Descriptions Appendix	Total Duplicates Removed	Total Samples Removed for Remark Codes
US Environmental Protection Agency (EPA) Legacy STORET	AA	AB	59	0
US Geological Survey	AC	AD	68	0
Oklahoma Water Resources Board	AE	AF	2	113
US EPA STORET	AG	AH	68	0
Cherokee Nation Culturally Significant Waters	AI	-	2,627	-

Table 23. Total count, sample number and missing samples for total phosphorus (STORET Code 00665) by source and season for the Cherokee Nation's Culturally Significant Waters contributing data sets. Total Count is equal to the sum of Sample Number and Missing Samples.

Source	Total or Season	Total Count	Sample Number	Missing Samples
US Geological Services	Total	3,228	2,842	386
	Winter	727	628	99
	Spring	910	814	96
	Summer	868	768	100
	Fall	723	632	91
US Environmental Protection Agency Legacy-STORET	Total	1,524	1524	0
	Winter	368	368	0
	Spring	362	362	0
	Summer	445	445	0
	Fall	349	349	0
US Environmental Protection Agency STORET	Total	3,549	3,394	155
	Winter	817	776	41
	Spring	939	886	53
	Summer	979	945	34
	Fall	814	787	27
Oklahoma Water Resources Board	Total	1,521	1,519	2
	Winter	24	24	0
	Spring	46	46	0
	Summer	84	84	0
	Fall	21	21	0

Analyze Data

Summarizing Data

Table 24 provides an overall description of the contributing data sets and the combined total data set. The mean for each data set and the combined data set were greater than the median, thus indicating positively skewed non-normal data. All but one data set, i.e. OWRB, had a 25^{th} percentile greater than the Oklahoma Scenic Rivers criterion of 0.037 mg/L TP. The US EPA STORET's maximum of 58.1 mg/L TP was significantly greater than the maximum detection limit for the US EPA STORET's 00665 Total Phosphorus Testing Method 365.4 of 20 mg/L TP. A total of three samples were above the maximum detection limit. All four databases had minimum P concentrations lower than the US EPA STORET's 00665 Total Phosphorus Testing Method 365.4 minimum detection limit of 0.01 mg/L TP. The entire data set had 201 samples reporting values at the minimum detection limit or lower. Samples outside of the detection limit did not exceed more than 25 percent of the data set, so the median and the interquartile range should be unaffected.

Graphical Data Analysis

Figure 24 provides a graphical distribution of each contributing data set distribution and the overall combined data set distribution. The combined data set, called the Cherokee Nation Culturally Significant Waters (CSW) data set, had a significant (α=0.05) decreasing trend for TP from 1969 to 2015. Haggard (2010) documented an overall decrease in phosphorus from 1997 to 2005 for the Ozark Highlands. Many of these data exceeded the Oklahoma Scenic Rivers criterion (Figure 25). Figure 26 show the frequency distribution of the log base 10 transformed TP data. The majority of sampling over the 46 year period was for the Arkansas River, Flint Creek and Illinois River (Figure 27). During the 46 year period, sampling increased for all water bodies beginning in 1998 (Figure 28).

All but one of the general population data sets within the Cherokee Nation CSWs compiled data set was greater than the Oklahoma Scenic Rivers criterion of 0.037 mg/L TP (Table 26). The OWRB 25th percentile was 0.029 mg/L TP for data from 1998 to 2015. Dodds and Oakes (2004) and Smith et al. (2003) found the 25th percentile of general population data from impacted streams would likely not be protective of water uses. Before the 25th percentile of the general population data are accepted as a TP criterion, algal response theory and reference conditions should be considered.

Table 24. Total Phosphorus sample summary descriptive statistics by data source for the Cherokee Nation Culturally Significant Waterbody data set.

Data Source	Sample Number	Total Phosphorus (mg/L)						
		Percentile			Mean	Minimum	Maximum	IQR[1]
		25th	50th	75th				
US Geological Survey	1,003	0.069	0.104	0.170	0.153	0.005	1.98	0.101
US Environmental Protection Agency Legacy-STORET	529	0.127	0.181	0.260	0.227	0.005	3.75	0.134
	1,263	0.029	0.105	0.171	0.124	0.005	2.53	0.142
US Environmental Protection Agency STORET	2,917	0.038	0.068	0.149	0.171	0.001	58.1	0.111
Total	5,712	0.044	0.090	0.175	0.163	0.001	58.1	0.131

[1] Interquartile range.

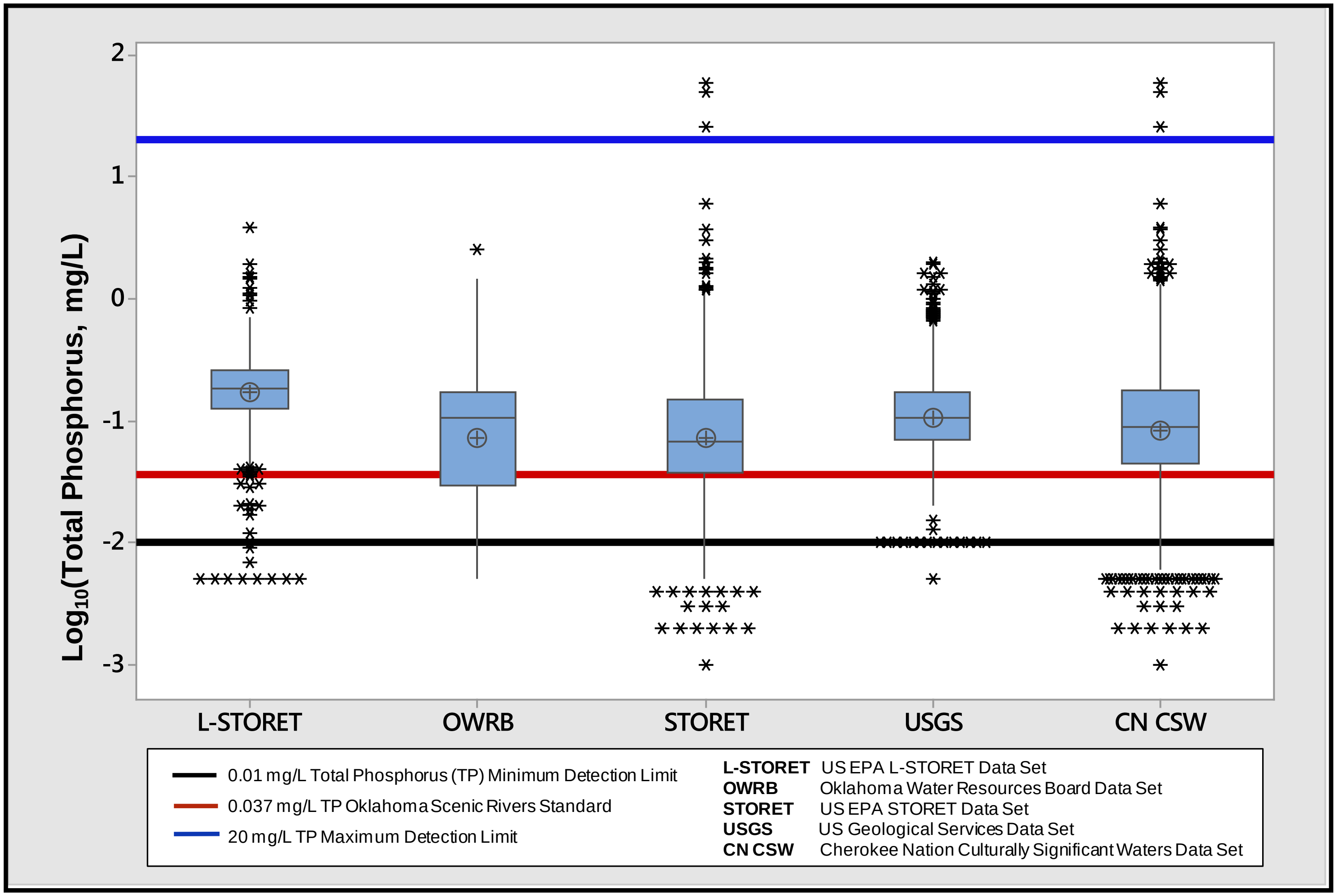


Figure 24. Distributions of total phosphorus samples for the individual data sets used to create the complete Cherokee Nation Culturally Significant Waterbodies data set and the combined Cherokee Nation Culturally Significant Waterbodies data set.

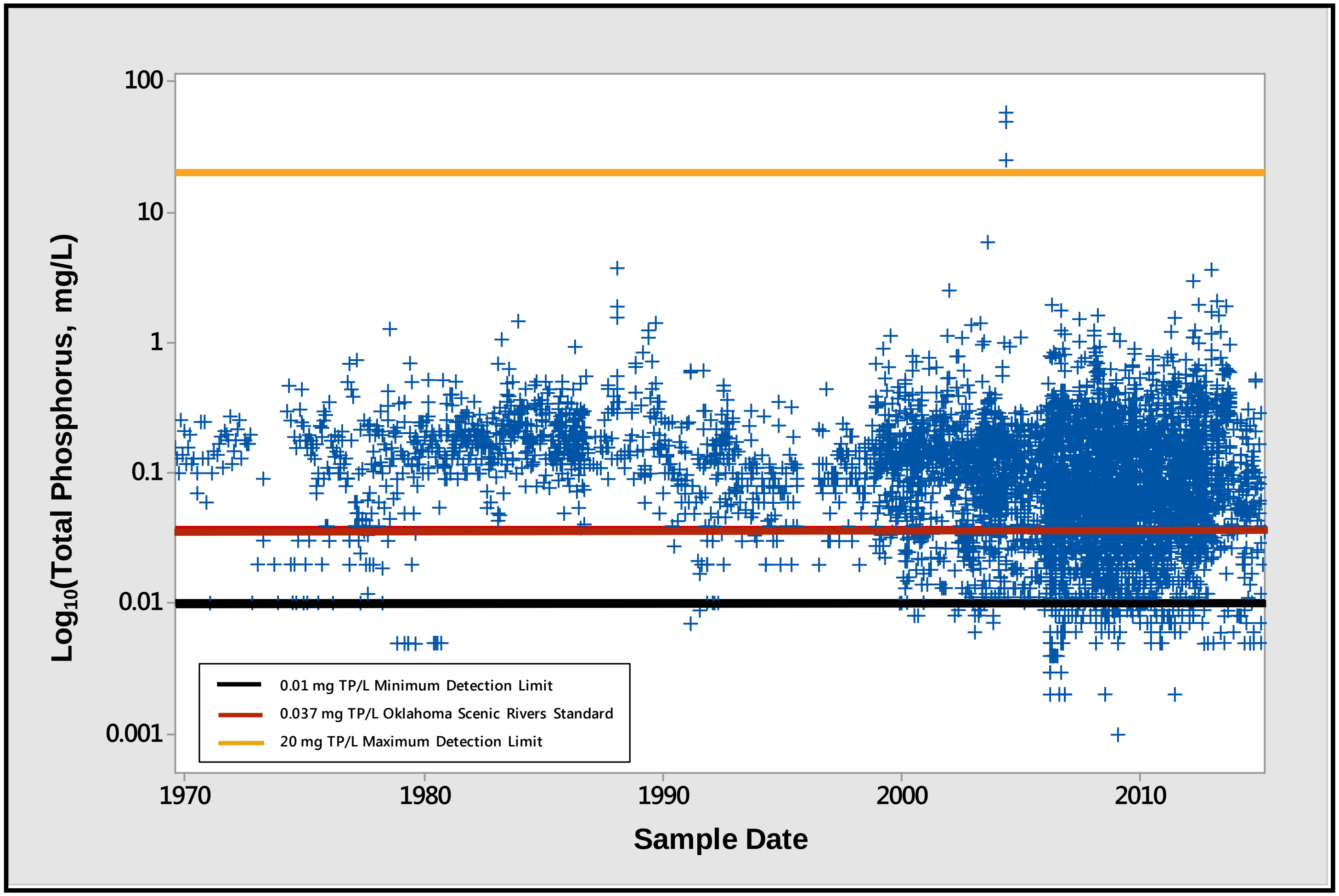


Figure 25. Total Phosphorus samples from 1969 to 2015 for Cherokee Nation's Culturally Significant Waters data set compared to the Oklahoma Scenic River criterion of 0.037 mg/L and the sample maximum detection limit.

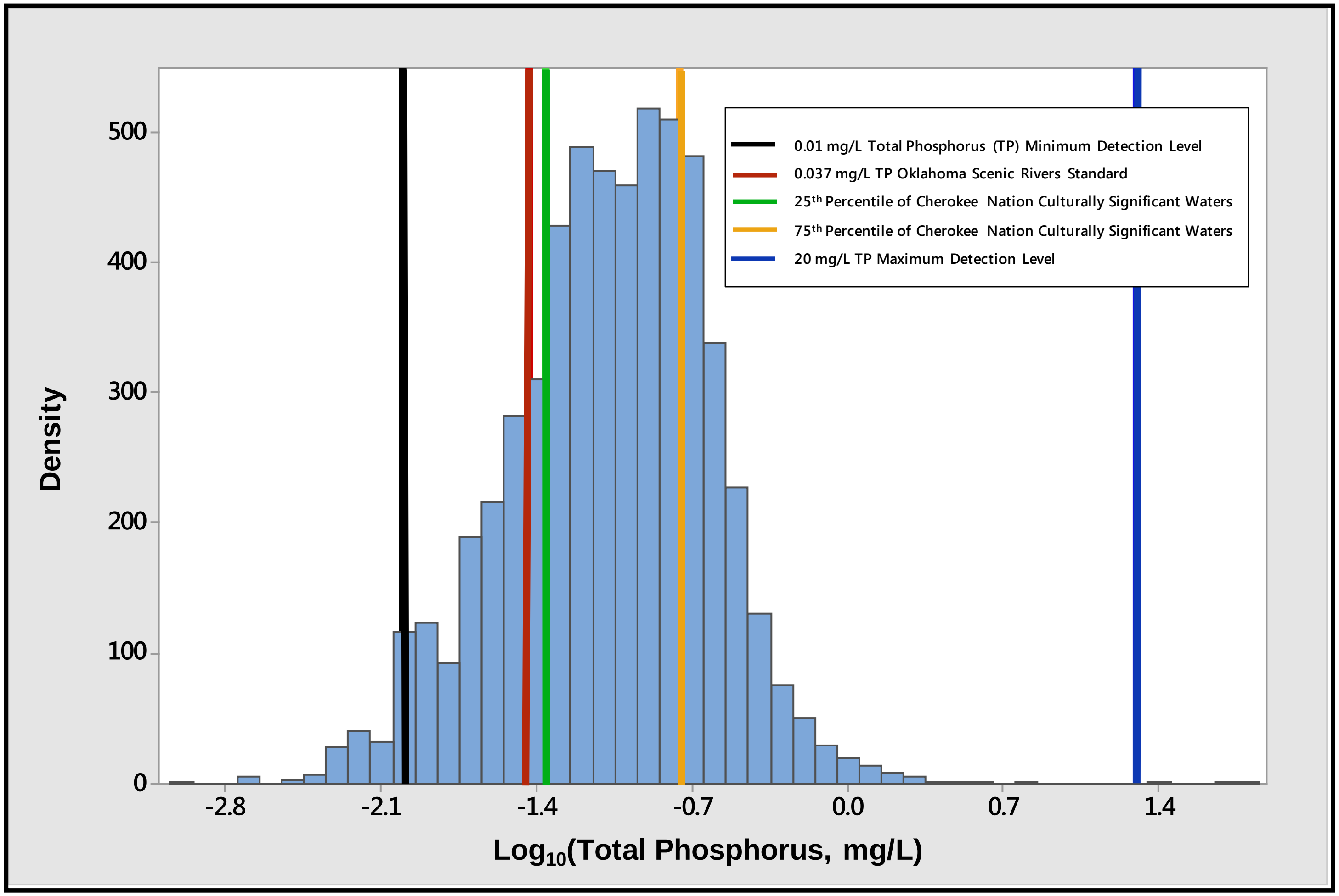


Figure 26. Frequency distribution of total phosphorus samples for the data sets used to create the complete Cherokee Nation Culturally Significant Waterbodies data set from 1969 to 2015 transformed using natural log with respect to the Oklahoma Scenic Rivers criterion, 0.037 mg/L TP.

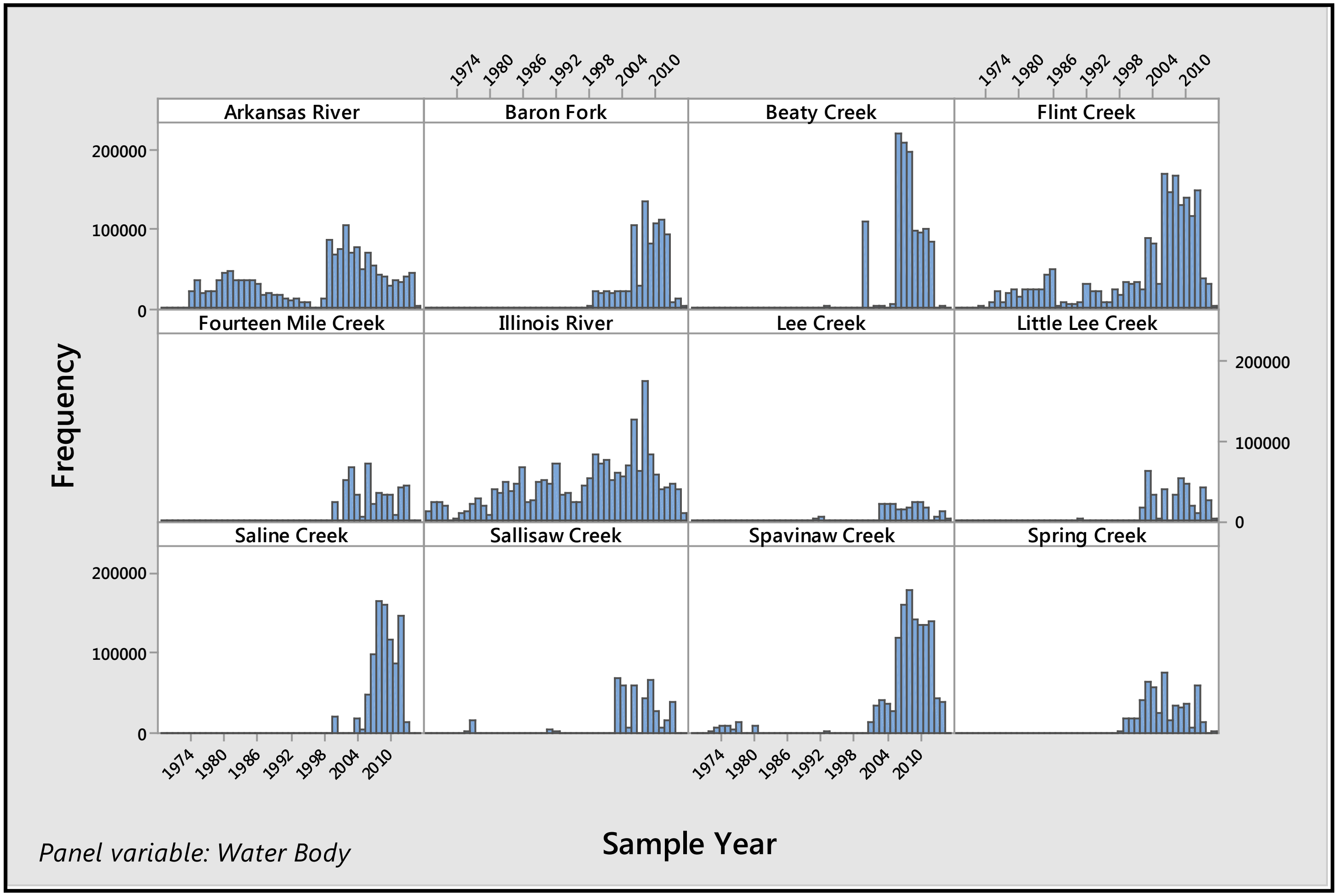


Figure 27. Frequency distributions for total phosphorus samples by year for each of the identified Cherokee Nation Culturally Significant Waterbodies.

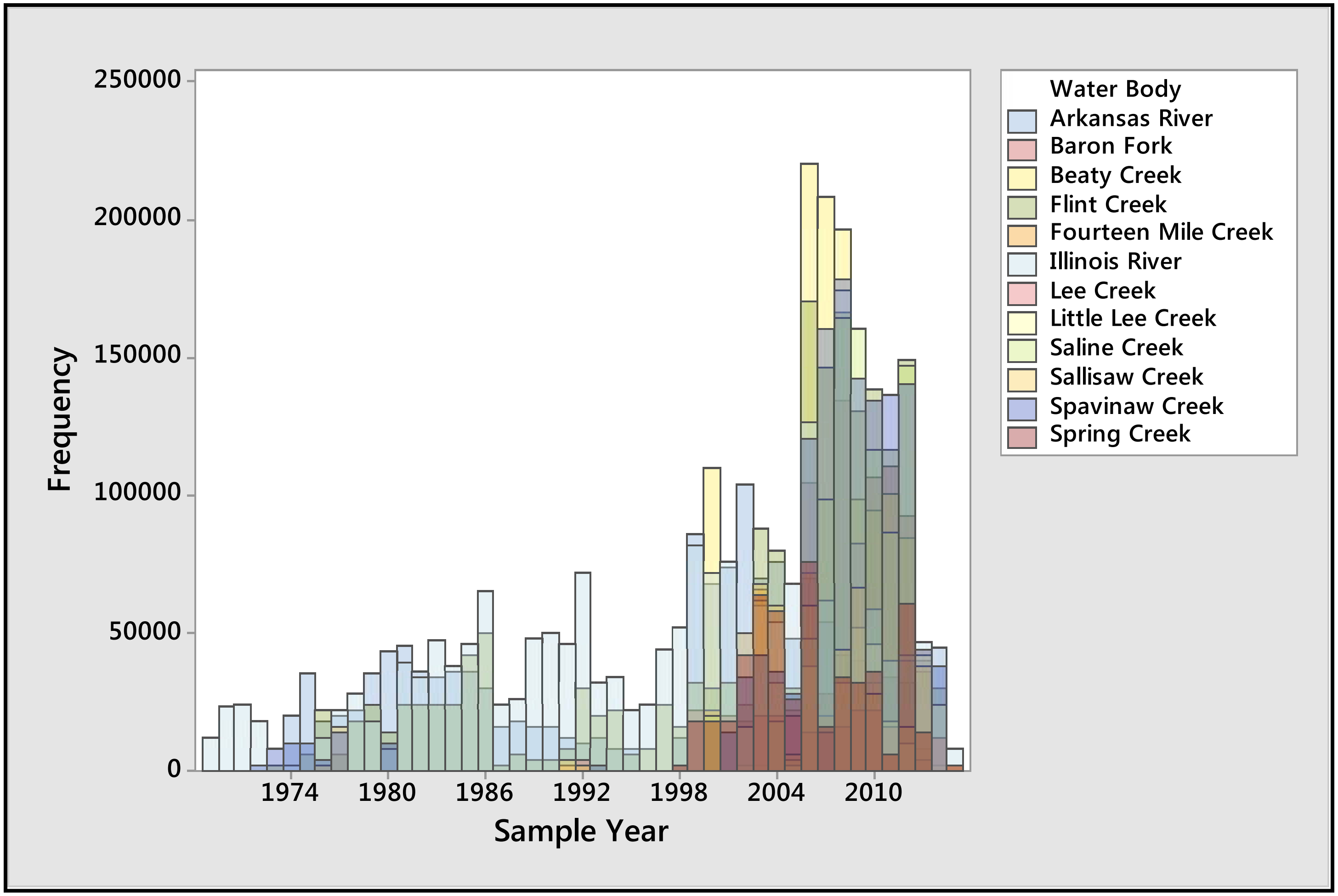


Figure 28. Frequency distribution of total phosphorus samples from 1969 to 2015 for each of the identified Cherokee Nation Culturally Significant Waterbodies.

Table 25. Summary of US EPA total phosphorus criteria guidance decadal annual medians of percentiles for Cherokee Nation's Culturally Significant Waters and by water body using 1969 to 2015 data.

	Sampling Period					Total Phosphorus (mg/L)				
Water Body	Start	End	Range (years)	Available (years)	Sample Number	Single Decadal Median of 25th Percentile	Single Decadal Mean of 25th Percentile	Single Decadal Median of Medians	Alternative Single Decadal Median of Medians	Single Decadal Median of 75th Percentile
Lee Creek	1991	2015	24	13	94	0.008	0.008	0.016	0.012	0.014
Spring Creek	1998	2015	17	16	261	0.013	0.013	0.030	0.013	0.068
Saline Creek	2000	2013	13	10	437	0.019	0.022	0.043	0.023	0.068
Little Lee Creek	1991	2015	24	13	189	0.022	0.024	0.020	0.020	0.101
Barren Fork	1998	2015	17	17	410	0.028	0.028	0.040	0.028	0.081
Sallisaw Creek	1976	2013	37	13	208	0.029	0.029	0.044	0.028	0.085
Fourteen Mile Creek	2000	2013	13	10	227	0.041	0.042	0.059	0.038	0.185
Spavinaw Creek	1972	2014	42	21	653	0.047	0.048	0.059	0.049	0.123
Beaty Creek	1993	2014	21	11	561	0.051	0.059	0.075	0.061	0.114
Illinois River	1969	2015	46	45	1,031	0.084	0.083	0.103	0.083	0.175
Flint Creek	1973	2015	42	41	914	0.117	0.119	0.139	0.113	0.241
Arkansas River	1974	2015	41	39	727	0.126	0.123	0.168	0.126	0.211
All Water Bodies	1969	2015	46	46	5,712	0.035	0.050	0.052	0.033	0.107

Table 26. Alternative reduction method to US Environmental Protection Agency Guidance for total phosphorus 25th, 50th and 75th percentile data by season, year and waterbody for the Cherokee Nation's Culturally Significant Waters data from 1969 to 2015.

			Total Phosphorus (mg/L)						
All Data			Percentile						
Percentile	Available Seasons	Missing Seasons	25th	50th	75th	Mean	Minimum	Maximum	IQR[1]
25th	1414	749	0.030	0.065	0.125	0.082	0.003	0.740	0.095
50th	1423	518	0.037	0.085	0.162	0.115	0.005	2.71	0.125
75th	1414	749	0.075	0.159	0.250	0.253	0.010	37.3	0.175

[1]Interquartile range.

Table 27. Descriptive statistics for total phosphorus data for Cherokee Nation's Culturally Significant Waters and by water body from 1969 to 2015.

		Total Phosphorus (mg/L)						
		Percentile						
Water Body	**Sample Number**	**25th**	**50th**	**75th**	**Mean**	**Minimum**	**Maximum**	**IQR[1]**
Lee Creek	94	0.010	0.013	0.018	0.017	0.005	0.149	0.008
Little Lee Creek	189	0.010	0.037	0.070	0.097	0.001	3.68	0.060
Spring Creek	261	0.013	0.030	0.060	0.058	0.004	0.960	0.047
Saline Creek	437	0.017	0.027	0.051	0.054	0.002	1.10	0.034
Barren Fork	410	0.028	0.043	0.086	0.080	0.005	1.58	0.059
Sallisaw Creek	208	0.030	0.058	0.091	0.127	0.002	5.90	0.061
Fourteen Mile Creek	227	0.034	0.057	0.091	0.695	0.013	58.1	0.057
Beaty Creek	561	0.049	0.070	0.113	0.103	0.022	1.78	0.064
Spavinaw Creek	653	0.052	0.072	0.104	0.122	0.005	1.90	0.053
Illinois River	1,031	0.066	0.111	0.200	0.167	0.002	3.75	0.134
Arkansas River	727	0.129	0.163	0.214	0.191	0.005	2.53	0.085
Flint Creek	914	0.130	0.180	0.261	0.225	0.008	3.00	0.131
Total	5,712	0.044	0.090	0.175	0.163	0.001	58.1	0.131

[1]Interquartile range.

US Environmental Protection Agency Numerical Nutrient Guidance

Data were evaluated based on reference nutrient conditions and nutrient goals using both the US EPA recommended guidance and, if reference watershed data were available, an alternative statistical analysis using the 75^{th} percentile of reference water bodies and 25^{th} percentile for all waterbodies. US EPA guidance required these data be reduced to a median value for each stream by season and year (Figure 9).

Table 25 provides a summary of the decadal annual medians of percentiles, the corrected median of medians for sample years lacking adequate data, and a decadal annual mean of the 25^{th} percentile for all data. Table 25 outlines the sample years by range, available years for each water body and the number of samples for the subset of data. The detailed reduction calculations are provided in Appendix AJ.

Table 26 provides the 25^{th}, 50^{th} and 75^{th} percentile of the 25^{th}, 50^{th} and 75^{th} percentiles for the season and year by water body. The 25^{th} percentile of the 25^{th}, 50^{th} and 75^{th} percentiles of season and year are less than the single decadal medians of the 25^{th}, 50^{th} and 75^{th} percentiles for Cherokee Nation CSWs as shown in Table 25. Table 27 provides a summary of the descriptive statistics for each water body without US EPA decadal annual median reduction as compared to the entire Cherokee Nation CSW data set. When compared to the single decadal annual medians of the 25^{th} percentile, 50^{th} percentile and 75^{th} percentile in Table 25 to their respective percentiles in Table 26, there are no consistent comparisons. Percentiles are greater than, lower than or equal to their counterparts. The Cherokee Nation CSW data set 25th, 50th and 75th percentiles are greater than the single decadal medians of the 25th, 50th and 75th percentiles shown in Table 25. If the Cherokee Nation CSWs data set had more available data, the single decadal annual medians of the three percentiles might show consistent comparison patterns by waterbody. Figure 23 and 24 illustrates the frequency of available samples by water body and year to visualize the detailed calculations used to reduce all seasons and years by water bodies to single decadal annual median of the 25th percentile of all data, which was 0.035 mg/L TP.

If the US EPA guidance was accepted, the TP criterion for Cherokee Nation Culturally Significant Waters should be 0.035 mg/L TP, which was less than the Oklahoma Scenic Rivers criterion of 0.037 mg/L TP. Lee Creek, Spring Creek and Saline Creek had the lowest decadal annual medians of the 25th percentiles, which were 0.008, 0.013 and 0.019 mg/L TP, respectively. Lee Creek, Spring Creek and Saline Creek were investigated as possible reference conditions. Note, the Lee Creek reduced decadal annual median of the 75th percentile is less than the reduced decadal annual median of the 50th percentile. The 75th percentile being less than the 50th percentile points to problems with the recommended US EPA numerical nutrient reduction process.

Develop Criteria

Determine Reference Conditions

When the water bodies were ranked by three-month rolling geometric mean using percent exceedance, Lee Creek, Spring Creek and Saline Creek appear to be least impacted by Total Phosphorus. When the water bodies were ranked by three-month rolling arithmetic mean using percent exceedance, Lee Creek, Spring Creek and Little Lee Creek appear to be least impacted by Total Phosphorus. The two different sets of three streams were considered as possible reference streams for Cherokee Nation CSWs to establish reference conditions.

Table 27 and 28 give the 75th percentile calculated decadal median for both sets of possible reference streams. To consider the US EPA nutrient criteria guidance assumptions, the distributions of the general population of the Cherokee Nation CSW data set were overlaid with the distribution of the reference populations in Figure 29 and 30.

The reference condition data sets for Lee Creek, Saline Creek and Spring Creek (Figure 29) and Lee Creek, Spring Creek and Little Lee Creek (Figure 30) were compared to the Oklahoma Scenic River criterion and the Cherokee Nation CSW data as general population data set. The Oklahoma Scenic Rivers criterion of 0.037 mg/L TP was below and within the interquartile range of the general populations and the reference population for the reduced decadal annual medians, respectfully. The median of the decadal annual 75th percentile for both reference sets was 0.068 mg/L TP, which is higher than the Oklahoma Scenic Rivers criterion. The reduced decadal annual median for Lee Creek, Spring Creek and Saline Creek was 0.030 mg/L TP compared to 0.020 mg/L TP for Lee Creek, Saline Creek and Little Lee Creek. The median of the decadal annual 25th percentile for both reference data sets was 0.013 mg/L TP.

The Oklahoma Scenic Rivers criterion was acceptable based on the two possible reference stream populations. .However, the 0.068 mg/L TP median of the decadal annual 75th percentile for both reference sets is higher than all TP criterion suggested to protect lotic waters from 100 mg/m^2 benthic chlorophyll *a* (Thomas, 1978; Welch et al., 1988; Biggs, 1996; Bothwell, 1989; Dodds et al., 1997; Dodds and Oak, 2004; Smith et al., 2003). The available data does not likely reflect natural reference conditions since the Illinois River and Eucha-Spavinaw Watersheds have contained large numbers of poultry production operations since the 1940s (Mittelstet, 2015).

The US EPA guidance requires three reference streams. However, if only Lee Creek was used for the reference condition, the median of the decadal annual 75th percentile was 0.014 mg/L TP, which is close to the US EPA recommended reduced median of the decadal annual 25th percentile for the US EPA Aggregate Nutrient Ecoregion XI, i.e. 0.010 mg/L TP. With respect to the Michaelis-Menten periphyton relative growth rate and Dodds (2006), the median of the decadal annual 75th percentile for Lee Creek minimizes the risk of eutrophication from benthic algae. Therefore, 0.014 mg/L TP should be considered as a possible total phosphorus criterion.

Total P data from OCC "High Quality Sites" for all of Oklahoma and a subset of the 14 counties of the Cherokee Nation were gathered to compare distributions to the Cherokee Nation CSW data set. The OCC determined High Quality Water (HQW) sites based on water quality and biological monitoring data. Biological data included habitat assessment, fish collection and macroinvertebrate collections. After evaluating almost 400 sites, OCC designated 58 sites of 'High Quality' with 12 sites in the 14 counties of the Cherokee Nation. The complete list of OCC 'High Quality Sites" is given in Appendix AK and a descriptive statistical total phosphorus data summary is given in Table 29. Figures 29 and 30 give the overlying distributions for both OCC HQW sites data sets and the Cherokee Nation CSW data set. The reduced decadal annual median interquartile for Cherokee Nation's CSW data set does overlap OCC data sets. Neither OCC data set 75th percentile approximates the 25th percentile of the Cherokee Nation CSW data set; thus the US EPA assumptions for reference stream conditions approximating the 25th percentile of general population data were not met. Therefore, the OCC HQW sites should not be used as reference conditions for the Cherokee Nation.

The four reference conditions considered do not meet US EPA guidance assumptions of matching percentiles with general population data or weight of evidence considerations. When compared to the US EPA recommended numerical nutrient criteria for Nutrient Ecoregion XI and the Ozark Highlands ecoregion, all four reference conditions investigated for the 25th and 75th percentiles are greater than the US EPA recommended numerical nutrient criteria. The 75th percentiles risk excessive algal growth and fall within the eutrophication range for both the literature findings and algal response theory. Therefore, the 75th percentiles for the four reference condition investigated should not be used as a TP criterion to protect Cherokee Nation's CSWs. Lee

Creek, however, may be considered as reference stream conditions although it is only a single water body.

Predictive Relationships and Established Thresholds

The Michaelis-Menten equation for TP is shown in Figure 33 using constants, K_{mn}, of 1.0, 5.0 and 12 µg/L. The Michaelis-Menten equation demonstrates the Oklahoma Scenic Rivers criterion of 0.037 mg/L was at or near critical saturation levels for all three algal growth rates displayed. Algal growth saturation in the literature ranged from 0.005 to 0.070 mg/L TP as shown in Appendix B. Therefore, the existing Oklahoma Scenic Rivers criterion is not overprotective and may be too high to protect the Cherokee Nation CSWs from excessive algal growth.

The corrected Dodds (2006) equations in Figure 34 predict the mean and maximum Chl *a* response to TP. Suplee et al. (2009) used surveys of recreational river users in Montana to identify an unacceptable benthic Chl *a* coverage of between 100 and 150 mg/m^2. Dodds (2006) indicated TP as low as 0.008 to 0.012 mg/L may produce 100 and 150 mg/m^2 benthic Chl *a*. Based on the CSW surveys, CSW users expected benthic algae cover to be less than 20 percent, which equated to approximately 100 mg Chl *a*/m^2. For predicted mean benthic Chl *a*, Dodds (2006) required TP remain below 0.026 mg/L to protect Cherokee Nation CSW from algal cover greater than 100 mg/m^2.

Excessive algal growth, defined as 100 mg/m^2 benthic chlorophyll *a,* and expected benthic algal cover less than 20 percent is supported throughout the literature (Thomas, 1978; Welch et al., 1988; Biggs, 1996; Bothwell, 1989; Dodds et al., 1997; Dodds, 2006; Dodds and Oak, 2004; Smith et al., 2003). Therefore, based on these predictive relationships and established algal thresholds, Cherokee Nation CSWs are at risk for excessive algal growth with the existing Oklahoma Scenic Rivers criterion of 0.037 mg/L.

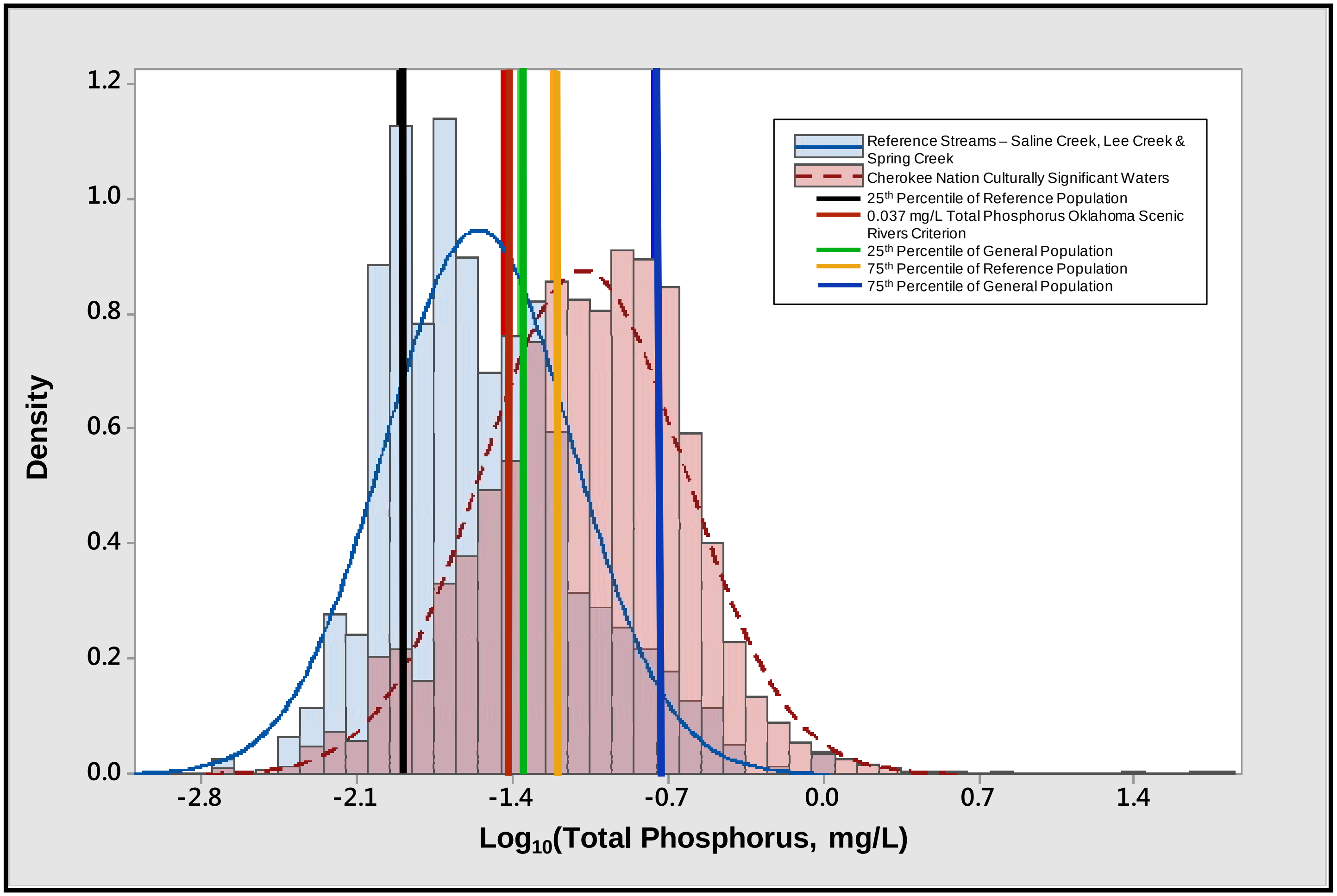


Figure 29. Distributions of total phosphorus data for the combined Cherokee Nation Culturally Significant Waters data set and the three reference streams, Lee Creek, Saline Creek and Spring Creek, with respect to the Oklahoma Scenic Rivers criterion and the 25th and 75th percentiles of both data sets with a fitted normal distribution line for each population.

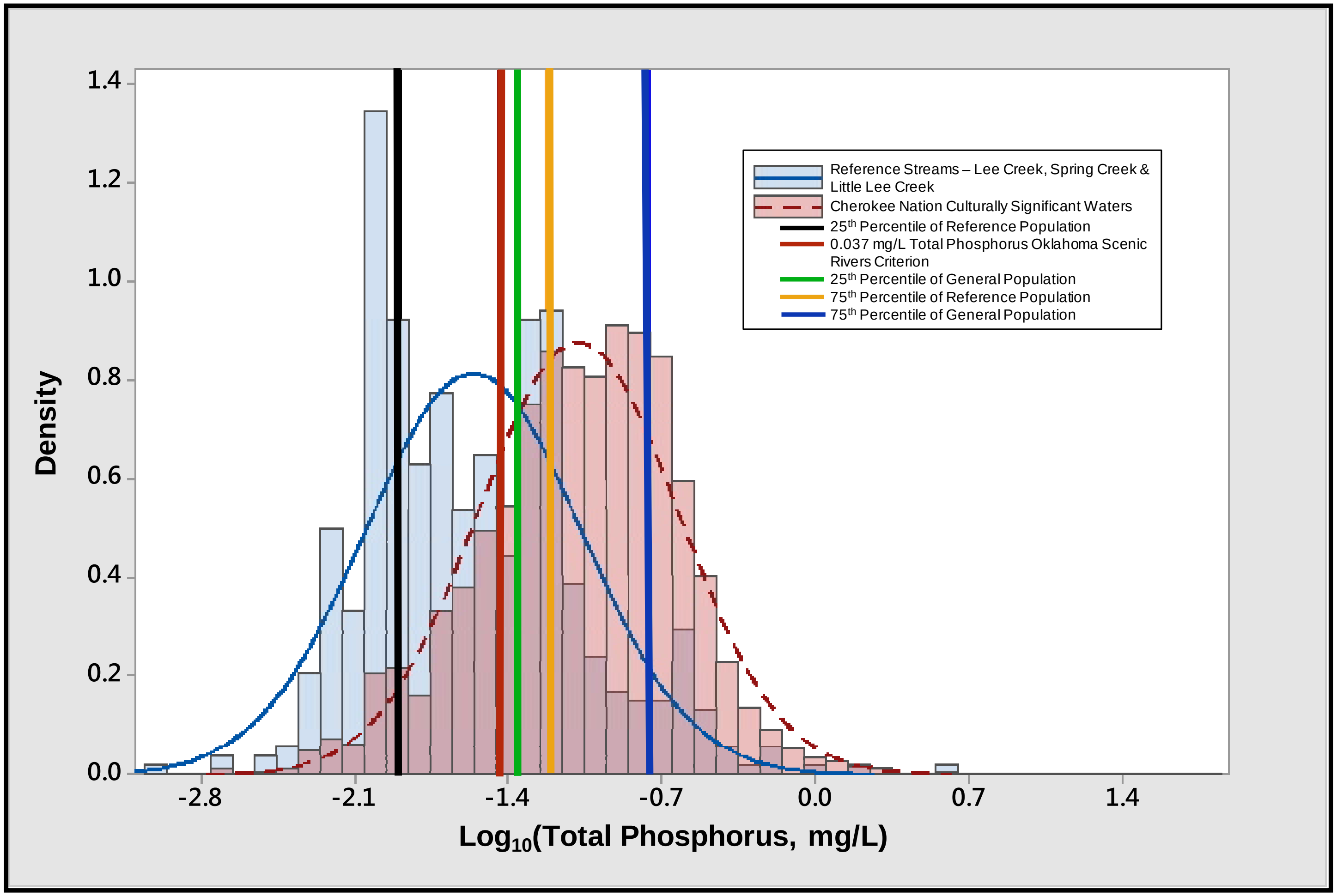


Figure 30. Distributions of total phosphorus data for the combined Cherokee Nation Culturally Significant Waters data set and the three reference streams, Lee Creek, Spring Creek and Little Lee Creek, with respect to the Oklahoma Scenic Rivers criterion and the 25^{th} and 75^{th} percentiles of both data sets with a fitted normal distribution line for each population.

Table 28. Summary data of Lee Creek, Spring Creek and Saline Creek as reference streams using the US EPA guidance for the decadal annual median reduction process for one set of median percentiles for a possible reference condition for Cherokee Nation's Culturally Significant Waters.

Water Body	Sampling Period Start	Sampling Period End	Sampling Period Range (yr)	Sampling Period Available Data (yr)	Number of Samples	Single Decadal Median of 25th Percentile	Single Decadal Mean of 25th Percentile	Single Decadal Median of Medians	Alternative Single Decadal Median of Medians	Single Decadal Median of 75th Percentile
Lee Creek	1991	2015	24	13	94	0.008	0.008	0.016	0.012	0.014
Spring Creek	1998	2015	17	16	261	0.013	0.013	0.030	0.013	0.068
Saline Creek	2000	2013	13	10	437	0.019	0.022	0.043	0.023	0.068
Reference Conditions	1991	2015	24	19	792	0.013	0.013	0.030	0.013	0.068

Table 29. Summary data of Lee Creek, Spring Creek and Little Lee Creek as reference streams using the US EPA guidance for the decadal annual median reduction process for one set of median percentiles for a possible reference condition for Cherokee Nation's Culturally Significant Waters.

	Sampling Period									
Water Body	**Start**	**End**	**Range (yr)**	**Available Data (yr)**	**Number of Samples**	**Single Decadal Median of 25th Percentile**	**Single Decadal Mean of 25th Percentile**	**Single Decadal Median of Medians**	**Alternative Single Decadal Median of Medians**	**Single Decadal Median of 75th Percentile**
Lee Creek	1991	2015	24	13	94	0.008	0.008	0.016	0.012	0.014
Spring Creek	1998	2015	17	16	261	0.013	0.013	0.030	0.013	0.068
Little Lee Creek	1991	2015	24	13	189	0.022	0.024	0.020	0.020	0.101
Reference Conditions	1991	2015	24	20	544	0.013	0.013	0.020	0.013	0.068

Table 30. Descriptive statistical total phosphorus data summary for the Oklahoma Conservation Commission (OCC) High Quality Waters (HQW) data for Cherokee Nation's Culturally Significant Waters.

		Total Phosphorus (mg/L)					
Data Set	**Number of Samples**	**Mean**	**Minimum**	**25th Percentile**	**Median**	**75th Percentile**	**Maximum**
All OCC HQW Sites	604	0.083	0.004	0.024	0.055	0.088	2.46
Cherokee Nation 14 Counties OCC HQW Sites	1741	0.093	0.001	0.020	0.047	0.092	3.70

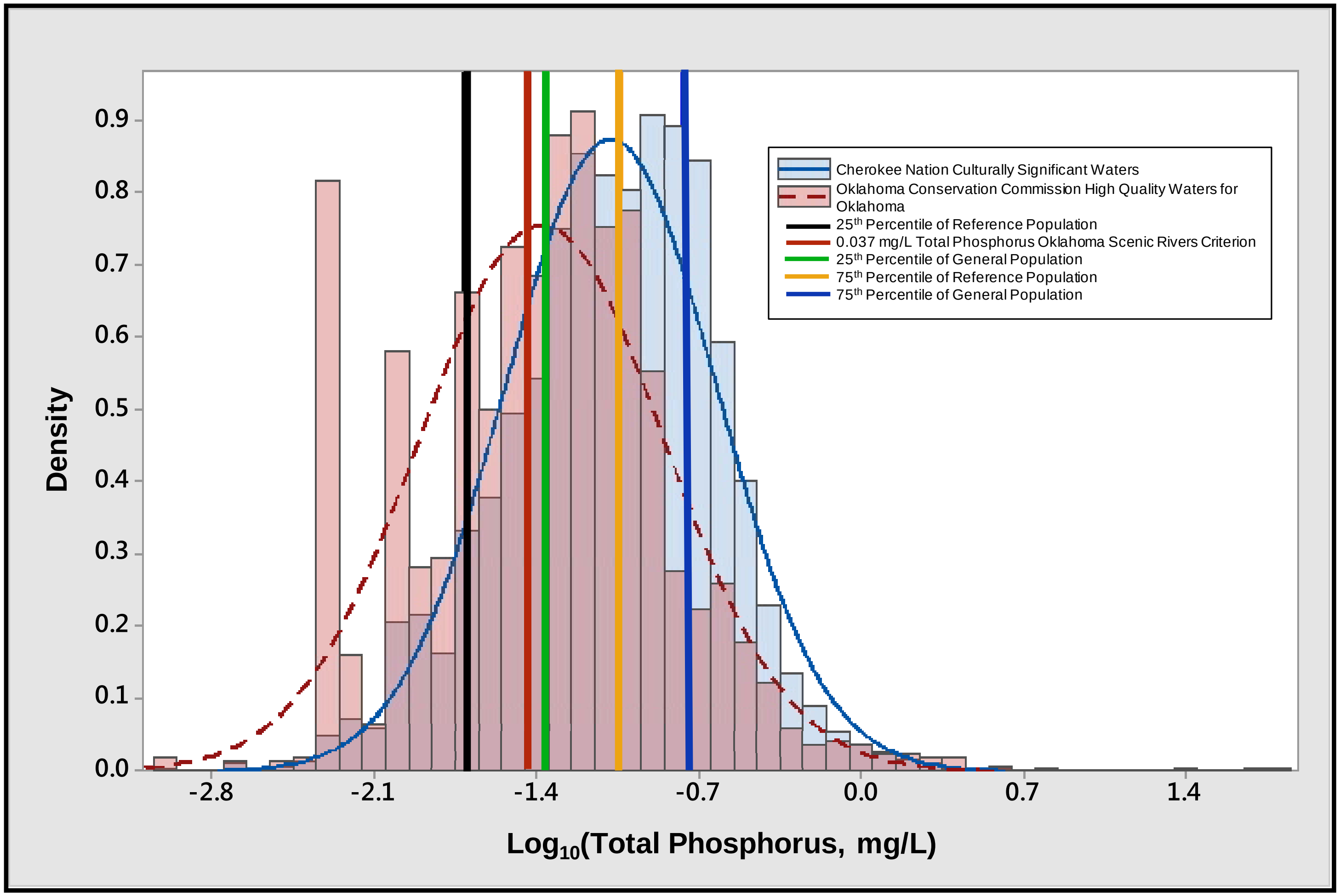


Figure 31. Distributions of total phosphorus data for the combined Cherokee Nation Culturally Significant Waters data set and all of the Oklahoma Conservation Commission's High Quality Waters data for Oklahoma with a fitted normal distribution line for each population.

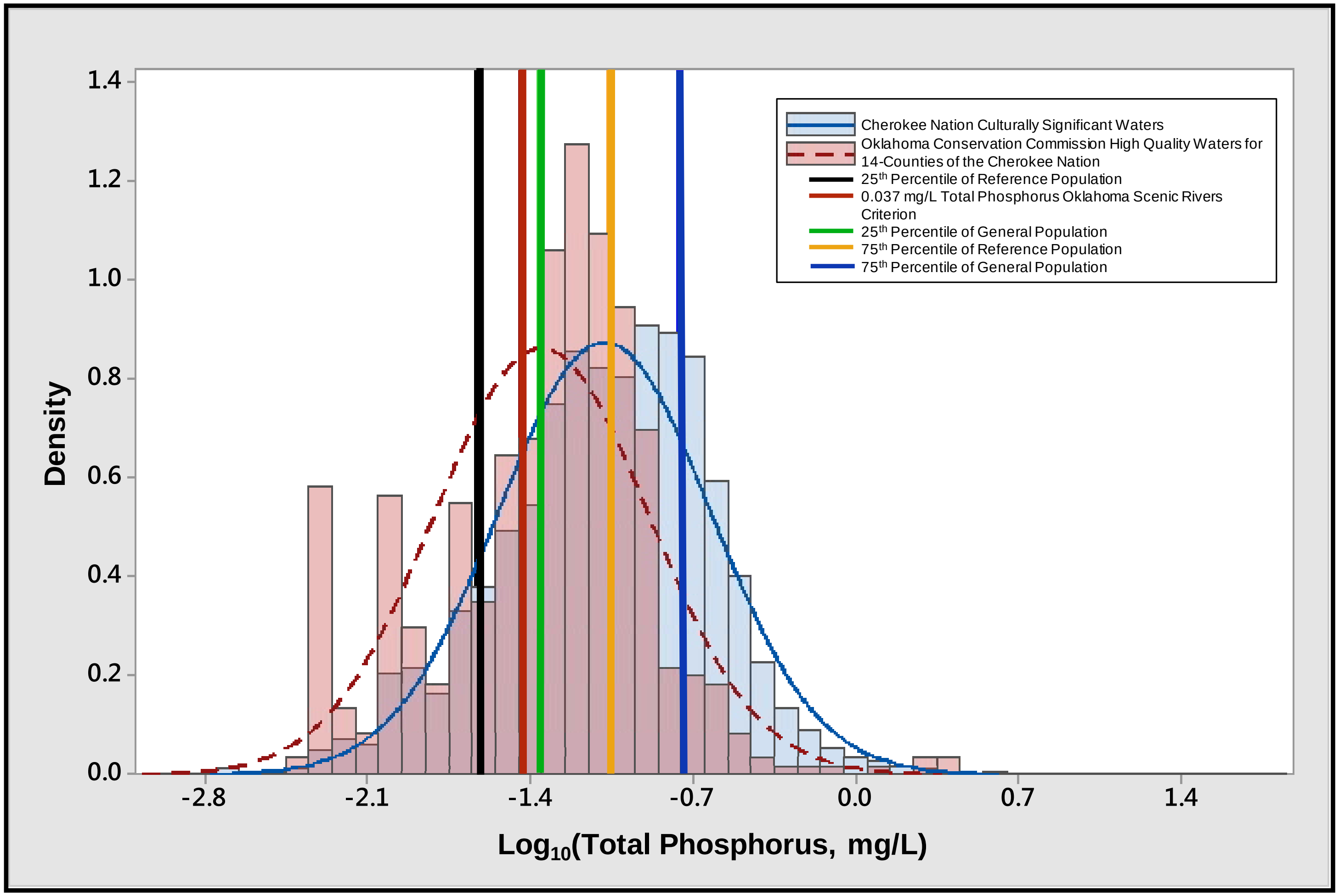


Figure 32. Distributions of total phosphorus data for the combined Cherokee Nation Culturally Significant Waters data set and only the Oklahoma Conservation Commission's High Quality Waters data in the 14 counties of the Cherokee Nation with a fitted normal distribution line for each population.

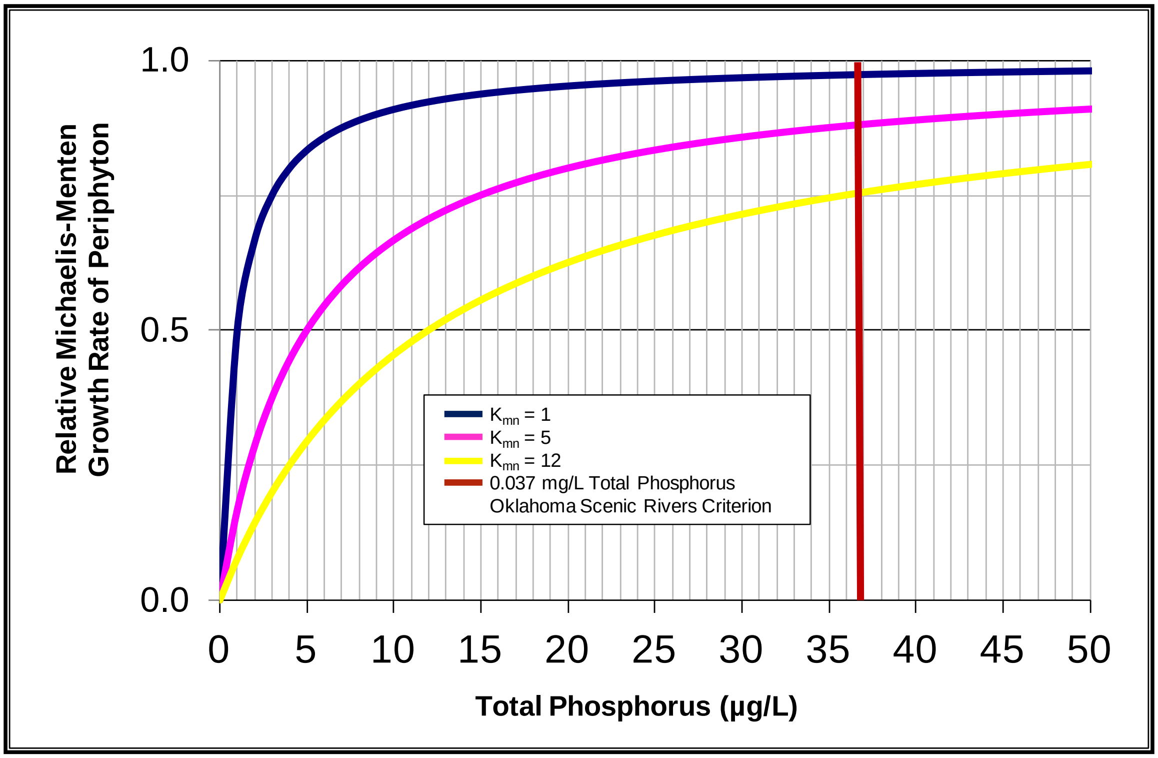


Figure 33. Michaelis-Menten periphyton relative growth rate in response to total phosphorus for Michaelis constants (K_{mn}, µg/L) ranging from one to twelve compared to the Oklahoma Scenic Rivers 0.037 mg/L total phosphorus criterion.

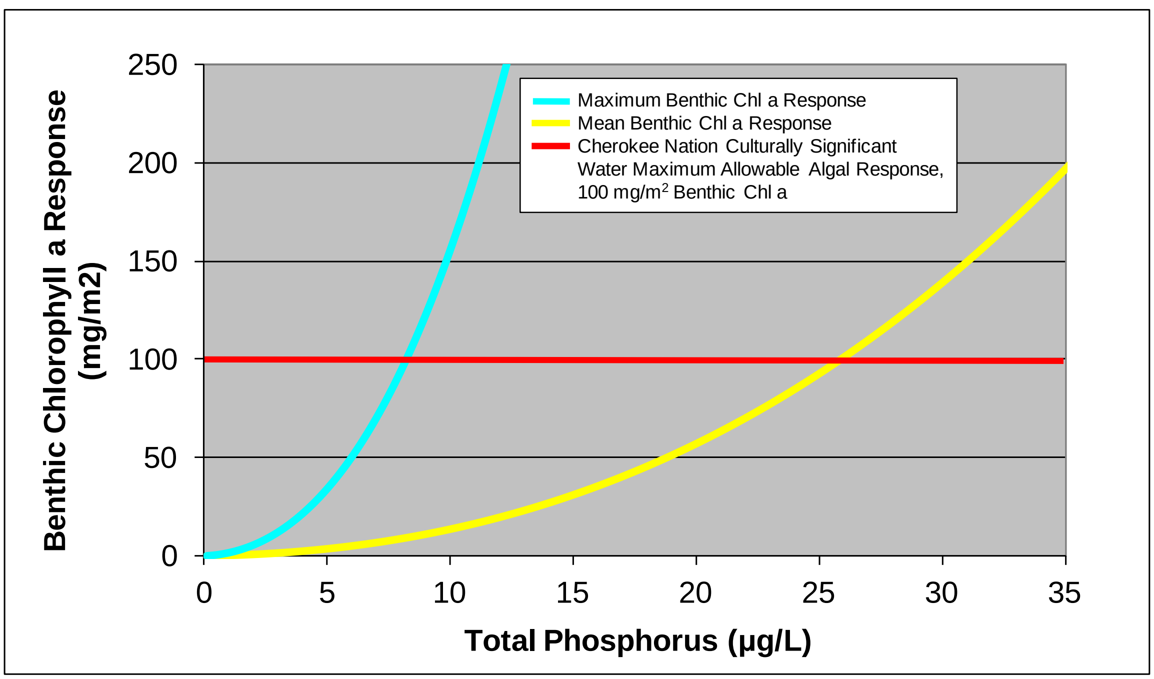


Figure 34. Corrected Dodds (2006) regression equations for benthic Chlorophyll *a* for mean and maximum predicted response to total phosphorus compared to the maximum acceptable range of benthic cholorophyll a of 100 mg/m^2 to protect Cherokee Nation's Culturally Significant Waters (Suplee et al., 2009).

Oklahoma Scenic Rivers Criterion

Existing Conditions

TP data for the identified Cherokee Nation CSWs were analyzed for compliance with the Oklahoma Scenic Rivers criterion. First, a direct comparison of these data with the 0.037 mg/L TP criterion was conducted. For the identified CSWs, 4506 out of 5712 samples exceeded 0.037 mg/L TP, which was 79% of all samples from 1969 to 2015 for the 12 water bodies in the Cherokee Nation.

Implementation of Oklahoma's water quality standard (OWRB, 2001; OWRB, 2002) for the Scenic River TP criterion requires one estimate per month for the geometric mean of all data available from the previous three months. In addition, no more than 25 percent of the monthly calculated three-month rolling geometric means may exceed 0.037 mg/L TP (State of Oklahoma, 2013 – should this be OWRB 2015?). The three-month rolling geometric mean was calculated for every month data were available from 1969 to 2015 for each water body, with the final decadal annual medians and mean given in Table 30. Intermediary calculations are provided in Appendix AL.

For comparison, the three-month rolling arithmetic mean was calculated utilizing the same method as the rolling geometric mean. The three-month rolling arithmetic mean was either equal to or higher than the three-month rolling geometric mean, as expected. A summary of the results are provided in Table 31 and intermediary summary calculations are shown in Appendix AM. Descriptive statistical data by water body for both the three-month rolling geometric mean and three-month rolling arithmetic mean are provided in Table

32. Note that for the four water bodies considered for reference conditions, the 75th percentile of both the rolling geometric mean and rolling arithmetic mean are lower than the 75th percentile of decadal annual medians, except for Lee Creek. In conclusion, every Cherokee Nation CSW, except for Lee Creek, was TP impaired.

Table 31. Exceedance summary by water body for Oklahoma Scenic River criterion using three-month rolling geometric mean for the Cherokee Nation Culturally Significant Waters data set.

Water Body	Exceedance Number	Percent Exceedance
Lee Creek	3	2.3
Spring Creek	51	28.3
Saline Creek	33	29.2
Little Lee Creek	43	35.0
Barren Fork	96	49.7
Sallisaw Creek	61	60.4
Fourteen Mile Creek	102	76.1
Spavinaw Creek	179	81.7
Illinois River	449	90.7
Beaty Creek	108	94.7
Flint Creek	420	99.3
Arkansas River	447	100.0

Table 32. Exceedance summary by water body based on Oklahoma Scenic River criterion using three-month rolling arithmetic mean for the Cherokee Nation Culturally Significant Waters data set.

Water Body	Exceedance Number	Percent Exceedance
Lee Creek	6	4.6
Spring Creek	75	41.7
Little Lee Creek	54	43.9
Saline Creek	51	45.1
Barren Fork	107	55.4
Sallisaw Creek	71	70.3
Fourteen Mile Creek	109	81.3
Spavinaw Creek	179	81.7
Illinois River	464	93.7
Beaty Creek	108	94.7
Flint Creek	420	99.3
Arkansas River	447	100.0

Table 33. Descriptive statistics for Cherokee Nation Culturally Significant waterbody dataset by three-month rolling geometric mean (RGM) and three-month rolling arithmetic mean (RAM) from 1969 to 2015.

Waterbody	Sample Number	Missing Samples	Type	Mean	SE[1] Mean	STD[2]	Min[3]	Q1[4]	Median	Q3[5]	Max[6]	Range	IQR[7]
Arkansas	447	99	RGM	0.174	0.003	0.069	0.042	0.137	0.164	0.193	0.593	0.551	0.056
			RAM	0.188	0.004	0.083	0.050	0.143	0.173	0.207	0.787	0.737	0.063
Spring	180	366	RGM	0.047	0.006	0.078	0.005	0.017	0.027	0.040	0.518	0.513	0.024
			RAM	0.061	0.007	0.095	0.005	0.019	0.032	0.051	0.620	0.615	0.032
Spavinaw	219	327	RGM	0.079	0.003	0.045	0.005	0.050	0.077	0.099	0.216	0.211	0.049
			RAM	0.107	0.006	0.092	0.005	0.056	0.090	0.119	0.502	0.497	0.063
Sallisaw	101	445	RGM	0.084	0.013	0.130	0.010	0.026	0.050	0.073	0.919	0.909	0.047
			RAM	0.105	0.016	0.156	0.010	0.030	0.055	0.079	0.937	0.927	0.049
Saline	113	433	RGM	0.051	0.006	0.067	0.007	0.020	0.027	0.045	0.294	0.287	0.025
			RAM	0.062	0.007	0.069	0.010	0.024	0.035	0.059	0.295	0.285	0.035
Little Lee	123	423	RGM	0.080	0.023	0.254	0.005	0.013	0.024	0.061	2.531	2.53	0.048
			RAM	0.103	0.028	0.311	0.006	0.017	0.032	0.070	2.710	2.70	0.053
Lee	130	416	RGM	0.016	0.001	0.008	0.006	0.010	0.013	0.019	0.060	0.054	0.009
			RAM	0.017	0.001	0.011	0.006	0.011	0.013	0.020	0.060	0.054	0.009
Illinois	495	51	RGM	0.137	0.005	0.114	0.009	0.068	0.115	0.175	1.229	1.220	0.107
			RAM	0.164	0.007	0.149	0.010	0.080	0.138	0.203	1.648	1.220	0.123
14M	134	412	RGM	0.408	0.311	3.596	0.016	0.037	0.058	0.088	41.7	1.638	0.051
			RAM	0.704	0.382	4.43	0.016	0.040	0.060	0.107	44.2	41.6	0.067
Flint	423	123	RGM	0.171	0.005	0.102	0.020	0.112	0.162	0.206	1.100	44.2	0.094
			RAM	0.191	0.006	0.117	0.020	0.117	0.175	0.228	1.100	1.080	0.111
Beaty	114	432	RGM	0.103	0.012	0.123	0.030	0.059	0.081	0.103	0.810	1.080	0.044
			RAM	0.120	0.012	0.123	0.030	0.070	0.097	0.125	0.810	0.780	0.056
Barren	193	353	RGM	0.045	0.002	0.028	0.006	0.027	0.037	0.055	0.169	0.780	0.028
			RAM	0.057	0.003	0.048	0.006	0.028	0.041	0.073	0.344	0.163	0.045

[1]Standard error
[2]Standard deviation
[3] Minimum
[4]25th percentile
[5]Maximum
[6]75th percentile
[7]Interquartile range

Clark et al. (2000)

The Oklahoma Scenic Rivers criterion of 0.37 mg/L TP was promulgated by the Cherokee Nation in 2004 to protect Culturally Significant Waters from excess TP. The criterion was based on the 75th percentile of all reference data from Clark et al. (2000). The use of Clark et al. (2000) data to establish the magnitude of the Oklahoma Scenic Rivers criterion assumes the study area was the same or comparable to the Nutrient Ecoregions IV, IX and XI, which included the Cherokee Nation.

The only Oklahoma and Cherokee Nation data included in Clark et al. (2000) were the USGS Illinois River near Tahlequah, OK Station 07196500 from 1993 to 1995, which included 30 USGS TP samples (see Appendix AN). The original Clark et al. (2000) data set included 25,634 TP samples (STORET Code 00665); thus the 30 Illinois River samples were a small fraction compared to the overall data set. Next, the original Clark et al. (2000) data (see Appendix AO) was combined with the Cherokee Nation CSW data set for analysis.

Figure 35 shows the frequency distributions of the Clark et al. (2000) reference population compared to the Cherokee Nation CSW general population. Although the distribution of the Cherokee Nation CSW general population does not overlap the Clark et al. (2000) reference population, as assumed in the US EPA numerical nutrient guidance, the reduced decadal annual medians interquartile range does include the 75th percentile of the Clark et al. (2000) data. If the decadal annual medians are considered, the 25th percentile of the general population, i.e. 0.035 mg/L TP, approximates the 75th percentile of the reference population of 0.037 mg/L TP. Without further analysis, using Clark et al. (2000) as a reference condition for Cherokee Nation's CSWs appears correct.

Oklahoma Use Support Assessment Protocol

Stream slope, stream order, US EPA Nutrient Ecoregion and US EPA Level III Ecoregions were determined for the 131 water quality sites in the Cherokee Nation CSW data set (Appendix X). Cherokee Nation CSW water quality sites and waterbodies were in US EPA Nutrient Ecoregion IX and XI, and no water quality sites or waterbodies were in US EPA Nutrient Ecoregion IV. The vast majority of Cherokee Nation CSW water quality sites were in the US Nutrient Ecoregion XI and US EPA Level III Ozark Highlands Ecoregion. The US EPA Numerical Nutrient Recommendation for the Ozark Highlands ecoregion in Nutrient Ecoregion XI was the 25th percentile of the general population, which was calculated as 0.066 mg/L TP (US EPA, 2000b).

To evaluate the Cherokee Nation CSW data set using the OK USAP, sites were placed in two groups; one with stream order of three or less and a second with a stream order greater than three. The sites were divided in two to additional groups based on stream flow, i.e. stream slopes 3.2 meters per kilometer or less and streams slopes greater than 3.2 meters per kilometer. The majority of sites had a stream order greater than three and a stream slope less than 3.2 meters per kilometer. The summary of the USAP assessment of water quality conditions for the Cherokee Nation CSW data set are given in Table 33, with the detailed calculations given in Appendix AQ.

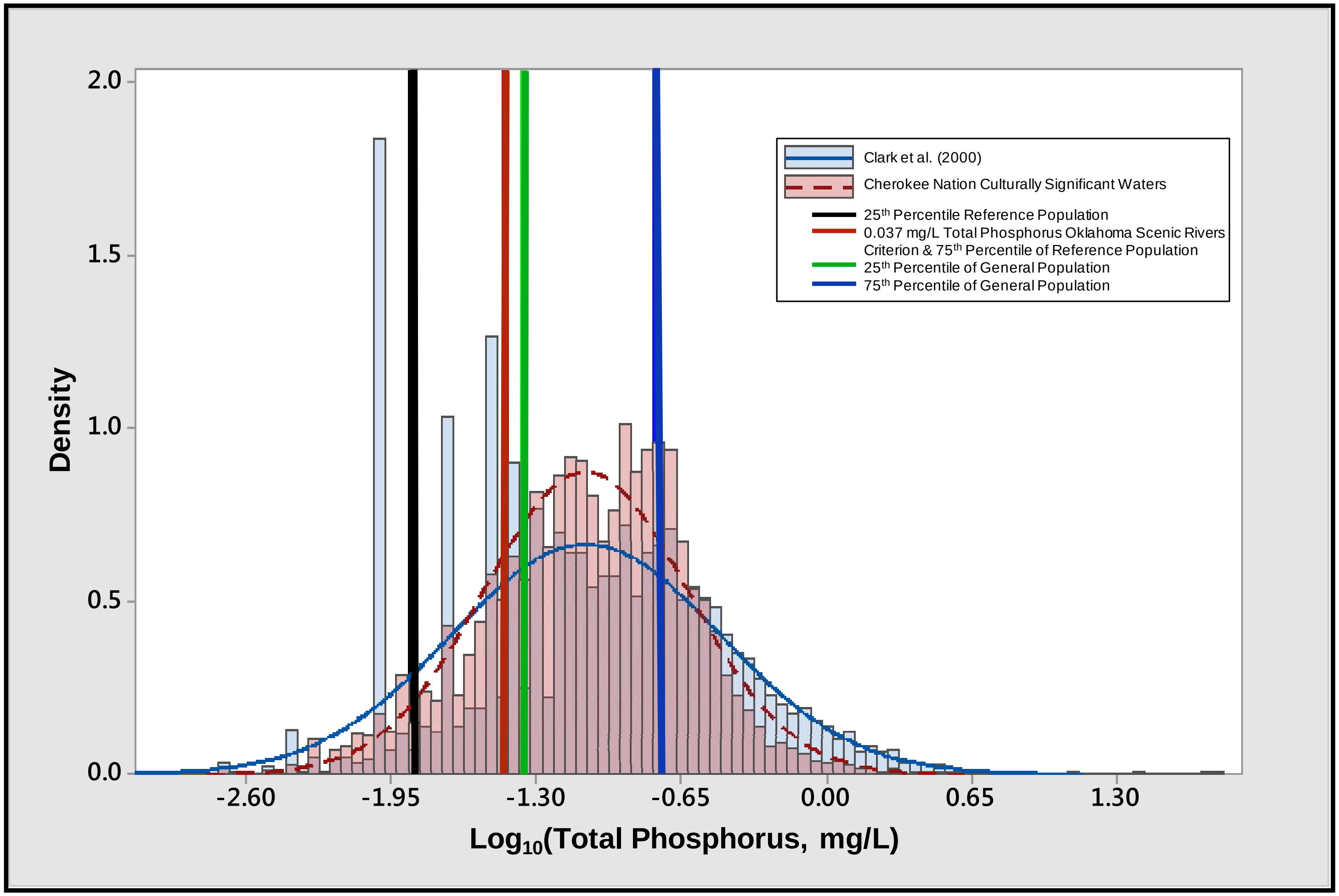


Figure 35. Frequency distributions of total phosphorus samples for the Cherokee Nation Culturally Significant Waters data set from 1969 to 2015 compared to the Clark et al. (2000) original data set with respect to the Oklahoma Scenic Rivers criterion of 0.037 mg/L TP with a fitted normal distribution line for each population.

When compared to literature findings and algal response theory, all four Oklahoma USAP TP criteria represent eutrophic conditions for lotic waters. Three of the four Oklahoma USAP criteria are greater than the Netherlands TP standard of 0.150 mg/L, which was recommended by Peeters and Gardeniers (1998). This TP standard is equivalent to the 50th percentile for the "upper reaches of lowland streams," which are "nearly the highest level" of trophic status (add reference for " "). Although none of the published materials provide the specific basis for the Oklahoma USAP criteria, the criteria are equivalent to the 50th percentile of "nearly highest level" or "highest level" trophic waters for hill stream upper and lower reaches and lowland stream upper and lower reaches. When compared to Haggard et al. (2003), all four Oklahoma USAP criteria were greater than the 75th percentile for corresponding stream categories in all four geographic regions. Oklahoma USAP conditions are greater than most conditions found in the Cherokee Nation's CSWs and for the State of Oklahoma.

Table 34. Oklahoma Use Support Assessment Protocol implementation (OK Statute 785: 46-15-10) of numerical criteria decision criteria (Haggard et al., 2003) for the Cherokee Nation Culturally Significant Waters data set.

Stream Order	Stream Slope (m/km)	Phosphorus Criterion (mg/L)	Sample Number	
			Impaired	Not Impaired
1, 2 or 3	> 3.2	> 0.24	69	614
1, 2 or 3	< 3.2	> 0.15	672	933
Other	> 3.2	> 1.0	1	122
Other	< 3.2	> 0.36	171	3,127

US EPA Nutrient Ecoregion Recommendations

The US EPA numerical nutrient criteria recommended for aggregate Nutrient Ecoregions IV, IX and XI applicable to the Cherokee Nation were compared to the Cherokee Nation CSW data set. Aggregate Nutrient Ecoregion IV (US EPA, 2001b) contained four counties in Oklahoma, Beaver, Cimarron, Harmon and Osage, and none were within the Cherokee Nation's jurisdiction. Nutrient Ecoregion IV data set included 9,944 samples of TP (STORET Code 00665), although only 10,035 samples were reported in the guidance document. No periphyton or benthic Chl *a* data were available. A column for 'Sample Year,' 'Sample Month' and 'Sample Season' based on sample date was created to compare US EPA Nutrient Ecoregion guidance data sets with Cherokee Nation's CSWs data set. Duplicates had been previously removed and quality assurance checks completed by US EPA. No additional work was performed on these data sets. The US EPA Nutrient Ecoregion IV data set is given in Appendix AP.

For Nutrient Ecoregion IV, the US EPA-recommended TP criterion (0.023 mg/L) was lower than most of the criteria in Appendix B except for the Nutrient Ecoregion IV criterion developed based on forested reference streams (Smith et al., 2003). The TP criterion may be too low for forested systems with natural nutrient loading (Smith et al., 2003). The US EPA-recommended TN criterion (0.56 mg/L) appears high for healthy waters when compared to Appendix B values (US EPA 2000a; Smith et al., 2003). Figure 36 compares the frequency distribution of the Cherokee Nation CSW data set to the US EPA Nutrient Ecoregion IV data set.

US EPA Aggregate Nutrient Ecoregion IX (US EPA, 2000c) contained 41 Oklahoma counties with 11 of the 14 counties within the Cherokee Nation: Cherokee, Mayes, McIntosh, Muskogee, Nowata, Ottawa, Rogers, Sequoyah, Tulsa, Wagoner and Washington County. The Arkansas River and Illinois River were the only Cherokee Nation CSW included in the data set. Nutrient Ecoregion IX data set included 168,806 samples of TP (STORET Code 00665), although 164,145 samples were reported in the guidance document. Columns for 'Sample Year,' 'Sample Month' and 'Sample Season' based on sample date were created to compare US EPA Nutrient Ecoregion guidance data sets with the Cherokee Nation's CSW data set. Duplicates were already assumed to be removed and quality assurance checks completed by US EPA. No additional work was performed on the data set. The US EPA Nutrient Ecoregion IX data set are given in Appendix AP. Figure 37 compares the frequency distribution of the Cherokee Nation CSW data set to the US EPA Nutrient Ecoregion IX data set.

For Nutrient Ecoregion IX rivers and streams, the US EPA-recommended TP criterion (0.366 mg/L TP) was within the range of most Appendix B criteria (US EPA, 2000c). Natural nutrient loading for forested streams was likely to be high (Smith et al., 2003). The US EPA-recommended (2000c) aggregate TN criterion (0.69 mg/L) for Nutrient Ecoregion IX may be high for healthy waters when compared to Appendix B values, although the area was significantly forested similar to the forested reference studies of Dodds and Oakes (2004) and

Smith et al. (2003). Figure 33 compares the frequency distribution of the Cherokee Nation CSW data set to the US EPA Nutrient Ecoregion IV data set.

US EPA Aggregate Nutrient Ecoregion XI (US EPA, 2000b) contained 10 Oklahoma counties with five of the 14 counties within the Cherokee Nation: Adair, Cherokee, Delaware, Mayes and Sequoyah County. Cherokee Nation CSWs reporting data were Spavinaw Creek, Snake Creek, Sallisaw Creek, Saline Creek, Little Lee Creek, Lee Creek, Illinois River, Flint Creek, Beaty Creek and Barren Fork. US EPA Nutrient Ecoregion XI data set included 81,001 samples of TP (STORET Code 00665), although 80,708 samples were reported in the guidance document. A column for 'Sample Year,' 'Sample Month' and 'Sample Season' based on sample date were created to compare US EPA Nutrient Ecoregion guidance data sets with the Cherokee Nation's CSWs data set. Duplicates were already assumed to be removed and quality assurance checks completed by US EPA. No additional work was performed on these data. The US EPA Nutrient Ecoregion XI data set are given in Appendix AR.

For Nutrient Ecoregion XI, the US EPA-recommended TP criterion (0.010 mg/L) as shown in Table 7 was lower than the other US EPA recommended criteria applicable to Cherokee Nation jurisdiction in Appendix B. The Nutrient Ecoregion IV criterion developed based on forested reference streams was much less than the Nutrient Ecoregion IV and IX US EPA-recommended criteria (US EPA, 2000b). The US EPA-recommended TN criterion, 0.305 mg/L TN, was within the range presented for healthy waters presented in Appendix B (US EPA, 2000b). Figure 35 compares the frequency distribution of the Cherokee Nation CSW data set to the US EPA Nutrient Ecoregion XI data set.

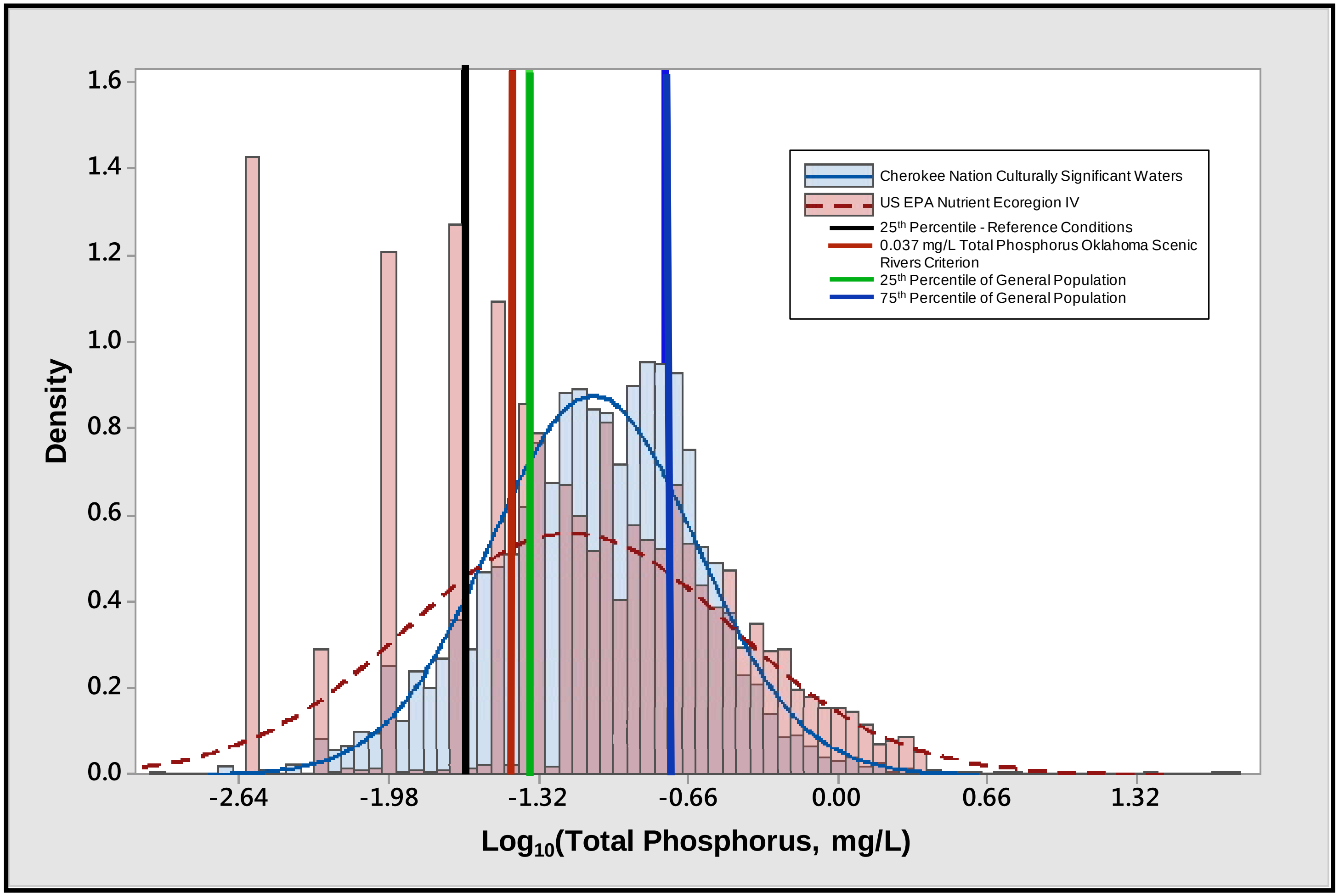


Figure 36. Frequency distributions of total phosphorus samples for the Cherokee Nation Culturally Significant Waters data set from 1969 to 2015 compared to the US EPA Nutrient Ecoregion IV data set respect to the Oklahoma Scenic Rivers criterion, 0.037 mg/L TP with a fitted normal distribution line for each population.

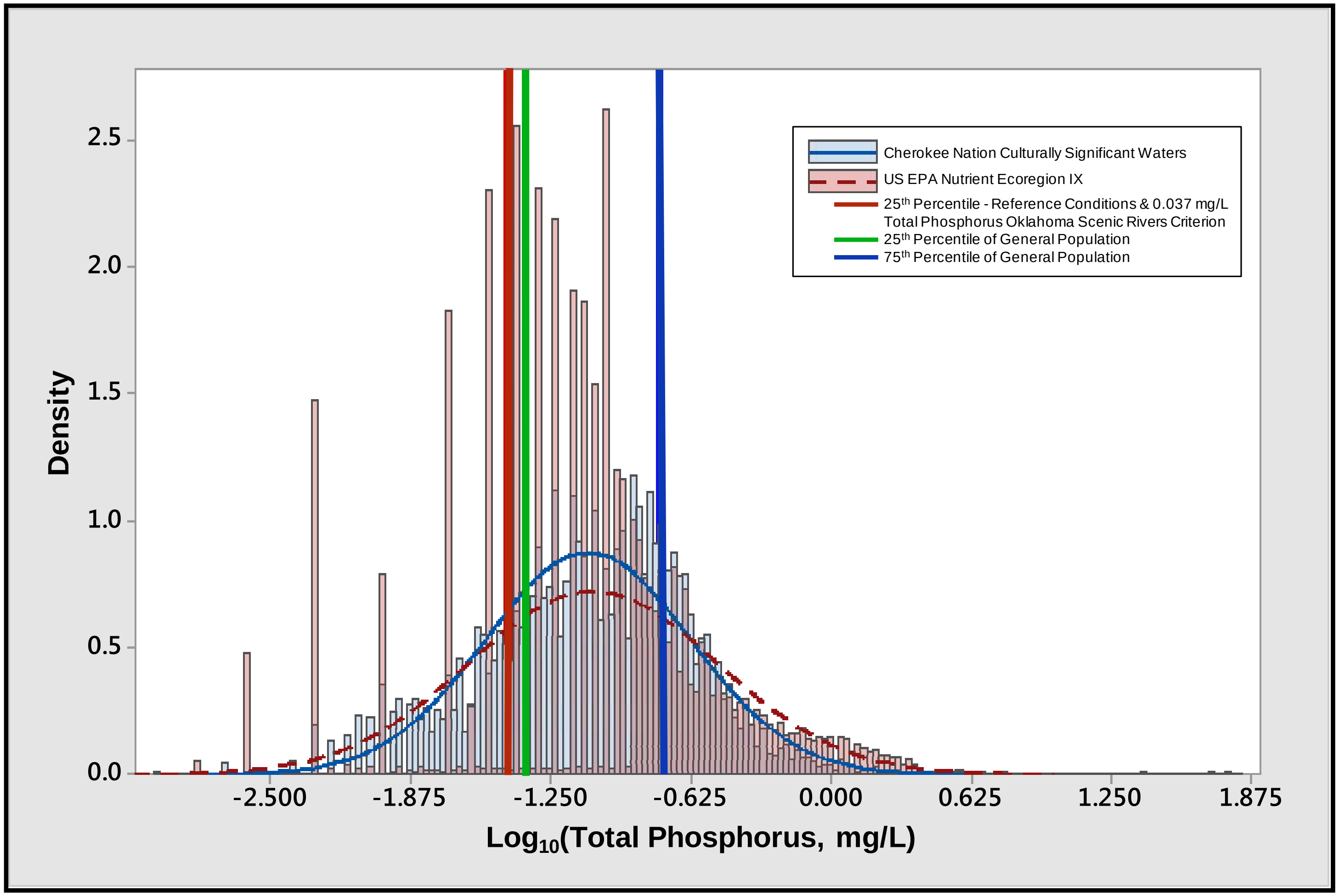


Figure 37. Frequency distributions of total phosphorus samples for the Cherokee Nation Culturally Significant Waters data set from 1969 to 2015 compared to the US EPA Nutrient Ecoregion IX data set with respect to the Oklahoma Scenic Rivers criterion, 0.037 mg/L TP with a fitted normal distribution line for each population.

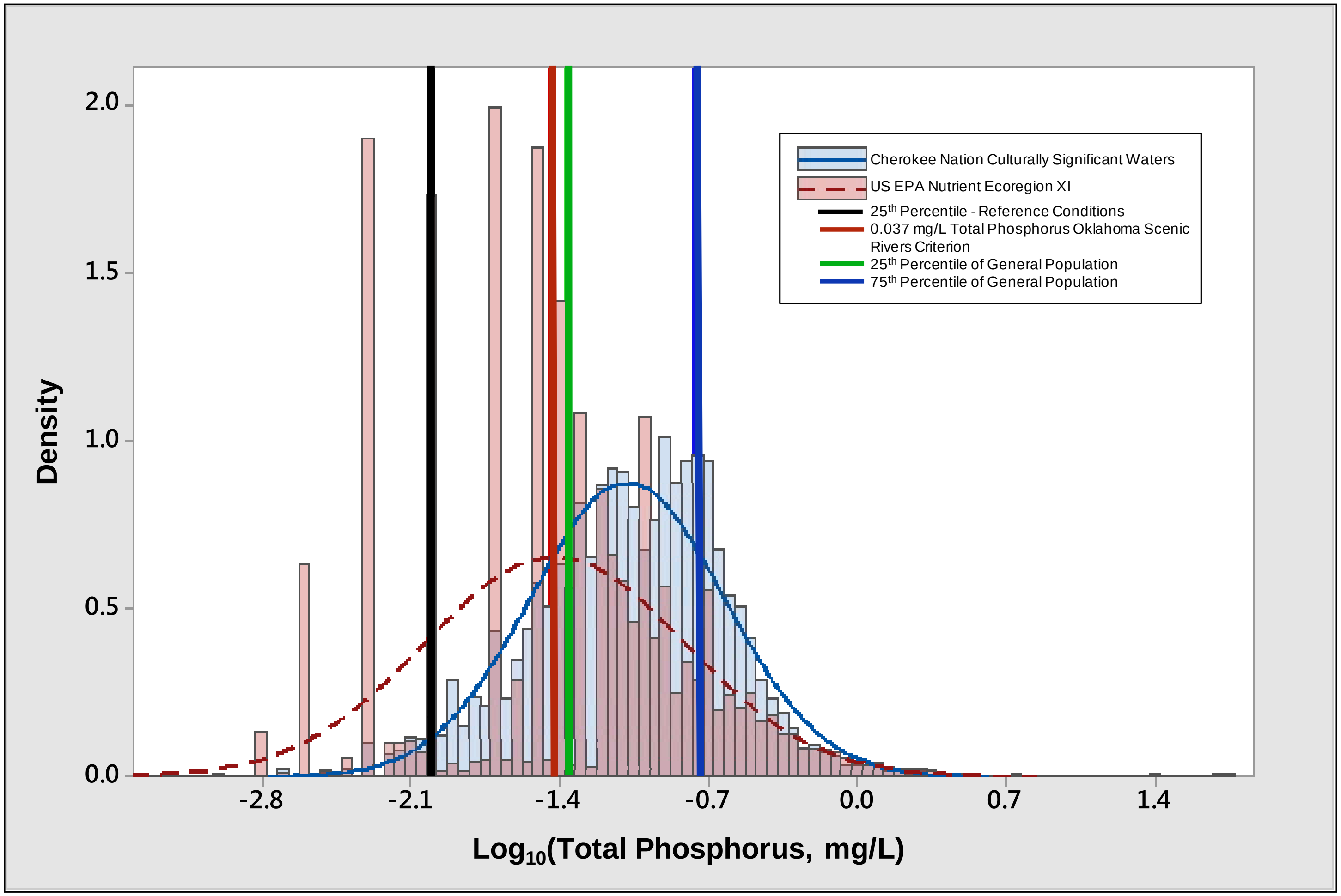


Figure 38. Frequency distributions of total phosphorus samples for the Cherokee Nation Culturally Significant Waters data set from 1969 to 2015 compared to the US EPA Nutrient Ecoregion XI data set with respect to the Oklahoma Scenic Rivers criterion, 0.037 mg/L TP with a fitted normal distribution line for each population.

Weight of Evidence Considerations

When evaluating the Oklahoma Scenic River Criterion, the weight of evidence approach per US EPA (2000a) guidance supports the existing Oklahoma Scenic Rivers criteria (Table 35) for waters "better than average" (OWRB, 2001; OWRB 2002). The literature findings, analysis of historical data to determine a baseline reference condition, consideration of the Oklahoma USAP, literature models, and the Regional Technical Advisory Group (RTAG) recommendations all supported 0.037 mg/L TP as a numerical criterion for the Cherokee Nation CSW, which may avoid excessive anthropogenic eutrophication. However, the Cherokee Nation CSWs require more pristine conditions to protect designated uses, such as intentional ingestion and full-body immersion. In addition, since the US EPA numerical nutrient guidance methodology does not provide for biological response considerations, weight of evidence, such as biological response, must be considered to determine a numerical nutrient criteria supportive of Cherokee Nation CSWs designated uses.

If available, natural reference conditions should be utilized to determine the numeric nutrient criteria to protect the water body(s) from a eutrophic algal response. If natural reference conditions and a known eutrophic TP algal response are unavailable, the US EPA numerical nutrient guidance for the 75th percentile of a reference population or 25th percentile of the general population should be considered as a baseline for establishing a numerical nutrient criterion. The numerical nutrient criteria must be selected to protect the water body(s) designated use(s) from eutrophication.

The literature findings (Appendix B) identified a reference range for TP of 0.010 to 0.060 mg/L and a nuisance range of 0.020 to 0.100 mg/L. The Oklahoma Scenic Rivers criterion falls within both ranges, and thus was acceptable based solely on the literature. Assuming mesotrophic conditions is an acceptable endpoint, the mesotrophic range for TP was 0.025 to 0.075 mg/L TP. Therefore, the Oklahoma Scenic Rivers criterion continues to appear reasonable (US EPA, 2000f; Haggard et al., 2003; Dodds et al., 1998).

Historical data and trends were used to evaluate conditions of the Cherokee Nation's CSWs. Analysis of almost 46 years of data showed the 0.037 mg/L TP was frequently exceeded in the 12 streams and rivers investigated, and TP concentrations exceeded the 25 percent frequency deemed acceptable in the Oklahoma USAP in all but two sites. The Oklahoma's Scenic Rivers standard was not being met, which puts Cherokee Nation's CSWs at risk. Based on the cultural survey responses, this discourages and may even prevent traditional Cherokees from cultural uses of waters.

The 25th percentile of all data for US EPA Nutrient Ecoregions IV, IX and XI within the Cherokee Nation ranged from 0.010 to 0.037 mg/L TP (US EPA 2000a) with a median value of 0.023 mg/L TP. If the US EPA numerical nutrient guidance was selected, the Cherokee Nation CSWs would have a baseline TP criterion lower than the current Oklahoma Scenic River criterion and thus be more protective.

The numerical nutrient criterion does not appear protective of Cherokee Nation's culturally significant waters. Both the State of Oklahoma and Cherokee

Nation have adopted the 0.037 mg/L TP for the designated scenic rivers. The Cherokee Nation water quality standards have not been acknowledged or approved by the US EPA. Whether or not the US EPA has approved the standards, the Cherokee Nation requires public participation before new standards may be approved or existing standards changed (Cherokee Nation Legislative Act (LA) 35-04). The scenic river standard has been applied to all CSW water bodies. If eutrophication occurs, the cultural uses of the water bodies would be prevented per the survey responses.

The tribal community identified 12 rivers and streams considered CSWs and defined uses for those waters. The publicly available data for the 10 rivers and streams plus two Oklahoma Scenic Rivers within the Cherokee Nation had adequate public data to provide the US EPA guidance for the reduced decadal annual median of the 25th percentile of all TP data (0.035 mg/L TP) as a percentile baseline specific to Cherokee Nation's CSWs.

Two reference stream sets considered were the Lee Creek, Saline Creek and Spring Creek and the Lee Creek, Spring Creek and Little Lee Creek. They both had a reduced decadal annual median of the 75th percentile of all TP data (0.068 mg/L TP), which was higher than the literature reference range. In addition, the OCC High Quality Water sites were considered as reference conditions using both the entire data set for Oklahoma and only data from the 14 counties of the Cherokee Nation. Both possible reference conditions presented 75th percentiles greater than the literature reference range and mesotrophic range. Therefore, no reference conditions or reference streams appear to be available to establish baseline conditions for Cherokee Nation's CSWs. This finding supports Smith et al. (2003), which concluded there were no "pristine reference sites" in the US and most streams and rivers would likely exceed the US EPA-recommended criteria. These findings also concur with the US EPA's recommendation to use the 25th percentile of all data.

The majority of all stream types met the Oklahoma USAP criteria. However, the Oklahoma USAP breakpoints exceeded the 25th percentile for the same stream types in all four Oklahoma and Arkansas regions investigated by Haggard et al. (2003). The Oklahoma USAP TP criteria are greater than *The US EPA Gold Book* (1986) based on the algal response to nutrients in sewage pond sludge (Mackenthum, 1973; Allen, 1955). The Oklahoma USAP exceeds all literature thresholds and models. Therefore, the Oklahoma USAP would not be protective of Cherokee Nation's CSWs designated uses.

Literature algal response models support a numeric nutrient criteria lower than the Oklahoma Scenic Rivers criterion to protect the Cherokee Nation's CSWs. For the 0.037 mg/L TP criterion, the Michaelis-Menten relationship predicted near maximum growth rate for Michaelis constants ranging from one to twelve. The Dodds (2006) regression analysis predicted mean and maximum benthic chlorophyll *a* exceeding 100 mg/m^2 for TP more than 0.026 mg/L.

The Regional Technical Advisory Group majority supported the Oklahoma Scenic Rivers criterion without increasing or decreasing the criterion based on established Oklahoma, Arkansas and Cherokee Nation needs. The Cherokee Nation's designated CSW were not specifically considered in their analysis. If they were considered, the recommendation might have been to lower the TP criterion.

Critical Review US EPA Numerical Nutrient Guidance

The US EPA numerical nutrient guidance was primarily based on the assumption that the 75th percentile of reference conditions would approximate the 25th percentile of the general population. Many of the water quality sites identified in the Cherokee Nation CSW data set were located in the US EPA Nutrient Ecoregion XI and the US EPA Level III Ozark Highlands Ecoregion. The 25th percentile of US EPA Nutrient Ecoregion XI and the US EPA Level III Ozark Highlands Ecoregion were 0.010 and 0.007 mg/L TP, respectfully. Most of the possible reference sites or 75th percentiles investigated did not approximate the 25th percentiles of the US EPA numerical nutrient criteria recommendations or the Cherokee Nation CSWs data set (Table 36). In addition, none of the possible reference streams met reference condition criteria and did not support the Oklahoma Scenic Rivers criteria. The Oklahoma USAP TP concentration was higher for all criteria compared to the 25th percentile of Haggard et al. (2003) for similar streams and rivers. The medians were significantly different, and thus the weight of evidence must be considered. Therefore, the US EPA numerical nutrient guidance assumption of comparable distributions alone was insufficient to set a criterion for TP.

The US EPA numerical nutrient guidance may be applicable to other Tribes and States. If data were available, Tribes and States with limited resources may use the same process to calculate a baseline reference condition specific to their watershed, designated use or other grouping of waterbodies. Although additional data, such as benthic chlorophyll *a*, may be used to establish a biological response to nutrients and validate the aesthetic criterion, the US EPA guidance does provide a documented public process.

Alternative Methods to US EPA Numerical Nutrient Guidance

Three alternative methods to the US EPA numerical nutrient guidance were considered, with a summary of the results shown in Table 37. The 25^{th} percentile for the aggregate Cherokee Nation CSW data set was greater for all three alternative methods in comparison to the US EPA single decadal annual median guidance. The results are mixed for the individual water bodies, Lee Creek and the Illinois River. The 25^{th}, 50^{th} and 75^{th} percentiles are fairly consistent for Lee Creek for all four methodologies. However, the Illinois River results are varied. Table 38 provides a summary of methods used to analyze the individual water bodies and the aggregate Cherokee Nation CSWs data set.

Lee Creek does appear to represent reference conditions. The US EPA recommends at least three streams to represent reference conditions. However, three reference streams are not available in the aggregate Cherokee Nation CSW data set. Lee Creek has publicly available TP data beginning in 1991, but adequate data was not available until 2003. Therefore, using the most recent decade analysis should be preferable. In this case the median of the 75^{th} percentile for the most recent decade was the same as the median of all seasons and years and the median for all years for Lee Creek. The US EPA recommended decadal annual median of the 75^{th} percentile of 0.014 mg/L TP was slightly less than the 75^{th} percentile of the three alternative methods, i.e. 0.016 mg/L.

Table 35. Weight of evidence findings summary with respect to the Oklahoma Scenic Rivers criterion (OSRC) of 0.037 mg/L total phosphorus.

Weight of Evidence Item	Data Set	TP[8] Findings (mg/L)	Supports OSRC
Literature Findings	Reference Range	0.010-0.060	Yes
	Nuisance Range	0.020-0.100	No
	Mesotrophic Range	0.025-0.075	Yes
Historical Data and Trends	CN CSW[9] - US EPA Decadal Annual Median	0.035	Yes
	CN CSW[9] 25th Percentile	0.044	No
Reference Conditions	LC[1], SC[2], SC[3] 75th Percentile	0.068	No
	LC, SC, LLC[4] 75th Percentile	0.068	No
	OCC HQWs[5] 75th Percentile	0.088	No
	OCC HQWs in CN[6] Counties 75th Percentile	0.092	No
	OK USAP[9] Lower Limit[10]	0.15	No
	OK USAP[9] Upper Limit[10]	1.00	No
	Clark et al. (2000) 75th Percentile	0.037	Yes
	NE[7] IV[10]	0.024	Yes
	NE[7] IX[10]	0.038	Yes
	NE[7] XI[10]	0.011	Yes
	Median of NE[7] IV, IX and XI[10]	0.024	Yes
Models	Dodds (2006)	< 0.030	Yes
	Michaelis-Menten Maximum Algal Growth Rate	0.037	Yes
Regional Technical Advisory Group	Review of OSRC	0.037	Yes

[1]Lee Creek
[2]Saline Creek
[3]Spring Creek
[4]Little Lee Creek
[5]Oklahoma Conservation Commission High Quality Waters
[6]Cherokee Nation
[7]US EPA Nutrient Ecoregion
[8]Total Phosphorus
[9]Oklahoma Use Support Assessment Protocol
[10]25th Percentile of General Population

Table 36. Total phosphorus summary of 75th percentile reference population data and 25th percentile decadal annual median for the Cherokee Nation Culturally Significant Waters data set.

General Population		Reference Population		TP[8] Difference 25th - 75th Percentile	
Data Set	TP[8] 25th Percentile (mg/L)	Data Set	TP[8] 75th Percentile (mg/L)	(mg/L)	(%)
Cherokee Nation Culturally Significant Waters - Decadal Annual Median per US EPA Guidance	0.035	LC[1], SC[2], SC[3]	0.068	-0.033	-94
		LC, SC, LLC[4]	0.068	-0.033	-94
		OCC HQWs[5]	0.088	-0.053	-151
		OCC HQWs in CN[6] Counties	0.092	-0.057	-163
		Clark et al. (2000)	0.037	-0.002	-6
		OK USAP[9] Lower Limit[10]	0.15	-0.115	-329
		OK USAP[9] Upper Limit[10]	1.00	-0.965	-2760
		CN CSW without reduction	0.04	-0.009	-26
		NE[7] IV[10]	0.024	0.011	32
		NE[7] IX[10]	0.038	-0.003	-8
		NE[7] XI[10]	0.011	0.024	69
		Median of NE[7] IV, IX and XI[10]	0.024	0.011	32
		Lee Creek	0.014	0.021	60
		Alternative Analysis of Lee Creek	0.016	0.019	54

[1]Lee Creek
[2]Saline Creek
[3]Spring Creek
[4]Little Lee Creek
[5]Oklahoma Conservation Commission's High Quality Waters
[6]Cherokee Nation
[7]US EPA Nutrient Ecoregion
[8]Total Phosphorus
[9]Oklahoma Use Support Assessment Protocol
[10]25th Percentile of General Population

Table 37. Comparison of three alternative analysis methods to the US EPA numerical nutrient guidance for total phosphorus in Lee Creek, the Illinois River and the Cherokee Nation Culturally Significant Waters data set to determine a numerical TP criterion.

	Total Phosphorus (mg/L)											
	Median of All Seasonal Medians Percentile			Median of All Annual Medians Percentile			Most Recent Decade Median Percentile			US EPA Guidance Single Decadal Median Percentile		
Data Set	**Q1[1]**	**Q2[2]**	**Q3[3]**	**Q1[1]**	**Q2[2]**	**Q3[3]**	**Q1[1]**	**Q2[2]**	**Q3[3]**	**Q1[1]**	**Q2[2]**	**Q3[3]**
Lee Creek	0.010	0.013	0.016	0.010	0.015	0.016	0.010	0.013	0.016	0.008	0.016	0.014
Illinois River	0.079	0.110	0.203	0.081	0.103	0.189	0.034	0.064	0.119	0.084	0.103	0.175
CN CSW[4]	0.065	0.085	0.159	0.060	0.077	0.141	0.040	0.059	0.118	0.035	0.052	0.107

[1] 25^{th} Percentile.
[2] 50^{th} Percentile
[3] 75^{th} Percentile.
[4] Cherokee Nation Culturally Significant Waters aggregate data set.

Table 38. Methodology summary for alternative analyses to the US EPA numerical nutrient guidance decadal annual median method.

	Waterbody Total Phosphorus Samples Reduced to Percentiles by		
Methodology	**Season**	**Year**	**Final Step(s)**
Median of All Seasonal Medians	Yes	No	Calculate percentiles of medians for all seasons for all years by waterbody
Median of All Annual Medians	Yes	Yes	Calculate percentiles of medians for all annual medians by waterbody
Aggregate Decadal Median for Most Recent Decade	Yes	Yes	US EPA guidance followed except only the most recent ten years of data utilized
US EPA Guidance Aggregate Decadal Medians	Yes	Yes	1) Median of annual percentiles reduced to decadal medians by waterbody 2) Decadal medians by waterbody reduced to aggregate decadal medians

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

Culturally Significant Waters of the Cherokee Nation are a definable Designated Use under the U.S. Clean Water Act. The draft Tribal Water Quality standard definition of CSWs provides a sufficient designated use for Cherokee Nation's CSWs, and is recommended to be adopted by the Cherokee Nation. The community UAA surveys identified 10 Culturally Significant Waterbodies with publicly available data necessary to determine a numerical nutrient criterion for the Cherokee Nation. Two Oklahoma Scenic Rivers were added to the data set for a total of 12 water bodies investigated

Culturally Significant Waters of the Cherokee Nation are protected, in part, from excess nutrient by the Oklahoma Scenic Rivers total phosphorus criterion of 0.037 mg/L. US EPA numerical nutrient guidance decadal annual median calculations for Cherokee Nation's Culturally Significant Waters supported the Oklahoma Scenic Rivers criterion based on the assumption that the 25th percentile of the general population of water quality data represented reference conditions. However, biological responses for the Cherokee Nation CSWs in the form of benthic algae data were unavailable to validate excess nutrients would or would not occur. The US EPA assumptions are arbitrary and should not be used without weight of evidence considerations to validate the numerical criterion. The US EPA reduction process would have more validity if, for example, five decades of sufficient data were required for single decadal medians of percentiles. In addition, aesthetics were also a measurable response with respect to percent algal cover to determine if CSW designated water uses were impaired. Suplee et al. (2009) determined 100 mg/m^2 benthic Chl *a* represented approximately 20 percent cover, which was assumed to meet the Cherokee Nation's CSW specific needs.

Although the Regional Technical Advisory Group majority report supported the existing criterion as adequate to protect Oklahoma's Scenic Rivers from excess nutrients, the literature findings, historical data analysis, US EPA data reduction guidance and literature algal response models indicated Cherokee Nation's CSWs may still be at risk from excessive algae.

The Lee Creek 75th percentile, 0.016 mg/L TP, for the three alternative methods is recommended to protect Cherokee Nation CSWs. The recommended criterion was similar to the US EPA aggregate Nutrient Ecoregion XI recommended TP criterion of 0.010 mg/L. The recommended criterion of 0.016 mg/L TP minimizes the risk of exceeding 100 mg/m^2 Chl *a* for both the Michaelis-Menten algal growth rate and the Dodds (2006) thresholds.

To further minimize risk from excess nutrient impacts in the Cherokee Nation, a numerical criterion for benthic Chl *a* is recommended. If benthic Chl *a* is added to the numerical nutrient criteria standards, additional algal field sampling will be required by the Cherokee Nation, State of Oklahoma or Federal agencies. Agencies should coordinate data collection activities to ensure consistency in sampling methods to create a legally defensible data set.

To strengthen a legally defensible standard to protect CSWs in the Cherokee Nation from excess nutrients, a comprehensive survey should be completed to further define and identify CSW. Since CSWs are of national significance, all waters requiring significant protections for cultural and ceremonial activities of the Cherokee Nation should be identified, characterized and analyzed.

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APPENDIX A

US ENVIRONMENTAL PROTECTION AGENCY-APPROVED

TRIBAL WATER QUALITY STANDARDS

US Environmental Protection Agency-Approved Tribal Water

Quality Standards (US EPA, 2006a; US EPA 2015)

Indian Tribal Approvals for the Water Quality Standards Program				
Tribe	**US EPA Region**	**Date of US EPA File for TWQS**	**Date Found Eligible to Administer a WQS Program**	**Date Initial WQS Approved by US EPA**
Pueblo of Isleta (NM)	6	18 March 2002	13 Oct 1992	24 Dec 1992
Pueblo of Sandia (NM)	6	29 Oct 1991	24 Dec 1992	10 Aug 1993
Ohkay Owingeh (Pueblo of San Juan) (NM)	6	6 July 2006	12 May 1993	16 Sep 1993
Puyallup Tribe of Indians (WA)	10	22 Aug 1994	25 May 1994	31 Oct 1994
Seminole Tribe (FL)	4	18 April 2000	01 Jun 1994	26 Sep 1997 (Big Cypress Reservation) 18 Nov 1998 (Brighton Reservation)
Miccosukee Tribe (FL)	4	6 Oct 1999	20 Dec 1994	25 May 1999 15 Mar 2001 (Miccosukee Reserve Area)
Confederated Salish and Kootenai Tribes of the Flathead Reservation (MT)	8	11 April 2006	01 Mar 1995	18 Mar 1996
Confederated Tribes of the Chehalis Reservation (WA)	10	15 Feb 1996	07 Mar 1995	03 Feb 1997
Pueblo of Santa Clara (NM)	6	5 Oct 2002	19 Jul 1995	19 Jul 1995
Pueblo of Picuris (NM)	6	May 2000	07 Aug 1995	07 Aug 1995
Pueblo of Nambe (NM)	6	7 April 2006	18 Aug 1995	18 Aug 1995

Mole Lake Band of the Lake Superior Tribe of Chippewa Indians, Sokaogan Chippewa Community (WI)	5	26 Jan 2005	29 Sep 1995	22 Jan 1996
Pueblo of Pojoaque (NM)	6	Sept 1999	21 Mar 1996	21 Mar 1996
Tulalip Tribes (WA)	10		09 May 1996	
Fond du Lac Band of Chippewa (MN)	5	11 Sept 2001	16 May 1996	27 Dec 2001
Hoopa Valley Tribe	9	6 Dec 2001	17 May 1996	11 Sep 2002
Grand Portage Band of Chippewa (MN)	5	8 Aug 2006	16 Jul 1996	02 Nov 2005
Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation (MT)	8	3 Feb 1998	29 Aug 1996	25 Apr 2000
White Mountain Apache Tribe (AZ)	9	27 March 2000	03 Feb 1997	27 Sep 2001
Pueblo of Tesuque (NM)	6	28 Oct 2005	29 Apr 1997	29 Apr 1997
Confederated Tribes of the Warm Springs Reservation (OR)	10	21 March 2006	25 May 1999	28 Sep 2001
Pueblo of Acoma (NM)	6	15 Dec 2005	17 Apr 2001	17 Apr 2001
Confederated Tribes of Umatilla (OR)	10	1 Sept 1999	30 Apr 2001	18 Oct 2001
Spokane Tribe of Indians (WA)	10	7 March 2003	23 Jul 2002	22 Apr 2003
St. Regis Band of Mohawk Indians NY)	2	14 Sept 2007	16 Oct 2002	14 Sep 2007

Kalispel Indian Community (WA)	10	18 March 2003	04 Nov 2002	24 Jun 2004
Port Gamble S'Klallam (WA)	10	13 Aug 2002	24 Sept 2003	27 Sept 2005
Makah Indian Nation (WA)	10	30 Sept 2006	23 Dec 2003	29 Sept 2006
Hualapai Indian Tribe (AZ)	9	12 Feb 2004	22 Jul 2004	17 Sept 2004
Pawnee Nation (OK)	6	29 April 1998	04 Nov 2004	
Coeur D'Alene Tribe (ID)	10	05 Aug 2005		12 June 2014
Ute Mountain Ute (CO)	8		26 Sept 2005	19 Oct 2011
Big Pine Band of Owens Valley (CA)	9	Nov 2005	24 Oct 2005	18 Jan 2006
Pueblo of Taos (NM)	6	13 Aug 2002	08 Dec 2005	19 Jun 2006
Navajo Nation (AZ, NM, UT)	9		20 Jan 2006	11 Apr 2006
Paiute-Shoshone Indians of the Bishop Community (CA)	9		11 Apr 2006	15 Aug 2008
Northern Cheyenne (MT)	8		11 Aug 2006	21 Mar 2013
Twenty-Nine Palms (CA)	9		26 Oct 2006	20 Aug 2015
Pyramid Lake Paiute (NV)	9		30 Jan 2007	
Lummi Tribe (WA)	10		05 Mar 2007	30 Sep 2008
Lac du Flambeau Band of Chippewa (WI)	5		08 Apr 2008	17 Sep 2010
Swinomish Indian Tribal Community (WA)	10		18 Apr 2008	
Hopi Tribe (AZ)	9	8 July 2008	23 Apr 2008	08 Jul 2008
Shoshone-Bannock Tribes (ID)	10		5 Sep 2008	

Confederated Tribes of the Colville Reservation (WA)	10	7 July 2003	Not applicable	Promulgated 6 Jul 1989
Bad River Band of Lake Superior Chippewa (WI)	5	26 Jun 2009		21 Sep 2011
Blackfeet Tribe (MT)	8	2 May 2012		
Dry Creek Rancheria Band of Pomo Indians (CA)	9	17 Oct 2011		
Eastern Band of Cherokee Indians (NC)	4	26 Jan 2015		
Havasupai Tribe (AZ)	9	26 Apr 2011		
Pueblo of Santa Ana (NM)	6	20 Jul 2015		31 Aug 2015

APPENDIX B

LITERATURE FINDINGS SUMMARY OF

NUMERICAL NUTRIENT CRITERIA

TP (µg/L)	Statistical Measure	TN (mg/L)	Statistical Measure	Benthic Chl a (mg/m^2)	Statistical Measure	Study Years	Area Studied	Agency - Organization	Reference
-	-	-	-	9.1 - 396	Maximum Monthly Recorded Range		25 Temperate New Zealand Streams and Rivers	-	Biggs (2000)
-	-	-	-	0.73 - 81	Mean Monthly Recorded Range		25 Temperate New Zealand Streams and Rivers	-	Biggs (2000)
5.0 - 54.0	Average of 3 Replicates for 2 Sampling Days for Actual Conditions	0.231 - 0.996	Average of 3 Replicates for 2 Sampling Days for Actual Conditions	4.8 - 54.6	Average of 12 Rock Sample Collected from Open and Shaded Sections for Actual Conditions	July and August 1994	12 Snowmelt Fed Streams in the Lower Laurentian Mountains of Quebec	-	Bourassa and Cattaneo (1998)
6.0 - 130.0	Mean Concentration Range for Actual Conditions for 33 Samples	0.179 - 2.873	Mean Concentration Range for Actual Conditions for 30 Samples	9.0 - 470	Mean Concentration Range for Actual Conditions for 33 Samples	Summers of 1993, 1995 & 1996	13 Temperate Lowland Rivers in Southern Ontario & Western Quebec	-	Chetelat et al. (1999)
0.56	Mean Concentration for Actual Conditions for 33 Samples	0.50	Mean Concentration for Actual Conditions for 30 Samples	-	-	Summers of 1993, 1995 & 1996	13 Temperate Lowland Rivers in Southern Ontario & Western Quebec	-	Chetelat et al. (1999)
20	Cladophora Nuisance Growth	-	-	-	-	Summers of 1993, 1995 & 1996	13 Temperate Lowland Rivers in Southern Ontario & Western Quebec		Chetelat et al. (1999)
< 20	"healthy surface waters" (p. 42)	-	-	-	-	-	Unknown	-	Chin (2006)
22	Relative undeveloped, flow-weighted median	0.01	Relative undeveloped, flow-weighted median	-	-	-	U.S.	-	Clark et al. (2000)
20	Nuisance growth were defined as 150 mg/m2 Periphyton Maximum	300	Nuisance growth were defined as 150 mg/m2 Periphyton Maximum	-	-	-	Streams	-	Clark Fork River (1998)
-	-	-	-	> 100	Nuisance growth when 100 mg/m^2 exceeded more than 30% of time	-	Rivers and Streams	Case Study Comparison	Dodds (2006)

59.0	Intercept of Multiple Linear Regression Models Based on Actual Land Use	0.659	Intercept of Multiple Linear Regression Models Based on Actual Land Use	-	-	Multiple Data Sets - Earliest 1970	Ecoregion IV	Kansas (Kings Creek) and USGS Data	Dodds and Oakes (2004)
31.0	Intercept of Multiple Linear Regression Models Based on Actual Land Use	0.370	Intercept of Multiple Linear Regression Models Based on Actual Land Use	-	-	Multiple Data Sets - Earliest 1970	Ecoregion IX	Kansas (Kings Creek) and USGS Data	Dodds and Oakes (2004)
43.0	Intercept of Multiple Linear Regression Models Based on Actual Land Use	1.102	Intercept of Multiple Linear Regression Models Based on Actual Land Use	-	-	Multiple Data Sets - Earliest 1970	Ecoregion XI	Kansas (Kings Creek) and USGS Data	Dodds and Oakes (2004)
60.0	Maximum for Streams and Rivers	0.600	Maximum for Streams and Rivers	-	-	Multiple Data Sets - Earliest 1970	Overall Recommendation	Kansas (Kings Creek) and USGS Data	Dodds and Oakes (2004)
59	Forested Streams in Lesser Developed Basins	0.659	Forested Streams in Lesser Developed Basins	-	-	-	Nutrient Ecoregion IV	-	Dodds and Oakes (2004)
31	Forested Streams in Lesser Developed Basins	0.37	Forested Streams in Lesser Developed Basins	-	-	-	Nutrient Ecoregion IX	-	Dodds and Oakes (2004)
43	Forested Streams in Lesser Developed Basins	1.102	Forested Streams in Lesser Developed Basins	-	-	-	Nutrient Ecoregion XI	-	Dodds and Oakes (2004)
60.0	Benthic Chl *a* < 100 mg/m^2 'most of the time'	0.47	Benthic Chl a < 100 mg/m^2 'most of the time'	Most of the Time' < 100	-	-	Literature Review Findings	-	Dodds and Welch (2000)
20.0	Tri-State Implementation Council, Clark Fork Voluntary Nutrient Reduction Program	0.30	Tri-State Implementation Council, Clark Fork Voluntary Nutrient Reduction Program	-	-	-	Clark Fork River, Montana	State of Montana	Dodds and Welch (2000)
38-90	Nuisance growth were defined as 100-200 mg/m^2 Periphyton Maximum	0.275-0.650	Nuisance growth were defined as 100-200 mg/m^2 Periphyton Max	100 - 200 Maximum	Nuisance Growth	-	Clark Fork River, Montana	State of Montana	Dodds et al. (1997)
30	Mean Reference Level &	0.35	Mean Reference Level &	< 150	-	-	Clark Fork River, Montana	State of Montana	Dodds et al. (1997)

	Suggested Target Level to Control Algae		Suggested Target Level to Control Algae						
35	Global Data Regression Analysis for Max 100 mg/m^2 Chl *a*	0.252	Global Data Regression Analysis for Max 100 mg/m^2 Chl *a*	< 100	-	-	Clark Fork River, Montana	State of Montana	Dodds et al. (1997)
20	Breakpoint in Algal Response - No Risk of 150 mg/m^2 Chl *a*	0.2	Breakpoint in Algal Response - No Risk of 150 mg/m^2 Chl *a*	<< 150	-	-	Clark Fork River, Montana	State of Montana	Dodds et al. (1997)
75	Eutrophy were defined as 200 mg/m2 Periphyton Maximum	1.5	Eutrophy were defined as 200 mg/m2 Periphyton Maximum	-	-	-	Streams	-	Dodds et al. (1998)
87.0	Current Median Concentration for 341 River Stations during Summer Months with 67% Exceeding US EPA Reference Median	0.956	Current Median Concentration for 65 River Stations during Summer Months with 100% Exceeding US EPA Reference Median	-	-	Unknown	Ecoregion IV	US EPA STORET & USGS Databases Used	Dodds et al.(2008)
80.0	Current Median Concentration for 2,104 River Stations during Summer Months with 68% Exceeding US EPA Reference Median	1.457	Current Median Concentration for 274 River Stations during Summer Months with 99% Exceeding US EPA Reference Median	-	-	Unknown	Ecoregion IX	US EPA STORET & USGS Databases Used	Dodds et al.(2008)
22.0	Current Median Concentration for 1,591 River Stations during Summer Months with 53% Exceeding US EPA Reference Median	0.712	Current Median Concentration for 290 River Stations during Summer Months with 94% Exceeding US EPA Reference Median	-	-	Unknown	Ecoregion XI	US EPA STORET & USGS Databases Used	Dodds et al.(2008)
55.0	Mean Benthic Chl *a* < 50 mg/m^2	0.47	Mean Benthic Chl *a* < 50 mg/m^2	Mean < 50	-	-	-	-	Dodds et al. (1997)

< 10	Oligotrophic Stream	-	-	-	-	-	Surface Waters	-	Dojlido and Best (1993)
10-35	Mesotrophic Stream	-	-	-	-	-	Surface Waters	-	Dojlido and Best (1993)
> 35	Eutrophic Stream	-	-	-	-	-	Surface Waters	-	Dojlido and Best (1993)
-	Linked to non-Hodgkin lymphoma	4 (Nitrates)	Linked to non-Hodgkin lymphoma	-	-	-	Drinking Water Study	-	US EPA (2000)
-	Human Health	10,000 (Nitrates)	Human Health	-	-	-	Any Water	-	US EPA (2006c)
0.1	Criteria Continuous Concentration (CCC)	-	Criteria Continuous Concentration (CCC)	-	-	-	Sea Water	-	US EPA (2006c)
2200	Nitrate, Nitrite, Ammonia & Kejldahl Nitrogen Summed	51.6	Nitrate, Nitrite, Ammonia & Kejldahl Nitrogen Summed	-	-	-	1989 UK Standards	-	Fifield and Haines (1995)
3.0 - 103	25th Percentile of Median Concentrations for All Data	0.84 - 2.15	25th Percentile of Median Concentrations for All Data	-	-	1973 - 2001	Ozark Highland Ecoregion 39 Oklahoma, only	USGS & OWRB Study	Haggard et al. (2003)
0.0 - 770	Actual Median Concentrations (Min./Max.) for All Data	0.15 - 6.18	Actual Median Concentrations (Min./Max.) for All Data	-	-	1973 - 2001	Ozark Highland Ecoregion 39 Oklahoma, only	USGS & OWRB Study	Haggard et al. (2003)
10.0 - 69.0	25th Percentile of Median Concentrations for All Data	0.22 - 0.73	25th Percentile of Median Concentrations for All Data	-	-	1973 - 2001	All Oklahoma and Part of Arkansas	USGS & OWRB Study	Haggard et al. (2003)
0.0 - 1315	Actual Median Concentrations (Min./Max.) for All Data	0.00 - 7.49	Actual Median Concentrations (Min./Max.) for All Data	-	-	1973 - 2001	All Oklahoma and Part of Arkansas	USGS & OWRB Study	Haggard et al. (2003)
20 – 6,000	“Range and Typical Concentrations for Water Quality Parameters in Streams and Rivers”	0.1 - 10	“Range and Typical Concentrations for Water Quality Parameters in Streams and Rivers”	-	-	-	1963 Data	-	Maidment (1993)
20 – 6,000		0.1 - 10	Tables 11.1.3 “Range and	-	-	-	Data sites were unknown but appear	-	Maidment (1993)

			Typical Concentrations for Water Quality Parameters in Streams and Rivers”				to exclude heavily polluted rivers.		
10 - 3,000		0.004 – 100 plus	Tables 11.1.3 “Range and Typical Concentrations for Water Quality Parameters in Streams and Rivers”	-	-	-	Data sites were unknown but appear to exclude heavily polluted rivers.	-	Maidment (1993)
approx. 10	Flow-Weighted 25th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped/ Reference Watersheds)	approx. 1.5	Flow-Weighted 25th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	-	-	1992 - 2001	Ecoregion IV	USGS National Water-Quality Assessment (NAWQA) Program (Ozark Plateau)	Mueller and Spahr (2006)
approx. 150	Flow-Weighted 75th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped/ Reference Watersheds)	approx. 2.8	Flow-Weighted 75th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	-	-	1992 - 2001	Ecoregion IV	USGS National Water-Quality Assessment (NAWQA) Program (Ozark Plateau)	Mueller and Spahr (2006)
approx. 30	Flow-Weighted 25th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	approx. 0.40	Flow-Weighted 25th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped/ Reference Watersheds)	-	-	1992 - 2001	Ecoregion IX	USGS National Water-Quality Assessment (NAWQA) Program (Ozark Plateau)	Mueller and Spahr (2006)

approx. 80	Flow-Weighted 75th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped/ Reference Watersheds)	approx. 0.5	Flow-Weighted 75th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	-	-	1992 - 2001	Ecoregion IX	USGS National Water-Quality Assessment (NAWQA) Program (Ozark Plateau)	Mueller and Spahr (2006)
approx. 22	Flow-Weighted 25th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	approx. 0.38	Flow-Weighted 25th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	-	-	1992 - 2001	Ecoregion XI	USGS National Water-Quality Assessment (NAWQA) Program (Ozark Plateau)	Mueller and Spahr (2006)
approx. 50	Flow-Weighted 75th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	approx. 1.0	Flow-Weighted 75th Percentile Concentrations Regression Models Based on Actual NAWQA Data (Undeveloped /Reference Watersheds)	-	-	1992 - 2001	Ecoregion XI	USGS National Water-Quality Assessment (NAWQA) Program (Ozark Plateau)	Mueller and Spahr (2006)
approx. 75.0	Undeveloped Land Use 75th Percentile	approx. 0.75	Undeveloped Land Use 75th Percentile	-	-	1992 - 2001	All Data for Undeveloped Watersheds	USGS National Water-Quality Assessment (NAWQA)	Mueller and Spahr (2006)
10.0 - 2160.0	Actual Mid Monthly Median Concentrations (Min./Max.) for All Data Reported	0.34 - 13.18	Actual Mid Monthly Median Concentrations (Min./Max.) for All Data Reported	-	-	1961 - 1999 (Available Data Varied)	Data from 234 sites across 14 Nutrient Ecoregions in upper Midwest U.S. temperate streams for watersheds ranging from 1.5 to 11,628.9 square miles	Variety of data sources including USGS NAWQA	Robertson et al. (2001)
20.0 -	25th Percentile	0.51 - 1.75	25th Percentile	-	-	1961 - 1999	Data from 234 sites	Variety of data	Robertson et

110.0	Range for General Population		Range for General Population			(Available Data Varied)	across 14 Nutrient Ecoregions in upper Midwest U.S. temperate streams for watersheds ranging from 1.5 to 11,628.9 square miles	sources including USGS NAWQA	al. (2001)
170	Mean for General Population	3.610	Mean for General Population	-	-	1961 - 1999 (Available Data Varied)	Data from 234 sites across 14 Nutrient Ecoregions in upper Midwest U.S. temperate streams for watersheds ranging from 1.5 to 11,628.9 square miles	Variety of data sources including USGS NAWQA	Robertson et al. (2001)
110	Median for General Population	2.260	Median for General Population	-	-	1961 - 1999 (Available Data Varied)	Data from 234 sites across 14 Nutrient Ecoregions in upper Midwest U.S. temperate streams for watersheds ranging from 1.5 to 11,628.9 square miles	Variety of data sources including USGS NAWQA	Robertson et al. (2001)
82	Median for General Population	1.452	Median for General Population	-	-	1972 to 1975	Nutrient Ecoregion IV over 52 sample sites	NES Data (No Point Sources)	Rohm et al. (2002)
40	Median for General Population	0.881	Median for General Population	-	-	1972 to 1975	Nutrient Ecoregion IX over 227 sample sites	NES Data (No Point Sources)	Rohm et al. (2002)
22	Median for General Population	0.894	Median for General Population	-	-	1972 to 1975	Nutrient Ecoregion XI over 164 sample sites	NES Data (No Point Sources)	Rohm et al. (2002)
60	Fully Forested Streams in Undeveloped Basins	0.095	Fully Forested Streams in Undeveloped Basins	-	-	-	Nutrient Ecoregion IV	-	Smith et al. (2003)
48	Fully Forested Streams in Undeveloped Basins	0.15	Fully Forested Streams in Undeveloped Basins	-	-	-	Nutrient Ecoregion IX	-	Smith et al. (2003)
20	Fully Forested	0.156	Fully Forested	-	-	-	Nutrient Ecoregion	-	Smith et al.

	Streams in Undeveloped Basins		Streams in Undeveloped Basins				XI		(2003)
60	Fully Forested Streams in Undeveloped Basins	0.095	Fully Forested Streams in Undeveloped Basins	-	-	-	Nutrient Ecoregion IV	-	Smith et al. (2003)
48	Fully Forested Streams in Undeveloped Basins	0.15	Fully Forested Streams in Undeveloped Basins	-	-	-	Nutrient Ecoregion IX	-	Smith et al. (2003)
20	Fully Forested Streams in Undeveloped Basins	0.156	Fully Forested Streams in Undeveloped Basins	-	-	-	Nutrient Ecoregion XI	-	Smith et al. (2003)
30	Maximum nutrient to avoid nuisance algae risks.	1.000	Maximum nutrient to avoid nuisance algae risks.	> 20% avg. & > 40% max.	Defined as nuisance algae and happens for less than 10% of streams	1996 & 1997	104 streams over 2 month period for 1st through 4th order streams in North Central U.S. and northwest Kentucky and Michigan	-	Stevenson et al. (2006)
10.0 - 30.0	Observed Nutrient Inputs Creating an Algal Response	0.400 - 1.000	Observed Nutrient Inputs Creating an Algal Response	-	-	1996 & 1997	104 streams over 2 month period for 1st through 4th order streams in North Central U.S. and northwest Kentucky and Michigan	-	Stevenson et al. (2006)
≤ 11	Oligotrophic Reference Value for Streams and Rivers	≤ 0.400	Oligotrophic Reference Value for Streams and Rivers	10.0 - 20.0	Oligotrophic Reference Value for Streams and Rivers	1996 & 1997	104 streams over 2 month period for 1st through 4th order streams in North Central U.S. and northwest Kentucky and Michigan	-	Stevenson et al. (2006)
10.0 - 20.0	Cladophora Nuisance Growth	-	-	-	-	-	Streams	-	Stevenson un-published data (US EPA 2000d)
48	Calculated summer (May-September) arithmetic mean	-	-	-	-	Unknown Years - Summer (May-	116 temperate streams from across the world but primarily from North	24 published or unpublished sources	Van Nieuwenhuyse and Jones (1996)

	25th percentile					September)	America for phytoplankton response		
16.0 - 138.0	Mean Nutrient Concentration	-	TN not measured	< 100	Filamentous Algae Cover Less than 20%	April - September 1984	22 Northwestern U.S. and Swedish Streams	-	Welch et al. (1988)
19	25th Percentile of Median Concentrations for All Data	0.44	25th Percentile of Median Concentrations for All Data	6.0 Closed Canopy; 7.2 Open Canopy	25th Percentile of Median Concentrations for All Data	2001, 2003 & 2004	65 Massachusetts USGS 1st through 4th order River and Stream Locations with Varied Anthropogenic Impacts	USGS Data	Zimmer-man and Campo (2007)
17.0 - 37.0	25th Percentile of Median Concentrations Range for All Data	0.369 - 0.710	25th Percentile of Median Concentrations Range for All Data	4.325 - 8.25 Closed Canopy; 4.725 - 8.75 Open Canopy	25th Percentile of Median Concentrations Range for All Data	2001, 2003 & 2004	65 Massachusetts USGS 1st through 4th order River and Stream Locations with Varied Anthropogenic Impacts	USGS Data	Zimmer-man and Campo (2007)

APPENDIX C

SAMPLE USE SURVEY

Cherokee Cultural Use of Waters
Blank Survey

Site Description

Oklahoma Stream Name:

Cherokee Stream Name:

Date & Time:

Site Description/Name:

Community/Town & County:

Legal Description:

Stream Description

Flow (upstream/downstream/pools/riffles)*:*

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other)*:*

River/Stream Type (permanent flow/permanent water/seasonal water)*:*

Personal Significance & Use (Role in Community)*:*

Current Quality of Water (appearance, taste, odor, color)*:*

Past Quality of Water (appearance, taste, odor, color)*:*

Family Memory of Quality of Water (appearance, taste, odor, color)*:*

Family Memory of Use of Water (appearance, taste, odor, color)*:*

APPENDIX D

VISUAL BASIC FUNCTIONS

Visual Basic Functions

3-month Rolling Geometric Mean

```
Function Geometric(oCalcDate As Range, oVal As Range, oSampleDate As
                                          Range) As Variant
    Dim dEnd As Date, dStart As Date
    Dim i As Integer, iCalcCol As Integer, iSampleCol As Integer, n As Integer
    Dim iFirstDateRow As Integer, iLastDateRow As Integer, bFirst As Boolean

        Application.Volatile False
    dEnd = oCalcDate.Value
    dStart = DateSerial(Year(dEnd), Month(dEnd) - 3, 1)
    iCalcCol = oCalcDate.Column
    iSampleCol = oSampleDate.Column
    With Cells(2, iSampleCol).Offset(n)
        Do While .Offset(n) < dEnd
            If .Offset(n) >= dStart And .Offset(n) < dEnd Then
                If bFirst = False Then
                    iFirstDateRow = .Offset(n).Row
                    bFirst = True
                End If
            End If
            n = n + 1
        Loop
        If bFirst = True Then iLastDateRow = .Offset(n - 1).Row
    End With
    If bFirst = False Then
        Geometric = "-"
    Else
        Geometric = WorksheetFunction.GeoMean(Range(Cells(iFirstDateRow,
                                          oVal.Column), Cells(iLastDateRow, oVal.Column)))
    End If
End Function
```

3-month Rolling Arithmetic Mean

```
Function ArithMean(oCalcDate As Range, oVal As Range, oSampleDate As
                                          Range) As Variant
    Dim dEnd As Date, dStart As Date
    Dim i As Integer, iCalcCol As Integer, iSampleCol As Integer, n As Integer
    Dim iFirstDateRow As Integer, iLastDateRow As Integer, bFirst As Boolean


    Application.Volatile False
```

```
    dEnd = oCalcDate.Value
    dStart = DateSerial(Year(dEnd), Month(dEnd) - 3, 1)
    iCalcCol = oCalcDate.Column
    iSampleCol = oSampleDate.Column
    With Cells(2, iSampleCol).Offset(n)
        Do While .Offset(n) < dEnd
            If .Offset(n) >= dStart And .Offset(n) < dEnd Then
                If bFirst = False Then
                    iFirstDateRow = .Offset(n).Row
                    bFirst = True
                End If
            End If
            n = n + 1
        Loop
        If bFirst = True Then iLastDateRow = .Offset(n - 1).Row
    End With
    If bFirst = False Then
        ArithMean = "-"
    Else
        ArithMean = WorksheetFunction.Average(Range(Cells(iFirstDateRow,
            oVal.Column), Cells(iLastDateRow, oVal.Column)))
    End If
End Function
```

APPENDIX E

ARKANSAS RIVER – SALLISAW, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Arkansas River**

Cherokee Stream Name:

Date & Time: **12/26/07**

Water Body Site Description/Name: **Arkansas River**

Community/Town & County: **Sallisaw, Sequoyah**

Legal Description and/or Lat/Long: **NE/4 SW/4 SW/4 Section 9, T10N R24E 35º 20’ 57” North, 94º 46’ 39” West**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Fish**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent flow**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Fishing**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current:

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX F

BARREN FORK – ELDON HILL, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Barren Fork**

*Cherokee Stream Name: **Iyohlii***

Date & Time: **02/12/08**

Water Body Site Description/Name:

Community/Town & County: **Bottom of Eldon hill**

Legal Description and/or Lat/Long:

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Downstream to Illinois River**

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **General fishing**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Fishing and general recreation**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current: **Clear but not for drinking. Summer time stream has a lot of bacteria although the stream continuously flows.**

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

I have only known the creek for 15 years and over that course, the river seems to have gotten 'dirtier'.

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

Recreational use and fishing.

APPENDIX G

BEATTY CREEK – DELAWARE COUNTY, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Beaty Creek**

Cherokee Stream Name: ***Clouds Creek***

Date & Time: **02/21/08**

Water Body Site Description/Name:

Community/Town & County: **Delaware County, Oklahoma**

Legal Description and/or Lat/Long:

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Flows from East Arkansas into Lake Eucha**

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Frogs are almost gone**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent flow**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Crawdad hunting, church baptisms and swimming**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current: **Do not know**

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX H

BLACKBIRD CREEK – GIDEON, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Blackbird Creek**

Cherokee Stream Name:

Date & Time: **06/17/07, 4:30pm**

Water Body Site Description/Name: **Creek**

Community/Town & County: **Gideon, OK**

Legal Description and/or Lat/Long: **36° 01' 40.82" N, 95° 02' 55.69" W**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Crawdads**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current:

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Harvest Crawdads**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current: **Clear & Flowing**

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX I

FOURTEEN MILE CREEK – GIDEON, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Fourteenmile Creek**

Cherokee Stream Name:

Date & Time: **07/07/07, 7:00am**

Water Body Site Description/Name: **Tributary of Creek**

Community/Town & County: **Gideon**

Legal Description and/or Lat/Long: **36° 00’ 59.62” N, 95° 01’ 48.34” W**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Crawdads**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current:

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Harvest Crawdads**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current:

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX J

FOURTEEN MILE CREEK – MOODY, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Fourteenmile Creek**

Cherokee Stream Name:

Date & Time: **07/07/07, 8:30am**

Water Body Site Description/Name: **Tributary of Creek**

Community/Town & County: **Moodys**

Legal Description and/or Lat/Long: **36° 00’ 59.77 N, 94° 58’ 52.64”**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Crawdads**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current:

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Harvest Crawdads**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current: **Clear**

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX K

ILLINOIS RIVER – CHEWEY, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Illinois River**

Cherokee Stream Name:

Date & Time: **2/12/08, 9:30 am**

Water Body Site Description/Name: **WQM 121700**

Community/Town & County: **Chewey, OK**

Legal Description and/or Lat/Long: **36 06 14 N – 94 46 58 W**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Moderate/large stream, becoming wider and shallower**

Past (If there has been change, when did it occur?): **Moderate/large stream**

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):
Current: High biodiversity

Past (If there has been change, when did it occur?): **High biodiversity**

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent**

Past (If there has been change, when did it occur?): **Permanent**

Personal Significance & Use (Role in Community):

Current: **Fishing, gigging and aesthetics**

Past (If there has been change, when did it occur?): **Fishing, gigging**

Quality of Water (appearance, taste, odor, color):

Current: **High, but degrading**

Past (If there has been change, when did it occur?): **High water quality**

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur? **Beautiful stream with clean gravel bottoms, 1980's**

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur? **NA**

APPENDIX L

ILLINOIS RIVER – CHEROKEE NATION

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Illinois River**

Cherokee Stream Name:

Date & Time: **2/14/08 & 2/15/08**

Water Body Site Description/Name: **Cherokee Nation**

Community/Town & County:

Legal Description and/or Lat/Long:

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Cloudy and contaminated by humans**

Past (If there has been change, when did it occur?): **Clear**

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):
Current:

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent**

Past (If there has been change, when did it occur?): **Permanent**

Personal Significance & Use (Role in Community):

Current:

Ceremonial use – primary body contact and ingestion on a monthly basis

Past (If there has been change, when did it occur?):

Ceremonial use – primary body contact and ingestion on a monthly basis

Quality of Water (appearance, taste, odor, color):

Current: **Poor**

Past (If there has been change, when did it occur?): **High water quality**

Family Memory of Quality of Water (appearance, taste, odor, color):

Remembered as clear and usable for ceremonies and medicine

If there has been change, when did it occur?

Past 50 years

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

Always used for medicine and ceremonies

APPENDIX M

ILLINOIS RIVER – PETTIT BAY

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Pettit Bay**

Cherokee Stream Name:

Date & Time: **02/02/08, 2:30pm**

Water Body Site Description/Name: **Pettit Bay of Illinois River**

Community/Town & County: **Pettit, OK**

Legal Description and/or Lat/Long: **35° 45' 06.63" N, 94° 56' 54.96" W**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Bay**

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Fish (Crappie, Catfish, Sand Bass, etc.)**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current:

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Harvest Fish**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current: **Extremely Cloudy**
Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX N

ILLINOIS RIVER – TAHLEQUAH & PARK HILL, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Illinois River**

Cherokee Stream Name:

Date & Time: **2/19/08**

Water Body Site Description/Name:

Community/Town & County: **Tahlequah/ Park Hill area**

Legal Description and/or Lat/Long: **Sec 35 17N 22E Cherokee County**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Aquatic life seams to be healthy.**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current:

River is used for annual cleansing ceremony in July during the Greencorn Dance.

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current:

Late summer the river has bad odor and rocks are covered with green slime.

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

Over the years, the river has lost clarity and has become cloudy. In the late summer months algae thrives and the water becomes a health risk.

If there has been change, when did it occur?

In my opinion, the major changes to the river quality came about with the introduction of the Chicken industry on a large scale. Many of the large hay fields along the river valley, upstream from Tahlequah are fertilized 2 or 3 times a year with chicken manure and rains wash it into the river.

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

The most major change in using the river is accessibility. Many of the natural access areas have been closed off by landowners & it becomes a challenge to find access that is private enough for ceremony. Currently, we use an access area that belongs to the corps of engineers. There is a very small parking area, and a ½ mile walk to the water passed the walk through gate which the corps owns. The walking distance has made our annual water ceremony impossible for our eldest community members who are left behind during this time. If access was better, the elders would be able to attend.

If there has been change, when did it occur?

Access changes have probably occurred since statehood. In the last 10 years access has become more of a problem since the area population has grown.

APPENDIX O

LITTLE LEE'S CREEK – NICUT, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Little Lee's Creek**

Cherokee Stream Name:

Date & Time: **Feb. 20, 2008**

Water Body Site Description/Name: **Bradley Ford**

Community/Town & County: **Nicut Community, Sequoyah County**

Legal Description and/or Lat/Long:

SE ¼ of the NE ¼ lying south of the county road in Section 6, Township 13 North, Range 26 East, County of Sequoyah, State of Oklahoma

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Flows downstream has gentle pools for swimming and some rapids

Past (If there has been change, when did it occur?):

The stream has changed considerably over the past 75 years. The swimming hole is now shallow where it used to be deep, due to several different floods

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current:

There is an abundance of frogs, crawdads/ many dragonflies, water beetles and some fish

Past (If there has been change, when did it occur?):

Gradually over the years

River/Stream Type (permanent flow/permanent water/seasonal water):

Current:

Usually there is permanent water flow but during extreme periods of drought the water becomes stagnant

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Our family has been camping there for the past 80 years. We swim, we used to use the water for cooking. There is still one good spring for drinking water. We ride inner tubes, rafts and use paddle canoes. Bradley Ford is a favorite place for Baptizing used by many of the local churches. It is a popular swimming hole used all summer long by Cherokees from Belfonte, Bell, Nicut, and Short. Many people camp here for several days at a time.

Current:

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current:

The water still looks good most of the time.

Past (If there has been change, when did it occur?):

Some of our family are fisherman and became concerned about fishing upstream about two years ago when they noticed an area below the Sanitary Landfill that had about a quarter mile of white sudsy foam and many dead fish. This concerned all of us.

Family Memory of Quality of Water (appearance, taste, odor, color):

We remember when it was so clean and we were not afraid to use the water for cooking or to make coffee. Now we don't even want to wash our vegetables in it.

If there has been change, when did it occur?

It has gradually changed over the years, however only slightly

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX P

SALINE CREEK – KENWOOD, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Saline Creek**

Cherokee Stream Name:

Date & Time: **02/12/08**

Water Body Site Description/Name:

Community/Town & County: **Kenwood**

Legal Description and/or Lat/Long: **Lat - 36.28528 Long - -95.09028**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Various pools such as "Blue hole"**

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Crayfish, perch, catfish**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent flow**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Recreational and fishing**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current: **Clear water, little odor but not for drinking**
Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur? Water was very clear and used for drinking about 30 years ago.

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur? Saline Creek used to be used as a main source of drinking water about 30 + years ago. Also used as a general source for fishing and gathering watercress for food and medicinal gathering of plants.

APPENDIX Q

SALLISAW CREEK - FLUTE SPRINGS, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Sallisaw Creek**

*Cherokee Stream Name: **Sallisaw Creek***

Date & Time: **2-12-08**

Water Body Site Description/Name: **Branch/Creek**

Community/Town & County: **Flute Springs**

Legal Description and/or Lat/Long: **sec. 7, township. 13, range 24**

Stream Description

Flow (upstream/downstream/pools/riffles):

> **pools are holding about 1 – 5 ft. water**
>
> Current:
>
> **Low water**
>
> Past (If there has been change, when did it occur?):
>
> **More water in the past.**

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

> Current:
>
> **Brown bass, black perch, black bass, red horse suckers and red fin perch.**
>
> Past (If there has been change, when did it occur?):
>
> **More fish were abundant.**

River/Stream Type (permanent flow/permanent water/seasonal water):

Current:

Creek catches excess water run off from various mountains.

Past (If there has been change, when did it occur?):

More water was available, perhaps due to less water reservoirs.

Personal Significance & Use (Role in Community):

Current:

Swimming is the majority usage of the creek, cooking and fishing

Past (If there has been change, when did it occur?):

More fishing for food was utilized, seems less waterweed were available.

Quality of Water (appearance, taste, odor, color):

Current:

No scientific data. Taste is fine, odor – creek has unique odor, mud bottoms smell very bad. Color is clean perhaps due to filtration of sand & gravel.

Past (If there has been change, when did it occur?):

Change occurred about 20 years ago.

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

More availability of water, currently a lime plant and chicken house are with ¼ mile of the creek.

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

Creek Drink water was utilized about 30 years, ceremonial usage is occurred during cleansing and washing one's body during prayer.

APPENDIX R

SALLISAW CREEK – MARBLE CITY, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Sallisaw Creek**

Cherokee Stream Name:

Date & Time: **02/12/2008 15:30**

Water Body Site Description/Name:

Community/Town & County: **Marble City, Oklahoma**

Legal Description and/or Lat/Long:

Stream Description

Sallisaw Creek flows by the small community of Marble City Oklahoma. The creek flows year round and is used by the community for swimming fishing and bathing. My parents and grand parents caught fish and collected water cress to eat when I was a boy and the water was very clean.

The only industry close to Marble City is a limestone quarry around 1970 the owners put a kiln in their process to produce hot lime. The creek is used as a water supply for the kiln's water scrubber. The suction pump for the scrubber was placed in the favorite swimming hole for the Marble City community.

During the summer when water flows are low I have seen turtles with white lime waste on their shells and kicked up white sediments while walking along the creek.

Creek water was utilized about 30 years including ceremonial usage for cleansing and washing one's body during prayer.

APPENDIX S

SALLISAW CREEK – SALLISAW, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Sallisaw Creek**

Cherokee Stream Name:

Date & Time: **02/09/08**

Water Body Site Description/Name: **Sallisaw Creek**

Community/Town & County: **Sallisaw, Sequoyah**

Legal Description and/or Lat/Long: **NW/4 NE/4 NE/4 Section 15, T11N R23E 35º 26’ 02” North, 94º 51’ 08” West**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Fish**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent flow**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Fishing/Swimming**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current:

Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

APPENDIX T

SNAKE CREEK – LOCUST GROVE & SALINA, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Snake Creek**

Cherokee Stream Name: ***Inadvyi***

Date & Time: **02/12/08**

Water Body Site Description/Name:

Community/Town & County: **Locust Grove/Salina - Mayes County**

Legal Description and/or Lat/Long: **Lat /** 36.185556 - Long / **-95.086944**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Downstream to Grand Lake**

Past (If there has been change, when did it occur?):

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **Grayfish, perch and general aquatic life**

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current: **Recreational and fishing**

Past (If there has been change, when did it occur?):

Quality of Water (appearance, taste, odor, color):

Current: **Clear water with little odor but not for drinking.**
Past (If there has been change, when did it occur?):

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur? Mostly used for drinking water about 30+ years ago. Very clear.

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur? Used for fishing, plant gathering, and family gatherings.

APPENDIX U

SPAVINAW CREEK – JAY, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Spavinaw Creek**

Cherokee Stream Name:

Date & Time: **2/12/08 & 2/12/08, 9:00am**

Water Body Site Description/Name: **Located in Delaware Co. (WQM Segment 121600)**

Community/Town & County: **Located near Jay, Ok**

Legal Description and/or Lat/Long: **36° 20’ 9” N 94° 44’ 58” W**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current:

Stream flow consists of riffles and pools. The streams flows year round, unless we are in a drought.

Past (If there has been change, when did it occur?):

Changes to the stream occur during unusually high water events. This will changed the path of the stream, the placement of the riffles/pools/etc.

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current:

There are fish and minnows present, the larger fish dwell in the deeper pools of the stream. Crayfish and macroinvertebrates are present, as well as an abundant of wildlife surrounding the stream

Past (If there has been change, when did it occur?):

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **The stream flows year round (permanent flow)**

Past (If there has been change, when did it occur?):

Personal Significance & Use (Role in Community):

Current:

My family uses the creek for swimming/fishing/other purposes.

Fishing, gigging, aesthetics

Past (If there has been change, when did it occur?):

Fishing, gigging, crawfishing, swimming, camping and aesthetics

Quality of Water (appearance, taste, odor, color):

Current:

The stream does have algal blooms during the hottest parts of the summer (in some areas), but water cress does continue grow in the stream. The stream is still clear and odor free.

High, but degrading

Past (If there has been change, when did it occur?):

The Algal blooms are more recent, they started about 5 years ago.

High water quality

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur?

Early 1980's

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur?

Algal blooms in the last 5 years

The stream has been used as a water source during times of power outages for some people. Families gather at the stream for swimming and fishing. Some may even use it for ceremonial purposes (such as baptism).

APPENDIX V

SPAVINAW CREEK – SPAVINAW, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Spavinaw Creek**

Cherokee Stream Name:

Date & Time: **14 Feb 2008**

Water Body Site Description/Name:

Origin in Benton Co., AR; flows westward through Delaware Co., OK and Mayes Co., OK into Grand River (Lake Hudson) above Salina, OK

Community/Town & County:

Spavinaw, OK

Legal Description and/or Lat/Long:

36°23’12”N 95°03’21”W

Stream Description

Flow (upstream/downstream/pools/riffles):

> Current: **Regulated by Spavinaw Dam; backwater from Lake Hudson; shallow, gravel bed**
>
> Past (If there has been change, when did it occur?): **Unregulated prior to construction of Spavinaw Dam in 1920s**

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

> Current: **Limited fish species, including occasional sand bass with backwater from Lake Hudson; gar; soft shell turtle**
>
> Past (If there has been change, when did it occur?): **Unknown**

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Perennial stream, but heavily regulated.**

Past (If there has been change, when did it occur?): **Perennial, unregulated.**

Personal Significance & Use (Role in Community):

Current: **Role significantly diminished following construction of Spavinaw Dam; any economic benefit of Spavinaw Lake as a tourist destination offset by land purchases by City of Tulsa and refusal to develop.**

Past (If there has been change, when did it occur?): **Defining feature of Spavinaw, a Cherokee community that has been continuously inhabited for at least 150 years; Previously, supported more wildlife diversity, and was a clear mountain stream with high quality water.**

Quality of Water (appearance, taste, odor, color):

Current: **Intermittent turbidity, low dissolved oxygen content (intolerant for sensitive species, occasional visible algae**
Past (If there has been change, when did it occur?): **Clear, potable water; oxygenated.**

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur? **No memory prior to changes in watershed.**

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):
If there has been change, when did it occur? **No memory prior to changes in watershed. For historical account, however, see following text:**

Chronicles of Oklahoma

Volume 5, No. 3

September, 1927

LYNCH'S MILL WAS SPAVINAW'S NAME IN EARLY DAY HISTORY

Sawmill and Gristmill Made Up Village in Prewar Days

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(Printed in Tulsa Daily World, November 1, 1925.)

Responsive to the great general interest in the Spavinaw country, and made modern by the Tulsa water project, the fascinating history of the region is coming out. Recently the World carried a story about an old house near the Spavinaw dam; and it has brought out a very valuable contribution to the chronicles of Spavinaw.

John L. Springston, 83 years old, a Cherokee native of the Spavinaw valley, responds to the old house story with the story here printed. In a reminiscent way it touches the Wickliffes, the Rogers family, the Ross family, Lynch, Downing, the Thompsons and other historic characters of the Cherokee nation, alludes to the greatest church in the nation, reveals that a wonderful hot spring exists up the Spavinaw Creek and that wealth and cultured people lived about the old mills. Incidentally, Mr. Springston recalls the wonderful animal and bird life of the early days. He alludes to two of the famous missionaries to the nation and to the disasters of the Civil War.

The World is glad that it has been able to elicit a voluntary story of so much interest from a native of Spavinaw. W. B. Springston of the First National Bank, Tulsa, is a son of J. L. Springston.

By JOHN L. SPRINGSTON.

Spavinaw, as a place or locality, was originally known as Lynch's mill later taking the name of Spavinau or Spavinaw. A sawmill was the first improvement on the place and a gristmill was added soon afterward. Later a colony of Mormons from the north came and took over the sawmill and gristmill. They then put in a large mill building, two or three stories high, and also they put in a flouring mill. That was the status of the place up to the Civil War; it was Known as Lynch's mill.

West and north of the mill Thomas L. Rogers builded

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himself a house, and it yet stands. It was a two-roomed log house, one story high. I see in the paper that it was said to have been the home of one West,

which is a mistake. It was the home of Rogers during the improvement and building of the mill properties.
Salt works were opened south of the mill, at the foot of the hill that borders the town of Spavinaw on the south. Both of these properties were operated under the same management until the war began, 1861.
Joseph M. Lynch, the original owner of the mill and salt works, resided five or six miles north of the settlement, on what was then and now known as Lynch's Prairie, near Grand River. He was one of the leading citizens of the Cherokee nation and one of its best lawyers. He had three boys, but I recall the names of only two—Joe, Jr., and Lon. Joe later lived in Canadian district of the Cherokee nation and died there. Lon, after the war, lived in Flint district and died there.
Joseph M. Lynch was a slaveholder and one of his slaves was Boson, the tanner. Lynch had a tannery business until after the war. Mr. Lynch was a tanner, too. He tanned Boson's hide and then Boson would tan the cow. Mr. Lynch operated a large farm and was generally well-to-do.
Between the Lynch place and the mill lived a full-blood Cherokee Indian named Doo-stoo, or Spring Frog, a Baptist preacher, who also owned a large farm and was plentifully supplied with this world's goods.
From Lynch's home due south two miles lived Mrs. Elizabeth Elliott, grandmother of the writer. Lynch lived on the north side of the prairie and Mrs. Elliott on the south. Just west of the Elliott house lived one Elliott Towers.
West, the man alluded to in a recent article, lived below the mill. Now he lives about two miles down the creek. He owned and operated a large, fine farm. His wife was named Mahala and his four children, as I remember them in order, were Walter, Will, Laura and John.
About two miles west of the West home lived Anderson Benge and his wife, Susan, and two children—,James and Osceola. The latter now lives at or near Adair, on the M. K. & T. Railroad. West's wife was a McLaughlin.
Directly north of the mill lived Hiram Landrum, head
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of one of the prominent families of the nation. Hiram,.Jr., after the Civil War represented the Cherokees at Washington as national delegate. West of Hiram there lived another Landrum—David. This home was east and north of the present dam.

<u>The Wicklifes.</u>

East of the dam, up the Spavinaw Creek, a mile or so, lived John Wickliffe, father of the boys who were some years ago hunted as outlaws and who are now good citizens of the country in which they live.
Just up stream from the Wickliffes there lived an Indian who had a sort of zoo. He owned two black bears and kept them in a log house. They were the first in captivity in the Western Cherokee nation. He also had a parrot, which could not learn Cherokee. Therefore this parrot had to live without talking.
Still on above the parrot and bear house there lived one George Seven, fullblood. Then farther up the creek was the largest farm on the creek, owned by Anderson

Springston, father of the writer. One Sixkiller lived yet above that place. There is only one of this family now living, Moses Ridge, a Baptist minister near Salina.

Delaware Town.

The Anderson Springston farm was about nine miles above the dam. Two miles east of this place was the place called Delaware Town, where the Osages were originally located. The Delaware Tribe ran them out of the locality and located there themselves. Hence the name of Delaware Town.

Before the Cherokees, as a nation, moved west, the Osages occupied the territory from Delaware River to where Vinita is now located. They owned from Vinita down the present line of the Katy Railroad to opposite Wagoner, from there to Grand River, across to Illinois River, across the Illinois to Lee’s Creek, now in Sequoyah County, opposite Fort Smith, Arkansas. The drive against the Osages by the Cherokees began not long prior to 1838 and when the main body of the Cherokees emigrated west, the Osages were obliged to leave the Cherokee land and go further west for a location. They encamped for a while at Claremore, but eventually left the country.

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The National Church.

Delaware Town was the seat of the Baptist church, the largest in the nation at that time. It was 60 by 60 feet. The entire nation attended church there each year in September. The church was surrounded with small kitchens and sleeping booths prUS EPAred especially for the women folks of the advanced class in education and wealth. They were well taken care of during the progress of services.

Evans Jones and his son, John B. Jones, were the founders and pastors. They were missionaries and they did more for the uplifting and civilization of the Cherokees than all other denominational workers of the period. But the Civil War broke them down and affected the work they had given to the cause up too the time of the war. Neither of the missionaries lived to renew the work after the war, except for the establishment of the Bacone school, first at Tahlequah, later at Muskogee.

The original missionary station of the Baptist denomination was near where Westville, Oklahoma, now is. It was then known as the Baptist Mission. It long ago passed out of service.

Chief Downing a Preacher.

At Delaware Town church, especially in the month of September, every year, the people from all over the nation congregated. Lewis Downing, later principal chief of the nation, was one of the favorite ministers for these occasions. Captain Spring Frog was also a leader. Representatives of district churches throughout

the nation attended officially. Captain Thomas Pegg, one of the leading Cherokee ministers, was a national representative of his people.
It is understood that Thomas Rogers of Lynch's mill was the brother of Charles Rogers of Coo-wee-scoo-wee district, Cherokee nation. It is said that Hon. C. V. Rogers, father of the noted Will Rogers, was also a brother. This is partly surmise with the writer.
In the mountain region south and west of the dam, as well as on the ridges south and east, were deer, turkey, and fox ranges prior to the war. They were then plenty. During the fall and winter wild pigeons clouded the skies by millions.
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Sulphur Springs.

Just northeast from the home of the writer's father, nine miles or so above the present dam, are two great springs. One of them is sulphur, and quite strong. Prior to the Civil War it was the stamping ground of cattle and horses from sections for miles around. This was particularly true during the summer season.
Up the creek from the surphur spring about a mile and half there is a spring that beats the record for pure and cool water in the summer and heated water in the winter. This spring is located on the road that leads from the writer's old home to the schoolhouse he attended for eleven or twelve years.
Central Delaware district was the home of Charles Thompson, chief of the Cherokees from 1875 to 1879. This was in the Charles Landrum settlement, eleven miles east from the Delaware Town Baptist Church. This was Spavinaw Creek and the district courthouse was located there at one time.
Three miles south from the home of the writer was the home of Ne-cow-ee Thompson, brother of Chief Charles Thompson. He was one of the strongest friends the Indians ever had anywhere at any time. His loyalty and activity developed during the Civil War and this will be detailed later.
Some distance south of the dam lived Lewis Ross, brother of the great chief of the Cherokees. He had a fine home and extra large farm holdings. He was a slave-owner and had great herds of cattle and horses. His home was near Salina and debris is yet too be seen. The place became the Cherokee orphans' home and was burned down several years ago.
Above is some of the story of what was once Lynch's mill, later Spavinau, now Spavinaw, and the location of a great dam. This story also bears on the territory that was Going-Snake, Delaware and Saline districts of the Cherokee nation, later Indian Territory, now Oklahoma—once home of the original North American—Indians.
The Cherokee nation had but one fullblood principal chief—Charles Thompson who lived near the present location of the Spavinaw dam. He was one of the strong men of the nation and was for many years a trusted counselor of his
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people. Both he and his brother, Ne-cow-ee Thompson were men of great force of character and of decided ability. Both lived in the Spavinaw region.

APPENDIX W

SPRING CREEK – LOCUST GROVE, OK

Cherokee Cultural Use of Waters
Survey – Actual Response

Water Body Site Description

Oklahoma Stream Name: **Spring Creek**

Cherokee Stream Name: **Unknown**

Date & Time: **2/12/08, 9:15 am**

Water Body Site Description/Name: **WQM 121600**

Community/Town & County: **Locust Grove, OK**

Legal Description and/or Lat/Long: **36 08 26 N – 95 10 23 W**

Stream Description

Flow (upstream/downstream/pools/riffles):

Current: **Moderate sized stream, becoming wider and shallower**

Past (If there has been change, when did it occur?): **Unknown**

Aquatic Life (fish/plants/frogs/crawdads/snails/insects/other):

Current: **High biodiversity**

Past (If there has been change, when did it occur?): **High biodiversity**

River/Stream Type (permanent flow/permanent water/seasonal water):

Current: **Permanent**

Past (If there has been change, when did it occur?): **Permanent**

Personal Significance & Use (Role in Community):

Current:

Fishing, snorkeling, SCUBA diving, aesthetics

Past (If there has been change, when did it occur?):

None of the above before 2002

Quality of Water (appearance, taste, odor, color):

Current:

High, but degrading

Past (If there has been change, when did it occur?):

Unknown/high quality

Family Memory of Quality of Water (appearance, taste, odor, color):

If there has been change, when did it occur? **NA**

Family Memory of Use of Water (drinking water, ceremonial, gathering, etc.):

If there has been change, when did it occur? **NA**

APPENDIX X

STREAM ORDER, STREAM SLOPE, US ENVIRONMENTAL PROTECTION AGENCY (EPA) NUTRIENT ECOREGION AND US EPA LEVEL III ECOREGION WITH OKLAHOMA USE SUPPORT ASSESSMENT PROTOCOLS CALCULATIONS

See Microsoft Excel® file, ‘CN CSW SO SL NE LIII OK USAP Calculations.’

APPENDIX Y

MASONER ET AL. (2002) DESCRIPTIVE INFORMATION FOR CHEROKEE NATION'S CULTURALLY SIGNIFICANT WATERS

See Microsoft Excel® file, ‘Masoner et al (2002) Cherokee Nation CSW Table of Descriptive Information.’

APPENDIX Z

DUPLICATE SITES KEY

See Microsoft Excel File, ‘Duplicate Site Key for CN CSW.’

APPENDIX AA

US ENVIRONMENTAL PROTECTION AGENCY LEGACY-STORET ORIGINAL DATA SET

See Microsoft Excel® file, ‘L-STORET Original Data.’

APPENDIX AB

US ENVIRONMENTAL PROTECTION AGENCY LEGACY-STORET WATER QUALITY STATION DESCRIPTIONS

Station Name	Count
ARKANSAS RIVER DOWNSTREAM OF THE ILLINOIS RIVER / ARKANSAS RIVER MAINSTEM / ARKA	33
ARKANSAS RIVER UPSTREAM OF THE ILLINOIS RIVER / ARKANSAS RIVER / ARKANSAS RIVER	212
DRIPPING SPRINGS / ARKANSAS RIVER / ILLINOIS RIVER	2
FARM POND WHICH CATCHES RUNOFF / ARKANSAS RIVER / ILLINOIS RIVER	28
FLINT CREEK 1/8 MILE ABOVE ILLINOIS RIVER / SOUTHWESTERN LOWER MISS / ARKANSAS R	22
FLINT CREEK 1/8 MILE BELOW FAGEN CREEK / ARKANSAS RIVER / ILLINOIS RIVER	232
FLINT CREEK AT FIDLERS BEND / ARKANSAS RIVER / ILLINOIS RIVER	12
FLINT CREEK NEAR KANSAS / ARKANSAS RIVER / ILLINOIS RIVER	326
FT GIBSON LAKE MOUTH OF SPRING CREEK / SC LOWER MISSISSIPPI RIV / GRAND NEOSHO R	33
ILLINOIS RIVER 1/8 MILE BELOW FLINT CREEK / /	20
ILLINOIS RIVER ABOVE FLINT CREEK CONFLUENCE / ARKANSAS RIVER / ILLINOIS RIVER	274
ILLINOIS RIVER AT ARKANSAS RIVER CONFLUENCE / ARKANSAS RIVER / ILLINOIS RIVER	32
ILLINOIS RIVER AT CAMP PADDLETRAILS / ARKANSAS RIVER / ILLINOIS RIVER	242
ILLINOIS RIVER AT CHEWEY BRIDGE / ARKANSAS RIVER / ILLINOIS RIVER	272
ILLINOIS RIVER AT HIGHWAY 64 BRIDGE / ARKANSAS RIVER / ILLINOIS RIVER	327
ILLINOIS RIVER AT OLD MILITARY ROAD / ARKANSAS RIVER / ILLINOIS RIVER	33
ILLINOIS RIVER AT RIVERSIDE CAMP / ARKANSAS RIVER / ILLINOIS RIVER	4
ILLINOIS RIVER BELOW FIDLERS BND / ARKANSAS RIVER / ILLINOIS RIVER	8
ILLINOIS RIVER IN LAKE FRANCIS AT DAM / SO.CEN-LOWER MISSISSIPPI / ARKANSAS RIVE	58
LAKE FRANCIS / ARKANSAS RIVER / ILLINOIS RIVER	2
LAKE FRANCIS MIDDLE / ARKANSAS RIVER / ILLINOIS RIVER	2
LAKE FRANCIS UPPER END / ARKANSAS RIVER / ILLINOIS RIVER	2
LAKE TENKILLER DAM AREA / ARKANSAS RIVER / ILLINOIS RIVER	4
ROBT S KERR LOCK/DAM NR SALLISAW / ARKANSAS RIVER / ARKANSAS RIVER	494
SAGER CREEK 1.5 MILES ABOVE ILLINOIS RIVER / SOUTHWESTERN LOWER MISS / ARKANSAS	4
SAGER CREEK JUST ABOVE CONFLUENCE WITH ILLINO / ARKANSAS RIVER / ILLINOIS RIVER	220
SALLISAW CREEK NEAR SALLISAW / ARKANSAS RIVER / CANADIAN RIVER	24
SALLISAW STP / ARKANSAS RIVER / ROBERT S KERR RES	46
SALT BRANCH CREEK AT CARLISLE ROAD BRIDGE / ARKANSAS RIVER / ILLINOIS RIVER	33
SPAVINAW CREEK ATMENT PLANT / ARKANSAS RIVER / GRAND NEOSHO RIVER	10
SPAVINAW CREEK NEAR SYCAMORE / ARKANSAS RIVER / NEOSHO RIVER	22
STILLWELL CANNERY EXTENDED AREATION PLANT / ARKANSAS RIVER / ILLINOIS RIVER	17
STILLWELL FOODS / ARKANSAS RIVER / ILLINOIS RIVER	6
WESTVILLE STP / ARKANSAS RIVER / ILLINOIS RIVER	30
N=	3086

APPENDIX AC

US GEOLOGICAL SURVEY ORIGINAL DATA SET

For the USGS data, less than (<) indicated values were below the detection limit of the machine analyzing the samples. "E" identified the data were estimated, which was likely below the detection limit but above zero. All data marked with a less than (<) symbol or E were changed to an (*) and therefore were not included in the final database.

See Microsoft Excel® file, 'USGS Original Data.'

APPENDIX AD

US GEOLOGICAL SURVEY DATA SET WATER QUALITY STATION DESCRIPTIONS

USGS Site name	DMS latitude	DMS longitude	Decimal latitude	Decimal longitude	Hydrologic Unit Code (HUC)	Drainage area	Contributing drainage area	Water-quality data begin date	Water-quality data end date	Water-quality data count	Site-visit data begin date	Site-visit data end date	Site-visit data count
Arkansas River at Sand Springs , OK	360648	960649	36.11342146	-96.1138908	11110101	74615		10/21/1905	9/24/1980	2279	6/19/2002	6/6/2003	6
Arkansas River at Tulsa, OK	360826	960022	36.14064807	-96.0063866	11110101	74460	62811	10/18/1930	6/17/2010	2137	9/23/1982	3/5/2015	230
Arkansas River at Bixby, OK	355726	955310	35.9573207	-95.8863792	11110101			10/1/1948	9/25/1949	99	3/13/2002	6/6/2003	8
Snake Creek near Leonard, OK	355453	955000	35.914822	-95.8335992	11110101			8/22/1960	5/26/1961	9	--	--	0
Arkansas River near Haskell, OK	354922	953816	35.82277778	-95.6377778	11110101	75293	63645	5/15/1972	6/17/2010	390	9/21/1982	2/9/2015	251
Spavinaw Creek near Row, OK	361950	943727	36.33063538	-94.6243881	11070209	128		5/27/1959	7/21/1992	40	--	--	0
Spavinaw Creek near Sycamore, OK	362005	943829	36.3347222	-94.6413889	11070209	132	132	10/3/1972	3/26/2015	452	10/7/1963	2/5/2015	275
Beaty Creek near Jay, OK	362119	944634	36.35535924	-94.7763388	11070209	59.1	59.1	8/6/1991	3/26/2015	376	12/14/1992	3/17/2015	136
Spavinaw Creek near Jay, OK	362059	944710	36.349804	-94.786339	11070209			6/6/1958	9/17/1981	17	--	--	0
Spavinaw Creek near Spavinaw, OK	362315	950315	36.38758676	-95.0544057	11070209			8/30/1944	5/15/1951	13	--	--	0
Saline Creek at Kenwood, OK	361854	945755	36.31508657	-94.9655123	11070209			8/6/1991	2/5/1992	3	--	--	0
Little Saline Creek near Salina, OK	361645	950437	36.27925668	-95.0771824	11070209			8/6/1991	7/22/1992	6	--	--	0
Spring Creek near Locust Grove, OK	360854	950926	36.1484276	-95.1574613	11070209			8/7/1958	5/7/1959	9	--	--	0
Illinois River near Watts, OK	360748	943419	36.13008185	-94.5721645	11110103	630	630	9/12/1955	3/27/2015	661	5/7/1961	3/16/2015	228
Illinois R abv Flint Creek nr Flint, OK	361026	944314	36.1739728	-94.7207809	11110103			7/22/1996	9/20/2000	120	7/22/1996	9/20/2000	19
Flint Creek near West Siloam Springs, OK	361258	943619	36.2161111	-94.6052778	11110103	59.8		7/11/1979	2/12/2015	328	7/11/1979	11/28/2014	266
Flint Creek near Kansas, OK	361111	944224	36.18647245	-94.7068913	11110103	116	116	9/7/1955	3/26/2015	629	6/8/1974	1/23/2015	216
Illinois R blw Flint Creek nr Flint, OK	361025	944322	36.17369509	-94.7230032	11110103			7/18/1996	9/20/2000	123	7/18/1996	9/20/2000	19
Illinois River at Chewey, OK	360615	944657	36.1042527	-94.7827283	11110103	825	825	7/17/1996	3/16/2015	484	7/17/1996	4/1/2015	195
Illinois River nr Scraper, OK	360540	944947	36.09453169	-94.8299522	11110103			7/17/1996	9/14/2000	134	7/17/1996	9/14/2000	19
Illinois River near Moodys, OK	360154	945438	36.03175654	-94.9107885	11110103			1/30/2001	6/14/2002	78	1/30/2001	6/14/2002	14
Illinois R at No Head Hollow nr Tahlequah, OK	355802	945439	35.96731274	-94.9110661	11110103			7/17/1996	9/19/2000	108	7/17/1996	9/19/2000	18
Illinois River nr Briggs, OK	355634	945457	35.94286858	-94.9160659	11110103			7/16/1996	9/19/2000	100	7/16/1996	9/19/2000	18
Illinois River near Tahlequah, OK	355522	945524	35.92286888	-94.9235658	11110103	950	950	8/23/1955	3/16/2015	753	8/19/1980	2/18/2015	268
Illinois R blw Tahlequah Creek nr Tahlequah, OK	355301	945637	35.8837029	-94.9438437	11110103			7/23/1997	8/11/1999	45	7/23/1997	8/11/1999	5
Illinois River nr Park Hill, OK	355111	945455	35.85314696	-94.915509	11110103			7/19/1996	6/11/2002	177	7/19/1996	6/11/2002	26
Barren Fork near Barren, OK	355510	943710	35.919529	-94.6196669	11110103			4/30/1958	9/7/1959	17	--	--	0
Barren Fork at Eldon, OK	355516	945018	35.92120037	-94.8385633	11110103	312	312	5/7/1958	3/16/2015	631	9/16/1983	2/27/2015	224

Barren Fork at Welling, OK	355208	945352	35.8689798	-94.8980088	11110103			7/15/1996	6/28/2007	181	7/15/1996	12/20/2000	45
Snake Creek near Blackgum, OK	353815	945738	35.6375938	-94.9607862	11110103			10/29/1991	2/4/1992	3	--	--	0
Illinois River near Gore, OK	353423	950407	35.5731511	-95.0688458	11110103	1615	1615	4/12/1940	8/16/1995	801	10/9/1980	3/25/2015	267
Sallisaw Creek at Bunch, OK	354035	944520	35.6764787	-94.75578	11110104			5/7/1958	9/2/1959	32	--	--	0
Sallisaw Creek at Marble City, OK	353449	944935	35.58036999	-94.8266147	11110104			8/6/1991	7/21/1992	7	--	--	0
Sallisaw Creek near Sallisaw, OK	352752	945143	35.46453847	-94.8621712	11110104	182	182	10/11/1959	9/13/1977	73	--	--	0
Lee Creek at Short, OK	353357	943155	35.5658333	-94.5319444	11110104	236		8/30/1987	10/3/1988	3	8/27/1958	12/12/2014	113
Little Lee Creek near Nicut, OK	353911	943718	35.65314328	-94.621887	11110104			8/6/1991	7/21/1992	7	--	--	0
LITTLE LEE CREEK NEAR SHORT, OKLA.	353432	943320	35.5756436	-94.5557736	11110104	103		10/3/1988	10/3/1988	1	6/18/1958	10/3/1988	29
Lee Creek near Short, OK	353102	942751	35.5172222	-94.4641667	11110104	420		10/12/1995	3/11/2015	150	8/14/1992	10/29/2014	123

APPENDIX AE

OKLAHOMA WATER RESOURCES BOARD ORIGINAL DATA SET

See Microsoft Excel® file, ‘OWRB Original Data.’

APPENDIX AF

OKLAHOMA WATER RESOURCES BOARD DATA SET WATER QUALITY STATION DESCRIPTION

STATION_ID	ADB Number	SOURCE	DESCRIPTION	STATION_STATUS	LONG	LAT	LEGAL SECTION	LEGAL TOWNSHIP	LEGAL RANGE	LL_DATUM	HUC	County
120400010260-002SR	OK120400010260_00	Arkansas River	ARKANSAS RIVER, OFF US 62, MUSKOGEE	Inactive 6/01-12/03	-95.2628772	35.7411401	26	15N	19EI	NAD83	11110102010	Muskogee
120420010010-001SR	OK120420010010_00	Arkansas River	ARKANSAS RIVER, OFF I-244, TULSA	Inactive 6/01-12/03	-95.9923102	36.1317254	14	19N	12EI	NAD83	11110101020	Tulsa
120420010010-002SR	OK120420010010_00	Arkansas River	ARKANSAS RIVER, OFF US 75, JENKS	Inactive 6/01-12/03	-95.9210814	35.9737439	10	17N	13EI	NAD83	11110101020	Tulsa
FW08OK070	OK120400010260_00	Arkansas River (R)	Arkansas River (R)	Inactive 2011-2012	-95.2930630	35.7480120	28	15N	19EI	NAD83	11110102030	Muskogee
OKRM-1011	OK220200010010_00	Arkansas River	Arkansas River	Inactive 2013-2014	-94.4462599	35.3815330	33	11N	27EI	WGS84	11110104060	Sequoyah
120410010080-001AT	OK120410010080_00	Arkansas River	ARKANSAS RIVER, SH 104, HASKELL	Active 11/98-present	-95.6399526	35.8209555	32	16N	16EI	NAD83	11110101040	Muskogee
120420010010-001AT	OK120420010010_00	Arkansas River	ARKANSAS RIVER, US 64, BIXBY	Active 11/98-present	-95.8862256	35.9558531	13	17N	13EI	NAD83	11110101020	Tulsa
120420010130-001AT	OK120420010130_00	Arkansas River	ARKANSAS RIVER, SH 97, SAND SPRINGS	Inactive 9/99-2012	-96.1157834	36.1239387	14	19N	11EI	NAD83	11110101020	Tulsa
121400010260-001AT	OK120400010260_00	Arkansas River	ARKANSAS RIVER, US 62, MUSKOGEE	9/99-present	-95.3003110	35.7701607	21	15N	19EI	NAD83	11100102010	Muskogee
220200010010-001AT	OK220200010010_00	Arkansas River	ARKANSAS RIVER, OFF US 64, MOFFETT	Inactive 5/99-6/2011	-94.4326780	35.3924290	27	11N	27EI	NAD83	11110104050	Sequoyah
OKPB01-024	OK121700050010_00	Barren Fork River	Barren Fork River	Inactive 2005-2007	-94.6613500	35.9514900	17	17N	25EI	WGS84	11110103090	Adair
OKPB01-372	OK121600050160_00	Beaty Creek OKPB01-372	Beaty Creek	Inactive 2005-2007	-94.7318900	36.3669400	22	22N	24EI	NAD27	11070209050	Delaware
OKRM-1016	OK121700030010_00	Illinois River	Illinois River	Inactive 2013-2014	-94.9195326	35.9378991	24	17N	22EI	WGS84	11110103080	Cherokee
OKSS-1405	OK121700030080_00	Illinois River	Illinois River	Inactive 2013-2014	-94.9162180	35.9869668	1	01S	22EI	WGS84	11110103080	Cherokee
121600010290-001AT	OK121600010290_00	Spring Creek	SPRING CREEK, OFF US 412, MURPHY	Active 11/98-present	-95.1901560	36.1310424	16	19N	20EI	NAD83	11070209100	Mayes
121700030010-001AT	OK121700030010_00	Illinois River	ILLINOIS RIVER, US 62, TAHLEQUAH	Active 11/98-present	-94.9238037	35.9260645	26	17N	22EI	NAD83	11110103060	Cherokee
121700030350-001AT	OK121700030350_00	Illinois River	ILLINOIS RIVER, US 59, WATTS	Active 11/98-present	-94.5715123	36.1299406	18	19N	26EI	NAD83	11110103050	Adair
121700050010-001AT	OK121700050010_00	Barren Fork River	BARREN FORK, SH 51, ELDON	Active 11/98-present	-94.8372649	35.9217338	27	17N	23EI	NAD83	11110103090	Cherokee
121700060010-001AT	OK121700060010_00	Flint Creek	FLINT CREEK, US 412, FLINT	Active 11/98-present	-94.7068049	36.1867733	25	20N	24EI	NAD83	11110103060	Delaware
220200050010-001AT	OK220200050010_10	Lee Creek	LEE CREEK, SH 101, NEAR SHORT	Active 1/03-present	-94.5315272	35.5658987	34	13N	26EI	NAD83	11110104070	Sequoyah
220200050040-001AT	OK220200050040_00	Little Lee Creek	LITTLE LEE CREEK, SH 101, near NICUT	Active 09/07-present	-94.5600000	35.5800000	28	13N	26EI	NAD83	11110104070	Sequoyah
OKI06594-002	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.8988333	35.9469167	19	17N	23EI	WGS84	11110103080	Cherokee
OKI06594-005	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.8319167	36.0921944	26	19N	23EI	WGS84	11110103080	Cherokee
OKI06594-008	OK121700060010_00	Flint Creek	Flint Creek	Inactive 2007-2009	-94.9197300	36.2126100	15	20N	25EI	WGS84	11110103060	Delaware
OKI06594-009	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.7213611	36.1670833	35	20N	24EI	WGS84	11110103060	Delaware
OKI06594-012	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.5271200	35.9063900	34	17N	26EI	WGS84	11110103080	Adair
OKI06594-020	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.7258889	35.9599444	14	17N	24EI	WGS84	11110103060	Adair
OKI06594-021	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.8143889	36.1112778	24	19N	23EI	WGS84	11110103080	Cherokee
OKI06594-024	OK121700060010_00	Flint Creek	Flint Creek	Inactive 2007-2009	-94.5888900	36.2196400	13	20N	25EI	WGS84	11110103060	Delaware
OKI06594-031	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.6842800	35.9513100	18	17N	25EI	WGS84	11110103090	Adair
OKI06594-033	OK121700060010_00	Flint Creek	Flint Creek	Inactive 2007-2009	-94.6714200	36.2118600	17	20N	25EI	WGS84	11110103060	Delaware
OKI06594-038	UNKWN	Tributary to Barren Fork	Tributary to Barren Fork	Inactive 2007-2009	-94.8352900	35.9355000	22	17N	23EI	WGS84	11110103090	Cherokee
OKI06594-041	OK121700030290_00	Flint Creek	Flint Creek	Inactive 2007-2009	-94.7112500	36.1757778	35	20N	24EI	WGS84	11110103060	Cherokee
OKI06594-042	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.7945900	35.8857500	9	16N	23EI	WGS84	11110103090	Cherokee
OKI06594-047	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.6441400	35.9369700	21	17N	25EI	WGS84	11110103090	Adair
OKI06594-053	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.7560833	36.1335278	9	19N	24EI	WGS84	11110103060	Adair
OKI06594-057	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.7661944	36.1206667	16	19N	24EI	WGS84	11110103080	Adair
OKI06594-060	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.5830000	35.9040278	36	17N	25EI	WGS84	11110103060	Adair
OKI06594-061	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.9219572	36.0016267	36	18N	22EI	WGS84	11110103060	Cherokee
OKI06594-062	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.8984908	35.8668931	18	16N	23EI	WGS84	11110103060	Cherokee
OKI06594-064	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.6267222	35.9238889	27	15N	25EI	WGS84	11110103060	Adair
OKI06594-066	OK720510000190_00	Illinois River	Illinois River	Inactive 2007-2009	-94.8739244	35.9726381	8	17N	23EI	WGS84	11110103080	Cherokee
OKI06594-071	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.7006689	35.9507847	13	17N	24EI	WGS84	11110103060	Adair
OKI06594-079	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.6379722	35.9333333	21	17N	25EI	WGS84	11110103060	Adair
OKI06594-081	OK121700060010_00	Flint Creek	Flint Creek	Inactive 2007-2009	-94.6333056	36.2166944	15	20N	25EI	WGS84	11110103050	Delaware
OKI06594-086	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.8270920	35.9299200	26	17N	23EI	WGS84	11110103060	Cherokee
OKI06594-090	OK720510000190_00	Barren Fork	Barren Fork	Inactive 2007-2009	-94.8606944	35.9033611	33	17N	23EI	WGS84	11110103060	Cherokee

APPENDIX AG

US ENVIRONMENTAL PROTECTION AGENCY STORET ORIGINAL DATA SET

See Microsoft Excel® file, ‘STORET Original Data.’

APPENDIX AH

US ENVIRONMENTAL PROTECTION AGENCY STORET DATA SET WATER QUALITY STATION DESCRIPTIONS

Org ID	Org Name	Station ID	Station Name	State	County	Generated HUC	Station Latitude	Station Longitude	Station Horizontal Datum	Converted Station Latitude	Converted Station Longitude	Converted Station Horizontal Datum	Sample Count
ARDEQH2O_WQX	Arkansas Department of Environmental Quality	ARK0146	Arkansas River near W.D. Mayo Lock and Dam (in OK) on CR7	OKLAHOMA	SEQUOYAH	11110104	35.3035	-94.537697	UNKWN	35.303501	-94.537697	NAD83	50
CHEROKEE	Cherokee Nation (Oklahoma)	BF1	Barren Fork 1	OKLAHOMA	ADAIR	11110103	35.90966	-94.5659833	WGS84	35.90966	-94.5659833	NAD83	1
CHEROKEE	Cherokee Nation (Oklahoma)	BF2	Barren Fork 2	OKLAHOMA	ADAIR	11110103	35.91988	-94.620635	WGS84	35.9198833	-94.620635	NAD83	10
CHEROKEE	Cherokee Nation (Oklahoma)	BF3	Barren Fork 3	OKLAHOMA	CHEROKEE	11110103	35.9468	-94.6912516	WGS84	35.9468	-94.6912516	NAD83	10
CHEROKEE	Cherokee Nation (Oklahoma)	BF4	Barren Fork 4	OKLAHOMA	CHEROKEE	11110103	35.92662	-94.828655	WGS84	35.9266216	-94.828655	NAD83	6
CHEROKEE	Cherokee Nation (Oklahoma)	BF5	Barren Fork 5	OKLAHOMA	CHEROKEE	11110103	35.86771	-94.8977	WGS84	35.86771	-94.8977	NAD83	10
OKCONCOM_WQX	Oklahoma Conservation Commission	OKR08715-026	Barren Fork Creek: Site # 026	OKLAHOMA	ADAIR	11110103	35.95087	-94.6528107	NAD83	35.9508674	-94.6528107	NAD83	9
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121700-05-0010K	Barren Fork: Butlers	OKLAHOMA	CHEROKEE	11110103	35.9047	-94.8552	NAD83	35.9047	-94.8552	NAD83	12
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121700-05-0010F	Barren Fork: Lower	OKLAHOMA	CHEROKEE	11110103	35.86286	-94.8991	NAD83	35.86286	-94.8991	NAD83	55
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121600-05-0160G	Beaty Creek: Lower	OKLAHOMA	DELAWARE	11070209	36.35544	-94.776	NAD83	36.3554444	-94.776	NAD83	12
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121600-05-0160F	Beaty Creek: Upper @ Betty C.	OKLAHOMA	DELAWARE	11070209	36.3704	-94.7191	NAD83	36.3704	-94.7191	NAD83	57
ARDEQH2O_WQX	Arkansas Department of Environmental Quality	ARK0004A	Flint Cr NW of W Siloam Springs OK	OKLAHOMA	DELAWARE	11110103	36.21716	-94.602409	UNKWN	36.217155	-94.602409	NAD83	59
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121700-06-0010G	Flint Creek	OKLAHOMA	DELAWARE	11110103	36.1961	-94.7078	NAD83	36.1961	-94.7078	NAD83	11
CHEROKEE	Cherokee Nation (Oklahoma)	FC2	Flint Creek 2	OKLAHOMA	DELAWARE	11110103	36.22009	-94.6397933	WGS84	36.2200933	-94.6397933	NAD83	61
CHEROKEE_WQX	Cherokee Nation (Oklahoma)	FC3	Flint Creek 3	OKLAHOMA	DELAWARE	11110103	36.21446	-94.6652583	WGS84	36.2144633	-94.6652583	NAD83	10
CHEROKEE	Cherokee Nation (Oklahoma)	FC4	Flint Creek 4	OKLAHOMA	DELAWARE	11110103	36.18687	-94.7071266	WGS84	36.1868666	-94.7071266	NAD83	62
CHEROKEE_WQX	Cherokee Nation (Oklahoma)	FC5	Flint Creek 5	OKLAHOMA	DELAWARE	11110103	36.17447	-94.7207083	WGS84	36.1744683	-94.7207083	NAD83	19
CHEROKEE	Cherokee Nation	FM1	Fourteen Mile Creek 1	OKLAHOMA	CHEROKEE	11070209	36.03115	-94.954975	WGS84	36.03115	-94.954975	NAD83	19

	(Oklahoma)												
CHEROKEE	Cherokee Nation (Oklahoma)	FM2	Fourteen Mile Creek 2	OKLAHOMA	CHEROKEE	11070209	36.01404	-94.9752916	WGS84	36.0140416	-94.9752916	NAD83	56
CHEROKEE	Cherokee Nation (Oklahoma)	FM3	Fourteen Mile Creek 3	OKLAHOMA	CHEROKEE	11070209	36.002	-95.0673633	WGS84	36.0019966	-95.0673633	NAD83	15
CHEROKEE	Cherokee Nation (Oklahoma)	FM4	Fourteen Mile Creek 4	OKLAHOMA	CHEROKEE	11070209	35.97694	-95.1538666	WGS84	35.9769416	-95.1538666	NAD83	64
CHEROKEE	Cherokee Nation (Oklahoma)	FM5	Fourteen Mile Creek 5	OKLAHOMA	CHEROKEE	11070209	35.95857	-95.1824383	WGS84	35.9585683	-95.1824383	NAD83	51
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121600-01-0100C	Fourteenmile Creek	OKLAHOMA	CHEROKEE	11070209	35.937	-95.17628	NAD83	35.937	-95.17628	NAD83	25
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121600-01-0100G	Fourteenmile Creek	OKLAHOMA	CHEROKEE	11070209	35.9591	-95.1825	NAD83	35.9591	-95.1825	NAD83	4
OKCONCOM_WQX	Oklahoma Conservation Commission	OKR08715-085	Illinois River	OKLAHOMA	CHEROKEE	11110103	36.05607	-94.8860884	NAD83	36.0560673	-94.8860884	NAD83	3
CHEROKEE	Cherokee Nation (Oklahoma)	ILL1	Illinois River 1	OKLAHOMA	ADAIR	11110103	36.10638	-94.7811666	WGS84	36.10638	-94.7811666	NAD83	11
CHEROKEE	Cherokee Nation (Oklahoma)	ILL2	Illinois River 2	OKLAHOMA	CHEROKEE	11110103	35.91719	-94.9281516	WGS84	35.917185	-94.9281516	NAD83	34
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121700-03-0010M	Illinois River: Intake	OKLAHOMA	CHEROKEE	11110103	35.915	-94.93	NAD83	35.915	-94.93	NAD83	312
OKCONCOM_WQX	Oklahoma Conservation Commission	OKR08715-108	Lee Creek	OKLAHOMA	SEQUOYAH	11110104	35.52357	-94.4925653	NAD83	35.5235664	-94.4925653	NAD83	351
CHEROKEE	Cherokee Nation (Oklahoma)	LL1	Little Lee Creek 1	OKLAHOMA	ADAIR	11110104	35.76997	-94.5846333	WGS84	35.7699683	-94.5846333	NAD83	405
CHEROKEE	Cherokee Nation (Oklahoma)	LL2	Little Lee Creek 2	OKLAHOMA	ADAIR	11110104	35.70393	-94.5872333	WGS84	35.7039266	-94.5872333	NAD83	150
CHEROKEE	Cherokee Nation (Oklahoma)	LL3	Little Lee Creek 3	OKLAHOMA	ADAIR	11110104	35.65204	-94.6219833	WGS84	35.6520416	-94.6219833	NAD83	61
CHEROKEE	Cherokee Nation (Oklahoma)	LL4	Little Lee Creek 4	OKLAHOMA	SEQUOYAH	11110104	35.63252	-94.5794716	WGS84	35.6325183	-94.5794716	NAD83	192
CHEROKEE	Cherokee Nation (Oklahoma)	LL5	Little Lee Creek 5	OKLAHOMA	SEQUOYAH	11110104	35.56233	-94.5337416	WGS84	35.5623333	-94.5337416	NAD83	24
GBMCASSOC2014	GBMc & Associates	LLC-2	Little Lee Creek Lower - 2	OKLAHOMA	SEQUOYAH	11110104	35.57515	-94.55596	WGS84	35.57515	-94.55596	NAD83	340
GBMCASSOC2014	GBMc & Associates	LLC-1	Little Lee Creek Upper - 1	OKLAHOMA	ADAIR	11110104	35.65304	-94.62138	WGS84	35.65304	-94.62138	NAD83	15
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121600-02-0030D	Saline Creek	OKLAHOMA	MAYES	11070209	36.282	-95.09292	NAD83	36.282	-95.09292	NAD83	16
CHEROKEE	Cherokee Nation (Oklahoma)	SLN1	Saline Creek 1	OKLAHOMA	DELAWARE	11070209	36.3039	-94.8790466	WGS84	36.3038966	-94.8790466	NAD83	1

CHEROKEE	Cherokee Nation (Oklahoma)	SLN2	Saline Creek 2	OKLAHOMA	DELAWARE	11070209	36.31124	-94.985915	WGS84	36.3112383	-94.985915	NAD83	1
CHEROKEE	Cherokee Nation (Oklahoma)	SLN3	Saline Creek 3	OKLAHOMA	MAYES	11070209	36.28248	-95.0923266	WGS84	36.2824833	-95.0923266	NAD83	1
CHEROKEE_WQX	Cherokee Nation (Oklahoma)	SLN5	Saline Creek 5	OKLAHOMA	MAYES	11070209	36.28194	-95.0925	WGS84	36.281944	-95.0925	NAD83	1
CHEROKEE	Cherokee Nation (Oklahoma)	SAL1	Sallisaw Creek 1	OKLAHOMA	ADAIR	11110104	35.75958	-94.6774966	WGS84	35.7595766	-94.6774966	NAD83	53
CHEROKEE	Cherokee Nation (Oklahoma)	SAL2	Sallisaw Creek 2	OKLAHOMA	ADAIR	11110104	35.73256	-94.72543	WGS84	35.732555	-94.72543	NAD83	12
CHEROKEE	Cherokee Nation (Oklahoma)	SAL3	Sallisaw Creek 3	OKLAHOMA	ADAIR	11110104	35.6415	-94.7735583	WGS84	35.6415016	-94.7735583	NAD83	53
CHEROKEE	Cherokee Nation (Oklahoma)	SAL4	Sallisaw Creek 4	OKLAHOMA	SEQUOYAH	11110104	35.58069	-94.8272383	WGS84	35.5806933	-94.8272383	NAD83	12
CHEROKEE	Cherokee Nation (Oklahoma)	SAL5	Sallisaw Creek 5	OKLAHOMA	SEQUOYAH	11110104	35.46652	-94.862025	WGS84	35.4665216	-94.862025	NAD83	50
OKCONCOM_WQX	Oklahoma Conservation Commission	OK220200-03-0010C	Sallisaw Creek: Lower	OKLAHOMA	SEQUOYAH	11110104	35.46461	-94.86175	NAD83	35.4646111	-94.86175	NAD83	64
OKCONCOM_WQX	Oklahoma Conservation Commission	OKR08715-086	Sallisaw Creek: Site # 086	OKLAHOMA	SEQUOYAH	11110104	35.52347	-94.8380414	NAD83	35.5234705	-94.8380414	NAD83	15
OKCONCOM_WQX	Oklahoma Conservation Commission	OK220200-03-0010G	Sallisaw Creek: Upper	OKLAHOMA	SEQUOYAH	11110104	35.5775	-94.829167	NAD83	35.5775	-94.829167	NAD83	57
OKCONCOM_WQX	Oklahoma Conservation Commission	OK121600-05-0150G	Spavinaw Creek	OKLAHOMA	DELAWARE	11070209	36.3437	-94.7716	NAD83	36.3437	-94.7716	NAD83	11
CHEROKEE	Cherokee Nation (Oklahoma)	SPV3	Spavinaw Creek 3	OKLAHOMA	DELAWARE	11070209	36.32516	-94.7237222	WGS84	36.3251638	-94.7237222	NAD83	54
CHEROKEE	Cherokee Nation (Oklahoma)	SPV4	Spavinaw Creek 4	OKLAHOMA	DELAWARE	11070209	36.34925	-94.7832194	WGS84	36.34925	-94.7832194	NAD83	63
CHEROKEE	Cherokee Nation (Oklahoma)	SC1	Spring Creek 1	OKLAHOMA	DELAWARE	11070209	36.18649	-94.8329083	WGS84	36.1864933	-94.8329083	NAD83	37
CHEROKEE_WQX	Cherokee Nation (Oklahoma)	SC2	Spring Creek 2	OKLAHOMA	CHEROKEE	11070209	36.13986	-94.9150016	WGS84	36.1398633	-94.9150016	NAD83	55
CHEROKEE	Cherokee Nation (Oklahoma)	SC3	Spring Creek 3	OKLAHOMA	CHEROKEE	11070209	36.106	-94.9893016	WGS84	36.106	-94.9893016	NAD83	26
CHEROKEE	Cherokee Nation (Oklahoma)	SC4	Spring Creek 4	OKLAHOMA	CHEROKEE	11070209	36.10274	-95.0943016	WGS84	36.1027416	-95.0943016	NAD83	4
CHEROKEE	Cherokee Nation (Oklahoma)	SC5	Spring Creek 5	OKLAHOMA	MAYES	11070209	36.13092	-95.1883716	WGS84	36.1309166	-95.1883716	NAD83	41
													3213

APPENDIX AI

CHEROKEE NATION CULTURALLY SIGNIFICANT WATERS DATA SET

See Microsoft Excel file, ‘CN CSW Data.’

APPENDIX AJ

CHEROKEE NATION CULTURALLY SIGNIFICANT WATERS MEDIAN CALCULATIONS

See Microsoft Excel® file, ‘CN CSW Decadal Median Calculations.’

APPENDIX AK

OKLAHOMA CONSERVATION COMMISSION HIGH QUALITY WATER SITES

FOR OKLAHOMA AND CHEROKEE NATION 14-COUNTIES

See Microsoft Excel file, ‘OCC HQW Sites and Sampling Data for OK and Cherokee Nation 14 Counties.’

APPENDIX AL

THREE-MONTH ROLLING GEOMETRIC MEAN AND ROLLING ARITHMETIC MEAN CALCULATIONS

See Microsoft Excel® file, ‘CN CSW RGM and RAM Analysis.’

APPENDIX AM

THREE-MONTH ROLLING GEOMETRIC MEAN AND ROLLING ARITHMETIC MEAN SUMMARY TABLE

See Microsoft Excel file, ‘CN CSW RGM and RAM Results Table.’

APPENDIX AN

CLARK STUDY ILLINOIS RIVER NEAR TAHLEQUAH US GEOLOGICAL SURVEY DATA

SU Year	Study Unit	Site Name	Site ID	STAID	Water year	Date	Time	Sampling Method	HydrologicStatus	R_Q daily	Q_daily	Q_source	R_Qinst	Q_instant	R_Temp	Temp	TP	M_TP	Nutrient National Synthesis Tea
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1993	4/29/93	1100	Unknown	NOT DETERMINED		1660	ADAPS		1680		18.0	0.0800	C	NH4: 0.01 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1993	5/26/93	800	Unknown	STABLE, NORMAL STAGE		1300	ADAPS		1320		15.0	0.0600	C	NH4: 0.01 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1993	6/23/93	1000	Unknown	STABLE, NORMAL STAGE		1390	ADAPS		1300		13.0	0.1300	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1993	7/21/93	1100	Unknown	STABLE, NORMAL STAGE		545	ADAPS		545		27.0	0.0800	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1993	9/1/93	930	Unknown	STABLE, NORMAL STAGE		255	ADAPS		253		24.0	0.0900	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1993	9/14/93	1510	Unknown	Rising stage		1230	ADAPS		1140		22.0	0.1100	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1993	9/22/93	945	Unknown	STABLE, NORMAL STAGE		986	ADAPS		997		21.0	0.0900	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	10/19/93	1330	Unknown	NOT DETERMINED		1600	ADAPS		1520		17.5	0.1200	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	11/23/93	900	Integrated	NOT DETERMINED		1680	ADAPS		1700		11.5	0.0700	C	NH4: 0.01 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	12/21/93	915	Unknown	NOT DETERMINED		988	ADAPS		991		7.0	0.0600	C	NH4: 0.01 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	1/25/94	915	Unknown	STABLE, NORMAL STAGE		487	ADAPS		485		7.8		C	TP: deleted <0.01
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	2/24/94	1000	Unknown	NOT DETERMINED		4440	ADAPS		4540		7.5	0.1500	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	3/22/94	1030	Unknown	FALLING STAGE		1470	ADAPS		1470		12.5	0.0700	C	NH4: <0.01 changed to <0.02
1991	OZRK	Illinois River near	07196500	07196500	1994	4/26/94	1230	Unknown	STABLE, NORMAL STAGE		1050	ADAPS		10		19.0	0.0200	C	

		Tahlequah, OK												50					
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	6/22/94	1000	Unknown	STABLE, NORMAL STAGE		341	ADAPS		349		26.0	0.1100	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	7/27/94	900	Unknown	PEAK STAGE		680	ADAPS		700		22.0	0.1000	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	8/24/94	1500	Unknown	STABLE, NORMAL STAGE		341	ADAPS		337		27.0	0.1000	C	NH4: 0.01 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1994	9/8/94	830	Unknown	STABLE, NORMAL STAGE		217	ADAPS		217		23.0	0.0900	C	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	10/26/94	1400	Integrated	STABLE, NORMAL STAGE		347	ADAPS		345		16.0	0.0800	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	11/7/94	1145	Integrated	STABLE, NORMAL STAGE		5750	ADAPS		5050		16.0	0.2300	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	11/30/94	1400	Integrated	STABLE, NORMAL STAGE		880	ADAPS		875		10.0	0.0700	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	12/20/94	1230	Integrated	STABLE, NORMAL STAGE		904	ADAPS		902		10.0	0.0700	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	1/25/95	1400	Integrated	FALLING STAGE		1680	ADAPS		1650		7.0	0.0700	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	2/24/95	1420	Integrated	STABLE, NORMAL STAGE		574	ADAPS		572		12.5	0.0400	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	3/28/95	1345	Integrated	STABLE, NORMAL STAGE		915	ADAPS		891		14.5	0.0600	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	4/12/95	1220	Integrated	RISING STAGE		2460	ADAPS		2610		14.5	0.1400	D	
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	5/16/95	845	Integrated	STABLE, NORMAL STAGE		1920	ADAPS		1960		20.5	0.1200	D	NH4: <0.015 changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	6/27/95	1430	Integrated	STABLE, NORMAL STAGE		921	ADAPS		915		24.0	0.0600	D	
1991	OZRK	Illinois River near	07196500	07196500	1995	7/27/95	1400	Integrated	STABLE, NORMAL STAGE		767	ADAPS		76		27.5	0.0700	D	NH4: <0.015

		Tahlequah, OK												1					changed to <0.02
1991	OZRK	Illinois River near Tahlequah, OK	07196500	07196500	1995	8/24/95	1430	Integrated	STABLE, NORMAL STAGE		257	ADAPS		259		30.0	0.0800	D	

APPENDIX AO

CLARK ET AL. (2002) STUDY ORIGINAL DATA SET

See Microsoft Excel® file, ‘Clark Study Original Data.’

APPENDIX AP

US ENVIRONMENTAL PROTECTION AGENCY NUTRIENT ECOREGION IV DATA SET

See Microsoft Excel file, ‘NE IV Data.’

APPENDIX AQ

US ENVIRONMENTAL PROTECTION AGENCY NUTRIENT ECOREGION IX

DATA SET

See Microsoft Excel® file, ‘NE IX Data.’

APPENDIX AR

US ENVIRONMENTAL PROTECTION AGENCY NUTRIENT ECOREGION XI

DATA SET

See Microsoft Excel® file, ‘NE XI Data.’

APPENDIX AS

OKLAHOMA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD

APPROVAL FORM

Oklahoma State University Institutional Review Board

Request for Determination of Non-Human Subject or Non-Research

6. **Signatures**

Signature of PI____________________ **Date** 1/30/08

Signature of Faculty Advisor____________________ **Date** 1/30/08
(If PI is a student)

☒ Based on the information provided, the OSU-Stillwater IRB has determined that this project **does not** qualify as human subject research as defined in 45 CFR 46.102(d) and (f) and **is not subject to oversight by the OSU IRB.**

☐ Based on the information provided, the OSU-Stillwater IRB has determined that this research **does** qualify as human subject research and **submission of an application for review by the IRB is required.**

Dr. ~~Sue C. Jacobs, IRB Chair~~ 1/31/08
Shelia Kennison, IRB Chair Date

Revision Date: 04/2006 5 of 5

APPENDIX AT

CHEROKEE NATION INSTITUTIONAL REVIEW BOARD

APPROVAL FORM

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CHEROKEE NATION™

P.O. Box 948 • Tahlequah, OK 74465-0948 • (918) 453-5000

Chad "Corntassel" Smith
Principal Chief

Joe Grayson, Jr.
Deputy Principal Chief

January 24, 2008

Cara Cowan Watts
P.O. Box 2922
Claremore, OK 74018

Dear Mrs. Watts:

The Cherokee Nation Institutional Review Board received your protocol entitled, "Culturally Significant Waters Interviews with Cherokees". After a careful review we have determined that this study is EXEMPT from IRB review under 45 CFR 46.101(b)(2).

Our decision is based on the following findings:

- The research presents **no more than minimal risk** of harm to subjects.
- The proposed study involves survey procedures and the information which will be obtained and recorded in such a manner that individual human subjects can not be identified, directly or through identifiers linked to the subjects.
- After the conclusion of the study the data will be reported in a cumulative manner and no individual facilities or individuals will be identified.

We have also waived the requirement to obtain an informed consent under 45 CFR 46.116(d)(1,2,4):

- The research presents **no more than minimal risk** of harm to subjects.
- The waiver or alteration will not adversely affect the rights and welfare of the subjects.
- Whenever appropriate, the subjects will be provided with additional pertinent information after participation.

In addition, we have waived the requirements to obtain documentation of informed consent under CFR 46.117(c)(2):

- The research presents **no more than minimal risk** of harm to subjects, and involves no procedures, for which written consent is normally required outside of the research context

However, we do have a few recommendations:

- You must not ask or record any unique identifiers, such as name, phone numbers, home address or any other contact information.
- You must agree to report the data in a cumulative fashion without mentioning the place of interview or individuals.
- Please develop an information sheet about this project and share with participating parents.

VITA

Cara Ailene Cowan Watts

Candidate for the Degree of Doctor of Philosophy

Thesis: CRITICAL REVIEW OF US ENVIRONMENTAL PROTECTION AGENCY NUMERICAL NUTRIENT CRITERIA WITH RESPECT TO CULTURALLY SIGNIFICANT WATERS AS A DESIGNATED USE

Major Field: Biosystems Engineering

Personal Data: Born in Shawnee, Oklahoma, the daughter of Clarence and Beverly Cowan, married to Douglas Watts.

Education: Graduated Seminole High School, Seminole, OK May 1992; Bachelor of Science degree in Mechanical Engineering from Oklahoma State University (OSU), Stillwater, OK December 1997; Master of Science degree in Telecommunications Management from OSU, Tulsa, OK May 2002; completed requirements for Doctor of Philosophy degree with major in Biosystems Engineering at OSU, Stillwater, OK December 2015.

Experience: Employed as mechanical engineer in New Product Introduction by Hewlett-Packard Colorado Springs, Colorado, January 1998 to October 1999; Technical Facilities Planning Engineer by WilTel Communications Tulsa, OK, October 1999 to July 2004; and National Science Foundation Louis-Stokes Bridge to Doctorate Fellow by OSU Stillwater, OK, June 2005 to May 2008, elected legislator of Cherokee Nation Tribal Council in Rogers County, OK, August 2003 to August 2015; currently, Vice-President Tulsa Pier Drilling.

Professional Memberships: American Water Resources Association member since 2006; American Society of Agricultural and Biological Engineers member since 2006; American Indian Science and Engineering Society, board of directors 2007–2008 and 2001–2005, Sequoyah (lifetime) member since 2001, member, 1994 to present; Society of Women Engineers, member, 1995-Present; Tau Beta Pi, member OK Gamma, 1998-Present; Pi Tau Sigma, member OK Lambda, 1997-Present; Engineer in Training (EI 10769), August 1998.